
Section 2

Physical and Chemical Data*

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PHYSICAL PROPERTIES OF PURE SUBSTANCES

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds*

Abbreviations Used in the Table						
a., acid	atm., atmosphere or 760 mm. of mercury pressure	d. 50, decomposes at 50°C; 50 d., melts at 50°C with decomposition	hyg., hygroscopic	pl., plates	trig., trigonal	
A., specific gravity with reference to air = 1	bk., black	delq., deliquescent	i., insoluble	pr., prisms or prismatic	v., very	
abs., absolute	brn., brown	dil., dilute	ign., ignites	pvr., pyridine	vac., in vacuo	
ac., acetic acid	bz., benzene	dk., dark	lq., liquid	rhb., rhombic (orthorhombic)	vl., violet	
act., acetone	c., cold	eff., effloresces or efflorescent	lt., light	s., soluble	volt., volatile or volatilizes	
al., 95 percent ethyl alcohol	cb., cubic	et., ethyl ether	m. al., methyl alcohol	satd., saturated	wh., white	
alk, alkali (i.e., aq. NaOH or KOH)	cc, cubic centimeter	expl., explodes	mn., monoclinic	sl., slightly	yel., yellow	
am., amyl (C_5H_{11})	chl., chloroform	gel., gelatinous	nd., needles	soln., solution	∞ , soluble in all proportions	
amor., amorphous	col., colorless or white	gly., glycerol (glycerin)	NH ₃ , liquid ammonia	subl., sublimes	<, less than	
anh., anhydrous	conc., concentrated	gn., green	NH ₄ OH, ammonium hydroxide	sulf., sulfides	>, greater than	
aq., aqueous or water	cr., crystals or crystalline	h., hot	solution	tart. a., tartaric acid	42 \pm , about or near 42	
aq. reg., aqua regia	d., decomposes	hex., hexagonal	oct., octahedral	tet., tetragonal	-3H ₂ O, 100, loses 3 moles of water per formula weight at 100°C	
	D., specific gravity with reference to hydrogen = 1		or., orange	tr., transition		
			pd., powder	tri., triclinic		

Formula weights are based upon the International Atomic Weights of 1941 and are computed to the nearest hundredth.

Refractive index, where given for a uniaxial crystal, is for the ordinary (ω) ray; where given for a biaxial crystal, the index given is for the median (β) value. Unless otherwise specified, the index is given for the sodium D-line ($\lambda = 589.3 \text{ m}\mu$).

Specific gravity values are given at room temperatures (15° to 20°C) unless otherwise indicated by the small figures which follow the value; thus, "5.6 $\frac{18}{4}$ " indicates a specific gravity of 5.6 for the substance at 18°C referred to water at 4°C. In this table the values for the specific gravity of gases are given with reference to air (A) = 1, or hydrogen (D) = 1.

Melting point is recorded in a certain case as "82 d." and in some other case as "d. 82," the distinction being made in this manner to indicate that the former is a melting point with decomposition at 82°C, while in the latter decomposition only occurs at 82°C. Where a value such as "-2H₂O, 82" is given it indicates loss of 2 moles of water per formula weight of the compound at a temperature of 82°C.

Boiling point is given at atmospheric pressure (760 mm. of mercury) unless otherwise indicated; thus, "82 $^{15\text{ mm.}}$ " indicates the boiling point is 82°C when the pressure is 15 mm.

Solubility is given in parts by weight (of the formula shown at the extreme left) per 100 parts by weight of the solvent; the small superscript indicates the temperature. In the case of gases the solubility is often expressed in some manner as " 5^{10} cc " which indicates that at 10°C, 5 cc. of the gas are soluble in 100 g. of the solvent. The symbols of the common mineral acids: H₂SO₄, HNO₃, HCl, etc., represent dilute aqueous solutions of these acids. See also special tables on Solubility.

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Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Aluminum	Al	26.97	silv., cb.	2.70 ^{20°}	660	2056	i.	i.	s. HCl, H ₂ SO ₄ , alk.
acetate, normal	Al(C ₂ H ₃ O ₂) ₃	204.10	wh. pd.	d. 200			s.	d.	s.a.; i. NH ₄ salts
acetate, basic	Al(OH)(C ₂ H ₃ O ₂) ₂	162.07	wh., amor.	d.			i.		s.al., act., CS ₂
bromide	AlBr ₃	266.72	trig.	3.01 ^{25°} ₄	97.5	268	s.	s.	s. al., CS ₂
bromide	AlBr ₃ ·6H ₂ O	374.82	col., delq. cr.	d. 100			d. to CH ₄		s. a.; i. act.
carbide	Al,C ₃	143.91	yel., hex., 2.70	2.95	d. >2200	182.7 ^{752mm} ; subl. 178	69.87 ^{15°}	s. d.	s. et., chl., CCl ₄ ; i. bz.
chloride	AlCl ₃	133.34	wh., delq., hex.	2.44 ^{25°} ₄	194 ^{5.2atm.}		400	v. s.	50 al.; s. et.
chloride	AlCl ₃ ·6H ₂ O	241.44	col., delq., trig., 1.560	2.17	d.		sl. s.		
fluoride (fluellite)	AlF ₃ ·H ₂ O	101.99	col., rhb., 1.490		-4H ₂ O, 120	-6H ₂ O, 250	i.	sl. s.	
fluoride	Al ₂ F ₆ ·7H ₂ O	294.05	wh., cr. pd.		-2H ₂ O, 300		0.000104 ^{18°}	i.	s. a., alk.; i. a.
hydroxide	Al(OH) ₃	77.99	wh., mn.	2.42	73	d. 134	v. s.	v. s. d.	s. al., CS ₂
nitrate	Al(NO ₃) ₃ ·9H ₂ O	375.14	rhb., delq.		2150 ^{4atm.}	d. >1400	d. slowly	i.	s. alk. d.
nitride	Al ₂ N ₂	81.96	yel., hex.	3.05 ^{25°} ₄				i.	v. sl. s. a., alk.
oxide	Al ₂ O ₃	101.94	col., hex., 1.67-8	3.99	1999 to 2032	2210	i.	i.	s. a., alk.; i. ac.
oxide (corundum)	Al ₂ O ₃	101.94	wh., trig., 1.768	4.00	1999 to 2032		i.	i.	
phosphate	AlPO ₄	121.95	col., hex.	2.59			i.	i.	

*By N. A. Lange, Ph.D., Handbook Publishers, Inc., Sandusky, Ohio. Abridged from table of Physical Constants of Inorganic Compounds in Lange, "Handbook of Chemistry."

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Aluminum (Cont.)									
potassium silicate (muscovite)	3Al ₂ O ₃ ·K ₂ O·6SiO ₂ ·2H ₂ O	796.40	mn., 1.590	2.9	d.		i.		
potassium silicate (orthoclase)	Al ₂ O ₃ ·K ₂ O·6SiO ₂	556.49	col., mn., 1.524	2.56	1450 (1150)		i.		
Aluminum potassium tartrate	AlK(C ₄ H ₄ O ₆) ₂	362.21	col.				s.	s.	
sodium fluoride (cryolite)	AlF ₃ ·3NaF	209.96	wh., mn., 1.3389	2.90	1000		sl. s.	i.	i. HCl
sodium silicate	Al ₂ O ₃ ·Na ₂ O·6SiO ₂	524.29	col., tri., 1.529	2.61	1100		i.	i.	d. a.
sulfate	Al ₂ (SO ₄) ₃	342.12	wh. cr.	2.71	d. 770		31.3°	89 ^{100°}	
Alum, ammonium (tschermigite)	Al ₂ (SO ₄) ₃ ·(NH ₄) ₂ SO ₄ ·24H ₂ O	906.64	col., oct., 1.4594	1.64 ^{20°} ₄	93.5	-20H ₂ O, 120; -24H ₂ O, 200	3.9°	∞ 100°	i. al.
ammonium chrome	Cr ₂ (SO ₄) ₃ ·(NH ₄) ₂ SO ₄ ·24H ₂ O	956.72	gn. or vl., oct., 1.4842	1.72	100 d.		21.2 ^{25°}		s. al.
ammonium iron	Fe ₂ (SO ₄) ₃ ·(NH ₄) ₂ SO ₄ ·24H ₂ O	964.40	vl., oct., 1.485	1.71	40		124 ^{25°}		i. al.
potassium (kalinite)	Al ₂ (SO ₄) ₃ ·K ₂ SO ₄ ·24H ₂ O	948.76	col., mn., 1.4564	1.76 ^{26°} ₄	92	-18H ₂ O, 64.5	5.7°	∞ 93°	
potassium chrome	Cr ₂ (SO ₄) ₃ ·K ₂ SO ₄ ·24H ₂ O	998.84	red or gn., cb., 1.4814	1.83	89		20	50	i. al.
sodium	Al ₂ (SO ₄) ₃ ·Na ₂ SO ₄ ·24H ₂ O	916.56	col., oct., 1.4388	1.675 ^{20°} ₄	61		106.4°	121.7 ^{45°}	i. al.
Ammonia†	NH ₃	17.03	col. gas, 1.325 (lq.)	0.817 ^{-79°} 0.5971 (A)	-77.7	-33.4	89.9°	7.4 ^{96°}	14.8 ^{20°} al.; s. et.
Ammonium acetate	NH ₄ C ₂ H ₃ O ₂	77.08	wh., hyg. cr.	1.073	114	d.	148 ^{4°}		s. al.; sl. s. act.
auricyanide	NH ₄ CN·Au(CN) ₃ ·H ₂ O	337.33	pl.		d. 200		s.	v. s.	i. al.
bicarbonate	NH ₄ HCO ₃	79.06	mn. or rhb., 1.5358	1.573	d. 35-60		11.9°	27 ^{30°}	i. al.
bromide	NH ₄ Br	97.96	col., cb., 1.7108	2.327 ^{15°} ₄	subl. 542		68 ^{10°}	145.6 ^{100°}	s. al., et., act.
carbonate	(NH ₄) ₂ CO ₃ ·H ₂ O	114.11	col. pl.		d. 58		100 ^{15°}		i. al., CS ₂ , NH ₃
carbonate, carbamate	NH ₄ HCO ₃ NH ₂ CO ₂ NH ₄ †	157.11	wh. cr.		subl.		25 ^{15°}	67 ^{65°}	
carbonate, sesqui-	(NH ₄) ₂ CO ₃ 2NH ₄ HCO ₃ ·H ₂ O	272.22	wh.		d.		20 ^{15°}	50 ^{49°}	
chloride (salammoniac)	NH ₄ Cl	53.50	wh., cb., 1.639, 1.6426	1.53 ^{17°}	d. 350	subl. 520	29.4 ^{0°} 0.7 ^{15°}	77.3 ^{100°} 1.25 ^{100°}	s. NH ₃ ; sl. s. al., m. al. 0.005 al.
chloroplatinate	(NH ₄) ₂ PtCl ₆	444.05	yel., cb.	3.065	d.		s.	v. s.	
chloroplatinite	(NH ₄) ₂ PtCl ₆	373.14	tet.		d.				
chlorostannate	(NH ₄) ₂ SnCl ₆	367.52	pink, cb.	2.4			33.3 ^{15°}		
chromate	(NH ₄) ₂ CrO ₄	152.09	yel., mn.	1.917 ^{12°}	d. 180		40.5 ^{30°}	d.	sl. s. act., NH ₃ ; i. al.
cyanide	NH ₄ CN	44.06	col., cb.	0.79 ^{100°} (A)	36		s.	v. s.	s. al.
dichromate	(NH ₄) ₂ Cr ₂ O ₇	252.10	or, mn.	2.15	d. 185		47.2 ^{30°}	v. s.	s. al.; i. act.
ferrocyanide	(NH ₄) ₂ Fe(CN) ₆ ·6H ₂ O	392.21	mn.		d.		s.		i. al.
fluoride	NH ₄ F	37.04	wh., hex.				v. s.	d.	s. al.; i. NH ₃
fluoride, acid	NH ₄ F·HF	57.05	wh., rhb., 1.390	2.21 ^{12°} ₁₂	114-116	d. 180; subl. in vac.	102 ^{0°}	531 ^{80°}	s. al.
formate	HCO ₂ NH ₄	63.06	col., mn., delq.	1.266		subl. 120	v. s.		
hydrosulfide	NH ₄ HS	51.11	col., rhb.		d.		s.		s. al.
hydroxide	NH ₄ OH	35.05	in soln. only				s.		
molybdate	(NH ₄) ₂ MoO ₄	196.03	mn.	2.27	d.		d.		i. al., NH ₃
molybdate, hepta-	(NH ₄) ₆ Mo ₇ O ₂₄ ·4H ₂ O†	1235.95	col., mn.				44 ^{25°}	d.	i. al.
nitrate (α), stable -16° to 32°	NH ₄ NO ₃	80.05	col., tet., 1.611	1.66 ^{25°} ₄	169.6	d. 210	118.3°	241.8 ^{30°}	
nitrate (β), stable 32° to 84°	NH ₄ NO ₃	80.05	col., rhb. or mn.	1.725 ^{25°} ₄		d. 210	365.8 ^{35°}	580 ^{80°}	3.8 ^{20°} al., 17.1 ^{20°} m. al.; v. s. NH ₃
nitrite	NH ₄ NO ₂	64.05	wh. nd.	1.69	expl.		s.	d.	s. al.
osmochloride	(NH ₄) ₂ OsCl ₆	439.02	cb.	2.93 ^{20°} ₄					
oxalate	(NH ₄) ₂ C ₂ O ₄ ·H ₂ O	142.12	col., rhb.	1.501			2.5°	11.8 ^{50°}	sl. s. al.; i. NH ₃
oxalate, acid	NH ₄ HC ₂ O ₄ ·H ₂ O	125.08	col., trimetric	1.556	d.		s.		
perchlorate	NH ₄ ClO ₄	117.50	col., rhb., 1.4833	1.95	d.		10.9°	46.9 ^{100°}	2 ^{20°} al.; s. act.; i. et.
persulfate	(NH ₄) ₂ S ₂ O ₈	228.20	wh., mn., 1.5016	1.98	d. 120		58.2°	d.	
phosphate, monobasic	NH ₄ H ₂ PO ₄	115.04	col., tet., 1.5246	1.803 ^{19°} ₄			22.7°	173.2 ^{100°}	i. ac.

phosphate, dibasic	$(\text{NH}_4)_2\text{HPO}_4$	132.07	col., mn., 1.53	1.619			131 ^{15°}	i. act.
phosphate, meta-	$(\text{NH}_4)_4\text{P}_4\text{O}_{12}$	388.08	col., mn.	2.21			s. 0.03 ^{15°}	s. alk.; i. al., HNO_3
Ammonium phosphomolybdate	$(\text{NH}_4)_3\text{PO}_4 \cdot 12\text{MoO}_3 \cdot 3\text{H}_2\text{O}$ (?)	1930.55	yel.		d.		i.	
silicofluoride	$(\text{NH}_4)_2\text{SiF}_6$	178.14	cb., 1.3696	2.01		subl.	18.5 ^{17.5°}	55.5
sulfamate	$\text{NH}_4\text{SO}_3\text{NH}_2$	114.12	col. pl.		132	d. 160	134 ^{0°}	357 ^{50°}
sulfate (mascagnite)	$(\text{NH}_4)_2\text{SO}_4$	132.14	col., rhb., 1.5230	1.769 ^{20°}	235 d.		70.6 ^{0°}	i. al., act., CS_2
sulfate, acid	NH_4HSO_4	115.11	col., rhb., 1.480	1.78	146.9	490	100	v. sl. s. al.; i. act.
sulfide	$(\text{NH}_4)_2\text{S}$	68.14	yel.-wh.		d.		120 ^{25°}	NH_3
sulfide, penta-	$(\text{NH}_4)_2\text{S}_5$	196.38	or-red pr.				s.	
sulfite	$(\text{NH}_4)_2\text{SO}_3 \cdot \text{H}_2\text{O}$	134.16	col., mn.	1.41	d.		100 ^{12°}	i. al., act.
sulfite, acid	NH_4HSO_3	99.11	rhb.	2.03 ^{12°}	d.		s.	
tartrate	$(\text{NH}_4)_2\text{C}_4\text{H}_4\text{O}_6$	184.15	col., mn.	1.60	d.		45 ^{0°}	87 ^{60°}
thiocyanate	NH_4CNS	76.12	col., mn., 1.685±	1.305	149.6	d. 170	120 ^{0°}	170 ^{20°}
vanadate, meta-	NH_4VO_3	116.99	col. cr.	2.326	d.		0.44 ^{18°}	3.05 ^{70°}
Antimony	Sb	121.76	tin wh., trig.	6.684 ^{25°}	630.5	1380	i.	s. aqu. reg., h. conc.
chloride, tri- (butter of antimony) ^a	SbCl_3	228.13	col., rhb., delq.	3.14 ^{20°}	73.4	220.2	601.6 ^{0°}	H_2SO_4
oxide, tri- (valentinite)	Sb_2O_3	291.52	rhb., 2.35	5.67	656	1570	v. sl. s.	s. al., HCl , HBr ,
oxide, tri- (senarmontite)	Sb_2O_3	291.52	cb., 2.087	5.2	652		sl. s.	$\text{H}_2\text{C}_4\text{H}_4\text{O}_6$
sulfide, tri- (stibnite)	Sb_2S_3	339.70	bk., rhb., 4.046	4.64	550		0.00017 ^{18°}	s. HCl ; alk., NH_4HS ,
sulfide, penta-	Sb_2S_5	403.82	golden	4.120 ^{0°}	-2S, 135		i.	K_2S ; i. ac.
telluride, tri-	Sb_2Te_3	626.35	gray		629		i.	s. HCl , alk., NH_4HS
Antimony potassium tartrate (tartar emetic)	$(\text{SbO})\text{KC}_4\text{H}_4\text{O}_6 \cdot \alpha\text{H}_2\text{O}$	333.94	wh., rhb.	2.60	- $\alpha\text{H}_2\text{O}$, 100		5.26 ^{8.7°}	s. gly.; i. al.
sulfate, normal	$(\text{SbO})_2\text{SO}_4$	371.58	wh. pd.	4.89			d.	
sulfate, basic	$(\text{SbO})_2\text{SO}_4 \cdot \text{Sb}(\text{OH})_4$	683.13	wh. pd.				d.	5.15 ^{15°} gly.
Argon	A	39.94	col. gas	1.65 ^{-288°} ; 1.402 ^{-185.7°} ; 1.38 (A)	-189.2	-185.7	5.6 ^{0°} cc	2.23 ^{50°} cc al.
Arsenic (crystalline) (α)	As_4	299.64	met., hex.	5.727 ^{14°}	814 ^{36atm.}	subl. 615	i.	s. HNO_3
Arsenic (black) (β)	As_4	299.64	bk., amor.	4.7 ^{20°}		i.	i.	s. HNO_3 , aq. reg., aq. Cl_2 , h. alk.
Arsenic (yellow) (γ)	As_4	299.64	yel., cb.	2.0 ^{20°}	d. 358			
acid, ortho-	$\text{H}_3\text{AsO}_4 \cdot \alpha\text{H}_2\text{O}$	150.94	col., hyg.	2.0-2.5	35.5	- H_2O , 160	16.7	s. alk.
acid, meta-	HASO_3	123.92	wh., hyg.		d.		d. to form	H_3AsO_4
acid, pyro-	$\text{H}_4\text{As}_2\text{O}_7$	265.85	col.		d. 206		d. to form	H_3AsO_4
pentoxide	As_2O_5	229.82	wh., amor.	4.086	d.		59.5 ^{0°}	s. alk., al.
sulfide, di- (realgar)	As_2S_2	213.94	red, mn., 2.68	(α)3.506 ^{19°} ; (β)3.254 ^{10°}	(α)tr. 267; (β)307	565	i.	$\text{s. K}_2\text{S}$, NaHCO_3
sulfide, penta-	As_2S_5	310.12	yel.			d. 500	0.000136 ^{0°}	i. s. HNO_3 , alk.
Arsenious chloride (butter of arsenic)	AsCl_3	181.28	oily lq.	lq. 2.163	-18	130	d.	s. HCl , HBr , PCl_3
hydride (arsine)	AsH_3	77.93	col. gas	2.695 (A)	-113.5	-55; d. 230	20 cc	sl. s. alk.
oxide (arsenolite)	As_2O_3	197.82	col., cb., fibrous, 1.755	3.865 ^{25°}	subl.		sl. s.	i. al., et.
oxide (claudeite)	As_2O_3	197.82	col., mn., 1.92	3.85	subl.		sl. s.	i. al., et.
oxide	As_2O_3	197.82	amor. or vitreous	3.738	315		1.21 ^{0°}	2.93 ^{40°} s. HCl , alk., Na_2CO_3 ; i. al., et.
Auric chloride	$\text{AuCl}_3 \cdot 2\text{H}_2\text{O}$	339.60	or. cr.		d.		v. s.	s. HCl , al., et.; sl. s. NH_3
cyanide	$\text{Au}(\text{CN})_3 \cdot 6\text{H}_2\text{O}$	383.35			d. 50		v. s.	s. al.
Aurous chloride	AuCl	232.66	yel. cr.	7.4	AuCl_3 , 170	d. 290	d.	s. HCl , HBr ; d. al.
cyanide	AuCN	223.22	yel. cr.		d.		i.	s. KCN ; i. al., et.
<i>Cf. also under Gold</i>								
Barium	Ba	137.36	silv. met.	3.5	850	1140	d.	s. a.; d. al.
acetate	$\text{Ba}(\text{C}_2\text{H}_3\text{O}_2)_2$	255.45	col.	2.468			58.8 ^{0°}	
acetate	$\text{Ba}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{H}_2\text{O}$	273.46	wh., tri. pr., 1.517	2.19	- H_2O , 41		75 ^{30°} (anh.)	75.0 ^{100°}
bromide	BaBr_2	297.19	col.	4.781 ^{24°}	847	d.	98 ^{0°}	79 ^{40°} (anh.)
							149 ^{100°}	v. s. m. al.; v. sl. s. act.

^aUsually the solution.

†See special tables.

‡Usual commercial form.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Barium (Cont.)									
bromide	BaBr ₂ ·2H ₂ O	333.22	col., mn., 1.7266	3.69	-2H ₂ O, 100 tr. 811 to α	d.	v. s. d. 1450	v. s. 0.0022 ^{18°}	s. al. s. a.; i. al.
carbonate (witherite)	BaCO ₃	197.37	wh., rhb., 1.676	4.29	tr. 982 to β		0.0065 ^{100°}		
carbonate (α)	BaCO ₃	197.37	wh., hex.		1740 ^{90atm}		0.0022 ^{18°} 20.35°	0.0065 ^{100°} 84.8 ^{90°}	
carbonate (β)	BaCO ₃	197.37	wh.		414		s.	s. al.; i. al.	
Barium chlorate	Ba(ClO ₃) ₂	304.27	col.		d. 120	1560	31° ^o	sl. s. al., act.	
chlorate	Ba(ClO ₃) ₂ ·H ₂ O°	322.29	col., mn., 1.577	3.179	tr. 925	1560	76.8 ^{100°} 1.67° ^o	sl. s. HCl, HNO ₃ ; i. al.	
chloride	BaCl ₂	208.27	col., mn., 1.7361	3.856 ^{24°}	962	1560	101.4 ^{80°}		
chloride	BaCl ₂	208.27	col., eb.						
chloride	BaCl ₂ ·2H ₂ O†	244.31	col., mn., 1.646	3.097 ^{24°}	-2H ₂ O, 100		39.3° ^o 5.6° ^o	76.8 ^{100°}	
hydroxide	Ba(OH) ₂	171.38	col., mn.	4.495	77.9	-8H ₂ O, 550	5.0° ^o	v. sl. s. al.; i. et.	
hydroxide	Ba(OH) ₂ ·8H ₂ O	315.50	col., mn., 1.5017	2.188 ^{16°}	592	d.	34.2 ^{100°} 0.0016 ^{8°}	sl. s. a.; i. al.	
nitrate (nitrobarite)	Ba(NO ₃) ₂	261.38	col., cb., 1.572	3.244 ^{28°}			0.0024 ^{24°}	s. a., NH ₄ Cl; i. al.	
oxalate	BaC ₂ O ₄	225.38	wh. cr.	2.658			90.8 ^{90°}	s. HCl, HNO ₃ , abs. al.; i. NH ₃ , act.	
oxide	BaO	153.36	col., cb., 1.98	5.72	1923	2000±	1.5° ^o		
peroxide	BaO ₂ ⁵	169.36	gray or wh. pd.	4.958	-O, 800		v. sl. s.	d.	
peroxide	BaO ₂ ·SH ₂ O	313.49	pearly sc.		-8H ₂ O, 100		0.168	s. dil. a.; i. act.	
phosphate, monobasic	BaH ₄ (PO ₄) ₂	331.35	tri.	2.9 ^{4°}			d.	s. dil. a.; i. al., et. act.	
phosphate, dibasic	BaHPO ₄	233.35	wh., rhb. nd., 1.635	4.165 ^{15°}			0.015	s. a.	
phosphate, tribasic	Ba ₃ (PO ₄) ₂	602.04	wh., cb.	4.1 ^{16°}			i.	s. a., NH ₄ salts	
phosphate, pyro-	Ba ₂ P ₂ O ₇	448.68	wh., rhb.	3.9 ^{20°}			0.01	s. a.	
silicofluoride	BaSiF ⁶	279.42	pr.	4.279 ^{15°}			0.026 ^{17°}	s. a., NH ₄ salts	
sulfate (barite, barytes)	BaSO ₄	233.42	col., rhb., 1.636	4.499 ^{15°}	1580 d.	tr. to mn. 1149	0.000115 ^{0°}	sl. s. HCl, NH ₄ Cl; i. al.	
sulfide, mono-	BaS	169.42	col., cb., 2.155	4.25 ^{15°}			0.09 ^{100°}	s. conc. H ₂ SO ₄ ; 0.006,	
sulfide, tri-	BaS ₃	233.54	yel.-gn.		d. 400		0.000285 ^{30°}	3% HCl	
sulfide, tetra-	BaS ₄ ·2H ₂ O	301.63	red. rhb.	2.988 ^{20°}	d. 200		d.	d. HCl; i. al.	
Beryllium (glucinum)	Be(Gl)	9.02	gray, met., hex.	1.816	1284	2767	s.		
Bismuth	Bi	209.00	silv. wh. or reddish, hex.	9.80 ^{20°}	271	1450	41 ^{15°} v. s.	s. d.	
carbonate, sub-	Bi ₂ O ₃ ·CO ₂ ·H ₂ O	528.03	wh. pd.	6.86	d.	i.	i.	s. a.	
chloride, di-	BiCl ₃ (?)	279.91	bk. nd.	4.86	163	300	d.	s. al.	
chloride, tri-	BiCl ₃ *	315.37	wh. cr.	4.75	230	447	d.	42 ^{19°} act.; s. a.; i. al.	
nitrate	Bi(NO ₃) ₃ ·5H ₂ O	485.10	col., tri.	2.82	d. 30	-5H ₂ O, 80	i.	s. a.	
nitrate, sub-	BiONO ₃ ·H ₂ O	305.02	hex. pl.	4.928 ^{15°}	d. 260		i.		
oxide, tri-	Bi ₂ O ₃	466.00	yel., rhb.	8.9	820	1900±	i.	s. a.	
oxide, tri-	Bi ₂ O ₃	466.00	yel., tet.	8.55	860		i.	s. a.	
oxide, tri-	Bi ₂ O ₃	466.00	yel., cb.	8.20	tr. 704		i.	s. a.	
oxychloride	BiOCl	260.46	wh., amor.	7.72 ^{15°}			sl. s.	s. a.; i. act., NH ₃ ,	
Boric acid	H ₃ BO ₃	61.84	wh., tri.	1.435 ^{15°}	185 d.		2.66 ^{0°} 40.2 ^{100°}	H ₃ C ₆ H ₄ O ₆ 22.2 ^{20°} gly., 0.24 ^{25°} et.; s. al.	
Boron	B	10.82	gray or bk., amor. or mn.	2.32	2300	2550	i.	i. s. HNO ₃ ; i. al.	
carbide	B ₄ C	55.29	bk. cr.	2.54	2450	>3500	i.	i. a.	
oxide	B ₂ O ₃	69.64	col. glass, 1.459	1.85	577	>1500	1.1° ^o sl. s.	s. a., al., gly.	
oxide (sassolite)	B ₂ O ₃ ·3H ₂ O	123.69	tri., 1.456	1.49	d.		s.		
Bromic acid	HBrO ₃	128.92	col.; in soln, only		d. 100		v. s.	d.	
Bromine	Br ₂	159.83	rhb., or red lq.	3.119 ^{20°} ; 5.87(Å)	-7.2	58.78	4.22 ^{0°}	3.13 ^{30°}	
hydrate	Br ₂ ·10H ₂ O	339.99	red, oct.		d. 6.8		s.		
Cadmium	Cd	112.41	silv. met., hex.	8.65 ^{20°}	320.9	767	i.	s. a., NH ₄ NO ₃	
acetate	Cd(C ₂ H ₃ O ₂) ₂	230.50	col.	2.341	256	d.	s. m. al.		
acetate	Cd(C ₂ H ₃ O ₂) ₂ ·2H ₂ O°	266.53	col., mn.	2.01	-H ₂ O, 130		s. al.		
carbonate	CdCO ₃	172.42	wh., trig.	4.258 ^{4°}	d. <500	i.	s. a., KCN, NH ₄ salts; i. NH ₃		
chloride	CdCl ₂	183.32	wh., cb.	4.047 ^{25°}	568	960	90 ^{0°}	1.52 ^{15°} al.; i. et., act.	

chloride	CdCl ₂ .2H ₂ O	228.36	col., mn., 1.6513	3.327	tr. 34	168 ^{20°}	180 ^{100°}	2.05 ^{15°} m. al.
cyanide	Cd(CN) ₂	164.45	wh., trig.	4.79 ^{15°} ₄	d. >200	0.0247 ^{18°}	s. a.; NH ₄ OH, KCN	
hydroxide	Cd(OH) ₂	146.43	col.	350	d. 300	0.00026 ^{25°}	s. a., NH ₄ salts; i. alk.	
nitrate	Cd(NO ₃) ₂	236.43	col. nd.	59.4	109.7° ⁰	109.7° ⁰	v. s. a.	
nitrate	Cd(NO ₃) ₂ .4H ₂ O*	308.49	brn., cb.	132	215.0° ⁰	326 ^{59.5°}	s. al., NH ₃ ; i. HNO ₃	
oxide	CdO	128.41	brn., amor. 2.49	i.	i.	s. a., NH ₄ salts; i. alk.		
oxide	CdO	128.41	6.95	i.	i.	s. a., NH ₄ salts; i. alk.		
oxide, sub-	Cd ₂ O	240.82	gn., amor. 8.192 ^{18°} _{3/4}	d. 900–1000	d. a. alk.			
Cadmium sulfate	CdSO ₄	208.47	rhb.	1000	76.5° ⁰	60.8 ^{100°}	i. act., NH ₃	
sulfate	CdSO ₄ .H ₂ O	226.49	mn.	tr. 108	S.	S.	i. al.	
sulfate	3CdSO ₄ .8H ₂ O*	769.54	col., mn., 1.565	3.09	114.2° ⁰	127.6 ^{60°}	i. al.	
sulfate	CdSO ₄ .H ₂ O	280.53	col.	41.5	S.	S.	i. al.	
sulfate	CdSO ₄ .7H ₂ O	334.58	mn.	3.05	350 ^{-5°}	Colloidal	s. a.; v. s. NH ₄ OH	
sulfide (greenockite)	CdS	144.47	yel.-or, hex., 2.506	tr. 4	1750 ^{100atm}	0.000001	s. a.; sl. s. al.	
Calcium	Ca	40.08	silv. met., cb.	810	1200 ± 30	d.	s. HCl	
acetate	Ca(C ₂ H ₃ O ₂) ₂ .H ₂ O	176.18	wh. nd.	1551	52° ⁰	45.5 ^{80°}	i. dil. a.	
aluminate	Ca(AlO ₂) ₂	158.02	col., rhb. or mn.	1600	d.	s. al., act.; sl. s. NH ₃		
aluminum silicate (anorthite)	CaO.Al ₂ O ₃ .2SiO ₂	278.14	tri., 1.5832	2.765	1810	312 ^{105°}	s. a., NH ₄ Cl	
arsenate	Ca ₃ (AsO ₄) ₂	398.06	wh. pd.	760	0.0012 ^{20°} †	0.002 ^{100°}	s. a., NH ₄ Cl	
bromide	CaBr ₃	199.91	delq. nd.	2.93	1339 ^{103atm} .	0.0014 ^{25°}	s. al.	
carbonate (aragonite)	CaCO ₃	100.09	col., rhb., 1.6809	772	>1600	0.002 ^{100°}	s. al.	
carbonate (calcite)	CaCO ₃	100.09	col., hex., 1.550	2.711 ^{25°} ₄	59.5° ⁰	347 ^{260°}	s. al.	
chloride (hydrophilite)	CaCl ₂ *	110.99	wh., delq., cb., 1.52	2.152 ^{15°} ₄	772	S.	s. al.	
chloride	CaCl ₂ .H ₂ O	129.01	col., delq.	1810	S.	s. al.	s. al.	
chloride	CaCl ₂ .6H ₂ O	219.09	col., trig., 1.417	1.68 ^{17°}	29.92	v. s.	0.0065 ^{18°} al.	
citrate	Ca ₃ (C ₆ H ₅ O ₇) ₂ .4H ₂ O	570.50	col. nd.	-6H ₂ O, 200	-2H ₂ O, 185	0.085 ^{18°}	0.096 ^{26°}	
cyanamide	CaCN ₂	80.11	col., rhombohedral	-2H ₂ O, 100	s. d.	d.	d.	
ferrrocyanide	Ca ₂ Fe(CN) ₆ .12H ₂ O	508.31	yel., tri., 1.5818	1.7	1330	150 ^{90°}	i. al.	
fluoride (fluorite)	CaF ₂	78.08	wh., cb., 1.4339	3.180 ^{20°}	1810	0.0016 ^{18°}	sl. s. a.	
formate	Ca(HCO ₃) ₂	130.12	col., rhb.	2.015	16.1° ⁰	0.0017 ^{26°}	i. al., et.	
hydride	CaH ₂	42.10	wh. cr. or pd.	6.75	d.	18.4 ^{100°}	d. a.; i. bz.	
hydroxide	Ca(OH) ₂	74.10	col., hex., 1.574	2.2	-H ₂ O, 580	0.185 ^{0°}	s. NH ₄ Cl	
hypochlorite	Ca(ClO) ₂ .4H ₂ O	215.06	wh., featherly cr.	d.	delq.; d.	0.077 ^{100°}	d. a.	
hypophosphate	Ca ₃ P ₂ O ₇ .2H ₂ O	274.15	granular	-2H ₂ O, 200	i.	d.	s. HCl, H ₄ P ₂ O ₆	
lactate	Ca(C ₃ H ₅ O ₃) ₂ .5H ₂ O	308.30	col., eff.	-3H ₂ O, 100	10.5	∞	∞h. al.; i. et.	
magnesium carbonate (dolomite)	CaO.Mg.O.2CO ₂	184.42	trig., 1.68174	2.872	d. 730–760	0.032 ^{18°}	14 ^{15°} al.; s. amyl al., NH ₃	
magnesium silicate (diopside)	CaO.Mg.O.2SiO ₃	216.52	wh., mn.	1391	i.	i.	i. dil. a.; i. abs. al.	
nitrate (nitrocalcite)	Ca(NO ₃) ₂	164.10	col., cb.	561	102° ⁰	376 ^{151°}	s. 90% al.	
nitrate	Ca(NO ₃) ₂ .4H ₂ O*	236.16	col., mn., 1.498	42.7	266° ⁰	v. s.	s. a.; i. ac.	
nitride	Ca ₃ N ₂	148.26	brn. cr.	900	77° ⁰	417 ^{90°}	s. a.; i. ac.	
nitrite	Ca(NO ₂) ₂ .H ₂ O	150.11	delq., hex.	2.23 ^{34°}	0.00067 ^{13°}	0.0014 ^{95°}	s. a.; i. ac.	
oxalate	CaC ₂ O ₄	128.10	col., cb.	d.	i.	i.	s. a.; i. ac.	
oxalate	CaC ₂ O ₄ .H ₂ O	146.12	col.	-H ₂ O, 200	Forms	Forms	s. a.; i. ac.	
oxide	CaO	56.08	col., cb., 1.837	3.32	2570	Ca(OH) ₂	sl. s.	
peroxide	CaO ₂ .8H ₂ O	216.21	pearly, tet.	-8H ₂ O, 100	expl. 275	d.	s. a. d.; i. al., et.	
phosphate, monobasic	CaH ₄ (PO ₄) ₂ .H ₂ O	252.09	wh., tri.	2.220 ^{16°} ₄	-H ₂ O, 100	d.	s. a. d.; i. al., et.	
phosphate, dibasic	CaHPO ₄ .2H ₂ O	172.10	wh., mn. pl.	2.306 ^{16°} ₄	d.	0.02 ^{24.5°}	0.075 ^{100°}	
phosphate, tribasic	Ca ₃ (PO ₄) ₂	310.20	wh., amor.	3.14	1670	0.0025	s. a.; i. al., ac.	
phosphate, meta-	Ca ₃ (PO ₄) ₂	198.04	wh., tet., 1.588	2.82	975	i.	i. a.	
phosphate, pyro-	Ca ₃ P ₂ O ₇	254.12	col., biaxial, 1.60	3.09	1230	i.	s. a.	
phosphate, pyro- (brushite)	Ca ₃ P ₂ O ₇ .5H ₂ O	344.20	wh., mn.	2.25	>1600	sl. s.	s. a.; i. NH ₄ Cl	
phosphide	Ca ₃ P ₂	182.20	red cr.	2.51 ^{15°}	1540	d.	s. dil. a.; i. al., et.	
silicate (α) (pseudowollastonite)	CaSiO ₃	116.14	col., pseudo hex., 1.6150 or mn.(?)	2.905	0.0095 ^{17°}	0.1619 ^{100°}	s. HCl	
silicate (β) (wollastonite)	CaSiO ₃	116.14	col., mn., 1.610	2.915	tr. 1190 to α	0.298 ^{20°}	s. a., Na ₂ S ₂ O ₃ , NH ₄ salts	
sulfate (anhydrite)	CaSO ₄	136.14	col., rhb., 1.576, or mn., 1.50	2.96	1450(mn.)	tr. 1193 to rhb.	i. act., NH ₃	

*Usual commercial form.

†The solubility of CaCO₃ in H₂O is greatly increased by increasing the amount of CO₂ in the H₂O.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Calcium (<i>Cont.</i>)									
sulfate (gypsum)	CaSO ₄ ·2H ₂ O	172.17	col., mn., 1.5226	2.32	-1 a H ₂ O, 128	-2 H ₂ O, 163	0.223 ^{0°}	0.257 ^{50°}	s. a., gly., Na ₂ S ₂ O ₃ , NH ₄ salts
sulphydrate	Ca(SH) ₂ ·6H ₂ O	214.31	col. pr.	d. 15			v. s.	v. s.	s. al.
sulfide (oldhamite)	CaS	72.14	col., cb.	2.8 ^{15°}	-2 H ₂ O, 100	d. 650	d.	d.	s. a.
sulfite	CaSO ₃ ·2H ₂ O	156.17	wh., cr., 1.595		d.		0.0043 ^{18°}	0.0027 ^{90°}	s. H ₂ SO ₃
tartrate	Ca ₄ H ₄ O ₆ ·4H ₂ O	260.22	col., rhb.				0.037 ^{0°}	0.22 ^{85°}	sl. s. al.
thiocyanate	Ca(CNS) ₂ ·3H ₂ O	210.28	wh., delq. cr.				s.	v. s.	v. s. al.
thiosulfate	CaS ₂ O ₃ ·6H ₂ O	260.30	col., tri., 1.56	1.873 ^{16°}	d.		71.2 ^{9°}	d.	i. al.
tungstate (scheelite)	CaWO ₄	288.00	wh., tet., 1.9200	6.06			0.2		s. NH ₄ Cl; i. a.
Carbon, cf. table of organic compounds									
Carbon, amorphous	C	12.01	bk., amor.	1.8-2.1	>3500	4200	i.	i.	i. a., alk.
Carbon, diamond	C	12.01	col., cb., 2.4195	3.51 ^{20°}	>3500	4200	i.	i.	i. a., alk.
Carbon, graphite	C	12.01	bk., hex.	2.26 ^{20°}	>3500	4200	i.	i.	i. a., alk.
dioxide	CO ₂	44.01	col. gas	lq. 1.101 ^{-87°} ; 1.53 (A); solid 1.56 ^{-79°}	-56.6 ^{5.2} atm.	subl. -78.5	179.7 ^{0°} cc	90.1 ^{20°} cc	s. a., alk.
disulfide	CS ₂	76.13	col. lq.	lq. 1.261 ^{22°} ; 2.63 (A)	-108.6	46.3	0.2 ^{0°}	0.014 ^{50°}	s. al.; et.
monoxide	CO	28.01	col., poisonous, odorless gas	lq. 0.814 ^{-195°} ; 0.968 (A)	-207	-192	0.0044 ^{0°} ; 3.5 ^{0°} cc	0.0018 ^{50°} ; 2.32 ^{20°} cc	s. al., Cu ₂ Cl ₂
oxychloride (phosgene)	COCl ₂	98.92	poisonous gas	1.392 ^{19°}	-104	8.2 ⁷⁵⁶ mm	v. s. sl. d.	d.	s. ac., CCl ₄ , bs.; d. a.
oxysulfide	COS	60.07	gas	lq. 1.24 ^{-87°} ; 2.10 (A)	-138.2	-50.2 ⁷⁶⁰ mm	133 ^{0°} cc	40.3 ^{30°} cc	v. s. alk., al.
suboxide	C ₂ O ₃	68.03	gas	lq. 1.114 ^{0°}	-107	7 ⁷⁶¹ mm	d.		s. et.
thionyl chloride	CS ₂ Cl ₂	114.98	yel.-red lq.	1.509 ^{15°}		73.5			
Ceric hydroxide	2CeO ₂ ·3H ₂ O	398.31	yel., gelatinous						s. a.; sl. s. alk. carb.; i. alk
hydroxynitrate	Ce(OH)(NO ₃) ₃ ·3H ₂ O	397.21	red, mn.						
oxide	CeO ₂	172.13	wh. or pa. yel., cb.	7.3	1950				
sulfate	Ce(SO ₄) ₂ ·4H ₂ O	404.31	yel., rhb.	3.91					
Cerium	Ce	140.13	steel gray, cb. or hex.	6.9 ^{20°} cb.; 6.7 hex.	645	1400	i.	Slowly oxidized	
Cerous sulfate	Ce ₂ (SO ₄) ₃	568.44	wh., mn. or rhb.	3.91			18.98 ^{0°}	0.4 ^{100°}	
sulfate	Ce ₂ (SO ₄) ₃ ·8H ₂ O	712.57	tri.	2.886 ^{17°}	-8 H ₂ O, 630		25 ^{0°}	7.6 ^{40°}	
Cesium	Ce	132.91	silv. met., hex.	1.90 ^{20°}	28.5	670	d.		s. a., al., NH ₃
Chloric acid	HClO ₃ ·7H ₂ O	210.58	lq.	1.282 ^{14.2°}	<-20	d. 40	v. s.		
Chlorine	Cl ₂	70.91	rmb., or gn.-yel. gas	lq. 1.56 ^{-33.6°} ; 2.49 ^{0°} (A)	-101.6	-34.6	1.46 ^{0°} ; 310 ^{10°} cc	0.57 ^{30°} ; 177 ^{30°} cc	s. alk.
hydrate	Cl ₂ ·8H ₂ O	215.04	rhb.	1.23	d. 9.6		s.		s. alk.
Chloroplatinic acid	H ₂ PtCl ₆ ·6H ₂ O	518.08	red-brn., delq.	2.431	60		v. s.	v. s.	s. al., et.
Chlorostannic acid	H ₂ SnCl ₆ ·6H ₂ O	441.55	delq.	1.971 ^{28°}	19.2		s.		
Chlorosulfonic acid	HO-SO ₂ -Cl	116.52	col. lq.	1.787 ^{25°}	-80	151.5 ⁷⁶⁵ mm	d.		d. al.; i. CS ₂
Chromic acetate	Cr ₂ (C ₂ H ₃ O ₂) ₂ ·2H ₂ O	494.32	gn.				s.		4.76 ^{15°} m. al.
chloride	CrCl ₃	158.38	pink, trig.	2.757 ^{15°}			i. §	sl. s.	i. a., act., CS ₂
chloride	CrCl ₃ ·6H ₂ O [°]	266.48	vl. or gn., hex. pl.	1.835 ^{25°}	subl. 83	1200-1500 d.	v. s. d.		s. al.; i. et.
fluoride	CrF ₃	109.01	gn., rhb.	3.8	>1000	d.	i.		sl. s. a.; i. al., NH ₃
hydroxide	Cr(OH) ₃	103.03	gn. or blue, gelatinous						
hydroxide	Cr(OH) ₃ ·2H ₂ O	139.07	gn.		-2 H ₂ O, 100		i.		s. a., alk.; sl. s. NH ₃
nitrate	Cr(NO ₃) ₃ ·9H ₂ O [°]	400.18	purple pr.	36.5	d. 100	i.	i.		s. a., alk.
nitrate	Cr(NO ₃) ₃ ·7aH ₂ O	373.15	purple, mn.	100	d.	s.	s.		s. a., alk., al., act.
oxide	Cr ₂ O ₃	152.02	dark gn., hex.	5.21	1900	i.	s.		
sulfate	Cr ₂ (SO ₄) ₃	392.20	rose pd.	3.012		i. †	i.		sl. s. a.
sulfate	Cr ₂ (SO ₄) ₃ ·5H ₂ O	482.28	gn.			i.	i. a.		
sulfate	Cr ₂ (SO ₄) ₃ ·15H ₂ O	662.44	vl.	1.867 ^{17°}	100	-10 H ₂ O, 100	s.	d. 67°	s. al., H ₂ SO ₄
sulfate	Cr ₂ (SO ₄) ₃ ·18H ₂ O	716.49	vl., cb., 1.564	1.7 ^{22°}		-12 H ₂ O, 100	120 ^{20°}	d.	sl. s. al.

sulfide	<chem>Cr2S3</chem>	200.02	brn.-bk. pd.	3.77 ^{19°}	-S, 1350		i.	d.	s. h. HNO ₃
Chromium	Cr	52.01	gray, met., cb.	7.1	1615	2200	i.	i.	s. HCl, dil. H ₂ SO ₄ ;
trioxide (chromic acid)	<chem>CrO3</chem>	100.01	red, rhb.	2.70	197 d.		164.9 ^{0°}	206.7 ^{100°}	i. HNO ₃
Chromous chloride	<chem>CrCl2</chem>	122.92	wh., delq.	2.75			v. s.	v. s.	s. H ₂ SO ₄ , al. et.
hydroxide	<chem>Cr(OH)2</chem>	86.03	yel.-brn.		d.		d.		sl. s. al.; i. et.
oxide	<chem>CrO</chem>	68.01	bk. pd.				i.	i.	s. conc. a.
sulfate	<chem>CrSO4·7H2O</chem>	274.18	blue				12.35 ^{0°}		i. dil. HNO ₃
sulfide (daubrelite)	<chem>CrS</chem>	84.07	bk. pd.	3.97	1550		i.		sl. s. al.
Chromyl chloride	<chem>CrO2Cl2</chem>	154.92	dark red lq.	1.92	-96.5	117.6	d.		v. s. a.
Cobalt	Co	58.94	silv. met., cb.	8.9 ^{20°}	1480	2900	i.	i.	s. et.
carbonyl	<chem>Co(CO)4</chem>	170.98	or. cr.	1.73 ^{18°}	51	d. 52	i.	d.	s. a.
sulfide, di-	<chem>CoS2</chem>	123.06	bk., cb.	4.269			i.		s. al., et., CS ₂
Cobaltic chloride	<chem>CoCl3</chem>	165.31	red cr.	2.94	subl.		s.	s.	s. HNO ₃ , aq. reg.
chloride, dichro	<chem>Co(NH3)2Cl3·H2O</chem>	234.42					s.		s. a.; al.
chloride, luteo	<chem>Co(NH3)2Cl3</chem>	267.50	or., mn.	1.7016 ^{20°}			4.26 ^{0°}	12.74 ^{46.5°}	i. al., NH ₄ OH
chloride, praseo	<chem>Co(NH3)3Cl3·H2O</chem>	251.46	gn., rhb.	1.847			v. s.		s. a.; i. al.
Cobaltic chloride, purpureo	<chem>Co(NH3)5Cl3</chem>	250.47	rhb.	1.819 ^{25°}			0.232 ^{0°}	1.031 ^{46.5°}	i. al.
chloride, roseo	<chem>Co(NH3)5Cl3·H2O</chem>	268.49	brick red		d. 100		16.12 ^{0°}	24.87 ^{16°}	sl. s. HCl
hydroxide	<chem>Co(OH)3</chem>	109.96	bk.		-12H ₂ O, 100		i.	i.	s. a.; i. al.
oxide	<chem>Co2O3</chem>	165.88	bk.	5.18	d. 900		i.	i.	s. a.
sulfate	<chem>Co2(SO4)3</chem>	406.06	blue cr.				d.		s. H ₂ SO ₄
sulfide	<chem>Co2S3</chem>	214.06	bk. cr.	4.8			i.		d. a.
Cobalto-cobaltic oxide	<chem>Co3O4</chem>	240.82	bk., cb.	6.07			i.	i.	s. H ₂ SO ₄ ; i. HCl, HNO ₃
Cobaltous acetate	<chem>Co(C2H3O2)2·4H2O</chem>	249.09	red-vl., mn., 1.542	1.7053 ^{18.7°}	-4H ₂ O, 140		s.	s.	s. a., al.
chloride	<chem>CoCl3</chem>	129.85	blue cr.	3.356	subl.	1049	45 ^{7°}	105 ^{96°}	31 al.; 8.6 act.
chloride	<chem>CoCl2·6H2O</chem>	237.95	red, mn.	1.924 ^{25°}	86	-6H ₂ O, 110	116.5 ^{0°}	177 ^{80°}	v. s. et., act.
nitrate	<chem>Co(NO3)2·6H2O</chem>	291.05	red, mn., 1.4	1.883 ^{25°}	<100	d.	84.03 ^{0°} (anh.)	334.9 ^{90°}	100 ^{12.5°} al.; s. act.; sl. s. NH ₃
oxide	CoO	74.94	brn., cb.	5.68	d. 1800		i.	i.	s. a., NH ₄ OH; i. al.
sulfate	<chem>CoSO4</chem>	155.00	red pd.	3.710 ^{25°}	d. 880		25.6 ^{0°}	83 ^{100°}	1.04 ^{18°} m. al.; i. NH ₃
sulfate	<chem>CoSO4·H2O</chem>	173.02	red pd., mn.(?), 1.639	3.13	d.		s.	s.	
sulfate (biebeorite)	<chem>CoSO4·7H2O</chem>	281.11	red, mn., 1.483	1.948 ^{25°}	96.8	-7H ₂ O, 420	33 ^{90°}		2.5 ^{0°} al.
sulfide (syeporite)	CoS	91.00	brn. nd.	5.45 ^{13°}	>1100		0.00038 ^{18°}		s. a., aq. reg.
Copper	Cu	63.57	yel.-red met., cb.	8.92 ^{20°}	1083	2300	i.	i.	s. HNO ₃ , h. H ₂ SO ₄
Cupric acetate	<chem>Cu(C2H3O2)2</chem>	181.66		1.930 ^{20°}			s.		
acetate	<chem>Cu(C2H3O2)2·H2O</chem>	199.67	dark gn., mn.	1.882	115	240 d.	7.2	20	7 al.; s. et.; gly.
aceto-arsenate (Paris green)	<chem>(CuOAs2O3)3</chem> , <chem>(Cu2H2O2)2</chem>	1013.83	gn.				i.		s. a., NH ₄ OH
ammonium chloride	<chem>CuCl2·2NH4Cl·2H2O</chem>	277.51	blue, tet., 1.670, 1.744	1.98	d. 110		33.8 ^{0°}	99.3 ^{80°}	s. a.
ammonium sulfate	<chem>CuSO4·4NH3·H2O</chem>	245.77	blue, rhb.	1.81	d. 150		18.05 ^{21.5°}		i. al.
carbonate, basic (azurite)	<chem>2CuCO3·Cu(OH)2</chem>	344.75	blue, mn., 1.758	3.88	d. 220		i.	d.	s. NH ₄ OH, h. aq.
carbonate, basic (malachite)	<chem>CuCO3·Cu(OH)2</chem>	221.17	dark gn., mn., 1.875	3.9	d.		107.9 ^{100°}		NaHCO ₃
chloride (eriochalcite)	<chem>CuCl2</chem>	134.48	brn.-yel. pd.	3.054	498	Forms Cu ₂ Cl ₂ 993	i.	d.	s. KCN; 0.03 aq. CO
chloride	<chem>CuCl2·2H2O</chem>	170.52	gn., rhb., 1.684	2.39 ^{22.4°}	-2H ₂ O, 110	d.	110.4 ^{0°}	192.4 ^{100°}	53 ^{15°} al.; 68 ^{15°} m. al.
chromate, basic	<chem>CuCrO4·2CuO·2H2O</chem>	374.75	yel.-brn.		-2H ₂ O, 260		i.		s. HNO ₃ , NH ₄ OH
cyanide	<chem>Cu(CN)2</chem>	115.61	yel.-gn.		d.		i.		s. KCN, C ₅ H ₅ N
dichromate	<chem>CuCr2O7·2H2O</chem>	315.62	bk., tri.	2.286 ^{18°}	-2H ₂ O, 100		sl. s.		s. a.; NH ₄ OH
ferricyanide	<chem>Cu3[Fe(CN)6]2</chem>	614.63	yel.-gn.				i.		s. NH ₄ OH; i. HCl
ferrocyanide	<chem>Cu2Fe(CN)6·7H2O</chem>	465.21	red-brn.				i.		s. NH ₄ OH; i. a., NH ₃
formate	<chem>Cu(HCO3)2</chem>	153.61	blue, mn.	1.831			12.5	d.	0.25 al.
hydroxide	<chem>Cu(OH)2</chem>	97.59	blue, gelatinous	3.368	-H ₂ O		i.	d.	s. a., NH ₄ OH, KCN, al.
lactate	<chem>Cu(C2H3O2)2·2H2O</chem>	277.74	dark blue, mn.				16.7	45 ^{100°}	sl. s. al.
nitrate	<chem>Cu(NO3)2·3H2O</chem>	241.63	blue, delq.	2.047 ^{3.9°}	114.5	-HNO ₃ , 170	381 ^{40°}	666 ^{80°}	100 ^{12.5°} al.
nitrate	<chem>Cu(NO3)2·6H2O</chem>	295.68	blue, rhb.	2.074	-3H ₂ O, 26.4		243.7 ^{0°}	∞	s. al.

*Usual commercial form.

†Also a soluble modification.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Cupric acetate (<i>Cont.</i>)									
oxide (paramelaconite)	CuO	79.57	bk., cb.	6.40	d. 1026		i.	i.	s. a.; KCN, NH ₄ Cl
oxide (tenorite)	CuO	79.57	bk., tri., 2.63	6.45	d. 1026		i.	i.	s. a., KCN, NH ₄ Cl
oxychloride	CuCl ₂ ·2CuO·4H ₂ O	365.69	blue-gn.		-3H ₂ O, 140		i.	i.	s. a.
phosphide	Cu ₃ P ₂	252.67	bk.	6.35	d.		i.	i.	s. HNO ₃ ; i. HCl
sulfate (hydrocyanite)	CuSO ₄	159.63	gn.-wh., rhb., 1.733	3.606 ^{15°}	d. >600	Forms CuO, 650	14.3 ^{0°}	75.4 ^{100°}	i. al.
sulfate (blue vitriol or chalcantite)	CuSO ₄ ·5H ₂ O°	249.71	blue, tri., 1.5368	2.286 ^{15.6°}	-4H ₂ O, 110	-5H ₂ O, 250	24.3 ^{0°}	205 ^{100°}	1.1 ^{8°} al.
sulfide (covellite)	CuS	95.63	blue, hex. or mn., 1.45	4.6	tr. 103	d. 220	0.000033 ^{18°}		s. HNO ₃ , KCN
tartate	CuC ₄ H ₆ O ₃ ·3H ₂ O	265.69	1 gn. pd.		d.		0.02 ^{15°}	0.14 ^{85°}	s. a., KOH
Cuprous ammonium iodide	CuI·NH ₄ I·H ₂ O	353.47	rhb. pl.				d.		s. NH ₄ I
carbonate	Cu ₂ CO ₃	187.15	yel.	4.4	d.		i.	i.	s. a., NH ₄ OH
chloride (nantokite)	Cu ₂ Cl ₂	198.05	wh., cb., 1.973	3.53	422	1366	1.52 ^{25°}		s. HCl, NH ₄ OH, al.
cyanide	Cu ₂ (CN) ₂	179.16	wh., mn.	2.9	474.5	d.	i.	i.	s. KCN, HCl, NH ₄ OH; sl. s. NH ₃
ferricyanide	Cu ₃ Fe(CN) ₆	402.67	brn.-red				i.		s. NH ₄ OH; i. HCl
ferrocyanide	Cu ₄ Fe(CN) ₆	466.24	brn.-red				i.		s. NH ₄ OH; i. NH ₄ Cl
fluoride	Cu ₂ F ₂	165.14	red cr.		908	subl. 1100	i.		s. HF, HCl, HNO ₃ ; i. al.
hydroxide	CuOH	80.58	yel.	3.4	-2H ₂ O, 360		i.	i.	s. a., NH ₄ OH
oxide (cuprite)	Cu ₂ O	143.14	red, cb., 2.705	6.0	1235	-O, 1800	i.	i.	s. HCl, NH ₄ Cl, NH ₄ OH
Cuprous phosphide	Cu ₆ P ₂	443.38	gray-bk.	6.4 to 6.8			i.		s. HNO ₃ ; i. HCl
sulfide (chalcoelite)	Cu ₂ S	159.20	bk., rhb.	5.6	1100		0.0005 ^{18°}		s. HNO ₃ , NH ₄ OH; i. act.
sulfide	Cu ₂ S	159.20	bk., cb.	5.80	1130		0.0005 ^{18°}		s. HNO ₃ , NH ₄ OH; i. act.
Cyanogen	C ₂ N ₂	52.02	poisonous gas	lq. 0.866 ^{-17.2°} ; 1.806 (A)	-34.4	-20.5	450 ^{20°} cc	2300 ^{20°} cc al.; 500 ^{18°} cc et.	
Cyanogen compounds, cf. table of organic compounds									
Ferric acetate, basic ammonium sulfate, cf. Alum	Fe(OH)(C ₂ H ₃ O ₂) ₂	190.95	brn., amor.				i.		s. a.; al.
chloride (molyosite)	FeCl ₃	162.22	blk.-brn., hex. delq.	2.804 ^{11°}	282	315	74.4 ^{0°}	535.8 ^{100°}	v. s. al.; et. +HCl
chloride	FeCl ₃ ·6H ₂ O°	270.32	red-yel., delq.		37	280	246 ^{0°}	∞	s. al., act., gly.
ferrocyanide (Prussian blue)	Fe ₄ [Fe(CN) ₆] ₃	859.27	dark blue		d.		i.	d.	s. HCl, conc. H ₂ SO ₄ ; i. al., et.
hydroxide	Fe(OH) ₃	106.87	red-brn.	3.4 to 3.9	-1aH ₂ O, 500		i.	i.	s. a.; i. al., et.
lactate	Fe(C ₃ H ₅ O ₃) ₃	323.06	brn., amor., delq.				v. s.	v. s.	i. et.
nitrate	Fe(NO ₃) ₃ ·6H ₂ O	349.97	rhb., delq.	1.684 ^{20°}	35	d.	150 ^{0°}	∞	s. al., act.
oxide (hematite)	Fe ₂ O ₃	159.70	red or blk., trig., 3.042	5.12	1560 d.		i.	i.	s. HCl
sulfate	Fe ₂ (SO ₄) ₃	399.88	rhb., 1.814	3.097 ^{18°}	d. 480		sl. s.	d.	i. H ₂ SO ₄ , NH ₃
sulfate (coquimbite)	Fe ₂ (SO ₄) ₃ ·9H ₂ O	562.02	yel., trig.	2.1			440	d.	s. abs. al.
Ferroso-ferric chloride	FeCl ₂ ·2FeCl ₃ ·18H ₂ O	775.49	yel., delq.		d. 50		s.		
ferricyanide (Prussian green)	Fe'' ₄ Fe'' ₃ [Fe(CN) ₆] ₆	1662.70	gn.		d. 180		i.		s. d. h. HCl
oxide (magnetite; magnetic iron oxide)	Fe ₃ O ₄	231.55	bk., cb., 2.42	5.2	1538 d.		i.	i.	i. al.
oxide, hydrated	Fe ₃ O ₄ ·4H ₂ O	303.61	bk.		d.		i.	i.	s. a.
Ferrous ammonium sulfate	FeSO ₄ ·(NH ₄) ₂ SO ₄ ·6H ₂ O	392.15	blue-gn., mn., 1.4915	1.864	d.		18 ^{0°}	100 ^{75°}	i. al.
chloride (lawrencite)	FeCl ₂	126.76	gn.-yel., hex., 1.567	2.7		delq.	64.4 ^{10°}	105.7 ^{100°}	100 al.; s. act.; i. et.
chloroplatinate	FePtCl ₆ ·6H ₂ O	571.92	yel., hex.	2.714			v. s.	v. s.	i. dil. a., al.
ferricyanide (Turnbull's blue)	Fe ₃ [Fe(CN) ₆] ₂	591.47	dark blue		d.		i.		
ferrocyanide	Fe ₂ Fe(CN) ₆	323.66	blue-wh., amor.				i.		
formate	Fe(HCO ₂) ₂ ·2H ₂ O	181.92			d.		sl. s.		
hydroxide	Fe(OH) ₂	89.87	lt. gn.	3.4			0.00067		s. a., NH ₄ Cl
nitrate	Fe(NO ₃) ₂ ·6H ₂ O	287.96	cr.		60.5		200 ^{0°}	300 ^{25°}	
oxide	FeO	71.85	bk.	5.7	1420		i.	i.	s. a.; i. alk.

phosphate (vivianite)	$\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$	501.64	blue, mn., 1.592, 1.603	2.58		i.	i.	s. a.; i. ac.
silicate	FeSiO_3	131.91	mn.	3.5	1550			
sulfate (siderotilite)	$\text{FeSO}_4 \cdot 5\text{H}_2\text{O}$	241.99	gn., tri., 1.536	2.2		-5 H_2O , 300	s.	i. al.
sulfate (copperas)	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}^*$	278.02	blue-gn., mn.	1.899 ^{14.8°}	64	-7 H_2O , 300	32.8° ^o	i. al.
sulfide	FeS	87.91	bk., hex.	4.84	1193	d.	0.000616 ^{18°}	s. a.; i. NH_3
cf. also under iron								
Fluoboric acid	HBF_4	87.83	col. lq.			130 d.	∞	s. al.
Fluorine	F_2	38.00	gn.-yel. gas	lq. 1.51 ^{-187°} ; 1.31 ^{15°} (A)	-223	-187	d.	
Fluosilicic acid	H_2SiF_6	144.08					s.	s.
Cadolinium	Gd	156.9					s.	s.
Gallium bromide	GaBr_3	309.47	delq. cr.				s.	s.
Glucinum cf. Beryllium								
Gold	Au	197.20	yel. met., cb.	19.3 ^{20°}	1063	2600	i.	i.
Gold, colloidal	Au	197.20	blue to vl.				s.	s. aq. reg., KCN ; i. a.
Gold salts cf. under Auric and Aurous								s. aq. reg., KCN ; i. a.
Hafnium	Hf	178.6	hex.	12.1	>1700	>3200(?)		
Helium	He	4.00	col. gas	0.1368 (A)	<-272.2	-268.9	0.97 ^{5°} cc	1.08 ^{50°} cc
Hydrazine	N_2H_4	32.05	col. lq.	1.011 ^{15°}	1.4	113.5	∞	Absorbed by Pt s. al.
formate	$\text{N}_2\text{H}_4 \cdot 2\text{HCO}_2\text{H}$	124.10	cb.		128		∞	
hydrate	$\text{N}_2\text{H}_4 \cdot \text{H}_2\text{O}$	50.06	col.	1.03 ^{21°}	-40	118.5 ^{739.5\text{mm}}	v. s.	∞ al.; i. et.
hydrochloride	$\text{N}_2\text{H}_4 \cdot \text{HCl}$	68.51	yel. lq.				v. s.	sl. s. al.
hydrochloride, di-	$\text{N}_2\text{H}_4 \cdot 2\text{HCl}$	104.98	wh., cb.	1.42	198		s.	s. al.
nitrate	$\text{N}_2\text{H}_4 \cdot \text{HNO}_3$	95.06	cr.		70.7	subl. 140	174.9 ^{10°}	v. s.
nitrate, di-	$\text{N}_2\text{H}_4 \cdot 2\text{HNO}_3$	158.08	nd.		104	d.		
sulfate	$\text{N}_2\text{H}_4 \cdot \text{H}_2\text{SO}_4$	81.09	delq. pl.		85		v. s.	i. al.
sulfate	$\text{N}_2\text{H}_4 \cdot \text{H}_2\text{SO}_4$	130.12	rhb.	1.378	254	3.055 ^{23°}	27.65 ^{60°}	v. sl. s. abs. al.
Hydrazoic acid (azoimide)	HN_3	43.03	col. lq.		-80	37	∞	∞ al.
Hydriodic acid	HI	127.93	col. gas	4.4 ^{0°} (A)	-50.8	-35.5	42500 ^{10°} cc	v. s.
Hydriodic acid	$\text{HI} \cdot \text{H}_2\text{O}$	145.94	col. lq.	1.7 ^{15°}		127 ^{774\text{mm}}	∞	s. al.
Hydriodic acid	$\text{HI} \cdot 2\text{H}_2\text{O}$	163.96	col. lq.		-43		∞	s. al.
Hydriodic acid	$\text{HI} \cdot 3\text{H}_2\text{O}$	181.98	col. lq.		-48		∞	s. al.
Hydriodic acid	$\text{HI} \cdot 4\text{H}_2\text{O}$	199.99	col. lq.		-36.5		∞	s. al.
Hydrobromic acid	HBr	80.92	col. gas; 1.325 (lq.)	2.71 ^{0°} (A)	-86	-67	221 ^{0°}	130 ^{100°}
Hydrobromic acid	$\text{HBr} \cdot \text{H}_2\text{O}$	98.94	col. lq.	1.78				Stable at -15.5° and 1 atm., and at -11.3° and 2.5 atm. s. al.
Hydrobromic acid	HBr (47.8% in H_2O)	80.92	col. lq.	1.486		126	∞	
Hydrobromic acid	$\text{HBr} \cdot 2\text{H}_2\text{O}$	116.96	wh. cr.	2.11 ^{-15°}	-11		s.	s.
Hydrochloric acid	HCl^\dagger	36.47	col. gas; 1.256 (lq.)	1.268 ^{0°} (A)	-111	-85	82.3 ^{0°}	56.1 ^{60°}
Hydrochloric acid	HCl (45.2% in H_2O)	36.47	col. lq.	1.48	-15.35		∞	s. al., et.
Hydrochloric acid	$\text{HCl} \cdot 2\text{H}_2\text{O}$	72.50	col. lq.	1.46 ^{-18.3°}	0	d.	∞	s. al.
Hydrochloric acid	$\text{HCl} \cdot 3\text{H}_2\text{O}$	90.51	col. lq.		-24.4	d.	∞	s. al.
Hydrocyanic acid (prussic acid)	HCN	27.03	poisonous gas or col. lq., 1.254	0.697 ^{18°}	-14	26	∞	∞ al., et.
Hydrofluoric acid	HF	20.01	gas or col. lq.	0.988 ^{13.6°}	-83	19.4	∞ 0° to 19.4°	v. s.
Hydrofluoric acid	HF (35.35% in H_2O)	20.01	col. lq.	1.15	-35	120	v. s.	
Hydrogen	H_2	2.016	col. gas or cb.	lq. 0.0709 ^{-252.7°} 0.06948 (A)	-259.1	-252.7	2.1 ^{0°} cc	0.85 ^{90°} cc
peroxide	$\text{H}_2\text{O}_2^\ddagger$	34.02	col. lq., 1.333	1.438 ^{20°}	-0.89	151.4 ^{760\text{mm}}	∞	s. a., et.; i. petr. et
selenide	H_2Se	81.22	col. gas	2.12 ^{-42°}	-64	-42	377 ^{4°} cc	s. CS_2 , COCl_2
sulfide	H_2S	34.08	col. gas	1.1895 (A)	-82.9	-59.6	437 ^{0°} cc	9.54 ^{15°} cc al.; s. CS_2
Hydroxylamine	NH_2OH	33.03	rhb., delq.	1.35 ^{18°}	34	56.5 ^{22\text{mm}}	s.	s. a., al.
hydrochloride	$\text{NH}_2\text{OH} \cdot \text{HCl}$	69.50	col., mn.	1.67 ^{17°}	151	d.	83.3 ^{17°}	s. al.; i. et.
nitrate	$\text{NH}_2\text{OH} \cdot \text{HNO}_3$	96.05	col. cr.		48	d. <100	v. s.	v. s. abs. al.
sulfate	$\text{NH}_2\text{OH} \cdot \text{H}_2\text{SO}_4$	82.07	col., mn.		170 d.		32.9 ^{0°}	68.5 ^{90°}

*Usual commercial form.

†Usual commercial form about 31 percent.

‡Usual commercial forms 3 or 30 percent.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Hypobromous acid	HBrO	96.92	yel.			40° ^{50mm}	s.	d.	
Ilinium	Il	146(?)							s. a.
Indium	In	114.76	soft, tet. met. col., rhb.	7.3 ^{20°} 4.629 ^{0°}	155 110 d.	1450	i. 286 ^{0°}	i. 576 ^{101°}	v. s. 87% al.; i. abs. al. et., chl.
Iodic acid	HIO ₃	175.93							s. al., KI, et. i. abs. al., et., chl.
Iodine	I ₂	253.84	blue-bk., rhb.	4.93 ^{20°}	113.5	184.35	0.0162 ^{0°} 187.4 ^{12°}	0.09566 ^{90°}	
oxide, penta-	I ₂ O ₅	333.84	wh., trimetric	4.799 ^{25°} ₄	d. 300				
Iodoplatinic acid	H ₂ PtI ₆ ·9H ₂ O	1120.91	brn., delq. mn.						
Iridium	Ir	193.10	wh. met., cb.	22.4 ^{20°}	2350	>4800	i.	i.	sl. s. aq. reg., aq. Cl ₂
Iron, cast†	Fe	55.85	gray	7.03	1275		i.	i.	s. a.; i. alk.
pure	Fe	55.85	silv. met., cb.	7.86 ^{20°}	1535	3000	i.	i.	s. a.; i. alk.
steel	Fe	55.85	silv. gray	7.6 to 7.8	1375		i.	i.	s. a.; i. alk.
white pig	Fe	55.85	gray	7.6 to 7.8	1075		i.	i.	s. a.; i. alk.
wrought	Fe	55.85	gray	7.86	1505		i.	i.	s. a.; i. alk.
carbide (cementite)	Fe ₂ C	179.56	pseudo hex.	7.4	1837		i.	i.	s. a.
carbonyl	Fe(CO) ₅	195.90	pa. yel. lq.	1.457 ^{21°}	-21	102.5 ^{760mm}	i.	d.	s. al., H ₂ SO ₄ , alk.
nitride	Fe ₂ N	125.71	gray	6.35	d. >560				s. HCl, H ₂ SO ₄
silicide	FeSi	83.91	yel.-gray, oct.	6.1 ^{20°} ₄			i.	i.	i. aq. reg.
sulfide, di- (marcasite)	FeS ₂	119.97	yel., rhb.	4.87	tr. 450	d.	0.00049		i. dil. a.
sulfide, di- (pyrite)	FeS ₂	119.97	yel., cb.	5.0	1171	d.	0.0005		i. dil. a.
sulfide (pyrrhotite)	Fe ₇ S ₈	647.43	hex.	4.6 ^{20°} ₄	d. >700		i.		
<i>Cf. also under ferric and ferrous</i>									
Krypton	Kr	83.70	col. gas	2.818 (A)	-169	-151.8	11.05 ^{0°} cc	3.57 ^{60°} cc	sl. s. al., bz.
Lanthanum	La	138.92	lead gray	6.15 ^{20°}	826	1800	d.		s. a.
Lead	Pb	207.21	silv. met., cb.	11.337 ^{20°} ₂₀	327.5	1620	i.	i.	s. HNO ₃ ; i. c. HCl, H ₂ SO ₄
acetate	Pb(C ₂ H ₃ O ₂) ₂	325.30	wh. cr.	3.251 ^{20°} ₄	280		19.7 ^{0°}	221 ^{50°}	s. gly.; v. sl. s. al.
acetate (sugar of lead)	Pb(C ₂ H ₃ O ₂) ₂ ·3H ₂ O†	379.35	wh., mn.	2.55	-3H ₂ O, 75		45.64 ^{15°}	200 ^{100°}	s. gly.; sl. s. al.
acetate	Pb(C ₂ H ₃ O ₂) ₂ ·IOH ₂ O	505.46	wh., rhb.	1.689	22		s.	s.	
acetate, basic	Pb ₂ (C ₂ H ₃ O ₂) ₃ OH	608.56	wh.				v. s.	sl. s. al.	
acetate, basic	Pb(C ₂ H ₃ O ₂) ₂ · Pb(OH) ₂ ·H ₂ O	584.54	wh. nd.				v. s.	s. al.	
acetate, basic	Pb(C ₂ H ₃ O ₂) ₂ · 2Pb(OH) ₂	807.75	wh. nd.				5.55	18.2	
arsenate, monobasic	PbH ₄ (AsO ₄) ₂	489.06	tri., 1.82	4.46 ^{15°}	d. 140		d.		s. HNO ₃
arsenate, dibasic (schultenite)	PbHASO ₄	347.13	wh., mn., 1.9097	5.94	d. >200	-H ₂ O, 280	i.	sl. s.	s. HNO ₃ , NaOH
arsenate, meta-	Pb(AsO ₃) ₂	453.03	hex.	6.42 ^{15°}			d.		s. HNO ₃
arsenate, pyro-	Pb ₂ As ₂ O ₇	676.24	rhb., 2.03	6.85 ^{15°} ₁₅	802		i.	d.	s. HCl, HNO ₃ ; i. sc.
Lead azide	PbN ₆	291.26	col. nd.		expl. 350		i.	0.05 ^{100°}	v. s. ac.; i. NH ₄ OH
bromide	PbBr ₂	367.05	col., rhb.	6.66	373	918	0.4554 ^{0°}	4.75 ^{100°}	s. a., KBr; sl. s. NH ₃ ; i. al.
carbonate (cerussite)	PbCO ₃	267.22	wh., rhb., 2.0763	6.6	d. 315		0.00011 ^{20°}	d.	s. a., alk.; i. NH ₃ , al.
carbonate, basic (hydrocerussite; white lead)	2PbCO ₃ ·Pb(OH) ₂ †	775.67	wh., hex.	6.14	d. 400		i.	i.	s. ac.; sl. s. aq. CO ₂
chloride (cotunnite)	PbCl ₂	278.12	wh., rhb., 2.2172	5.80	501	954 ^{760mm}	0.673 ^{0°}	3.34 ^{100°}	sl. s. dil. HCl, NH ₃ , i. al.
chromate (crocoite)	PbCrO ₄	323.22	yel., mn., 2.42	6.12	844	d.	0.000007 ^{20°}	i.	s. a., alk.; i. NH ₃ , ac.
chromate, basic	PbCrO ₄ ·PbO	546.43	or-yel. nd.				i.	i.	s. a., alk.
formate	Pb(HCO ₃) ₂	297.25	wh., rhb.	4.56	d. 190		1.6 ^{16°}	18 ^{100°} d.	i. al.
hydroxide	3PbO·H ₂ O	687.65	cb.	7.592	-H ₂ O, 130		0.014		s. a., alk.
nitrate	Pb(NO ₃) ₂	331.23	col., cb. or mn., 1.7815	4.53	d. 470		38.8 ^{0°}	138.8 ^{100°}	8.8 ^{22°} al.
oxide, sub-	Pb ₂ O	430.42	bk., amor.	8.34	d. red heat		i.	i.	s. a., alk.
oxide, mono- (litharge)	PbO	223.21	yel., tet.	9.53	888		0.0068 ^{18°}		s. alk., PbAc, NH ₄ Cl, CaCl ₂
oxide, mono (massicotite)	PbO	223.21	yel., rhb., 2.61	8.0					

oxide, mono-	PbO	223.21	amor.	9.2 to 9.5		i.	i.	s. alk., PbAc, NH ₄ Cl, CaCl ₂	
oxide, red (minium)	Pb ₃ O ₄	685.63	red, amor.	9.1	d. 500	i.	i.	s. ac., h. HCl	
oxide, sesqui-	Pb ₂ O ₃	462.42	red-yel., amor.		d. 360	i.	i.	s. a., alk.	
oxide, di- (plattnerite)	PbO ₂	239.21	brn., tet., 2.229	9.375	d. 290	i.	i.	s. ac., h. alk.; i. al.	
silicate	PbSiO ₃	283.27	col., mn., 1.961	6.49	766	i.	i.	s. a.	
sulfate (anglesite)	PbSO ₄	303.27	wh., mn. or rhb., 1.8823	6.2	1170	0.0028 ^{0°}	0.0056 ^{40°}	s. conc. a., NH ₄ salts; i. al.	
sulfate, acid	Pb(HSO ₄) ₂ ·H ₂ O	419.36	cr.		d.	0.0001 ^{18°}		sl. s. H ₂ SO ₄	
sulfate, basic (lanarkite)	PbSO ₄ ·PbO	526.48	col., mn.	6.92	977	0.0044 ^{18°}		sl. s. H ₂ SO ₄	
sulfide (galena)	PbS	239.27	lead gray, cb., 3.912	7.5	1120	0.00009 ^{18°}	i.	s. a.; i. alk.	
thiocyanate	Pb(CNS) ₂	323.37	col., mn.	3.82	d. 190	0.05 ^{30°}	s.	s. KCNS, HNO ₃	
Lithium	Li	6.94	silv. met. cb.	0.53 ^{20°}	186	1336 ± 5	d.	s. a., NH ₃	
benzoate	LiC ₇ H ₅ O ₂	128.05	wh. leaflets			33 ^{25°}	40 ^{100°}	7.7 ^{25°} , 10 ^{28°} al.	
bromide	LiBr	86.86	wh., delq., cb., 1.784	3.464 ^{25°} 4	547	1265	143 ^{0°} (H ₂ O) (1H ₂ O)	266 ^{100°} s. al., act.	
bromide	LiBr·2H ₂ O	122.89	wh. pr.		44		246 ^{20°}	s. al.	
carbonate	Li ₂ CO ₃	73.89	col., mn., 1.567	2.11 ^{0°}	618	d.	1.54 ^{0°}	0.72 ^{100°}	
chloride	LiCl	42.40	wh., delq., cb., 1.662	2.068 ^{25°} 4	614	1360	67 ^{0°}	127.5 ^{100°}	
citrate	Li ₃ C ₆ H ₅ O ₇ ·4H ₂ O	281.98	wh. cr.		d.	61.2 ^{15°}	66.7 ^{100°}	sl. s. al., et.	
fluoride	LiF	25.94	wh., cb., 1.3915	2.295 ^{21.5°}	870	1670	0.27 ^{18°}	0.135 ^{35°}	
formate	LiHCO ₂ ·H ₂ O	69.97	col., rhb.	1.46	-H ₂ O, 94		49.2 ^{0°}	346.6 ^{104°}	
hydride	LiH	7.95	wh., cb.	0.820	680		d.	i. et.	
hydroxide	LiOH	23.95	wh. cr.	2.54	445	925±	12.7 ^{0°}	sl. s. al.	
hydroxide	LiOH·H ₂ O	41.96	col., mn.	1.83		d.	22.3 ^{10°}	26.8 ^{90°}	
nitrate	LiNO ₃	68.95	col., trig., 1.735	2.38	261		53.4 ^{0°}	194 ^{70°}	
nitrate	LiNO ₃ ·3H ₂ O	123.00	col.		29.88	v. s.	∞	s. al., NH ₃	
oxide	Li ₂ O	29.88	col., 1.644	2.013 ^{25°} 4		subl. <1000	forms LiOH		
phosphate, monobasic	LiH ₂ PO ₄	103.94	col.	2.461	>100				
phosphate, tribasic	Li ₃ PO ₄	115.80	wh., rhb.	2.537 ^{17.5°}	837		0.034 ^{18°}	v. sl. s.	
phosphate, tribasic	Li ₃ PO ₄ ·12H ₂ O	331.99	wh., trig.	1.645	100		v. sl. s.	s. a., NH ₄ Cl; i. act.	
salicylate	LiC ₇ H ₅ O ₃	144.05	col.		d.	128 ^{26°}	v. s. al.		
sulfate	Li ₂ SO ₄	109.94	col., mn., 1.465	2.22	860		35.34 ^{0°}	i. act., 80% al.	
sulfate	Li ₂ SO ₄ ·H ₂ O†	127.96	col., mn., 1.477	2.06	-H ₂ O, 130		43.6 ^{0°}	i. 80% al.	
sulfate, acid	LiHSO ₄	104.01	pr.	2.123 ^{13°}	170.5	d.	35 ^{100°}		
Lutecium	Lu	174.99							
Magnesium	Mg	24.32	silv. met., hex.	1.74 ^{20°}	651	1110	i.	sl. s. d.	
acetate	Mg(C ₂ H ₃ O ₂) ₂	142.41	wh.	1.42	323		v. s.	s. a., NH ₄ salts 5.25 ^{15°} m. al.	
acetate	Mg(C ₂ H ₃ O ₂) ₂ ·4H ₂ O†	214.47	wh., mn. pr., 1.491	1.454	80		v. s.	v. s. al.	
aluminate (spinel)	MgO·Al ₂ O ₃	142.26	col. cb., 1.718–23	3.6	2135		i.	v. sl. s. dil. HCl; i. dil. HNO ₃	
ammonium chloride	MgCl ₂ ·NH ₄ Cl·6H ₂ O	256.83	wh., rhb., delq.	1.456	-4H ₂ O, 195	16.7	s.		
ammonium phosphate (struvite)	Mg ₂ NH ₄ PO ₄ ·6H ₂ O	245.44	col., rhb., 1.496	1.715	d. 100	0.0231 ^{0°}	0.0195 ^{80°}	s. a., i. al.	
ammonium sulfate	MgSO ₄ ·(NH ₄) ₂ SO ₄ ·6H ₂ O	360.62	col., mn.	1.72	>120	16.86 ^{0°}	130 ^{100°}		
(boussingaultite)									
benzoate	Mg(C ₇ H ₅ O ₂) ₂ ·3H ₂ O	320.59	wh. pd.		-3H ₂ O, 110	4.5 ^{25°} (anh.)	s.	s. act.	
carbonate (magnesite)	MgCO ₃	83.43	wh., trig., 1.700	3.037	d. 350	0.0106	s. a., aq. CO ₂ ; i. act., NH ₃		
carbonate (nesquehonite)	MgCO ₃ ·3H ₂ O	138.38	col., rhb., 1.501	1.852	-H ₂ O, 100	0.1518 ^{19°}	d.	s. a., aq. CO ₂	
carbonate, basic (hydrromagnesite)	3MgCO ₃ ·Mg(OH) ₂ ·3H ₂ O	365.37	wh., rhb., 1.530	2.16	d.	0.04	0.011	s. a., NH ₄ salts; i. al.	
Magnesium chloride (chloromagnesite)	MgCl ₂	95.23	col., hex., 1.675	2.325 ^{25°}	712	1412	52.8 ^{0°}	73 ^{100°}	50 al.
chloride (bischoffite)	MgCl ₂ ·6H ₂ O†	203.33	wh., delq., mn., 1.507	1.56	118 d.		281 ^{0°}	918 ^{100°}	50 al.
hydroxide (brucite)	Mg(OH) ₂	58.34	wh., trig., 1.5617	2.4	d.	0.0009 ^{18°}		s. NH ₄ salts, dil. a.	
nitride	Mg ₃ N ₂	100.98	gn.-yel., amor.			i.	d.	s. a.; i. al.	
oxide (magnesia; periclase)	MgO	40.32	col., cb., 1.7364	3.65	2800	3600	0.00062	s. a., NH ₄ salts; i. al.	
perchlorate	Mg(ClO ₄) ₂ †	223.23	wh., delq.	2.60 ^{25°}	d.	99.6 ^{25°}	v. s.	24 ²⁵ al., 51.8 ^{25°} m. al.; 0.29 et.	

[°]See also a table of alloys.

†Usual commercial form.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Magnesium chloride (<i>Cont.</i>)									
peroxide	MgO ₂	56.32	wh. pd.		expl. 275		i.	i.	s. a.
phosphate, pyro-	Mg ₂ P ₂ O ₇	222.60	col., mn., 1.604	2.598 ^{22°}	1383		i.	i.	s. a.; i. alk.
phosphate, pyro-	Mg ₂ P ₂ O ₇ ·3H ₂ O	276.65	wh., amor.	2.56	-3H ₂ O, 100		i.	sl. s.	s. a.; i. al.
potassium chloride (carnallite)	MgCl ₂ ·KCl·6H ₂ O	277.88	delq., rhb., 1.475	1.60 ^{19.4°} ₄	265		64.5 ^{19°} d.	d.	d. al.
potassium sulfate (picromerite)	MgSO ₄ ·K ₂ SO ₄ ·6H ₂ O	402.73	mn., 1.4629	2.15	d. 72		19.26 ^{0°}	81.7 ^{75°}	
silicofluoride	MgSiF ₆ ·6H ₂ O	274.48	col., trig., 1.3439	1.788 ^{17.5°} ₄	d.		64.8 ^{17.5°}	s.	d. HF
sodium chloride	MgCl ₂ ·NaCl·H ₂ O	171.70	col.				s.	s.	
sulfate	MgSO ₄	120.38	col.	2.66	1185		26.9 ^{0°}	68.3 ^{100°}	s. al.
sulfate (epsom salt; epsomite)	MgSO ₄ ·7H ₂ O°	246.49	col., rhb., 1.4554	1.68	70 d.		72.4 ^{0°}	178 ^{40°}	s. al.
Manganese	Mn	54.93	gray-pink met.	7.2 ^{20°}	1260	1900	d.	s. dil. a.	
acetate	Mn(C ₂ H ₃ O ₂) ₂	173.02		1.74 ^{20°} ₄			s.	s.	s. al., m. al.
acetate	Mn(C ₂ H ₃ O ₂) ₂ ·4H ₂ O°	245.08	pa. pink, mn.	1.589			s.	64.5 ^{50°}	s. aq. CO ₂ , dil. a.; l.
carbonate (rhodocrosite)	MnCO ₃	114.94	rose, trig., 1.817	3.125	d.		0.0065 ^{25°}		NH ₃ , al.
chloride (scacchite)	MnCl ₂	125.84	rose, delq., cb.	2.977 ^{25°} ₄	650		63.4 ^{0°}	123.8 ^{100°}	s. al.; i. et., NH ₃
chloride	MnCl ₂ ·4H ₂ O°	197.91	rose red, delq., mn.	2.01	58.0	-H ₂ O, 106;	151 ^{8°}	∞	s. al.; i. et.
chloride, per-	MnCl ₄	196.76	gn.				s.	s.	s. al., et.
hydroxide (ous) (pyrochroite)	Mn(OH) ₂	88.95	wh., trig.	3.258 ^{18°}	d.		0.002 ^{20°}	i.	s. a., NH ₄ salts; i. alk.
hydroxide (ic) (manganite)	Mn ₂ O ₃ ·H ₂ O	175.88	brn., rhb., 2.24	3.258	d.		i.	i.	s. h. H ₂ SO ₄
nitrate	Mn(NO ₃) ₂ ·6H ₂ O	287.04	rose red, mn.	1.82 ^{21°}	25.8	129.5	426 ^{0°}	∞	v. s. al.
oxide (ous) (manganosite)	MnO	70.93	gray-gn., cb., 2.16	5.18	1650		i.	i.	s. a., NH ₄ Cl
oxide (ic)	Mn ₂ O ₃	157.86	brn.-bk., cb.	4.81	-0, 1080		i.	i.	s. a.; i. act.
oxide, di-(pyrolusite; polianite)	MnO ₂ °	86.93	bk., rhb.	5.026	-0, >230		i.	i.	s. HCl; i. HNO ₃ , act.
sulfate (ous)	MnSO ₄	150.99	red-wh.	3.235	700	d. 850	53 ^{0°}	73 ^{50°}	s. al.; i. et.
sulfate (ous) (szmikite)	MnSO ₄ ·H ₂ O	169.01	pa. pink, mn., 1.595	2.87	Stable 57 to 117		98.47 ^{48°}	79.77 ^{100°}	
sulfate (ous)	MnSO ₄ ·2H ₂ O	187.02		2.526 ^{15°}	Stable 40 to 57		85.27 ^{35°}	106.8 ^{55°}	
sulfate (ous)	MnSO ₄ ·3H ₂ O	205.04		2.356 ^{15°}	Stable 30 to 40		74.22 ^{5°}	99.31 ^{57°}	
sulfate (ous)	MnSO ₄ ·4H ₂ O°	223.05	pink, rhb. or mn., 1.518	2.107	Stable 18 to 30	-4H ₂ O, 450	136 ^{16°}	169 ^{50°}	i. al.
sulfate (ous)	MnSO ₄ ·5H ₂ O	241.07	pink, tri., 1.508	2.103 ^{15°}	Stable 8 to 18		142 ^{5°}	200 ^{35°}	
sulfate (ous)	MnSO ₄ ·6H ₂ O	259.09			Stable -5 to +8		204 ^{0°}	247 ^{9°}	
sulfate (ous)	MnSO ₄ ·7H ₂ O	277.10	pink, mn. or rhb.	2.092	Stable -10 to -5; 19 d.	-7H ₂ O, 280	176 ^{0°}	251 ^{14°}	
sulfate (ic)	Mn ₂ (SO ₄) ₃	398.04	gn., delq. cr.	3.24	d. 160		v. s.	d.	s. HCl, dil. H ₂ SO ₄ ; l. conc. H ₂ SO ₄ , HNO ₃
Masurium	Ma	98-99.5		11.5	2300 (?)				
Mercuric acetate	Hg(C ₂ H ₃ O ₂) ₂	318.70	wh. pl.	3.270	d.		25 ^{10°}	100 ^{100°}	s. al., sl. d.
bromide	HgBr ₂	360.44	wh., rhb.	6.053	237	322	0.5 ^{20°}	25 ^{100°}	25 ^{20°} al.; v. sl. s. et.
carbonate, basic	HgCO ₃ ·2HgO	693.84	brn.-red				i.		s. aq. CO ₂ , NH ₄ Cl
chloride (corrosive sublimate)	HgCl ₂	271.52	wh., rhb., 1.859	5.44	277	304	3.6 ^{0°}	61.3 ^{100°}	33 ²³ 99% al.; 33 et.
fulminate	Hg(CNO) ₂	284.65	cb.	4.42	expl.		sl. s.		s. NH ₄ OH, al.
hydroxide	Hg(OH) ₂	234.63			-H ₂ O, 175		i.	i.	s. a.
oxide (montroydite)	HgO	216.61	yel. or red, rhb., 2.5	11.14	d. 100		0.0052 ^{25°}	0.041 ^{100°}	s. a.; i. al.
oxychloride (kleinitie)	HgCl ₂ ·3HgO	921.35	yel., hex.	7.93	d. 260		i.	d.	s. HCl
silicofluoride, basic	HgSiF ₆ ·HgO·3H ₂ O	613.33	yel. nd.				d.		s. a.
sulfate	HgSO ₄	296.67	wh., rhb.	6.47	d.		d.		s. a.; i. al., act., NH ₃
sulfate, basic (turpeth)	HgSO ₄ ·2HgO	729.89	yel., tet.	6.44			0.005	0.167 ^{100°}	s. a.; i. al.
Mercurous acetate	Hg ₂ C ₂ H ₃ O ₂	259.65	wh. sc.		d.		0.75 ^{13°}	d.	s. H ₂ SO ₄ , HNO ₃ ; i. al.
bromide	HgBr	280.53	wh., tet.	7.307	subl. 345		7 × 10 ⁻⁹	i.	s. a.; i. al., act.
carbonate	Hg ₂ CO ₃	461.23	yel. pd.		d. 130		i.	d.	s. NH ₄ Cl

chloride (calomel)	HgCl	236.07	wh., tet., 1.9733	7.150	302	383.7	0.0014°	0.0007 ^{43°}	s. aq. reg., Hg(NO ₃) ₂ ; sl. s. HNO ₃ ; HCl; i. al., etc.
iodide	HgI	327.53	yel., tet.	7.70	290 d.	subl. 140; 310d.	2×10^{-8}	v. sl. s.	s. KI; i. al.
nitrate	HgNO ₃ ·H ₂ O	280.63	wh. mn.	4.785 ^{3.9°}	70	expl.	v. s.	d.	s. HNO ₃ ; i. al., etc.
Mercurous oxide	Hg ₂ O	417.22	bk.	9.8	d. 100		i.	0.0007	s. h. ac.; i. alk., dil. HCl, NH ₃
sulfate	Hg ₂ SO ₄	497.28	wh., mn.	7.56	d.		0.055 ^{16.5°}	0.092 ^{100°}	s. H ₂ SO ₄ , HNO ₃
Mercury†	Hg	200.61	silv. lq. or hex.(?)	13.546 ^{20°}	-38.87	356.9	i.	i.	s. HNO ₃ ; i. HCl
Molybdenum	Mo	95.95	gray, cb.	10.2	2620 ± 10	3700	i.	i.	s. h. conc. H ₂ SO ₄ ; i. HCl, HF, NH ₃ , dil. H ₂ SO ₄ , Hg
chloride, di-	MoCl ₂	166.85	yel., amor.	3.714 ^{25°}	d.		i.	i.	s. HCl, H ₂ SO ₄ , NH ₄ OH, al., etc.
chloride, tri-	MoCl ₃	202.32	dark red pd.	3.578 ^{25°}	d.		i.	d.	s. HNO ₃ , H ₂ SO ₄ ; v. sl. s. al., etc.
chloride, tetra-	MoCl ₄	237.78	brn., delq.		volt.	d.	s.	d.	s. HNO ₃ , H ₂ SO ₄ ; sl. s. al., etc.
chloride, penta-	MoCl ₅	273.24	bk. cr.	2.928 ^{25°}	194	268	s.	d.	s. HNO ₃ , H ₂ SO ₄ ; i. abs. al., etc.
oxide, tri-(molybdite)	MoO ₃	143.95	col., rhb.	4.50 ^{19.5°}	795	subl.	0.107 ^{18°}	2.106 ^{79°}	s. a., NH ₄ OH
sulfide, di-(molybdenite)	MoS ₂	160.07	bk., hex., 4.7	4.801 ^{14°}	1185		i.	i.	s. H ₂ SO ₄ , aq. reg.
sulfide, tri-	MoS ₃	192.13	red-brn.		d.		sl. s.	s.	s. alk. sulfides
sulfide, tetra-	MoS ₄	224.19	brn. pd.		d.		i.	i.	s. alk. sulfides; i. NH ₃
Molybdcic acid	H ₂ MoO ₄	161.97	yel-wh., hex.		d. 115		v. sl. s.	sl. s.	s. NH ₄ OH, H ₂ SO ₄ ; i. NH
Molybdcic acid	H ₂ MoO ₄ ·H ₂ O	179.98	yel., mn.	3.124 ^{15°}	-H ₂ O, 70	-2H ₂ O, 200	0.133 ^{18°}	2.13 ^{70°}	s. a., NH ₄ OH, NH ₄ , salts
Neodymium	Nd	144.27	yellowish	6.9 ^{20°}	840		d.	d.	
Neon	Ne	20.18	col. gas	lq. 1.204 ^{-245.9°} 0.674 (A)	-248.67	-245.9	2.6° cc	1.1 ^{45°} cc	s. lq. O ₂ , al., act., bz.
Neptunium	Np ²³⁹	239							
Nickel	Ni	58.69	silv. met., cb.	8.90 ²⁰					
acetate	Ni(C ₂ H ₃ O ₂) ₂	176.78	gn. pr.	1.798	d.		16.6		
ammonium chloride	NiCl ₂ ·NH ₄ Cl·6H ₂ O	291.20	gn., delq., mn.	1.645			150 ^{25°}	v. s.	s. dil. HNO ₃ ; sl. s. H ₂ SO ₄ , HCl; i. NH ₃
ammonium sulfate	NiSO ₄ ·(NH ₄) ₂ SO ₄ ·6H ₂ O	394.99	blue-gn., mn., 1.5007	1.923			2.5 ^{3.5°}	39.2 ^{88°}	v. sl. s. (NH ₄) ₂ SO ₄
bromate	Ni(BrO ₃) ₂ ·6H ₂ O	422.62	gn., cb.	2.575	d.		28		s. NH ₄ OH
bromide	NiBr ₂	218.52	yel., delq.	4.64 ^{28°}	d.		112.8°	156 ^{100°}	s. al., et., NH ₄ OH
bromide	NiBr ₂ ·3H ₂ O	272.57	gn., delq.		-3H ₂ O, 200		199°	316 ^{100°}	s. al., et., NH ₄ OH
bromide, ammonia	NiBr ₂ ·6NH ₃	320.71	vl. pd.	1.837			v. s.	d.	i. c. NH ₄ OH
bromoplatinate	NiPtBr ₆ ·6H ₂ O	841.51	trig.	3.715					
carbonate	NiCO ₃	118.70	lt. gn., rhb.		d.		0.0093 ^{25°}	i.	s. a.
carbonate, basic	2NiCO ₃ ·3Ni(OH) ₂ ·4H ₂ O	587.58	lt. gn.		d.		i.	d.	s. a., NH ₄ salts
carbonyl	Ni(CO) ₄	170.73	lq.	1.31 ^{17°}	-25	43 ^{75.1mm}	0.018 ^{9.8°}	i.	s. aq. reg., HNO ₃ , al., et.
chloride	NiCl ₂	129.60	yel., delq.	3.544	subl.	973	53.8°	87.6 ^{100°}	s. NH ₄ OH, al.; i. NH ₃
chloride	NiCl ₂ ·6H ₂ O°	237.70	gn., delq., mn., 1.57±		subl. 250		180	v. s.	v. s. al.
chloride, ammonia	NiCl ₂ ·6NH ₃	231.80							s. NH ₄ OH; i. al.
cyanide	Ni(CN) ₂ ·4H ₂ O	182.79	gn. pl.		-4H ₂ O, 200	d.	i.	i.	s. KCN; i. dil. KCl
dimethylglyoxime	NiC ₈ H ₁₄ O ₄ N ₄	288.91	scarlet red cr.				i.	i.	s. abs. al., a.; i. ac., NH ₄ OH
formate	Ni(HCO ₃) ₂ ·2H ₂ O	184.76	gn. cr.	2.154	d.		s.		s. a., NH ₄ OH, NH ₄ Cl
hydroxide (ie)	Ni(OH) ₃	109.71	bk.		d.		i.	i.	s. a., NH ₄ OH; i. alk.
hydroxide (ous)	Ni(OH) ₂ ·4H ₂ O	97.21	lt. gn.	4.36	d.		v. sl. s.	v. sl. s.	s. NH ₄ OH; i. abs. al.
nitrate	Ni(NO ₃) ₂ ·6H ₂ O	290.80	gn., mn.	2.05	56.7	136.7	243.0 ^{0°}	$\infty^{56.7°}$	i. al.
nitrate, ammonia	Ni(NO ₃) ₂ ·4NH ₃ ·2H ₂ O	286.87					v. s.		s. a., NH ₄ OH
oxide, mono-(bunsenite)	NiO	74.69	gn.-bk., cb., 2.37	7.45		Forms Ni ₂ O ₃ at 400	i.	i.	d. a.
potassium cyanide	Ni(CN) ₂ ·2KCN·H ₂ O	258.97	red yel., mn.	1.875 ^{11°}	-H ₂ O, 100		s.		i. al., et. act.
sulfate	NiSO ₄	154.75	yel., cb.	3.68	-SO ₃ , 840		27.2°	76.7 ^{100°}	

[°]Usual commercial form.

†See also Tables 2-28 and 2-280.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Nickel (<i>Cont.</i>) sulfate	NiSO ₄ ·6H ₂ O°	262.85	gn. mn. or blue, tet., 1.5109	2.07	tr. 53.3	-6H ₂ O, 280	131° ^{50°}	280° ^{100°}	v. s. NH ₄ OH, al.
sulfate (morenosite)	NiSO ₄ ·7H ₂ O	280.86	gn., rhb., 1.4893	1.948	98–100	-6H ₂ O, 103	63.5° ^{0°}	117.8° ^{30°}	s. al.
Nitric acid	HNO ₃	63.02	col. lq.	1.502	-42	86	∞	∞	expl. with al.
Nitric acid	HNO ₃ ·H ₂ O	81.03	col. lq.		-38		∞	∞	d. al.
Nitric acid	HNO ₃ ·3H ₂ O	117.06	col. lq.		-18.5		263° ^{20°}	∞	d. al.
Nitro acid sulfite	NO ₂ HSO ₃	127.08	col., rhb.		73 d.		d.	s. H ₂ SO ₄	
Nitrogen	N ₂	28.02	col. gas or cb. cr.	1.026° ^{-252.5°} 0.808° ^{-195.8°}	-209.86	-195.8	2.35° ^{0°} cc	1.55° ^{20°} cc	sl. s. al.
Nitrogen oxide, mono- (ous)	N ₂ O	44.02	col. gas	lq. 1.226° ^{-89°} 1.530 (A)	-102.3	-90.7	130.52° ^{0°} cc	60.82° ^{24°} cc	s. H ₂ SO ₄ , al.
oxide, di- (ic)	NO or (NO) ₂	30.01 (60.02)	col. gas	lq. 1.269° ^{-150.2°} 1.0367 (A)	-161	-151	7.34° ^{0°} cc	0.0° ^{100°}	26.6 cc al.; 3.5 cc H ₂ SO ₄ ; s. aq. FeSO ₄
oxide, tri-	N ₂ O ₃	76.02	red-brn. gas or blue	1.447° ^{2°}	-102	3.5	s.		s. a. et.
oxide, tetra- (per- or di-)	NO ₂ or (NO ₂) ₂	46.01 (92.02)	lq. or solid yel. lq., col. solid, red-brn. gas	1.448° ^{20°}	-9.3	21.3	d.		s. HNO ₃ , H ₂ SO ₄ , chl., CS ₂
oxide, penta-	N ₂ O ₅	108.02	wh., rhb.	1.63° ^{18°}	30	47	s.		Forms HNO ₃
oxybromide	NOBr	109.92	brn. lq.	>1.0	-55.5	-2	d.		
oxychloride	NOCl	65.47	red-yel. lq. or gas	1.417° ^{-12°} 2.31 (A)	-64.5	-5.5	d.		s. fuming H ₂ SO ₄
Nitroxyl chloride	NO ₂ Cl	81.47	yel.-brn. gas	lq. 1.32° ^{14°}	<-30	5	d.		
Osmium	Os	190.2	blue, hex.	22.48° ^{20°}	2700	>5300	i.	i.	sl. s. aq. reg., HNO ₃ ; i. NH ₃
chloride, di-	OsCl ₂	261.11	gn., delq.				s. d.		s. NaCl, al.
chloride, tri-	OsCl ₃	296.57	brn., cb.				sl. s.		s. a., alk. al.; sl. s. et.
chloride, tetra-	OsCl ₄	332.03	red-yel. nd.				s. d.		s. HCl, al.
Oxygen	O ₂	32.00	col. gas or hex. solid	1.14° ^{-188°} 1.426° ^{-252.5°}	-218.4	-183	4.89° ^{0°} cc	2.6° ^{30°} cc 1.7° ^{100°} cc	sl. s. al., s. fused Ag
Ozone	O ₃	48.00	col. gas	1.71° ^{-183°} 3.03° ^{-80°} 1.658 (A)	-251	-112	0.494° ^{0°} cc	0° ^{60°} cc	s. oil turp., oil cinn.
Palladium	Pd	106.70	silv. met., cb.	12.0° ^{30°} 11° ^{1550°}	1555	2200	i.	i.	s. aq. reg., h. H ₂ SO ₄ ; i. NH ₃
bromide (ous)	PdBr ₂	266.53	brn.				i.	i.	s. HBr
chloride	PdCl ₂	177.61	brn., cb.		500 d.		s.	s.	s. HCl, act., al.
chloride	PdCl ₂ ·2H ₂ O	213.65	brn. pr.				s.	s.	s. HCl, act., al.
cyanide	Pd(CN) ₂	158.74	yel.		d.		i.	i.	s. HCN, KCN, NH ₄ OH; i. dil. a.
hydride	Pd ₂ H	214.41	met.	11.06	d.				s. a., NH ₄ OH
Palladous dichlorodiammine	Pd(NH ₃) ₂ Cl ₂	211.68	red or yel., tet.	2.5			s.		
Perchloric acid	HClO ₄	100.46	unstable, col. lq	1.768° ^{22°} ₄	-112	16° ^{18mm}	s.		
Perchloric acid	HClO ₄ ·H ₂ O	118.48	fairly stable nd.	1.88	50	d.	s.		
Perchloric acid	HClO ₄ ·2H ₂ O°	136.50	stable lq., col.	1.71° ^{25°} ₄	-17.8	200	v. s.		s. al.
Periodic acid	HIO ₄	191.93	wh. cr.		d. 138	subl. 110	s.		
Periodic acid	HIO ₄ ·2H ₂ O	227.96	delq., mn.		d. 110		v. s.	v. s.	sl. s. al., et.
Permanganic acid	HMnO ₄	119.94	exists only in solution				v. s.	d.	d. al.
Permolybodic acid	HMoO ₄ ·2H ₂ O	196.99	wh. cr.				v. s.	v. s.	
Persulfuric acid	H ₂ S ₂ O ₈	194.14	hyg. cr.		<60		v. s.	d.	
Phosphamic acid	PONH ₂ ·(OH) ₂	97.02	cb.		d.		v. s.	v. s.	i. al.
Phosphatomolybdc acid	H ₂ P(Mo ₂ O ₇) ₆ ·28H ₂ O	2365.88	yel. cb.		78	-25H ₂ O, 140	s.	s. HNO ₈	
Phosphine	PH ₃	34.00	col. gas	lq. 0.746° ^{-90°} 1.146 (A)	-132.5	-85	26° ^{17°} cc	i.° ^{100°}	s. Cu ₂ Cl ₂ , al., et.
Phosphonium chloride	PH ₄ Cl	70.47	wh., cb.		28° ^{46atm}	subl.	d.		

Phosphoric acid, hypo-	H ₄ P ₂ O ₆	161.99	cr.	55	d. 70	s.	450 ^{62°}	i. lq. CO ₂
Phosphoric acid, meta-	HPO ₃	79.99	vitreous, delq.	2.2–2.5	subl.	s.	Forms H ₃ PO ₄	
Phosphoric acid, ortho-	H ₃ PO ₄ [†]	98.00	col., rhb.	1.834 ^{18,2°}	42.35	– α H ₂ O, 213	v. s.	s. al.
Phosphoric acid, pyro-	H ₄ P ₂ O ₇	177.99	wh. nd.	61		2340 ^{26°}	Forms H ₃ PO ₄	v. s. al., et.
Phosphorous acid, hypo-	H ₃ PO ₂	66.00	syrupy	1.493 ^{18,8°}	26.5	d.	∞	∞
Phosphorous acid, ortho-	H ₃ PO ₃	82.00	col.	1.651 ^{21,2°}	74	d. 200	307.3 ^{0°}	730 ^{40°}
Phosphorous acid, pyro-	H ₄ P ₂ O ₆	145.99	nd.	38	d. 130	d.		
Phosphorus, black	P ₄	123.92	rhombohedral	2.69		ign. in air, 400	i.	i. CS ₂
Phosphorus, red	P ₄	123.92	red, cb.	2.20 ^{30°}	590 ^{63atm}	ign. in air, 725	i.	s. alk.; i. CS ₂ , NH ₃ , et.
Phosphorus, yellow	P ₄	123.92	yel., hex., 2.1168	1.82 ^{20°} ; lq. 1.745 ^{44,5°}	44.1; ign. 34	280	0.0003	0.4 al.; 1000 ^{10°} CS ₂ ; 1.5 ^{0°} , 10 ^{31°} bs.; s. NH ₃
chloride, tri-	PCl ₃	137.35	col., fuming lq.	1.574 ^{20,8°}	–111.8	75.95 ^{760mm}	d.	s. et., chl., CS ₂
chloride, penta-	PCl ₅	208.27	delq., tet.	solid 1.6; 3.60 ^{205°} (A)	148 under pressure	subl. 160	d.	s. CS ₂ , C ₆ H ₅ COCl
oxide, penta-	P ₂ O ₅	141.96	wh., delq., amor.	2.387	subl. 250			s. H ₂ SO ₄ ; i. NH ₃ , act.
oxychloride	POCl ₂	153.35	col., fuming lq.	1.675	2	107.2 ^{760mm}	Forms H ₃ PO ₄	d. al.
Phosphotungstic acid	P ₂ O ₅ ·2WO ₃ ·4H ₂ O	3681.67	yel.-gn. cr.				s.	s. al., et.
Platinum	Pt	195.23	silv. met., cb.	21.45 ^{30°} lq. 19 ^{1755°}	1755	4300	i.	s. aq. reg., fused alk.
chloride (ic)	PtCl ₄	337.06	brn.		d. 370		140 ^{25°}	v. s.
chloride (ous)	PtCl ₂	266.14	brn.	5.87 ^{11°}	d. 581		i.	i.
chloride (ic)	PtCl ₄ ·8H ₂ O	481.19	red, mn.	2.43	–4H ₂ O, 100		v. s.	s. al., et.
cyanide (ous)	Pt(CN) ₂	247.27	yel.-brn.				i.	i. alk.
Plutonium	Pu	238						
Plutonium	Pu	239						
Potassium	K	39.10	silv. met., cb.					
acetate	KC ₂ H ₃ O ₂	98.14	wh. pd.					
acetate, acid	KH(C ₂ H ₃ O ₂) ₂	158.19	delq. nd. or pl.					
aluminate	K ₂ (AlO ₂) ₂ ·3H ₂ O	250.18	cr.					
amide	KNH ₂	55.12	yel.-grn.					
arsenate (monobasic)	KH ₂ AsO ₄	180.02	col., tet., 1.5674	2.867	338	subl. 400		
auricyanide	KAu(CN) ₄ ·1.5H ₂ O	367.39	pl.		288		18.87 ^{6°}	v. s.
aurocyanide	KAu(CN) ₂	288.33	rhb.		d. 200		s.	i. al.
bicarbonate	KHCO ₃	100.11	mn., 1.482	2.17	d. 100–200		200 ^{100°}	s. al.; 3.6 ^{25°} NH ₃
bisulfate	KHSO ₄	136.16	rhb., or mn., 1.480	2.35	210	d.	22.4 ^{0°}	sl. s. al.; i. et.
bromate	KBrO ₃	167.01	trig.	3.27 ^{17.5°}	370 d.		36.3 ^{0°}	i. satd. K ₂ CO ₃ , al.
bromide	KBr	119.01	col., cb., 1.5594	2.75 ^{25°}	730	1380	3.11 ^{0°}	d. al.
carbonate	K ₂ CO ₃	138.20	wh., delq. pd., 1.531	2.29	891	d.	49.75 ^{100°}	sl. s. al.; i. act.
carbonate	K ₂ CO ₃ ·2H ₂ O	174.23	rhb.	2.043			53.5 ^{0°}	sl. s. al., et.
carbonate	2K ₂ CO ₃ ·3H ₂ O	330.45	mn.	2.13			105.5 ^{0°}	i. al.
chlorate	KClO ₃	122.56	col., mn., 1.5167	2.32	368	d. 400	183 ^{0°}	131 ^{100°}
chloride (sylvite)	KCl	74.56	col., cb., 1.4904	1.988	790	1500	129.4 ^{0°}	268 ^{100°}
chloroplatinate	K ₂ PtCl ₆	486.16	yel., cb., 1.825±	3.499	d. 250		57 ^{100°}	0.83 al.; s. alk.
chromate (tarapacaite)	K ₂ CrO ₄	194.20	yel., rhb., 1.7261	2.732 ^{18°}	975		27.6 ^{0°}	s. al., alk.
cyanate	KCNO	81.11	wh., tet.	2.048			56.7 ^{100°}	i. al., et.
cyanide	KCN	65.11	wh., cb., delq., 1.410	1.52 ^{16°}	634.5		0.74 ^{0°}	5.2 ^{100°}
dichromate	K ₂ Cr ₂ O ₇	294.21	red, tri.	2.69	398	d.	58.0 ^{0°}	i. al.
ferricyanide	K ₃ Fe(CN) ₆	329.25	red, mn. pr., 1.5689	1.84	d.		122.2 ^{108.8°}	s. gly.; 0.9 ^{19.5°} al.; 1.3 h. al.
ferrocyanide	K ₃ Fe(CN) ₆ ·3H ₂ O	422.39	yel., mn., 1.5772	1.853 ^{17°}	–3HO ₂ , 70		4.9 ^{0°}	i. al.
formate	KHCO ₂	84.11	col., rhb.	1.91	167.5	d.	80 ^{100°}	33 ^{4.4°}
hydride	KH	40.10	cb., 1.453	0.80	d.		77.5 ^{100°}	s. act.; sl. s. al.; i. NH ₃
hydrosulfide	KHS	72.16	wh., delq., rhab.	2.0	455		27.8 ^{12.2°}	s. act.; i. NH ₃ , al., et.
hydroxide	KOH	56.10	wh., delq., rhab.	2.044	380	1320	90.6 ^{6.8°}	sl. s. al.; i. et., bz., CS ₂
iodate	KIO ₃	214.02	col., mn.	3.89	560		65 ^{90°}	s. al.
iodide	KI	166.02	wh., cb., 1.6670	3.13	723	1330	4 ^{20°} al.; s. NH ₃ ; sl. s. et.	32.2 ^{100°}
							127.5 ^{0°}	178 ^{100°}
								v. s. al., et.; i. NH ₃
								s. KI; i. al., NH ₃
								4 ^{20°} al.; s. NH ₃ ; sl. s. et.

*One commercial form 70 to 72 per cent.

†Common commercial form 85 per cent H₃PO₄ in aqueous solution.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Potassium (Cont.)									
iodide, tri-iodoplatinate	KI ₃	419.86	dark blue, delq., mn.	3.498	45	d. 225	v. s.		s. KI, al.
manganate	K ₂ PtI ₆	1034.94	cb.	5.18	d. 190		s.		
metabisulfite	K ₂ MnO ₄	197.12	gn., rhb.		d. 150		d.		
nitrate (salt peter)	K ₂ S ₂ O ₅	222.31	mn., pl.		25°		25°	120 ^{94°}	s. KOH
nitrite	KNO ₃	101.10	col., rhb., 1.5038	2.11 ^{10.6°}	tr. 129; 333	d. 400	13.3°	246 ^{100°}	sl. s. al.; i. et.
oxalate	KNO ₂	85.10	pr.	1.915	297	d. 350	281°	413 ^{100°}	0.1 ^{30°} al.; i. et.
oxalate, acid	K ₂ C ₂ O ₄ ·H ₂ O	184.23	wh., mn.	2.13	d.		28.7°	83.2 ^{100°}	v. s. NH ₃ ; sl. s. al.
oxalate, acid	KHC ₂ O ₄ °	128.12	mn., 1.545	2.0	d.		14.3 ^{30°}	48.1 ^{100°}	
oxide	KHC ₂ O ₄ ·aH ₂ O	137.13	trimetric		d.		2.2°	51.5 ^{100°}	
perchlorate	K ₂ O	94.19	wh., cb.	2.32 ^{20°}			Forms KOH	v. s.	s. al., et.
permanganate	KClO ₄	138.55	col., rhb., 1.4737	2.524 ^{11°}	d. 400		0.75°	21.8 ^{100°}	0.105 ^{20°} m. al.; i. et.
persulfate	KMnO ₄	158.03	purple, rhb.	2.703	d. <240		2.83°	32.35 ^{75°}	s. H ₂ SO ₄ ; d. al.
phosphate, monobasic	K ₂ S ₂ O ₃	270.31	wh., tri., 1.4669		d. <100		1.77°	10°	i. al.
phosphate, dibasic	KH ₂ PO ₄	136.09	col., delq., tet., 1.5095	2.338	256		14.8°	83.5 ^{90°}	i. al.
phosphate, tribasic	K ₂ HPO ₄	174.18	wh., delq.		d.		33 ^{25°}	v. s.	sl. s. al.
phosphate, meta-phosphate, meta-phosphate, pyro-	K ₂ PO ₄	212.27	wh., rhb.	2.564 ^{17°}	1340		193.1 ^{25°}	v. s.	i. al.
phosphate, meta-phthalate, acid	KPO ₃	118.08	wh. pd.	2.258 ^{14.5°}	tr. 450; 798	1320	s.		
platinocyanide	K ₄ Pt ₂ O ₁₂ ·2H ₂ O	508.34	amor.	2.264 ^{14.5°}	-2H ₂ O, 100	d.	s.	83	s. a.
silicate	K ₄ Pt ₂ O ₇ ·3H ₂ O	384.39	delq.	2.33	-2H ₂ O, 180	-3H ₂ O, 300	s.	v. s.	i. al.
silicate, tetra-	KHC ₈ H ₄ O ₄	204.22	wh. cr.	1.63	d.		10.2 ^{25°}	36	
sulfate (arcanite)	K ₂ Pt(CN) ₄ ·3H ₂ O	431.54	yel., rhb., 1.62±	2.45 ^{16°}			sl. s.	v. s.	s. al., et.
Potassium sulfate, pyro-sulfide, mono-sulfite	K ₂ SiO ₃	154.25	hyg. 1.521±		976		s.	s.	i. al.
sulfite, acid	K ₂ SO ₃ ·2H ₂ O	352.45	rhb., 1.530	2.417	d. 400		s.	s.	i. al.
tartrate	KHSO ₃	174.25	col., rhb., 1.4947	2.662	tr. 588		7.35°	24.1 ^{100°}	i. al., act., CS ₂
tartrate, acid	K ₂ S ₂ O ₇	254.31	col.	2.277	300		s.	d.	
thiocyanate	K ₂ S·5H ₂ O	200.33	rbh., delq.		60	-3H ₂ O, 150	s.		
thiosulfate	K ₂ SO ₃ ·2H ₂ O	194.28	wh., rhb.		d.		100	>100	sl. s. al.; i. NH ₃
Praseodymium	Pr	120.16	wh., mn.		d. 190		45.5 ^{15°}	91.5 ^{75°}	i. abs. al.
Radium	Ra	235.27	col., mn., 1.526	1.98	d.		12.5 ^{17.5°}	278 ^{100°}	sl. s. al.
bromide	RaBr ₂	385.88	col., rhb.	1.956			0.37°	6.1 ^{100°}	s. a., alk.; i. al., ac.
Radon (Niton)	Rn	188.18	col., delq., mn., 1.886	1.886	172.3	d. 500	177°	217 ^{20°}	20.8 ^{22°} act.; s. al.
Rhenium	Re	186.31	hex.		3440				i. HF, HCl; s. H ₂ SO ₄ ; HNO ₃
Rhodium	Rh	102.91	gray-wh., cb.	12.5	1955	>2500	i.	i.	sl. s. aq. reg., a.
chloride	RhCl ₃	209.28	red		d. 450	subl. 800±	i.	i.	v. sl. s. alk.; i. aq. reg., a.
chloride	RhCl ₃ ·4H ₂ O	281.35	dark red				v. s.		s. HCl, al.; i. et.
Rubidium	Rb	85.48	silv. wh.	lq. 1.475 ^{88.5°} ; 1.53 ^{20°}	38.5	700	d.		s. a., al.
Ruthenium	Ru	101.70	bk., porous	8.6	>1950		i.	i.	sl. s. aq. reg., a.
Ruthenium	Ru	101.70	gray, hex.	12.2 ^{20°}	2450	>2700	i.	i.	
Samarium	Sm (also Sa)	150.43		7.7	>1300				
Scandium	Sc	45.10		2.5?	1200	2400			
Selenic acid	H ₂ SeO ₄	144.98	hex. pr.	2.950 ^{15°}	58	260	1300 ^{30°}	∞ ^{60°}	s. H ₂ SO ₄ ; d. al.; i. NH ₃
Selenic acid	H ₂ SeO ₄ ·H ₂ O	162.99	nd.	2.627 ^{15°}	26	205	v. s.		
Selenium	Se ₈	631.68	red pd., amor., 2.92	4.26 ^{25°}	50	688	i.	i.	s. CS ₂ , H ₂ SO ₄ , CH ₂ I ₂
Selenium	Se ₈	631.68	gray, trig., 3.00; red, hex.	4.80; 4.50	220	688	i.	i.	s. CS ₂ , H ₂ SO ₄

Selenium	Se ₈	631.68	steel gray	4.8 ^{25°}	217	688	i.	i.	i. CS ₂ ; s. H ₂ SO ₄
Selenous acid	H ₂ SeO ₃	128.98	hex.	3.004 ^{15°} ₄	d.	90°	400 ^{90°}	v. s. al.; i. NH ₃	v. s. al.; i. NH ₃
Silicic acid, meta-	H ₂ SiO ₃	78.08	amor., 1.41	2.1–2.3		i.	i.	s. alk.; i. NH ₄ Cl	s. alk.; i. NH ₄ Cl
Silicic acid, ortho-	H ₄ SiO ₄	96.09	amor.	1.576 ^{17°}		sl. s.	sl. s.	s. HNO ₃ + HF; Ag; sl. s.	s. HNO ₃ + HF; Ag; sl. s.
Silicon, crystalline	Si	28.06	gray, cb., 3.736	2.4 ^{20°}	1420	2600	i.	Pb, Zn; i. HF	Pb, Zn; i. HF
Silicon, graphitic	Si	28.06	cr.	2.0–2.5		2600	i.	s. HNO ₃ + HF, fused alk.; i. HF	s. HNO ₃ + HF, fused alk.; i. HF
Silicon, amorphous	Si	28.06	brn., amor.	2		2600	i.	s. HF, KOH	s. HF, KOH
carbide	SiC	40.07	blue-bk, trig., 2.654	3.17	>2700	subl. 2200	i.	s. fused alk.; i. a.	s. fused alk.; i. a.
chloride, tri-	Si ₂ Cl ₆	268.86	lf. or lq.	1.58 ^{0°}	-1	144 ^{760mm}	d.	d. alk.	d. alk.
chloride, tetra-	SiCl ₄	169.89	col., fuming lq., 1.412	1.50	-70	57.6	d.	d. conc. H ₂ SO ₄ , al.	d. conc. H ₂ SO ₄ , al.
fluoride	SiF ₄	104.06	gas	3.57 (A)	-95.7	-65 ^{1810mm}	v. s. d.	s. HNO ₃ , al. et.	s. HNO ₃ , al. et.
hydride (silane)	SiH ₄	32.09	col. gas	lq. 0.68 ^{-185°}	-185	-112 ^{760mm}	i.	i. al. et.; d. KOH	i. al. et.; d. KOH
oxide, di- (opal)	SiO ₂ ·H ₂ O		iridescent, amor.	2.2	1600–1750	subl. 1750	i.	s. HF, h. alk., fused CaCl ₂	s. HF, h. alk., fused CaCl ₂
oxide, di- (cristobalite)	SiO ₂	60.06	col., cb. or tet., 1.487	2.32	1710	2230	i.	s. HF; i. alk.	s. HF; i. alk.
oxide, di- (lechatelierite)	SiO ₂	60.06		2.20		2230	i.	s. HF; i. alk.	s. HF; i. alk.
oxide, di- (quartz)	SiO ₂	60.06	hex., 1.5442	2.650 ^{20°}	tr. <1425	2230	i.	s. HF; i. alk.	s. HF; i. alk.
oxide, di- (tridymite)	SiO ₂	60.06	trig., rhb., 1.469	2.26	tr. 1670	2230	i.	s. HF; i. alk.	s. HF; i. alk.
Silver	Ag	107.88	silv. met., cb.	10.5 ^{30°}	960.5	1950	i.	s. HNO ₃ , h. H ₂ SO ₄ ; i. alk.	s. HNO ₃ , h. H ₂ SO ₄ ; i. alk.
bromide (bromyrite)	AgBr	187.80	pa. yel., cb., 2.252	6.473 ^{25°} ₄	434	d. 700	0.00002 ^{20°}	0.00037 ^{100°}	0.51 ^{18°} NH ₄ OH; s. KCN, Na ₂ S ₂ O ₃
carbonate	Ag ₂ CO ₃	275.77	yel. pd.	6.077	218 d.		0.003 ^{20°}	0.05 ^{100°}	s. NH ₄ OH, Na ₂ S ₂ O ₃ ; i. al.
chloride (cerargyrite)	AgCl	143.34	wh., cb., 2.071	5.56	455	1550	0.000089 ^{10°}	0.00217 ^{100°}	s. NH ₄ OH, KCN; sl. s. HCl
cyanide	AgCN	133.90	wh., 1.685±	3.95	-(CN) ₂ , 320		0.000022 ^{20°}	952 ^{100°}	s. NH ₄ OH, KCN, HNO ₃
nitrate (lunar caustic)	AgNO ₃	169.89	col., rhb., 1.744	4.352 ^{19°} ₄	212	444 d.	1220°		s. gly.; v. sl. s. al.
Sodium	Na	22.997	silv. met., cb.	0.97 ^{30°}	97.5	880	d., forms NaOH	i. bz.; d. al.	i. bz.; d. al.
acetate	NaC ₂ H ₅ O ₂	82.04	wh., mn., 1.464	1.528	324	46.5 ^{20°}	170 ^{100°}	2.1 ^{18°} al.	2.1 ^{18°} al.
acetate	NaC ₂ H ₅ O ₂ ·3H ₂ O	136.09	wh., mn.	1.45	58	-3H ₂ O, 120	v. s.	7.8 ^{35°} abs. al.	7.8 ^{35°} abs. al.
aluminate	NaAlO ₂	81.97			1650			i. al.	i. al.
amide	NaNH ₂	39.02	olive gn.	210	400			d. al.	d. al.
Sodium ammonium phosphate	NaNH ₄ HPO ₄ ·4H ₂ O	209.09	col., mn.	1.574	79 d.	16.7	100	i. al.	i. al.
antimonate, meta-	2NaSbO ₃ ·7H ₂ O	511.63	cb.			0.031 ^{12.8°}		sl. s. al., NH ₄ salts; i. ac.	sl. s. al., NH ₄ salts; i. ac.
arsenate	Na ₃ AsO ₄ ·12H ₂ O	424.09	hex., 1.4589	1.759	86.3	26.7 ^{77°}		1.67 al., 50 ^{15°} gly.	1.67 al., 50 ^{15°} gly.
arsenate, acid (monobasic)	NaH ₂ AsO ₄ ·H ₂ O	181.94	rhb., 1.5535	2.535	d. 100	61 ^{15°}	v. s.	sl. s. al.	sl. s. al.
arsenate, acid (dibasic)	Na ₂ As ₂ O ₇ ·7H ₂ O*	312.02	col., mn., 1.4658	1.871	125	-7H ₂ O, 100	140.7 ^{30°}	sl. s. al.	sl. s. al.
arsenate, acid (dibasic)	Na ₂ As ₂ O ₇ ·12H ₂ O	402.10	mn., 1.4496	1.72	28	-12H ₂ O, 100			
arsenite, acid	Na ₂ AsO ₃	169.91	col.	1.87		v. s.			
benzoate	NaC ₇ H ₅ O ₂	144.11	col. cr.			62.5 ^{25°}	76.9 ^{100°}	2.3 ^{25°} , 8.3 ^{78°} al.	2.3 ^{25°} , 8.3 ^{78°} al.
bicarbonate	NaHCO ₃	84.01	wh., mn., 1.500	2.20	-CO ₂ , 270	6.9°	16.4 ^{60°}	i. al.	i. al.
bifluoride	NaHF ₂	62.00	col. cr.	d.		3.7 ^{20°}	s.		
bisulfate	NaHSO ₄	120.06	col., tri.	2.742	>315	d., -H ₂ O	50°	100 ^{100°}	d. al.; i. NH ₃
bisulfite	NaHSO ₃	104.06	col., mn., 1.526	1.48	d.	sl. s.	s.	i. al., act.	i. al., act.
borate, tetra-	Na ₂ B ₄ O ₇	201.27		2.367	741	1.3°	8.79 ^{40°}	i. al.	i. al.
borate, tetra-	Na ₂ B ₄ O ₇ ·5H ₂ O	291.35	col., rhb., 1.461	1.815		22 ^{63°} (anh.)	52.3 ^{100°}		
borate, tetra- (borax)	Na ₂ B ₄ O ₇ ·10H ₂ O*	381.43	wh., mn., 1.4694	1.73	75	-10H ₂ O, 200	1.3 ^{0.5} (anh.)	20.3 ^{80°} (anh.)	s. gly.; i. abs. al.
bromate	NaBrO ₃	150.91	col., cb.	3.339 ^{17.5°}	381		27.5°	90.9 ^{100°}	i. al.
bromide	NaBr	102.91	col., cb., 1.6412	3.205 ^{17.5°}	755	1390	90 ^{30°}	121 ^{100°}	sl. s. al.
bromide	NaBr·2H ₂ O	138.95	col., mn.	2.176	50.7		79.5° (anh.)	118.3 ^{80°} (anh.)	sl. s. al.
carbonate (soda ash)	Na ₂ CO ₃	106.00	wh. pd., 1.535	2.533	851	d.	7.1°	48.5 ^{104°}	i. al., et.
carbonate	Na ₂ CO ₃ ·H ₂ O	124.02	wh., rhb., 1.506–1.509	1.55	-H ₂ O, 100	s.	s.	s. gly.; i. al., et.	s. gly.; i. al., et.
carbonate	Na ₂ CO ₃ ·7H ₂ O	232.12	rhb. or trig.	1.51	d. 35.1				
carbonate (sal soda)	Na ₂ CO ₃ ·10H ₂ O	286.16	wh., mn., 1.425	1.46			21.5°	238 ^{30°}	i. al.

*Usual commercial form.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Continued)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Sodium ammonium phosphate (Cont.)									
carbonate, sesqui- (trona)	Na ₃ H(CO ₃) ₂ ·2H ₂ O	226.05	wh., mn., 1.5073	2.112	d.	13°	42 ^{100°}		
chlorate	NaClO ₃	106.45	wh., cb., or trig., 1.5151	2.490 ^{15°}	248	d.	79°	230 ^{100°}	s. al.
chloride	NaCl	58.45	col., cb., 1.5443	2.163	800.4	1413	35.7°	39.8 ^{100°}	sl. s. al.; i. conc. HCl
chromate	Na ₂ CrO ₄	162.00	yel., rhb.	2.723	392		32°	126 ^{100°}	
chromate	Na ₂ CrO ₄ ·10H ₂ O	342.16	yel., delq., mn.	1.483	19.9		v. s.	∞	sl. s. al.
citrate	2Na ₃ C ₆ H ₅ O ₇ ·11H ₂ O	714.36	wh., rhb.	1.857 ^{23.5°}	-11H ₂ O, 150	d.	91 ^{25°}	250 ^{100°}	i. al.
cyanide	NaCN	49.02	wh., cb., 1.452	563.7	1496		48 ^{10°}	82 ^{35°}	s. NH ₃ ; sl. s. al.
dichromate	Na ₂ Cr ₂ O ₇ ·2H ₂ O	298.05	red, mn., 1.6994	2.52 ^{18°}	-2H ₂ O, 84.6; 356 (anh.)	d. 400	238°	508 ^{80°}	
ferricyanide	Na ₃ Fe(CN) ₆ ·H ₂ O	298.97	red, delq.				18.9°	67 ^{100°}	i. al.
ferrocyanide	Na ₄ Fe(CN) ₆ ·10H ₂ O	484.11	yel., mn.	1.458			17.9 ^{20°} (anh.)	63 ^{98.5°} (anh.)	i. al.
fluoride (villiaumite)	NaF	42.00	tet., 1.3258	2.79	992		4°	5 ^{100°}	v. sl. s. al.
formate	NaHCO ₂	68.01	wh., mn.	1.919	253		44°	160 ^{100°}	sl. s. al.; i. et.
hydride	NaH	24.005	silv. nd., 1.470	0.92	d. 800		d.		i. bz., CS ₂ , CCl ₄ , NH ₃ ; s. molten metal
hydrosulfide	NaSH·2H ₂ O	92.10	col., delq., nd.		d.		s.	s.	s. al.; d. a.
hydrosulfide	NaSH·3H ₂ O	110.11	rhb.		22		s.	s.	s. al.; d. a.
hydrosulfite	Na ₂ S ₂ O ₄ ·2H ₂ O	210.15	col. cr.		d.		22 ^{20°}	d.	i. al.
hydroxide	NaOH	40.00	wh., delq.	2.130	318.4	1390	42°	347 ^{100°}	v. s. al., et., gly.; i. act.
hydroxide	NaOH·3aH ₂ O	103.06	mn.		15.5		s.	v. s.	
hypochlorite	NaOCl	74.45	pa. yel., in soln. only		d.		26°	158 ^{56°}	
iodide	NaI°	149.92	col., cb., 1.7745	3.667 ^{0°}	651	1300	158.7°	302 ^{100°}	v. s. al., act.
iodide	NaI·2H ₂ O	185.95	col., mn.	2.448			v. s.	v. s. NH ₃	v. s. NH ₃
lactate	NaC ₃ H ₅ O ₃	112.07	col., amor.		d.		v. s.	s. al.; i. et.	
nitrate (soda niter)	NaNO ₃	85.01	col., trig., 1.5874	2.257	308	d. 380	75°	180 ^{100°}	s. NH ₃ ; sl. s. gly., al.
nitrite	NaNO ₂	69.01	pa. yel., rhb.	2.168 ^{0°}	271	d. 320	72.1°	163.2 ^{100°}	0.3 ^{30°} et.; 0.3 abs. al.; 4.4 ^{20°} m. al.; v. s. NH ₃
oxide	Na ₂ O	61.99	wh., delq.	2.27	subl.		Forms NaOH		d. al.
perborate	NaBO ₃ ·H ₂ O	99.83	wh. pd.		d. 40		sl. s.	d.	s. gly., alk.
perchlorate	NaClO ₄	122.45	rhb., 1.4617		482 d.		170°	320 ^{100°}	s. al.; 51 m. al.; 52 act.; i. et.
perchlorate	NaClO ₄ ·H ₂ O	140.47	hex.	2.02	d. 130		209 ^{15°}	284 ^{50°}	s. al.
peroxide	Na ₂ O ₂ °	77.99	yel.-wh. pd.	2.805	d.		s. d.	d.	s. dil. a.
peroxide	Na ₂ O ₂ ·SH ₂ O	222.12	wh., hex.		d. 30		s. d.	d.	
phosphate, monobasic	NaH ₂ PO ₄ ·H ₂ O°	138.01	col., rhb., 1.4852	2.040	-H ₂ O, 100	d. 200	71°	390 ^{83°}	i. al.
phosphate, monobasic	NaH ₂ PO ₄ ·2H ₂ O	156.03	col., rhb., 1.4629	1.91	60		91.1°	305 ^{40°}	
phosphate, dibasic	Na ₂ HPO ₄ ·7H ₂ O	268.09	col., mn., 1.4424	1.679	d.		185 ^{40°}	2000 ^{100°}	
phosphate, dibasic	Na ₂ HPO ₄ ·12H ₂ O	358.17	col., mn., 1.4361	1.52	34.6	-12H ₂ O, 180	4.3°	76.7 ^{30°}	i. al.
phosphate, tribasic	Na ₃ PO ₄	163.97	wh.	2.537 ^{17.5°}	1340		4.5°	77 ^{100°}	
phosphate, tribasic	Na ₃ PO ₄ ·12H ₂ O°	380.16	wh., trig., 1.4458	1.62	73.4	-11H ₂ O, 100	28.3 ^{15°}	∞	i. CS ₂
phosphate, meta-	Na ₄ P ₂ O ₁₂	407.91	col.	2.476	616 d.		s.	s. a., alk.	
phosphate, pyro-	Na ₄ P ₂ O ₇ °	265.95	wh.	2.45	988		2.26°	45 ^{96°}	d. a.
phosphate, pyro-	Na ₄ P ₂ O ₇ ·10H ₂ O	446.11	mm., 1.4525	1.82	d.		5.4°	93 ^{100°}	i. al., NH ₃
phosphate (pyrodisodium)	Na ₃ H ₂ P ₂ O ₇	221.97	col., mn., 1.510	1.862	d. 220		4.5°	21 ^{40°}	
potassium tartrate	NaKC ₄ H ₄ O ₆ ·4H ₂ O	282.23	rhb., 1.493	1.790	70 to 80	-4H ₂ O, 215	6.9°	36 ^{40°}	
silicate, meta-	Na ₂ SiO ₃	122.05	col., rhb., 1.520		1088		26°	66 ^{26°}	sl. s. al.
Sodium silicate, meta-	Na ₂ SiO ₃ ·9H ₂ O	284.20	rhb.		47	-6H ₂ O, 100	s.	s. d.	i. Na or K salts, al.
silicate, ortho-	Na ₄ SiO ₄	184.05	col., hex., 1.530		1018		v. s.	v. s.	29 ^{18°} , aN NaOH
silicofluoride	Na ₂ SiF ₆	188.05	wh., hex., 1.312	2.679	d.		0.44°	2.45 ^{100°}	i. al.
stannate	Na ₂ SnO ₃ ·3H ₂ O	266.74	hex. tablets		140		50°	67 ^{30°}	i. al., act.
sulfate (thenardite)	Na ₂ SO ₄	142.05	col., rhb., 1.477	2.698	tr. 100 to mn.		5°	42 ^{100°}	i. al.
sulfate	Na ₂ SO ₄	142.05	col., mn.		tr. 500 to hex.		48.8 ^{40°}	42.5 ^{100°}	d. HI; s. H ₂ SO ₄

sulfate	Na ₂ SO ₄	142.05	col., hex.		884		19.4 ^{20°}	45.3 ^{60°}	
sulfate	Na ₂ SO ₄ .7H ₂ O	268.17	tet.				44.9 ^{0°}	202.6 ^{26°}	
sulfate (Glauber's salt)	Na ₂ SO ₄ .10H ₂ O	322.21	col., mn., 1.396	1.464	32.4	-10H ₂ O, 100	36 ^{15°}	412 ^{34°}	i. al.
sulfide, mono-	Na ₂ S	78.05	pink or wh., amor.	1.856			15.4 ^{10°}	57.3 ^{90°}	sl. s. al.; i. et.
sulfide, tetra-	Na ₂ S ₄	174.23	yel., cb.		275		s.	s.	s. al.
sulfide, penta-	Na ₂ S ₅	206.29	yel.		251.8		s.	s.	s. al.
sulfite	Na ₂ SO ₃	126.05	hex. pr., 1.565	2.633 ^{15°} ₄	d.		13.9 ^{0°}	28.3 ^{84°}	i. al., NH
sulfite	Na ₂ SO ₃ .7H ₂ O	252.17	mn.	1.561	-7H ₂ O, 150	d.	34.7 ^{2°}	67.8 ^{18°}	i. al.
tartrate	Na ₃ C ₄ H ₄ O ₆ .2H ₂ O	230.10	rhb.	1.818			29 ^{6°}	66 ^{43°}	i. al.
thiocyanate	NaCNS	81.08	delq., rhb., 1.625±		287		110 ^{10°}	225 ^{100°}	v. s. al.
thiosulfate	Na ₂ S ₂ O ₃	158.11	mn.	1.667			50°	231 ^{80°}	
thiosulfate (hypo)	Na ₂ S ₂ O ₃ .5H ₂ O°	248.19	mn. pr., 1.5079	1.685	d. 48.0		74.7 ^{0°}	301.8 ^{60°}	s. NH ₃ ; v. sl. s. al.
tungstate	Na ₂ WO ₄	293.91	wh., rhb.	4.179	692		57.5S ^{0°}	97 ^{100°}	sl. s. NH ₃ ; i. a., al.
tungstate	Na ₂ WO ₄ .2H ₂ O°	329.95	wh., rhb.	3.245	-2H ₂ O, 100		88 ^{0°}	123.5 ^{100°}	
tungstate, para-	Na ₂ WO ₄ .16H ₂ O	2097.68	wh., tri.	3.987 ^{14°}	-16H ₂ O, 300		8	d.	
uranate	Na ₂ UO ₄	348.06	yel.				i.	i.	s. alk. carb., dil. a.
vanadate	Na ₃ VO ₄ .16H ₂ O	472.20	col. nd.		866 (anh.)		v. s.	d.	i. al.
vanadate, pyro-	Na ₄ V ₂ O ₇	305.89	hex.		654		s.	d.	i. al.
Stannic chloride	SnCl ₄	260.53	col., fuming lq.	2.226	-30.2	114.1	s.	d.	s. abs. al., act., NH ₃ ; s. ∞ CS ₂
oxide (cassiterite)	SnO ₂	150.70	wh., tet., 1.9968	7.0	1127		i.	i.	s. conc. H ₂ SO ₄ ; i. alk.;
sulfate	Sn(SO ₄) ₂ .2H ₂ O	346.85	col., delq., hex.				v. s.	d.	s. dil. H ₂ SO ₄ , HCl; d.
Stannous bromide	SnBr ₃	278.53	yel., rhb.	5.12 ^{17°}	215.5	620	s.	d.	abs. al.
chloride	SnCl ₂	189.61	wh., rhb.		246.8	623	83.9 ^{0°}	269.8 ^{15°}	s. C ₆ H ₅ N
chloride (tin salt)	SnCl ₂ .2H ₂ O°	225.65	wh., tri.	2.71 ^{15.5°}	37.7	d.	∞	s. alk., abs. al., et.	
sulfate	SnSO ₄	214.76	wh. cr.		-SO ₂ , 360		118.7 ^{0°}	s. tart. a., alk., al.	
Strontrium	Sr	87.63	silv. met.	2.6	800	1150	19 ^{10°}	s. H ₂ SO ₄	
							18 ^{100°}	s. al., a.	
acetate	Sr(C ₂ H ₃ O ₂) ₂	205.72	wh. cr.	2.099			Forms Sr(OH) ₂		
carbonate (strontianite)	SrCO ₃	147.64	wh., rhb., 1.664	3.70	1497 ^{0atm}		36.9 ^{0°}	36.4 ^{47°}	0.26 ^{15°} m. al.
chloride	SrCl ₂	158.54	wh., cb., 1.6499	3.052	873	-CO ₂ , 1350	0.0011 ^{18°}	0.065 ^{100°}	s. a., NH ₃ salts, aq. CO ₂
chloride	SrCl ₂ .6H ₂ O°	266.64	wh., rhb., 1.5364	1.933 ^{17°}	-4H ₂ O, 61	-6H ₂ O, 100	43.5 ^{0°}	100.8 ^{100°}	v. sl. s. act., abs. al.; i. NH ₃
hydroxide	Sr(OH) ₂	121.65	wh., delq.	3.625	375		104 ^{0°}	198 ^{40°}	
hydroxide	Sr(OH) ₂ .8H ₂ O°	265.77	col., tet., 1.499	1.90	-7H ₂ O in dry air		0.41 ^{0°}	21.83 ^{100°}	s. NH ₄ Cl
							0.90 ^{0°}	47.7 ^{100°}	s. NH ₄ Cl; i. act.
nitrate	Sr(NO ₃) ₂ °	211.65	col., cb., 1.5878	2.986	570		40 ^{0°}	100 ^{80°}	s. NH ₃ ; 0.012 abs. al.
nitrate	Sr(NO ₃) ₂ .4H ₂ O	283.71	wh., mn.	2.2			62.2 ^{0°}	124 ^{20°}	i. HNO ₃
oxide (strontia)	SrO	103.63	col., cb., 1.870	4.7	2430		Forms Sr(OH) ₂		sl. s. al.; i. et.
peroxide	SrO ₂	119.63	wh. pd.		d.		0.008 ^{20°}	d.	s. al., NH ₄ Cl; i. act.
peroxide	SrO ₂ .8H ₂ O	263.76	wh. cr.		-8H ₂ O, 100	d.	0.018 ^{20°}	d.	s. al.; i. NH ₄ OH
sulfate (celestite)	SrSO ₄	183.69	col., rhb., 1.6237	3.96	1580 d.		0.0113 ^{0°}	0.0114 ^{32°}	sl. s. a.; i. dil. H ₂ SO ₄ , al.
sulfate, acid	Sr(HSO ₄) ₂	281.77	col., granular		d.		d.	14 ^{70°} H ₂ SO ₄	
Sulfamic acid	NH ₂ SO ₃ H	97.09	wh., rhb.	2.03 ^{12°} ₄	205 d.		20 ^{0°}	40 ^{70°}	sl. s. al., act.; i. et.
Sulfur, amorphous	S	32.06	pa. yel. pd., 2.0–2.9	2.046	120	444.6	i.	i.	sl. s. CS ₂
Sulfur, monoclinic	S _s	256.48	pa. yel., mn.	1.96	119.0	444.6	i.	i.	s. CS ₂ , al.
Sulfur, rhombic	S _s	256.48	pa. yel., rhb.	2.07	112.8	444.6	i.	i.	24 ^{40°} , 181 ^{55°} CS ₂
Sulfur bromide, mono-	S _s Br ₂	223.95	red, fuming lq.	2.635	-46	54 ^{0°} 18mm	d.		
chloride, mono-	S _s Cl ₂	135.03	red-yel. lq.	1.687	-80	138	d.		s. CS ₂ , et., bz.
chloride, di-	SCl ₂	102.97	dark red fuming lq.	1.621 ^{15°} ₁₅	-78	59	d.		d. al.
chloride, tetra-	SCL ₄	173.89	yel.-brn. lq.		-30	d. > -20	d.		
oxide, di-	SO ₂	64.06	col. gas	lq., 1.434 ^{0°} ; 2.264 (A)	-75.5	-10.0	22.8 ^{0°}	4.5 ^{50°}	s. H ₂ SO ₄ , al., ac.
oxide, tri-(α)	SO ₃	80.06	col. pr.	lq., 1.923; 2.75 (A)	16.83	44.6	d.		s. H ₂ SO ₄
oxide, tri-(β)	(SO ₃) ₂	160.12	col., silky, nd.	1.97 ^{20°}	50		Forms H ₂ SO ₄		s. H ₂ SO ₄
Sulfuric acid	H ₂ SO ₄ °	98.08	col., viscous lq.	1.834 ^{18°} ₄	10.49	d. 340	∞	∞	d. al.
Sulfuric acid	H ₂ SO ₄ .H ₂ O	116.09	pr. or lq.	1.842 ^{15°} ₄	8.62	290	∞	∞	d. al.

*Usual commercial form.

TABLE 2-1 Physical Properties of the Elements and Inorganic Compounds (Concluded)

Name	Formula	Formula weight	Color, crystalline form and refractive index	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Cold water	Hot water	Other reagents
Sulfuric acid	H ₂ SO ₄ ·2H ₂ O	134.11	col. lq.	1.650 ^{0°} ₄	-38.9	167	∞	∞	d. al.
Sulfuric acid, pyro-	H ₂ S ₂ O ₇	178.14	cr.	1.9 ^{20°}	35	d.	d.	d.	d. al.
Sulfuric oxychloride	SO ₂ Cl ₂	134.97	col. lq.	1.667 ^{20°} ₄	-54.1	69.1 ^{760mm}	d.	d.	s. ac.; d. al.
Sulfurous oxybromide	SOBr ₂	207.89	or-yel. lq.	2.68 ^{18°}	-50	68 ^{40mm}	d.	d.	s. bz., CS ₂ , CCl ₄ ; d. act.
oxychloride	SOCl ₂	118.97	col. lq.	1.638	-104.5	78.8	d.	d.	s. bz., chl.
Tantalum	Ta	180.88	bk.-gray, cb.	16.6	2850	>4100	i.	i.	s. fused alk., HF; i. HCl, HNO ₃ , H ₂ SO ₄
Tellurium	Te	127.61	met., hex.	(α) 6.24; (β) 6.00	452	1390	i.	i.	s. H ₂ SO ₄ , HNO ₃ , KCN, KOH, aq. reg.; i. CS ₂
Terbium	Tb	159.20							
Thallium acetate	TlC ₂ H ₃ O ₂	204.39	blue-wh., tet.	11.85	303.5	1650	i.	i.	s. HNO ₃ , H ₂ SO ₄ ; i. NH ₃
chloride, mono-	TlCl	263.43	silky nd.	3.68	110		v. s.	v. s. al.	
chloride, sesqui-	Tl ₂ Cl ₃	239.85	wh., cb.	7.00	430	806	0.21 ^{0°}	1.8 ^{100°}	sl. s. HCl; i. al., NH ₄ OH
chloride, tri-	TlCl ₃	515.15	yel., hex.	5.9	400-500	d.	0.26 ^{15°}	1.9 ^{100°}	
chloride, tri-	TlCl ₃	310.76	hex. pl.		25	d.	v. s.	s. al., et.	
sulfate (ic)	TlCl ₃ ·4H ₂ O	382.83	nd.		37	-4H ₂ O, 100	86.2 ^{17°}	d.	s. al., et.
sulfate (ous)	Tl ₂ (SO ₄) ₃ ·7H ₂ O	823.07	lf.		-6H ₂ O, 200	d.	d.	s. dil. H ₂ SO ₄	
sulfate, acid	TlSO ₄	504.84	col., rhb., 1.8671	6.77	632	d.	2.70 ^{0°}	18.45 ^{100°}	v. sl. s. dil. H ₂ SO ₄
Thio, cf. sulfo or sulfur	TlHSO ₄	301.46	trimorphous		115 d.				
Thorium	Th	232.12	cb.	11.2	1845	>3000	i.	i.	s. HCl, H ₂ SO ₄ ; sl. s. HNO ₃ ; i. HF, alk.
oxide, di- (thorianite)	ThO ₂	264.12	wh., cb.	9.69	>2800	4400	i.	i.	s. h. H ₂ SO ₄ ; i. alk.
sulfate	Th(SO ₄) ₂	424.24		4.225 ^{17°}			0.74 ^{0°}	5.22 ^{50°}	
sulfate	Th(SO ₄) ₂ ·9H ₂ O	586.38	mn. pr.	2.77	-9H ₂ O, 400		sl. s.	sl. s.	
Thulium	Tm	169.40					i.	i.	
Tin	Sn	118.70	silv. met., tet.	7.31	231.85	2260	i.	i.	s. HCl, H ₂ SO ₄ , dil. HNO ₃ h. aq. KOH
Tin	Sn	118.70	gray, cb.	5.750	Stable -163 to +18	2260	i.	i.	s. a., h. alk. solns.
Tin salts, cf. stannic and stannous									
Titanic acid	H ₂ TiO ₃	97.92	wh. pd.				i.	i.	s. alk.; v. sl. s. dil. a.; i. al.
Titanium chloride, di-	Ti	47.90	dark gray, cb.	4.50 ^{17.5°}	1800	>3000	i.	d.	s. a.
	TiCl ₂	118.81	bk., delq.		Unstable in air		d.		i. CS ₂ , et., chl.
chloride, tri-	TiCl ₃	154.27	vl., delq.		d. 440		s.	s.	
chloride, tetra-	TiCl ₄ *	189.73	col. lq.	lq., 1.726	-30	136.4	s.	d.	s. dil. HCl
oxide, di- (anatase)	TiO ₂	79.90	brn. or bk., tet., 2.534-2.564	3.84			i.	i.	sl. s. alk.
oxide, di- (brookite)	TiO ₂	79.90	brn. or bk., rhb., 2.586				i.	i.	
oxide, di- (rutile)	TiO ₂	79.90	col. if pure, tet., 2.615	4.17			i.	i.	
Tungsten	W	183.92	gray-bk., cb.	19.3	3370	5900	i.	i.	s. h. conc. KOH; sl. s. NH ₃ , HNO ₃ , aq. reg.
carbide	WC	195.93	gray pd., cb.	15.7 ^{18°}	2777	6000	i.	i.	s. F ₂ ; i. a.
carbide	W ₂ C	379.85	iron gray	16.06 ^{18°}	2877	6000	i.	i.	s. h. HNO ₃ ; sl. s. HCl, H ₂ SO ₄
oxide, tri-	WO ₃	231.92	yel., rhb.	7.16	>2130		i.	i.	s. alk.; i. a.
Tungstic acid (tungstate)	H ₂ WO ₄	249.94	yel., rhb. 2.24	5.5	- α H ₂ O, 100; 1473		sl. s.	sl. s.	s. HF, alk., NH ₃
Uranic acid	H ₂ UO ₄	304.09	yel. pd.	5.926 ^{15°} ₄	-H ₂ O, 250 to 300		i.	i.	s. a., alk. carb.; i. alk.
Uranium carbide	U	238.07	wh. cr.	18.485 ^{13°} ₄	1133	3500	i.	i.	s. a.; i. alk.
oxide, di- (uraninite)	U ₃ C ₃	512.14	cr.	11.28	2400		d. a.	d. a.	
	UO ₂	270.07	bk., rhb.	10.9	2176		i.	i.	s. HNO ₃ , conc. H ₂ SO ₄

oxide (pitchblende)	U_3O_8	842.21	olive gn.	7.31	d.	i.	i.	s. HNO_3 , H_2SO_4
sulfate (ous)	$\text{U}(\text{SO}_4)_{2.4}\text{H}_2\text{O}$	502.25	gn., rhb.	2.89 ^{15°}	-4 H_2O , 300	23 ^{11°}	9.6 ^{33°}	s. dil. a.
Uranyl acetate	$\text{UO}_2(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$	424.19	yel., rhb.	5.6	-2 H_2O , 110	9.2 ^{17°}	d.	s. al., act.
carbonate (rutherfordine)	UO_2CO_3	330.08	tet.					
nitrate	$\text{UO}_4(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	502.18	yel., rhb., 1.4967	2.807	60.2	118	170.3 ^{0°}	v. s. ac., al., et.; i. dil., alk.
sulfate	$\text{UO}_2\text{SO}_4 \cdot 3\text{H}_2\text{O}$	420.18	yel. cr.	3.28 ^{6.5°}	d. 100		18.9 ^{13.2°}	4 al.; s. a.
Vanadic acid, meta-	HVO_3	99.96	yel. scales				230 ^{25°}	s. a., alk.; i. NH_3
Vanadic acid, pyro-	$\text{H}_4\text{V}_2\text{O}_7$	217.93	pa. yel., amor.					s. a., alk., NH_4OH
Vanadium	V	50.95	lt. gray, cb.	5.96	1710	3000	i.	s. al., et.
chloride, di-	VCl_2	121.86	gn., hex., delq.	3.23 ^{18°}			s.	s. abs. al., et.
chloride, tri-	VCl_3	157.23	pink, tabular, delq.	3.00 ^{18°}	d.		d.	s. abs. al., chl., ac.
chloride, tetra-	VCl_4	192.78	red lq.	1.816 ^{30°}	-109	148.5 ^{75mm}	s. d.	s. a.
oxide, di-	V_2O_2	133.90	lt. gray cr.	3.64			i.	s. HNO_3 , HF, alk.
oxide, tri-	V_2O_3	149.90	bk. cr.	4.87 ^{18°}	1970		sl. s.	s. a., alk.
oxide, tetra-	V_2O_4	165.90	blue cr.	4.399	1967		i.	s. a., alk.; i. abs. al.
oxide, penta-	V_2O_5	181.90	red-yel., rhb.	3.357 ^{18°}	800	d. 1750	0.8 ^{20°}	v. s. HNO_3
oxychloride, mono-	VOCl	102.41	brn. pd.	2.824			i.	s. HNO_3
Vanadyl chloride	$(\text{VO})_2\text{Cl}$	169.36	yel. cr.	3.64	d. in air		i.	s. abs. al., dil. HNO_3
chloride, di-	VOCl_2	137.86	gn., delq.	2.88 ^{13°}			d.	s. al., et., ∞Br_2
chloride, tri-	VOCl_3	173.32	yel. lq.	1.829	<-15	127.19	s. d.	∞ al.; sl. s. et.
Water†	H_2O	18.016	col. lq., 1.33300 ^{20°} ; hex. solid, 1.309	1.00 ^{4°} (lq.); 0.915 ^{0°} (ice)	0	100		
Water, heavy	D_2O	20.029	col. lq., 1.32844 ^{20°}	1.107 ^{20°}	3.82	101.42	∞	∞ al.; sl. s. et.
Xenon	Xe	131.30	col. gas	lq., 3.06 ^{-109.1} $2.7^{-140°}$	-140	-109.1	24.2 ^{0°} cc	7.3 ^{50°} cc
Ytterbium	Yb	173.04		4.53 (A)				
Yttrium	Y	88.92	dark gray, hex.	5.51	1490	2500	sl. d.	d.
Zinc	Zn	65.38	silv. met., hex.	7.140	419.4	907	i.	v. s. dil. a., h. KOH
acetate	$\text{Zn}(\text{C}_2\text{H}_3\text{O}_2)_2$	183.47	mn.	1.840	242	subl. in vac.	$2.8^{35°}$, $166^{79°}$ al.	
acetate	$\text{Zn}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{H}_2\text{O}^\circ$	219.50	wh., mn., 1.494	1.735	237	-2 H_2O , 100	$40^{25°}$	
bromide	ZnBr_3	225.21	rhb.	4.219 ^{4°}	394	650	$66.6^{100°}$	
carbonate	ZnCO_3	125.39	wh., trig., 1.818	4.42	-CO ₂ , 300	0.001 ^{15°}	$390^{0°}$	
chloride	ZnCl_2	136.29	wh., delq., 1.687, uniaxial	2.91 ^{25°}	283	732	432 ^{25°}	$615^{100°}$
cyanide	$\text{Zn}(\text{CN})_2$	117.42	col., rhb.		d. 80		0.00005 ^{18°}	NH ₃
hydroxide	$\text{Zn}(\text{OH})_2$	99.40	col., rhb.	3.053	d. 125		0.000052 ^{18°}	s. KCN, NH ₃ , alk.; i. al.
iodide	ZnI_2	319.22	cb.	4.666 ^{14.2°}	446	624	430 ^{0°}	s. a., alk., NH ₃ , aq.
nitrate	$\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	297.49	col., tet.	2.065 ^{14°}	36.4	-6 H_2O , 105	324.5	$(\text{NH}_4)_2\text{CO}_3$
oxide (zincite)	ZnO	81.38	wh., hex., 2.004	5.606	>1800		0.000042 ^{18°}	v. s. al.
oxide	ZnO	81.38	wh., amor.	5.47	>1800		0.000042 ^{18°}	s. a., alk., NH ₄ Cl; i. NH ₃
peroxide	ZnO_2	97.38	yel.	1.571	expl. 212		0.0022	i. NH ₄ OH; d. a.
phosphide	Zn_3P_2	258.10	steel gray, cb.	4.55 ^{13°}	>420	1100	i.	s. dil. a.
silicate	ZnSiO_3	141.44	hex. or rhb.; glass, 1.650	3.52	1437		i.	
sulfate (zincosite)	ZnSO_4	161.44	wh., rhb., 1.669	3.74 ^{15°}	d. 740		42 ^{0°}	sl. s. al.; s. gly.
sulfate	$\text{ZnSO}_4 \cdot \text{H}_2\text{O}$	179.46	col.	3.28 ^{15°}	d. 238		s.	
sulfate	$\text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$	269.54	mn.	2.072 ^{15°}	-5 H_2O , 70		s.	sl. s. al.; i. act.; NH ₃
sulfate (gosalite)	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}^\circ$	287.55	rhb., 1.4801	1.966 ^{16.5°}	tr. 39	-7 H_2O , 280	115.2 ^{0°}	sl. s. al.; i. act.; NH ₃
sulfide (α) (wurzite)	ZnS	97.44	wh., hex., 2.356	4.087	1850 ^{150atm}	subl. 1185	0.00069 ^{18°}	v. s. a.; i. ac.
sulfide (β) (sphalerite)	ZnS	97.44	wh., cb.; glass (?) 2.18-2.25	4.102 ^{25°}	tr. 1020		i.	s. a.
sulfide (blende)	ZnS	97.44	wh., granular	4.04	-2 a H_2O , 100	d. 200	i.	v. s. a.; i. ac.
sulfite	$\text{ZnSO}_3 \cdot 2\text{a} \text{H}_2\text{O}$	190.48	mn.			0.16	d.	H_2SO_3 , NH_4OH ; i. al.
Zirconium	Zr	91.22	cb., pd. ign. easily	6.4	1700	>2900	i.	s. HF, aq. reg.; sl. s. a.
oxide, di- (baddeleyite)	ZrO_2	123.22	yel. or brn., mn., 2.19	5.49	2700		i.	H_2SO_4 , HF
oxide, di- (free from Hf)	ZrO_2	123.22	wh., mn.	5.73	4300		i.	H_2SO_4 , HF

*Usual commercial form.

† Cf. special tables on water and steam, Tables 2-3, 2-4, 2-5, 2-185, 2-186 and 2-351 through 2-357.

NOTE: °F = % °C + 32.

TABLE 2-2 Physical Properties of Organic Compounds*

Abbreviations Used in the Table

(A), density referred to air	cr., crystalline	i-, iso-, containing the group	nd., needles	s-, sec-, secondary	v. s., very soluble
al., ethyl alcohol	d., decomposes	(CH ₃) ₂ CH-	o-, ortho	silv., silvery	v. sl. s., very slightly soluble
amor., amorphous	d., dextrorotatory	i., insoluble	or., orange	sl., slightly	wh., white
aq., aqua, water	dl., dextro-laevorotatory	ign., ignites	pd., powder	subl., sublimes	yel., yellow
brn., brown	et., ethyl ether	l-, laevorotatory	pet., petroleum ether	sym., symmetrical	(+), right rotation
bz., benzene	expl., explodes	lf., leaflets	pl., plates	t-, tertiary	>, greater than
c., cubic	gn., green	lq., liquid	pr., prisms	tet., tetragonal	<, less than
cc., cubic centimeter	h., hot	m-, meta	rhb., rhombic	tri., triclinic	∞, infinitely
chl., chloroform	hex., hexagonal	mn., monoclinic	s., soluble	uns., unsymmetrical	
col., colorless		n-, normal	v., very		

This table of the physical properties includes the organic compounds of most general interest. For the properties of other organic compounds, reference must be made to larger tables in Lange's *Handbook of Chemistry* (Handbook Publishers), *Handbook of Chemistry and Physics* (Chemical Rubber Publishing Co.), Van Nostrand's *Chemical Annual, International Critical Tables* (McGraw-Hill), and similar works.

The **molecular weights** are based on the 1941 atomic weight values. The **densities** are given for the temperature indicated and are usually referred to water at 4°C, e.g., 1.028⁹⁵⁴ a density of 1.028 at 95°C

referred to water at 4°C, the 4 being omitted when it is not clear whether the reference is to water at 4°C or at the temperature indicated by the upper figure. The melting and boiling points given have been selected from available data as probably the most accurate. The **solubility** is given in grams of the substance in 100 g. of the solvent. In the case of gases, the solubility is often expressed in some manner as "5¹⁰ cc." which indicates that, at 10°C, 5 cc. of the gas are soluble in 100 g. of the solvent.

Name	Synonym	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
								Water	Alcohol	Ether
Abietic acid	sylic acid, abietinic acid	C ₂₀ H ₃₀ O ₂	302.44	lf.	1.069 ^{95/95}	182	278-9	i.	v. s.	v. s.
Acenaphthene	naphthalene ethylene	C ₁₀ H ₈ (CH ₂) ₂	154.20	rhb./al.	1.021 ^{22/4}	95	102.2	i.	s. h.	s. chl.
Acetal	acetaldehyde diethylacetal	CH ₃ CH(OCH ₂ H) ₂	118.17	lq.	0.821 ^{18/4}	-123.5	20.2	∞	∞	∞
Acet-aldehyde	ethanal	CH ₃ CHO	44.05	col. lq.	0.783 ^{18/4}	10.5-12	124.4 ⁷⁵²	∞	∞	∞
-aldehyde, par-	paraldehyde	(C ₂ H ₅ O) ₃	132.16	col. cr.	0.994 ^{20/4}	97	100-10 d.	12 ¹³	∞	∞
-aldehyde ammonia		CH ₃ CHOHNH ₂	61.08	col. cr.				v. s.	v. s.	sl. s.
-amide	ethanamide	CH ₃ CONH ₂	59.07	col. cr.	1.159	81(69.4)	222	s.	s.	v. sl. s.
-anilide	antifebrin	C ₆ H ₅ NHOCH ₃	135.16	rhb./al.	1.21 ⁴	113-4	305	0.5 ⁶	21 ²⁰	7 ²⁵
-phenetidide (o-)	o-ethoxacetanilide	CH ₃ CONHC ₆ H ₄ OCH ₃	179.21	lf./al.		79	>250	i.	s.	
(m-)	acetyl- <i>m</i> -phenetidine	CH ₃ CONHC ₆ H ₄ OCH ₃	179.21	lf./al.		96-7		sl. s.	s.	
-toluidide (o-)	N-tolylacetamide	CH ₃ C ₆ H ₄ NHOCH ₃	149.19	rhb.	1.168 ¹⁵	110	296	0.86 ¹⁹	s.	s.
(p-)	N-tolylacetamide	CH ₃ C ₆ H ₄ NHOCH ₃	149.19	rhb. or mn.	1.212 ¹⁵	153	306-7	0.09 ³²	10 ²⁵	s.
Acetic acid	ethanoic acid, vinegar acid	CH ₃ CO ₂ H	60.05	col. lq.	1.049 ^{20/4}	16.7	118.1	∞	∞	∞
anhydride	acetyl oxide, acetic oxide	(CH ₃ CO) ₂ O	102.09	col. lq.	1.082 ^{20/4}	-73	139.6	12 c.	∞	∞
nitrile	methyl cyanide	CH ₃ CN	41.05	col. lq.	0.783 ^{20/4}	-41	81.6-2.0	∞	∞	∞
Acetone	propanone, dimethyl ketone	CH ₃ COCH ₃	58.08	col. lq.	0.792 ^{20/4}	-94.6	56.5	∞	∞	∞
Acetyl urea	dimethyl hydantoin	<NHCONHCOC>(CH ₃) ₂	128.13	tri./al.		175	subl.	s.	s.	s.
Acetophenone benzoyl hydride	methyl-phenyl ketone	CH ₃ COC ₆ H ₅	120.14	lf.	1.033 ^{15/15}	20.5	202.3 ⁷⁴⁹	i.	s.	s.
Acetyl-chloride	ethanoyl chloride	CH ₃ COCl	78.50	col. lq.	1.105 ^{20/4}	-112.0	51-2	d.	d.	∞
-phenylenediamine (-p)	amino-acetanilide (p)	C ₆ H ₅ ONHC ₆ H ₄ NH ₂	150.18	nd./aq.		162		s. h.	v. s.	v. s.
Acetylene	ethyne; ethine	HC≡CH	26.04	col. gas	(A) 0.906	-81.5 ⁸⁰¹	-84 ⁷⁶⁰	100 cc. ¹⁸	600 cc. ¹⁸	
dichloride (<i>cis</i>)	1,2-dichloroethene	CHCl ₂ CHCl	96.95	col. lq.	1.291 ^{15/4}	-80.5	60.3	0.35 ²⁰	∞	∞
(<i>trans</i>)	dioform	CHCl ₂ CHCl	96.95	col. lq.	1.265 ^{15/4}	-50	48.4	0.63 ³⁰	∞	∞
Aconitic acid	equisitic acid; citridic acid	C ₆ H ₃ (CO ₂ H) ₃	174.11	cr./aq.		192 d.		33 ¹⁵	sl. s.	v. sl. s.
Acridine	C ₆ H ₄ <(CH)(N)>C ₆ H ₄	179.21	rhb./aq. al.		110-1	346	sl. s. h.	s.	s.	
Acrolein ethylene aldehyde	acrylic aldehyde; propenal	CH ₂ =CH-CHO	56.06	col. lq.	0.841 ^{20/4}	-87.7	52.5	40	s.	s.
Acrylic acid	propenoic acid	CH ₂ =CH-COOH	72.06	col. lq.	1.062 ^{16/4}	12-13	141-2	∞	∞	
nitrile	vinyl cyanide	CH ₂ =CH-CN	53.06	col. lq.	0.811 ²⁰	-82	78-9	s.		
Adipic acid	hexandioic acid, adipinic acid	(CH ₂ CH ₂ CO ₂ H) ₂	146.14	mn. pr.	1.360 ^{25/4}	151-3	265 ¹⁰	1.4 ¹⁵	v. s.	0.6 ¹⁵
amide		(CH ₂ CH ₂ CONH ₂) ₂	144.17	cr. pd.		226-7		0.4 ¹²		
nitrile	tetramethylene	(CH ₂ CH ₂ CN) ₂	108.14	col. oil	0.951 ^{19/19}	1	295	v. sl. s.	v. sl. s.	v. sl. s.
Adrenaline (1-) (3,4,1)	1-suprenamine	C ₆ H ₅ (OH) ₂ CHOHCH ₂ NHCH ₃	183.20	col. pd.		d. 207-11		0.03 ²⁰	v. sl. s.	i.
Alanine (α) (dl-)	2-hydroxybutyraldehyde	CH ₃ CH(OH)CH ₂ CO ₂ H	89.09	nd./aq.		295 d.	subl. >200	22 ¹⁷	v. sl. s.	
Aldol acetaldol	Anthraquinic acid	C ₆ H ₅ (CO) ₂ C ₆ H ₅ (OH) ₂	240.20	col. lq.	1.103 ^{20/4}	83 ²⁰	∞	∞	s.	
Alizarin	propen-1-ol-3-propenyl alcohol	CH ₃ CH ₂ CH(OH) ₂	58.08	red rhb.		289-90	430	0.03 ¹⁰⁰	v. s.	v. s.
Allyl alcohol	3-bromo-propene-1	CH ₃ CH ₂ CH ₂ Br	120.99	col. lq.	0.854 ^{20/4}	-129	96.6	∞	∞	∞
bromide	3-chloro-propene-1	CH ₃ CH ₂ CH ₂ Cl	76.53	col. lq.	1.398 ^{20/4}	-119.4	70-1 ⁷⁵³	i.	∞	∞
chloride	mustard oil	CH ₃ CH ₂ CH ₂ ClS	99.15	col. oil	1.013 ^{20/4}	-136.4	44.6	<0.1	∞	∞
thiocyanate (i)	thiosinamide	CH ₃ CH ₂ CH ₂ NHCSNH ₂	116.18	col. pr.	1.219 ^{20/20}	-80	152	0.2	∞	∞
thiourea		Al(OCH ₂ CH ₃) ₃	164.15	pd.	1.142 ^{20/0}	77-8	3 ⁰	s.	v. sl. s.	
Aluminum ethoxide		C ₆ H ₅ (CO) ₂ C ₆ H ₅ NH ₂	223.22	red nd.		150-60	200-5 ¹⁰	d.	i.	v. sl. s.
Amino-anthraquinone (α)		C ₆ H ₅ (CO) ₂ C ₆ H ₅ NH ₂	223.22	red nd.		256	subl.	i.	s.	s.
(β)		C ₆ H ₅ N ₂ C ₆ H ₅ NH ₂	197.23	col. lq.	302	subl.	i.	s.	i.	
-azobenzene		H ₂ N-C ₆ H ₄ CO ₂ H	137.13	nd./aq.	1.511 ^{4*}	126-7	225 ¹²⁰	sl. s. h.	s. h.	s.
-benzoic acid (m-)		H ₂ N-C ₆ H ₄ CO ₂ H	137.13	mn. pr.		173-4	187-8	2 ¹⁰	1.8 ⁶	8.2 ⁶
(p-)	aminodracylic acid							0.3 ¹³	11 ¹⁰	

Amino-diphenylamine (<i>p</i>)		H ₂ N·C ₆ H ₄ NH·C ₆ H ₅	184.23	nd./aq. al.					sl. s.	s.	
-G-acid (2-)(6-8-), Na ₂ salt		C ₁₀ H ₅ (NH ₂)(SO ₃ Na) ₂	347.28					v. sl. s.			
-mono-potassium salt		C ₁₀ H ₅ (NH ₂) ₂ S ₂ O ₈ HK	341.39					12.8 ²⁰			
-sodium salt		C ₁₀ H ₅ (NH ₂) ₂ S ₂ O ₈ HN _a	325.29					2.7 ¹⁸			
-J-acid (2-)(5-7-)		C ₁₀ H ₅ (NH ₂) ₂ (SO ₄ H) ₂	303.30					10.0 ²⁰			
-mono-potassium salt		C ₁₀ H ₅ (NH ₂) ₂ (SO ₄ H)·H ₂ O	341.39					3.4 ¹⁸			
-naphthol sulfonic (1-2-4-)(<i>α</i> -(1-8-4-))		C ₁₀ H ₅ (OH)C ₆ H ₅ SO ₃ H	248.25					v. s.			
-phenol (<i>o</i> -)		NH ₂ (OH)C ₆ H ₅ SO ₃ H	239.24					v. sl. s.			
(<i>m</i> -)	2-aminophenol	H ₂ N·C ₆ H ₄ OH	109.12	col. nd.				1.7 ⁰	4.3 ⁰		
(<i>p</i> -)	3-aminophenol	H ₂ N·C ₆ H ₃ OH	109.12	pr.				2.6 ⁰	S.		
-toluene sulfonic acid (1-2-3-)	<i>p</i> -hydroxyaniline	H ₂ N·C ₆ H ₄ OH	109.12	lf.				1.1 ⁰	4 ⁰		
(1-4-2-)		C ₆ H ₃ (CH ₃)(NH ₂)SO ₃ H	187.21					0.97 ¹¹	i. bz.		
(1-4-3-)		C ₆ H ₃ (CH ₃)(NH ₂)SO ₃ H·H ₂ O	205.23	nd.				0.5 ²⁰			
(1-2-5-)		C ₆ H ₃ (CH ₃)(NH ₂)SO ₃ H·H ₂ O	196.22	mn.				0.47			
Amyl acetate (<i>n</i>)		C ₆ H ₃ (CH ₃)(NH ₂)SO ₃ H·H ₂ O	205.23	tri./aq.				3 ¹¹			
(<i>i</i> -)	common amyl acetate	CH ₃ CO ₂ CH ₂ (CH ₂) ₃ CH ₃	130.18	col. lq.	0.879 ^{20/20}	-H ₂ O, 120	148.4 ⁷³⁷	v. sl. s.			
(<i>s</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.876 ^{15/4}	-70.8	142 ⁷³⁷	∞			
(<i>s</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.880 ¹³		141-2	0.3 ¹⁵	∞		
(<i>t</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.922 ⁰		133.5	v. sl. s.	∞		
alcohol (<i>n</i>)- fusel oil,		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.871 ^{20/4}		133	sl. s.	∞		
(<i>s,n</i>)- methyl-propyl carbinol,		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.817 ^{20/20}	-78.5	124.5 ⁷⁴⁹	∞			
(prim., <i>i</i>)- isobutyl carbinol,		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.810 ^{20/20}		137.9	2.7 ²²	∞		
(<i>s,i</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.813 ^{15/4}	-117.2	119.5	4 ²⁰	∞		
(<i>t</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.815 ^{25/4}		132.0	2 ¹⁴	∞		
(<i>d</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.819 ¹⁹	-11.9	113-4	5.5 ³⁰	∞		
-amine (<i>n</i>)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.809 ^{20/4}	52-3	102	2.8 ³⁰	∞		
(<i>s,n</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	cr.			128	sl. s.	S.		
(<i>i</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.816 ^{20/4}		103-4	sl. s.	S.		
(<i>s</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.766 ¹⁹	-105	91-2	∞	∞		
(<i>t</i> -)		CH ₃ CO ₂ CH ₂ CH(CH ₃) ₂	130.18	col. lq.	0.749 ^{20/4}		95	∞	∞		
1-NH ₂ -2-Me-butane		(C ₂ H ₅) ₂ CH ₂ NH ₂	87.16	col. lq.	0.751 ^{18/4}	-105	77-8	∞	∞		
3-amino pentane		(C ₂ H ₅) ₂ CH ₂ CH ₂ NH ₂	87.16	col. lq.	0.731 ^{25/4}		95-6	∞	∞		
3-NH ₂ -2-Me-butane		(C ₂ H ₅) ₂ CH ₂ CH ₂ NH ₂	87.16	col. lq.	0.749 ^{20/4}		90-1	∞	∞		
aniline (<i>i</i> -)		(C ₂ H ₅) ₂ CH ₂ CH ₂ NH ₂	87.16	col. lq.	0.757 ¹⁸		83-4	∞	∞		
benzoate (<i>i</i> -)		(C ₂ H ₅) ₂ CH ₂ CH ₂ NH ₂	87.16	col. lq.	0.928 ^{15/4}		254.5	i.	∞		
bromide (<i>n</i> -)		(C ₂ H ₅) ₂ CH ₂ CH ₂ NH ₂	87.16	col. lq.	0.992 ^{14/14}		261 ¹⁴⁶	i.	∞		
(<i>i</i> -)	1-bromopentane	CH ₃ Br(C ₂ H ₅) ₂	151.05	col. lq.	1.218 ^{20/4}	-95	129.7	i.	S.		
(<i>t</i> -)	4-Br-2-Me-butane	CH ₃ Br(C ₂ H ₅) ₂	151.05	col. lq.	1.220 ^{17/15}		120 ⁴⁵	0.02 ¹⁶	S.		
2-Br-2-Me-butane		CH ₃ Br(C ₂ H ₅) ₂	151.05	col. lq.	1.216 ^{19/0}		108 ⁷⁶⁵	i.	S.		
<i>n</i> -butyrate (<i>n</i> -)		C ₂ H ₅ CH ₂ CO ₂ (CH ₃) ₂	158.23	col. lq.	0.871 ^{15/4}	-73.2	186.4	0.05 ⁵⁰	∞		
(<i>i</i> -)		C ₂ H ₅ CH ₂ CO ₂ (CH ₃) ₂	158.23	col. lq.	0.866 ^{19/15}		178.6	i.	∞		
(<i>t</i> -)		C ₂ H ₅ CH ₂ CO ₂ (CH ₃) ₂	158.23	col. lq.	0.865 ^{15/0}		164	sl. s.	∞		
<i>i</i> -butyrate (<i>i</i> -)		C ₂ H ₅ CH ₂ CO ₂ (CH ₃) ₂	158.23	col. lq.	0.876 ^{9/4}		168.8	i.	S.		
chloride (<i>n</i> -)		C ₂ H ₅ CH ₂ CO ₂ (CH ₃) ₂	158.23	col. lq.	0.875 ^{20/4}	-99	108.4	i.	S.		
(<i>s</i> -)	1-chloropentane	C ₂ H ₅ CH ₂ CH ₂ Cl	106.60	col. lq.	0.870 ^{20/4}		96.7	i.	S.		
(<i>s</i> -)	2-chloropentane	C ₂ H ₅ CH ₂ CH ₂ Cl	106.60	col. lq.	0.895 ²¹		97.3	i.	∞		
(<i>i</i> -)	3-chloropentane	C ₂ H ₅ CH ₂ CH ₂ Cl	106.60	col. lq.	0.893 ^{20/4}		99.7 ⁷⁵⁸	i.	S.		
4-Cl-2-Me-butane		C ₂ H ₅ CH ₂ CH ₂ Cl	106.60	col. lq.	0.883 ⁰	-72.9	91 ⁷⁵³	i.	S.		
3-Cl-2-Me-butane		C ₂ H ₅ CH ₂ CH ₂ Cl	106.60	col. lq.	0.871 ^{20/4}		85.7	sl. s.	S.		
2-Cl-2-Me-butane		C ₂ H ₅ CH ₂ CH ₂ Cl	106.60	col. lq.	0.881 ^{17.5}		98-9	i.	S.		
1-Cl-2-Me-butane		C ₂ H ₅ CH ₂ CH ₂ Cl	106.60	col. lq.			137-9	i.	S.		
iso-caproic iso-nitrile		C ₂ H ₅ CH ₂ CH ₂ NC	97.16	col. lq.			137-9	i.	S.		
<i>i</i> -cyanide (<i>i</i> -)		HCO ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	0.902 ⁰	-73.5	132	v. sl. s.	∞		
formate (<i>n</i> -)		HCO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	0.882 ^{20/4}	-93.5	123.5	0.3 ²²	∞		
(<i>i</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	1.510 ^{20/4}	-86	157.0	i.	S.		
iodide (<i>n</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	1.471 ^{19/15}		144-5	i.	∞		
(<i>i</i> -)	1-iodopentane	CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	1.507 ^{17/4}		127 ⁷⁶⁵	i.	∞		
(<i>s,n</i> -)	4-I-2-Me-butane	CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	1.471 ^{19/15}		147 ⁷⁶⁵	i.	∞		
(<i>t</i> -)	2-iodopentane	CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	1.471 ^{19/15}		144-5	i.	∞		
mercaptop (<i>n</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	1.524 ^{20/4}		148	i.	∞		
(<i>n</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	0.857 ²⁰		126 ⁷⁶⁷	i.	∞		
(<i>i</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	0.835 ^{20/4}		105	i.	∞		
phenol (<i>t</i>)(<i>p</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	104.21	col. lq.			120	i.	∞		
propionate (<i>n</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	104.21	col. lq.			93	265-7	sl. s.	S.	
(<i>i</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	104.21	col. lq.	0.876 ^{15/4}	-73.1	168.7	i.	∞		
(act.)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	104.21	col. lq.	0.870 ^{20/4}		160.2	0.1 ²⁵	∞		
salicylate (<i>n</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	104.21	col. lq.	0.866 ^{20/4}		58 ¹⁶	v. sl. s.	∞		
Amyl <i>i</i> -valerate (<i>i</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	104.21	col. lq.	1.065 ¹⁵		265	i.	∞		
(<i>t</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	104.21	col. lq.	0.858 ^{20/15}		194	v. sl. s.	∞		
		CH ₃ CO ₂ CH ₂ CH ₂ CH ₂ CH ₃	104.21	col. lq.	0.861 ^{14/0}		173-4	sl. s.	S.		

*By N. A. Lange, Ph.D., Handbook Publishers, Inc., Sandusky, Ohio. Abridged from table of Physical Constants of Organic Compounds in Lange's "Handbook of Chemistry."

TABLE 2-2 Physical Properties of Organic Compounds (Continued)

Name	Synonym	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
								Water	Alcohol	Ether
Amylene (<i>n</i>)(α)- (<i>i</i>)- (α -) (- <i>n</i>)(β)- (<i>i</i>)(β)-	pentene-1 2-methyl-butene-3 2-methyl-butene-1 pentene-2 2-methyl-butene-2	C ₆ H ₅ CH ₂ CH ₂ CH ₂ (CH ₃) ₂ CHCH ₂ CH ₂ (C ₆ H ₅)(CH ₃)C ₂ CH ₂ C ₆ H ₅ CH ₂ CHCH ₃ (CH ₃) ₂ C ₂ CHCH ₃	70.13 70.13 70.13 70.13 70.13	lp. col. lp. col. lp. col. lp. col. lp.	0.644 ²⁰ 0.632 ¹⁵ 0.667 ^{0.0} 0.650 ^{20/4} 0.663 ^{10/4}	-135 31-2 ⁷⁵⁸ 36.4 -139 -124	30-1 20.5 ⁷⁷¹ v. sl. s. 37-8	i. i. i. i. i.	∞ ∞ ∞ ∞ ∞	
Anethole (<i>p</i> -)	<i>p</i> -propenyl anisole	CH ₃ CH ₂ CH-C ₆ H ₅ OCH ₃	148.20	lf./al.	0.991 ^{20/20}	22.5	235.3	v. sl. s. i. i.	s. s. s.	∞ ∞ ∞
Anhydroformald-aniline	methylene aniline	(CH ₂ NCO ₂ H) ₃	315.40	pr/al.		143	185	v. sl. s. i.	sl. s. sl. s.	S. S.
Aniline	amino benzene, phenyl amine, cyanol	C ₆ H ₅ NH ₂	93.12	col. oil	1.022 ^{20/4}	-6.2	184.4	3.6 ¹⁸	∞	∞
hydrochloride	aniline salt, aniline chloride	C ₆ H ₅ NH ₂ ·HCl	129.59	cr.	1.222 ⁴	198	245	18 ¹⁵	s.	i.
nitrate		C ₆ H ₅ NH ₂ ·HNO ₃	156.14	rhb.	1.356 ⁴	d. 190		s. s.	sl. s. sl. s.	sl. s. i.
sulfate		(C ₆ H ₅ NH ₂) ₂ ·H ₂ SO ₄	284.32	lf./al.	1.377 ⁴	d.		5 ¹⁴	sl. s.	v. s.
Anisal-acetone (<i>p</i> -)	MeO-benzalacetone	CH ₃ OCH ₂ CH-COOCH ₃	176.22	lf./et.		73-4		i.	v. s.	v. s.
Anisic acid (<i>p</i> -)		CH ₃ OCH ₂ CO ₂ H	152.14	mn./aq.	1.385 ⁴	184.2	275-80	0.03 ¹⁹	v. s.	v. s.
aldehyde (<i>p</i> -)		CH ₃ OCH ₂ CHO	136.14	col. oil	1.123 ^{20/4}	2.5	247-8	∞	∞	∞
Anisidine (<i>o</i> -)	2-amino-anisole	CH ₃ OCH ₂ NH ₂	123.15	col. lp.	1.095 ^{15/15}	5.2	225	v. sl. s.	∞	∞
(<i>m</i> -)	MeO-aniline(<i>m</i>)	CH ₃ OCH ₂ NH ₂	123.15	oil	1.096 ^{20/4}	<12	251	v. sl. s.	s.	s.
(<i>p</i> -)	4-amino anisole	CH ₃ OCH ₂ NH ₂	123.15	pl./aq.	1.089 ^{55/55}	57.2	243	s. h.	s.	s.
Anisole	methyl phenyl ether	CH ₃ OCH ₂ H ₅	108.13	col. lp.	0.990 ^{22/4}	-37.3	154-5	i.	s.	s.
Anthracene	paranaphthalene, anthracin green oil	C ₆ H ₄ : (CH) ₂ :C ₆ H ₄	178.22	col. mn.	1.25 ^{27/4}	217-8	340-2	i.	1.5 ²⁰	
Anthramine (α)- (β)-	α -amino-anthracene β -amino-anthracene	C ₆ H ₄ : (CH) ₂ :C ₆ H ₃ NH ₂ C ₆ H ₄ : (CH) ₂ :C ₆ H ₃ NH ₂	193.24 193.24	yel./al. yel./al.		130± 238		i. i.	s. sl. s.	sl. s. sl. s.
Anthranil		C ₆ H ₄ : (NH)CO	119.12	col. oil	1.187 ^{15/4}	<18	d. >215	sl. s. h. subl.	s. s.	s. s.
Anthranilic acid (<i>o</i> -)		H ₂ NC ₆ H ₄ CO ₂ H	137.13	col. rhb.		144-5		0.35 ¹⁴	11 ¹⁰	16 ⁷
Anthrapurpurin (1-,2-,7-)		C ₆ H ₅ O ₂ (OH) ₃	256.20	or. nd./al.		369	462	sl. s. h.	v. s. h.	sl. s.
Anthraquinone	diphenyleneketone, dihydrodiketoanthracene	C ₆ H ₄ : (CO) ₂ :C ₆ H ₄	208.20	yel. rhb.	1.438 ^{20/4}	286	379-81	i.	0.05 ¹⁸	v. sl. s.
disulfonate Na ₂ (1-5-) (1-8-) (2-6-) (2-7-)	<i>p</i> -anthraquinone disulfonate x-anthraquinone disulfonate	C ₁₄ H ₈ O ₂ (SO ₃ Na) ₂ ·5H ₂ O C ₁₄ H ₈ O ₂ (SO ₃ Na) ₂ ·4H ₂ O C ₁₄ H ₈ O ₂ (SO ₃ Na) ₂ ·7H ₂ O C ₁₄ H ₈ O ₂ (SO ₃ Na) ₂ ·4H ₂ O C ₁₄ H ₈ O ₂ SO ₃ Na	502.38 484.37 538.41 484.37 310.25	yel. lf. yel. pr. col. cr. er. yel. lf.				v. s. sl. s. 3.9 ²⁰	i.	i.
sulfonate Na (1-) (2-)		C ₁₄ H ₈ O ₂ SO ₃ Na	310.25	silv. lf.				0.53 ²⁰	i.	i.
Anthrarufin (1-,5-)	1-ph-2,3-diMepyrazolone-5	C ₁₄ H ₈ O ₂ (OH) ₂	240.20	yel. lf.	1.088 ^{113/4}	280	subl.	0.84 ²⁵	sl. s.	i.
Antipyrene	1-allyl-2,5-diMeO-3,4 methylenedioxybenzene	C ₁₄ H ₁₂ O ₂	188.22	mn./aq.	1.02 ^{20/4}	113(109)	319 ⁷⁴	100 ²⁵	100	sl. s.
Apiole		C ₁₂ H ₁₄ O ₂	222.23	col. nd.		30	294	i	s.	s.
Arabinose (α)(<i>d</i> - or <i>L</i>)- (<i>dl</i>)-		CH ₂ OH(CHOH) ₃ CHO	150.13	rhb. pr.	1.585 ^{20/4}	159.5		46 ⁰	0.5 ⁹	i.
Arachidic acid	eicosanoic acid	CH ₂ OH(CHOH) ₃ CHO	150.13			164.5		16.9 ¹⁰		
Arsanilic acid (<i>p</i> -)		CH ₃ (CH ₂) ₁₈ CO ₂ H	312.52	col. lf.		77	328	i.	s. h.	v. s.
Asparagine (<i>L</i> -)		H ₂ N-C ₆ H ₄ AsO ₃ H ₂	217.04	nd./aq.		232		v. s. h.	v. s. h.	i.
Aspirin (<i>o</i> -)		HO-C ₆ H ₄ (NH ₂)-CONH ₂	132.12	rhb.	1.543 ^{15/4}	227-35	d. 235	3.1 ²⁸	i. c.	
Atropic acid	α -phenyl acrylic acid	CH ₃ CO ₂ -C ₆ H ₄ -OH	180.15	nd./aq.		135-6		1 ³⁷	s.	5 ²⁰
Auramine	4,4'-dimethylaminobenzo-phenomide	C ₆ H ₅ C(C ₂ H ₅) ₂ -CO ₂ H [(CH ₃) ₂ NC ₆ H ₄] ₂ C:NH	267.36	col./al.		106-7	267 d.	0.1 c.	s.	s.
Aurine, coralline (4-,4'-)		(HOC ₆ H ₄) ₂ C ₆ H ₄ O	290.30	red		136		i.	7 ²⁰	2.3 ²⁰
Azo-anisole (2-,2'-)	diMeO-azobenzene	(CH ₃ O-C ₆ H ₄ N): ₂	242.27	or. pr.		310 d.		s.	s.	s.
benzene	diphenyldiimide	C ₆ H ₅ N:N-C ₆ H ₅	182.22	or. mn.	1.203 ^{20/4}	153		i.	4.2 ²⁰	
Azoxobenzene		(C ₆ H ₅) ₂ N ₂ O	198.22	yel. rhb.	1.248 ^{20/20}	68	297	i.	11.4 ¹⁵	
Barbituric acid	malonyl urea	CO:(NHCO) ₂ :CH ₂ :2H ₂ O	164.12	col./aq.		36	d.	s. h.	sl. s.	s.
Benzal acetone	Me-cinnamyl ketone	C ₆ H ₅ CH:CHCOCH ₃	146.18	pl.	1.035 ^{20/20}	245		sl. s.	sl. s.	
Benzaldehyde	artificial almond oil	C ₆ H ₅ CHO	106.12	col. lp.	1.046 ^{20/4}	41-2	260-2	i.	s.	
Benzamide		C ₆ H ₅ CONH ₂	121.13	col. pr.		26	179	0.3	∞	∞
Benzanilide		C ₆ H ₅ CONHC ₆ H ₅	197.23	lf./al.	1.341	130	290	1.35 ²⁵	17 ²⁵	sl. s.
Benzene	benzol, phenyl hydride, cyclohexatriene	C ₆ H ₆	78.11	col. lp.	1.31 ⁴	163	117-9 ¹⁰	i.	4 ³⁰	sl. s.
sulfinic acid		C ₆ H ₅ SO ₂ H	142.17	pr./aq.	0.879 ^{20/4}	5.5	80.1	0.07 ²²	s.	∞
sulfonic acid		C ₆ H ₅ SO ₃ H	158.17	col. nd.		65-6	d.	v. s. h.	v. s.	v. s.
sulfonic amide	benzene sulfonamide	C ₆ H ₅ SO ₂ NH ₂	157.18	mn./aq.		156		0.43 ¹⁶	v. s.	v. s.
sulfonic chloride	benzene sulfonyl chloride	C ₆ H ₅ SO ₂ Cl	176.62	cr.	1.384 ^{15/15}	14.5	251.5	i.	v. s.	s.
Benzidine (4-,4')		NH ₂ :C ₆ H ₄ :C ₆ H ₄ :NH ₂	184.23	cr./aq.		128-9	400 ⁷⁴⁰	1 h.	1 h.	2
disulfonic acid (2-,2')		(C ₆ H ₄ :NH ₂) ₂ SO ₂ H ₂	398.40	pr./aq.		d. >175		0.09 ²⁵	i.	i.
(3-,3')	dibenzoyl	(C ₆ H ₅ CO) ₂ H ₅	344.35					v. sl. s.		
Benzil		C ₆ H ₅ CO-COC ₆ H ₅	210.22	pr.	1.23 ¹⁵	95	348 d.	i.	v. s.	v. s.
Benzoic acid		C ₆ H ₅ CO ₂ H	122.12	mn. pr.	1.266 ^{15/4}	121.7	249.2	0.2 ¹⁷	46 ¹⁵	66 ¹⁵
anhydride		(C ₆ H ₅ CO) ₂ O	226.22	rhb./et.	1.199 ^{15/4}	42	360	i.	s.	s.
nitrile	phenyl cyanide	C ₆ H ₅ CN	103.12	col. lp.	1.001 ^{25/6}	-12.9	190.7	1 ¹⁰⁰	∞	∞

Benzoin (<i>dl</i> -)	diphenyl ketone	C ₆ H ₅ CO·CHOHC ₆ H ₅	212.24	mn.	133–7	344 ⁷⁶⁸	v. sl. s.	s. h.	sl. s.
Benzophenone	phenyl chloroform	C ₆ H ₅ COCl ₃	182.21	col. rhb.	1.083 ⁵⁴	48.5	305.4	6.5 ¹⁵	15 ¹³
Benzotrichloride		C ₆ H ₅ COCl ₃	195.48	col. lq.	1.380 ¹⁴	–4.75	220.7	i.	s.
Benzoyl-benzoic acid (<i>o</i> -)		C ₆ H ₅ COCl ₂ H ₂ O	244.24	tri./aq.	93(128)		sl. s.		
-chloride		C ₆ H ₅ COCl	140.57	col. lq.	1.212 ^{20/4}	–0.5	197.2	d.	d. h.
-peroxide		(C ₆ H ₅ CO) ₂ O ₂	242.22	rhb./et.		108 d.	expl.	s. h.	s.
Benzyl acetate	phenyl carbinol	CH ₃ CO ₂ CH ₂ C ₆ H ₅	150.17	col. lq.	1.057 ¹⁷	–51.5	213.5	i.	∞
alcohol	ω-amino toluene	C ₆ H ₅ CH ₂ OH	108.13	col. lq.	1.043 ^{20/4}	–15.3	204.7	4 ¹⁷	∞
amine	aniline	C ₆ H ₅ CH ₂ NH ₂	107.15	lq.	0.982 ^{20/4}		184.5	∞	∞
aniline	phenyl-benzylamine	C ₆ H ₅ CH ₂ NHC ₆ H ₅	183.24	mn. pr.	1.065 ^{25/25}	37–8	306 ⁷⁹⁰	i.	S.
benzoate		C ₆ H ₅ CO ₂ CH ₂ C ₆ H ₅	212.24	nd.	1.12 ^{30/4}	21	323–4	i.	∞
butyrate		C ₆ H ₅ CH ₂ CO ₂ CH ₂ C ₆ H ₅	178.22	col. lq.	1.016 ^{16/18}	238–40	i.	v. s.	v. s.
chloride		C ₆ H ₅ CH ₂ Cl	126.58	col. lq.	1.100 ^{20/20}	–39	179.4	i.	∞
ether	ω-chlorotoluene	(C ₆ H ₅ CH ₃) ₂ O	198.25	lq.	1.036 ¹⁶		295–8	i.	s. h.
formate	dibenzyl ether	HCO ₂ CH ₂ C ₆ H ₅	136.14	col. lq.	1.081 ²³	3.6	202–3 ⁷⁴⁷	i.	∞
propionate		C ₆ H ₅ CO ₂ CH ₂ C ₆ H ₅	164.20	lq.	1.036 ^{16/17}		220–2	i.	
Berberonic acid (2-,4-,5-)		C ₆ H ₅ N(CO ₂ H) ₃ ·2H ₂ O	247.16	tri.		243		v. sl. s.	sl. s. h.
Biuret	allophanamide	NHCONH ₂) ₂	103.08	nd./al.		192–3 d.	1.3 ⁰	s.	i.
Borneol (<i>dl</i> -)		C ₁₀ H ₁₇ OH	154.24	col. cr.	1.011 ^{20/4}	210.5	subl.	v. sl. s.	V. S.
(<i>d</i> - or <i>l</i> -)		C ₁₀ H ₁₇ OH	154.24	col. cr.	1.011 ^{20/4}	208–9	212–3	v. sl. s.	V. S.
(iso-)		C ₁₀ H ₁₇ OH	154.24	col. cr.		212	i.		
Bornyl acetate (<i>d</i> -)		CH ₃ CO ₂ C ₁₀ H ₁₇	196.28	rhb./pet.	0.991 ¹⁵	29	226–7	i.	S.
Bromo-aniline (<i>p</i> -)		BrC ₆ H ₄ NH ₂	172.03	rhb.	1.8 ²⁰	63–4	i. c.	V. S.	V. S.
-benzene	phenyl bromide	C ₆ H ₅ Br	157.02	col. lq.	1.495 ^{20/4}	–30.6	156.2	i.	∞
-camphor (3-) (<i>d</i> -)		BrC ₁₀ H ₁₅ O	231.14	cr./al.	1.449 ^{20/4}	77–8	274	20 ²⁰	V. S.
-diphenyl (<i>p</i> -)		BrC ₆ H ₄ C ₆ H ₅	233.11	col. oil	1.482 ^{20/4}	5–6	281.1	34 ²⁵	V. S.
-naphthalene (<i>α</i> -)	α-naphthyl bromide	C ₁₀ H ₇ Br	207.07	lf./al.	1.605 ⁰	59	281–2	i.	6 ²⁰
(<i>β</i> -)		C ₁₀ H ₇ Br	207.07	col. lq.	1.553 ⁸⁰	5.6	194–5	s.	∞
-phenol (<i>o</i> -)		BrC ₆ H ₅ OH	173.02	cr.		32–3	236–7	s.	
(<i>m</i> -)		BrC ₆ H ₅ OH	173.02	tet. cr.	1.588 ⁸⁰	63.5	238	1.4 ¹⁵	V. S.
(<i>p</i> -)		C ₆ H ₅ CH ₂ CHBr	183.05	lq.	1.422 ^{20/4}	7	221	i.	∞
-styrene (<i>ω</i>)(1)		C ₆ H ₅ CH ₂ CHBr	183.05	lq.	1.427 ^{20/4}	–7.5	108 ³⁶	i.	∞
(2)		CH ₃ :C ₆ H ₅ Br	171.04	col. lq.	1.429 ^{20/4}	–28	181.8	i.	∞ ²⁵
-toluene (<i>o</i> -)		CH ₃ :C ₆ H ₅ Br	171.04	col. lq.	1.410 ^{20/4}	–39.8	183.7	i.	S.
(<i>m</i> -)		CH ₃ :C ₆ H ₄ Br	171.04	cr./al.	1.390 ^{20/4}	28.5	184–5	i.	∞ ²⁵
(<i>p</i> -)		CHBr ₃	252.77	col. lq.	2.890 ^{20/4}	8–9	150.5	0.1 c.	∞
Bromoform	tribromo-methane	CH ₃ CH ₂ CH ₂ CH ₂	54.09	lq.		18–9	i.	∞	∞
Butadiene (1-,2-)	methyl-allene	CH ₂ CH ₂ CH ₂ CH ₂	54.09	col. gas	0.621 ^{20/4}	–108.9	–4.41	i.	∞
(1-,3-)	erythrene	CH ₂ :CH ₂ CH ₂ :CH	78.11	col. lq.	0.773 ^{20/4}	83–6	i.	S.	S.
Butadienyl acetylene	diethyl	CH ₂ CH ₂ CH ₂ CH ₃	58.12	col. gas	0.60 ⁰	–135	–0.6	i.	S.
Butane	trimethyl-methane	(CH ₃) ₃ CHCH ₃	58.12	col. gas	0.60 ⁰	–145	–10	i.	S.
(<i>i</i> -)		CH ₃ CO ₂ (CH ₃) ₂ C ₂ H ₅	116.16	col. lq.	0.882 ²⁰	–76.3	125 ⁷⁴⁰	0.7	∞
Butyl acetate (<i>n</i> -)	butanol-1	CH ₃ CO ₂ (CH ₃) ₃	116.16	col. lq.	0.865 ^{25/4}		112 ⁷⁴⁴	i.	∞
(<i>s</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	0.871 ^{20/4}	–98.9	118	0.6 ²⁵	∞
(<i>i</i> -)		CH ₃ CO ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	0.866 ^{20/4}		95–6 ⁷⁶⁰	i.	∞
(<i>tert</i> -)	2-methyl-propanol-1	CH ₃ CO ₂ CH ₂ CH ₂ CH ₃	116.16	col. lq.	0.810 ^{20/4}	–79.9	117	9 ¹⁵	∞
alcohol (<i>n</i> -)	butanol-2	CH ₃ CO ₂ (CH ₃) ₂ CH ₃	74.12	col. lq.	0.808 ^{20/4}	–114.7	99.5	12.5 ³⁰	∞
(<i>s</i> -)		(CH ₃) ₃ CHCH ₂ OH	74.12	col. lq.	0.805 ^{17.5}	–108	107–8	10 ¹⁵	∞
(<i>i</i> -)		(CH ₃) ₃ COH	74.12	lq.	0.779 ²⁶	25.5	82.9	∞	∞
(<i>tert</i> -)		C ₃ H ₇ CH ₂ CH ₂ NH ₂	73.14	col. lq.	0.739 ^{25/4}	–50	77.8	∞	∞
amine (<i>n</i> -)		C ₃ H ₇ CH ₂ CH ₂ NH ₂	73.14	col. lq.	0.724 ^{20/4}	–104	66 ⁷⁷²	∞	∞
(<i>s</i> -)		(CH ₃) ₃ CHCH ₂ NH ₂	73.14	col. lq.	0.732 ^{20/20}	–85	68–9	∞	∞
(<i>i</i> -)		(CH ₃) ₃ CNH ₂	73.14	col. lq.	0.698 ^{18/4}	–67.5	45.2	∞	∞
(<i>t</i> -)		C ₄ H ₉ NH-C ₆ H ₄ -OH	165.23	lq.		71	i.		
<i>p</i> -aminophenol (<i>N</i>)(<i>n</i>)		C ₄ H ₉ NH-C ₆ H ₄ -OH	165.23	lq.		79	i.		
(<i>N</i>)(<i>i</i> -)		C ₄ H ₉ NH ₂ C ₆ H ₅	149.23	oil	0.940 ^{20/4}		235 ⁷²⁰	i.	V. S.
aniline (<i>n</i> -)		C ₄ H ₉ NH ₂ C ₆ H ₅	149.23	oil			231–2	0.01 ¹⁵	V. S.
(<i>i</i> -)		C ₄ H ₉ As(O)OH ₂	182.04	col. lf.		158–9	s.	S.	i.
arsonic acid (<i>n</i> -)		C ₄ H ₉ CO ₂ C ₆ H ₅	178.22	col. oil	1.005 ^{25/25}	–22	249–50	i.	S.
benzoate (<i>n</i> -)		C ₄ H ₉ CO ₂ C ₆ H ₅	178.22	col. oil	0.997 ^{25/25}		241.5	i.	∞
(<i>i</i> -)		C ₄ H ₉ CO ₂ C ₆ H ₅	178.22	col. oil			91.5	0.06 ¹⁶	∞
bromide (<i>n</i> -)	1-bromo-butane	C ₂ H ₅ CH ₂ CH ₂ Br	137.03	lq.	1.277 ^{20/4}	–112.4	101.6	0.06 ¹⁸	∞
(<i>s</i> -)	2-bromo-butane	C ₂ H ₅ CH ₂ (Br)CH ₃	137.03	lq.	1.251 ^{25/4}	–112	91.3	i.	∞
(<i>i</i> -)	1-Br-2-Me-propane	(CH ₃) ₂ CHCH ₂ Br	137.03	lq.	1.258 ^{25/4}	–118.5	91.5	0.06 ¹⁸	∞
(<i>t</i> -)	2-Br-2-Me-propane	(CH ₃) ₃ CBr	137.03	lq.	1.211 ^{20/4}	–16.2	73.3	i.	∞
butyrate (<i>n</i>)-(<i>n</i> -)		C ₂ H ₅ CH ₂ CO ₂ CH ₂ CH ₂ C ₂ H ₅	144.21	col. lq.	0.872 ^{20/20}		165.7 ⁷³⁶	i.	∞
(<i>n</i>)-(i-)		C ₂ H ₅ CH ₂ CO ₂ CH ₂ CH(CH ₃) ₂	144.21	col. lq.	0.863 ^{18/4}		156.9	i.	∞
(i-)(i-)		(CH ₃) ₂ CHCO ₂ CH ₂ CH(CH ₃) ₂	144.21	col. lq.	0.875 ^{0/4}	–80.7	148–9	i.	∞
caproate		CH ₂ (CH ₂) ₅ CO ₂ C ₆ H ₅	172.26	col. lq.	0.882 ^{0/0}		204.3	i.	∞
carbamate (<i>i</i>)		NH ₂ CO ₂ CH ₂ CH(CH ₃) ₂	117.15	col. lf.	0.956 ^{76/4}	65	206–7	i.	S.
cellosolve (<i>n</i>)	2-BuO-ethanol-1	C ₄ H ₉ OCH ₂ CH ₂ OH	118.17	col. lq.	0.903 ^{20/4}		171.2	∞	∞

TABLE 2-2 Physical Properties of Organic Compounds (Continued)

Name	Synonym	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
								Water	Alcohol	Ether
chloride (<i>n</i>) (<i>s</i> -) (<i>i</i> -) (<i>t</i> -)	1-chloro-butane 2-chloro-butane 1-Cl ₂ -2-Me-propane 2-Cl ₂ -2-Me-propane	C ₂ H ₅ CH ₂ CH ₂ Cl C ₂ H ₅ CHCl-CH ₃ (CH ₃) ₂ CHCH ₂ Cl (CH ₃) ₂ CCl (CH ₃) ₂ C ₆ H ₃ -(CH ₃) ₂ HCO ₂ CH ₂ CH ₂ C ₂ H ₅ HCO ₂ CH(CH ₃) ₂ C ₂ H ₅ HCO ₂ CH ₂ CH(CH ₃) ₂ OC ₄ H ₉ CO ₂ C ₄ H ₉	92.57 92.57 92.57 92.57 162.26 102.13 102.13 102.13 102.13 168.19	col. lq. col. lq. col. lq. col. lq. col. lq. lq. lq. lq. lq. col. lq.	0.887 ²⁰ 0.871 ^{20/4} 0.884 ¹⁵ 0.847 ¹⁵ 0.911 ⁰ 0.882 ^{20/4} 0.885 ^{20/4} 0.856 ^{20/4} 0.953	-123.1 -131 -131.2 -26.5 106.9 97 98.2 118-20 ²⁵ 98.2	77.9 ⁷⁶³ 67.8 ⁷⁶⁷ 65.9 51-2 106.9 sl. s. 1.1 ²² i. i.	0.07 ¹⁸ ∞ ∞ ∞ ∞ ∞ ∞ ∞ ∞	∞ ∞ ∞ ∞ ∞ ∞ ∞ ∞ ∞	
dimethylbenzene (<i>t</i>)-(1-3,5-) formate (<i>n</i>) (<i>s</i> -) (<i>i</i> -)										
furoate (<i>n</i>) iodide (<i>n</i>) (<i>s</i> -) (<i>i</i> -) (<i>t</i> -)	1-iodo-butane 2-iodo-butane 1-iodo-2-Me-propane 2-iodo-2-Me-propane	C ₂ H ₅ CH ₂ CH ₂ I C ₂ H ₅ CHI-CH ₃ (CH ₃) ₂ CHCH ₂ I (CH ₃) ₂ CI	184.03 184.03 184.03 184.03	lq. lq. lq. lq.	1.617 ^{20/4} 1.595 ²⁰ 1.606 ^{20/4} 1.370 ^{19/15}	-103.5 -104 -90.7 -34	129.9 118-9 120 99	i. i. i. i.	∞ ∞ ∞ ∞	∞ ∞ ∞ ∞
lactate (<i>n</i>) mercaptan (<i>n</i>) (<i>i</i> -) (<i>t</i> -)	butanethiol-1 2-Me-propanthiol-1	C ₃ H ₉ CH ₂ SH (CH ₃) ₂ CHCH ₂ SH (CH ₃) ₂ CSH CH ₃ C(CH ₃)CO ₂ C ₄ H ₉ CH ₃ C(CH ₃)CO ₂ C ₄ H ₉	90.18 90.18 90.18 142.19 142.19	col. lq. col. lq. lq. lq. lq.	0.837 ^{25/4} 0.836 ^{20/4} 0.968 0.889 ^{15/6} 0.889 ^{15/6}	-116 <-79	97-8 88 155 155	sl. s. v. sl. s. i. i.	∞ V. S. V. S. S.	∞ V. S. S.
methacrylate (<i>n</i>) (<i>i</i> -)										
phenol (<i>p</i>)-(<i>t</i>) propionate (<i>n</i>) (<i>s</i> -) (<i>i</i> -)		C ₂ H ₅ CO ₂ C ₄ H ₉ (CH ₃) ₂ C ₆ H ₅ OH C ₂ H ₅ CO ₂ C ₄ H ₉ C ₂ H ₅ CO ₂ C ₄ H ₉ C ₂ H ₅ CO ₂ C ₄ H ₉	150.21 130.18 130.18 130.18 130.18	nd./aq. col. lq. col. lq. col. lq. col. lq.	0.908 ^{11/4} 0.883 ¹⁵ 0.866 ^{20/4} 0.888 ^{0/4} 0.855 ^{25/25}	99 -89.55 -71.4 27.5	236-8 146 136.8 220-5 ²⁵	sl. s. i. i. 0.3 ²⁵	S. S.	S. S.
stearate (<i>n</i>) (<i>i</i> -)		CH ₃ (CH ₂) ₁₆ CO ₃ C ₄ H ₉ CH ₃ (CH ₂) ₁₆ CO ₃ C ₄ H ₉	340.57	col. lq.			25	i.		
iso-thiocyanate (<i>n</i>) (<i>i</i> -) (<i>s</i> -(<i>d</i>)-) (<i>t</i> -)	butyl mustard oil iso-Bu mustard oil	C ₂ H ₅ CH ₂ N:CS (CH ₃) ₂ CHCH ₂ N:CS C ₄ H ₉ N:CS (CH ₃) ₂ C:N:CS CH ₃ (CH ₂) ₃ CO ₂ (CH ₂) ₃ CH ₃ (CH ₃) ₂ CHCH ₂ CO ₂ (CH ₂) ₃ CH ₃	115.19 115.19 115.19 115.19 158.23 158.23 158.23 158.23 158.23	lq. lq. lq. lq. lq. col. lq. col. lq. col. lq.	0.956 ¹¹ 0.964 ^{14/4} 0.943 ^{20/4} 0.919 ¹⁰ 0.870 ^{15/4} 0.862 ^{25/4} 0.848 ^{20/4} 0.874 ^{0/4}		165 ⁷²⁴ 162 159-63 10.5 140 ⁷⁷⁰ 186 168.8 163-4 ⁷⁵² 168.7	i. i. S. S. i. v. sl. s. i. i.	S. S. S. S. S. S. S. S.	
valerate (<i>n</i>)-(<i>n</i>) (<i>i</i>)-(<i>n</i>) (<i>i</i>)-(<i>s</i>) (<i>i</i>)-(<i>i</i>)		CH ₃ (CH ₂) ₃ CO ₂ (CH ₂) ₃ CH ₃ (CH ₃) ₂ CHCH ₂ CO ₂ (CH ₂) ₃ CH ₃ (CH ₃) ₂ CHCH ₂ CO ₂ C ₄ H ₉	158.23 158.23 158.23	col. lq. col. lq. col. lq.		-93	140 ⁷⁷⁰ 186 168.8 163-4 ⁷⁵² 168.7	i. i. S. d. d.	∞ ∞ ∞ ∞ ∞	
Butylene (<i>α</i> -) (<i>β</i> -)	butene-1 butene-2	C ₂ H ₅ CH-CH ₂ CH ₃ CH:CHCH ₃	56.10 56.10	col. gas col. gas	0.6 ⁹	-130	-5 ⁷⁵⁸	i.	V. S.	V. S.
Butyraldehyde (<i>n</i>) (<i>i</i> -)		CH ₃ CH ₂ CH ₂ CHO	72.10	col. lq.	0.817 ^{20/4}	-99	75.7	4	∞	∞
Butyric acid (<i>n</i>) (<i>i</i> -)	2-Me-propanol butanoic acid 2-Me-propanoic acid	(CH ₃) ₂ CHCHO C ₂ H ₅ CH ₂ CO ₂ H (CH ₃) ₂ CHCO ₂ H	72.10 88.10 88.10	col. lq. col. lq. col. lq.	0.794 ^{20/4} 0.964 ^{20/4} 0.949 ^{20/4}	-65.9 -4.7 -47	64 ⁷⁵⁷ 163.5 ⁷⁵⁷ 154.5	11 ²⁰ ∞ 20 ²⁰	∞ ∞ ∞	
amide (<i>n</i>) (<i>i</i> -)	<i>n</i> -butyramide	C ₅ H ₁₁ CONH ₂	87.12	rhb.	1.032	115-6	216	16.3 ¹⁵	sl. s.	sl. s.
anhydride (<i>n</i>) (<i>i</i> -)	iso-butyramide	(CH ₃) ₂ CHCONH ₂ (C ₂ H ₅ CH ₂) ₂ O [(CH ₃) ₂ CHCO] ₂ O	87.12 158.19 158.19	mm. pl. col. lq. col. lq.	1.013 0.968 ^{20/20} 0.950 ^{25/4}	129-30 -75 -53.5	216-20 199.5 181.5 ⁷³⁴	v. s. d. d.	sl. s. d. d.	
anilide (<i>n</i>)		C ₆ H ₅ CONHC ₆ H ₅	163.21	mm. pr.	1.134	92	189 ¹⁵	i.	s.	s.
Caffeic acid (3-4-) Caffeine		(HO) ₂ C ₆ H ₃ C ₆ CO ₂ H C ₁₀ H ₁₀ O ₄ N ₄ H ₂ O	180.15 212.21	yel./aq. nd./al.	1.015 1.23 ¹⁹	195-213	d.	s. h.	sl. s.	sl. s.
Camphene (<i>dl</i> -) (<i>d</i> - or <i>l</i> -)		C ₁₀ H ₁₆ C ₁₀ H ₁₆ C ₁₀ H ₁₆ O C ₁₀ H ₁₆ (CO ₂ H) ₂	136.23 136.23 152.23 200.23	cr. cr. trig. mn.	0.829 ⁷⁸ 0.845 ^{50/4} 0.999 ^{9/9} 1.186	237 50 178-9 187	subl. i. 209.1 ⁷⁵⁹ 187	2 i. 0.1 0.6 ¹²	2 s. s. s.	0.3
Camphor (<i>d</i>) Camphoric acid (<i>d</i> -)		C ₁₀ H ₁₆ O ₄	196.20	cr.		212		0.003		
Caprylic acid Caproic acid (<i>n</i>) (<i>i</i> -)	decanoic acid hexanoic acid 2-Me-pentanoic-5-acid	CH ₃ (CH ₂) ₈ CO ₂ H CH ₃ (CH ₂) ₆ CO ₂ H (CH ₃) ₂ CH(CH ₂) ₂ CO ₂ H	172.26 116.16 116.16	col. nd. oily lq. col. oil	0.889 ⁵⁷ 0.922 ^{20/4} 0.925 ^{20/4}	31.5 -1.5 -35	268-70 202 ⁷⁶¹ 207.7	0.003 1.1 ²⁰ v. sl. s.	S. S. S.	S. S. S.
Caprylic acid (<i>n</i>) Carbazole Carbitol Carbon disulfide monoxide suboxide	octanoic acid diphenylenelimine, dibenzopyrrole diethylene glycol mono-Et ether	CH ₃ (CH ₂) ₈ CO ₂ H CH ₃ (CH ₂) ₆ CO ₂ H CH ₃ (CH ₂) ₂ NH C ₆ H ₅ O(CH ₂) ₂ O(CH ₂) ₂ OH CS ₂ CO	144.21 167.20 134.17 76.13 28.01	col. lf. lf. col. lq. col. lq. col. gas	0.910 ^{20/4} 0.990 ^{20/20} 1.263 ^{20/4} 1.114 ⁰ 0.81-195 ⁴	16 244.8 -108.6 -107 -207	237.5 354.8 46.3 7 ⁷⁶¹ 3.5 ⁰ cc.	0.07 ¹⁵ i. 0.2 ⁰ d. S.	S. S. S. S. S.	S. S. S. S. S.
tetrabromomethane tetrachloromethane tetrafluoromethane		CBr ₄ CCl ₄ CF ₄ COS	331.67 153.84 88.01 60.07	col. mn. col. lq. gas col. lq.	3.42 1.595 ^{20/4} 1.114 ⁰ 1.24 ⁸⁷	90.1(48) -22.6 -107 -138.2	189.5 76.8 191.9 -50.2 ⁷⁶⁰	0.02 ³⁰ 0.08 ²⁰ d. 80 ¹⁴ cc.	S. S. S. S.	S. S. S. v. sl. s.
Carbonyl sulfide Carminic acid Carvacrol (1-2-4-)		C ₂₂ H ₂₀ O ₁₃ CH ₃ C ₆ H ₃ (OH)CH(CH ₃) ₂	492.40 150.21	red pd. col. lq.	0.977 ^{20/4} 0.977 ^{20/4}	0.136 0.5	238	v. sl. s. ∞	v. sl. s. ∞	v. sl. s. ∞

Carvacrylamine (2-,1-,4-)	H ₂ NCH ₂ CH(CH ₃)C ₃ H ₇	149.23	oil	0.994 ²⁰	-16	241 ⁶⁶	v. sl. s.	s.	s.
Carvone (<i>d</i> -)	C ₁₀ H ₁₄ O	150.21	col. lq.	0.961 ^{20/4}	230 ⁶⁶	i.	∞	∞	∞
Cellosolve	C ₅ H ₅ O(CH ₂) ₂ OH	90.12	col. lq.	0.931 ^{20/4}	-70	135.1	∞	∞	∞
acetate	CH ₃ CO ₂ CH ₂ CH ₂ OC ₂ H ₅	132.16	col. lq.	0.975 ^{20/4}	156.3	22	∞	∞	∞
Cellulose	(C ₆ H ₁₀ O ₅) _x	162.14	amor.	1.3-1.4	i.	i.	i.	i.	i.
Cetyl acetate	CH ₃ CO ₂ (CH ₂) ₁₅ CH ₃	284.47	nd.	0.855 ²⁰	22-3	200 ¹⁵	v. sl. s. c.	v. sl. s. c.	v. sl. s. c.
alcohol	CH ₃ (CH ₂) ₁₄ CH ₂ OH	242.43	lf.	0.818 ^{50/4}	49-50	189.5 ¹⁵	s.	s.	s.
Chloral	CCl ₃ CHO	147.40	col. lq.	1.505 ^{25/4}	-57	97.6 ⁷⁶⁸	∞	∞	∞
hydrate	CCl ₃ CH(OH) ₂	165.42	mn. pr.	1.619 ^{50/4}	51.7	d. 98	474 ¹⁷	v. s.	s.
Chloranil	OC:(CCl-CCl) ₂ :CO	245.89	yel./bz.		290	subl.	i.	i. c.	i. c.
Chloretone	Cl ₂ C:C(OH)(CH ₃) ₂	177.47	col. cr.		97	167	0.8 c.	111	s.
Chloro-acetanilide (<i>p</i> -)	CH ₃ CO ₂ NHC ₆ H ₄ Cl	169.61	rhb.	1.385 ²⁰	175-6	i.	s.	v. s.	v. s.
-acetic acid	ClCH ₂ CO ₂ H	94.50	col. cr.	1.58 ^{20/20}	61.2	189.5	s.	s.	s.
-acetone	CH ₃ COCH ₂ Cl	92.53	col. lq.	1.162 ¹⁶	-44.5	121	∞	∞	∞
-acetophenone (<i>ω</i> -)	C ₆ H ₅ COCH ₂ Cl	154.59	rhb.	1.324 ¹⁵	58-9	245-7	0.11	v. s.	v. s.
-acetyl chloride	ClCH ₂ COCl	112.95	col. lq.	1.498 ^{20/20}		105	d.	d.	d.
-aniline (<i>o</i> -)	ClC ₆ H ₅ NH ₂	127.57	lq.	1.213 ^{20/4}	0	210.5	i.	s.	s.
(<i>m</i> -)	ClC ₆ H ₄ NH ₂	127.57	lq.	1.216 ^{20/4}	-10.4	230 ⁷⁶⁷	i.	s.	s.
(<i>p</i> -)	ClC ₆ H ₄ NH ₂	127.57	rhb.	1.427 ¹⁹	70-1	230-1	s. h.	s.	s.
-anthraquinone (1-)	CaH ₄ (CO) ₂ C ₆ H ₃ Cl	242.65	yel. nd.		162	subl.	i.	sl. s. h.	sl. s. h.
(2-)	CaH ₄ (CO) ₂ C ₆ H ₅ Cl	242.65	nd./al.		208-9	i.	i.	i.	i.
-benzaldehyde (<i>o</i> -)	ClC ₆ H ₅ CHO	140.57	nd.	1.29 ⁸	11	208 ⁷⁴⁸	v. sl. s.	v. s.	v. s.
(<i>m</i> -)	ClC ₆ H ₄ CHO	140.57	pr.	1.250 ¹⁵	17-8	213-4	v. sl. s.	v. s.	v. s.
(<i>p</i> -)	ClC ₆ H ₃ CHO	140.57	pr.	1.196 ⁶¹	47.8	213 ⁷⁴⁸	s. h.	v. s.	v. s.
-benzene	C ₆ H ₆ Cl	112.56	col. lq.	1.107 ^{20/4}	-45.2	132.1	0.049 ²⁰	∞	∞
-benzoic acid (<i>o</i> -)	ClC ₆ H ₅ CO ₂ H	156.57	mn./aq.	1.544 ^{25/4}	141-2	205 ²⁵	s.	s.	s.
(<i>m</i> -)	ClC ₆ H ₄ CO ₂ H	156.57	pr.	1.496 ^{25/4}	158	0.041 ²⁵	s.	s.	s.
(<i>p</i> -)	ClC ₆ H ₃ CO ₂ H	156.57	tri.	1.541 ²⁴	242-3	0.008 ²⁵	s.	s.	s.
-buta-1,3-diene (2-)	CH ₂ :CCl-CH:CH ₂	88.54	col. lq.	0.958 ^{20/20}		59.4	v. sl. s.	∞	∞
(1-)	CH ₂ :CH-CH:CHCl	88.54	col. lq.	0.965 ^{20/20}		69	v. sl. s.	∞	∞
-buta-1,2-diene (4-)	CH ₂ :C(CH ₂) ₂ Cl	88.54	col. lq.	0.991 ^{20/20}		88	d.	d.	d.
-dimethylhydantoin	—C(CH ₃) ₂ N(Cl)CON(Cl)CO—	197.03		1.5 ^{20/20}	130	0.21 ²⁵			
-dinitrobenzene (<i>α</i>)(1-,2-)(4-)	ClC ₆ H ₃ (NO ₂) ₂	202.56	cr./et.		39(36)	315 d.	i.	v. s. h.	v. s.
(<i>α</i>)(1-,3-)(4-)	ClC ₆ H ₃ (NO ₂) ₂	202.56	rhb./et.	1.697 ²²	53(43)	315 d.	i.	s. h.	s.
-diphenyl (<i>o</i> -)	C ₆ H ₅ :C ₆ H ₅ Cl	188.65	cr.		34	267-8	i.	i.	i.
(<i>m</i> -)	C ₆ H ₅ :C ₆ H ₄ Cl	188.65	cr.		89	284-5	i.	i.	i.
(<i>p</i> -)	C ₆ H ₅ :C ₆ H ₃ Cl	188.65	lf.		77.5	282	i.	i.	i.
-hydroquinone	ClC ₆ H ₃ (OH) ₂	144.56	mn.		106	263 sl. d.	v. s.	v. s.	v. s.
-naphthalene (<i>α</i> -)	C ₁₀ H ₈ Cl	162.61	col. lq.	1.194 ^{20/4}	-20	259.3	i.	∞	∞
(<i>β</i> -)	C ₁₀ H ₇ Cl	162.61	lf./al.	1.266 ¹⁶	56-7	264 ⁷⁵¹	i.	v. s.	v. s.
-nitrobenzene (<i>o</i> -)	ClC ₆ H ₄ NO ₂	157.56	mn. nd.	1.305 ^{80/4}	32.5	245.5 ⁷³³	i.	s. h.	s.
(<i>m</i> -)	ClC ₆ H ₃ NO ₂	157.56	yel./al.	1.343 ^{50/4}	44.4(24)	235.6	i.	v. s. h.	v. s.
(<i>p</i> -)	ClC ₆ H ₂ NO ₂	157.56	mn. pr.	1.298 ⁹¹	83-4	242 ⁷⁶¹	i.	v. s. h.	v. s.
-nitrotoluene (2-,4-)	CH ₃ C ₆ H ₃ (NO ₂)(Cl)	171.56	cr.	1.256 ⁵⁰	38.2	240 ⁷¹⁸	i.	i.	i.
(2-,6-)	CH ₃ C ₆ H ₃ (NO ₂)(Cl)	171.56	cr.		37.5	238	i.	i.	i.
-phenol (<i>o</i> -)	ClC ₆ H ₅ OH	128.56	col. lq.	1.241 ^{18/15}	7(0)	175-6	2.85 ³⁰	s.	s.
(<i>m</i> -)	ClC ₆ H ₄ OH	128.56	nd.	1.268 ²⁵	32-3	214	2.60 ³⁰	s.	s.
(<i>p</i> -)	ClC ₆ H ₃ OH	128.56	nd.	1.306 ^{20/4}	41-3	217	2.71 ³⁰	v. s.	v. s.
-propionic acid (<i>α</i>)(dl-)	CH ₃ :CHCl-CO ₂ H	108.53	col. lq.	1.306 ⁹	<20	186	∞	∞	∞
-toluene (<i>o</i> -)	CH ₃ :C ₆ H ₄ Cl	126.58	col. lq.	1.082 ^{20/4}	-34	159.5	i.	s.	s.
(<i>m</i> -)	CH ₃ :C ₆ H ₃ Cl	126.58	col. lq.	1.072 ^{20/4}	-47.8	161.6	i.	s.	s.
(<i>p</i> -)	CH ₃ :C ₆ H ₂ Cl	126.58	col. lq.	1.070 ^{20/4}	7.5	162.2	i.	s.	s.
Chloroform	CHCl ₃	119.39	col. lq.	1.489 ²⁰	-63.5	61.2	0.82 ²⁰	∞	∞
Chlorophyll (<i>α</i> -)	C ₅₅ H ₇₂ O ₅ N ₄ Mg	893.48		d.	i.	s.			
Chloropicrin	Cl ₂ CNO ₂	164.39	lq.	1.651 ^{23/4}	-64	112.3 ⁷⁶⁶	0.17 ¹⁸	s.	s.
Cholesterol	C ₂₈ H ₄₈ OH-H ₂ O	404.65	rhb./al.	1.067	149-51	subl.	0.26 ²⁰	1.1 ¹⁷	18
Chrysene	C ₁₈ H ₁₂	228.28	col. rhb.		253-4	448	i.	0.1 ¹⁶	v. sl. s.
Chrysoidine (2-,4-)	C ₆ H ₅ :N:N-C ₆ H ₃ (NH ₂) ₂	212.25	yel. cr.		117.5	sl. s. h.	s.	s.	s.
Chrysophanic acid	C ₁₄ H ₁₀ (OH) ₂ (CH ₃) ₂ O ₂	254.23	yel./al.		195	subl.	i. c.	s. h.	sl. s.
Cincheronic acid (3-,4-)	C ₆ H ₅ N(CO ₂ H) ₂	167.12	cr./HCl		258-9 d.	subl. d.	v. sl. s.	sl. s.	i.
Cineole, eucalyptole	C ₁₀ H ₁₈ O	154.24	col. oil	0.927 ²⁰	1.5	176-7	1.9 ¹⁵	∞	∞
Cinnamic acid (<i>cis</i> -)	C ₉ H ₇ CH:CHCO ₂ H	148.15	mn. pr.	1.284 ⁴	68	125 ¹⁹	0.04 ¹⁸	24 ³⁰	v. s.
(<i>trans</i> -)	C ₉ H ₇ CH:CHCO ₂ H	148.15	mn. pr.	1.245	133	300			
aldehyde	C ₉ H ₇ CH:CHCHO	132.15	lq.	1.110 ^{20/20}	-7.5	252 sl. d.	v. sl. s.	s.	∞
Cinnamyl alcohol	C ₉ H ₇ CH:CHCH ₂ OH	134.17	nd.	1.040 ^{35/35}	33	257.5	sl. s.	v. s.	v. s.
cinnamate	C ₉ H ₇ CO ₂ C ₆ H ₅	264.31	nd. or pr.	1.085 ^{16.5}	44	i.	4 c.	33	33
Citraconic acid (<i>cis</i> -)	CH ₂ C(CH ₂) ₂ :CHCO ₂ H	130.10	nd.	1.617	92-3	360 ²⁵	s.	s.	s.
Citral (<i>α</i>)	C ₉ H ₁₅ CHO	152.23	col. oil	0.890 ^{17/4}		229	i.	∞	∞
Citric acid	C ₆ H ₅ (OH)(CO ₂ H) ₃	192.12	cr.	1.542 ^{20/4}	153	d.	207.7 ²⁵	76 ¹⁵	2 ¹⁵
Citronellal (<i>d</i> -)	C ₉ H ₁₇ CHO	154.24	col. oil	0.855 ^{17.5}		204-8	v. sl. s.	∞	∞
Citronellol (<i>d</i> -)	C ₁₀ H ₂₀ O	156.26	col. oil	0.848 ^{20/4}		224-5	v. sl. s.	∞	∞
Conifine (<i>d</i>)-(2-)	C ₉ H ₇ C ₅ H ₁₀ N	127.22	col. lq.	0.847 ¹⁷	-2	166-7	1.1	V. S.	V. S.

TABLE 2-2 Physical Properties of Organic Compounds (Continued)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Coumaric acid (<i>o</i> -) (<i>p</i> -)	HOC ₆ H ₄ CH:CHCO ₂ H HOC ₆ H ₄ CH:CHCO ₂ H	164.15 164.15	nd/aq. cr./aq.	0.935 ^{20/4} 0.935 ^{15/15}	207–8 206–7 d. 70	subl. 290–1 173–4	sl. s. c. s. h. v. s. h. v. s.	s. v. s. s.	v. sl. s. v. s.
Coumarin	C ₉ H ₈ O ₂	146.14	rbh./et.	1.078 ^{15/15}	<18	295	i.	s.	s.
Coumarone	C ₈ H ₈ O	118.13	oil	1.078 ^{15/15}	260 d.	1.4 ¹⁸ 8.7 ¹⁶	0.01 ¹⁷ 1 ¹⁶	0.01 ¹⁷ i.	i.
Creatine	C ₄ H ₁₀ N ₂ O ₂ ·H ₂ O	149.15	mn./aq.						
Creatinine	C ₄ H ₁₀ N ₂ O	113.12	mn.						
Creosol (3-,1-,4-)	CH ₃ O·C ₆ H ₅ (CH ₃)OH	138.16	pr.	1.092 ^{20/20}	5.5	221–2 ⁷⁵	v. sl. s.	∞	∞
Cresidine (1-,2-,4-)	CH ₃ (NH ₂)C ₆ H ₅ ·OCH ₃	137.18	nd./pet.		93–4	235	v. sl. s.	S. ∞ ³⁰	S. ∞ ³⁰
Cresol (<i>o</i> -) (<i>m</i> -) (<i>p</i> -)	CH ₃ C ₆ H ₅ OH CH ₃ C ₆ H ₄ OH CH ₃ C ₆ H ₃ OH	108.13 105.13 105.13	cr. lq. pr.	1.048 ^{20/4} 1.034 ^{20/4} 1.035 ^{20/4}	30.8 10.9 35–6	190.8 202.8 202	2.5 0.5 1.8	∞ ∞ ³⁶	∞ ∞ ³⁶
Cresyl benzoate (<i>o</i> -) (<i>m</i> -) (<i>p</i> -)	C ₆ H ₅ CO ₂ C ₆ H ₅ CH ₃ C ₆ H ₅ CO ₂ C ₆ H ₄ CH ₃ C ₆ H ₅ CO ₂ C ₆ H ₃ CH ₃	212.24 212.24 212.24	lq. cr. cr.		55 71.5 71.5	308 314 316	i. i. i.		
Crotonic acid (<i>α</i> -) acid (<i>β</i>)-(<i>cis</i>)- aldehyde (<i>α</i>)	CH ₃ CH:CHCO ₂ H CH ₃ CH:CHCO ₂ H CH ₃ CH:CHCHO	86.09 86.09 70.09	col. mn. nd. col. lq.	0.964 ^{79.7} 1.031 ^{15/4} 0.853 ^{20/20}	15.5 170–1 d. −69	189 170–1 d. 102.2	8.3 ¹⁵ ∞ ²⁵	S. ∞ ∞	S. ∞ ∞
Cumene	C ₆ H ₅ CH(CH ₃) ₂	120.19	col. lq.	0.862 ^{20/4}	−96.9	152.5	i.	∞ ∞	∞ ∞
Cumic acid (<i>p</i> -)	(CH ₃) ₂ CH·C ₆ H ₄ CO ₂ H	164.20	tri.	1.16 ⁴	116–7	subl.	0.02 ²⁵	S.	S.
Cumidine (<i>p</i> -)	(CH ₃) ₂ CH·C ₆ H ₄ NH ₂	135.20	lq.	0.953	<20	225 ⁷⁶¹	i.		
Cyanamide	H ₂ N·CN	42.04	col. nd.	1.073 ^{48/4}	44–5	140 ¹⁹	v. s.	v. s.	v. s.
Cyanic acid	HOCN or HNCO	43.03	gas	1.140 ⁰	−80	−64 ⁰	sl. s.	s.	s.
Cyanoacetic acid	CH ₂ (CN)CO ₂ H	85.06	col. lq.		65–6	105 ^{0.2}	s.	s.	s.
Cyanogen	(CN) ₂	52.04	col. gas	0.866 ¹⁷	−34.4	−21	450 ²⁰ cc.	2300 ²⁰ cc.	500 ²⁰ cc.
bromide	BrCN	105.93	nd.	2.015 ^{20/4}	52	61.3 ⁷⁵⁰	s.	s.	s.
chloride	ClCN	61.48	gas	1.292 ⁰	−6.5	12.5–13	2500 ²⁰ cc.	5000 ²⁰ cc.	5000 ²⁰ cc.
Cyanuric acid	C ₃ H ₃ O ₃ N ₃ ·2H ₂ O	165.11	mm./aq.	1.768 ^{9/4}	>360	d.	0.27 ¹⁷	0.1 ²²	
Cyclo-butane	CH ₂ < (CH ₂) ₂ > CH ₂	56.10	col. gas	0.703 ^{1/4}	−50	11–12 ⁷²⁶	i.	v. s.	
-heptane	CH ₂ < (CH ₂ CH ₂ CH ₂) ₂ >	95.18	oil	0.810 ^{20/4}	−12	118–20	i.	∞	∞
-hexane	CH ₂ < (CH ₂ CH ₂ CH ₂) ₂ > CH ₂	84.16	col. lq.	0.779 ^{20/4}	6.5	80–1	i.	s.	s.
-hexanol	CH ₂ < (CH ₂ CH ₂ CH ₂) ₂ > CHOH	100.16	col. nd.	0.962 ^{20/4}	23.9	160–1	3.6 ²⁰	s.	s.
-hexanone	CH ₂ < (CH ₂ CH ₂ CH ₂) ₂ > CO	95.14	col. oil	0.947 ^{19/4}	−45	155–6	s.	s.	s.
-hexene	(CH ₂) ₅ CH ₂ CH ₂) ₂	82.14	lq.	0.810 ^{20/4}	−103.7	83.3	v. sl. s.	v. s.	v. s.
-hexyl acetate	CH ₃ CO ₂ C ₆ H ₁₁	142.19	oil	0.985 ^{1/4}		174 ⁷⁵⁰	i.	∞	∞
amine	CH ₂ < (CH ₂ CH ₂) ₂ > CHNH ₂	99.17	col. lq.	0.865 ^{20/0}		134	i.	s.	s.
bromide	CH ₂ < (CH ₂ CH ₂) ₂ > CHBr	163.06	col. lq.	1.324 ^{20/20}		165 ⁷¹⁴	i.	s.	s.
chloride	CH ₂ < (CH ₂ CH ₂) ₂ > CHCl	118.61	col. lq.	0.977 ^{18/4}	−43.9	142	i.	∞	∞
-pentadiene (1-,3-)	CH ₂ < (CH ₂ CH ₂) ₂ >	66.10	col. lq.	0.805 ^{19/4}	−85	41–2	i.	∞	∞
-pentane	CH ₂ < (CH ₂ CH ₂) ₂ >	70.13	col. oil	0.745 ^{20/4}	−93.3	49–50	i.		
-pentanone	<(CH ₂ CH ₂) ₂ >CO	84.11	col. oil	0.948 ²⁰	−58.2	129–30	v. sl. s.		
-propane	<CH ₂ CH ₂ CH ₂ >	42.08	col. gas	0.720 ⁷⁹	−126.6	−34 ⁴⁹	i.	s.	s.
Cymene (<i>o</i> -) (<i>m</i> -) (<i>p</i> -)	CH ₃ ₂ C ₆ H ₃ CH(CH ₃) ₂ CH ₃ ₂ C ₆ H ₄ CH(CH ₃) ₂ CH ₃ ₂ C ₆ H ₅ CH(CH ₃) ₂	134.21 134.21 134.21	col. lq. col. lq. col. lq.	0.875 ^{20/4} 0.862 ²⁰ 0.857 ^{20/4}	<25 −73.5	175–6 176–7	i.	s.	s.
Cystine (<i>I</i> -)	[·SCH ₂ CH(CH ₂ NH ₂)CO ₂ H] ₂	240.29	pl.		d. 258–61	0.01 ¹⁹	i.		
Dambose	C ₆ H ₆ (OH) ₆	180.16	mm./aq.	1.752	253	319 ¹⁵	2 ¹²	i.	i.
Decahydronaphthalene (<i>cis</i> -) (<i>trans</i> -)	C ₁₀ H ₁₈	138.24	lq.	0.895 ^{18/4}	−51	193.3	i.	s.	s.
Decane (<i>n</i> -)	C ₁₀ H ₂₂	138.24	lq.	0.872 ^{20/4}	−32	185.3	i.	s.	s.
Decyl alcohol	CH ₃ (CH ₂) ₉ CH ₃	142.28	col. lq.	0.730 ²	−29.7	174.0	i.	∞	∞
Dextrin	CH ₃ (CH ₂) ₉ CH ₂ OH	158.28	col. oil	0.830 ^{20/4}	7	232.9	i.	s.	i.
Diacetone alcohol	(C ₆ H ₁₀ O ₂) ₂	162.14	amor.	1.038			s.	i.	i.
Diamino-benzophenone (4-,4'-)	(CH ₃) ₂ C(OH)·CH ₂ COCH ₃	116.16	lq.	0.931 ²⁵	−47	167.9	∞	∞	∞
-diphenylamine (4-,4')	H ₂ NC ₆ H ₄ CO ₂ C ₆ H ₄ NH ₂	212.24	yel. nd.		237–9	sl. s. h.	s.	s.	s.
-diphenylmethane (4-,4')	H ₂ NC ₆ H ₄ NHC ₆ H ₄ NH ₂	199.25	lf./aq.		158	d.	sl. s.	s.	s.
-diphenylurea (4-,4')	H ₂ NC ₆ H ₄ CH ₂ C ₆ H ₄ NH ₂	198.26	nd./aq.		93–4	249–53 ¹⁵	sl. s. c.	s.	s.
Diamyl-amine (<i>I</i> -)	(H ₂ NC ₆ H ₄ NH ₂) ₂ O	242.28	cr.		subl. 310	v. sl. s.			
ether (<i>n</i> -) (<i>i</i> -)	[(CH ₃) ₂ CHCH ₂ CH ₂) ₂]NH	157.29	col. lq.	0.767 ^{21/4}	−44	188–90	sl. s.	s.	∞
Diamyl ketone (<i>I</i> -)	(C ₆ H ₅ CH ₂ CH ₂ CH ₂) ₂ O	158.28	col. lq.	0.774 ^{20/4}	−69	190	i.	∞	∞
phthalate (<i>n</i> -) (<i>i</i> -)	[(CH ₃) ₂ CHCH ₂ CH ₂) ₂ O	158.28	col. lq.	0.777 ^{20/4}		173.4	i.	∞	∞
tartrate (<i>I</i> -)	[(CH ₃) ₂ CHCH ₂ CH ₂) ₂ CO	170.29	yel. oil	0.821 ^{25/4}	14.6	228	i.	s.	s.
Dianisidine (<i>o</i> -(4-,3-) ₂)	C ₆ H ₄ (CO ₂ C ₆ H ₁₁) ₂	306.39	col. lq.	1.03		204–6 ¹¹			
Diazo-aminobenzene	(HOCH ₂ CO ₂ C ₆ H ₁₁) ₂	290.35	lq.	1.063 ^{15/4}		195 ¹⁶	i.	s.	s.
-aminotoluene (2-,2'-)	[NH ₂ (OCH ₃)C ₆ H ₃ ·] ₂	244.28	col. lf.		131.5	i.	s.	s.	s.
-methane	C ₆ H ₅ N:N·NH ₂ C ₆ H ₇	197.23	yel. lf.		96–8	expl.	i.	s. h.	v. s.
	C ₇ H ₇ N:N·NH ₂ C ₆ H ₇	225.28	or. cr.		51	0.05	d.		
	CH ₂ ₂ N ₂	42.04	gas		−145	−23			s.

Dibenzothiazyl-disulfide (2,2')	(C ₆ H ₅ NSC) ₂ S ₂	232.46	cr.	1.50	180	d.	i.	4.4 ²⁰	s.
Dibensoyl methane	(C ₆ H ₅ CO) ₂ CH ₂	224.25	rhb./al.	78	219–21 ¹⁸	i.	s.		
Dibensyl-amine	(C ₆ H ₅ CH ₂) ₂ NH	197.27	col. oil	1.028 ^{25/25}	–26	268–71 ²⁵⁰	i.	s.	
-aniline			pr./al.		70–1	>300	i.	v. sl. h.	s.
ketone			cr.		34–5	330.6	i.		
phthalate (o-)	C ₆ H ₄ (CO ₂ CH ₂ C ₆ H ₅) ₂	273.36	pr./al.		42–3	274 ¹²	v. sl. s.	s.	s.
succinate	(C ₆ H ₅ CH ₂) ₂ CO	210.26	lf./al.		45–6	238 ¹⁴	i.	s.	s.
Dibromo-benzene (o-)	C ₆ H ₄ (CO ₂ CH ₂ C ₆ H ₅) ₂	346.36	col. iq.	1.956 ^{20/4}	1.8	221–2	i.	s.	s.
(m-)	C ₆ H ₅ Br ₂	298.32	col. iq.	1.952 ^{20/4}	–6.9	219 ⁷⁵	i.	s.	s.
(p-)	C ₆ H ₅ Br ₂	235.92	pl./al.	2.261 ¹⁸	87–8	218.6 ⁷⁵⁸	i.	1.6	71 ²⁵
-diphenyl (4-,4'-)	BrC ₆ H ₅ C ₆ H ₄ Br	312.02	mn. pr.	1.897	164–5	355–60	i.	v. sl. s. h.	
Dibutyl-adipate (n-)	(·CH ₂ CH ₂ CO ₂ C ₆ H ₅) ₂	258.35	col. iq.	0.965 ^{20/4}	–38	183 ¹⁴	i.	∞	∞
(i-)	(·CH ₂ CH ₂ CO ₂ C ₆ H ₅) ₂	258.35	col. iq.	0.950 ²⁵	–20	278–80	i.		
-amine (n-)	(C ₆ H ₅ CH ₂) ₂ NH	129.24	col. iq.	0.768 ^{20/20}		159 ⁷⁶¹	∞	∞	∞
(i-)	[(CH ₃) ₂ CHCH ₂] ₂ NH	129.24	col. iq.	0.741 ^{35/4}	–70	139–40	v. sl. s.	s.	s.
-p-aminophenol (s-)	(C ₆ H ₅) ₂ N·C ₆ H ₄ OH	221.33	iq.			170 ¹⁰	i.		
-aniline (n-)	C ₆ H ₅ N(C ₆ H ₅) ₂	205.33	iq.			262.8	i.	∞	∞
carbonate (n-)	CO(OC ₄ H ₉) ₂	174.23	col. iq.	0.924 ^{20/4}		207 ⁷⁴⁰	i.		
(i-)	CO(OC ₄ H ₉) ₂	174.23	col. iq.	0.919 ¹⁵		190	i.	s.	
(s-)	CO(OC ₄ H ₉) ₂	174.23	col. iq.			178–80			
ether (n-)	(C ₂ H ₅ CH ₂ CH ₂) ₂ O	130.22	iq.	0.769 ^{20/20}	–98	142.4	<0.05	∞	∞
(i-)	[(CH ₃) ₂ CHCH ₂] ₂ O	130.22	iq.	0.762 ¹⁵		122.5	i.	∞	∞
(s-)	[C ₃ H ₅ (CH ₃)CH ₂] ₂ O	130.22	iq.	0.756 ²¹		121	i.	∞	∞
ketone (n-)	(C ₂ H ₅ CH ₂ CH ₂) ₂ CO	142.23	iq.	0.827 ^{18/4}	–5.9	187.7	i.	s.	v. s.
(i-)	[(CH ₃) ₂ CHCH ₂] ₂ CO	142.23	oil	0.805 ^{21/4}		168.1	<0.06	∞	∞
malate (L)(n-)	C ₂ H ₅ O(CO ₂ C ₆ H ₅) ₂	246.30	iq.	1.038 ^{20/4}		170–1 ¹⁸	v. sl. s.		
oxalate (n-)	(·CO ₂ C ₆ H ₅) ₂	202.24	col. iq.	0.986 ^{20/4}	–29.6	245.5	i.	s.	s.
phthalate (n-)	C ₆ H ₄ (CO ₂ C ₆ H ₅) ₂	278.34	col. iq.	1.045 ²¹		340	0.04 ²⁵	∞	∞
tartrate (d-)(n-)	(CHOHCO ₂ C ₆ H ₅) ₂	262.30	pr.	1.098 ¹⁵	22–2.5	200–3 ³¹⁸	i.		
(d-)(i-)	(CHOHCO ₂ C ₆ H ₅) ₂	262.30	cr.	1.031 ⁷⁵⁴	73–4	323–5	v. sl. s.		
Dichloro-acetic acid	Cl ₂ CH-CO ₂ H	128.95	iq.	1.560 ^{25/25}	9.7(–4)	194.4	∞	∞	∞
-acetone (αα-)	Cl ₂ CHCOCH ₃	126.98	iq.	1.234 ¹⁵		120	v. sl. s.	s.	s.
-aniline (2-,5-)	Cl ₂ C ₆ H ₅ NH ₂	162.02	nd.		50	251	v. sl. s.	s.	s.
-anthraquinone (1,-3-)	C ₉ H ₆ (CO) ₂ C ₆ H ₅ Cl ₂	277.10	yel. nd.		208–9	i.	v. sl. s.	v. sl. s.	
(1,-4-)	C ₉ H ₆ (CO) ₂ C ₆ H ₅ Cl ₂	277.10	yel. nd.		157.5	i.	sl. s.		
(1,-5-)	C ₉ H ₆ Cl ₂ (CO) ₂ C ₆ H ₅ Cl	277.10	yel. nd.		251	i.			
(1,-6-)	C ₉ H ₆ Cl ₂ (CO) ₂ C ₆ H ₅ Cl	277.10	yel. nd.		203–4	i.			
(1,-8-)	C ₉ H ₆ Cl ₂ (CO) ₂ C ₆ H ₅ Cl	277.10	yel. nd.		202–3	i.	sl. s.		
(2,-3-)	C ₉ H ₆ Cl ₂ (CO) ₂ C ₆ H ₅ Cl	277.10	yel. nd.		268–70	i.	sl. s.		
(2,-6-)	C ₉ H ₆ Cl ₂ (CO) ₂ C ₆ H ₅ Cl	277.10	yel. nd.		282	i.			
(2,-7-)	C ₉ H ₆ Cl ₂ (CO) ₂ C ₆ H ₅ Cl	277.10	yel. nd.		210–11	i.			
-benzene (o-)	C ₆ H ₅ Cl ₂	147.01	col. iq.	1.305 ^{20/4}	–17.6	179	i.	∞	∞
(m-)	C ₆ H ₅ Cl ₂	147.01	col. iq.	1.288 ^{20/4}	–24.8	172 ⁷⁶⁶	i.	s.	s.
(p-)	C ₆ H ₅ Cl ₂	147.01	col. mn.	1.458 ²¹	53	174 ⁷⁶⁴	i.	v. s.	v. s.
-butane (n-)(1-,4-)	ClCH ₂ (CH ₂) ₂ CH ₂ Cl	127.02	iq.		–38.7	161–3	i.		
-diphenyl (4-,4'-)	ClC ₆ H ₅ CH ₂ Cl	223.10	pr.	1.442 ^{0/4}	148	315–9	i.	v. sl. s.	4 ²⁵
-ethane (1,-2-)	ClCH ₂ CH ₂ Cl	98.97	col. iq.	1.256 ^{20/20}	–35.3	83.7	0.9 ⁰	∞	∞
-naphthalene (β-)(1-,4-)	C ₁₀ H ₈ Cl ₂	197.06	nd/al.	1.300 ⁷⁶⁴	67–8	286–7 ⁷⁴⁰	i.	v. sl. s.	
(γ-)(1,-5-)	C ₁₀ H ₈ Cl ₂	197.06	lf./al.		107	subl.	i.	s.	s.
-nitrobenzene (2-,5-)	C ₆ H ₅ C ₆ H ₃ NO ₂	192.01	tri./al.	1.669 ³²	54.6	266	i.	v. s. h.	
-pentane (1-,5-)	ClCH ₂ (CH ₂) ₂ CH ₂ Cl	141.04	col. iq.	1.094 ^{25/4}		180–1	i.	s.	s.
-phenol (2-,4-)	Cl ₂ C ₆ H ₅ OH	163.01	nd.	1.383 ^{90/25}	45	209–10	0.45 ²⁰	v. s.	v. s.
Dichloramine T (p-)	CH ₃ C ₆ H ₅ SO ₂ Cl ₂	240.11	cr.		83	sl. s.			
Dicyandiamide	H ₂ N-C:(NH)-NH-CN	84.08	mn. pl.	1.40 ¹⁴	207–8	d.	2.3 ¹⁸	1.3 ¹⁸	0.01 ¹⁸
Diethanolamine	HN(CH ₂ CH ₂ OH) ₂	105.14	pr.	1.097 ^{20/4}	28	270 ⁷⁴⁸	∞	v. sl. s.	
Diethyl adipate	(·CH ₂ CH ₂ CO ₂ C ₂ H ₅) ₂	202.24	col. iq.	1.009 ^{20/4}	–21	239–41 ⁷⁶¹	0.43 ⁸⁰	s.	s.
-amine	(C ₂ H ₅) ₂ NH	73.14	col. iq.	0.712 ^{15/15}	–38.9	55.5 ⁷⁵⁹	v. s.	∞	
-aminophenol (m-)	(C ₂ H ₅) ₂ N·C ₆ H ₄ ·OH	165.23	rhb.		78	276–80	s.		
-aniline	(C ₂ H ₅) ₂ N·C ₆ H ₅	149.23	oil	0.934 ^{20/4}	–34.4	216	1.4 ¹²	s.	s.
sulfonic acid (m-)	(C ₂ H ₅) ₂ N·C ₆ H ₅ SO ₃ H	229.29	cr.		270 d.				
carbonate	OC(OC ₂ H ₅) ₂	118.13	col. iq.	0.975 ^{20/4}	–43	126 ⁷⁵⁹	i.	∞	∞
diethyl malonate	(C ₂ H ₅) ₂ C(OC ₂ H ₅) ₂	216.27	col. iq.	0.985 ^{20/4}		230	i.	∞	∞
Diethyl dimethyl malonate	(CH ₃) ₂ C(CO ₂ C ₂ H ₅) ₂	188.22	col. iq.	0.994 ^{25/25}		196.7	i.	∞	∞
glutarate	CH ₂ (CH ₂ CO ₂ C ₂ H ₅) ₂	188.22	syrup	1.025 ²¹	–24	237	0.88 ²⁰	v. s.	s.
ketone	(C ₂ H ₅) ₂ CO	86.13	col. iq.	0.816 ^{19/4}	–42	101.7	4.7 ²⁰	∞	∞
malonate	CH ₂ (CO ₂ C ₂ H ₅) ₂	160.17	col. iq.	1.055 ^{20/4}	–49.8	198.9	2.08 ²⁰	∞	∞
-malonic acid	(C ₂ H ₅) ₂ C(CO ₂ H) ₂	160.17	pr./aq.		125	d. 170–80	65 ¹⁶	v. s.	v. s.
-naphthylamine (α-)	C ₁₀ H ₈ N(C ₂ H ₅) ₂	199.28	col. oil	1.005		285–90	i.	∞	∞
(β-)	C ₁₀ H ₈ N(C ₂ H ₅) ₂	199.28	col. oil	1.026		318	i.	∞	∞
oxalate	(·CO ₂ C ₂ H ₅) ₂	146.14	col. iq.	1.079 ^{20/4}	–40.6	186	v. sl. s.	∞	∞
phthalate (o-)	C ₆ H ₄ (CO ₂ C ₂ H ₅) ₂	222.23	col. iq.	1.121 ^{25/25}		298–9	i.	∞	∞
sulfate	O ₂ S(OC ₂ H ₅) ₂	154.18	col. iq.	1.172 ^{25/4}	–25	210	i.	s.	∞
sulfide	(C ₂ H ₅) ₂ S	90.18	col. iq.	0.837 ^{20/4}	–99.5	92–3 ⁷⁵⁴	0.31 ²⁰	∞	∞

TABLE 2-2 Physical Properties of Organic Compounds (Continued)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
tartrate (<i>d</i> -)	(CHOH-CO ₂ C ₂ H ₅) ₂	206.19	lq.	1.204 ^{20/4}	17	280 208-9 ⁷⁵⁵	sl. s.	∞	∞
-toluidine (<i>o</i> -)	CH ₃ C ₆ H ₄ N(C ₂ H ₅) ₂	163.25	lq.			i.	s.	s.	
(<i>m</i> -)	CH ₃ -C ₆ H ₄ -N(C ₂ H ₅) ₂	163.25	lq.			231-2	i.	s.	
(<i>p</i> -)	CH ₃ -C ₆ H ₄ -N(C ₂ H ₅) ₂	163.25	lq.	0.924 ^{15.5}		228-9	i.		
Diethylene-glycol dinitrate	O(CH ₂ CH ₂) ₂ ONO ₂	196.12	lq.	1.377 ^{25/4}	-11.3		i.		
Difluorodichloromethane	F ₂ CCl ₂	120.92	gas	1.486 ³⁰	-155	-29.2 220-30 ¹⁰	5.7 cc. ³⁶	s.	s.
Diglycerol	[HO(C ₂ H ₅) ₂ O	166.17	lq.			s. h.	i.	i.	
Dihydroxy-dinaphthyl (<i>α</i> -)	(HO-C ₁₀ H ₆) ₂	286.31	pl./al.		300			v. s.	
(-2,-2',-1,-1')	(HO-C ₁₀ H ₆) ₂	286.31	nd./al.		218	subl.	i.	s.	
-diphenyl (4,-4')	(HO-C ₆ H ₄) ₂	186.20	rhb./al.	1.25	270-2	subl.	sl. s.	v. s.	v. s.
-ethyl formal (<i>β</i> -)	CH ₃ OCH ₂ CH ₂ OH ₂	136.15	lq.	1.154 ²⁵	-5.3	264	∞	v. s.	v. s.
-naphthalene (1,-5')	C ₁₀ H ₈ (OH) ₂	160.16	pr./aq.		258-60	d.	sl. s.	s.	v. s.
(1,-8')	C ₁₀ H ₈ (OH) ₂	160.16	nd.		140		sl. s. h.	v. s.	v. s.
Dimethoxy-benzene (<i>p</i> -)	(CH ₃ O) ₂ C ₆ H ₄	138.16	lf.	1.053 ^{55/55}	56	212.6	v. sl. s.	v. s.	v. s.
-diphenylamine (4,-4')	HNC ₆ H ₄ OCH ₃) ₂	229.26	er.		103		i.		
-ethyl adipate	(CH ₃) ₂ (CO ₂ CH ₃) ₂	262.30	lq.	1.075 ^{15.6}		145-50 ²	5		
Dimethyl adipate	(CH ₃) ₂ (CO ₂ CH ₃) ₂	174.19	col. lf.	1.063 ^{20/4}	10-1	115 ¹⁸	i.		
-amine	(CH ₃) ₂ NH	45.08	col. lf.	0.680 ^{0/4}	-96	7.4	v. s.	s.	s.
-aminoasobenzene (<i>p</i> -)	C ₆ H ₅ N:N-C ₆ H ₄ N(CH ₃) ₂	225.28	yel./al.		116-7	d.	i.	s.	
-aminoethanol	(CH ₃) ₂ NCH ₂ CH ₂ OH	89.14	col. lf.	0.887 ^{20/4}		135 ⁷⁵⁶	∞		
-aminophenol (<i>m</i> -)	(CH ₃) ₂ NCH ₂ OH	137.18	nd.		85	265-8	sl. s. h.	s.	s.
-aniline	(CH ₃) ₂ NC ₆ H ₅	121.18	yel. lf.	0.956 ^{20/4}	2.5	193	i.	s.	
sulfonic acid (<i>m</i> -)	(CH ₃) ₂ NC ₆ H ₄ SO ₃ H	201.24	cr.		d. 266		s.		
(<i>p</i> -)	(CH ₃) ₂ NC ₆ H ₄ SO ₃ H·H ₂ O	219.25	pr.		257		s. h.	v. sl. s.	v. sl. s.
carbonate	OC(OCH ₃) ₂	90.08	col. lf.	1.070 ^{20/4}	0.5	89-90	i.	∞	∞
ether	CH ₃ OCH ₃	46.07	gas		-138.5	-23.7	3700 cc. ¹⁸	s.	s.
-formamide	HCON(CH ₃) ₂	73.09	lq.	0.945 ²⁵	-58.3	152.8	∞		
fumarate	(:CHCO ₂ CH ₃) ₂	144.12	col. tri.		102	192	i.	sl. s.	sl. s.
glutarate	(CH ₃) ₂ (CO ₂ CH ₃) ₂	160.17	lq.	1.089 ^{15.6}	-37	130 ⁵⁰			
glyoxime	(CH ₃) ₂ C(NOH) ₂	116.12	col. cr.		240-6		0.06 ³⁰	v. s.	v. s.
-naphthalene (1,-4')	C ₁₀ H ₈ (CH ₃) ₂	156.22	lq.	1.016 ^{20/4}	<-18	264-6	i.		
(2,-3')	C ₁₀ H ₈ (CH ₃) ₂	156.22	lf./al.		104	265 ⁶⁷	i.	sl. s.	
-naphthylamine (<i>α</i> -)	C ₁₀ H ₇ N(CH ₃) ₂	171.23	col. oil	1.042 ²⁰		274.5 ⁷¹¹	i.	s.	s.
(<i>β</i> -)	C ₁₀ H ₇ N(CH ₃) ₂	171.23	col. cr.	1.039 ^{70/70}	46	304-5	i.	s.	s.
oxalate	(CO ₂ CH ₃) ₂	118.09	col. mn.	1.148 ⁵⁴	54	163.3	6	s.	s.
phthalate (<i>o</i> -)	C ₆ H ₅ (CO ₂ CH ₃) ₂	194.18	col. ld.	1.189 ^{25/25}		280 ³⁴	0.43		
sulfate	(CH ₃ O) ₂ SO ₂	126.13	col. oil	1.352 ^{0/4}	-26.8	188.3	v. sl. s.	∞	∞
sulfide	(CH ₃) ₂ S	62.13	oil	0.846 ^{21/4}	-83.2	37.3	i.	s.	s.
tartrate (<i>d</i> -)	(CHOH-CO ₂ CH ₃) ₂	178.14	cr.	1.328 ^{20/4}	61.5	280	s.	200 ¹⁵	
-vinyl-ethenyl carbinol	(CH ₃) ₂ COH:C:CH:CH ₂	110.15	lq.	0.887 ^{20/4}		150	6 ²⁰		
Dimaphthyl (<i>αα'</i> -)	C ₁₀ H ₈ -C ₁₀ H ₇	254.31	lf./al.		160	240-4 ¹²	i.	s. h.	s.
-methane (<i>αα'</i> -)	(C ₁₀ H ₈) ₂ CH ₂	268.34	pr./al.		109	>360	i.	0.8 c.	v. s.
(<i>β</i> , <i>β'</i> -)	(C ₁₀ H ₈) ₂ CH ₂	268.34	nd./al.		92		i.	s.	
Dinitro-anisole (1)-(2,-4')	CH ₃ O ₂ C ₆ H ₃ (NO ₂) ₂	198.13	col. mn.	1.341 ²⁰	94-5	sl. s. h.	1.5 ³⁰		
-benzene (<i>o</i> -)	C ₆ H ₅ (NO ₂) ₂	168.11	col. mn.	1.59 ¹⁸	117-8	319 ⁷⁷⁴	0.01 c.	1.9 ²¹	
(<i>m</i> -)	C ₆ H ₅ (NO ₂) ₂	168.11	col. rhb.	1.575 ^{20/4}	89.8	300-2	0.3 ⁹⁹	3 ²⁰	
(<i>p</i> -)	C ₆ H ₅ (NO ₂) ₂	168.11	col. mn.	1.625 ¹⁸	173-4	299 ⁷⁷⁷	0.18 ¹⁰⁰	0.18 ²¹	
sulfonic acid (2,-4)-(1)	(NO ₂) ₂ C ₆ H ₃ SO ₃ H·3H ₂ O	302.22	pr.		106-8		s.	s.	v. sl. s.
-benzoic acid (2,-4')	(NO ₂) ₂ C ₆ H ₂ CO ₂ H	212.12	cr./aq.		179-80		1.85 ²⁵	s.	
(3,-5')	(NO ₂) ₂ C ₆ H ₃ CO ₂ H	212.12	mn. pr.		204-5	subl.	s. h.	v. s.	sl. s.
-benzophenone (4,-4')	(NO ₂) ₂ C ₆ H ₄ CO	272.21	col. nd.		189		i.		
-diphenyl (4,-4')	(NO ₂) ₂ C ₆ H ₄ ₂	244.20	nd./al.	1.445	233		i.	1.5 ²⁰	
(2,-4')	(NO ₂) ₂ C ₆ H ₄ ₂	244.20	mn.	1.474	93.5		i.	v. s. h.	
-naphthalene (1,-5')	C ₁₀ H ₈ (NO ₂) ₂	218.16	nd.		216	subl.	i.		
(1,-8')	C ₁₀ H ₈ (NO ₂) ₂	218.16	rhb.		170-2	d.	i.	0.2 c.	
Dinitro-phenol (2,-3')	(NO ₂) ₂ C ₆ H ₃ OH	184.11	yel. mn.	1.681 ²⁰	144-5		sl. s.	v. s. h.	v. s.
(2,-4')	(NO ₂) ₂ C ₆ H ₃ OH	184.11	yel. rhb.	1.683 ²⁴	114-5	subl.	0.5 c.	4 ²⁰	v. s. h.
(2,-6')	(NO ₂) ₂ C ₆ H ₃ OH	184.11	yel. rhb.		63-4		s. h.	s.	
-salicylic acid (3,-5')	(NO ₂) ₂ C ₆ H ₃ (OH)CO ₂ H·H ₂ O	246.13	pl./aq.		173 d.		s. c.	v. s.	v. s. l. s.
-stilbene (4,-4')	(NO ₂) ₂ C ₆ H ₄ CH ₃	270.24	yel. lf.		210-6	i.	v. sl. s.	1.2 ¹⁵	9 ¹⁶
-toluene (2,-4')	(NO ₂) ₂ C ₆ H ₃ CH ₃	182.13	nd.	1.321 ⁷¹	70	300	0.03 ³²		
(3,-4')	(NO ₂) ₂ C ₆ H ₃ CH ₃	182.13	nd.	1.259 ¹¹¹	60-1	i.			
(3,-5')	(NO ₂) ₂ C ₆ H ₃ CH ₃	182.13	mn. pr.	1.277 ¹¹¹	92-3	subl.	sl. s.	s. h.	s.
Dioxane	O < (CH ₂) ₂ CH ₂ > O	88.10	col. lf.	1.033 ^{20/4}	9.5-10.5	101.1	∞	s.	s.
Dipentene	C ₁₅ H ₃₀	136.23	col. lf.	0.865 ¹⁸		178	i.		

Diphenyl	<chem>C6H5C6H5</chem>	154.20	col. mn.	0.992 ^{73/4}	69–70	254.9	i.	10 ²⁰	6.6 ²⁰
-amine	<chem>C6H5NHC6H5</chem>	169.22	col. mn.	1.160 ^{20/20}	52.9	302	0.03 ²⁵	56 ^{19,5}	s.
carbonate	<chem>O(COC6H5)2</chem>	214.21	nd./al.	1.272 ¹⁴	80	302–6	v. s.	s.	s.
-chloroarsine	<chem>(C6H5)2AsCl</chem>	264.57	rhb.	1.583 ⁴⁰	43–4	d. 327	0.2 d.	20	s.
-ethane	<chem>(C6H5CH3)2</chem>	182.25	col. pr.	0.978 ^{50/50}	52–3	284	i.	s.	v. s.
ether	<chem>C6H5OC6H5</chem>	170.20	col. rhb.	1.073 ²⁰	27	259	v. sl. s.	s.	∞
guanidine	<chem>(C6H5NH)2C:NH</chem>	211.26	mn./al.		147–8	d. > 170	v. sl. s.	9 ²⁰	sl. s.
-methane	<chem>(C6H5)2CH2</chem>	168.23	col. pr.	1.001 ^{26/4}	26–7	265	i.	v. s.	v. s.
phenylenediamine (<i>p</i> -)	<chem>(C6H5NH)2C6H4</chem>	260.32	cr.		152	i.			
succinate	<chem>(-CH2CO2C6H5)2</chem>	270.27	lf./al.		122–3	330	i.	s. h.	s.
sulfide	<chem>(C6H5)2S</chem>	186.26	col. lq.	1.119 ^{15/15}	<40	296–7	i.	sl. s. h.	∞
sulfone	<chem>(C6H5)2SO2</chem>	218.26	nd./aq.	1.248 ^{25/4}	128–9	379	v. sl. s.	s. h.	s.
urea (uns.)	<chem>(C6H5)2NCONNH2</chem>	212.24	rhb.	1.276	189		v. sl. s.	s.	s.
Diphenylene oxide	<(C6H5)2O	168.18	lf./al.		86–7	287–8	i.	s. h.	s.
Dipropyl adipate (<i>n</i> -)	<chem>(-CH2CH2CO2C6H5)2</chem>	230.30	col. lq.	0.979 ^{20/4}	-20.3	143–5 ¹⁰	i.	s. h.	v. s.
-amine (<i>n</i> -)	<chem>(C6H5CH2)2NH</chem>	101.19	col. lq.	0.739 ^{20/4}	-39.6	110–1	s.	∞	∞
(<i>i</i> -)	<chem>[((CH3)2CH]2NH</chem>	101.19	col. lq.	0.722 ²²	-61	83.5 ⁷⁴³	s.	s.	s.
aniline (<i>n</i> -)	<chem>C6H5N(C6H5)2</chem>	177.28	yel. oil	0.910 ²⁰		245.4	i.	s.	s.
carbonate (<i>n</i> -)	<chem>O(COCH2C6H5)2</chem>	146.18	col. lq.	0.968 ²²		168.2	v. sl. s.		
ether (<i>n</i> -)	<chem>(C6H5CH2)2O</chem>	102.17	col. lq.	0.744 ^{21/0}	-122	91	sl. s.	∞	∞
(<i>i</i> -)	<chem>[((CH3)2CH]2O</chem>	102.17	col. lq.	0.725 ^{21/0}	-60	69	0.2	∞	∞
ketone (<i>n</i> -)	<chem>(C6H5CH2)2CO</chem>	114.18	col. lq.	0.822 ^{20/4}	-32.6	144.2	0.43	∞	∞
(<i>i</i> -)	<chem>[((CH3)2CH]2CO</chem>	114.18	col. lq.	0.806 ^{20/4}		123.7	v. sl. s.	∞	∞
oxalate (<i>n</i> -)	<chem>(CO2CH2C6H5)2</chem>	174.19	col. lq.	1.038 ^{0/0}	-51.7	213.5	d. h.		
(<i>i</i> -)	<chem>[CO2CH(CH3)2]2</chem>	174.19	col. lq.		190				
Disalicyl ethylenediamine	<chem>[HOCH2CH2NHC6H4CH2NHC6H4]2</chem>	268.30	cr.	1.34	125–6		0.03 ²⁸		
Ditetyl guanidine (<i>o</i> -)	<chem>(C6H5NH)2C:NH</chem>	239.31	cr.	1.10 ^{20/4}	178–9		v. sl. s.	s. h.	s.
Divinyl acetylene	<chem>(H2C=CH-C:)2</chem>	78.11	lq.	0.776 ^{20/4}		85	i.		
Docosane (<i>n</i> -)	<chem>CH3(CH2)20CH3</chem>	310.59	cr.	0.778 ^{44/4}	44.5	224.5 ¹⁵	i.	4 h.	v. s.
Dodecane (<i>n</i> -)	<chem>CH3(CH2)10CH3</chem>	170.33	lq.	0.751 ^{20/4}	-9.6	214.5	i.	v. s.	v. s.
Duletol	<chem>CH3OH(CHOH)2CH2OH</chem>	182.17	mn.	1.466 ¹⁵	189	290–5 ³	3.2 ¹⁵	v. sl. s.	i.
Durene (1-,2-,4-,5-)	<chem>(CH3)₄C6H2</chem>	134.21	mn.	0.838 ^{81/4}	79–80	193–5	i.	s.	s.
Elaidic acid	<chem>C6H17CH:CH(CH2)7CO2H</chem>	282.45	lf./al.	0.851 ^{79/4}	51–2	288 ¹⁰⁰	i.	v. s.	v. s.
Eosine	<chem>C6H5O2Br4</chem>	647.93	col. cr.				i.	s.	s.
Ephedrine (<i>L</i>)	<chem>C6H5CHOCH(CH3)NHCH3</chem>	165.23	cr./et.		40	255	5	500	s.
Epichlorhydrin (α -)	<chem>C3H5O-CH2Cl</chem>	92.53	lq.	1.183 ^{25/25}	-25.6	117 ⁵⁶	<5	∞	∞
Epidichlorhydrin (α -)	<chem>CH2CCl-CH2Cl</chem>	110.98	col. lq.	1.204 ²⁵		94	i.	∞	∞
Erythritol (<i>dl</i> -)	<chem>CH2OH(CHOH)2CH2OH</chem>	122.12	tet. pr.	1.451 ^{20/4}	126	329–31	60	sl. s. c.	i.
tetranitrate	<chem>C6H6(ONO2)4</chem>	302.12	lf./af.	61		4.7 cc. ²⁰	150 cc.		1
Ethane	<chem>CH3CH3</chem>	30.07	col. gas	0.546 ⁻⁸⁸	-172	-88.6			
Ethanol-amine	<chem>HOCH2CH2NH2</chem>	61.08	col. oil	1.022 ²⁰	10.5	171 ⁵⁷	∞	∞	1
formamide	<chem>HCONHCH2CH2OH</chem>	89.09	lq.	1.169 ²⁵	<40	d.	∞	∞	
Ether	<chem>(CH3CH2)2O</chem>	74.12	col. lq.	0.708 ^{25/4}	-116.3	34.6	7.5 ²⁰	∞	
Ethyl abietate	<chem>C14H20CO2C6H5</chem>	330.49	lq.	1.020 ^{20/20}		200 ⁴	i.		
acetate	<chem>CH3CO2C6H5</chem>	88.10	col. lq.	0.901 ^{20/4}	-82.4	77.1	8.5 ¹⁵	∞	∞
acetoacetate	<chem>CH3COCH2CO2C6H5</chem>	130.14	col. lq.	1.025 ^{20/4}	-45	180 ⁷⁵	13 ¹⁷	∞	∞
alcohol	<chem>CH3CH2OH</chem>	46.07	col. lq.	0.789 ^{20/4}	-112	78.4	∞	∞	
-amine	<chem>C6H5NH3</chem>	45.08	col. lq.	0.689 ^{15/15}	-80.6	16.6	∞	∞	
hydrochloride	<chem>C6H5NH2-HCl</chem>	81.55	mn.	1.216	108–9		240 ¹⁷	v. s.	i.
aniline	<chem>C6H5NH2C6H5</chem>	121.18	lq.	0.963 ^{20/4}	-63.5	204	i.	∞	∞
sulfonic acid (<i>m</i> -)	<chem>C6H5NHCO2C6H4SO3H</chem>	201.24	nd./aq.	d. 294			2.15 ¹⁵		
anisate (<i>p</i> -)	<chem>CH3OC6H4CO2C6H5</chem>	180.20	lq.	1.103 ^{25/25}	7–8	269–70	i.	s.	s.
anthranilate (<i>o</i> -)	<chem>NH2C6H4CO2C6H5</chem>	165.19	cr.	1.117 ^{20/4}	13	266–8	v. sl. s.	s.	s.
benzene	<chem>C6H6</chem>	106.16	col. lq.	0.867 ^{20/4}	-94.4	136.2	0.01 ¹⁵	∞	∞
benzoate	<chem>C6H5CO2C6H5</chem>	150.17	col. lq.	1.052 ^{15/15}	-34.6	211–2	0.08 ²⁰	∞	∞
-benzyl-aniline	<chem>C6H5N(C6H5)CH2C6H5</chem>	211.29	yel. oil	1.034 ^{18,5}		285 ¹⁰	i.	18	∞
bromide	<chem>C6H5Br</chem>	108.98	col. lq.	1.431 ^{20/4}	-117.8	38.4	1.06 ⁰	∞	∞
butyrate (<i>n</i> -)	<chem>C5H9CH2CO2C6H5</chem>	116.16	col. lq.	0.879 ^{20/4}	-93.3	120–1	0.68 ³⁵	∞	∞
(<i>i</i> -)	<chem>(CH3)2CHCO2C6H5</chem>	116.16	col. lq.	0.871 ^{20/4}	-88.2	110–1	sl. s.	∞	∞
caprate (<i>n</i> -)	<chem>CH3(CH2)8CO2C6H5</chem>	200.31	lq.	0.859 ²⁸	-20	244.6 ⁷⁵⁸	0.002 ²⁰	∞	∞
Ethyl caproate (<i>n</i> -)	<chem>CH3(CH2)6CO2C6H5</chem>	144.21	col. lq.	0.873 ^{20/20}	-67.5	165–6 ⁷³⁶	i.	∞	∞
caprylate (<i>n</i> -)	<chem>CH3(CH2)8CO2C6H5</chem>	172.26	col. lq.	0.878 ¹⁷	-45	207–8 ⁷⁵³	i.	∞	∞
chloride	<chem>CH3CH2Cl</chem>	64.52	col. lq.	0.917 ^{6/6}	-139	13	0.45 ⁰	∞	∞
chloroacetate	<chem>ClCH2CO2C6H5</chem>	122.55	col. lq.	1.159 ^{20/4}	-26	144	i.	∞	∞
chlorocarbonate	<chem>ClCO2CH2CH3</chem>	108.53	col. lq.	1.138 ^{20/4}	-80.6	94–5	d.	∞	∞
cinnamate (<i>trans</i> -)	<chem>C6H5CH:CHCO2H</chem>	176.21	col. lq.	1.049 ^{20/4}	12	271	i.	∞	∞
cyanacetate	<chem>CH3(CN)CO2C6H5</chem>	113.11	col. lq.	1.062 ^{20/4}	-22.5	208 ⁷⁵³	2 ²⁵	∞	∞
formate	<chem>HCO2CH2CH3</chem>	74.08	col. lq.	0.923 ^{20/4}	-79	54 ⁷⁶⁰	11 ¹⁸	∞	∞
furoate (α)	<chem>OC4H5CO2C2H5</chem>	140.13	lf.	1.117 ^{21/4}	34	195 ⁷⁶⁶	i.	∞	∞
heptoate	<chem>CH3(CH2)6CO2C2H5</chem>	158.23	col. lq.	0.879 ^{20/20}	-66.1	187–8	0.029 ²⁰	∞	∞
hypochlorite	<chem>ClOCH2CH3</chem>	80.52	yel. lq.	1.013 ^{-6/4}	expl.	36 ⁷⁵²	0.4 ²⁰	∞	∞
iodide	<chem>CH3CH2I</chem>	155.98	col. lq.	1.933 ^{20/4}	-105	72.4	0.4 ²⁰	∞	∞
lactate	<chem>CH3CH(OH)CO2C2H5</chem>	118.13	oil	1.030 ^{25/4}		155	∞	∞	∞

TABLE 2-2 Physical Properties of Organic Compounds (Continued)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
laurate	CH ₃ (CH ₂) ₁₀ CO ₂ C ₂ H ₅	228.36	oil	0.868 ^{13/4}	-10.7	269	i.	s.	∞
mercaptan	CH ₃ CH ₂ SH	62.13	lq.	0.839 ^{20/4}	-121	36-7	1.5	s.	s.
methacrylate	CH ₂ C(CH ₃)CO ₂ C ₂ H ₅	114.14	col. lq.	0.913 ^{15.6}	118	i.	s.	s.	
naphthylamine (α-)	C ₉ H ₇ NHC ₂ H ₅	171.23	oil	1.060 ^{20/4}	303 ⁷²³	i.	s.	s.	
naphthyl ether (α-)	C ₁₀ H ₇ OC ₂ H ₅	172.22	cr.	1.061 ^{20/20}	5.5	276.4	i.	s.	s.
nitrate	C ₂ H ₅ ONO ₂	91.07	col. lq.	1.100 ^{25/4}	-102	87-8	1.3 ⁵⁵	∞	∞
nitrite	C ₂ H ₅ ONO	75.07	lq.	0.900 ^{15.5}	17	v. sl. s.	∞	∞	
oleate	C ₁₇ H ₃₃ CO ₂ C ₂ H ₅	310.50	oil	0.867 ²⁵	<-15	216-8 ¹⁵	i.	∞	∞
palmitate	CH ₃ (CH ₂) ₁₄ CO ₂ C ₂ H ₅	284.47	col. nd.	0.858 ^{25/4}	24-5	191 ¹⁰	i.	s.	s.
pelargonate	CH ₃ (CH ₂) ₇ CO ₂ C ₂ H ₅	186.29	col. lq.	0.866 ^{17.5}	-44.5	227-8 ⁷⁵⁷	i.	∞	∞
propionate	CH ₃ CH ₂ CO ₂ C ₂ H ₅	102.13	col. lq.	0.891 ^{20/4}	-72.6	99.1	2.4 ²⁰	∞	∞
salicylate (α-)	HOCH ₂ CO ₂ C ₂ H ₅	166.17	col. lq.	1.136 ^{15/4}	1.3	233-4	i.	∞	∞
stearate	CH ₃ (CH ₂) ₁₆ CO ₂ C ₂ H ₅	312.52	col. cr.	0.848 ^{36.3}	33.4(31)	201 ¹⁰	i.	s.	s.
toluate (o-)	CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅	164.20	lq.	1.032 ^{25/25}	<-10	227	i.	∞	∞
(m-)	CH ₃ C ₆ H ₄ CO ₂ C ₂ H ₅	164.20	lq.	1.030 ^{20/20}	231 ⁷⁵⁰	i.	∞	∞	
toluene sulfonate (p-)	CH ₃ C ₆ H ₄ SO ₃ C ₂ H ₅	200.25	pr/al.	1.166 ^{48/4}	33-4	221.3	i.	s.	s.
toluidine (o-)	CH ₃ C ₆ H ₄ NHC ₂ H ₅	135.20	lq.	0.945 ^{25/4}	<-15	215-6	i.		
(p-)	CH ₃ C ₆ H ₄ NHC ₂ H ₅	135.20	lq.	0.942 ^{25/4}	217	i.			
urea	C ₂ H ₅ NH-CO-NH ₂	88.11	nd.	1.213 ¹⁸	92	v. s.	80	i.	
valerate (n-)	CH ₃ (CH ₂) ₃ CO ₂ C ₂ H ₅	130.18	col. lq.	0.877 ²⁰	-91.2	145.5	0.24 ²⁵	∞	∞
(i-)	(CH ₃) ₂ CH(CH ₂) ₂ CO ₂ C ₂ H ₅	130.18	col. lq.	0.867 ^{20/4}	-99.3	135	0.17 ²⁰	∞	∞
Ethylal	CH ₃ (OC ₂ H ₅) ₂	104.15	lq.	0.824 ^{25/4}	-66.5	89	9 ¹⁸	∞	∞
Ethylene	H ₂ C ₂ CH ₂	28.05	col. gas	0.57 ^{-102/4}	-169	-103.9	26 cc. ⁰	360 cc.	s.
bromide	BrCH ₂ -CH ₂ Br	187.88	col. lq.	2.180 ^{20/4}	10	131.5	0.43 ³⁰	∞	∞
bromohydrin	BrCH ₂ -CH ₂ OH	124.98	col. lq.	1.772 ^{20/4}	150.3	sl. s.	s.		
chlorobromide	ClCH ₂ -CH ₂ Br	143.43	lq.	1.689 ¹⁹	-16.6	106.7	0.69 ³⁰		
chlorohydrin	ClCH ₂ -CH ₂ OH	80.52	col. lq.	1.213 ^{20/4}	-69	128.8	∞	∞	∞
diamine	H ₂ NCH ₂ -CH ₂ NH ₂	60.10	col. lq.	0.900 ^{20/20}	8.5	117.2	∞	∞	0.3
oxide	<(CH ₂) ₂ >O	44.05	lq.	0.887 ^{7/4}	-111.3	13.5 ⁷⁴⁷	∞	∞	v. s.
Ethyldene diacetate	CH ₂ CH(O ₂ CCH ₃) ₂	146.14	col. lq.	1.061 ¹²	18.85	168 ⁴⁰	sl. s.	∞	
Eugenol (1,4-,3-)	C ₆ H ₅ C ₆ H ₃ (OH)OCH ₃	164.20	oil	1.070 ^{15/15}	10.3	253.5	v. sl. s.	∞	∞
(i)-(1,3-,4-)	C ₆ H ₅ C ₆ H ₃ (OCH ₃)OH	164.20	oil	1.091 ^{15/15}	-10	267.5	v. sl. s.	∞	∞
Fenchyl alcohol (dl-)	C ₁₀ H ₁₁ OH	154.24	col. cr.	0.935 ⁴⁰	35	201	sl. s.	s.	s.
(d)-(α-)	C ₉ H ₁₁ OH	154.24	col. pr.	0.964 ^{20/4}	45-7	201-2	sl. s.	s.	s.
(i)-(L)	C ₉ H ₁₁ OH	154.24	col. cr.	0.961	61-2	201-2	i.		
Ferric dimethyl-dithiocarbamate	Fe[SSCN(CH ₃) ₂] ₃	416.47	cr.	d. 100-30	ign. >150	v. sl. s.			
Fluorene	(C ₆ H ₅) ₂ >CH ₂	166.21	cr./al.	1.203 ^{0/4}	115-6	293-5	i.	s. h.	s.
Fluorescein	C ₂₀ H ₁₁ O ₅	332.30	yel. red	d. >290		v. sl. s. h.	s. h.		
Fluoro-dichloromethane	FCHCl ₂	102.93	gas	1.426 ⁰	-127	14.5	i.	s.	s.
-trichloromethane	Cl ₃ CF	137.38	col. lq.	1.494 ^{17.2}	24.9	∞	∞		
Formaldehyde	HCHO	30.03	gas	0.815 ⁻²⁰	-92	-21	v. s.	v. s.	v. s.
(m-)	(CH ₂ O) ₃	90.08	wh.	1.17 ⁶⁵	64	114.5 ⁷⁵⁹	21 ²⁵	s.	s.
(p-)	(CH ₂ O) ₃ ·xH ₂ O	(30.03)	amor.	150-60	subl.	20-30 ¹⁸	i.	∞	
Formamide	HCONH ₂	45.04	lq.	1.139 ^{20/4}	2	193	∞	∞	v. sl. s.
Formanilide	HCONHC ₆ H ₅	121.13	mn.	1.147 ^{15/15}	47	216 ²⁰	sl. s.	v. s.	s.
Formic acid	HCO ₂ H	46.03	col. pr.	1.220 ^{20/4}	8.6	100.8	∞	∞	
Fructose	CH ₂ OH(CHOH) ₃ COCH ₂ OH	180.16	nd./aq.	1.669 ^{17.5}	95-105	v. s.	S ¹⁸		
Fuchsin	C ₉ H ₁₀ N ₃ HCl	337.84	red	1.22	d. >200	0.3	s.	i.	
Fulminic acid	C:N=O	43.03							
Fumaric acid (trans-)	HO ₂ CCH:CHCO ₂ H	116.07	col. pr.	1.635 ^{20/4}	286-7	290	0.7 ¹⁷	5.8 ³⁰	0.7 ²⁵
Furfural	C ₅ H ₈ O-CHO	96.08	lq.	1.159 ^{20/4}	-38.7	161.7 ⁷⁶⁰	9.1 ¹³	∞	
Furfuran	C ₄ H ₆ O	68.07	col. lq.	0.937 ^{20/4}	31-2 ⁷⁵⁶	i.	s.		
Furfuryl acetate	CH ₃ CO ₂ CH ₂ C ₄ H ₉ O	140.13	col. oil	1.118 ^{20/4}	175-7	i.	s.		
alcohol	C ₄ H ₉ O-CH ₂ OH	98.10	oil	1.129 ^{25/4}	169.5 ⁷⁵²	∞	s.		
butyrate	C ₄ H ₉ CO ₂ CH ₂ C ₄ H ₉ O	168.19	col. lq.	1.053 ^{20/4}	212-3	v. sl. s.	s.	∞	
propionate	C ₄ H ₉ CO ₂ CH ₂ C ₄ H ₉ O	154.16	col. lq.	1.109 ^{20/4}	195-6	v. sl. s.	s.	∞	
Euroic acid	C ₄ H ₉ O-CO ₂ H	112.08	mn. pr.		133-4	230-2	3.6 ¹⁵	s.	
G-acid, K salt (2)-(6,-8-)	HOC ₁₀ H ₅ (SO ₃ K) ₂	380.46	cr.			8 ²⁵			
Na salt (2)-(6,-8-)	HOC ₁₀ H ₅ (SO ₃ Na) ₂	348.26	cr.			34 ²⁰			
Galactose (d)-(α-)	C ₆ H ₁₁ O ₅ -CHO	180.16	pr.	1.694 ^{4/4}	165.5	10.3 ⁰	0.6 ⁴⁰	28 ¹⁵	2.5 ¹⁵
Gallic acid (3,4-,5-)	(HO) ₃ C ₆ H ₂ CO ₂ H-H ₃ O	188.13	mn./aq.		d. 220	1 ¹³			
Gamma acid (2,8-,6-)	C ₁₀ H ₈ N(H ₂)(OH)SO ₃ H	239.24	cr.						
Geraniol	C ₁₀ H ₁₅ CH ₂ OH	154.24	col. lq.	0.883 ¹⁵	<-15	230	i.	∞	∞
Glucose (d)-(α-)	C ₆ H ₁₁ O ₅ -CHO	180.16	rhb.	1.544 ²⁵	146	82 ^{17.5}	sl. s.	i.	
(d)-(β-)	C ₆ H ₁₁ O ₅ -H ₂ O	198.17	cr.	1.562 ^{18/4}	150	154 ¹⁵	v. s.		
Glucuronic acid	CHO(CHOH) ₄ CO ₂ H	194.14	cr.		154	d.	1.5 ²⁰	v. sl. s.	v. sl. s.
Glutam(in)ic acid (dl-)	[·CHNH ₂ (CH ₂) ₂ ·](CO ₂ H) ₂	147.13	cr./aq.	1.460	199 d.				

Glutaric acid	<chem>CH2(CH2CO2H)2</chem>	132.11	col. cr.	1.429 ¹⁵	97.5	200 ²⁰	63.9 ²⁰	v. s.	v. s.
Glycerol	<chem>CH3OH-CHOH-CH2OH</chem>	92.09	col. lq.	1.260 ^{50/4}	17.9	290	∞	∞	i.
acetate (mono-)	<chem>C6H10O4</chem>	134.13	col. oil	1.20 ^{20/4}	158 ¹⁶⁵	v. s.	sl. s.	v. s.	sl. s.
(di-)	<chem>(CH3CO2)2C6H5OH</chem>	176.17	col. lq.	1.178 ^{15/15}	40	175-6 ⁴⁰	s.	s.	sl. s.
nitrate (mono-) (α -)	<chem>CH3OH-CHOH-CH2NO3</chem>	137.09	col. pr.	1.40 ¹⁵	58-9	155-60	70 ¹⁵	v. s.	v. sl. s.
(β -)	<chem>CH3OH-CHNO3-CH3OH</chem>	137.09	lf.	1.40 ¹⁵	54	155-60	v. s.	v. s.	sl. s.
dinitrate (1-,3-)	<chem>CHOH(CH2ONO2)2</chem>	182.09	oil	1.47 ¹⁵	<-30	146-8 ¹⁵	v. s.	v. s.	v. s.
Glyceryl triacetate	<chem>(CH3CO2)3C6H5</chem>	218.20	col. lq.	1.161 ^{17/4}	-78	258-9	7.17 ¹⁵	∞	∞
tribenzoate	<chem>(C6H5CO2)3C6H5</chem>	404.40	nd.	1.228 ¹²	75-6	d.	s. h.	s. h.	s.
tributyrate	<chem>C6H5CH2CO2)3C6H5</chem>	302.36	col. lq.	1.032 ^{20/4}	<-75	305-9	i.	s.	s.
tricaprate	<chem>[CH3(CH2)6CO2]3C6H5</chem>	554.83	col. cr.	0.921 ^{40/4}	31(25)	i.	s. h.	v. s.	v. s.
tricaproate	<chem>[CH3(CH2)5CO2]3C6H5</chem>	386.51	col. lq.	0.987 ^{20/4}	-25	i.	s.	s.	s.
tricaprylate	<chem>[CH3(CH2)4CO2]3C6H5</chem>	470.67	col. lq.	0.954 ^{20/4}	8.3(-21)	i.	s.	s.	s.
trilauroate	<chem>[CH3(CH2)10CO2]3C6H5</chem>	638.98	col. nd.	0.894 ^{60/4}	45-6	i.	sl. s. c.	v. s.	v. s.
trimyristate	<chem>[CH3(CH2)12CO2]3C6H5</chem>	723.14	lf.	0.885 ^{60/6}	56.5	i.	s.	s.	s.
trinonanoate	<chem>CH3NO3-CHNO3-CH2NO3</chem>	227.09	yel. oil	1.601 ¹⁵	13.3(2)	160 ¹⁵	0.18 ²⁰	50 ²⁰	∞
trinitrate	<chem>CH3NO2-CHNO2-CH2NO2</chem>	179.09	yel. lq.	1.291 ^{10/16}	150 sl. d.	d.	d.	d.	s.
trioleate	<chem>(C7H5CO2)3C6H5</chem>	885.40	col. oil	0.915 ¹⁵	-4	240 ¹⁵	i.	sl. s.	v. s.
tripalmitate	<chem>[CH3(CH2)14CO2]3C6H5</chem>	807.29	col. nd.	0.866 ^{80/4}	65.1	310-20 ¹	0.004 ²¹	v. s.	v. s.
tristearate	<chem>[CH3(CH2)16CO2]3C6H5</chem>	891.45	col. pr.	0.862 ^{80/4}	70.8(55)	i.	s. h.	s. h.	s. h.
Glycide	<chem>C6H5O-CH2OH</chem>	74.08	col. lq.	1.114 ^{16/16}	166 sl. d.	∞	∞	∞	∞
Glycine, Glycocoll	<chem>NH2CH2-CO2H</chem>	75.07	mn.	1.161	232-6 d.	23 c.	0.1 c.	i.	i.
Glycol	<chem>CH3OH-CH2OH</chem>	62.07	col. lq.	1.113 ^{19/4}	-15.6	197.4	∞	∞	1.0
diacetate	<chem>(CH3CO2CH2)2</chem>	146.14	col. lq.	1.109 ^{14/4}	-31	190.5	14.3 ²²	∞	∞
dibenzoate	<chem>(C6H5CO2CH2)2</chem>	270.27	rhb./et.	73-4	>360	i.	s.	s.	s.
dibutyoate	<chem>(C8H7CO2CH2)2</chem>	202.24	col. lq.	1.024 ⁰	240	i.	v. s.	v. s.	v. s.
dicaprylate	<chem>(C11H23CO2CH2)2</chem>	314.45	lq.	22	i.	v. sl. s.	v. sl. s.	v. sl. s.	v. s.
diformate	<chem>(HCO2CH2)2</chem>	118.09	lq.	174	i.	v. s.	v. s.	v. s.	v. s.
dilaurate	<chem>(C11H22CO2CH2)2</chem>	426.66	amor.	52-4	188 ²⁰	i.	v. s.	v. s.	v. s.
dinitrate	<chem>(O2NO-CH2)2</chem>	152.07	yel. lq.	1.482 ^{21/2}	-20	expl. 114	0.92 ²⁵	s.	∞
dinitrite	<chem>(ONO-CH2)2</chem>	120.07	lq.	1.216 ⁰	<-15	96-8	i.	s. d.	s.
dipalmitate	<chem>(C15H31CO2CH2)2</chem>	538.87	nd.	71-2	260 ^{0.1}	i.	s.	s.	s.
dipropionate	<chem>(C9H19CO2CH2)2</chem>	174.19	lq.	1.045 ²⁵	211-2	sl. s.	∞	∞	i.
ether	<chem>(HO-CH2CH2)2O</chem>	106.12	lq.	1.118 ^{20/20}	-10.5	244.8	∞	∞	∞
formal	<chem><O-CH2CH2OCH2></chem>	74.08	lq.	1.060 ^{20/4}	75-6	i.	s.	s.	s.
formate (mono-)	<chem>HCO2CH2CH2OH</chem>	90.08	lq.	1.199 ^{15/4}	180	∞	∞	∞	∞
Glycolic acid	<chem>HOCH2CO2H</chem>	76.05	nd./aq.	79(63)	d.	∞	90 ²⁵	v. s.	v. s.
Guaiacol (σ)	<chem>CH3O-C6H4-OH</chem>	124.13	pr.	1.140 ^{15/15}	28.3	205	1.7 ¹⁵	v. s.	v. s.
Guanidine	<chem>NH2C(CN)3</chem>	59.07	col. cr.	50	0.17 ²⁰	i.	v. s.	v. s.	v. s.
H-acid, Na salt (1-,8-,3-,6-)	<chem>C10H8O4NS2Na·1&#8226;H2O</chem>	368.31	cr.						
Heptacosane (n -)	<chem>CH2(CH2)25CH3</chem>	380.72	col. cr.	0.780 ^{60/4}	59.5	270 ¹⁵	i.		
Heptane (n -)	<chem>CH3(CH2)6CH3</chem>	100.20	col. lq.	0.684 ^{20/4}	-90.6	98.4 ⁷⁶⁰	0.005 ¹⁵	sl. s.	∞
(<i>i</i> -)	<chem>(CH3)2CH(CH2)5CH3</chem>	100.20	col. lq.	0.679 ^{20/4}	-118.2	90.0	i.	s.	∞
Heptoic acid	<chem>C5H7CH(CH3)2-C6H5</chem>	100.20	col. lq.	0.687 ^{20/4}	-119.4	91.8	i.	s.	∞
aldehyde	<chem>(CH3)2C-CH2-C6H5</chem>	100.20	col. lq.	0.674 ^{20/4}	-125	79.1	i.	s.	∞
Heptyl acetate (n -)	<chem>[(CH3)2CH]2CH2</chem>	100.20	col. lq.	0.675 ^{20/4}	-119.4	80.8	i.	s.	∞
alcohol (n -)	<chem>(CH3)2C(C2H5)2</chem>	100.20	col. lq.	0.693 ^{20/4}	-135.0	86.0	i.	s.	∞
mercaptan	<chem>(C5H5)2CH</chem>	100.20	col. lq.	0.698 ^{20/4}	-118.7	93.5	i.	s.	∞
Hexachloro-benzene	<chem>(CH3)2C(CH3)2-C6H5</chem>	100.20	col. lq.	0.690 ^{20/4}	-25	80.8	i.	s.	∞
-ethane	<chem>CH2(CH2)5CO2H</chem>	130.18	col. lq.	0.918 ²⁰	-10	221-2	0.25 ¹⁵	s.	s.
Hexacosane (n -)	<chem>CH3CO2CH2(CH2)18CH3</chem>	114.18	col. lq.	0.850 ^{20/7}	-42	155	0.02 ²⁰	∞	∞
Hexadecane (n -)	<chem>CH3CO2CH2(CH2)14CH3</chem>	158.24	col. lq.	0.874 ^{16/16}	191.5 ⁷⁵⁹	i.	s.	s.	s.
Hexaethylbenzene	<chem>CH3(CH2)6CH2OH</chem>	116.20	col. lq.	0.824 ^{20/4}	34.6	175 ⁷⁵⁶	0.18 ²⁵	∞	∞
Hexamethylbenzene	<chem>[(CH3)2CH]2CH2</chem>	116.20	col. lq.	0.829 ^{20/4}	140	v. sl. s.	∞	∞	∞
Hexamethylene-diamine	<chem>(C6H5CH2)2CH2</chem>	116.20	lq.	0.820 ^{20/4}	-37	156	i.	s.	s.
-diisocyanate	<chem>CH2CH(SH)-C5H11</chem>	132.26	lq.	0.835 ²⁰	174-5 ⁷⁶⁵	i.			
-glycol	<chem>C6Cl6</chem>	294.80	mn.	2.044 ²⁴	228-31	309 ⁷⁴²	i.	v. sl. s. h.	s. h.
tetramine	<chem>CCl3-CCl3</chem>	236.76	rhb.	2.091 ^{20/4}	186-7	186 ⁷⁷⁷	0.005 ²²	v. s.	v. s.
Hexane (n -)	<chem>CH3(CH2)6CH3</chem>	366.69	cr.	0.779 ^{57/4}	56.6	262 ¹⁵	i.	v. sl. s.	∞
(<i>i</i> -)	<chem>CH3(CH2)4CH3</chem>	226.43	lf.	0.774 ^{20/4}	18.5	287.5	i.	∞	∞
(neo-)	<chem>C6(C2H5)6</chem>	246.42	pr./al.	0.831 ^{130/4}	130	298.3	i.	0.75 ²⁵	S ²⁵
	<chem>C6(CH3)6</chem>	162.26	pl/al.	166	265	i.	0.2 ⁰	v. s.	
	<chem>NH2(CH2)6NH2</chem>	116.20	lf.	42	204-5	v. s.	s.	s.	
	<chem>OCN(CH2)6NCO</chem>	168.19	lq.	1.04 ²⁸	143-4 ²⁰	d.	d.	d.	
	<chem>HO(CH2)6OH</chem>	118.17	nd./aq.	42	250	s.	s.	sl. s. h.	sl. s. h.
	<chem>(CH2)6N4</chem>	140.19	col. rhb.	subl.	81 ¹²	3	v. sl. s.	v. sl. s.	v. sl. s.
	<chem>CH3(CH2)6CH3</chem>	86.17	col. lq.	0.659 ^{20/4}	-94	69	0.014 ¹⁵	50 ³³	∞
	<chem>(CH3)2CH(CH2)5CH3</chem>	86.17	lq.	0.654 ^{20/4}	-153.7	60.2	i.	s.	s.
	<chem>(CH3)2C-C2H5</chem>	86.17	lq.	0.649 ^{20/20}	-98.2	49.7	i.	s.	s.
	<chem>(CH3)2CH-CH(CH3)2</chem>	86.17	lq.	0.662 ^{20/4}	-129.8	58.0 ⁷⁶⁰	i.	s.	s.
	<chem>(C2H5)2CHCH3</chem>	86.17	lq.	0.664 ^{20/4}	-118	63.2	i.	s.	s.

TABLE 2-2 Physical Properties of Organic Compounds (Continued)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Hexyl acetate (<i>n</i> -)	CH ₃ CO ₂ (CH ₂) ₅ CH ₃	144.21	col. lq.	0.890 ^{0.0}	169.2	i.	v. s.	v. s.	v. s.
alcohol (<i>n</i> -)	CH ₃ (CH ₂) ₅ CH ₂ OH	102.17	col. lq.	0.820 ^{20.20}	157.2	0.6 ²⁰	∞	∞	∞
formate (<i>n</i> -)	(CH ₃) ₂ CH-C(CH ₃) ₂ OH	102.17	lq.	0.821 ^{20.0}	-14	120-1	v. sl. s.	∞	∞
resorcinol (2-,4-)	(CH ₃) ₂ COH-CH ₂ C ₆ H ₅	102.17	lq.	0.809 ^{20.4}	-107	123 ^{76.2}	v. sl. s.	∞	∞
Hippuric acid	HCO ₂ CH ₂ (CH ₂) ₅ CH ₃	130.18	lq.	0.898 ⁰	153.6	d.	v. s.	∞	∞
Histidine (<i>I</i> -)	CH ₃ (CH ₂) ₅ C ₆ H ₅ (OH) ₂	194.26	col. nd.	68-70	179 ⁷	0.05	v. s.	s.	s.
Homophthalic acid (<i>o</i> -)	C ₆ H ₅ CONHC ₆ H ₂ CO ₂ H	179.17	rhb.	1.371 ^{20.4}	187-8	0.4 ²⁰	s. h.	0.25 ¹⁸	s.
Hydrylic acid	C ₆ H ₅ O ₂ N ₃	155.16	lf./aq.	d. 287	s.	v. sl. s.	i.	v. s.	s.
Hydro-cyanic acid	HO ₂ C-C ₆ H ₄ -CH ₂ CO ₂ H	180.15	cr./aq.	175-80	s. h.	v. s.	sl. s.	sl. s.	sl. s.
-quinoine (<i>p</i> -)	HOCH ₂ CH ₂ CO ₂ H	90.08	syrup	d.	v. s.	sl. s.	sl. s.	sl. s.	sl. s.
Hydroxy-benzaldehyde (<i>p</i> -)	HCN	27.03	lq.	0.697 ¹⁸	-12	25-6	∞	∞	∞
-benzanilide (<i>o</i> -)	C ₆ H ₅ (OH) ₂	110.11	cr.	1.332 ¹⁵	170.3	255 ^{73.0}	6 ¹⁵	v. s.	v. s.
-quinoline (2-)(<i>α</i> -)	HO-C ₆ H ₄ -CHO	122.12	nd./aq.	1.129 ¹³⁰	116-7	subl.	1.38 ³¹	v. s.	v. s.
(8-)(<i>o</i> -)	HO-C ₆ H ₄ -CONHC ₆ H ₅	213.23	pr./al.	135	d.	v. sl. s. h.	s.	s.	s.
C ₆ H ₆ -N-OH	C ₆ H ₅ -OH	145.15	pr./al.	199-200	subl.	s. h.	v. s.	v. s.	v. s.
C ₆ H ₆ -N-OH	C ₆ H ₅ -OH	145.15	pr.	75-6	266.6 ^{75.2}	v. sl. s. c.	s.	sl. s.	sl. s.
Indigo	[C ₆ H ₅ (CO)(NH)C ₆ H ₅] ₂	262.26	cr.	1.35	390-2	subl.	i.	i.	i.
White	C ₁₆ H ₁₂ O ₂ N ₂	264.27	gray				i.	s.	s.
Indole	C ₈ H ₇ N	117.14	lf./aq.	52	253-4	s. h.	s. h.	s.	s.
Indoxyl	C ₈ H ₉ NOH	133.14	yel. pr.	85	110	s.	s.	s.	s.
Iodo-benzene	C ₆ H ₅ I	204.02	col. lq.	1.824 ^{25/4}	-28.5	188.6	0.034 ²⁰	s.	∞
-phenol (<i>p</i> -)	IC ₆ H ₅ OH	220.02	nd./aq.	1.857 ¹¹²	93-4	d.	sl. s.	v. s.	v. s.
Iodoform	HCl ₃	393.78	yel. hex.	4.008 ¹⁷	119	subl.	0.01 ²⁵	1.5 ¹⁷	13.6 ²⁵
Ionone (<i>α</i> -)	C ₁₀ H ₁₆ :CHCOCH ₃	192.29	col. oil	0.930 ²⁰	136.1 ¹⁷	sl. s.	∞	∞	∞
(<i>β</i> -)	C ₁₀ H ₁₆ :CHCOCH ₃	192.29	col. oil	0.944 ²⁰	140 ¹⁸	sl. s.	∞	∞	∞
Iron (<i>β</i> -)	C ₁₄ H ₂₂ O	206.32	col. oil	0.939 ²⁰	144 ¹⁶	v. sl. s.	v. s.	v. s.	v. s.
Isatin	C ₈ H ₇ <(CO)(N)>COH	147.13	yel. red	200-1	subl.	s. h.	v. s. h.	sl. s.	sl. s.
Isoprene	CH ₂ :CH-C(CH ₃):CH ₂	68.11	col. lq.	0.681 ^{20/4}	-120	34	i.	∞	∞
Ketene	H ₂ :CO	42.04	col. gas	-151	-56	d.	d.	d.	s.
Koch acid (1-)(3-,6-,8-)	C ₁₀ H ₈ (NH ₂)S ₂ O ₉ Na ₂	427.34	cr.			7.2 ²⁰			
Lactic acid (<i>dl</i> -)	CH ₃ CH(OH)CO ₂ H	90.08	hyg.	1.249 ^{15/4}	16.8	122 ¹⁴	∞	∞	∞
anhydride	C ₆ H ₁₀ O ₅	162.14	yel. oil	d. 250	v. sl. s.	s.	s.	s.	s.
Lactide (<i>dl</i> -)	C ₆ H ₁₀ C ₄	144.12	tri./al.	0.862 ^{10/4}	124.5	255 ^{75.7}	v. sl. s.	v. sl. s. c.	
Lactose	C ₁₂ H ₂₂ O ₁₁ ·H ₂ O	360.31	col. rhb.	1.525 ²⁰	202	d.	17 ¹⁰	i.	i.
Lauric acid	CH ₃ (CH ₂) ₁₀ CO ₂ H	200.31	col. nd.	0.869 ^{20/4}	48(44)	225 ¹⁰⁰	i.	s.	s.
Laurone	[CH ₃ (CH ₂) ₁₀]CO	338.60	pl.	0.809 ^{20/4}	69-70	i.	i. c.		
Lauryl alcohol	CH ₃ (CH ₂) ₁₀ CH ₂ OH	186.33	lf.	0.831 ^{24/4}	24	255-9	i.	s.	s.
Lead tetraethyl	Pb(C ₆ H ₅) ₄	323.45	col. lq.	1.659 ^{18/4}	-136	152 ²⁹¹	i.	sl. s.	∞
tetramethyl	Pb(CH ₃) ₄	267.35	col. lq.	1.995 ^{20/4}	-27.5	110 ⁷⁶⁰	i.	∞	∞
Lecithin (protagon)	C ₁₈ H ₃₆ O ₂ PN	778.08	wax	150-200 d.		i.	s. h.	s. h.	s. h.
Lepidine (<i>py</i> -4)	C ₈ H ₆ N-CH ₃	143.18	lq.	1.086 ²⁰	9-10	261-3	sl. s.	∞	∞
Leucine (<i>I</i> -)	(CH ₃) ₂ CHCH ₂ CH(NH ₂)CO ₂ H	131.17	cr.	1.293 ¹⁸	295	subl.	2.2 ¹⁸		
Levulinic acid	CH ₃ CO(CH ₂) ₂ CO ₂ H	116.11	lf.	1.140 ^{20/20}	33.5	245-6	v. s.	v. s.	v. s.
Limonene (<i>d</i> - or <i>I</i> -)	C ₁₀ H ₁₆	136.23	lq.	0.842 ^{20/4}	-96.9	177	i.	∞	∞
Linalool (<i>d</i> - or <i>I</i> -)	C ₁₀ H ₁₇ OH	154.24	col. oil	0.868 ²⁰	198-200	v. sl. s.	s.	∞	∞
Linalyl acetate	CH ₃ CO ₂ C ₁₀ H ₁₇	196.28	col. lq.	0.895 ²⁰	220 ^{76.5}	d.	v. sl. s.	∞	∞
Linoleic acid	C ₁₇ H ₃₄ CO ₂ H	280.44	yel. oil	0.903 ^{18/4}	-9.5	229-30 ¹⁶	i.	∞	∞
Maleic acid	HO ₂ C-CH-CH ₂ CO ₂ H	116.07	mm.	1.609	130.5	135 d.	79 ²⁵	70 ³⁰	8 ²⁵
anhydride	<(-CHCO) ₂ >O	98.06	cr.	1.5	57-60	202	16.3 ⁸⁰		
Malic acid (<i>dl</i> -)	HO ₂ CCCH ₂ CH(NH ₂)CO ₂ H	134.09	col. cr.	1.601 ^{20/4}	128-9	150 d.	144 ²⁶	v. s.	v. s.
(<i>d</i> - or <i>I</i> -)	HO ₂ CCCH ₂ CH(OH)CO ₂ H	134.09	col. cr.	1.595 ^{20/4}	99-100	140 d.	v. s.	S ₄ ¹⁵	S ₄ ¹⁵
Mandelic acid (<i>dl</i> -)	H ₂ C(CO ₂ H) ₂	104.06	col. tri.	1.631 ¹⁵	130-5 d.		138 ¹⁶	42 ²⁵	S ₁₅
Mannitol (<i>d</i> -)	C ₁₂ H ₂₂ O ₁₁ ·H ₂ O	360.31	col. nd.	1.540 ¹⁷	d.		108 ²⁵	v. sl. s. c.	i.
Maltose	C ₆ H ₁₂ CH(OH)CO ₂ H	152.14	rhb./aq.	1.300 ^{20/4}	118.1	d.	16 ²⁰	s.	s.
Mandelic acid (<i>dl</i> -)	CH ₃ OH(CHOH)CH ₂ OH	182.17	col. rhb.	1.489 ^{20/4}	166	290-5 ³	13 ¹⁴	0.01 ¹⁴	i.
Mannose (<i>d</i> -)	CH ₂ OH(CHOH)CHO	180.16	rhb.	1.539 ^{20/4}	132		248 ¹⁷	v. sl. s.	i.
Margaric acid	CH ₃ (CH ₂) ₁₃ CO ₂ H	270.44	col. pl.	0.853 ⁶⁰	60-1	227 ¹⁰⁰	i.	32 ²⁸	v. s.
Mellitic acid	C ₆ (CO ₂ H) ₆	342.17	nd./al.		286-8	d.	v. s.	v. s.	v. s.
Menthol (<i>l</i> -)(<i>α</i> -)	C ₁₀ H ₁₉ OH	156.26	col. cr.	0.890 ^{15/15}	42-3	212	0.04 c.	v. s.	v. s.
Mercapto-benzothiazole (2-)	<C ₆ H ₄ N-C(SH)S>	167.24	nd.	1.42 ^{20/4}	179	d.	i.	s.	sl. s.
-thiazoline (2-)	<C ₆ H ₄ N-C(SH)SCH ₂ >	119.20	cr.	1.50	106		1.6 ⁶⁰		
Mercuric cyanide	Hg(CN) ₂	252.65	cr.	4.003 ²²	d. 320		12.5 ¹⁵		
fulminate	Hg(O ⁺) ₂ · ^a H ₂ O	293.65	cr./aq.	4.4	expl.		0.07 ¹²	s.	
Mesityl oxide	(CH ₃) ₂ C:CHCOCH ₃	98.14	lq.	0.858 ^{20/4}	-59	130 ⁷⁵⁰	3 ²⁰	∞	∞
Mesitylene (1-,3-,5-)	C ₉ H ₁₂ (CH ₃) ₃	120.19	col. lq.	0.863 ^{20/4}	-45(-52)	164.8	i.	s.	∞
Metanilic acid (<i>m</i> -)	H ₂ NC ₆ H ₄ SO ₃ H	173.18	col. nd.	d.			2 ¹⁵	v. sl. s.	v. sl. s.
Methane	CH ₄	16.04	gas	0.415 ¹⁶⁴	-182.6	-161.4	0.4 ²⁰ cc.	47 ²⁰ cc.	104 ¹⁰ cc.

Methoxy-methoxyethanol	CH ₃ (OCH ₂) ₂ CH ₂ OH	106.12	lq.	1.038 ²⁵	<-70	167.5	∞		
Methyl acetate	CH ₃ CO ₂ CH ₃	74.08	col. lq.	0.924 ^{20/4}	-98.7	57.1	33 ²²	∞	∞
acrylic acid (α -)	CH ₂ C(CH ₃)CO ₂ H	86.09	pr.	1.015 ^{20/4}	15-16	161-3	s. h.	∞	∞
alcohol	CH ₃ OH	32.04	col. lq.	0.792 ^{20/4}	-97-8	64.7	∞	∞	∞
-amine	CH ₄ NH ₂	31.06	col. gas	0.699 ¹¹	-92.5	-6.7 ⁷⁵⁸	v. s.	v. s.	i.
-amine hydrochloride	CH ₃ NH ₂ ·HCl	67.52	pl/al.	1.23	226-8	230 ¹⁵	v. s.	23 h.	s.
aniline	CH ₆ H ₅ NHCH ₃	107.15	lq.	0.989 ^{20/4}	-57	195.5	0.01 ²⁵	∞	∞
anthracene (α -)	CH ₆ H ₄ :CH(CH ₃) ₂	192.25	lf/al.	1.047 ^{99,4}	86	i.	v. sl. s.	v. sl. s.	v. sl. s.
(β -)	CH ₆ H ₄ :C(CH ₃) ₂ CH ₃	192.25	col. lf.	1.181 ^{0/4}	207	i.	s.	s.	s.
anthranilate (α -)	NH ₂ C ₆ H ₄ CO ₂ CH ₃	151.16	col. lq.	1.168 ^{19/4}	24	135.5 ¹⁵	sl. s.	s.	s.
anthraquinone (2-)	CH ₆ H ₄ :CO ₂ :CH ₆ H ₃	222.23	col. nd.		176-7	subl.	i.	s.	s.
benzoate	CH ₆ H ₅ CO ₂ CH ₃	136.14	col. lq.	1.087 ^{25/25}	-12.5	198-9	0.02 ²⁰	∞	∞
benzylaniline	CH ₆ N(H ₃)CH ₂ C ₆ H ₅	197.27	lq.		9.2	305-6	i.	S.	S.
bromide	CH ₃ Br	94.95	gas	1.732 ^{0/0}	-93	4.5 ⁷⁵⁸	v. sl. s.	S.	S.
butyrate (n -)	CH ₃ (CH ₂) ₂ CO ₂ CH ₃	102.13	col. lq.	0.898 ^{20/4}	<95	102.3	1.7	∞	∞
(i -)	(CH ₃) ₂ CHCO ₂ CH ₃	102.13	col. lq.	0.891 ^{20/4}	-84.7	92.6	v. sl. s.	∞	∞
caprate	CH ₃ (CH ₂) ₆ CO ₂ CH ₃	186.29	lq.		-18	223-4	i.	∞	∞
caproate (n -)	CH ₃ (CH ₂) ₅ CO ₂ CH ₃	130.18	col. lq.	0.904 ^{0/0}	149.5	i.	∞	∞	∞
caprylate	CH ₃ (CH ₂) ₈ CO ₂ CH ₃	158.23	col. lq.	0.887 ¹⁸	-40	192-4	i.	∞	∞
cellosolve	CH ₃ OCH ₂ CH ₂ OH	76.09	col. lq.	0.965 ^{20/4}		124-5	∞	∞	∞
chloride	CH ₃ Cl	50.49	gas	0.952 ⁰	-97.7	-24	280 ¹⁶ cc.	V. S.	V. S.
chloroacetate	CHClCH ₂ CO ₂ CH ₃	108.53	col. lq.	1.236 ^{20/4}	-32.7	130 ⁷⁴⁰	v. sl. s.	∞	∞
chloroformate	ClCO ₂ CH ₃	94.50	col. lq.	1.236 ¹⁵		71-2	d.	∞	∞
cinnamate	C ₆ H ₅ CH:CHCO ₂ CH ₃	162.18	cr.	1.042 ^{36/0}	33.4	263	i.	V. S.	V. S.
cyclohexane	CH ₂ <(CH ₂ CH ₃) ₂ >CHCH ₃	98.18	col. lq.	0.769 ^{20/4}	-126.3	101	i.	S.	S.
ethyl carbonate	CH ₃ O-CO-OC ₂ H ₅	104.10	lq.	1.002 ²⁷	-14.5	109.2	i.	∞	∞
ethyl ketone	CH ₃ CO-C ₂ H ₅	72.10	col. lq.	0.805 ^{20/4}	-85.9	79.6	35 ¹⁰	∞	∞
ethyl oxalate	CH ₃ OOC-CO ₂ C ₂ H ₅	132.11	lq.	1.156 ^{0/0}		173.7	i.	V. S.	V. S.
formate	HCO ₂ CH ₃	60.05	lq.	0.974 ^{20/4}	-99.8	32	30 ²⁰	∞	∞
furoate	C ₄ H ₉ O-CO ₂ CH ₃	126.11	col. lq.	1.179 ^{21/4}		181.3	i.	∞	∞
glucamine	CH ₂ OH(CHOOH).CH ₂ NHCH ₃	195.21							
glycolate	HOCH ₂ CO ₂ CH ₃	90.08	lq.	1.168 ¹⁸		151.2			
heptape	CH ₃ (CH ₂) ₅ CO ₂ CH ₃	144.21	lq.	0.881 ^{15/4}		172-3	i.		
hypochlorite	ClOCH ₃	66.49	gas			12 ⁷²⁶			
iodide	CH ₃ I	141.95	col. lq.	2.279 ^{20/4}	-64.4	42.4	1.8 ¹⁵	∞	∞
lactate	CH ₃ CH(OH)CO ₂ CH ₃	104.10	lq.	1.090 ¹⁹		144.8	i.	S.	S.
laurate	CH ₃ (CH ₂) ₁₀ CO ₂ CH ₃	214.34	lq.		5	148 ¹⁸	i.		
mercaptan	CH ₃ SH	48.10	gas	0.896 ⁰	-121	5.5 ³⁵²	s.	V. S.	V. S.
methacrylate	CH ₂ C(CH ₃)CO ₂ CH ₃	100.11	lq.	0.950 ^{15,6}	-48	100.3	i.		
myristate	CH ₃ (CH ₂) ₁₂ CO ₂ CH ₃	242.39	cr/al.		18-9	295 ⁷¹⁵	i.		
naphthalene (α -)	C ₁₀ H ₇ CH ₃	142.19	oil	1.025 ^{14/4}	-19	244.6	i.	V. S.	V. S.
(β -)	C ₁₀ H ₇ CH ₃	142.19	mn.	0.994 ^{40/4}	35-6	241-2	i.	V. S.	V. S.
nitrate	CH ₃ ONO	77.04	lq.	1.203 ²⁵	expl.	65	sl. s.	S.	S.
nitrite	CH ₃ ONO	61.04	gas	0.991 ¹⁵		<12	i.	∞	∞
nonyl ketone (n -)	CH ₃ (CH ₂) ₈ COCH ₃	170.29	col. oil	0.828 ^{20/20}	13.5	228	i.	S.	S.
oleate	C ₁₇ H ₃₃ CO ₂ CH ₃	296.48	oil	0.879 ¹⁸		190-1 ¹⁰	i.	∞	∞
orange	(CH ₃) ₂ NC ₆ H ₅ N ₃ C ₆ H ₅ SO ₃ Na	327.33	red pd.			0.2 c.			
palmitate	CH ₃ (CH ₂) ₁₄ CO ₂ CH ₃	270.44	col. cr.		30-1	196 ¹⁵	i.	S.	S.
phosphine	CH ₃ PH ₂	48.03	gas			-14 ⁷⁵⁹	i.	sl. s.	
propionate	CH ₃ CH ₂ CO ₂ CH ₃	88.10	col. lq.	0.915 ^{20/4}	-87.5	79.7	0.5 ²⁰	∞	∞
propyl ketone (n -)	CH ₃ COCH ₂ CH ₂ CH ₃	86.13	col. lq.	0.812 ^{15/15}	-77.8	102	v. sl. s.	∞	∞
salicylate (α -)	HO-C ₆ H ₄ CO ₂ CH ₃	152.14	col. lq.	1.182 ^{25/25}	-8.3	222.2	0.07 ³⁰	∞	∞
stearate	CH ₃ (CH ₂) ₁₀ CO ₂ CH ₃	298.49	col. cr.		38-9	215 ¹⁵	i.	S.	S.
toluate (α -)	CH ₃ -C ₆ H ₄ CO ₂ CH ₃	150.17	col. lq.	1.073 ¹⁵	<-50	213	i.	∞	∞
(m -)	CH ₃ -C ₆ H ₄ CO ₂ CH ₃	150.17	col. lq.	1.066 ¹⁵		215	i.		
(p -)	CH ₃ -C ₆ H ₄ CO ₂ CH ₃	150.17	cr.		33-4	217	i.	V. S.	V. S.
Methyl toluidine (o -)	CH ₃ -C ₆ H ₄ NHCH ₃	121.18	lq.	0.973 ¹⁵		206-7	i.	∞	∞
(m -)	CH ₃ -C ₆ H ₄ NHCH ₃	121.18	lq.			206-7	i.	∞	∞
(p -)	CH ₃ -C ₆ H ₄ NHCH ₃	121.18	lq.	0.935 ^{55/4}		211 ⁷⁶¹	i.	∞	∞
valerate (n -)	CH ₃ (CH ₂) ₈ CO ₂ CH ₃	116.16	lq.	0.895 ^{15/4}	-91	127.3	v. sl. s.	∞	∞
(i -)	(CH ₃) ₂ CHCH ₂ CO ₂ CH ₃	116.16	col. lq.	0.881 ^{20/4}		116.7 ⁷⁶⁴	v. sl. s.	∞	∞
vinyl ketone	CH ₃ COCH ₂ CH ₃	70.09	lq.	0.836 ^{20/4}		81	>85		
Methylal	HCH(OCH ₂) ₂	76.09	col. lq.	0.866 ^{15/4}	-104.8	42-3	33	∞	∞
Methylene-bis-(phenyl-4-isocyanate)	(OCN-C ₆ H ₄) ₂ CH ₂	250.25	lq.	1.222 ³⁰		210-2 ¹³	d.	d.	
bromide	CH ₃ Br ₂	173.86	col. lq.	2.495 ^{20/4}	-52.8	98.5 ⁷⁵⁶	1.1 ⁷⁰	∞	∞
chloride	CH ₃ Cl ₂	84.94	col. lq.	1.336 ^{20/4}	-96.7	40-1	2 ²⁰	∞	∞
dianiline	(C ₆ H ₅ NH) ₂ CH ₂	198.26	cr.		65	208-9 d.	i.	S.	S.
iodide	CH ₃ I ₂	267.87	col. lq.	3.325 ^{20/4}	5.7	180 d.	1.4 ²⁰	∞	∞
Michler's hydrol (p -, p' -)	[(CH ₃) ₂ NC ₆ H ₄) ₂ CHOH	270.36	gn.		96-7	i.	s. h.	S.	S.
ketone	[(CH ₃) ₂ NC ₆ H ₄) ₂ CO	268.35	lf/al.		174	>360 d.	i.	sl. s.	v. sl. s.
Morphine	C ₁₇ H ₁₉ O ₃ N·H ₂ O	303.35	pr/al.	1.317	254 d.	0.02 ²⁰	sl. s.	S.	
Mucic acid	(-CHOHCHOCHO ₂ H) ₂	210.14	pd.		206-14	0.33 ¹⁴	i.		

TABLE 2-2 Physical Properties of Organic Compounds (Continued)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Mustard gas	(ClCH ₂ -CH ₂) ₂ S	159.08	oil	1.275 ^{20/4}	13-4	217	0.07 ²⁵	s.	s.
Myricyl alcohol	C ₂₀ H ₄₀ O(?)	452.82	cr.	0.777 ⁹⁵	88	i.	v. sl. s.	v. s.	
Myristic acid	CH ₄ (CH ₂) ₁₂ CO ₂ H	228.36	col. lf.	0.853 ^{70/4}	57-8	250.5 ¹⁰⁰	i.	v. s.	v. s.
Myristyl alcohol	CH ₃ (CH ₂) ₁₂ CH ₂ OH	214.38	cr.	0.824 ^{38/4}	38	167 ¹⁵	<0.02	sl. s.	s.
Naphthalene	C ₁₀ H ₈	128.16	pl./al.	1.145 ^{20/4}	80.2	217.9	0.003 ²⁵	9.5 ²⁰	v. s.
disulfonic acid (1-,5-)	C ₁₀ H ₆ (SO ₃ H) ₂	288.28	lf.		d.	102 ²⁰	s.	i.	
(1-,6-)	C ₁₀ H ₆ (SO ₃ H) ₂	288.28	er.		d. 125	164 ²⁰	s.	i.	
sulfonic acid (α-)	C ₁₀ H ₇ SO ₃ H·2H ₂ O	244.26	cr.		90	v. s.	v. s.	sl. s.	
(β-)	C ₁₀ H ₇ SO ₃ H·H ₂ O	226.24	cr.		125	77 ³⁰			
Naphthasultam (1-,S-)	C ₁₀ H ₈ ONS	205.22	nd.		177-8	s. h.	sl. s.	s.	
disulfonate Na (1-,8-)	C ₁₀ H ₆ OS ₂ Na ₂ ·2H ₂ O	445.35	er.			v. s.	sl. s.		
(2-,4-)	C ₁₀ H ₆ OS ₂ Na ₂ ·8H ₂ O	584.45	lf.			v. s.	sl. s.		
Naphthoic acid (α-)	C ₁₀ H ₇ CO ₂ H	172.17	nd.		160-1	300	v. sl. s. h.	s. h.	s.
(β-)	C ₁₀ H ₇ CO ₂ H	172.17	mn.	1.077 ^{100/4}	184	>300	0.007 ²⁵	s.	s.
Naphthol (α-)	C ₁₀ H ₈ OH	144.16	mn.	1.224 ⁴	96	278-80	sl. s. h.	v. s.	v. s.
(β-)	C ₁₀ H ₈ OH	144.16	mn.	1.217 ⁴	122-3	285-6	0.074 ²⁵	v. s.	v. s.
sulfonic acid (α-)(1-,2-)	HO-C ₁₀ H ₆ SO ₃ H	224.22	pl./aq.		>250	v. s. h.			
(β-)(2-,6-)	HO-C ₁₀ H ₆ SO ₃ H	224.22	lf.		125	v. s.	v. s.		
Naphthyl acetate (α-)	CH ₃ CO ₂ C ₁₀ H ₇	186.20	nd./al.		46-9	sl. s. h.	s.	s.	
(β-)	CH ₃ CO ₂ C ₁₀ H ₇	186.20	nd./al.		69-70	i.	s.	s.	
amine (α-)	C ₁₀ H ₈ NH ₂	143.18	rhb.	1.123 ^{25/25}	50	300.8	0.17 c.	v. s.	v. s.
(β-)	C ₁₀ H ₈ NH ₂	143.18	lf./aq.	1.061 ^{98/4}	111-2	306.1	v. s. h.	s.	s.
amine hydrochloride (α-)	C ₁₀ H ₈ NH ₂ -HCl	179.65	nd.		subl.	3.8 ²⁰	s.	s.	
(β-)	C ₁₀ H ₈ NH ₂ -HCl	179.65	lf.			v. s.	v. s.		
amine sulfonic acid (1-,4-)	NH ₃ ·C ₁₀ H ₆ SO ₃ H	223.24	nd.		d.	0.2 ¹⁰⁰	i.	i.	
(1-,5-)	NH ₃ ·C ₁₀ H ₆ SO ₃ H·H ₂ O	241.26	cr.			sl. s.			
(1-,7-)	NH ₃ ·C ₁₀ H ₆ SO ₃ H·H ₂ O	241.26	cr.			0.46 ²⁵			
(1-,8-)	NH ₃ ·C ₁₀ H ₆ SO ₃ H·H ₂ O	241.26	cr.			0.42 ¹⁰⁰			
(2-,5-)	NH ₃ ·C ₁₀ H ₆ SO ₃ H	223.24	cr.			0.08			
(2-,6-)	NH ₃ ·C ₁₀ H ₆ SO ₃ H·H ₂ O	241.26	cr.			0.38 ¹⁰⁰			
(2-,7-)	NH ₃ ·C ₁₀ H ₆ SO ₃ H·H ₂ O	241.26	cr.			0.28 ¹⁰⁰			
isocyanate (α-)	C ₁₀ H ₈ N ₂ CO	169.17	col. lq.	1.18	269-70	d.	s.	s.	
Nicotine	C ₁₀ H ₈ N ₂	162.23	oil	1.009 ^{20/4}	<80	246 ⁷³⁰	s.	∞	∞
Nicotinic acid (3-)	C ₈ H ₇ NO ₂ H	123.11	nd./al.		235.2	subl.	s. h.	s. h.	v. sl. s.
(i-)(4-)	C ₈ H ₇ NO ₂ H	123.11	nd./aq.		317	d.	s. h.	sl. s. h.	v. sl. s.
Nitro-acetanilide (p-)	CH ₃ CONHC ₆ H ₄ NO ₂	180.16	rhb.		215-6	s. h.	s. h.	s.	s.
-acetophenone (m-)	CH ₃ CO ₂ C ₆ H ₄ NO ₂	165.14	nd.		80-1	202	i.	s.	
-aminoanisole (4-,1-,2-)	NO ₂ ·C ₆ H ₄ (OCH ₃)NH ₂	168.15	red nd.	1.207 ¹⁵⁶	118	i.	s.		
(5-,1-,2-)	NO ₂ ·C ₆ H ₄ (OCH ₃)NH ₂	168.15	yel. nd.	1.211 ¹⁵⁶	139-40	i.	s.		
(3-,1-,4-)	NO ₂ ·C ₆ H ₄ (NH ₂)OH	168.15	red		123	sl. s.	s.	s.	
-aminophenol (4-,2-,1-)	NO ₂ ·C ₆ H ₄ (NH ₂)OH	154.12	pr. or.		142-3	sl. s. c.	v. s.	v. s.	
-aniline (o-)	NO ₂ ·C ₆ H ₄ NH ₂	138.12	yel. rhb.	1.442 ¹⁵	71.5	284.1	s. h.	v. s.	v. s.
(m-)	NO ₂ ·C ₆ H ₄ NH ₂	138.12	yel. rhb.	1.43	114	306.4	0.11 ²⁰	7.1 ²⁰	7.9 ²⁰
(p-)	NO ₂ ·C ₆ H ₄ NH ₂	138.12	yel. mn.	1.437 ¹⁴	146-7	331.7	0.08 ¹⁹	5.8 ²⁰	6.1 ²⁰
-anisole (o-)	CH ₃ OC ₆ H ₄ NO ₂	153.13	col. cr.	1.254 ^{20/4}	9.4	272-3	0.17 ²⁰	∞	∞
(p-)	CH ₃ OC ₆ H ₄ NO ₂	153.13	pr./al.	1.233 ²⁰	54	274	0.06 ²⁰	v. s.	v. s.
-anthraquinone (α-)	C ₁₀ H ₈ (CO) ₂	253.20	nd.		230	270 ⁷	i.	sl. s.	v. sl. s.
-anthraquinone sulfonic acid (1-,5-)	NO ₂ ·C ₁₄ H ₈ O ₂ ·SO ₃ H	333.26	yel. cr.			s.	i.		
-benzal chloride (m-)	NO ₂ ·C ₆ H ₄ ·CHCl ₂	206.03	mn.		65	i.	v. s. h.	v. s.	
-benzaldehyde (m-)	NO ₂ ·C ₆ H ₄ CHO	151.12	nd./aq.		58	164 ²³	1.95 ¹¹²	v. s. h.	v. s.
Nitro-benzene	C ₆ H ₅ NO ₂	123.11	yel. lq.	1.205 ^{18/4}	5.7	210.9	0.19 ²⁰	v. s.	∞
-benzidine (2-)	NH ₃ ·C ₆ H ₄ C ₆ H ₄ (NH ₂)NO ₂	229.23	red nd.		143	sl. s. h.			
-benzoic acid (o-)	NO ₂ ·C ₆ H ₄ ·CO ₂ H	167.12	tri./aq.	1.575 ^{4/4}	147.5	284.1	0.65 ²⁰	28 ¹¹	22 ¹¹
(m-)	NO ₂ ·C ₆ H ₄ ·CO ₂ H	167.12	mn.	1.494 ^{4/4}	140-1		0.24 ¹⁶⁵	31 ¹²	25 ¹⁰
(p-)	NO ₂ ·C ₆ H ₄ ·CO ₂ H	167.12	yel. mn.	1.550 ^{22/4}	240-2	subl.	0.02 ¹⁵	0.9 ¹⁰	2.2 ¹⁸
-benzyl alcohol (m-)	NO ₂ ·C ₆ H ₄ ·CH ₂ OH	153.13	cr.		27	175-80 ³	i.	2 ¹⁹	v. s.
-benzyl bromide (p-)	NO ₂ ·C ₆ H ₄ ·CH ₂ Br	216.04	nd./al.		99-100	i.			
-chlorotoluene (1-,2-,6-)	CH ₃ ·C ₆ H ₄ (NO ₂)Cl	171.58	cr.		37.5	238	i.		
-cresol (1-,3-,4-)	CH ₃ ·C ₆ H ₄ (NO ₂)OH	153.13	oil	1.240 ^{89/4}	32	125 ²²	v. sl. s.	v. s.	v. s.
-cymene (1-,2-,4-)	CH ₃ ·C ₆ H ₄ (NO ₂)CH(CH ₃) ₂	179.21	oil	1.067 ^{20/4}		152 ¹⁵	i.		
-dimethylaniline (o-)	NO ₂ ·C ₆ N ₂ NHCH ₃	166.18	yel. oil	1.179 ^{20/4}		151-3 ⁸⁰	v. sl. s.	v. s.	v. s.
(m-)	NO ₂ ·C ₆ N ₂ NHCH ₃	166.18	red mn.	1.313 ¹⁷	60-1	280-5	i.	s.	s.
(p-)	NO ₂ ·C ₆ N ₂ NHCH ₃	166.18	yel. nd.		163-4	i.	s. h.		
-diphenyl (o-)	C ₆ H ₅ ·C ₆ H ₄ NO ₂	199.20	rhb.	1.44	37	320	i.	s.	v. s.
(p-)	C ₆ H ₅ ·C ₆ H ₄ NO ₂	199.20	nd./al.		113-4	340	i.	sl. s. c.	v. s.
-diphenylamine (o-)	C ₆ H ₅ ·NH·C ₆ H ₄ NO ₂	214.22	or. cr.		75-6	9 ¹⁰⁰	sl. s.	v. sl. s.	
-guanidine	H ₂ NC(NH)NHNO ₂	104.07	nd./aq.		246-7				

-naphthalene (α -)		C ₁₀ H ₈ NO ₂	173.16	yel/al.	1.223 ⁶²	59-60	304	i.	s.	s.
-phenol (σ -)	(β -)	C ₁₀ H ₇ NO ₂	173.16	col/al.	1.295 ⁴⁵	79	165 ¹⁵	i.	v. s.	v. s.
(m -)		NO ₂ ·C ₆ H ₄ ·OH	139.11	yel. mn.	1.485 ²⁰	44-5	214.5	1.08 ¹⁰⁰	v. s.	v. s.
(p -)		NO ₂ ·C ₆ H ₄ ·OH	139.11	col. mn.	1.479 ²⁰	96-7	194 ⁷⁰	1.35 ²⁰	v. s.	s.
-phenol sulfonic acid (1-,4-,2-)	(1-,2-,4-)	HO·C ₆ H ₃ (NO ₂)·SO ₃ H·3H ₂ O	273.22	yel. pr.	1.479 ²⁰	113-4	subl.	1.6 ²⁵	v. s.	v. s.
-phthalic acid (3-)	(4-)	HO·C ₆ H ₃ (NO ₂) ₂	273.22	nd.		d. 110		v. s.	v. s.	sl. s.
-toluene (σ -)		NO ₂ ·C ₆ H ₄ (CO ₂ H) ₂	211.13	nd/aq.		51.5		2.05 ²⁵	v. s. h.	sl. s.
(m -)		NO ₂ ·C ₆ H ₄ (CO ₂ H) ₂	211.13	yel. cr.		222		v. s.	v. s.	s.
(p -)		CH ₃ ·C ₆ H ₄ NO ₂	137.13	yel. lq.	1.163 ^{20/4}	164-5		0.07 ⁵⁰	oo	oo
-toluene sulfonic acid (1-,4-,2-)		CH ₃ ·C ₆ H ₄ NO ₂	137.13	lq.	1.160 ^{18/4}	15-16	230-1	0.05 ⁵⁰	oo	oo
-toluidine (4-,1-,2-)		CH ₃ ·C ₆ H ₄ NO ₂	137.13	rhb.	1.139 ^{55/55}	51.9	237.7	0.04 ⁵⁰	8.6 ¹⁵	80.8 ¹⁵
Nitron		CH ₃ ·C ₆ H ₃ (NO ₂)SO ₃ H·2H ₂ O	253.23	pl./aq.		130		47.7 ²⁸	v. s.	v. s.
Nitroso-dimethylaniline (p -)		NO ₂ ·C ₆ H ₃ (CH ₃)NH ₂	152.15	yel. mn.	1.365 ¹⁵	105-7	v. sl. s.	s.	v. s.	s.
-naphthol (β)(1-)		NO ₂ ·C ₆ H ₃ (CH ₃)NH ₂	152.15	red mn.	1.312 ¹⁷	116-7	sl. s. h.	s.	s. h.	v. sl. s.
Nonadecane (n -)		C ₉ H ₁₉ N ₄	312.36	yel. lf.		189-90 d.		i.	s. h.	s.
Nonane (n -)		ON·C ₉ H ₁₉ N(CH ₃) ₂	150.18	gn. tri.		86-7		i.	s. h.	v. sl. s.
Octadecane (n -)		ON·C ₉ H ₁₉ O ₂	173.16	brn. pr.		109.5		0.1 ²⁰	2.4 ¹⁸	s.
Octane (n -)		CH ₃ (CH ₂) ₁₇ CH ₃	268.51	cr.	0.777 ^{32/4}	32	330	i.	sl. s.	s.
(iso-)		CH ₃ (CH ₂) ₁₇ CH ₃	268.51	col. lq.	0.718 ^{20/4}	-53.7	150.5 ⁷⁵⁹	i.	sl. s.	s.
Octyl acetate (n -)	(sec-)	CH ₃ (CH ₂) ₆ CH ₃	254.48	cr.	0.775 ^{28/4}	28	317	i.	sl. s.	s.
alcohol (n -)	(sec-)	CH ₃ (CH ₂) ₆ CH ₃	114.22	col. lq.	0.703 ^{20/4}	-56.5	125.7	0.002 ¹⁶	sl. s.	s.
Octylene (n -)		(CH ₃) ₃ CCH ₂ CH(CH ₃) ₂	114.22	col. lq.	0.692 ^{20/4}	-107.4	99.3 ⁷⁶⁰	i.	sl. s.	s.
Oleic acid		CH ₃ CO ₂ CH ₂ (CH ₂) ₆ CH ₃	172.26	col. lq.	0.885 ^{0/4}	-38.5	210	i.	s.	s.
Orcinol (1-,3-,5-)		CH ₃ CO ₂ CH ₂ (CH ₂) ₆ CH ₃	172.26	col. lq.	0.863 ^{14/4}	195	i.	S.	S.	S.
Oxalic acid		CH ₃ (CH ₂) ₆ CH ₂ OH	130.22	col. lq.	0.827 ^{20/4}	-16	194-5	0.054 ²⁵	oo	oo
Palmitic acid		CH ₃ (CH ₂) ₆ CH ₂ OH	130.22	col. lq.	0.829 ^{20/4}	-38.6	179-80	0.096 ²⁵	oo	oo
Pelargonic acid		CH ₃ (CH ₂) ₅ CH(CH ₃) ₂	112.21	lq.	0.721 ^{18/4}	126	i.	oo	oo	oo
Penta-chloroethane		C ₅ H ₁₁ CH(CH ₂) ₂ CO ₂ H	282.45	col. nd.	0.854 ^{78/4}	14	285-6 ¹⁰⁰	i.	S.	V. S.
-decane (n -)		(HO) ₂ C ₆ H ₃ CH ₃	124.13	pr./bz.	1.290 ⁴	107-8	287-90	v. s.	V. S.	V. S.
-erythritol		HO ₂ C ₆ H ₃ CH ₃	126.07	col. mn.	1.653 ^{19/4}	101.5	subl.	s.	S.	1.3
Pentanol		CH ₃ (CH ₂) ₄ CO ₂ H	256.42	col. pl.	0.849 ^{70/4}	63-4	271.5 ¹⁰⁰	i.	9 ²⁰	s.
Pentane (n -)	(<i>i</i> -)	CH ₃ (CH ₂) ₅ CO ₂ H	158.23	col. oil	0.906 ^{20/4}	12.5	253-4	v. sl. s.	S.	S.
(neo-)		CHCl ₃ ·CCl ₃	202.31	col. lq.	1.671 ^{25/4}	-22	162	0.05 ²⁰	oo	oo
Phenacetin		CH ₃ (CH ₂) ₁₃ CH ₃	212.41	col. lq.	0.770 ^{20/4}	10	270.5	i.	V. S.	V. S.
Phenanthrene		C(CH ₂ OH) ₄	136.15	er.		262	276 ³⁰	5.6 ¹⁵	v. sl. s.	i.
Phenetidine (σ -)	(p -)	HOCH ₂ (CH ₂) ₃ CH ₂ OH	104.15	lq.	0.994 ^{20/4}	239.4	oo			
Phenetole		CH ₃ (CH ₂) ₃ CH ₃	72.15	col. lq.	0.630 ^{18/4}	-129.7	36.3	0.036 ¹⁶	oo	oo
Phenol		(CH ₃) ₃ CHCH ₂ CH ₃	72.15	col. lq.	0.621 ¹⁹	-160.0	27.95	i.	oo	oo
-phthalein		(CH ₃) ₃ C(CH ₃) ₂	72.15	col. lq.	0.613 ^{20/4}	-20	9.5	i.	S.	S.
-sulfonic acid (σ -)		C ₅ H ₉ O ₆ H ₃ NHCOC ₃ H ₅	179.21	col. mn.	1.34-5	d.	0.7 ²⁰	40 h.	1.6 ²⁵	
Phenyl acetaldehyde		<(C ₆ H ₅ CH ₃) ₂ >	178.22	pl./al.	1.179 ²⁵	99-100	340	i.	10 h.	V. S.
acetic acid		C ₅ H ₉ O·C ₆ H ₄ ·NH ₂	137.18	oil		<-21	228-9	i.	S.	S.
-acetylene		C ₅ H ₉ O·C ₆ H ₄ ·NH ₂	137.18	lq.	1.061 ¹⁵	3-4	254-5	i.	S.	S.
aniline (σ -)	(p -)	C ₅ H ₉ O·C ₆ H ₄ ·NH ₂	122.16	col. lq.	0.967 ^{20/4}	-30.2	172	i.	oo	oo
Phenyl-ethyl alcohol		C ₅ H ₉ O ₂	94.11	col. nd.	1.071 ^{25/4}	42-3	181.4	8.2 ¹⁵	oo	oo
-glycine		C ₅ H ₉ O ₄	318.31	col. rhb.	1.299 ^{25/4}	261-2	50 d.	0.2 ²⁰	10 ³⁵	5.9 c.
-hydrazine		HO·C ₆ H ₅ SO ₃ H· ϵ H ₂ O	187.68	er.		v. s.	V. S.			
-hydrazine sulfonic acid (p -)		C ₆ H ₅ CH ₂ CHO	120.14	lq.	1.025 ²⁰	193-4	v. sl. s.	oo	oo	
isocyanate		C ₆ H ₅ CH ₂ CO ₂ H	136.14	lf.	1.081 ^{80/4}	76-7	265.5	1.66 ²⁰	V. S.	V. S.
-methylpyrazolone (3-)(N -)		C ₆ H ₅ C ₂ H ₃ CH ₃	102.13	col. lq.	0.930 ^{20/4}	-43	142-3	i.	oo	oo
-mustard oil		C ₆ H ₅ C ₆ H ₄ ·NH ₂	169.22	er.		45-6	299 ⁷⁶⁰	v. sl. s.	S.	S.
naphthalene (α -)		C ₆ H ₅ C ₆ H ₄ ·NH ₂	169.22	lf.		50-2	302	s. h.	S.	S.
(β -)		C ₆ H ₅ CH ₂ CH ₂ OH	122.16	col. oil	1.023 ^{18/4}	127	219-21 ⁷⁵⁰	1.6 ²⁰	s.	sl. s.
naphthylamine (α -)	(β -)	C ₆ H ₅ NHCH ₂ CO ₂ H	151.16	cr.		286	sl. s. h.	oo	oo	
phenol (σ -)	(p -)	C ₆ H ₅ NH ₂	108.14	yel. oil	1.097 ^{23/4}	19.6	243.5	0.61 ¹²	sl. s.	
propyl alcohol (γ)		H ₂ NNHC ₆ H ₄ SO ₃ H	188.20	cr./al.		286	d.	v. s.	V. S.	
quinoline (2-)(α -)		C ₆ H ₅ N ₂ CO ₂ H	119.12	lq.	1.096 ^{20/4}	166 ⁷⁶⁹	d.	v. s.	v. s.	
(8-)(0-)		C ₆ H ₅ ON ₂ ·C ₆ H ₅	174.20	pr./aq.		128	191 ¹⁷	1 ²⁰	v. s. h.	v. sl. s.
salicylate, salol		C ₆ H ₅ N:CS	135.18	col. lq.	1.138 ^{15/15}	-21	219-20	i.	S.	S.
stearate		C ₆ H ₅ H ₄ C ₆ H ₅	204.26	waxy		45	336-7	i.	V. S.	V. S.
urethane		C ₁₀ H ₇ ·C ₆ H ₅	204.26	lf./al.		102.5	345-6	i.	sl. s.	sl. s.
		C ₁₀ H ₇ ·NH ₂ C ₆ H ₅	219.27	pr./al.	1.17	62	335 ²⁵⁵	0.08 ⁶⁰	s.	s.
		C ₁₀ H ₇ ·NH ₂ C ₆ H ₅	219.27	rhb.	1.18	107-8	399.5	0.4 ⁶⁰	v. s. h.	v. s. h.
		C ₆ H ₅ ·C ₆ H ₄ ·OH	170.20	nd.		56-7	275	i.	S.	S.
		C ₆ H ₅ ·C ₆ H ₄ ·OH	170.20	nd.		164-5	305-8	i.	S.	S.
		C ₆ H ₅ CH ₂ OH	136.19	oil	1.008 ^{20/4}	<-18	235-7	sl. s.	oo	oo
		C ₆ H ₅ ·C ₆ H ₆ N	205.25	nd.		86	363	sl. s.	S. h.	S.
		C ₆ H ₅ ·C ₆ H ₆ N	205.25	lq.		283 ¹⁸⁷	sl. s.	S.	S.	S.
		HO·C ₆ H ₅ CO ₂ C ₆ H ₅	214.21	rhb./al.	1.250 ^{20/4}	42-3	172-31 ²	0.015 ²⁵	V. S.	S.
		CH ₃ (CH ₂) ₁₆ CO ₂ C ₆ H ₅	360.56	cr.		52	267 ¹⁵	i.	S.	S.
		C ₆ H ₅ NHCO ₂ C ₆ H ₅	165.19	pl./al.	1.106 ^{30/4}	52-3	237-8	i. c.	S.	S.

TABLE 2-2 Physical Properties of Organic Compounds (Continued)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Phenylene-diamine (<i>o</i> -) (<i>m</i> -) (<i>p</i> -)	C ₆ H ₄ (NH ₂) ₂ C ₆ H ₄ (NH ₂) ₂ C ₆ H ₄ (NH ₂) ₂	108.14 108.14 108.14	lf./aq. rhb. mn.	1.139 ^{15/15}	103-4 62.8 140	256-8 284-7 267	733 ³¹ 35.1 ²⁵ 669 ¹⁰⁷	v. s. v. s. s.	v. s. s. s.
Phloroglucinol (1,3,5-)	C ₆ H ₃ (OH) ₃ ·2H ₂ O	162.14	rhb.		117	subl.	1.13 ²⁵	v. s.	v. s.
Phorone	[C(CH ₃) ₂ :CH] ₂ CO	138.20	yel. pr.	0.885 ^{20/4}	28	197.2 ⁷⁴³	0.1 ⁵⁰	s.	s.
Phosgene	OCCl ₂	98.92	gas	1.392 ^{19/4}	-104	8.2 ⁵⁶	v. sl. s.		
Phthalic acid (<i>o</i> -) (<i>m</i>)-(iso-) anhydride (<i>o</i> -) nitrile (<i>o</i> -)	C ₈ H ₄ (CO ₂ H) ₂ C ₈ H ₄ (CO ₂ H) ₂ C ₆ H ₄ <(CO) ₂ >O C ₆ H ₄ (CN) ₂	166.13 166.13 148.11 128.13	mn./aq. nd./aq. rhb. cr.	1.593 ^{20/4}	208 330	d. subl.	0.70 ²⁵ 0.2 ¹⁰⁰	12 ¹⁸	0.68 ¹⁵
Phthalide	[C ₆ H ₄ (CH ₃)(CO)>O	134.13	nd./aq.	1.164 ^{99/4}	73(65)	290	v. sl. s.		
Phthalimide (<i>o</i> -)	C ₆ H ₄ <(CO) ₂ >NH	147.13	cr./et.		238	subl.	0.04 ²⁵	5	s. h.
Picoline (<i>α</i> -) (<i>β</i> -) (<i>γ</i> -)	C ₈ H ₁₁ N-CH ₃ C ₈ H ₁₁ N-CH ₃ C ₈ H ₁₁ N-CH ₃	93.12 93.12 93.12	col. lq. col. lq. lq.	0.950 ^{15/4} 0.961 ^{15/4} 0.957 ^{15/4}	-70	128.8 143.5 143.1	v. s. ∞ ∞	∞ ∞ ∞	
Pieramic acid (1,2-,4-,6-)	HO-C ₆ H ₄ (NH ₂)(NO ₂) ₂	199.12	red nd.		169		0.14 ²²		
Picric acid (2-,4-,6-)	HO-C ₆ H ₂ (NO ₂) ₃	229.11	yel. rhb.	1.763 ^{20/4}	121.8	expl.	1.23 ²⁰	S. 6 ²⁰	sl. s. 1 ¹³
Picryl chloride (2-,4-,6-)	ClC ₆ H ₂ (NO ₂) ₃	247.56	yel. mn.	1.797 ²⁰	83	d.	0.018 ¹⁵	4.8 ¹⁷	
Pinacol	[(CH ₃) ₂ :C(OH) ₂	118.17	col. nd.	0.967 ¹⁵	43(38)	171-2 ⁷⁸⁹	sl. s. c.	V. S.	V. S.
Pinacoline	CH ₃ COC(CH ₃) ₃	100.16	col. lq.	0.800 ¹⁶	-52.5	106.2	2.5 ¹⁵	s.	s.
Pinene (<i>α</i>)-(<i>dl</i> -)	C ₁₀ H ₁₆	136.23	col. lq.	0.878 ^{20/4}	-55	154-6	v. sl. s.	∞	∞
hydrochloride						207-8	i.	33	s.
Pinol (<i>dl</i> -)	C ₁₀ H ₁₇ Cl	172.69	lf.		131-2	183-4	s.	s.	s.
Piperidine	carboxylic acid (<i>α</i>)-(dl-)					106	∞	∞	
Piperidinium pentamethylene dithiocarbamate									
Propane									
Propionic acid									
aldehyde									
anhydride									
Propyl acetate (<i>n</i> -) (<i>i</i> -)	CH ₃ CO ₂ CH ₂ CH ₃	85.15	lq.	0.860 ^{20/4}	-9	106	∞	∞	
alcohol (<i>n</i> -) (<i>i</i> -)	CH ₃ CH ₂ CH ₂ OH	129.16	cr.		264		s.	∞	
amine (<i>n</i> -) (<i>i</i> -)	HO-C:CH<(CH ₂ CH ₂) ₂ >NH	232.41	cr.	1.13	175		6 ²⁸		
aniline (<i>n</i> -)	(CH ₃) ₂ CS-H-NH(CH ₂) ₅	130.14	col. lq.	0.585 ^{-45/4}	-187.1	-42.2	6.5 ¹⁸ cc.	s.	V. S.
benzoate (<i>n</i> -) (<i>i</i> -)	CH ₃ CO ₂ CH ₂ CH ₂ CH ₃	102.13	col. lq.	0.992 ^{20/4}	-22	141.1	∞	∞	
bromide (<i>n</i> -) (<i>i</i> -)	CH ₃ CO ₂ CH ₂ CH ₂ CH ₃	102.13	col. lq.	0.807 ^{20/4}	-81	49.5 ⁷⁴⁰	20 ²⁰	∞	
<i>n</i> -butyrate (<i>n</i> -)	CH ₃ CH ₂ CH ₂ CO ₂ H	164.20	col. lq.	1.012 ^{20/4}	-45	168.8 ⁷⁸⁰	d.	d.	
<i>i</i> -butyrate (<i>n</i> -)	CH ₃ CH ₂ CH ₂ CO ₂ H	164.20	col. lq.	0.886 ^{20/4}	-92.5	101.6	1.6 ¹⁶	∞	∞
<i>n</i> -butyrate (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CO ₂ H	123.00	col. lq.	0.874 ^{20/20}	-73.4	88.4	3 ²⁰	∞	∞
<i>i</i> -butyrate (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CO ₂ H	123.00	col. lq.	0.804 ^{20/4}	-127	97.8	∞	∞	
chloride (<i>n</i> -) (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	135.20	col. lq.	0.789 ^{20/4}	-85.8	82.5	∞	∞	
Propyl formate (<i>n</i> -) (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	159.11	col. lq.	0.718 ^{20/20}	-83	49-50 ⁷⁶¹	∞	∞	
furoate (<i>n</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	164.20	col. lq.	0.694 ^{15/4}	-101	33-4	∞	∞	
lactate (<i>n</i> -) (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	164.20	col. lq.	0.949 ¹⁸	222	i.	V. S.	V. S.	
mercaptan (<i>n</i> -) (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	123.00	col. lq.	1.021 ^{25/25}	-51.6	231	i.	S.	S.
propionate (<i>n</i> -) (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	123.00	col. lq.	1.010 ^{25/25}	218.5	i.	S.	S.	
thiocyanate (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	130.18	col. lq.	1.353 ^{20/4}	-109.9	70.8	0.25 ²⁰	∞	
<i>n</i> -valerate (<i>n</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	130.18	col. lq.	1.310 ^{20/4}	-89	60	0.32 ²⁰	∞	
<i>i</i> -valerate (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	130.18	col. lq.	0.884 ^{0/4}	142.7	134-5	v. sl. s.	∞	
thiocyanate (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₃	130.18	col. lq.	0.885 ¹⁸	134-5	v. sl. s.	∞	∞	
<i>n</i> -valerate (<i>n</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	144.21	col. lq.	0.865 ¹⁸	128	v. sl. s.	∞	∞	
<i>i</i> -valerate (<i>i</i> -)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₃	144.21	col. lq.	0.869 ^{0/4}	120.8	v. sl. s.	∞	∞	
Propylene									
bromide									
chlorhydrin									
chloride									
glycol									
oxide									
Protocatechic acid (3-,4-)	(HO) ₂ C ₆ H ₃ CO ₂ H·H ₂ O	172.13	nd./aq.	1.542 ^{4/4}	199 d.		1.82 ¹⁴	V. S.	S.

Pulegol (iso-)(d-)	C ₁₀ H ₁₉ OH	154.24	col. lq.	0.911 ^{20/4}		86-9 ¹⁰	v. sl. s.		
Pulegone	C ₁₀ H ₁₈ O	152.23	col. lq.	0.932 ^{20/20}	70	224 ⁷⁵⁴	i.	∞	∞
Pyrazole	—NH-N:CH-CH:CH—	68.08	nd./et.			186-8	s.	s.	
Pyrazoline	—NH-N:CH-CH ₂ :CH ₂ —	70.09	lq.			144	∞	∞	sl. s.
Pyrazolone	—NH-CO-CH ₂ :N—	84.08	nd.		165	subl. d.	v. S.	v. sl. s.	v. sl. s.
Pyrene	C ₁₆ H ₁₀	202.24	yel. pr.	1.277 ^{0/4}	>360	i.	3 h.	v. S.	
Pyridazine	N ₂ <(CHCH) ₂ >	80.09	lq.	1.107 ^{20/4}	208	∞	s.	s.	
Pyridine	CH <(CHCH) ₂ > N	79.10	col. lq.	0.982 ^{20/4}	-42	115-6	∞	∞	S.
Pyrocatechol (o-)	C ₆ H ₄ (OH) ₂	110.11	nd./aq.	1.344 ⁴	104-5	240-5	45.1 ²⁰	v. S.	v. S.
Pyrogallol (1-,2-,3-)	C ₆ H ₃ (OH) ₃	126.11	nd.	1.453 ⁴	133-4	309	40 ¹³	S.	S.
Pyrone	CO <(CHCH) ₂ > O	96.08	cr.	1.190 ^{40,3}	32.5	215-7	v. sl. s.	v. S.	v. S.
Pyrrole	<(CH:CH) ₂ > NH	67.09	lq.	0.948 ^{20/4}	131	∞	s.	s.	
Pyrrolidine	<(CH ₂ :CH ₂) ₂ > NH	71.12	lq.	0.852 ^{22,5}	87-8	∞	∞	∞	
Pyrroline	<(CH:CH ₂) ₂ > NH	69.10	lq.	0.910 ^{20/4}	90-1	v. S.	∞	∞	
Pyruvic acid	CH ₃ COCO ₂ H	88.06	col. lq.	1.267 ^{20/4}	165	∞	∞	∞	
Quercitrin	C ₂₃ H ₂₀ O ₁₁ :2H ₂ O	484.40	yel. nd.	1.267 ^{20/4}	13.6	0.04 ²⁰	S.	sl. s.	
Quinaldine (py-2)	CH ₃ C ₆ H ₅ N	143.18	lq.	1.059 ^{20/4}	-1	244-5 ⁷⁵⁰	v. sl. s.	s.	
Quinoline (iso-)	C ₈ H ₇ N	129.15	lq.	1.095 ²⁰	-15	237.1 ⁷⁴⁷	6	∞	∞
-diol (1-,3-)	C ₉ H ₇ N	129.15	pl.	1.099 ^{21/4}	24.6	240.5 ⁷⁶³	sl. s.	s.	
Quinone (p-)	—C ₆ H ₄ CH:C(OH)N:C(OH)—	161.15	cr.		237	v. sl. s.	sl. s. h.	s.	s.
R-acid Ca salt (2-)(3-,6-)	CO <(CHCH) ₂ > CO	108.09	yel. mn.	1.318 ^{20/4}	115.7	subl.	30.6 ²⁵	29.5 ²⁵	
K salt	HOC ₁₀ H ₅ (SO ₃) ₂ Ca	342.35	cr.			25.2 ²⁵	25.2 ²⁵		
Na salt	HOC ₁₀ H ₅ (SO ₃ K) ₂	380.46	cr.			29.5 ²⁵	29.5 ²⁵		
Raffinoose	HOC ₁₀ H ₅ (SO ₃ Na) ₂	348.26	cr.			30.6 ²⁵	30.6 ²⁵		
Resorcinol (m-)	C ₁₈ H ₁₂ O ₆ :5H ₂ O	594.52	cr./aq.	1.465 ⁰	119	d. 130	14.3 ²⁰	0.1 ²⁰	
Retene	C ₆ H ₄ (OH) ₂	110.11	col. rhb.	1.272 ¹⁵	110.7	276.5	147 ¹²	v. S.	v. s. h.
Rhamnose (β-)	C ₁₈ H ₁₈	234.32	lf./al.	1.13 ¹⁶	98-9	390-4	i.	69 h.	i.
Ricinoleic acid	CH ₃ (CHOH) ₄ CHO·H ₂ O	182.17	col. mn.	1.471 ^{20/4}	126	60.8 ²¹			
Rosaniline	C ₁₇ H ₁₃ (OH)CO ₂ H	298.45	lq.	0.954 ¹⁶	4-5	226-8 ¹⁰	i.	∞	∞
Rosolic acid	C ₉ H ₁₁ ON ₃	319.39	col. nd.		186 d.	v. sl. s.	sl. s.	sl. s.	sl. s.
Saccharin	C ₉ H ₁₀ O ₃	304.33	red lf.		308-10 d.	0.12 ²⁵	v. s. h.	0.12 ²⁵	0.12 ²⁵
Safrole (1-,3-,4-)	C ₆ H ₄ (CO)(SO ₂)> NH	183.18	mn.		225-8	0.4 ²⁵	3.1 c.	3.1 c.	1.05 c.
(iso-)(1-,3-,4-)	CH ₃ CHCH ₂ :C ₆ H ₅ :O ₂ CH ₂	162.18	col. mn.	1.100 ^{20/4}	11.2	233-4	i.	s.	∞
Salicylic acid (o-)	CH ₃ :CH:CH-C ₆ H ₃ :O ₂ CH ₂	162.18	col. lq.	1.122 ^{20/4}	6-7	252-3	i.	∞	∞
aldehyde (o-)	HO-C ₆ H ₄ :CO ₂ H	138.12	mn.	1.443 ^{20/4}	159	211 ²⁰	0.2 ²³	49 ¹⁵	51 ¹⁵
Salgenin	HO-C ₆ H ₄ :CHO	122.12	col. oil	1.153 ^{25/4}	-7	196.5	1.7 ⁸⁶	∞	∞
Schaeffer's salt, Ca	HO-C ₆ H ₄ :CH ₂ OH	124.13	rhb./aq.	1.161 ²⁵	86-7	subl.	6.6 ¹⁵	v. S.	v. S.
K	(HOC ₁₀ H ₅ SO ₃) ₂ Ca·5H ₂ O	576.59	cr.			4.76 ²⁰			
Na	HOC ₁₀ H ₅ SO ₃ K	262.31	cr.			3.46 ²⁵			
Semicarbazide	HOC ₁₀ H ₅ SO ₃ Na	246.21	cr.			6.29 ²⁵			
hydrochloride	NH ₂ :CO-NH-NH ₂	75.07	pr./al.		96	v. s.	v. s.	i.	
Skatole (3-)	NH ₂ :CO-NH-NH ₃ Cl	111.54	pr.		173 d.	v. s.	sl. s.	i.	
Sodium methylate	CH ₃ :C ₆ H ₅ N	131.17	lf.		95	265-6 ⁷⁵⁵	0.05 c.	s.	s.
Sorbitol	CH ₃ ONa	54.03	pd.		d. 300	d.			
Sorbitose (d- or l-)	[CH ₂ OH(CHOH) ₂] ₂	182.17	cr.		110-2	v. s.	v. s. h.		
Starch	C ₆ H ₁₂ O ₆	180.16	rhb.	1.654 ¹⁵	165	55 ¹⁷	sl. s.		
Stearic acid	(C ₆ H ₅ O ₅) _x	162.14	amor.	1.50 ²¹	d.	i.	i.	i.	
amide	CH ₃ (CH ₂) ₁₆ CO ₂ H	284.47	mn.	0.847 ^{69,3}	70-1	291 ¹¹⁰	0.03 ²⁵	2 ²⁰	6 ⁴
Styrene	CH ₃ (CH ₂) ₁₆ CONH ₂	283.48	col. cr.		108-9	251 ¹²	i.	s. h.	s. h.
Suberic acid	C ₆ H ₅ CH:CH ₂	104.14	col. lq.	0.903 ^{20/4}	-31	145-6	v. sl. s.	∞	∞
Succinic acid	HO ₂ C(CH ₂) ₂ CO ₂ H	174.19	nd./aq.	1.266 ^{25/4}	140-4	279 ¹⁰⁰	0.14 ¹⁶	s.	0.8 ¹⁵
Sucrose	HO ₂ C(CH ₂) ₂ CO ₂ H	118.09	col. mn.	1.572 ^{25/4}	189-90	235 d.	6.8 ²⁰	9.9 ¹⁵	1.2 ¹⁵
Sulfanilic acid (p-)	C ₆ H ₅ NO ₂	342.30	col. mn.	1.588 ¹⁵	170-86 d.	179 ⁰	0.9	v. sl. s.	
Sylvestrene (d-)	H ₂ N-C ₆ H ₄ :SO ₃ H	173.18	col. cr.		d. > 280	0.8 ¹⁰			
Tartaric acid (meso-)	C ₆ H ₁₆	136.23	lq.	0.863 ^{20/4}		176-7			
(racemic)	(CHOHCO ₂ H) ₂	150.09	cr.	1.737	159-60	120 ¹⁵			
(d- or l-)	(CHOHCO ₂ H) ₂ :H ₂ O	168.10	tri.	1.697 ^{20/4}	205-6	20.6 ²⁰	2 ⁰	0.09	0.4 ¹⁵
Tartronic acid	(CHOHCO ₂ H) ₂	150.09	mn.	1.760 ^{20/4}	168-70	d.	139 ²⁰	25 ¹⁵	
Terephthalic acid (p-)	CH(OH)(CO ₂ H) ₂ :H ₂ O	129.07	pr./aq.		d. 155-8	subl.	0.001 c.		
Terpin hydrate (cis-)	C ₆ H ₁₀ (CO ₂ H) ₂	166.13	cr.	1.510		v. s.	v. s.	i.	
Terpineol (α-)(d- or l-)	C ₁₀ H ₁₈ O ₂	190.28	rhb.		117	d.	0.4 ¹⁵	10 ¹⁵	1 ¹⁵
(dl-)	C ₁₀ H ₁₈ O	154.24	col. cr.	0.935 ¹⁵	38-40	219-21	i.	v. S.	v. S.
Terpinyl acetate (α-)(dl-)	C ₁₀ H ₁₈ O ₂	154.24	col. cr.	0.935 ^{20/20}	35	218.9 ⁷⁵²	i.	v. S.	v. S.
Tetrabromo-ethane (sym)	CH ₂ CO ₂ :C ₆ H ₁₇	196.28	lq.	0.966 ^{20/4}	<-50	220 d.	i.	20	
(uns)	Br ₂ CH-CH ₂ Br ₂	345.70	col. lq.	2.964 ^{20/4}	-1.0	151 ⁵⁴	i.	∞	∞
Tetrachloro-ethane (sym)	Br ₃ C-CH ₂ Br ₂	345.70	col. lq.	2.875 ^{20/4}	0	104 ¹³	s.		
(uns)	Cl ₂ CH-CHCl ₂	167.86	col. lq.	1.600 ^{20/4}	-36	146.3	0.29 ²⁰	∞	∞
-ethylene	Cl ₃ C-CH ₂ Cl	167.86	lq.	1.588 ^{20/4}		129-30	i.	∞	∞
Tetracosane (n-)	Cl ₃ C:CCl ₂	165.85	col. lq.	1.624 ^{15/4}	-19	120.8	0.02 ²⁰	∞	∞
Tetradecene (n-)	CH ₃ (CH ₂) ₂₂ CH ₃	338.64	cr.	0.779 ^{51/4}	51.1	324	i.	s.	
Tetraethyl-thiuram disulfide	[(C ₂ H ₅) ₂ NCS] ₂	296.52	col. lq.	0.765 ^{20/4}	5.5	252.5	i.	v. S.	v. S.
			cr.	1.17	70				

TABLE 2-2 Physical Properties of Organic Compounds (Concluded)

Name	Formula	Formula weight	Form and color	Specific gravity	Melting point, °C	Boiling point, °C	Solubility in 100 parts		
							Water	Alcohol	Ether
Tetrafluoro-ethylene	F ₂ C=CF ₂	100.02	gas	1.58 ⁷⁸	-142.5	-76.3	0.01 ³⁰		
Tetrahydro-furan	—CH ₂ (CH ₂) ₂ CH ₂ —O—	72.10	col. lq.	0.888 ^{21/4}	-65	65.6	s.	s.	s.
-furfuryl alcohol	C ₆ H ₅ O—CH ₂ OH	102.13	col. lq.	1.050 ^{20/4}		177.8 ⁷⁴³	∞	∞	∞
-pyran	—CH ₂ (CH ₂) ₂ CH ₂ —O—	86.13	lq.	0.881 ^{20/4}		88	s.		
Tetralin	—C ₆ H ₅ CH ₃ (CH ₂) ₂ CH ₂ —	132.20	col. lq.	0.973 ^{18/4}	-31	206 ⁷⁶⁴	i.	s.	s.
Tetramethyl-thiuram disulfide	[{(CH ₃) ₂ NCS] ₂ S ₂ }	240.41	cr.	1.29	155.6				
Tetryl (2-,4-,6-)	(NO ₂) ₂ C ₆ H ₃ N(CH ₃)NO ₂	287.15	yel. mn.	1.57 ¹⁰	130.5	expl.	i.	s. h.	s.
Theobromine	C ₇ H ₈ O ₂ N ₄	180.17	rhb.		330		0.06 ¹⁵	0.06 c.	0.03 h.
Thio-acetic acid	CH ₃ CO—SH	76.11	yel. lq.	1.074 ¹⁰	<-17	93	s.	∞	∞
-aniline (4-, 4'-)	(NH ₂) ₂ C ₆ H ₄) ₂ S	216.29	nd./aq.		108		sl. s. h.	s.	s.
-carbanilide	(C ₆ H ₅ NH) ₂ CS	228.30	rhb./al.	1.3 ²⁴	154	d.	i.	v. s.	v. s.
-naphthol (β-)	C ₁₀ H ₇ —SH	160.22	cr./al.		81	286.8	v. sl. s.	v. s.	v. s.
-phenol	C ₆ H ₅ —SH	110.17	col. lq.	1.074 ^{23/4}		168.9	v. sl. s.	v. s.	∞
-salicylic acid (o-)	HS—C ₆ H ₄ CO ₂ H	154.18	yel. nd.		164	subl.	sl. s. h.	s.	
-urea	NH ₂ —CS—NH ₂	76.12	rhb./al.	1.405 ^{20/4}	180.2	d.	9.2 ¹³	s.	sl. s.
Thiophene	<(CH ₂ CH ₂) ₂ >S	84.13	col. lq.	1.070 ^{15/4}	-30	84	i.	s.	
Thymol (5-,2-,1-)	(CH ₃) ₂ C ₆ H ₇ —C ₆ H ₅ OH	150.21	cr.	0.972 ^{25/25}	51.5	232 ⁷⁵²	0.09 ¹⁹	v. s.	v. s.
Tofidime (0-)(3-,3'-,4-,4')	[CH ₃ (NH ₂) ₂ C ₆ H ₃] ₂	212.28	lf.		128.9		v. sl. s.	s.	∞
Toluene	C ₆ H ₅ —CH ₃	92.13	col. lq.	0.866 ^{20/4}	-95	110.8	0.05 ¹⁶	s.	
sulfonic acid (o-)	CH ₃ —C ₆ H ₄ SO ₃ H—2H ₂ O	208.23	cr.		d.	128.8 ^o	v. s.	s.	
(p-)	CH ₃ —C ₆ H ₄ SO ₃ H—H ₂ O	190.21	mn.		104.5	146.7 ^o	v. s.	s.	
sulfonic amide (p-)	CH ₃ —C ₆ H ₄ SO ₂ NH ₂	171.21	mn.		137		0.2 ⁹	7.4 ⁵	
Toluic acid (o-)	CH ₃ —C ₆ H ₄ —SO ₂ Cl	190.64	tri.		69	134.5 ¹⁰	i.	s.	s.
(m-)	CH ₃ —C ₆ H ₄ —CO ₂ H	136.14	cr./aq.	1.062 ^{115/4}	104.5	259 ⁵¹	2.17 ¹⁰⁰	v. s.	
(p-)	CH ₃ —C ₆ H ₄ —CO ₂ H	136.14	pr./aq.	1.054 ^{112/4}	110.1	263	1.6 ¹⁰⁰	v. s.	v. s.
Toluidine (o-)	CH ₃ —C ₆ H ₄ —NH ₂	107.15	col. lq.	0.999 ^{20/4}	-16.3	199.7	1.5 ²⁵	∞	∞
(m-)	CH ₃ —C ₆ H ₄ —NH ₂	107.15	col. lq.	0.989 ^{20/4}	-31.5	203.3	sl. s.	∞	∞
(p-)	CH ₃ —C ₆ H ₄ —NH ₂	107.15	cr.	1.046 ^{20/4}	44.5	200.3	0.74 ²¹	v. s.	v. s.
hydrochloride (o-)	CH ₃ —C ₆ H ₄ —NH ₃ Cl	143.62	mn. pr.		218-20	242	s.	sl. s.	
sulfonic acid (1-,2-,3-)	CH ₃ (NH ₂) ₂ C ₆ H ₃ SO ₃ H	187.21	cr.				0.97 ¹¹		
Tolylenediamine (1-,2-,4-)	CH ₃ —C ₆ H ₄ (NH ₂) ₂	122.17	rhb.		99	283.5	s. h.	s.	s.
Tolylene diisocyanate (1-,2-,4-)	CH ₃ —C ₆ H ₄ (NCO) ₂	174.15	lq.	1.23 ²⁸		134.5 ²⁰	d.	d.	sl. s. h.
Trehalose	C ₁₂ H ₂₂ O ₁₁ ·2H ₂ O	378.33	rhb./al.		97		s. h.		i.
Triamylamine (n-)	[CH ₃ (CH ₂) ₂ CH ₂] ₃ N	227.42	lq.			240.5	i.		
(i-)	[CH ₃ (CH ₂) ₂ CH(CH ₂) ₂] ₃ N	227.42	col. lq.	0.786 ^{20/4}		235	i.	s.	∞
Tributyl-amine (n-)	[CH ₃ (CH ₂) ₂ CH ₂] ₃ N	185.34	col. lq.	0.778 ^{20/20}		216.5 ⁷⁶¹	i.		
phosphite	[CH ₃ (CH ₂) ₂ O] ₃ P	250.32	lq.	0.925 ^{20/4}		122.3 ¹²	i.		
Trichloro-acetic acid	Cl ₃ C—CO ₂ H	163.40	cr.	1.617 ^{46/15}	58	195.5 ⁷⁴	120 ²⁵	s.	s.
-benzene (s-)(1-,3-,5-)	C ₆ H ₅ Cl ₃	181.46	nd.		63.5	208.5 ⁷⁶⁴	sl. s.		
-ethane (1-,1-,1-)	Cl ₃ C—CH ₃	133.42	lq.	1.325 ^{26/4}		74.1	i.	∞	∞
-ethylene	Cl ₃ C—CHCl	131.40	col. lq.	1.466 ^{20/20}	-73	87.2	0.1 ²⁵	∞	∞
-phenol	Cl ₃ C—H ₂ O	197.46	nd.	1.490 ^{75/4}	68.9	246	0.09 ²⁵	v. s.	v. s.
Tricosane (n-)	CH ₃ (CH ₂) ₂₀ CH ₃	324.61	lf.	0.779 ^{48/4}	47.7	234 ¹⁵	i.		
Tricosyl phosphate (o-)	OP(OC ₆ H ₅ CH ₃) ₃	368.36	lq.						
Tridecane (n-)	CH ₃ (CH ₂) ₁₁ CH ₃	184.35	col. lq.	0.757 ^{20/4}	-6.2	234	i.	v. s.	v. s.
Triethanol amine	(HOCH ₂ CH ₂) ₃ N	149.19	col. lq.	1.126 ^{20/20}	20.1	277.9 ¹⁵⁰	∞	sl. s.	
Triethyl-amine	(CH ₃ CH ₂) ₃ N	101.19	col. oil	0.729 ^{20/20}	-114.8	89.4	∞ > 19 ⁰	∞	
-benzene (1-,3-,5-)	(C ₆ H ₅) ₃ C ₆ H ₃	162.26	lq.	0.861 ^{20/4}		215	i.	s.	s.
(1-,2-,4-)	(C ₆ H ₅) ₃ C ₆ H ₃	162.26	lq.	0.882 ^{17/4}		217.8 ⁷⁵⁵	i.	s.	s.
borate	B(OCH ₃ CH ₃) ₃	146.00	lq.	0.864 ^{20/20}		120	d.		
citrate	HO ₃ C ₆ H ₅ (CO ₂ C ₂ H ₅) ₃	276.28	oil	1.137 ^{20/4}		294	i.	∞	∞
Triethylene glycol	(—CH ₂ OCH ₂ CH ₂ OH) ₂	150.17	col. lq.	1.125 ^{20/20}	-5	290	∞	∞	v. sl. s.
Trifluoro-chloromethane	CF ₃ Cl	104.47	gas	1.726 ¹³⁰	-182	-80			
chloroethylene	F ₂ C=CFCl	116.48	gas		-157.5	-27.9	d.		
-trichloroethane	Cl ₃ C—CClF ₂	187.39	lq.	1.576 ^{20/4}	-35	47.6	i.	∞	∞
Trimethoxybutane (1-,3-,3-)	CH ₂ (OCH ₃) ₂ CH ₂ C(OCH ₃) ₂ CH ₃	148.20	lq.	0.932		63.5 ²⁵	d.		
Trimethylamine	(CH ₃) ₃ N	59.11	gas	0.662 ⁻⁵	-124	3.5	41 ¹⁹	s.	s.
Trimethylene bromide	BrCH ₂ CH ₂ CH ₂ Br	201.91	lq.	1.987 ^{15/4}	-34.4	167.5	0.17 ²⁰	s.	s.
chloride	ClCH ₂ CH ₂ CH ₂ Cl	112.99	lq.	1.201 ¹⁵		123.5	0.27 ²⁵	s.	s.
glycol	HOCH ₂ CH ₂ CH ₂ OH	76.09	oil	1.060 ^{20/4}		214	∞	∞	
Trinitro-benzene (1-,3-,5-)	C ₆ H ₃ (NO ₂) ₃	213.11	col. rhb.	1.688 ^{20/4}	121	d.	0.03 ¹⁵	1.9 ¹⁸	1.5 ¹⁸
-benzoic acid (2-,4-,6-)	(NO ₂) ₂ C ₆ H ₃ CO ₂ H	257.12	rhb./aq.		210-20 d.		2.05 ²⁴		
-tert-butylxylene	(NO ₂) ₂ C ₆ H ₃ C ₄ H ₉	297.26	nd./al.		110	i.	sl. s.	s.	
-naphthalene (α-)(1-,3-,5-)	C ₁₀ H ₈ (NO ₂) ₃	263.16	rhb.		122-3	i.	0.05 ²³	0.13 ¹⁵	0.11 ¹⁹
(β-)(1-,3-,8-)	C ₁₀ H ₇ (NO ₂) ₃	263.16	cr./al.		218-9	0.02 ¹⁰⁰	i.		0.4 ¹⁹
(γ-)(1-,4-,5-)	C ₁₀ H ₅ (NO ₂) ₃	263.16	yel. cr.		148-9				

-phenol (2-,3-,6-)	$(NO_2)_3C_6H_5OH$	229.11	nd.	117-8	s. h.	v. s.	v. s.
-toluene (β)-(2-,3-,4-)	$CH_3C_6H_5(NO_2)_3$	227.13	cr.	1,620 ^{20/4}	112	expl.	i.
(γ)-(2-,4-,5-)	$CH_3C_6H_5(NO_2)_3$	227.13	yel. pl.	1,620 ^{20/4}	104	expl.	sl. s. c.
(α)-(2-,4-,6-)	$CH_3C_6H_5(NO_2)_3$	227.13	cr./al.	1,654	80.8	expl.	s. h.
Trional	$C_6H_5(CH_3)C(SO_2C_2H_5)_3$	242.34	pl./al.	1,199 ^{85/4}	76	d.	v. s.
Triphenyl-arsine	$(C_6H_5)_3As$	306.21	pl.	1,306	59-60	>360	5 ⁹³
carbinol	$(C_6H_5)_3COH$	260.32	cr.	1,188 ^{20/4}	162.5	>360	5 ²²
guanidine (α -)	$C_6H_5N:C(NHC_6H_5)_2$	287.35	rhb./al.	1.13	144-5	d.	5 ⁰
methane	$(C_6H_5)_3CH$	244.32	er.	1,014 ^{99/4}	93.4	359 ^{75/4}	6.6 ¹⁵
methyl	$(C_6H_5)_3C...$	243.31	col. cr.		145-7	d.	v. s. h.
phosphate	$OP(OC_6H_5)_3$	326.28	pr./al.	1,206 ^{55/4}	49-50	245 ¹¹	v. s. h.
Tripropylamine (<i>n</i> -)	$(CH_3CH_2CH_2)_3N$	143.27	col. lq.	0.757 ^{20/4}	-93.5	156.5	v. s. h.
Undecane (<i>n</i> -)	$CH_3(CH_2)_9CH_3$	156.30	col. lq.	0.741 ^{20/4}	-25.6	194.5	v. s. h.
Urea	$H_2N-CO-NH_2$	60.06	col. pr.	1,335 ^{20/4}	132.7	d.	155 ²⁵
nitrate	$CO(NH_2)_2\cdot HNO_3$	123.07	col. mn.		152 d.	v. s. h.	v. s.
Uric acid	$C_5H_4O_3N_4$	168.11	cr.	1,893 ²⁰	d.	0.06 h.	i.
Valeric acid (<i>n</i> -)	$C_5H_8CH_2CH_2CO_2H$	102.13	col. lq.	0.939 ^{20/4}	-34.5	187	3.3 ¹⁶
(<i>i</i> -)	$(CH_3)_2CHCH_2CO_2H$	102.13	col. lq.	0.931 ^{20/20}	-37.6	176	4.2 ²⁰
aldehyde (<i>n</i> -)	$C_5H_5CH_2CH_2CHO$	86.13	lq.	0.819 ¹¹	-92	103.4	v. sl. s.
(<i>i</i> -)	$(CH_3)_2CHCH_2CHO$	86.13	col. lq.	0.803 ¹⁷	-51	92.5	sl. s.
amide (<i>n</i> -)	$C_5H_5CH_2CH_2CONH_2$	101.15	mn. pl.	1.023	106	v. s.	v. s.
(<i>i</i> -)	$(CH_3)_2CHCH_2CONH_2$	101.15	mn.	0.965 ^{20/4}	135-7	232	v. s.
Vanillic acid (3-,4-,1-)	$CH_3O(OH)C_6H_3CO_2H$	168.14	nd./aq.		207	subl.	0.12 ¹⁴
alcohol (3-,4-,1-)	$CH_3O(OH)C_6H_3CH_2OH$	154.16	mn./aq.		115	d.	v. s. h.
hyd-thiuram disulfide	$[(C_2H_5)_2NCS]_2S_2$	296.52	cr.	1.17	70	i.	v. s.
Vanillin (3-,4-,1-)	$CH_3O(OH)C_6H_3CHO$	152.14	mn.	1.056	81-2	285	1 ¹⁴
Veratrole (<i>o</i> -)	$C_6H_5(OCH_3)_3$	138.16	cr.	1,091 ^{15/15}	22.5	207.1	v. sl. s.
Vinyl acetate	$CH_3CO_2CH_2CH_2$	86.09	col. lq.	0.932 ^{20/4}	<-60	72-3	2 ²⁰
(poly-)	$(CH_3CO_2CH_2CH_2)_x$	(86.09)		1.19 ⁵⁰	100-25	i.	∞
acetic acid	$CH_3CO_2CH_2CO_2H$	86.09	col. lq.	1,013 ^{15/15}	-39	163	v. s.
acetylene	$CH_2=CH\cdot CH_2CO_2H$	52.07	gas	0.705 ^{1,5}	5.5	0.67 ^{0,6}	∞
alcohol	CH_3CHOH	44.06					
(poly-)	$(CH_2CHOH)_x$	(44.06)		1.3 ²⁰	d. >200	s.	
chloride	$CH_2ClCHCl$	62.50	gas	0.908 ^{25/25}	-160	-12	
propionate	$C_5H_9CO_2CH_2CH_2$	100.11	lq.		93.5	v. sl. s.	
Xylene (<i>o</i> -)	$C_6H_5(CH_3)_2$	106.16	col. lq.	0.881 ^{20/4}	-25	i.	∞
(<i>m</i> -)	$C_6H_4(CH_3)_2$	106.16	col. lq.	0.867 ^{17/4}	-47.4	139.3	v. s.
(<i>p</i> -)	$C_6H_4(CH_3)_2$	106.16	col. lq.	0.861 ^{20/4}	13.2	138.5	v. s.
sulfonic acid (1-,4-,2-)	$(CH_3)_2C_6H_3SO_3H \cdot 2H_2O$	222.25	col. lf.	86	149 ^{1,1}	s.	
Xyldine (1:2)(3-)	$(CH_3)_2C_6H_3NH_2$	121.18	lq.	0.991 ¹⁵	<-15	223	v. sl. s.
(1:2)(4-)	$(CH_3)_2C_6H_3NH_2$	121.18	pr.	1,076 ^{17,5}	49-50	224-6	v. sl. s.
(1:3)(2-)	$(CH_3)_2C_6H_3NH_2$	121.18	lq.	0.980 ¹⁵		216-7	v. sl. s.
(1:3)(4-)	$(CH_3)_2C_6H_3NH_2$	121.18	lq.	0.978 ^{20/4}		213-4	v. sl. s.
(1:3)(5-)	$(CH_3)_2C_6H_3NH_2$	121.18	oil	0.979 ^{20/4}		221-2	v. sl. s.
(1:4)(2-)	$(CH_3)_2C_6H_3NH_2$	121.18	oil	0.979 ^{21/4}	15.5	215 ⁷⁸⁹	v. sl. s.
Xylose (<i>I</i>)(+)	$CH_3OH(CHOH)_3CHO$	150.13	nd.	1,535 ⁰	153-4	117 ²⁰	v. sl. s.
Xylylene dichloride (<i>p</i> -)	$C_6H_4(CH_2Cl)_2$	175.06	mn.	1,417 ⁰	100.5	240-5 d.	i.
Zinc diethyl	$Zn(CH_3CH_3)_2$	123.50	col. lq.	1,182 ¹⁸	-28	118	d.
dimethyl	$Zn(CH_3)_2$	95.45	col. lq.	1,386 ¹¹	-40	46	d.
dimethyl-dithiocarbamate	$Zn[S_2CN(CH_3)_2]$	305.79		2,00 ^{0/4}	248-50	i.	

NOTE: °F = % °C + 32.

VAPOR PRESSURES OF PURE SUBSTANCES

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$^{\circ}\text{F} = \% \text{ } ^{\circ}\text{C} + 32.$$

To convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

ADDITIONAL REFERENCES

Additional compilations of vapor-pressure data include Boublík, Fried, and Hala, *The Vapor Pressures of Pure Substances*, Elsevier, Amsterdam, 1984. See also Hirata, Ohe, and Nagahama, *Computer Aided Data Book of Vapor-Liquid Equilibria*, Kodansha/Elsevier, Tokyo, 1975; Weishaupt, *Landolt-Börnstein New Series Group IV*, vol. 3; *Thermodynamic Equilibria of Boiling Mixtures*, Springer-Verlag, Berlin, 1975; Wichterle, Linek, and Hala, *Vapor-Liquid Equilibrium Data Bibliography*, Elsevier, Amsterdam, 1973; suppl. 1, 1976; suppl. 2, 1982.

TABLE 2-3 Vapor Pressure of Water Ice from -15 to 0°C *
mmHg

$t, ^{\circ}\text{C}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
-14	1.361	1.348	1.336	1.324	1.312	1.300	1.288	1.276	1.264	1.253
-13	1.490	1.477	1.464	1.450	1.437	1.424	1.411	1.399	1.386	1.373
-12	1.632	1.617	1.602	1.588	1.574	1.559	1.546	1.532	1.518	1.504
-11	1.785	1.769	1.753	1.737	1.722	1.707	1.691	1.676	1.661	1.646
-10	1.950	1.934	1.916	1.899	1.883	1.866	1.849	1.833	1.817	1.800
-9	2.131	2.112	2.093	2.075	2.057	2.039	2.021	2.003	1.985	1.968
-8	2.326	2.306	2.285	2.266	2.246	2.226	2.207	2.187	2.168	2.149
-7	2.537	2.515	2.493	2.472	2.450	2.429	2.408	2.387	2.367	2.346
-6	2.765	2.742	2.718	2.695	2.672	2.649	2.626	2.603	2.581	2.559
-5	3.013	2.987	2.962	2.937	2.912	2.887	2.862	2.838	2.813	2.790
-4	3.280	3.252	3.225	3.198	3.171	3.144	3.117	3.091	3.065	3.039
-3	3.568	3.539	3.509	3.480	3.451	3.422	3.393	3.364	3.336	3.308
-2	3.880	3.848	3.816	3.785	3.753	3.722	3.691	3.660	3.630	3.599
-1	4.217	4.182	4.147	4.113	4.079	4.045	4.012	3.979	3.946	3.913
-0	4.579	4.542	4.504	4.467	4.431	4.395	4.359	4.323	4.287	4.252

*For data at 0(0.2)–30(2)–98°C see p. 2324, *Handbook of Chemistry and Physics*, 40th ed., Chemical Rubber Publishing Co.

TABLE 2-4 Vapor Pressure of Liquid Water from -16 to 0°C *
mmHg

$t, ^{\circ}\text{C}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
-15	1.436	1.425	1.414	1.402	1.390	1.379	1.368	1.356	1.345	1.334
-14	1.560	1.547	1.534	1.522	1.511	1.497	1.485	1.472	1.460	1.449
-13	1.691	1.678	1.665	1.651	1.637	1.624	1.611	1.599	1.585	1.572
-12	1.834	1.819	1.804	1.790	1.776	1.761	1.748	1.734	1.720	1.705
-11	1.987	1.971	1.955	1.939	1.924	1.909	1.893	1.878	1.863	1.848
-10	2.149	2.134	2.116	2.099	2.084	2.067	2.050	2.034	2.018	2.001
-9	2.326	2.307	2.289	2.271	2.254	2.236	2.219	2.201	2.184	2.167
-8	2.514	2.495	2.475	2.456	2.437	2.418	2.399	2.380	2.362	2.343
-7	2.715	2.695	2.674	2.654	2.633	2.613	2.593	2.572	2.553	2.533
-6	2.931	2.909	2.887	2.866	2.843	2.822	2.800	2.778	2.757	2.736
-5	3.163	3.139	3.115	3.092	3.069	3.046	3.022	3.000	2.976	2.955
-4	3.410	3.384	3.359	3.334	3.309	3.284	3.259	3.235	3.211	3.187
-3	3.673	3.647	3.620	3.593	3.567	3.540	3.514	3.487	3.461	3.436
-2	3.956	3.927	3.898	3.871	3.841	3.813	3.785	3.757	3.730	3.702
-1	4.258	4.227	4.196	4.165	4.135	4.105	4.075	4.045	4.016	3.986
-0	4.579	4.546	4.513	4.480	4.448	4.416	4.385	4.353	4.320	4.289

*Computed from the above table with the aid of the thermodynamic equation

$$\log_{10} \frac{P_w}{P_i} = \frac{-1.1489t}{273.1+t} - 1.330 \times 10^{-5}t^2 + 9.084 \times 10^{-8}t^3$$

TABLE 2-5 Vapor Pressure of Liquid Water from 0 to 100°C*
mmHg

<i>t</i> , °C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	4.579	4.613	4.647	4.681	4.715	4.750	4.785	4.820	4.855	4.890
1	4.926	4.962	4.998	5.034	5.070	5.107	5.144	5.181	5.219	5.256
2	5.294	5.332	5.370	5.408	5.447	5.486	5.525	5.565	5.605	5.645
3	5.685	5.725	5.766	5.807	5.848	5.889	5.931	5.973	6.015	6.058
4	6.101	6.144	6.187	6.230	6.274	6.318	6.363	6.408	6.453	6.498
5	6.543	6.589	6.635	6.681	6.728	6.775	6.822	6.869	6.917	6.965
6	7.013	7.062	7.111	7.160	7.209	7.259	7.309	7.360	7.411	7.462
7	7.513	7.565	7.617	7.669	7.722	7.775	7.828	7.882	7.936	7.990
8	8.045	8.100	8.155	8.211	8.267	8.323	8.380	8.437	8.494	8.551
9	8.609	8.668	8.727	8.786	8.845	8.905	8.965	9.025	9.086	9.147
10	9.209	9.271	9.333	9.395	9.458	9.521	9.585	9.649	9.714	9.779
11	9.844	9.910	9.976	10.042	10.109	10.176	10.244	10.312	10.380	10.449
12	10.518	10.588	10.658	10.728	10.799	10.870	10.941	11.013	11.085	11.158
13	11.231	11.305	11.379	11.453	11.528	11.604	11.680	11.756	11.833	11.910
14	11.987	12.065	12.144	12.223	12.302	12.382	12.462	12.543	12.624	12.706
15	12.788	12.870	12.953	13.037	13.121	13.205	13.290	13.375	13.461	13.547
16	13.634	13.721	13.809	13.898	13.987	14.076	14.166	14.256	14.347	14.438
17	14.530	14.622	14.715	14.809	14.903	14.997	15.092	15.188	15.284	15.380
18	15.477	15.575	15.673	15.772	15.871	15.971	16.071	16.171	16.272	16.374
19	16.477	16.581	16.685	16.789	16.894	16.999	17.105	17.212	17.319	17.427
20	17.535	17.644	17.753	17.863	17.974	18.085	18.197	18.309	18.422	18.536
21	18.650	18.765	18.880	18.996	19.113	19.231	19.349	19.468	19.587	19.707
22	19.827	19.948	20.070	20.193	20.316	20.440	20.565	20.690	20.815	20.941
23	21.068	21.196	21.324	21.453	21.583	21.714	21.845	21.977	22.110	22.243
24	22.377	22.512	22.648	22.785	22.922	23.060	23.198	23.337	23.476	23.616
25	23.756	23.897	24.039	24.182	24.326	24.471	24.617	24.764	24.912	25.060
26	25.209	25.359	25.509	25.660	25.812	25.964	26.117	26.271	26.426	26.582
27	26.739	26.897	27.055	27.214	27.374	27.535	27.696	27.858	28.021	28.185
28	28.349	28.514	28.680	28.847	29.015	29.184	29.354	29.525	29.697	29.870
29	30.043	30.217	30.392	30.568	30.745	30.923	31.102	31.281	31.461	31.642
30	31.824	32.007	32.191	32.376	32.561	32.747	32.934	33.122	33.312	33.503
31	33.695	33.888	34.082	34.276	34.471	34.667	34.864	35.062	35.261	35.462
32	35.663	35.865	36.068	36.272	36.477	36.683	36.891	37.099	37.308	37.518
33	37.729	37.942	38.155	38.369	38.584	38.801	39.018	39.237	39.457	39.677
34	39.898	40.121	40.344	40.569	40.796	41.023	41.251	41.480	41.710	41.942
35	42.175	42.409	42.644	42.880	43.117	43.355	43.595	43.836	44.078	44.320
36	44.563	44.808	45.054	45.301	45.549	45.799	46.050	46.302	46.556	46.811
37	47.067	47.324	47.582	47.841	48.102	48.364	48.627	48.891	49.157	49.424
38	49.692	49.961	50.231	50.502	50.774	51.048	51.323	51.600	51.879	52.160
39	52.442	52.725	53.009	53.294	53.580	53.867	54.156	54.446	54.737	55.030
40	55.324	55.61	55.91	56.21	56.51	56.81	57.11	57.41	57.72	58.03
41	58.34	58.65	58.96	59.27	59.58	59.90	60.22	60.54	60.86	61.18
42	61.50	61.82	62.14	62.47	62.80	63.13	63.46	63.79	64.12	64.46
43	64.80	65.14	65.48	65.82	66.16	66.51	66.86	67.21	67.56	67.91
44	68.26	68.61	68.97	69.33	69.69	70.05	70.41	70.77	71.14	71.51
45	71.88	72.25	72.62	72.99	73.36	73.74	74.12	74.50	74.88	75.26
46	75.65	76.04	76.43	76.82	77.21	77.60	78.00	78.40	78.80	79.20
47	79.60	80.00	80.41	80.82	81.23	81.64	82.05	82.46	82.87	83.29
48	83.71	84.13	84.56	84.99	85.42	85.85	86.28	86.71	87.14	87.58
49	88.02	88.46	88.90	89.34	89.79	90.24	90.69	91.14	91.59	92.05

<i>t</i> , °C	0	1	2	3	4	5	6	7	8	9
50	92.51	97.20	102.09	107.20	112.51	118.04	123.80	129.82	136.08	142.60
60	149.38	156.43	163.77	171.38	179.31	187.54	196.09	204.96	214.17	223.73
70	233.7	243.9	254.6	265.7	277.2	289.1	301.4	314.1	327.3	341.0
80	355.1	369.7	384.9	400.6	416.8	433.6	450.9	468.7	487.1	506.1
90	525.76	527.76	529.77	531.78	533.80	535.82	537.86	539.90	541.95	544.00
91	546.05	548.11	550.18	552.26	554.35	556.44	558.53	560.64	562.75	564.87
92	566.99	569.12	571.26	573.40	575.55	577.71	579.87	582.04	584.22	586.41
93	588.60	590.80	593.00	595.21	597.43	599.66	601.89	604.13	606.38	608.64
94	610.90	613.17	615.44	617.72	620.01	622.31	624.61	626.92	629.24	631.57
95	633.90	636.24	638.59	640.94	643.30	645.67	648.05	650.43	652.82	655.22
96	657.62	660.03	662.45	664.88	667.31	669.75	672.20	674.66	677.12	679.69
97	682.07	684.55	687.04	689.54	692.05	694.57	697.10	699.63	702.17	704.71
98	707.27	709.83	712.40	714.98	717.56	720.15	722.75	725.36	727.98	730.61
99	733.24	735.88	738.53	741.18	743.85	746.52	749.20	751.89	754.58	757.29
100	760.00	762.72	765.45	768.19	770.93	773.68	776.44	779.22	782.00	784.78
101	787.57	790.37	793.18	796.00	796.82	801.66	804.50	807.35	810.21	813.06

*From the Physikalisch-technische Reichsanstalt, Holborn, Scheel, and Henning, *Wärmetabellen*, Friedrich Vieweg & Sohn, Brunswick, 1909. By permission. For data at 50(0.2)101.8°C, see *Handbook of Chemistry and Physics*, 40th ed., p. 2326, Chemical Rubber Publishing Co. For a tabulation of temperature for pressures 700(1)779 mm Hg, see Atack, *Handbook of Chemical Data*, p. 117, Reinhold, New York, 1957. For a tabulation of pressure for 105(5)200(10)370°C, see Atack, p. 134, and for 100(1)374°C, see *Handbook of Chemistry and Physics*, 40th ed., pp. 2328-2330, Chemical Rubber Publishing Co.

TABLE 2-6 Vapor Pressure of Inorganic and Organic Liquids

Cmpd. no.	Name	Formula	CAS no.	C1	C2	C3	C4	C5	T _{min} , K	P _s at T _{min}	T _{max} , K	P _s at T _{max}
1	Methane	CH ₄	74828	39.205	-1324.4	-3.4366	3.1019E-05	2	90.69	1.1687E+04	190.56	4.5897E+06
2	Ethane	C ₂ H ₆	74840	51.857	-2598.7	-5.1283	1.4913E-05	2	90.35	1.1273E+00	305.32	4.8522E+06
3	Propane	C ₃ H ₈	74986	59.078	-3492.6	-6.0669	1.0919E-05	2	85.47	1.6788E-04	369.83	4.2135E+06
4	n-Butane	C ₄ H ₁₀	106978	66.343	-4363.2	-7.046	9.4509E-06	2	134.86	6.7441E-01	425.12	3.7699E+06
5	n-Pentane	C ₅ H ₁₂	109660	78.741	-5420.3	-8.8253	9.6171E-06	2	143.42	6.8642E-02	469.7	3.3642E+06
6	n-Hexane	C ₆ H ₁₄	110543	104.65	-6995.5	-12.702	1.2381E-05	2	177.83	9.0169E-01	507.6	3.0449E+06
7	n-Heptane	C ₇ H ₁₆	142825	87.829	-6994.6	-9.8802	7.2099E-06	2	182.57	1.8269E-01	540.2	2.7192E+06
8	n-Octane	C ₈ H ₁₈	111659	96.084	-7900.2	-11.003	7.1802E-06	2	216.38	2.1083E+00	568.7	2.4673E+06
9	n-Nonane	C ₉ H ₂₀	111842	109.35	-9030.4	-12.882	7.8544E-06	2	219.66	4.3055E-01	594.6	2.3054E+06
10	n-Decane	C ₁₀ H ₂₂	124185	112.73	-9749.6	-13.245	7.1266E-06	2	243.51	1.3930E+00	617.7	2.0908E+06
11	n-Undecane	C ₁₁ H ₂₄	1120214	131	-11143	-15.855	8.1871E-06	2	247.57	4.0836E-01	639	1.9493E+06
12	n-Dodecane	C ₁₂ H ₂₆	112403	137.47	-11976	-16.698	8.0906E-06	2	263.57	6.1534E-01	658	1.8223E+06
13	n-Tridecane	C ₁₃ H ₂₈	629505	137.45	-12549	-16.543	7.1275E-06	2	267.76	2.5096E-01	675	1.6786E+06
14	n-Tetradecane	C ₁₄ H ₃₀	629594	140.47	-13231	-16.859	6.5877E-06	2	279.01	2.5265E-01	693	1.5693E+06
15	n-Pentadecane	C ₁₅ H ₃₂	629629	135.57	-13478	-16.022	5.6136E-06	2	283.07	1.2884E-01	708	1.4743E+06
16	n-Hexadecane	C ₁₆ H ₃₄	544763	156.06	-15015	-18.941	6.8172E-06	2	291.31	9.2265E-02	723	1.4106E+06
17	n-Heptadecane	C ₁₇ H ₃₆	629787	156.95	-15557	-18.966	6.4559E-06	2	295.13	4.6534E-02	736	1.3438E+06
18	n-Octadecane	C ₁₈ H ₃₈	593453	157.68	-16093	-18.954	5.9272E-06	2	301.31	3.3909E-02	747	1.2555E+06
19	n-Nonadecane	C ₁₉ H ₄₀	629925	182.54	-17897	-22.498	7.4008E-06	2	305.04	1.5909E-02	758	1.2078E+06
20	n-Eicosane	C ₂₀ H ₄₂	112958	203.66	-19441	-25.525	8.8382E-06	2	309.58	9.2574E-03	768	1.1746E+06
21	2-Methylpropane	C ₄ H ₁₀	75285	100.18	-4841.9	-13.541	2.0063E-02	1	113.54	1.4051E-02	408.14	3.6199E+06
22	2-Methylbutane	C ₅ H ₁₂	78784	72.35	-5010.9	-7.883	8.9795E-06	2	113.25	1.1569E-04	460.43	3.3709E+06
23	2,3-Dimethylbutane	C ₆ H ₁₄	79298	77.235	-5695.9	-8.5109	8.0163E-06	2	145.19	1.5081E-02	499.98	3.1255E+06
24	2-Methylpentane	C ₆ H ₁₄	107835	77.36	-5791.7	-8.4912	7.7939E-06	2	119.55	9.2204E-06	497.5	3.0192E+06
25	2,3-Dimethylpentane	C ₇ H ₁₆	565593	78.282	-6347	-8.502	6.4169E-06	2	160	1.2631E-02	537.35	2.8823E+06
26	2,3,3-Trimethylpentane	C ₈ H ₁₈	560214	83.105	-6903.7	-9.1858	6.4703E-06	2	172.22	1.6820E-02	573.5	2.8116E+06
27	2,2,4-Trimethylpentane	C ₈ H ₁₈	540841	87.868	-6831.7	-9.9783	7.7729E-06	2	165.78	1.6187E-02	543.96	2.5630E+06
28	Ethylene	C ₂ H ₄	74851	74.242	-2707.2	-9.8462	2.2457E-02	1	104	1.2361E+02	282.34	5.0296E+06
29	Propylene	C ₃ H ₆	115071	57.263	-3382.4	-5.7707	1.0431E-05	2	87.89	9.3867E-04	365.57	4.6346E+06
30	1-Butene	C ₄ H ₈	106989	68.49	-4350.2	-7.4124	1.0503E-05	2	87.8	7.1809E-07	419.95	4.0391E+06
31	cis-2-Butene	C ₄ H ₈	590181	102.62	-5260.3	-13.764	1.9183E-02	1	134.26	2.4051E-01	435.58	4.2388E+06
32	trans-2-Butene	C ₄ H ₈	624646	70.589	-4530.4	-7.7229	1.0928E-05	2	167.62	7.4729E+01	428.63	4.0811E+06
33	1-Pentene	C ₅ H ₁₀	109671	120.15	-6192.4	-16.597	2.1922E-02	1	107.93	3.5210E-06	464.78	3.5557E+06
34	1-Hexene	C ₆ H ₁₂	592416	85.3	-6171.7	-9.702	8.9604E-06	2	133.39	2.5272E-04	504.03	3.1397E+06
35	1-Heptene	C ₇ H ₁₄	592767	92.68	-7055.2	-10.679	8.4459E-06	2	154.27	1.2810E-03	537.29	2.8225E+06
36	1-Octene	C ₈ H ₁₆	111660	97.57	-7836	-11.272	7.7267E-06	2	171.45	2.7570E-03	566.65	2.5735E+06
37	1-Nonene	C ₉ H ₁₈	124118	144.45	-9676.2	-19.446	1.8031E-02	1	191.78	8.5514E-03	593.25	2.3308E+06
38	1-Decene	C ₁₀ H ₂₀	872059	78.808	-8367.9	-7.9553	8.7744E-18	6	206.89	1.7305E-02	616.4	2.2092E+06
39	2-Methylpropene	C ₄ H ₈	115117	102.5	-5021.8	-13.88	2.0296E-02	1	132.81	6.2213E-01	417.9	3.9760E+06
40	2-Methyl-1-butene	C ₅ H ₁₀	563462	97.33	-5631.8	-12.589	1.5395E-02	1	135.58	1.9687E-02	465	3.4544E+06
41	2-Methyl-2-butene	C ₅ H ₁₀	513359	82.605	-5606.6	-9.4236	1.0512E-05	2	139.39	1.9447E-02	471	3.3769E+06
42	1,2-Butadiene	C ₄ H ₆	590192	39.714	-3769.9	-2.6407	6.9379E-18	6	136.95	4.4720E-01	452	4.3613E+06
43	1,3-Butadiene	C ₄ H ₆	106990	73.522	-4564.3	-8.1958	1.1580E-05	2	164.25	6.9110E+01	425.17	4.3041E+06
44	2-Methyl-1,3-butadiene	C ₅ H ₈	78795	79.656	-5239.6	-9.4314	9.5850E-03	1	127.27	2.4768E-03	484	3.8509E+06
45	Acetylene	C ₂ H ₂	74862	172.06	-5318.5	-27.223	5.4619E-02	1	192.4	1.2603E+05	308.32	6.1467E+06
46	Methylacetylene	C ₃ H ₄	74997	119.42	-5364.5	-16.81	2.5523E-02	1	170.45	3.7264E+02	402.39	5.6206E+06
47	Dimethylacetylene	C ₄ H ₆	503173	66.592	-4999.8	-6.8387	6.6793E-06	2	240.91	6.1212E+03	473.2	4.8699E+06
48	3-Methyl-1-butyne	C ₅ H ₈	598232	69.459	-5250	-7.1125	7.9289E-17	6	183.45	4.3551E+01	463.2	4.1986E+06
49	1-Pentyne	C ₅ H ₈	627190	82.805	-5683.8	-9.4301	1.0767E-05	2	167.45	2.3990E+00	481.2	4.1701E+06
50	2-Pentyne	C ₅ H ₈	627214	137.29	-7447.1	-19.01	2.1415E-02	1	163.83	2.0462E-01	519	4.0198E+06
51	1-Hexyne	C ₆ H ₁₀	693027	133.2	-7492.9	-18.405	2.2062E-02	1	141.25	3.9157E-04	516.2	3.6352E+06
52	2-Hexyne	C ₆ H ₁₀	764352	123.71	-7639	-16.451	1.6495E-02	1	183.65	5.4026E-01	549	3.5301E+06
53	3-Hexyne	C ₆ H ₁₀	928494	47.091	-5104	-3.6371	5.1621E-04	1	170.05	2.1950E-01	544	3.5397E+06
54	1-Heptyne	C ₇ H ₁₂	628717	66.447	-6395.6	-6.35848	1.1250E-17	6	192.22	6.7026E-01	559	3.1343E+06
55	1-Octyne	C ₈ H ₁₄	629050	82.353	-7240.6	-9.1843	5.8038E-03	1	193.55	1.0092E-01	585	2.8202E+06
56	Vinylacetylene ¹	C ₄ H ₄	689974	55.682	-4439.3	-5.0136	1.9650E-17	6	173.15	6.6899E+01	454	4.8874E+06

57	Cyclopentane	C ₅ H ₁₀	287923	51.434	-4770.6	-4.3515	1.9605E-17	6	179.28	9.4420E+00	511.76	4.502SE+06
58	Methylcyclopentane	C ₆ H ₁₂	96377	79.673	-6086.6	-8.7933	7.4046E-06	2	130.73	6.7059E-05	532.79	3.7808E+06
59	Ethylcyclopentane	C ₇ H ₁₄	1640897	88.622	-7011	-10.038	7.4481E-06	2	134.71	3.7061E-06	569.52	3.3970E+06
60	Cyclohexane	C ₆ H ₁₂	110827	116.51	-7103.3	-15.49	1.6959E-02	1	279.69	5.3802E+03	553.58	4.0958E+06
61	Methylcyclohexane	C ₇ H ₁₄	108872	92.611	-7077.8	-10.684	8.1239E-06	2	146.58	1.5256E-04	572.19	3.4828E+06
62	1,1-Dimethylcyclohexane	C ₈ H ₁₆	590669	81.184	-6927	-8.8498	5.4580E-06	2	239.66	6.0584E+01	591.15	2.9387E+06
63	Ethylcyclohexane	C ₈ H ₁₆	1678917	80.208	-7203.2	-8.6023	4.5901E-06	2	161.84	3.5747E-04	609.15	3.0411E+06
64	Cyclopentene	C ₅ H ₈	142290	49.88	-4649.7	-4.1191	1.9564E-17	6	135.13	1.6884E-02	507	4.8062E+06
65	1-Methylcyclopentene	C ₆ H ₁₀	693890	52.732	-5286.9	-4.4509	1.0883E-17	6	146.62	3.9787E-03	542	4.1303E+06
66	Cyclohexene	C ₆ H ₁₀	110838	88.184	-6624.9	-10.059	8.2566E-06	2	169.67	1.0377E-01	560.4	4.3922E+06
67	Benzene	C ₆ H ₆	71432	83.918	-6517.7	-9.3453	7.1182E-06	2	278.68	4.7620E+03	562.16	4.8819E+06
68	Toluene	C ₇ H ₈	108883	80.877	-6902.4	-8.7761	5.8034E-06	2	178.18	4.2348E-02	591.8	4.1012E+06
69	<i>o</i> -Xylene	C ₈ H ₁₀	95476	90.356	-7948.7	-10.081	5.9756E-06	2	247.98	2.1968E+01	630.33	3.7424E+06
70	<i>m</i> -Xylene	C ₈ H ₁₀	108383	84.782	-7598.3	-9.2612	5.5445E-06	2	225.3	3.2099E+00	617.05	3.5286E+06
71	<i>p</i> -Xylene	C ₈ H ₁₀	106423	85.475	-7595.8	-9.378	5.6875E-06	2	286.41	5.8144E+02	616.23	3.4984E+06
72	Ethylbenzene	C ₈ H ₁₀	100414	88.09	-7688.3	-9.7708	5.8844E-06	2	178.15	4.0140E-03	617.2	3.5968E+06
73	Propylbenzene	C ₉ H ₁₂	103651	136.83	-9544.8	-18.190	1.6590E-02	1	324.18	2.0014E+03	638.32	3.2001E+06
74	1,2,4-Trimethylbenzene	C ₉ H ₁₂	95636	60.658	-7260.4	-5.3772	4.5816E-18	6	229.33	7.9735E-01	649.13	3.2533E+06
75	Isopropylbenzene	C ₉ H ₁₂	98828	143.62	-9687.7	-19.305	1.7703E-02	1	177.14	3.8034E-04	631.1	3.1837E+06
76	1,3,5-Trimethylbenzene	C ₉ H ₁₂	108678	48.603	-6545.2	-3.6412	1.9307E-18	6	228.42	1.1889E+00	637.36	3.1119E+06
77	<i>p</i> -Isopropyltoluene	C ₁₀ H ₁₄	99876	107.71	-9402.7	-12.545	6.6661E-06	2	205.25	9.9261E-03	653.15	2.7957E+06
78	Naphthalene	C ₁₀ H ₈	91203	62.447	-8109	-5.5571	2.0800E-18	6	353.43	9.9229E+02	748.35	3.9941E+06
79	Biphenyl	C ₁₂ H ₁₀	92524	76.811	-9878.5	-7.4384	2.0436E-18	6	342.2	9.3752E+01	789.26	3.8615E+06
80	Styrene	C ₈ H ₈	100425	105.93	-8685.9	-12.42	7.5583E-06	2	242.54	1.0613E+01	636	3.8234E+06
81	<i>m</i> -Terphenyl	C ₁₈ H ₁₄	92068	88.044	-13367	-8.6482	8.8784E-19	6	360	1.0112E+00	924.85	3.5297E+06
82	Methanol	CH ₄ O	67561	81.768	-6876	-8.7078	7.1926E-06	2	175.47	1.1147E-01	512.64	8.1402E+06
83	Ethanol	C ₂ H ₆ O	64175	74.475	-7164.3	-7.327	3.1340E-06	2	159.05	4.8459E-04	513.92	6.1171E+06
84	1-Propanol	C ₃ H ₈ O	71238	88.134	-8498.6	-9.0766	8.3303E-18	6	146.95	3.0828E-07	536.78	5.1214E+06
85	1-Butanol	C ₄ H ₁₀ O	71363	93.173	-9185.9	-9.7464	4.7796E-18	6	184.51	5.7220E-04	563.05	4.3392E+06
86	2-Butanol	C ₄ H ₁₀ O	78922	152.54	-11111	-19.025	1.0426E-05	2	158.45	1.1323E-06	536.05	4.2014E+06
87	2-Propanol	C ₃ H ₈ O	67630	76.964	-7623.8	-7.4924	5.9436E-18	6	185.28	3.6606E-02	508.3	4.7908E+06
88	2-Methyl-2-propanol	C ₄ H ₁₀ O	75650	172.31	-11590	-22.118	1.3709E-05	2	298.97	5.9356E+03	506.21	3.9910E+06
89	1-Pentanol	C ₅ H ₁₂ O	71410	168.96	-12659	-21.366	1.1591E-05	2	195.56	3.1816E-04	586.15	3.8657E+06
90	2-Methyl-1-butanol	C ₅ H ₁₂ O	137326	410.44	-20262	-62.366	6.3353E-02	1	203	3.7992E-04	565	3.8749E+06
91	3-Methyl-1-butanol	C ₅ H ₁₂ O	123513	107.02	-10237	-11.695	6.8003E-18	6	155.95	2.1036E-08	577.2	3.9013E+06
92	1-Hexanol	C ₆ H ₁₄ O	111273	117.31	-11239	-13.149	9.3676E-18	6	228.55	3.7401E-02	611.35	3.4557E+06
93	1-Heptanol	C ₇ H ₁₆ O	111706	160.08	-14095	-19.211	1.7043E-17	6	239.15	1.6990E-02	631.9	3.1810E+06
94	Cyclohexanol	C ₆ H ₁₂ O	108930	135.01	-12238	-15.702	1.0349E-17	6	296.6	7.9382E+01	650	4.2456E+06
95	Ethylene glycol	C ₂ H ₆ O ₂	107211	79.276	-10105	-7.521	7.3408E-19	6	260.15	2.4834E-01	719.7	7.7100E+06
96	1,2-Propylene glycol	C ₃ H ₈ O ₂	57556	212.8	-15420	-28.109	2.1564E-05	2	213.15	9.2894E-05	626	6.0413E+06
97	Phenol	C ₆ H ₆ O	108952	95.444	-10113	-10.09	6.7603E-18	6	314.06	1.8779E+02	694.25	6.0585E+06
98	<i>o</i> -Cresol	C ₇ H ₈ O	95487	210.88	-13928	-29.483	2.5182E-02	1	304.19	6.5326E+01	697.55	5.0583E+06
99	<i>m</i> -Cresol	C ₇ H ₈ O	108394	95.403	-10581	-10.004	4.3032E-18	6	285.39	5.8624E+00	705.85	4.5221E+06
100	<i>p</i> -Cresol	C ₇ H ₈ O	106445	118.53	-11957	-13.293	8.6988E-18	6	307.93	3.4466E+01	704.65	5.1507E+06
101	Dimethyl ether	C ₂ H ₆ O	115106	44.704	-3525.6	-3.4444	5.4574E-17	6	131.65	3.0496E+00	400.1	5.2735E+06
102	Methyl ethyl ether	C ₃ H ₈ O	540670	205.79	-9834.5	-28.739	3.5317E-05	2	160	5.3423E-01	437.8	4.4658E+06
103	Methyl <i>n</i> -propyl ether	C ₄ H ₁₀ O	557175	50.83	-4781.7	-4.1773	9.4076E-18	6	133.97	4.8875E-03	476.3	3.7721E+06
104	Methyl isopropyl ether	C ₄ H ₁₀ O	598538	55.096	-4793.2	-4.8689	2.9518E-17	6	127.93	2.4971E-03	464.5	3.8892E+06
105	Methyl <i>n</i> -butyl ether	C ₅ H ₁₂ O	628284	102.04	-6954.9	-12.278	1.2131E-05	2	157.48	1.9430E-02	510	3.3089E+06
106	Methyl isobutyl ether	C ₅ H ₁₂ O	625445	58.165	-5362.1	-5.2568	2.0194E-17	6	150	1.9801E-02	497	3.4130E+06
107	Methyl <i>tert</i> -butyl ether	C ₅ H ₁₂ O	1634044	55.875	-5131.6	-4.9604	1.9123E-17	6	164.55	5.3566E-01	497.1	3.4106E+06
108	Diethyl ether	C ₄ H ₁₀ O	60297	136.9	-6954.3	-19.254	2.4508E-02	1	156.85	3.9545E-01	466.7	3.6412E+06
109	Ethyl propyl ether	C ₅ H ₁₂ O	628320	143.11	-8353.7	-18.751	2.0620E-05	2	145.65	7.3931E-04	500.23	3.3729E+06
110	Ethyl isopropyl ether	C ₅ H ₁₂ O	625547	57.723	-5236.9	-5.2136	2.2998E-17	6	140	4.3092E-03	489	3.4145E+06
111	Methyl phenyl ether	C ₇ H ₈ O	100663	128.06	-9307.7	-16.693	1.4919E-02	1	235.65	2.4466E+00	645.6	4.2731E+06
112	Diphenyl ether	C ₁₂ H ₁₀ O	101848	59.969	-8585.5	-5.1538	1.9983E-18	6	300.03	7.0874E+00	766.8	3.0971E+06

TABLE 2-6 Vapor Pressure of Inorganic and Organic Liquids (Continued)

Cmpd. no.	Name	Formula	CAS no.	C1	C2	C3	C4	C5	T _{min} , K	P _s at T _{min}	T _{max} , K	P _s at T _{max}
113	Formaldehyde	CH ₂ O	50000	101.51	-4917.2	-13.765	2.2031E-02	1	181.15	8.8700E+02	408	6.5935E+06
114	Acetaldehyde	C ₂ H ₄ O	75070	193.69	-8036.7	-29.502	4.3678E-02	1	150.15	3.2320E-01	466	5.5652E+06
115	1-Propanal	C ₃ H ₆ O	123386	80.581	-5896.1	-8.9301	8.2236E-06	2	170	1.3133E+00	504.4	4.9189E+06
116	1-Butanal	C ₄ H ₈ O	123728	99.33	-7083.6	-11.733	1.0027E-05	2	176.75	3.1699E-01	537.2	4.3232E+06
117	1-Pentanal	C ₅ H ₁₀ O	110623	149.58	-8890	-20.697	2.2101E-02	1	182	5.2282E-02	566.1	3.9685E+06
118	1-Hexanal	C ₆ H ₁₂ O	66251	81.507	-7776.8	-8.4516	1.5143E-17	6	217.15	1.2473E+00	591	3.4607E+06
119	1-Heptanal	C ₇ H ₁₄ O	111717	107.17	-9070.3	-12.503	7.4446E-06	2	229.8	1.1177E+00	617	3.1829E+06
120	1-Octanal	C ₈ H ₁₆ O	124130	250.25	-16162	-33.927	2.2349E-05	2	246	4.1640E-01	638.1	2.9704E+06
121	1-Nonanal	C ₉ H ₁₈ O	124196	337.71	-18506	-50.224	4.7345E-02	1	255.15	3.4172E-01	658	2.7430E+06
122	1-Decanal	C ₁₀ H ₂₀ O	112312	201.64	-15133	-26.264	1.4625E-05	2	267.15	4.8648E-01	674.2	2.5989E+06
123	Acetone	C ₃ H ₆ O	67641	69.006	-5599.6	-7.0985	6.2237E-06	2	178.45	2.7851E+00	508.2	4.7091E+06
124	Methyl ethyl ketone	C ₄ H ₈ O	78933	72.698	-6143.6	-7.5779	5.6476E-06	2	186.48	1.3904E+00	535.5	4.1201E+06
125	2-Pentanone	C ₅ H ₁₀ O	107879	84.635	-7078.4	-9.3	6.2702E-06	2	196.29	7.5235E-01	561.08	3.7062E+06
126	Methyl isopropyl ketone	C ₅ H ₁₀ O	563804	308.74	-13693	-47.557	5.7002E-02	1	181.15	2.2648E-02	553	3.8413E+06
127	2-Hexanone	C ₆ H ₁₂ O	591786	65.841	-7042	-6.1376	7.2196E-18	6	217.35	1.5111E+00	587.05	3.3120E+06
128	Methyl isobutyl ketone	C ₆ H ₁₂ O	108101	153.23	-10055	-19.848	1.6426E-05	2	189.15	3.3536E-02	571.4	3.2659E+06
129	3-Methyl-2-pentanone	C ₆ H ₁₂ O	565617	64.641	-6457.4	-6.218	3.4543E-06	2	167.15	3.2662E-03	573	3.3213E+06
130	3-Pentanone	C ₅ H ₁₀ O	96220	44.286	-5415.1	-3.0913	1.8580E-18	6	234.18	7.3422E+01	560.95	3.6993E+06
131	Ethyl isopropyl ketone	C ₆ H ₁₂ O	565695	206.77	-12537	-27.894	2.2462E-05	2	200	6.0339E-02	567	3.3424E+06
132	Diisopropyl ketone	C ₇ H ₁₄ O	565800	96.919	-8014.2	-11.093	7.3452E-06	2	204.81	3.9036E-01	576	3.0606E+06
133	Cyclohexanone	C ₆ H ₁₀ O	108941	95.118	-8300.4	-10.796	6.5037E-06	2	242	6.9667E+00	653	4.0126E+06
134	Methyl phenyl ketone	C ₈ H ₈ O	98862	62.688	-8088.8	-5.5434	2.0774E-18	6	292.81	3.5899E+01	709.5	3.8451E+06
135	Formic acid	CH ₂ O ₂	64186	50.323	-5378.2	-4.203	3.4697E-06	2	281.45	2.4024E+03	588	5.8074E+06
136	Acetic acid	C ₂ H ₄ O ₂	64197	53.27	-6304.5	-4.2985	8.8865E-18	6	289.81	1.2769E+03	591.95	5.7390E+06
137	Propionic acid	C ₃ H ₆ O ₂	79094	54.552	-7149.4	-4.2769	1.1843E-18	6	252.45	1.3142E+01	600.81	4.6080E+06
138	n-Butyric acid	C ₄ H ₈ O ₂	107926	93.815	-9942.2	-9.8019	9.3124E-18	6	267.95	6.7754E+00	615.7	4.0705E+06
139	Isobutyric acid	C ₄ H ₈ O ₂	79312	110.38	-10540	-12.262	1.4310E-17	6	227.15	7.8244E-02	605	3.6834E+06
140	Benzoylic acid	C ₇ H ₆ O ₂	65850	88.513	-11529	-8.6826	2.3248E-19	6	395.45	7.9550E+02	751	4.4691E+06
141	Acetic anhydride	C ₄ H ₆ O ₃	108247	100.95	-8873.2	-11.451	6.1316E-06	2	200.15	2.1999E-02	606	3.9702E+06
142	Methyl formate	C ₂ H ₄ O ₂	107313	77.184	-5606.1	-8.392	7.8468E-06	2	174.15	6.8808E+00	487.2	5.9829E+06
143	Methyl acetate	C ₃ H ₆ O ₂	79209	61.267	-5618.6	-5.6473	2.1080E-17	6	175.15	1.0170E+00	506.55	4.6948E+06
144	Methyl propionate	C ₄ H ₈ O ₂	554121	70.717	-6439.7	-6.9845	2.0129E-17	6	185.65	6.3409E-01	530.6	4.0278E+06
145	Methyl n-butyrate	C ₅ H ₁₀ O ₂	623427	71.87	-6885.7	-7.0944	1.4903E-17	6	187.35	1.3435E-01	554.5	3.4797E+06
146	Ethyl formate	C ₃ H ₆ O ₂	109944	73.833	-5817	-7.809	6.3200E-06	2	193.55	1.8119E+01	508.4	4.7080E+06
147	Ethyl acetate	C ₄ H ₈ O ₂	141786	66.824	-6227.6	-6.41	1.7914E-17	6	189.6	1.4318E+00	523.3	3.8502E+06
148	Ethyl propionate	C ₅ H ₁₀ O ₂	105373	105.64	-8007	-12.477	9.0000E-06	2	199.25	7.7988E-01	546	3.3365E+06
149	Ethyl n-butyrate	C ₆ H ₁₂ O ₂	105544	57.661	-6346.5	-5.032	8.2534E-18	6	175.15	1.0390E-02	571	2.9352E+06
150	n-Propyl formate	C ₄ H ₈ O ₂	110747	104.08	-7535.9	-12.348	9.6020E-06	2	180.25	2.1101E-01	538	4.0310E+06
151	n-Propyl acetate	C ₅ H ₁₀ O ₂	109604	115.16	-8433.9	-13.934	1.0346E-05	2	178.15	1.7113E-02	549.73	3.3657E+06
152	n-Butyl acetate	C ₆ H ₁₂ O ₂	123864	71.34	-7285.8	-6.9459	9.9895E-18	6	199.65	1.4347E-01	579.15	3.1097E+06
153	Methyl benzoate	C ₈ H ₈ O ₂	93583	82.976	-9226.1	-8.4427	5.9115E-18	6	260.75	1.8653E+00	693	3.5896E+06
154	Ethyl benzoate	C ₉ H ₁₀ O ₂	93890	53.024	-7676.8	-4.1593	1.6850E-18	6	238.45	1.4385E-01	698	3.2190E+06
155	Vinyl acetate	C ₄ H ₆ O ₂	108054	57.406	-5702.8	-5.0307	1.1042E-17	6	180.35	7.0586E-01	519.13	3.9298E+06
156	Methylamine	CH ₃ N	74895	75.206	-5082.8	-8.0919	8.1130E-06	2	179.69	1.7671E+02	430.05	7.4139E+06
157	Dimethylamine	C ₂ H ₅ N	124403	71.738	-5302	-7.3324	6.4200E-17	6	180.96	7.5575E+01	437.2	5.2583E+06
158	Trimethylamine	C ₃ H ₈ N	75503	134.68	-6055.8	-19.415	2.8619E-02	1	156.08	9.9206E+00	433.25	4.1020E+06
159	Ethylamine	C ₂ H ₅ N	75047	81.56	-5596.9	-9.0779	8.7920E-06	2	192.15	1.5183E+02	456.15	5.5937E+06
160	Diethylamine	C ₄ H ₁₁ N	109897	49.314	-4949	-3.9256	9.1978E-18	6	223.35	3.7411E+02	496.6	3.6744E+06
161	Triethylamine	C ₆ H ₁₅ N	121448	56.55	-5681.9	-4.9815	1.2363E-17	6	158.45	1.0646E-02	535.15	3.0373E+06
162	n-Propylamine	C ₃ H ₉ N	107108	58.398	-5312.7	-5.2876	1.9913E-06	2	188.36	1.3004E+01	496.95	4.7381E+06
163	di-n-Propylamine	C ₆ H ₁₅ N	142847	54	-6018.5	-4.4981	9.9684E-18	6	210.15	3.6942E+00	550	3.1113E+06
164	Isopropylamine	C ₃ H ₉ N	75310	136.66	-7201.5	-18.934	2.2255E-02	1	177.95	7.7251E+00	471.85	4.5404E+06
165	Diisopropylamine	C ₆ H ₁₅ N	108189	462.84	-18227	-73.734	9.2794E-02	1	176.85	4.4724E-03	523.1	3.1987E+06
166	Aniline	C ₆ H ₇ N	62533	66.287	-8207.1	-6.0132	2.8414E-18	6	267.13	7.1322E+00	699	5.3514E+06

167	<i>N</i> -Methylaniline	C ₇ H ₉ N	100618	70.843	-8517.5	-6.7007	5.6411E-18	6	216.15	1.0207E-02	701.55	5.1935E+06
168	<i>N,N</i> -Dimethylaniline	C ₈ H ₁₁ N	121697	51.352	-7160	-4.0127	8.1481E-07	2	275.6	1.7940E+01	687.15	3.6262E+06
169	Ethylene oxide	C ₂ H ₄ O	75218	91.944	-5293.4	-11.682	1.4902E-02	1	160.65	7.7879E+00	469.15	7.2553E+06
170	Furan	C ₄ H ₆ O	110009	74.738	-5417	-8.0636	7.4700E-06	2	187.55	5.0026E+01	490.15	5.5497E+06
171	Thiophene	C ₄ H ₈ S	110021	89.171	-6860.3	-10.104	7.4769E-06	2	234.94	1.8538E+02	579.35	5.7145E+06
172	Pyridine	C ₅ H ₅ N	110861	82.154	-7211.3	-8.8646	5.2528E-06	2	231.51	2.0535E+01	619.95	5.6356E+06
173	Formamide	CH ₃ NO	75127	100.3	-10763	-10.946	3.8503E-06	2	275.6	1.0350E+00	771	7.7514E+06
174	<i>N,N</i> -Dimethylformamide	C ₃ H ₇ NO	68122	82.762	-7955.5	-8.8038	4.2431E-06	2	212.72	1.9532E-01	649.6	4.3653E+06
175	Acetamide	C ₂ H ₅ NO	60355	125.81	-12376	-14.589	5.0824E-06	2	353.33	3.3637E+02	761	6.5688E+06
176	<i>N</i> -Methylacetamide	C ₃ H ₇ NO	79163	79.128	-9523.9	-7.7355	3.1616E-18	6	301.15	2.8618E+01	718	4.9973E+06
177	Acetonitrile	C ₂ H ₄ N	75058	58.302	-5385.6	-5.4954	5.3634E-06	2	229.32	1.8694E+02	545.5	4.8517E+06
178	Propionitrile	C ₃ H ₅ N	107120	82.699	-6703.5	-9.1506	7.5424E-06	2	180.26	1.6936E-01	564.4	4.1906E+06
179	<i>n</i> -Butyronitrile	C ₄ H ₇ N	109740	66.32	-6714.9	-6.3087	1.3516E-17	6	161.25	6.1777E-04	582.25	3.7870E+06
180	Benzonitrile	C ₇ H ₅ N	100470	55.463	-7430.8	-4.548	1.7501E-18	6	260.4	5.1063E+00	699.35	4.2075E+06
181	Methyl mercaptan	CH ₃ S	74931	54.15	-4337.7	-4.8127	4.5000E-17	6	150.18	3.1479E+00	469.95	7.2309E+06
182	Ethyl mercaptan	C ₂ H ₅ S	75081	65.551	-5027.4	-6.6853	6.3208E-06	2	125.26	1.1384E-03	499.15	5.4918E+06
183	<i>n</i> -Propyl mercaptan	C ₃ H ₈ S	107039	62.165	-5624	-5.8595	2.0597E-17	6	159.95	6.5102E-02	536.6	4.6272E+06
184	<i>n</i> -Butyl mercaptan	C ₄ H ₁₀ S	109795	65.382	-6262.4	-6.2585	1.4943E-17	6	157.46	2.3532E-03	570.1	3.9730E+06
185	Isobutyl mercaptan	C ₄ H ₁₀ S	513440	61.736	-5909.2	-5.7554	1.5119E-17	6	128.31	4.7502E-06	559	4.0603E+06
186	<i>sec</i> -Butyl mercaptan	C ₄ H ₁₀ S	513531	60.649	-5755.9	-5.6113	1.5877E-17	6	133.02	3.3990E-05	554	4.0598E+06
187	Dimethyl sulfide	C ₂ H ₆ S	75183	83.485	-5711.7	-9.4999	9.8449E-06	2	174.88	7.9009E+00	503.04	5.5324E+06
188	Methyl ethyl sulfide	C ₃ H ₈ S	624895	79.07	-6114.1	-8.631	6.5333E-06	2	167.23	2.2456E-01	533	4.2610E+06
189	Diethyl sulfide	C ₄ H ₁₀ S	352932	60.867	-5969.6	-5.5979	1.4530E-17	6	169.2	4.3401E-02	557.15	3.9629E+06
190	Fluoromethane	CH ₃ F	593533	59.123	-3043.7	-6.1845	1.6637E-05	2	131.35	4.3287E+02	317.42	5.8754E+06
191	Chloromethane	CH ₃ Cl	74873	64.697	-4048.1	-6.8066	1.0371E-05	2	175.43	8.7091E+02	416.25	6.6905E+06
192	Trichloromethane	CHCl ₃	67663	146.43	-7792.3	-20.614	2.4578E-02	1	207.15	5.2512E+01	536.4	5.5543E+06
193	Tetrachloromethane	CCl ₄	56235	78.441	-6128.1	-8.5766	6.8465E-06	2	250.33	1.1225E+03	556.35	4.5436E+06
194	Bromomethane	CH ₃ Br	74839	72.586	-4698.6	-7.9966	1.1553E-05	2	179.47	1.9544E+02	467	7.9972E+06
195	Fluoroethane	C ₂ H ₃ F	353366	56.639	-3576.5	-5.5801	9.8969E-06	2	129.95	8.3714E+00	375.31	5.0060E+06
196	Chloroethane	C ₂ H ₅ Cl	75003	70.159	-4786.7	-7.5387	9.3370E-06	2	134.8	1.1658E-01	460.35	5.4578E+06
197	Bromoethane	C ₂ H ₅ Br	74964	62.217	-5113.3	-5.9761	4.7174E-17	6	154.55	3.7155E-01	503.8	6.2903E+06
198	1-Chloropropane	C ₃ H ₇ Cl	540545	79.24	-5718.8	-8.789	8.4486E-06	2	150.35	6.9630E-02	503.15	4.5812E+06
199	2-Chloropropane	C ₃ H ₆ Cl	75296	46.854	-4445.5	-3.6533	1.3260E-17	6	155.97	9.0844E-01	489	4.5097E+06
200	1,1-Dichloropropane	C ₃ H ₆ Cl ₂	78999	83.495	-6661.4	-9.2386	6.7652E-06	2	200	4.5248E+00	560	4.2394E+06
201	1,2-Dichloropropane	C ₃ H ₅ Cl ₂	78875	65.955	-6015.6	-6.5509	4.3172E-06	2	172.71	8.2532E-02	572	4.2319E+06
202	Vinyl chloride	C ₂ H ₃ Cl	75014	91.432	-5141.7	-10.981	1.4318E-05	2	119.36	1.9178E-02	432	5.7495E+06
203	Fluorobenzene	C ₆ H ₅ F	462066	51.915	-5439	-4.2896	8.7527E-18	6	230.94	1.5142E+02	560.09	4.5437E+06
204	Chlorobenzene	C ₆ H ₅ Cl	108907	54.144	-6244.4	-4.5343	4.7030E-18	6	227.95	8.4456E+00	632.35	4.5293E+06
205	Bromobenzene	C ₆ H ₅ Br	108861	63.749	-7130.2	-5.879	5.2136E-18	6	242.43	7.8364E+00	670.15	4.5196E+06
206	Air ³		13225910	21.662	-692.39	-0.39208	4.7574E-03	1	59.15	5.6421E+03	132.45	3.7934E+06
207	Hydrogen	H ₂	1333740	12.69	-94.896	1.1125	3.2915E-04	2	139.5	7.2116E+03	33.19	1.3154E+06
208	Helium-4 ⁴	He	7440597	11.533	-8.99	0.6724	2.7430E-01	1	1.76	1.4625E+03	5.2	2.2845E+05
209	Neon	Ne	7440019	29.755	-271.06	-2.6081	5.2700E-04	2	24.56	4.3800E+04	44.4	2.6652E+06
210	Argon	Ar	7440371	42.127	-1093.1	-4.1425	5.7254E-05	2	83.78	6.8721E+04	150.86	4.8963E+06
211	Fluorine	F ₂	7782414	42.393	-1103.3	-4.1203	5.7815E-05	2	53.48	2.5272E+02	144.12	5.1674E+06
212	Chlorine	Cl ₂	7782505	71.334	-3855	-8.5171	1.2378E-02	1	172.12	1.3660E+03	417.15	7.7930E+06
213	Bromine	Br ₂	7726956	108.26	-6592	-14.16	1.6043E-02	1	265.85	5.8534E+03	584.15	1.0276E+07
214	Oxygen	O ₂	7782447	51.245	-1200.2	-6.4361	2.8405E-02	1	54.36	1.4754E+02	154.58	5.0206E+06
215	Nitrogen	N ₂	7727379	58.282	-1084.1	-8.3144	4.4127E-02	1	63.15	1.2508E+04	126.2	3.3906E+06
216	Ammonia	NH ₃	7664417	90.483	-4669.7	-11.607	1.7194E-02	1	195.41	6.1111E+03	405.65	1.1301E+07
217	Hydrazine	N ₂ H ₄	302012	76.858	-7245.2	-8.22	6.1557E-03	1	274.69	4.0847E+02	653.15	1.4731E+07
218	Nitrous oxide	N ₂ O	10024972	96.512	-4045	-12.277	2.8860E-05	2	182.3	8.6908E+04	309.57	7.2782E+06

TABLE 2-6 Vapor Pressure of Inorganic and Organic Liquids (Concluded)

Cmpd. no.	Name	Formula	CAS no.	C1	C2	C3	C4	C5	T _{min} , K	P _s at T _{min}	T _{max} , K	P _s at T _{max}
219	Nitric oxide	NO	10102439	72.974	-2650	-8.261	9.7000E-15	6	109.5	2.1956E+04	180.15	6.5156E+06
220	Cyanogen	C ₂ N ₂	460195	88.589	-5059.9	-10.483	1.5403E-05	2	245.25	7.3385E+04	400.15	5.9438E+06
221	Carbon monoxide	CO	630080	45.698	-1076.6	-4.8814	7.5673E-05	2	68.15	1.5430E+04	132.92	3.4940E+06
222	Carbon dioxide	CO ₂	124389	140.54	-4735	-21.268	4.0909E-02	1	216.58	5.1867E+05	304.21	7.3896E+06
223	Carbon disulfide	CS ₂	75150	67.114	-4820.4	-7.5303	9.1695E-03	1	161.11	1.4944E+00	552	8.0408E+06
224	Hydrogen fluoride	HF	7664393	59.544	-4143.8	-6.1764	1.4161E-05	2	189.79	3.3683E+02	461.15	6.4872E+06
225	Hydrogen chloride	HCl	7647010	104.27	-3731.2	-15.047	3.1340E-02	1	158.97	1.3522E+04	324.65	8.3564E+06
226	Hydrogen bromide ²	HBr	10035106	29.315	-2424.5	-1.1354	2.3806E-18	6	185.15	2.9501E+04	363.15	8.4627E+06
227	Hydrogen cyanide	HCN	74908	36.75	-3927.1	-2.1245	3.8948E-17	6	259.83	1.8687E+04	456.65	5.3527E+06
228	Hydrogen sulfide	H ₂ S	7783064	85.584	-3839.9	-11.199	1.8848E-02	1	187.68	2.2873E+04	373.53	8.9988E+06
229	Sulfur dioxide	SO ₂	7446095	47.365	-4084.5	-3.6469	1.7990E-17	6	197.67	1.6743E+03	430.75	7.8596E+06
230	Sulfur trioxide	SO ₃	7446119	180.99	-12060	-22.839	7.2350E-17	6	289.95	2.0934E+04	490.85	8.1919E+06
231	Water	H ₂ O	7732185	73.649	-7258.2	-7.3037	4.1653E-06	2	273.16	6.1056E+02	647.13	2.1940E+07

All substances are listed in alphabetical order in Table 2-6a.

Compiled from Daubert, T. E., R. P. Danner, H. M. Sibul, and C. C. Stebbins, DIPPR Data Compilation of Pure Compound Properties, Project 801 Sponsor Release, July, 1993, Design Institute for Physical Property Data, AIChE, New York, NY; and from Thermodynamics Research Center, "Selected Values of Properties of Hydrocarbons and Related Compounds," Thermodynamics Research Center Hydrocarbon Project, Texas A&M University, College Station, Texas (extant 1994).

Temperatures are in K; vapor pressures are in Pa.

P_s × 9.869233E-06 = atm; P_a × 1.450377E-04 = psia; vapor pressure = exp [C1 + (C2/T) + C3 × ln (T) + C4 × T^{C5}].

¹ Decomposes violently on heating. Forms explosive peroxides with air or oxygen. Polymerizes under pressure and heat.

² Coefficients are hypothetical above the decomposition temperature.

³ At the bubble point.

⁴ Exhibits superfluid properties below 2.2 K.

TABLE 2-6a Alphabetical Index to Substances in Tables 2-6, 2-30, 2-164, 2-193, 2-196, 2-198, and 2-221

Name	Synonym	Cmpd. no.	Formula	Name	Synonym	Cmpd. no.	Formula
Acetaldehyde	Ethanal	114	C ₂ H ₄ O	1-Hexene		34	C ₆ H ₁₂
Acetamide		175	C ₂ H ₅ NO	1-Hexyne		51	C ₆ H ₁₀
Acetic acid	Ethanoic acid	136	C ₂ H ₄ O ₂	2-Hexyne		52	C ₆ H ₁₀
Acetic anhydride		141	C ₄ H ₆ O ₃	3-Hexyne		53	C ₆ H ₁₀
Acetone	2-Propanone	123	C ₃ H ₆ O	Hydrazine		217	N ₂ H ₄
Acetonitrile	Methyl cyanide	177	C ₂ H ₃ N	Hydrogen		207	H ₂
Acetophenone	Methyl phenyl ketone	134	C ₈ H ₈ O	Hydrogen bromide		226	HBr
Acetylene		45	C ₂ H ₂	Hydrogen chloride		225	HCl
Air		206	NH ₃	Hydrogen cyanide		227	HCN
Ammonia		216	C ₆ H ₇ N	Hydrogen fluoride		224	HF
Aniline		166	C ₆ H ₅ N	Hydrogen sulfide		228	H ₂ S
Anisole	Methyl phenyl ether	111	C ₇ H ₈ O				
Argon		210	Ar	Isobutyl mercaptan		185	C ₄ H ₁₀ S
Benzene		67	C ₆ H ₆	Isobutyric acid		139	C ₄ H ₈ O ₂
Benzoic acid		140	C ₇ H ₆ O ₂	Isooctane		27	C ₈ H ₁₈
Benzonitrile	Phenyl cyanide	180	C ₇ H ₃ N	Isoprene		44	C ₅ H ₈
Biphenyl	1,1'-Biphenyl	79	C ₁₂ H ₁₀	Isopropylamine		164	C ₃ H ₉ N
Bromine		213	Br ₂	Mesitylene	1,3,5-Trimethylbenzene	76	C ₉ H ₁₂
Bromobenzene		205	C ₆ H ₅ Br	Methane	Methyl alcohol	1	CH ₄
Bromoethane		197	C ₂ H ₅ Br	Methanol		82	CH ₄ O
Bromomethane	Methyl bromide	194	CH ₃ Br	N-Methylacetamide		176	C ₃ H ₇ NO
1,2-Butadiene		42	C ₄ H ₆	Methyl acetate		143	C ₃ H ₆ O ₂
1,3-Butadiene		43	C ₄ H ₆	Methylacetylene		46	C ₃ H ₄
n-Butane		4	C ₄ H ₁₀	Methylamine		156	CH ₅ N
1-Butanol		85	C ₄ H ₁₀ O	N-Methylaniline		167	C ₇ H ₉ N
2-Butanol	sec-Butyl alcohol	86	C ₄ H ₁₀ O	Methyl benzoate		153	C ₈ H ₈ O ₂
1-Butene		30	C ₄ H ₈	2-Methylbutane	Isopentane	22	C ₅ H ₁₂
cis-2-Butene	Z-2-Butene	31	C ₄ H ₈	2-Methyl-1-butanol		90	C ₅ H ₁₂ O
trans-2-Butene	E-2-Butene	32	C ₄ H ₈	3-Methyl-1-butanol	Isoamyl alcohol	91	C ₅ H ₁₂ O
n-Butyl acetate		152	C ₆ H ₁₂ O ₂	2-Methyl-1-butene		40	C ₅ H ₁₀
n-Butyl mercaptan	1-Butanethiol	184	C ₄ H ₁₀ S	2-Methyl-2-butene	Amylene	41	C ₅ H ₁₀
sec-Butyl mercaptan	2-Butanethiol	186	C ₄ H ₁₀ S	Methyl butyl ether		105	C ₅ H ₁₂ O
Butyraldehyde	Butanal	116	C ₄ H ₈ O	3-Methyl-1-butyne		48	C ₅ H ₈
n-Butyric acid		138	C ₄ H ₈ O ₂	Methyl butyrate		145	C ₅ H ₁₀ O ₂
n-Butyronitrile	Propyl cyanide	179	C ₄ H ₇ N	Methylcyclohexane		61	C ₇ H ₁₄
Carbon dioxide		222	CO ₂	Methylcyclopentane		58	C ₆ H ₁₂
Carbon disulfide		223	CS ₂	1-Methylcyclopentene		65	C ₆ H ₁₀
Carbon monoxide		221	CO	Methyl ethyl ether		102	C ₃ H ₈ O
Carbon tetrachloride	Tetrachloromethane	193	CCl ₄	Methyl ethyl ketone	2-Butanone	124	C ₄ H ₈ O
Chlorine		212	Cl ₂	Methyl ethyl sulfide	2-Thiabutane	188	C ₅ H ₈ S
Chlorobenzene		204	C ₆ H ₅ Cl	Methyl formate		142	C ₂ H ₄ O ₂
Chloroethane	Ethyl chloride	196	C ₂ H ₅ Cl	Methyl isobutyl ether		106	C ₅ H ₁₂ O
Chloroform	Trichloromethane	192	CHCl ₃	Methyl isobutyl ketone		128	C ₆ H ₁₂ O
Chloromethane	Methyl chloride	191	CH ₃ Cl	Methyl isopropyl ether		104	C ₄ H ₁₀ O
1-Chloropropane	Propyl chloride	198	C ₃ H ₇ Cl	Methyl isopropyl ketone		126	C ₅ H ₁₀ O
2-Chloropropane	Isopropyl chloride	199	C ₃ H ₇ Cl	Methyl mercaptan	Methanethiol	181	CH ₄ S
o-Cresol	2-Methylphenol	98	C ₇ H ₈ O	2-Methylpentane	Isohexane	24	C ₆ H ₁₄
m-Cresol	3-Methylphenol	99	C ₇ H ₈ O	3-Methyl-2-pentanone	Methyl sec-butyl ketone	129	C ₆ H ₁₂ O
p-Cresol	4-Methylphenol	100	C ₇ H ₈ O	2-Methylpropane	Iosbutane	21	C ₄ H ₁₀
Cumene	Isopropylbenzene	75	C ₉ H ₁₂	2-Methyl-2-propanol	tert-Butyl alcohol	88	C ₄ H ₁₀ O
Cyanogen		220	C ₂ N ₂	2-Methylpropene	Iosbutene	39	C ₄ H ₈
Cyclohexane		60	C ₆ H ₁₂	Methyl propionate		144	C ₄ H ₈ O ₂
Cyclohexanol	Cyclohexyl alcohol	94	C ₆ H ₁₂ O	Methyl propyl ether		103	C ₄ H ₁₀ O
Cyclohexanone	Cyclohexyl ketone	133	C ₆ H ₁₀ O	Methyl tert-butyl ether		107	C ₅ H ₁₂ O
Cyclohexene		66	C ₆ H ₁₀	Naphthalene		78	C ₁₀ H ₈
Cyclopentane		57	C ₅ H ₁₀	Neon		209	Ne
Cyclopentene		64	C ₅ H ₈	Nitric oxide		219	NO
p-Cymene	p-Isopropyltoluene	77	C ₁₀ H ₁₄	Nitrogen		215	N ₂
1-Decanal		122	C ₁₀ H ₂₀ O	Nitrous oxide		218	N ₂ O
n-Decane		10	C ₁₀ H ₂₂	n-Nonadecane	n-Nonaldehyde	19	C ₁₉ H ₄₀
1-Decene		38	C ₁₀ H ₂₀	1-Nonanal		121	C ₉ H ₁₈ O
1,1-Dichloropropane		200	C ₃ H ₆ Cl ₂	n-Nonane		9	C ₉ H ₂₀
1,2-Dichloropropane		201	C ₃ H ₆ Cl ₂	1-Nonene		37	C ₉ H ₁₈
Diethylamine		160	C ₄ H ₁₁ N	n-Octadecane			
Diethyl ether	Ethyl ether	108	C ₄ H ₁₀ O	1-Octanal	n-Octaldehyde	18	C ₁₈ H ₃₈
Diethyl sulfide	Ethyl sulfide	189	C ₄ H ₁₀ S	n-Octane		120	C ₈ H ₁₆ O
Diisopropylamine		165	C ₆ H ₁₅ N	1-Octene		8	C ₈ H ₁₈
Diisopropyl ketone	2,4-Dimethyl-3-pentanone	132	C ₇ H ₁₄ O	1-Octyne		36	C ₈ H ₁₆
Dimethylacetylene	2-Butyne	47	C ₄ H ₆	Oxygen		55	C ₈ H ₁₄
Dimethylamine		157	C ₂ H ₇ N			214	O ₂
N,N-Dimethylaniline	N,N-Dimethylbenzamine	168	C ₈ H ₁₁ N	n-Pentadecane		15	C ₁₅ H ₃₂
2,3-Dimethylbutane	Diisopropyl	23	C ₆ H ₁₄	1-Pentanal	Valeraldehyde	117	C ₅ H ₁₀ O
1,1-Dimethylcyclohexane		62	C ₈ H ₁₆	n-Pentane		5	C ₅ H ₁₂
Dimethyl ether	Methyl ether	101	C ₂ H ₆ O	1-Pentanol	n-Amyl alcohol	89	C ₅ H ₁₂ O

2-56 PHYSICAL AND CHEMICAL DATA

TABLE 2-6a Alphabetical Index to Substances in Tables 2-6, 2-30, 2-164, 2-193, 2-196, 2-198, and 2-221 (Concluded)

Name	Synonym	Cmpd. no.	Formula	Name	Synonym	Cmpd. no.	Formula
<i>N,N</i> -Dimethylformamide		174	C ₃ H ₇ NO	2-Pentanone	Methyl <i>n</i> -propyl ketone	125	C ₅ H ₁₀ O
2,3-Dimethylpentane		25	C ₇ H ₁₆	3-Pentanone	Diethyl ketone	130	C ₅ H ₁₀ O
Dimethyl sulfide	Methyl sulfide	187	C ₂ H ₆ S	1-Pentene		33	C ₅ H ₁₀
Diphenyl ether		112	C ₁₂ H ₁₀ O	1-Pentyne		49	C ₅ H ₈
<i>n</i> -Dodecane		12	C ₁₂ H ₂₆	2-Pentyne		50	C ₅ H ₈
				Phenol		97	C ₆ H ₆ O
<i>n</i> -Eicosane		20	C ₂₀ H ₄₂	1-Propanal	Propionaldehyde	115	C ₃ H ₆ O
Ethane		2	C ₂ H ₆	<i>n</i> -Propane		3	C ₃ H ₈
Ethanol	Ethyl alcohol	83	C ₂ H ₆ O	1-Propanol	<i>n</i> -Propyl alcohol	84	C ₃ H ₈ O
Ethyl acetate		147	C ₃ H ₈ O ₂	2-Propanol	Isopropyl alcohol	87	C ₃ H ₈ O
Ethylamine		159	C ₂ H ₇ N	<i>n</i> -Propionic acid		137	C ₃ H ₆ O ₂
Ethylbenzene	Phenylethane	72	C ₈ H ₁₀	<i>n</i> -Propionitrile	Ethyl cyanide	178	C ₃ H ₃ N
Ethyl benzoate		154	C ₉ H ₁₀ O ₂	<i>n</i> -Propyl acetate		151	C ₅ H ₁₀ O ₂
Ethyl butyrate		149	C ₉ H ₁₂ O ₂	<i>n</i> -Propylamine		162	C ₃ H ₈ N
Ethylyclohexane		63	C ₉ H ₁₆	di- <i>n</i> -Propylamine		163	C ₆ H ₁₅ N
Ethylyclopentane		59	C ₇ H ₁₄	<i>n</i> -Propylbenzene		73	C ₉ H ₁₂
Ethylene		28	C ₂ H ₄	Propylene		29	C ₃ H ₆
Ethylene glycol	1,2-Ethanediol	95	C ₂ H ₆ O ₂	1,2-Propylene glycol	1,2-Propanediol	96	C ₃ H ₆ O ₂
Ethylene oxide	1,2-Epoxyethane	169	C ₂ H ₄ O	<i>n</i> -Propyl formate		150	C ₄ H ₈ O ₂
Ethyl formate		146	C ₃ H ₆ O ₂	<i>n</i> -Propyl mercaptan	Propanethiol	183	C ₃ H ₈ S
Ethyl isopropyl ether		110	C ₅ H ₁₂ O	Pyridine		172	C ₅ H ₅ N
Ethyl isopropyl ketone		131	C ₆ H ₁₀ O				
Ethyl mercaptan	Ethanethiol	182	C ₂ H ₆ S	Styrene		80	C ₈ H ₈
Ethyl propionate		148	C ₅ H ₁₀ O ₂	Sulfur dioxide		229	SO ₂
Ethyl propyl ether		109	C ₅ H ₁₂ O	Sulfur trioxide		230	SO ₃
Fluorine		211	F ₂	<i>m</i> -Terphenyl		81	C ₁₈ H ₁₄
Fluorobenzene		203	C ₆ H ₅ F	<i>n</i> -Tetradecane		14	C ₁₄ H ₃₀
Fluoroethane	Ethyl fluoride	195	C ₂ H ₅ F	Thiophene		171	C ₄ H ₈ S
Fluoromethane	Methyl fluoride	190	CH ₃ F	Toluene		68	C ₇ H ₈
Formaldehyde	Methanal	113	CH ₂ O	<i>n</i> -Tridecane		13	C ₁₃ H ₂₈
Formamide		173	CH ₃ NO	Triethylamine		161	C ₆ H ₁₅ N
Formic acid	Methanoic acid	135	CH ₂ O ₂	Trimethylamine		158	C ₃ H ₈ N
Furan		170	C ₄ H ₄ O	1,2,4-Trimethylbenzene		74	C ₉ H ₁₂
				2,3,3-Trimethylpentane		26	C ₈ H ₁₈
Helium-4		208	He				
<i>n</i> -Heptadecane		17	C ₁₇ H ₃₆	<i>n</i> -Undecane		11	C ₁₁ H ₂₄
1-Heptanal	<i>n</i> -Heptaldehyde	119	C ₇ H ₁₄ O				
<i>n</i> -Heptane		7	C ₇ H ₁₆	Vinyl acetate		155	C ₄ H ₈ O ₂
1-Heptanol	<i>n</i> -Heptyl alcohol	93	C ₇ H ₁₆ O	Vinylacetylene		56	C ₄ H ₄
1-Heptene		35	C ₇ H ₁₄	Vinyl chloride		202	C ₂ H ₃ Cl
1-Heptyne		54	C ₇ H ₁₂	Water		231	H ₂ O
<i>n</i> -Hexadecane		16	C ₁₆ H ₃₄				
1-Hexanal	Caproaldehyde	118	C ₆ H ₁₂ O	<i>o</i> -Xylene	1,2-Dimethylbenzene	69	C ₈ H ₁₀
1-Hexane		6	C ₆ H ₁₄	<i>m</i> -Xylene	1,3-Dimethylbenzene	70	C ₈ H ₁₀
1-Hexanol	<i>n</i> -Hexyl alcohol	92	C ₆ H ₁₄ O	<i>p</i> -Xylene	1,4-Dimethylbenzene	71	C ₈ H ₁₀
2-Hexanone	Methyl <i>n</i> -butyl ketone	127	C ₆ H ₁₂ O				

TABLE 2-7 Vapor Pressures of Inorganic Compounds, up to 1 atm*

Compound		Pressure, mm Hg										Melting point, °C
Name	Formula	1	5	10	20	40	60	100	200	400	760	
		Temperature, °C										
Aluminum borohydride	Al	1284	1421	1487	1555	1635	1684	1749	1844	1947	2056	660
bromide	AlBr ₄) ₃	-52.2	-42.9	-32.5	-20.9	-13.4	-3.9	+11.2	28.1	45.9	-64.	
chloride	Al ₂ Cl ₆	81.3	103.8	118.0	134.0	150.6	161.7	176.1	199.8	227.0	256.3	97.
fluoride	AlF ₃	100.0	116.4	123.8	131.8	139.9	145.4	152.0	161.8	171.6	180.2	192.4
iodide	AlI ₃	1238	1298	1324	1350	1378	1398	1422	1457	1496	1537	1040
oxide	Al ₂ O ₃	178.0	207.7	225.8	244.2	265.0	277.8	294.5	322.0	354.0	385.5	
Ammonia heavy	NH ₃	2148	2306	2385	2465	2549	2599	2665	2766	2874	2977	2050
Ammonium bromide	ND ₃	-109.1	-97.5	-91.9	-85.8	-79.2	-74.3	-68.4	-57.0	-45.4	-33.6	-77.7
carbamate	N ₂ H ₆ CO ₂	198.3	234.5	252.0	270.6	290.0	303.8	320.0	345.3	370.8	396.0	
chloride	NH ₄ Cl	-26.1	-10.4	-2.9	+5.3	14.0	19.6	26.7	37.2	48.0	58.3	
cyanide	NH ₄ CN	160.4	193.8	209.8	226.1	245.0	256.2	271.5	293.2	316.5	337.8	520
hydrogen sulfide	NH ₄ HS	-50.6	-35.7	-28.6	-20.9	-12.6	-7.4	-0.5	+9.6	20.5	31.7	36
iodide	NH ₄ I	-51.1	-36.0	-28.7	-20.8	-12.3	-7.0	0.0	+10.5	21.8	33.3	
Antimony tribromide	Sb	210.9	247.0	263.5	282.8	302.8	316.0	331.8	355.8	381.0	404.9	
trichloride	SbBr ₃	93.9	126.0	142.7	158.3	177.4	188.1	203.5	225.7	250.2	275.0	96.6
pentachloride	SbCl ₃	49.2	71.4	85.2	100.6	117.8	128.3	143.3	165.9	192.2	219.0	73.4
trifluoride	SbCl ₅	22.7	48.6	61.8	75.8	91.0	101.0	114.1				2.8
triodide	SbI ₃	163.6	203.8	223.5	244.8	267.8	282.5	303.5	333.8	368.5	401.0	167
trioxide	Sb ₂ O ₆	574	626	666	729	812	873	957	1085	1242	1425	656
Argon	A	-218.2	-213.9	-210.9	-207.9	-204.9	-202.9	-200.5	-195.6	-190.6	-185.6	-189.2
Arsenic	As	372	416	437	459	483	498	518	548	579	610	814
Arsenic tribromide	AsBr ₃	41.8	70.6	85.2	101.3	118.7	130.0	145.2	167.7	193.6	220.0	
trichloride	AsCl ₃	-11.4	+11.7	+23.5	36.0	50.0	58.7	70.9	89.2	109.7	130.4	-18
trifluoride	AsF ₃	-117.9	-108.0	-103.1	-98.0	-92.4	-88.5	-84.3	-75.5	-64.0	-52.8	-79.8
pentafluoride	AsF ₅	-212.5	242.6	259.7	279.2	299.2	310.3	332.5	370.0	412.2	457.2	312.8
Arsine	AsH ₃	-142.6	-130.8	-124.7	-117.7	-110.2	-104.8	-98.0	-87.2	-75.2	-62.1	-116.3
Barium	Ba	984	1049	1120	1195	1240	1301	1403	1518	1638	1850	
Beryllium borohydride	Be(BH ₄) ₂	+1.0	19.8	28.1	36.8	46.2	51.7	58.6	69.0	79.7	90.0	123
bromide	BeBr ₂	289	325	342	361	379	390	405	427	451	474	490
chloride	BeCl ₂	291	328	346	365	384	395	411	435	461	487	405
iodide	BeI ₂	283	322	341	361	382	394	411	435	461	487	488
Bismuth tribromide	Bi	1021	1099	1136	1177	1217	1240	1271	1319	1370	1420	271
trichloride	BiBr ₃	261	282	305	327	340	360	392	425	461	218	
trifluoride	BiCl ₃	242	264	287	311	324	343	372	405	441	230	
Diborane hydrobromide	B ₂ H ₅ Br	-93.3	-75.3	-66.3	-56.4	-45.4	-38.2	-29.0	-15.4	0.0	+16.3	-104.2
Borine carbonyl	BH ₃ CO	-139.2	-127.3	-121.1	-114.1	-106.6	-101.9	-95.3	-85.5	-74.8	-64.0	-137.0
triamine	B ₃ N ₃ H ₆	-63.0	-45.0	-35.3	-25.0	-13.2	-5.8	+4.0	18.5	34.3	50.6	-58.2
Boron hydrides												
dihydrodecaborane	B ₁₀ H ₁₄	60.0	80.8	90.2	100.0	117.4	127.8	142.3	163.8			99.6
dihydrodiborane	B ₂ H ₆	-159.7	-149.5	-144.3	-138.5	-131.6	-127.2	-120.9	-111.2	-99.6	-86.5	-169
dihydropentaborane	B ₂ H ₉	-40.4	-30.7	-20.0	-8.0	-0.4	+9.6	24.6	40.8	58.1	58.1	-47.0
tetrahydropentaborane	B ₃ H ₁₁	-50.2	-29.9	-19.9	-9.2	+2.7	10.2	20.1	34.8	51.2	67.0	
tetrahydrotetraborane	B ₄ H ₁₀	-90.9	-73.1	-64.3	-54.8	-44.3	-37.4	-28.1	-14.0	+0.8	16.1	-119.9
Boron tribromide	BBBr ₃	-41.4	-20.4	-10.1	+1.5	14.0	22.1	33.5	50.3	70.0	91.7	-45
trichloride	BCL ₃	-91.5	-75.2	-66.9	-57.9	-47.8	-41.2	-32.4	-18.9	-3.6	+12.7	-107
trifluoride	BF ₃	-154.6	-145.4	-141.3	-136.4	-131.0	-127.6	-123.0	-115.9	-108.3	-100.7	-126.8
Bromine pentafluoride	Br ₂	-48.7	-32.8	-25.0	-16.8	-8.0	-0.6	+9.3	24.3	41.0	58.2	-7.3
Cadmium	BrF ₅	-69.3	-51.0	-41.9	-32.0	-21.0	-14.0	-4.5	+9.9	25.7	40.4	-61.4
chloride	Cd	394	455	484	516	553	578	611	658	711	765	320.9
fluoride	CdF ₂	1112	1231	1286	1344	1400	1436	1486	1561	1651	1751	520
iodide	CdI ₂	416	481	512	546	584	608	640	688	742	796	385
oxide	CdO	1000	1100	1149	1200	1257	1295	1341	1409	1484	1559	
Calcium	Ca	926	983	1046	1111	1152	1207	1288	1388	1487	1851	
Carbon (graphite)	C	3586	3828	3946	4069	4196	4273	4373	4516	4660	4827	
dioxide	CO ₂	-134.3	-124.4	-119.5	-114.4	-108.6	-104.8	-100.2	-93.0	-85.7	-78.2	-57.5
disulfide	CS ₂	-73.8	-54.3	-44.7	-34.3	-22.5	-15.3	-5.1	+10.4	28.0	46.5	-110.8
monoxide	CO	-222.0	-217.2	-215.0	-212.8	-210.0	-208.1	-205.7	-201.3	-196.3	-191.3	-205.0
oxyselemeide	COSe	-117.1	-102.3	-95.0	-86.3	-76.4	-70.2	-61.7	-49.8	-35.6	-21.9	
oxysulfide	COS	-132.4	-119.8	-113.3	-106.0	-98.3	-93.0	-85.9	-75.0	-62.7	-49.9	-138.8
selenosulfide	CSeS	-47.3	-26.5	-16.0	-4.4	+8.6	17.0	28.3	45.7	65.2	85.6	-75.2
subsulfide	CS ₂	14.0	41.2	54.9	69.3	85.6	96.0	109.9	130.8			+0.4
tetrabromide	CBr ₄	-50.0	-30.0	-19.6	-8.2	+4.3	12.3	23.0	38.3	57.8	76.7	-22.6
tetrachloride	CCl ₄	-184.6	-174.1	-169.3	-164.3	-158.8	-155.4	-150.7	-143.6	-135.5	-127.7	-183.7
tetrafluoride	CF ₄	279	341	375	409	449	474	509	561	624	690	28.5
Cesium bromide	CsBr	748	838	887	938	993	1026	1072	1140	1221	1300	636
chloride	CsCl	744	837	884	934	989	1023	1069	1139	1217	1300	646
fluoride	CsF	712	798	844	893	947	980	1025	1092	1170	1251	683
iodide	CsI	738	828	873	923	976	1009	1055	1124	1200	1280	621

*Compiled from the extended tables published by D. R. Stull in *Ind. Eng. Chem.*, **39**, 517 (1947).

2-58 PHYSICAL AND CHEMICAL DATA

TABLE 2-7 Vapor Pressures of Inorganic Compounds, up to 1 atm (Continued)

Compound		Pressure, mm Hg										Melting point, °C
Name	Formula	1	5	10	20	40	60	100	200	400	760	
		Temperature, °C										
Chlorine	Cl ₂	-118.0	-106.7	-101.6	-93.3	-84.5	-79.0	-71.7	-60.2	-47.3	-33.8	-100.7
fluoride	ClF		-143.4	-139.0	-134.3	-128.8	-125.3	-120.8	-114.4	-107.0	-100.5	-145
trifluoride	ClF ₃		-80.4	-71.8	-62.3	-51.3	-44.1	-34.7	-20.7	-4.9	+11.5	-83
monoxide	Cl ₂ O	-98.5	-81.6	-73.1	-64.3	-54.3	-48.0	-39.4	-26.5	-12.5	+2.2	-116
dioxide	ClO ₂			-59.0	-51.2	-42.8	-37.2	-29.4	-17.8	-4.0	+11.1	-59
heptoxide	Cl ₂ O ₇	-45.3	-23.8	-13.2	-2.1	+10.3	+18.2	29.1	44.6	62.2	78.8	-91
Chlorosulfonic acid	HSO ₃ Cl	32.0	53.5	64.0	75.3	87.6	95.2	105.3	120.0	136.1	151.0	-80
Chromium	Cr	1616	1768	1845	1928	2013	2067	2139	2243	2361	2482	1615
carbonyl	Cr(CO) ₆	36.0	58.0	68.3	79.5	91.2	98.3	108.0	121.8	137.2	151.0	
oxychloride	CrO ₂ Cl ₂	-18.4	+3.2	13.8	25.7	38.5	46.7	58.0	75.2	95.2	117.1	
Cobalt chloride	CoCl ₂				770	801	843	904	974	1050	735	
nitrosyl tricarbonyl	Co(CO) ₃ NO			-1.3	+11.0	18.5	29.0	44.4	62.0	80.0	-11	
Columbium fluoride	CbF ₅		86.3	103.0	121.5	133.2	148.5	172.2	198.0	225.0	225.0	75.5
Copper	Cu	1628	1795	1879	1970	2067	2127	2207	2325	2465	2595	1083
Cuprous bromide	Cu ₂ Br ₂	572	666	718	777	844	887	951	1052	1189	1355	504
chloride	Cu ₂ Cl ₂	546	645	702	766	838	886	960	1077	1249	1490	422
iodide	Cu ₂ I ₂		610	656	716	786	836	907	1018	1158	1336	605
Cyanogen	C ₂ N ₂	-95.8	-83.2	-76.8	-70.1	-62.7	-57.9	-51.8	-42.6	-33.0	-21.0	-34.4
bromide	CNBr	-35.7	-18.3	-10.0	-1.0	+8.6	14.7	22.6	33.8	46.0	61.5	58
chloride	CNCl	-76.7	-61.4	-53.8	-46.1	-37.5	-32.1	-24.9	-14.1	-2.3	+13.1	-6.5
fluoride	CNF	-134.4	-123.8	-118.5	-112.8	-106.4	-102.3	-97.0	-89.2	-80.5	-72.6	
Deuterium cyanide	DCN	-68.9	-54.0	-46.7	-38.8	-30.1	-24.7	-17.5	-5.4	+10.0	26.2	-12
Fluorine	F ₂	-223.0	-216.9	-214.1	-211.0	-207.7	-205.6	-202.7	-198.3	-193.2	-187.9	-223
oxide	F ₂ O	-196.1	-186.6	-182.3	-177.8	-173.0	-170.0	-165.8	-159.0	-151.9	-144.6	-223.9
Germanium bromide	GeBr ₄		43.3	56.8	71.8	88.1	98.8	113.2	135.4	161.6	189.0	26.1
chloride	GeCl ₄	-45.0	-24.9	-15.0	-4.1	+8.0	16.2	27.5	44.4	63.8	84.0	-49.5
hydride	GeH ₄	-163.0	-151.0	-145.3	-139.2	-131.6	-126.7	-120.3	-111.2	-100.2	-88.9	-165
Trichlorogermaine	GeHCl ₃	-41.3	-22.3	-13.0	-3.0	+8.8	16.2	26.5	41.6	58.3	75.0	-71.1
Tetramethylgermaine	Ge(CH ₃) ₄	-73.2	-54.6	-45.2	-35.0	-23.4	-16.2	-6.3	+8.8	26.0	44.0	-88
Digermane	Ge ₂ H ₆	-88.7	-69.8	-60.1	-49.9	-38.2	-30.7	-20.3	-4.7	+13.3	31.5	-109
Trigermane	Ge ₃ H ₈	-36.9	-12.8	-0.9	+11.8	26.3	35.5	47.9	67.0	88.6	110.8	-105.6
Gold	Au	1869	2059	2154	2256	2363	2431	2521	2657	2807	2966	1063
Helium	He	-271.7	-271.5	-271.1	-270.7	-270.6	-270.3	-269.8	-269.3	-268.6		
para-Hydrogen	H ₂	-263.3	-261.9	-261.3	-260.4	-259.6	-258.9	-257.9	-256.3	-254.5	-252.5	-259.1
Hydrogen bromide	HBr	-138.8	-127.4	-121.8	-115.4	-108.3	-103.8	-97.7	-88.1	-78.0	-66.5	-87.0
chloride	HCl	-150.8	-140.7	-135.6	-130.0	-123.8	-119.6	-114.0	-105.2	-95.3	-84.8	-114.3
cyanide	HCN	-71.0	-55.3	-47.7	-39.7	-30.9	-25.1	-17.8	-5.3	+10.2	25.9	-13.2
fluoride	H ₂ F ₂		-74.7	-65.8	-56.0	-45.0	-37.9	-28.2	-13.2	+2.5	19.7	-83.7
iodide	HI	-123.3	-109.6	-102.3	-94.5	-85.6	-79.8	-72.1	-60.3	-48.3	-35.1	-50.9
oxide (water)	H ₂ O	-17.3	+1.2	11.2	22.1	34.0	41.5	51.6	66.5	83.0	100.0	0.0
sulfide	H ₂ S	-134.3	-122.4	-116.3	-109.7	-102.3	-97.9	-91.6	-82.3	-71.8	-60.4	-85.5
disulfide	HSSH	-43.2	-24.4	-15.2	-5.1	+6.0	12.8	22.0	35.3	49.6	64.0	-89.7
selenide	H ₂ Se	-115.3	-103.4	-97.9	-91.8	-84.7	-80.2	-74.2	-65.2	-53.6	-41.1	-64
telluride	H ₂ Te	-96.4	-82.4	-75.4	-67.8	-59.1	-53.7	-45.7	-32.4	-17.2	-2.0	-49.0
Iodine	I ₂	38.7	62.2	73.2	84.7	97.5	105.4	116.5	137.3	159.8	183.0	112.9
heptafluoride	IF ₇	-87.0	-70.7	-63.0	-54.5	-45.3	-39.4	-31.9	-20.7	-8.3	+4.0	5.5
Iron	Fe	1787	1957	2039	2128	2224	2283	2360	2475	2605	2735	1535
pentacarbonyl	Fe(CO) ₅		-6.5	+4.6	16.7	30.3	39.1	50.3	68.0	86.1	105.0	-21
Ferric chloride	Fe ₂ Cl ₆	194.0	221.8	235.5	246.0	256.8	263.7	272.5	285.0	298.0	319.0	304
Ferrous chloride	FeCl ₂		700	737	779	805	842	897	961	1026		
Krypton	Kr	-199.3	-191.3	-187.2	-182.9	-178.4	-175.7	-171.8	-165.9	-159.0	-152.0	-156.7
Lead	Pb	973	1099	1162	1234	1309	1358	1421	1519	1630	1744	327.5
bromide	PbBr ₂	513	578	610	646	686	711	745	796	856	914	373
chloride	PbCl ₂	547	615	648	684	725	750	784	833	893	954	501
fluoride	PbF ₂		861	904	950	1003	1036	1080	1144	1219	1293	855
iodide	PbI ₂	479	540	571	605	644	668	701	750	807	872	402
oxide	PbO	943	1039	1085	1134	1189	1222	1265	1330	1402	1472	890
sulfide	PbS	852	928	975	1005	1048	1074	1108	1160	1221	1281	1114
Lithium	Li	723	838	881	940	1003	1042	1097	1178	1273	1372	186
bromide	LiBr	748	840	888	939	994	1028	1076	1147	1226	1310	547
chloride	LiCl	783	880	932	987	1045	1081	1129	1203	1290	1382	614
fluoride	LiF	1047	1156	1211	1270	1333	1372	1425	1503	1591	1681	870
iodide	LiI	723	802	841	883	927	955	993	1049	1110	1171	446
Magnesium	Mg	621	702	743	789	838	868	909	967	1034	1107	651
chloride	MgCl ₂	778	877	930	988	1050	1088	1142	1223	1316	1418	712
Manganese	Mn	1292	1434	1505	1583	1666	1720	1792	1900	2029	2151	1260
chloride	MnCl ₂		736	778	825	879	913	960	1028	1108	1190	650
Mercury	Hg	126.2	164.8	184.0	204.6	228.8	242.0	261.7	290.7	323.0	357.0	-38.9
Mercuric bromide	HgBr ₂	136.5	165.3	179.8	194.3	211.5	221.0	237.8	262.7	290.0	319.0	237
chloride	HgCl ₂	136.2	166.0	180.2	195.8	212.5	222.2	237.0	256.5	275.5	304.0	277
iodide	HgI ₂	157.5	189.2	204.5	220.0	238.2	249.0	261.8	291.0	324.2	354.0	259
Molybdenum	Mo	3102	3393	3535	3690	3859	3964	4109	4322	4553	4804	2622
hexafluoride	MoF ₆	-65.5	-49.0	-40.8	-32.0	-22.1	-16.2	-8.0	+4.1	17.2	36.0	17
oxide	MoO ₃	734	785	814	851	892	917	955	1014	1082	1151	795

TABLE 2-7 Vapor Pressures of Inorganic Compounds, up to 1 atm (Continued)

Compound		Pressure, mm Hg										Melting point, °C
Name	Formula	1	5	10	20	40	60	100	200	400	760	
		Temperature, °C										
Neon	Ne	-257.3	-255.5	-254.6	-253.7	-252.6	-251.9	-251.0	-249.7	-248.1	-246.0	-248.7
Nickel carbonyl chloride	Ni(CO) ₄	1810	1979	2057	2143	2234	2289	2364	2473	2603	2732	1452
Nitrogen	N ₂	-226.1	-221.3	-219.1	-216.8	-214.0	-212.3	-209.7	-205.6	-200.9	-195.8	-210.0
Nitric oxide	NO	-184.5	-180.6	-178.2	-175.3	-171.7	-168.9	-166.0	-162.3	-156.8	-151.7	-161
Nitrogen dioxide	NO ₂	-55.6	-42.7	-36.7	-30.4	-23.9	-19.9	-14.7	-5.0	+8.0	21.0	-9.3
Nitrogen pentoxide	NO ₅	-36.8	-23.0	-16.7	-10.0	-2.9	+1.8	7.4	15.6	24.4	32.4	30
Nitrous oxide	N ₂ O	-143.4	-133.4	-128.7	-124.0	-118.3	-114.9	-110.3	-103.6	-96.2	-85.5	-90.9
Nitrosyl chloride fluoride	NOCl	-132.0	-120.3	-114.3	-107.8	-100.3	-95.7	-60.2	-54.2	-46.3	-34.0	-20.3
Osmium tetroxide (yellow) (white)	OsO ₄	3.2	22.0	31.3	41.0	51.7	59.4	71.5	89.5	109.3	130.0	56
Oxygen	O ₂	-219.1	-213.4	-210.6	-207.5	-204.1	-201.9	-198.8	-194.0	-188.8	-183.1	-218.7
Ozone	O ₃	-180.4	-168.6	-163.2	-157.2	-150.7	-146.7	-141.0	-132.6	-122.5	-111.1	-251
Phosgene	COCl ₂	-92.9	-77.0	-69.3	-60.3	-50.3	-44.0	-35.6	-22.3	-7.6	+8.3	-104
Phosphorus (yellow) (violet)	P	76.6	111.2	128.0	146.2	166.7	179.8	197.3	227.2	251.0	280.0	44.1
Phosphorus (yellow) (violet)	P	237	271	287	306	323	334	349	370	391	417	590
tribromide	PBr ₃	7.8	34.4	47.8	62.4	79.0	89.8	103.6	125.2	149.7	175.3	-40
trichloride	PCl ₃	-51.6	-31.5	-21.3	-10.2	+2.3	10.2	21.0	37.6	56.9	74.2	-111.8
pentachloride	PCl ₅	55.5	74.0	83.2	92.5	102.5	108.3	117.0	131.3	147.2	162.0	
Phosphine	PH ₃					-129.4	-125.0	-118.8	-109.4	-98.3	-87.5	-132.5
Phosphonium bromide	PH ₄ Br	-43.7	-28.5	-21.2	-13.3	-5.0	+0.3	7.4	17.6	28.0	38.3	
chloride	PH ₄ Cl	-91.0	-79.6	-74.0	-68.0	-61.5	-57.3	-52.0	-44.0	-35.4	-27.0	-28.5
iodide	PH ₄ I	-25.2	-9.0	-1.1	+7.3	16.1	21.9	29.3	39.9	51.6	62.3	
Phosphorus trioxide	P ₄ O ₆	39.7	53.0	67.8	84.0	94.2	108.3	129.0	150.3	173.1	22.5	
pentoxide	P ₄ O ₁₀	384	424	442	462	481	493	510	532	556	591	569
oxychloride	POCl ₃		2.0	13.6	27.3	35.8	47.4	65.0	84.3	105.1	2	
thiobromide	PSBr ₃	50.0	72.4	83.6	95.5	108.0	116.0	126.3	141.8	157.8	175.0	38
thiochloride	PSCl ₃	-18.3	+4.6	16.1	29.0	42.7	51.8	63.8	82.0	102.3	124.0	-36.2
Platinum	Pt	2730	3007	3146	3302	3469	3574	3714	3923	4169	4407	1755
Potassium	K	341	408	443	483	524	550	586	643	708	774	62.3
bromide	KBr	795	892	940	994	1050	1087	1137	1212	1297	1383	730
chloride	KCl	821	919	968	1020	1078	1115	1164	1239	1322	1407	790
fluoride	KF	885	988	1039	1096	1156	1193	1245	1323	1411	1502	880
hydroxide	KOH	719	814	863	918	976	1013	1064	1142	1233	1327	380
iodide	KI	745	840	887	938	995	1030	1080	1152	1238	1324	723
Radon	Rn	-144.2	-132.4	-126.3	-119.2	-111.3	-106.2	-99.0	-87.7	-75.0	-61.8	-71
Rhenium heptoxide	Re ₂ O ₇	212.5	237.5	248.0	261.0	272.0	280.0	289.0	307.0	336.0	362.4	296
Rubidium	Rb	297	358	389	422	459	482	514	563	620	679	38.5
bromide	RbBr	781	876	923	975	1031	1066	1114	1186	1267	1352	682
chloride	RbCl	792	887	937	990	1047	1084	1133	1207	1294	1381	715
fluoride	RbF	921	982	1016	1052	1096	1123	1168	1239	1322	1408	760
iodide	RbI	748	839	884	935	991	1026	1072	1141	1223	1304	642
Selenium	Se	356	413	442	473	506	527	554	594	637	680	217
dioxide	SeO ₂	157.0	187.7	202.5	217.5	234.1	244.6	258.0	277.0	297.7	317.0	340
hexafluoride	SeF ₆	-118.6	-105.2	-98.9	-92.3	-84.7	-80.0	-73.9	-64.8	-55.2	-45.8	-34.7
oxychloride	SeOCl ₂	34.8	59.8	71.9	84.2	98.0	106.5	118.0	134.6	151.7	168.0	8.5
tetrachloride	SeCl ₄	74.0	96.3	107.4	118.1	130.1	137.8	147.5	161.0	176.4	191.5	
Silicon	Si	1724	1835	1888	1942	2000	2036	2083	2151	2220	2287	1420
dioxide	SiO ₂		1732	1798	1867	1911	1969	2053	2141	2227	2310	
tetrachloride	SiCl ₄	-63.4	-44.1	-34.4	-24.0	-12.1	-4.8	+5.4	21.0	38.4	56.8	-68.8
tetrafluoride	SiF ₄	-144.0	-134.8	-130.4	-125.9	-120.8	-117.5	-113.3	-170.2	-100.7	-94.8	-90
Trichlorofluorosilane	SiFCl ₃	-92.6	-76.4	-68.3	-59.0	-48.8	-42.2	-33.2	-19.3	-4.0	+12.2	-120.8
Iodosilane	SiH ₃ I		-53.0	-47.7	-33.4	-21.8	-14.3	-4.4	+10.7	27.9	45.4	-57.0
Diiodosilane	SiH ₂ I ₂		3.8	18.0	34.1	52.6	64.0	79.4	101.8	125.5	149.5	-1.0
Disiloxan	(SiH ₃) ₂ O	-112.5	-95.8	-88.2	-79.8	-70.4	-64.2	-55.9	-43.5	-29.3	-15.4	-144.2
Trisilane	Si ₃ H ₈	-68.9	-49.7	-40.0	-29.0	-16.9	-9.0	+1.6	17.8	35.5	53.1	-117.2
Trisilazane	(SiH ₃) ₃ N	-68.7	-49.9	-40.4	-30.0	-18.5	-11.0	-1.1	+14.0	31.0	48.7	-105.7
Tetrasilane	SiH ₁₀	-27.7	-6.2	+4.3	15.8	28.4	36.6	47.4	63.6	81.7	100.0	-93.6
Octachlorotrisilane	Si ₃ Cl ₉	46.3	74.7	89.3	104.2	121.5	132.0	146.0	166.2	189.5	211.4	
Hexachlorodisiloxane	(SiCl ₃) ₂ O	-5.0	17.8	29.4	41.5	55.2	63.8	75.4	92.5	113.6	135.6	-33.2
Hexachlorodisilane	Si ₂ Cl ₆	+4.0	27.4	38.8	51.5	65.3	73.9	85.4	102.2	120.6	139.0	-1.2
Tribromosilane	SiHBr ₃	-30.5	-8.0	+3.4	16.0	30.0	39.2	51.6	70.2	90.2	111.8	-73.5
Trichlorosilane	SiHCl ₃	-80.7	-62.6	-53.4	-43.8	-32.9	-25.8	-16.4	-1.8	+14.5	31.8	-126.6
Trifluorosilane	SiHF ₃	-152.0	-142.7	-138.2	-132.9	-127.3	-123.7	-118.7	-111.3	-102.8	-95.0	-131.4
Dibromosilane	SiH ₂ Br ₂	-60.9	-40.0	-29.4	-18.0	-5.2	+3.2	14.1	31.6	50.7	70.5	-70.2
Diffluorosilane	SiH ₂ F ₂	-146.7	-136.0	-130.4	-124.3	-117.6	-113.3	-107.3	-98.3	-87.6	-77.8	
Monobromosilane	SiH ₃ Br		-85.7	-77.3	-68.3	-57.8	-51.1	-42.3	-28.6	-13.3	+2.4	-93.9
Monochlorosilane	SiH ₃ Cl	-117.8	-104.3	-97.7	-90.1	-81.8	-76.0	-68.5	-57.0	-44.5	-30.4	
Monofluorosilane	SiH ₃ F	-153.0	-145.5	-141.2	-136.3	-130.8	-127.2	-122.4	-115.2	-106.8	-98.0	
Tribromofluorosilane	SiFBr ₃	-46.1	-25.4	-15.1	-3.7	+9.2	17.4	28.6	45.7	64.6	83.8	-82.5
Dichlorodifluorosilane	SiF ₂ Cl ₂	-124.7	-110.5	-102.9	-94.5	-85.0	-78.6	-70.3	-58.0	-45.0	-31.8	-139.7
Trifluorobromosilane	SiF ₃ Br							-69.8	-55.9	-41.7	-70.5	

2-60 PHYSICAL AND CHEMICAL DATA

TABLE 2-7 Vapor Pressures of Inorganic Compounds, up to 1 atm (Concluded)

Compound		Pressure, mm Hg										Melting point, °C
Name	Formula	1	5	10	20	40	60	100	200	400	760	
		Temperature, °C										
Trifluorochlorosilane	SiF ₃ Cl	-144.0	-133.0	-127.0	-120.5	-112.8	-108.2	-101.7	-91.7	-81.0	-70.0	-142
Hexafluorodisilane	Si ₂ F ₆	-81.0	-68.8	-63.1	-57.0	-50.6	-46.7	-41.7	-34.2	-26.4	-18.9	-18.6
Dichlorofluorobromosilane	SiFCl ₂ Br	-86.5	-68.4	-59.0	-48.8	-37.0	-29.0	-19.5	-3.2	+15.4	35.4	-112.3
Dibromochlorofluorosilane	SiFClBr ₂	-65.2	-45.5	-35.6	-24.5	-12.0	-4.7	+6.3	23.0	43.0	59.5	-99.3
Silane	SiH ₄	-179.3	-168.6	-163.0	-156.9	-150.3	-146.3	-140.5	-131.6	-122.0	-111.5	-185
Disilane	Si ₂ H ₆	-114.8	-99.3	-91.4	-82.7	-72.8	-66.4	-57.5	-44.6	-29.0	-14.3	-132.6
Silver chloride	Ag	1357	1500	1575	1658	1743	1795	1865	1971	2090	2212	960.5
iodide	AgI	912	1019	1074	1134	1200	1242	1297	1379	1467	1564	455
Sodium bromide	NaBr	439	511	549	589	633	662	701	758	823	892	97.5
chloride	NaCl	865	967	1017	1072	1131	1169	1220	1296	1379	1465	800
cyanide	NaCN	817	928	983	1046	1115	1156	1214	1302	1401	1497	564
fluoride	NaF	1077	1186	1240	1300	1363	1403	1455	1531	1617	1704	992
hydroxide	NaOH	739	843	897	953	1017	1057	1111	1192	1286	1378	318
iodide	NaI	767	857	903	952	1005	1039	1083	1150	1225	1304	651
Strontium	Sr	847	898	953	1018	1057	1111	1192	1285	1384	800	
Strontium oxide	SrO	2068	2198	2262	2333	2410						2430
Sulfur	S	183.8	223.0	243.8	264.7	288.3	305.5	327.2	359.7	399.6	444.6	112.8
monochloride	S ₂ Cl ₂	-7.4	+15.7	27.5	40.0	54.1	63.2	75.3	93.5	115.4	138.0	-80
hexafluoride	SF ₆	-132.7	-120.6	-114.7	-108.4	-101.5	-96.8	-90.9	-82.3	-72.6	-63.5	-50.2
Sulfuryl chloride	SO ₂ Cl ₂	-35.1	-24.8	-13.4	-1.0	+7.2	17.8	33.7	51.3	69.2	74.1	-54.1
Sulfur dioxide	SO ₂	-95.5	-83.0	-76.8	-69.7	-60.5	-54.6	-46.9	-35.4	-23.0	-10.0	-73.2
trioxide (α)	SO ₃	-39.0	-23.7	-16.5	-9.1	-1.0	+4.0	10.5	20.5	32.6	44.8	16.8
trioxide (β)	SO ₃	-34.0	-19.2	-12.3	-4.9	+3.2	8.0	14.3	23.7	32.6	44.8	32.3
trioxide (γ)	SO ₃	-15.3	-2.0	+4.3	11.1	17.9	21.4	28.0	35.8	44.0	51.6	62.1
Tellurium	Te	520	605	650	697	753	789	838	910	997	1087	452
chloride	TeCl ₄		233	253	273	287	304	330	360	392	424	
fluoride	TeF ₆	-111.3	-98.8	-92.4	-86.0	-78.4	-73.8	-67.9	-57.3	-48.2	-38.6	-37.8
Thallium	Tl	825	931	983	1040	1103	1143	1196	1274	1364	1457	3035
Thallous bromide	TlBr	490	522	559	598	621	653	703	759	819	860	
chloride	TlCl	487	517	550	589	612	645	694	748	807	843	
iodide	TlI	440	502	531	567	607	631	663	712	763	823	440
Thionyl bromide	SOBr ₂	-6.7	+18.4	31.0	44.1	58.8	68.3	80.6	99.0	119.2	139.5	-52.2
Thionyl chloride	SOCl ₂	-52.9	-32.4	-21.9	-10.5	+2.2	10.4	21.4	37.9	56.5	75.4	-104.5
Tin	Sn	1492	1634	1703	1777	1855	1903	1968	2063	2169	2270	231.9
Stannic bromide	SnBr ₄		58.3	72.7	88.1	105.5	116.2	131.0	152.8	177.7	204.7	31.0
Stannous chloride	SnCl ₂	316	366	391	420	450	467	493	533	577	623	246.8
Stannic chloride	SnCl ₄	-22.7	-1.0	+10.0	22.0	35.2	43.5	54.7	72.0	92.1	113.0	-30.2
iodide	SnI ₄		156.0	175.8	196.2	218.8	234.2	254.2	283.5	315.5	348.0	144.5
hydride	SnH ₄	-140.0	-125.8	-118.5	-111.2	-102.3	-96.6	-89.2	-78.0	-65.2	-52.3	-149.9
Tin tetramethyl	Sn(CH ₃) ₄	-51.3	-31.0	-20.6	-9.3	+3.5	11.7	22.8	39.8	58.5	78.0	
trimethyl-ethyl												
trimethyl-propyl	Sn(CH ₃) ₃ C ₂ H ₅	-30.0	-7.6	+3.8	16.1	30.0	38.4	50.0	67.3	87.6	108.8	
Titanium chloride	TiCl ₄	-12.0	+10.7	21.8	34.0	48.5	57.5	69.8	88.0	109.6	131.7	
Tungsten	W	3990	4337	4507	4690	4886	5007	5168	5403	5666	5927	3370
Tungsten hexafluoride	WF ₆	-71.4	-56.5	-49.2	-41.5	-33.0	-27.5	-20.3	-10.0	+1.2	17.3	-0.5
Uranium hexafluoride	UF ₆	-38.8	-22.0	-13.8	-5.2	+4.4	10.4	18.2	30.0	42.7	55.7	69.2
Vanadyl trichloride	VOCl ₃	-23.2	+0.2	12.2	26.6	40.0	49.8	62.5	82.0	103.5	127.2	
Xenon	Xe	-168.5	-158.2	-152.8	-147.1	-141.2	-137.7	-132.8	-125.4	-117.1	-108.0	-111.6
Zinc	Zn	487	558	593	632	673	700	736	788	844	907	419.4
chloride	ZnCl ₂		428	481	508	536	566	584	610	648	689	732
fluoride	ZnF ₂	970	1055	1086	1129	1175	1207	1254	1329	1417	1497	872
diethyl	Zn(C ₂ H ₅) ₂	-22.4	0.0	+11.7	24.2	38.0	47.2	59.1	77.0	97.3	118.0	-28
Zirconium bromide	ZrBr ₄	207	237	250	266	281	289	301	318	337	357	450
chloride	ZrCl ₄	190	217	230	243	259	268	279	295	312	331	437
iodide	ZrI ₄	264	297	311	329	344	355	369	389	409	431	499

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm*

Compound	Name	Formula	Pressure, mm Hg										Melting point, °C
			1	5	10	20	40	60	100	200	400	760	
Temperature, °C													
Acenaphthalene		C ₁₂ H ₁₀	114.8	131.2	148.7	168.2	181.2	197.5	222.1	250.0	277.5	95	
Acetal		C ₆ H ₁₄ O ₂	-23.0	-2.3	+8.0	19.6	31.9	39.8	50.1	66.3	84.0	102.2	
Acetaldehyde		C ₃ H ₆ O	-81.5	-65.1	-56.8	-47.8	-37.8	-31.4	-22.6	-10.0	+4.9	20.2	-123.5
Acetamide		C ₂ H ₅ NO	65.0	92.0	105.0	120.0	135.8	145.8	158.0	178.3	200.0	222.0	81
Acetanilide		C ₈ H ₉ NO	114.0	146.6	162.0	180.0	199.6	211.8	227.2	250.5	277.0	303.8	113.5
Acetic acid		C ₂ H ₄ O ₂	-17.2	+6.3	17.5	29.9	43.0	51.7	63.0	80.0	99.0	118.1	16.7
anhydride		C ₄ H ₆ O ₃	1.7	24.8	36.0	48.3	62.1	70.8	82.2	100.0	119.8	139.6	-73
Acetone		C ₃ H ₆ O	-59.4	-40.5	-31.1	-20.8	-9.4	-2.0	+7.7	22.7	39.5	56.5	-94.6
Acetonitrile		C ₂ H ₃ N	-47.0	-26.6	-16.3	-5.0	+7.7	15.9	27.0	43.7	62.5	81.8	-41
Acetophenone		C ₈ H ₈ O	37.1	64.0	78.0	92.4	109.4	119.8	133.6	154.2	178.0	202.4	20.5
Acetyl chloride		C ₂ H ₅ OCl	-50.0	-35.0	-27.6	-19.6	-10.4	-4.5	+3.2	16.1	32.0	50.8	-112.0
Acetylene		C ₂ H ₂	-142.9	-133.0	-128.2	-122.8	-116.7	-112.8	-107.9	-100.3	-92.0	-84.0	-81.5
Acridine		C ₁₃ H ₉ N	129.4	165.8	184.0	203.5	224.2	238.7	256.0	284.0	314.3	346.0	110.5
Acrolein (2-propenal)		C ₃ H ₄ O	-64.5	-46.0	-36.7	-26.3	-15.0	-7.5	+2.5	17.5	34.5	52.5	-87.7
Acrylic acid ¹		C ₃ H ₄ O ₂	+3.5	27.3	39.0	52.0	66.2	75.0	86.1	103.3	122.0	141.0	14
Adipic acid		C ₆ H ₁₀ O ₄	159.5	191.0	205.5	222.0	240.5	251.0	265.0	287.8	312.5	337.5	152
Allene (propadiene)		C ₃ H ₄	-120.6	-108.0	-101.0	-93.4	-85.2	-78.8	-72.5	-61.3	-48.5	-35.0	-136
Allyl alcohol (propen-1-ol-3)		C ₃ H ₆ O	-20.0	+0.2	10.5	21.7	33.4	40.3	50.0	64.5	80.2	96.6	-129
chloride (3-chloropropene)		C ₃ H ₅ Cl	-70.0	-52.0	-42.9	-32.8	-21.2	-14.1	-4.5	10.4	27.5	44.6	-136.4
isopropyl ether		C ₆ H ₁₂ O	-43.7	-23.1	-12.9	-1.8	+10.9	18.7	29.0	44.3	61.7	79.5	
isothiocyanate		C ₄ H ₅ NS	-2.0	+25.3	38.3	52.1	67.4	76.2	89.5	108.0	129.8	150.7	-80
n-propyl ether		C ₆ H ₁₂ O	-39.0	-18.2	-7.9	+3.7	16.4	25.0	35.8	52.6	71.4	90.5	
4-Allylveratrole		C ₁₁ H ₁₄ O ₂	85.0	113.9	127.0	142.8	158.3	169.6	183.7	204.0	226.2	248.0	
iso-Amyl acetate		C ₇ H ₁₄ O ₂	0.0	+23.7	35.2	47.8	62.1	71.0	83.2	101.3	121.5	142.0	
n-Amyl alcohol		C ₅ H ₁₂ O	+13.6	34.7	44.9	55.8	68.0	75.5	85.8	102.0	119.8	137.8	
iso-Amyl alcohol		C ₅ H ₁₂ O	+10.0	30.9	40.8	51.7	63.4	71.0	80.7	95.8	113.7	130.6	-117.2
sec-Amyl alcohol (2-pentanol)		C ₅ H ₁₂ O	+1.5	22.1	32.2	42.6	54.1	61.5	70.7	85.7	102.3	119.7	
tert-Amyl alcohol		C ₈ H ₁₂ O	-12.9	+7.2	17.2	27.9	38.8	46.0	55.3	69.7	85.7	101.7	-11.9
sec-Amylbenzene		C ₁₁ H ₁₆	29.0	55.8	69.2	83.8	100.0	110.4	124.1	145.2	168.0	193.0	
iso-Amyl benzoate		C ₁₂ H ₁₆ O ₂	72.0	104.5	121.6	139.7	158.3	171.4	186.8	210.2	235.8	262.0	
bromide (1-bromo-3-methylbutane)		C ₅ H ₁₁ Br	-20.4	+2.1	13.6	26.1	39.8	48.7	60.4	78.7	99.4	120.4	
n-butrate		C ₆ H ₁₈ O ₂	21.2	47.1	59.9	74.0	90.0	99.8	113.1	133.2	155.3	178.6	
formate		C ₆ H ₁₂ O ₂	-17.5	+5.4	17.1	30.0	44.0	53.3	65.4	83.2	102.7	123.3	
iodide (1-iodo-3-methylbutane)		C ₅ H ₁₁ I	-2.5	+21.9	34.1	47.6	62.3	71.9	84.4	103.8	125.8	148.2	
isobutyrate		C ₆ H ₁₈ O ₂	14.8	40.1	52.8	66.6	81.8	91.7	104.4	124.2	146.0	168.8	
Amyl isopropionate		C ₈ H ₁₆ O ₂	+8.5	33.7	46.3	60.0	75.5	85.2	97.6	117.3	138.4	160.2	
iso-Amyl isovalerate		C ₁₀ H ₂₀ O ₂	27.0	54.4	68.6	83.8	100.6	110.3	125.1	146.1	169.5	194.0	
n-Amyl levulinate		C ₁₀ H ₁₈ O ₃	81.3	110.0	124.0	139.7	155.8	165.2	180.5	203.1	227.4	253.2	
iso-Amyl levulinic		C ₁₀ H ₁₈ O ₃	75.6	104.0	118.8	134.4	151.7	162.6	177.0	198.1	222.7	247.9	
nitrate		C ₅ H ₁₁ NO ₃	+5.2	28.8	40.3	53.5	67.6	76.3	88.6	106.7	126.5	147.5	
4- <i>tert</i> -Amylphenol		C ₁₁ H ₁₆ O	109.8	125.5	142.3	160.3	172.6	189.0	213.0	239.5	266.0	93	
Anethole		C ₁₀ H ₁₂ O	62.6	91.6	106.0	121.8	139.3	149.8	164.2	186.1	210.5	235.3	22.5
Angelonitrile		C ₅ H ₇ N	-8.0	+15.0	28.0	41.0	55.8	65.2	77.5	96.3	117.7	140.0	
Aniline		C ₆ H ₇ N	34.8	57.9	69.4	82.0	96.7	106.0	119.9	140.1	161.9	184.4	-6.2
2-Anilinoethanol		C ₈ H ₁₁ NO	104.0	134.3	149.6	165.7	183.7	194.0	209.5	230.6	254.5	279.6	
Anisaldehyde		C ₆ H ₈ O ₂	73.2	102.6	117.8	133.5	150.5	161.7	176.7	199.0	223.0	248.0	2.5
o-Anisidine (2-methoxyaniline)		C ₇ H ₈ NO	61.0	88.0	101.7	116.1	132.0	142.1	155.2	175.3	197.3	218.5	5.2
Anthracene		C ₁₄ H ₁₀	145.0	173.5	187.2	201.9	217.5	231.8	250.0	279.0	310.2	342.0	217.5
Anthraquinone		C ₉ H ₆ O ₂	190.0	219.4	234.2	248.3	264.3	273.3	285.0	314.6	346.2	379.9	286
Azelaic acid		C ₉ H ₁₆ O ₄	178.3	210.4	225.5	242.4	260.0	271.8	286.5	309.6	332.8	356.5	106.5
Azelaldehyde		C ₉ H ₁₈ O	33.3	58.4	71.6	85.0	100.2	110.0	123.0	142.1	163.4	185.0	
Azobenzene		C ₁₂ H ₁₀ N ₂	103.5	135.7	151.5	168.3	187.9	199.8	216.0	240.0	266.1	293.0	68
Benzal chloride (α,α-Dichlorotoluene)		C ₇ H ₆ Cl ₂	35.4	64.0	78.7	94.3	112.1	123.4	138.3	160.7	187.0	214.0	-16.1
Benzaldehyde		C ₇ H ₆ O	26.2	50.1	62.0	75.0	90.1	99.6	112.5	131.7	154.1	179.0	-26
Benzanthrone		C ₁₇ H ₁₀ O	225.0	274.5	297.2	322.5	350.0	368.8	390.0	426.5			174
Benzene		C ₆ H ₆	-36.7	-19.6	-11.5	-2.6	+7.6	15.4	26.1	42.2	60.6	80.1	+5.5
Benzenesulfonylchloride		C ₆ H ₅ ClO ₂ S	65.9	96.5	112.0	129.0	147.7	158.2	174.5	198.0	224.0	251.5	14.5
Benzil		C ₁₄ H ₁₀ O ₂	128.4	165.2	183.0	202.8	224.5	238.2	255.8	283.5	314.3	347.0	95
Benzoic acid		C ₇ H ₆ O ₂	96.0	119.5	132.1	146.7	162.6	172.8	186.2	205.8	227.0	249.2	121.7
anhydride		C ₁₄ H ₁₀ O ₃	143.8	180.0	198.0	218.0	239.8	252.7	270.4	299.1	328.8	360.0	42
Benzoin		C ₁₄ H ₁₂ O ₂	135.6	170.2	188.1	207.0	227.6	241.7	258.0	284.4	313.5	343.0	132
Benzonitrile		C ₇ H ₅ N	28.2	55.3	69.2	83.4	99.6	109.8	123.5	144.1	166.7	190.6	-12.9
Benzophenone		C ₁₃ H ₁₀ O	108.2	141.7	157.6	175.8	195.7	208.2	224.4	249.8	276.8	305.4	48.5
Benzotrichloride (α,α,α-Trichlorotoluene)		C ₇ H ₅ Cl ₃	45.8	73.7	87.6	102.7	119.8	130.0	144.3	165.6	189.2	213.5	-21.2
Benzotrifluoride (α,α,α-Trifluorotoluene)		C ₇ H ₅ F ₃	-32.0	-10.3	-0.4	12.2	25.7	34.0	45.3	62.5	82.0	102.2	-29.3
Benzoyl bromide		C ₇ H ₅ BrO	47.0	75.4	89.8	105.4	122.6	133.4	147.7	169.2	193.7	218.5	0
chloride		C ₇ H ₅ ClO	32.1	59.1	73.0	87.6	103.8	114.7	128.0	149.5	172.8	197.2	-0.5
nitrile		C ₆ H ₅ NO	44.5	71.7	85.5	100.2	116.6	127.0	141.0	161.3	185.0	208.0	33.5
Benzyl acetate		C ₉ H ₁₀ O ₂	45.0	73.4	87.6	102.3	119.6	129.8	144.0	165.5	189.0	213.5	-51.5
alcohol		C ₇ H ₉ O	58.0	80.8	92.6	105.8	119.8	129.3	141.7	160.0	183.0	204.7	-15.3

*Compiled from the extended tables published by D. R. Stull in *Ind. Eng. Chem.*, **39**, 517 (1947). For information on fuels see Hibbard, N.A.C.A. Research Mem. E56121, 1956. For methane see Johnson (ed.), WADD-TR-60-56, 1960.

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
Benzylamine	C ₇ H ₉ N	29.0	54.8	67.7	81.8	97.3	107.3	120.0	140.0	161.3	184.5	
Benzyl bromide (α -bromotoluene)	C ₇ H ₇ Br	32.2	59.6	73.4	88.3	104.8	115.6	129.8	150.8	175.2	198.5	-4
chloride (α -chlorotoluene)	C ₇ H ₇ Cl	22.0	47.8	60.8	75.0	90.7	100.5	114.2	134.0	155.8	179.4	-39
cinnamate	C ₉ H ₁₄ O ₂	173.8	206.3	221.5	239.3	255.8	267.0	281.5	303.8	326.7	350.0	39
Benzylidchlorosilane	C ₇ H ₅ Cl ₂ Si	45.3	70.2	83.2	96.7	111.8	121.3	133.5	152.0	173.0	194.3	
Benzyl ethyl ether	C ₉ H ₁₂ O	26.0	52.0	65.0	79.6	95.4	105.5	118.9	139.6	161.5	185.0	
phenyl ether	C ₁₃ H ₁₂ O	95.4	127.7	144.0	160.7	180.1	192.6	209.2	233.2	259.8	287.0	
isothiocyanate	C ₈ H ₇ NS	79.5	107.8	121.8	137.0	153.0	163.8	177.7	198.0	220.4	243.0	
Biphenyl	C ₁₂ H ₁₀	70.6	101.8	117.0	134.2	152.5	165.2	180.7	204.2	229.4	254.9	69.5
1-Biphenyloxy-2,3-epoxypropane	C ₁₅ H ₁₄ O ₂	135.3	169.9	187.2	205.8	226.3	239.7	255.0	280.4	309.8	340.0	
d-Bornyl acetate	C ₁₃ H ₂₀ O ₂	46.9	75.7	90.2	106.0	123.7	135.7	149.8	172.0	197.5	223.0	29
Bornyl n-butylate	C ₁₄ H ₂₄ O ₂	74.0	103.4	118.0	133.8	150.7	161.8	176.4	198.0	222.2	247.0	
formate	C ₁ H ₂ O ₂	47.0	74.8	89.3	104.0	121.2	131.7	145.8	166.4	190.2	214.0	
isobutyrate	C ₁₄ H ₂₄ O ₂	70.0	99.8	114.0	130.0	147.2	157.6	172.2	194.2	218.2	243.0	
propionate	C ₁₃ H ₂₂ O ₂	64.6	93.7	108.0	123.7	140.4	151.2	165.7	187.5	211.2	235.0	
Brassicidic acid	C ₂₂ H ₄₂ O ₂	209.6	241.7	256.0	272.9	290.0	301.5	316.2	336.8	359.6	382.5	61.5
Bromoacetic acid	C ₂ H ₃ BrO ₂	54.7	81.6	94.1	108.2	124.0	133.8	146.3	165.8	186.7	208.0	49.5
4-Bromoanisole	C ₇ H ₇ BrO	48.8	77.8	91.9	107.8	125.0	136.0	150.1	172.7	197.5	223.0	12.5
Bromobenzene	C ₆ H ₅ Br	+2.9	27.8	40.0	53.8	68.6	78.1	90.8	110.1	132.3	156.2	-30.7
4-Bromobiphenyl	C ₁₂ H ₉ Br	98.0	133.7	150.6	169.8	190.8	204.5	221.8	248.2	277.7	310.0	90.5
1-Bromo-2-butanol	C ₄ H ₉ BrO	23.7	45.4	55.8	67.2	79.5	87.0	97.6	112.1	128.3	145.0	
1-Bromo-2-butane	C ₄ H ₇ BrO	+6.2	30.0	41.8	54.2	68.2	77.3	89.2	107.0	126.3	147.0	
cis-1-Bromo-1-butene	C ₄ H ₇ Br	-44.0	-23.2	-12.8	-1.4	+11.5	19.8	30.8	47.8	66.8	86.2	
trans-1-Bromo-1-butene	C ₄ H ₇ Br	-38.4	-17.0	-6.4	+5.4	18.4	27.2	38.1	55.7	75.0	94.7	-100.3
2-Bromo-1-butene	C ₄ H ₇ Br	-47.3	-27.0	-16.8	-5.3	+7.2	15.4	26.3	42.8	61.9	81.0	-133.4
cis-2-Bromo-2-butene	C ₄ H ₇ Br	-39.0	-17.9	-7.2	+4.6	17.7	26.2	37.5	54.5	74.0	93.9	-111.2
trans-2-Bromo-2-butene	C ₄ H ₇ Br	-45.0	-24.1	-13.8	-2.4	+10.5	18.7	29.9	46.5	66.0	85.5	-114.6
1,4-Bromochlorobenzene	C ₆ H ₅ BrCl	32.0	59.5	72.7	87.8	103.8	114.8	128.0	149.5	172.6	196.9	
1-Bromo-1-chloroethane	C ₂ H ₄ BrCl	-36.0	-18.0	-9.4	0.0	+10.4	17.0	28.0	44.7	63.4	82.7	16.6
1-Bromo-2-chloroethane	C ₂ H ₃ BrCl	-28.8	-7.0	+4.1	16.0	29.7	38.0	49.5	66.8	86.0	106.7	-16.6
2-Bromo-4,6-dichlorophenol	C ₆ H ₃ BrCl ₂ O	84.0	115.6	130.8	147.7	165.8	177.6	193.2	216.5	242.0	268.0	68
1-Bromo-4-ethyl benzene	C ₈ H ₉ Br	30.4	42.5	74.0	90.2	108.5	121.0	135.5	156.5	182.0	206.0	-45.0
(2-Bromoethyl)-benzene	C ₈ H ₉ Br	48.0	76.2	90.5	105.8	123.2	133.8	148.2	169.8	194.0	219.0	
2-Bromoethyl 2-chloroethyl ether	C ₄ H ₈ BrClO	36.5	63.2	76.3	90.8	106.6	116.4	129.8	150.0	172.3	195.8	
(2-Bromoethyl)-cyclohexane	C ₈ H ₁₅ Br	38.7	66.6	80.5	95.8	113.0	123.7	138.0	160.0	186.2	213.0	
1-Bromoethylene	C ₂ H ₃ Br	-95.4	-77.8	-68.8	-58.8	-48.1	-41.2	-31.9	-17.2	-1.1	+15.8	-138
Bromoform (tribromomethane)	CHBr ₃	22.0	34.0	48.0	63.6	73.4	85.9	106.1	127.9	150.5	185	
1-Bromonaphthalene	C ₁₀ H ₇ Br	84.2	117.5	133.6	150.2	170.2	183.5	198.8	224.2	252.0	281.1	5.5
2-Bromo-4-phenylphenol	C ₁₂ H ₉ BrO	100.0	135.4	152.3	171.8	193.8	207.0	224.5	251.0	280.2	311.0	95
3-Bromopyridine	C ₅ H ₄ BrN	16.8	42.0	55.2	69.1	84.1	94.1	107.8	127.7	150.0	173.4	
2-Bromotoluene	C ₇ H ₇ Br	24.4	49.7	62.3	76.0	91.0	100.0	112.0	133.6	157.3	181.8	-28
3-Bromotoluene	C ₇ H ₇ Br	14.8	50.8	64.0	78.1	93.9	104.1	117.8	138.0	160.0	183.7	39.8
4-Bromotoluene	C ₇ H ₇ Br	10.3	47.5	61.1	75.2	91.8	102.3	116.4	137.4	160.2	184.5	28.5
3-Bromo-2,4,6-trichlorophenol	C ₆ H ₂ BrCl ₃ O	112.4	146.2	163.2	181.8	200.5	213.0	229.3	253.0	278.0	305.8	
2-Bromo-1,4-xylene	C ₈ H ₉ Br	37.5	65.0	78.8	94.0	110.6	121.6	135.7	156.4	181.0	206.7	+9.5
1,2-Butadiene (methyl allene)	C ₄ H ₆	-89.0	-72.7	-64.2	-54.9	-44.3	-37.5	-28.3	-14.2	+1.8	18.5	
1,3-Butadiene	C ₄ H ₆	-102.8	-87.6	-79.7	-71.0	-61.3	-55.1	-46.8	-33.9	-19.3	-4.5	-108.9
n-Butane	C ₄ H ₁₀	-101.5	-85.7	-77.8	-68.9	-59.1	-52.8	-44.2	-31.2	-16.3	-0.5	-135
iso-Butane (2-methylpropane)	C ₄ H ₁₀	-109.2	-94.1	-86.4	-77.9	-68.4	-62.4	-54.1	-41.5	-27.1	-11.7	-145
1,3-Butanediol	C ₄ H ₁₀ O ₂	22.2	67.5	85.3	100.0	117.4	127.5	141.2	161.0	183.8	206.5	77
1,2,3-Butanetriol	C ₄ H ₁₀ O ₃	102.0	132.0	146.0	161.0	178.0	188.0	202.5	222.0	243.5	264.0	
1-Butene	C ₄ H ₈	-104.8	-89.4	-81.6	-73.0	-63.4	-57.2	-48.9	-36.2	-21.7	-6.3	-130
cis-2-Butene	C ₄ H ₈	-96.4	-81.1	-73.4	-64.6	-54.7	-48.4	-39.8	-26.8	-12.0	+3.7	-138.9
trans-2-Butene	C ₄ H ₈	-99.4	-84.0	-76.3	-67.5	-57.6	-51.3	-42.7	-29.7	-14.8	+0.9	-105.4
3-Butenenitrile	C ₄ H ₅ N	-19.6	+2.9	14.1	26.6	40.0	48.8	60.2	78.0	98.0	119.0	
iso-Butyl acetate	C ₆ H ₁₂ O ₂	-21.2	+1.4	12.8	25.5	39.2	48.0	59.7	77.6	97.5	118.0	-98.9
n-Butyl acrylate	C ₇ H ₁₂ O ₂	-0.5	+23.5	35.5	48.6	63.4	72.6	85.1	104.0	125.2	147.4	-64.6
alcohol	C ₄ H ₁₀ O	-1.2	+20.0	30.2	41.5	53.4	60.3	70.1	84.3	100.8	117.5	-79.9
iso-Butyl alcohol	C ₄ H ₁₀ O	-9.0	+11.6	21.7	32.4	44.1	51.7	61.5	75.9	91.4	108.0	-108
sec-Butyl alcohol	C ₄ H ₁₀ O	-12.2	+7.2	16.9	27.3	38.1	45.2	54.1	67.9	83.9	99.5	-114.7
tert-Butyl alcohol	C ₄ H ₁₀ O	-20.4	-3.0	+5.5	14.3	24.5	31.0	39.8	52.7	68.0	82.9	25.3
iso-Butyl amine	C ₄ H ₁₁ N	-50.0	-31.0	-21.0	-10.3	+1.3	8.8	18.8	32.0	50.7	68.6	-85.0
n-Butylbenzene	C ₉ H ₁₄	22.7	48.8	62.0	76.3	92.4	102.6	116.2	136.9	159.2	183.1	-88.0
iso-Butylbenzene	C ₁₀ H ₁₄	14.1	40.5	53.7	67.8	83.3	93.3	107.0	127.2	149.6	172.8	-51.5
sec-Butylbenzene	C ₁₀ H ₁₄	18.6	44.2	57.0	70.6	86.2	96.0	109.5	128.8	150.3	173.5	-75.5
tert-Butylbenzene	C ₁₀ H ₁₄	13.0	39.0	51.7	65.6	80.8	90.6	103.8	123.7	145.8	168.5	-58
iso-Butyl benzoate	C ₁₁ H ₁₄ O ₂	64.0	93.6	108.6	124.2	141.8	152.0	166.4	188.2	212.8	237.0	
n-Butyl bromide (1-bromobutane)	C ₄ H ₉ Br	-33.0	-11.2	-0.3	+11.6	24.8	33.4	44.7	62.0	81.7	101.6	-112.4
iso-Butyl n-butyrate	C ₈ H ₁₆ O ₂	+4.6	30.0	42.2	56.1	71.7	81.3	94.0	113.9	135.7	156.9	
carbamate	C ₅ H ₁₁ NO ₂	83.7	96.4	110.1	125.3	134.6	147.2	165.7	186.0	206.5	231.2	65
Butyl carbitol (diethylene glycol butyl ether)	C ₈ H ₁₈ O ₃	70.0	95.7	107.8	120.5	135.5	146.0	159.8	181.2	205.0	231.2	
n-Butyl chloride (1-chlorobutane)	C ₄ H ₉ Cl	-49.0	-28.9	-18.6	-7.4	+5.0	13.0	24.0	40.0	58.8	77.8	-123.1
iso-Butyl chloride	C ₄ H ₉ Cl	-53.8	-34.3	-24.5	-13.8	-1.9	+5.9	16.0	32.0	50.0	68.9	-131.2

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C	
			1	5	10	20	40	60	100	200	400		
Temperature, °C													
<i>sec</i> -Butyl chloride (2-Chlorobutane)	C ₄ H ₉ Cl	-60.2	-39.8	-29.2	-17.7	-5.0	+3.4	14.2	31.5	50.0	68.0	-131.3	
<i>tert</i> -Butyl chloride	C ₄ H ₉ Cl					-19.0	-11.4	-1.0	+14.6	32.6	51.0	-26.5	
<i>sec</i> -Butyl chloroacetate	C ₆ H ₁₁ ClO ₂	17.0	41.8	54.6	68.2	83.6	93.0	105.5	124.1	146.0	167.8		
2- <i>tert</i> -Butyl-4-cresol	C ₁₁ H ₁₆ O	70.0	98.0	112.0	127.2	143.9	153.7	167.0	187.8	210.0	232.6		
4- <i>tert</i> -Butyl-2-cresol	C ₁₁ H ₁₆ O	74.3	103.7	118.0	134.0	150.8	161.7	176.2	197.8	221.8	247.0		
iso-Butyl dichloroacetate	C ₆ H ₁₀ Cl ₂ O ₂	28.6	54.3	67.5	81.4	96.7	106.6	119.8	139.2	160.0	183.0		
2,3-Butylene glycol (2,3-butanediol)	C ₄ H ₁₀ O ₂	44.0	68.4	80.3	93.4	107.8	116.3	127.8	145.6	164.0	182.0	22.5	
2-Butyl-2-ethylbutane-1,3-diol	C ₁₀ H ₂₀ O ₂	94.1	122.6	136.8	151.2	167.8	178.0	191.9	212.0	233.5	255.0		
2- <i>tert</i> -Butyl-4-ethylphenol	C ₁₂ H ₁₅ O	76.3	106.2	121.0	137.0	154.0	165.4	179.0	200.3	223.8	247.8		
<i>n</i> -Butyl formate	C ₅ H ₁₀ O ₂	-26.4	-4.7	+6.1	18.0	31.6	39.8	51.0	67.9	86.2	106.0		
iso-Butyl formate	C ₅ H ₁₀ O ₂	-32.7	-11.4	-0.8	+11.0	24.1	32.4	43.4	60.0	79.0	98.2	-95.3	
<i>sec</i> -Butyl formate	C ₅ H ₁₀ O ₂	-34.4	-13.3	-3.1	+8.4	21.3	29.6	40.2	56.8	75.2	93.6		
<i>sec</i> -Butyl glycolate	C ₆ H ₁₂ O ₃	28.3	53.6	66.0	79.8	94.2	104.0	116.4	135.5	155.6	177.5		
iso-Butyl iodide (1-iodo-2-methylpropane)	C ₄ H ₉ I	-17.0	+5.8	17.0	29.8	42.8	51.8	63.5	81.0	100.3	120.4	-90.7	
isobutyrate	C ₅ H ₁₀ O ₂	+4.1	28.0	39.9	52.4	67.2	75.9	88.0	106.3	126.3	147.5	-80.7	
isovalerate	C ₆ H ₁₂ O ₂	16.0	41.2	53.8	67.7	82.7	92.4	105.2	124.8	146.4	168.7		
levulinic acid	C ₆ H ₁₀ O ₃	65.0	92.1	105.9	120.2	136.2	147.0	160.2	181.8	205.5	229.9		
naphthalketone (1-isovaleronaphthone)	C ₁₅ H ₁₆ O	136.0	167.9	184.0	201.6	219.7	231.5	246.7	269.7	294.0	320.0		
2- <i>sec</i> -Butylphenol	C ₁₀ H ₁₄ O	57.4	86.0	100.8	116.1	133.4	143.9	157.3	179.7	203.8	228.0		
2- <i>tert</i> -Butylphenol	C ₁₀ H ₁₄ O	56.6	84.2	98.1	113.0	129.2	140.0	153.5	173.8	196.3	219.5		
4-iso-Butylphenol	C ₁₀ H ₁₄ O	72.1	100.9	115.5	130.3	147.2	157.0	171.2	192.1	214.7	237.0		
4- <i>sec</i> -Butylphenol	C ₁₀ H ₁₄ O	71.4	100.5	114.8	130.3	147.8	157.9	172.4	194.3	217.6	242.1		
4- <i>tert</i> -Butylphenol	C ₁₀ H ₁₄ O	70.0	99.2	114.0	129.5	146.0	156.0	170.2	191.5	214.0	238.0	99	
2-(4- <i>tert</i> -Butylphenoxy)ethyl acetate	C ₁₄ H ₂₀ O ₃	118.0	150.0	165.8	183.3	201.5	212.8	228.0	250.3	277.6	304.4		
4- <i>tert</i> -Butylphenyl dichlorophosphate	C ₁₀ H ₁₃ Cl ₂ O ₂ P	96.0	129.6	146.0	164.0	184.3	197.2	214.3	240.0	268.2	299.0		
<i>tert</i> -Butyl phenyl ketone (pivalophenone)	C ₁₁ H ₁₄ O	57.8	85.7	99.0	114.3	130.4	140.8	154.0	175.0	197.7	220.0		
iso-Butyl propionate	C ₇ H ₁₄ O ₂	-2.3	+20.9	32.3	44.8	58.5	67.6	79.5	97.0	116.4	136.8	-71	
4- <i>tert</i> -Butyl-2,5-xylenol	C ₁₂ H ₁₈ O	88.2	119.8	135.0	151.0	169.8	180.3	195.0	217.5	241.3	265.3		
4- <i>tert</i> -Butyl-2,6-xylenol	C ₁₂ H ₁₈ O	74.0	103.9	119.0	135.0	152.2	163.6	176.0	196.0	217.8	239.8		
6- <i>tert</i> -Butyl-2,4-xylenol	C ₁₂ H ₁₈ O	70.3	100.2	115.0	131.0	148.5	158.2	172.0	192.3	214.2	236.5		
6- <i>tert</i> -Butyl-3,4-xylenol	C ₁₂ H ₁₈ O	83.9	113.6	127.0	143.0	159.7	170.0	184.0	204.5	226.7	249.5		
Butyric acid	C ₄ H ₈ O ₂	25.5	49.8	61.5	74.0	88.0	96.5	108.0	125.5	144.5	163.5	-74	
iso-Butyric acid	C ₄ H ₈ O ₂	14.7	39.3	51.2	64.0	77.8	86.3	98.0	115.8	134.5	154.5	-47	
Butyronitrile	C ₄ H ₇ N	-20.0	+2.1	13.4	25.7	38.4	47.3	59.0	76.7	96.8	117.5		
iso-Valerophenone	C ₁₁ H ₁₄ O	58.3	87.0	101.4	116.8	133.8	144.6	158.0	180.1	204.2	228.0		
Campophene	C ₁₀ H ₁₆				47.2	60.4	75.7	85.0	97.9	117.5	138.7	160.5	50
Campholenic acid	C ₁₀ H ₁₆ O ₂	97.6	125.7	139.8	153.9	170.0	180.0	193.7	212.7	234.0	256.0		
d-Camphor	C ₁₀ H ₁₆ O	41.5	68.6	82.3	97.5	114.0	124.0	138.0	157.9	182.0	209.2	178.5	
Camphylamine	C ₁₀ H ₁₉ N	45.3	74.0	83.7	97.6	112.5	122.0	134.6	153.0	173.8	195.0		
Capraldehyde	C ₁₀ H ₂₀ O	51.9	78.8	92.0	106.3	122.2	132.0	145.3	164.8	186.3	208.5		
Caprylic acid	C ₈ H ₁₆ O ₂	125.0	142.0	152.2	165.0	179.9	189.8	200.0	217.1	240.3	268.4	31.5	
<i>n</i> -Caproic acid	C ₆ H ₁₂ O ₂	71.4	89.5	99.5	111.8	125.0	133.3	144.0	160.8	181.0	202.0	-1.5	
iso-Caproic acid	C ₆ H ₁₂ O ₂	66.2	83.0	94.0	107.0	120.4	129.6	141.4	158.3	181.0	207.7	-35	
iso-Caprolactone	C ₆ H ₁₀ O ₂	38.3	66.4	80.3	95.7	112.3	123.2	137.2	157.8	182.1	207.0		
Capronitrile	C ₆ H ₁₁ N	9.2	34.6	47.5	61.7	76.9	86.8	99.8	119.7	141.0	163.7		
Capryl alcohol (2-octanol)	C ₈ H ₁₈ O	32.8	57.6	70.0	83.3	98.0	107.4	119.8	138.0	157.5	178.5	-38.6	
Caprylaldehyde	C ₈ H ₁₆ O	73.4	92.0	101.2	110.2	120.0	126.0	133.9	145.4	156.5	168.5		
Caprylic acid (octanoic acid)	C ₈ H ₁₆ O ₂	92.3	114.1	124.0	136.4	150.6	160.0	172.2	190.3	213.9	237.5	16	
Caprylonitrile	C ₈ H ₁₅ N	43.0	67.6	80.4	94.6	110.6	121.2	134.8	155.2	179.5	204.5		
Carbazole	C ₁₂ H ₉ N					248.2	265.0	292.5	323.0	354.8	374.8		
Carbon dioxide	CO ₂	-134.3	-124.4	-119.5	-114.4	-108.6	-104.8	-100.2	-93.0	-85.7	-78.2	-57.5	
disulfide	CS ₂	-73.8	-54.3	-44.7	-34.3	-22.5	-15.3	-5.1	+10.4	28.0	46.5	-110.8	
monoxide	CO	-222.0	-217.2	-215.0	-212.8	-210.0	-208.1	-205.7	-201.3	-196.3	-191.3	-205.0	
oxyselenide (carbonyl selenide)	COSe	-117.1	-102.3	-95.0	-86.3	-76.4	-70.2	-61.7	-49.8	-35.6	-21.9		
oxysulfide (carbonyl sulfide)	COS	-132.4	-119.8	-113.3	-106.0	-98.3	-93.0	-85.9	-75.0	-62.7	-49.9	-138.8	
tetrabromide	CCl ₄	-50.0	-30.0	-19.6	-8.2	+4.3	12.3	23.0	38.3	57.8	76.7	-22.6	
tetrachloride	CF ₄	-184.6	-174.1	-169.3	-164.3	-158.8	-155.4	-150.7	-143.6	-135.5	-127.7	-183.7	
Carvacrol	C ₁₀ H ₁₄ O	70.0	98.4	113.2	127.9	145.2	155.3	169.7	191.2	213.8	237.0	+0.5	
Carvone	C ₁₀ H ₁₄ O	57.4	86.1	100.4	116.1	133.0	143.8	157.3	179.6	203.5	227.5		
Chavibetol	C ₁₀ H ₁₂ O ₂	83.6	113.3	127.0	143.2	159.8	170.7	185.5	206.8	229.8	254.0		
Chloral (trichloroacetaldehyde)	C ₃ H ₃ Cl ₃ O	-37.8	-16.0	-5.0	+7.2	20.2	29.1	40.2	57.8	77.5	97.7	-57	
hydrate (trichloroacetaldehyde hydrate)	C ₂ H ₃ Cl ₃ O ₂	-9.8	+10.0	19.5	29.2	39.7	46.2	55.0	68.0	82.1	96.2	51.7	
Chloranil	C ₆ Cl ₄ O ₂	70.7	89.3	97.8	106.4	116.1	122.0	129.5	140.3	151.3	162.6	290	
Chloroacetic acid anhydride	C ₂ H ₃ ClO ₂	43.0	68.3	81.0	94.2	109.2	118.3	130.7	149.0	169.0	189.5	61.2	
2-Chloroaniline	C ₆ H ₅ ClN	67.2	94.1	108.0	122.4	138.2	148.0	159.8	177.8	197.0	217.0	46	
3-Chloroaniline	C ₆ H ₅ ClN	46.3	72.3	84.8	99.2	115.6	125.7	139.5	160.0	183.7	208.8	0	
4-Chloroaniline	C ₆ H ₅ ClN	59.3	87.9	102.1	117.8	135.0	145.8	159.9	182.3	206.6	230.5	70.5	
Chlorobenzene	C ₆ H ₅ Cl	-13.0	+10.6	22.2	35.3	49.7	58.3	70.7	89.4	110.0	132.2	-45.2	
2-Chlorobenzotrichloride (2- α , α , α -tetrachlorotoluene)	C ₇ H ₄ Cl ₄	69.0	101.8	117.9	135.8	155.0	167.8	185.0	208.0	233.0	262.1	28.7	

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg										Melting point, °C
			1	5	10	20	40	60	100	200	400	760	
2-Chlorobenzotrifluoride (2-chloro- α,α,α -trifluorotoluene)	C ₇ H ₆ ClF ₃	0.0	24.7	37.1	50.6	65.9	75.4	88.3	108.3	130.0	152.2	-6.0	
2-Chlorobiphenyl	C ₁₂ H ₉ Cl	89.3	109.8	134.7	151.2	169.9	182.1	197.0	219.6	243.8	267.5	34	
4-Chlorobiphenyl	C ₁₂ H ₉ Cl	96.4	129.8	146.0	164.0	183.8	196.0	212.5	237.8	264.5	292.9	75.5	
α -Chlorocrotonic acid	C ₄ H ₅ ClO ₂	70.0	95.6	108.0	121.2	135.6	144.4	155.9	173.8	193.2	212.0		
Chlorodifluoromethane	CHClF ₂	-122.8	-110.2	-103.7	-96.5	-88.6	-83.4	-76.4	-65.8	-53.6	-40.8	-160	
Chlorodimethylphenylsilane	C ₈ H ₁₁ ClSi	29.8	56.7	70.0	84.7	101.2	111.5	124.7	145.5	168.6	193.5		
1-Chloro-2-ethoxybenzene	C ₈ H ₉ ClO	45.8	72.8	86.5	101.5	117.8	127.8	141.8	162.0	185.5	208.0		
2-(2-Chloroethoxy) ethanol	C ₄ H ₉ ClO ₂	53.0	78.3	90.7	104.1	118.4	127.5	139.5	157.2	176.5	196.0		
bis-2-Chloroethyl acetacetal	C ₆ H ₁₂ Cl ₂ O ₂	56.2	83.7	97.6	112.2	127.8	138.0	150.7	169.8	190.5	212.6		
1-Chloro-2-ethylbenzene	C ₈ H ₉ Cl	17.2	43.0	56.1	70.3	86.2	96.4	110.0	130.2	152.2	177.6	-80.2	
1-Chloro-3-ethylbenzene	C ₈ H ₉ Cl	18.6	45.2	58.1	73.0	89.2	99.6	113.6	133.8	156.7	181.1	-53.3	
1-Chloro-4-ethylbenzene	C ₈ H ₉ Cl	19.2	46.4	60.0	75.5	91.8	102.0	116.0	137.0	159.8	184.3	-62.6	
2-Chloroethyl chloroacetate	C ₄ H ₆ Cl ₂ O ₂	46.0	72.1	86.0	100.0	116.0	126.2	140.0	159.8	182.2	205.0		
2-Chloroethyl 2-chloroisopropyl ether	C ₅ H ₁₀ Cl ₂ O	24.7	50.1	63.0	77.2	92.4	102.2	115.8	135.7	156.5	180.0		
2-Chloroethyl 2-chloropropyl ether	C ₅ H ₁₀ Cl ₂ O	29.8	56.5	70.0	84.8	101.5	111.8	125.6	146.3	169.8	194.1		
2-Chloroethyl α -methylbenzyl ether	C ₁₀ H ₁₃ ClO	62.3	91.4	106.0	121.8	139.6	150.0	164.8	186.3	210.8	235.0		
Chloroform (trichloromethane)	CHCl ₃	-58.0	-39.1	-29.7	-19.0	-7.1	+0.5	10.4	25.9	42.7	61.3	-63.5	
1-Chloronaphthalene	C ₁₀ H ₇ Cl	80.6	104.8	118.6	134.4	153.2	165.6	180.4	204.2	230.8	259.3	-20	
4-Chlorophenethyl alcohol	C ₈ H ₉ ClO	84.0	114.3	129.0	145.0	162.0	173.5	188.1	210.0	234.5	259.3		
2-Chlorophenol	C ₆ H ₅ ClO	12.1	38.2	51.2	65.9	82.0	92.0	106.0	126.4	149.8	174.5	7	
3-Chlorophenol	C ₆ H ₅ ClO	44.2	72.0	86.1	101.7	118.0	129.4	143.0	164.8	188.7	214.0	32.5	
4-Chlorophenol	C ₆ H ₅ ClO	49.8	78.2	92.2	108.1	125.0	136.1	150.0	172.0	196.0	220.0	42	
2-Chloro-3-phenylphenol	C ₁₂ H ₉ ClO	118.0	152.2	169.7	186.7	207.4	219.6	237.0	261.3	289.4	317.5	+6	
2-Chloro-6-phenylphenol	C ₁₂ H ₉ ClO	119.8	153.7	170.7	189.8	208.2	220.0	237.1	261.6	289.5	317.0		
Chloropicrin (trichloronitromethane)	CCl ₃ NO ₂	-25.5	-3.3	+7.8	20.0	33.8	42.3	53.8	71.8	91.8	111.9	-64	
1-Chloropropene	C ₃ H ₅ Cl	-81.3	-63.4	-54.1	-44.0	-32.7	-25.1	-15.1	+1.3	18.0	37.0	-99.0	
2-Chloropyridine	C ₅ H ₄ ClN	13.3	38.8	51.7	65.8	81.7	91.6	104.6	125.0	147.7	170.2		
3-Chlorostyrene	C ₈ H ₇ Cl	25.3	51.3	65.2	80.0	96.5	107.2	121.2	142.2	165.7	190.0		
4-Chlorostyrene	C ₈ H ₇ Cl	28.0	54.5	67.5	82.0	98.0	108.5	122.0	143.5	166.0	191.0	-15.0	
1-Chlorotetradecane	C ₁₄ H ₂₉ Cl	98.5	131.8	148.2	166.2	187.0	199.8	215.5	240.3	267.5	296.0	+0.9	
2-Chlorotoluene	C ₇ H ₇ Cl	+5.4	30.6	43.2	56.9	72.0	81.8	94.7	115.0	137.1	159.3		
3-Chlorotoluene	C ₇ H ₇ Cl	+4.8	30.3	43.2	57.4	73.0	83.2	96.3	116.6	139.7	162.3		
4-Chlorotoluene	C ₇ H ₇ Cl	+5.5	31.0	43.8	57.8	73.5	83.3	96.6	117.1	139.8	162.3	+7.3	
Chlorotriethylsilane	C ₆ H ₁₅ ClSi	-4.9	+19.8	32.0	45.5	60.2	69.5	82.3	101.6	123.6	146.3		
1-Chloro-1,2,2-trifluoroethylene	C ₂ ClF ₃	-116.0	-102.5	-95.9	-88.2	-79.7	-74.1	-66.7	-55.0	-41.7	-27.9	-157.5	
Chlorotrifluoromethane	CClF ₃	-149.5	-139.2	-134.1	-128.5	-121.9	-117.3	-111.7	-102.5	-92.7	-81.2		
Chlorotrimethylsilane	C ₃ H ₉ ClSi	-62.8	-43.6	-34.0	-23.2	-11.4	-4.0	+6.0	+21.9	39.4	57.9		
<i>trans</i> -Cinnamic acid	C ₉ H ₈ O ₂	127.5	157.8	173.0	189.5	207.1	217.8	232.4	253.3	276.7	300.0	133	
Cinnamyl alcohol	C ₉ H ₁₀ O	72.6	102.5	117.8	133.7	151.0	162.0	177.8	199.8	224.6	250.0	33	
Cinnamylaldehyde	C ₉ H ₈ O	76.1	105.8	120.0	135.7	152.2	163.7	177.7	199.3	222.4	246.0	-7.5	
Citraconic anhydride	C ₅ H ₄ O ₃	47.1	74.8	88.9	103.8	120.3	131.3	145.4	165.8	189.8	213.5		
<i>cis</i> - α -Citral	C ₉ H ₁₆ O	61.7	90.0	103.9	119.4	135.9	146.3	160.0	181.8	205.0	228.0		
<i>d</i> -Citronellal	C ₁₀ H ₁₈ O	44.0	71.4	84.8	99.8	116.1	126.2	140.1	160.0	183.8	206.5		
Citronellic acid	C ₁₀ H ₁₈ O ₂	99.5	127.3	141.4	155.6	171.9	182.1	195.4	214.5	236.6	257.0		
Citronellol	C ₁₀ H ₁₉ O	66.4	93.6	107.0	121.5	137.2	147.2	159.8	179.8	201.0	221.5		
Citronellyl acetate	C ₁₂ H ₂₂ O ₂	74.7	100.2	113.0	126.0	140.5	149.7	161.0	178.8	197.8	217.0		
Coumarin	C ₉ H ₆ O ₂	106.0	137.8	153.4	170.0	189.0	200.5	216.5	240.0	264.7	291.0	70	
<i>o</i> -Cresol (2-cresol; 2-methylphenol)	C ₇ H ₈ O	38.2	64.0	76.7	90.5	105.8	115.5	127.4	146.7	168.4	190.8	30.8	
<i>m</i> -Cresol (3-cresol; 3-methylphenol)	C ₇ H ₈ O	52.0	76.0	87.8	101.4	116.0	125.8	138.0	157.3	179.0	202.8	10.9	
<i>p</i> -Cresol (4-cresol; 4-methylphenol)	C ₇ H ₈ O	53.0	76.5	88.6	102.3	117.7	127.0	140.0	157.3	179.4	201.8	35.5	
<i>cis</i> -Crotonic acid	C ₄ H ₆ O ₂	33.5	57.4	69.0	82.0	96.0	104.5	116.3	133.9	152.2	171.9	15.5	
<i>trans</i> -Crotonic acid	C ₄ H ₆ O ₂	33.5	57.4	80.0	93.0	107.8	116.7	128.0	146.0	165.5	185.0	72	
<i>cis</i> -Crotononitrile	C ₄ H ₅ N	-29.0	-7.1	+4.0	16.4	30.0	38.5	50.1	68.0	88.0	108.0		
<i>trans</i> -Crotononitrile	C ₄ H ₅ N	-19.5	+3.5	15.0	27.8	41.8	50.9	62.8	81.1	101.5	122.8		
Cumene	C ₉ H ₁₂	+2.9	26.8	38.3	51.5	66.1	75.4	88.1	107.3	129.2	152.4	-96.0	
4-Cumidene	C ₉ H ₁₃ N	60.0	88.2	102.2	117.8	134.2	145.0	158.0	180.0	203.2	227.0		
Cuminal	C ₁₀ H ₁₂ O ₂	58.0	87.3	102.0	117.9	135.2	146.0	160.0	182.8	206.7	232.0		
Cuminalyl alcohol	C ₁₀ H ₁₁ O	74.2	103.7	118.0	133.8	150.3	161.7	176.2	197.9	221.7	246.6		
2-Cyano-2- <i>n</i> -butyl acetate	C ₇ H ₁₁ NO ₂	42.0	68.7	82.0	96.2	111.8	121.5	133.8	152.2	173.4	195.2		
Cyanogen	C ₂ N ₂	-95.8	-83.2	-76.8	-70.1	-62.7	-57.9	-51.8	-42.6	-33.0	-21.0	-34.4	
bromide	CBrN	-35.7	-18.3	-10.0	-1.0	+8.6	14.7	22.6	33.8	46.0	61.5	58	
chloride	CClN	-76.7	-61.4	-53.8	-46.1	-37.5	-32.1	-24.9	-14.1	-2.3	+13.1	-6.5	
iodide	CIN	25.2	47.2	57.7	68.6	80.3	88.0	97.6	111.5	126.1	141.1		
Cyclobutane	C ₄ H ₈	-92.0	-76.0	-67.9	-58.7	-48.4	-41.8	-32.8	-18.9	-3.4	+12.9	-50	
Cyclobutene	C ₄ H ₆	-99.1	-83.4	-75.4	-66.6	-56.4	-50.0	-41.2	-27.8	-12.2	+2.4		
Cyclohexane	C ₆ H ₁₂	-45.3	-25.4	-15.9	-5.0	+6.7	14.7	25.5	42.0	60.8	80.7	+6.6	
Cyclohexaneethanol	C ₆ H ₁₆ O	50.4	77.2	90.0	104.0	119.8	129.8	142.7	161.7	183.5	205.4		
Cyclohexanol	C ₆ H ₁₂ O	21.0	44.0	56.0	68.8	83.0	91.8	103.7	121.7	141.4	161.0	23.9	
Cyclohexanone	C ₆ H ₁₀ O	+1.4	26.4	38.7	52.5	67.8	77.5	90.4	110.3	132.5	155.6	-45.0	
2-Cyclohexyl-4,6-dinitrophenol	C ₁₂ H ₁₄ N ₂ O ₅	132.8	161.8	175.9	191.2	206.7	216.0	229.0	248.7	269.8	291.5		
Cyclopentane	C ₅ H ₁₀	-68.0	-49.6	-40.4	-30.1	-18.6	-11.3	-1.3	+13.8	31.0	49.3	-93.7	
Cyclopropane	C ₃ H ₆	-116.8	-104.2	-97.5	-90.3	-82.3	-77.0	-70.0	-59.1	-46.9	-33.5	-126.6	
Cymene	C ₁₀ H ₁₄	17.3	43.9	57.0	71.1	87.0	97.2	110.8	131.4	153.5	177.2	-68.2	

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
Temperature, °C												
cis-Decalin	C ₁₀ H ₁₈	22.5	50.1	64.2	79.8	97.2	108.0	123.2	145.4	169.9	194.6	-43.3
trans-Decalin	C ₁₀ H ₁₈	-0.8	+30.6	47.2	65.3	85.7	98.4	114.6	136.2	160.1	186.7	-30.7
Decane	C ₁₀ H ₂₂	16.5	42.3	55.7	69.8	85.5	95.5	108.6	128.4	150.6	174.1	-29.7
Decan-2-one	C ₁₀ H ₂₀ O	44.2	71.9	85.8	100.7	117.1	127.8	142.0	163.2	186.7	211.0	+3.5
1-Decene	C ₁₀ H ₂₀	14.7	40.3	53.7	67.8	83.3	93.5	106.5	126.7	149.2	172.0	
Decyl alcohol	C ₁₀ H ₂₀ O	69.5	97.3	111.3	125.8	142.1	152.0	165.8	186.2	208.8	231.0	+7
Decyltrimethylsilane	C ₁₃ H ₃₀ Si	67.4	96.4	111.0	126.5	140.0	154.3	169.5	191.0	215.5	240.0	
Dehydroacetic acid	C ₅ H ₈ O ₄	91.7	122.0	137.3	153.0	171.0	181.5	197.5	219.5	244.5	269.0	
Desoxybenzoin	C ₁₄ H ₁₂ O	123.3	156.2	173.5	192.0	212.0	224.5	241.3	265.2	293.0	321.0	60
Diacetamide	C ₄ H ₇ NO ₂	70.0	95.0	108.0	122.6	138.2	148.0	160.6	180.8	202.0	223.0	78.5
Diacetylene (1,3-butadiyne)	C ₄ H ₂	-82.5	-68.0	-61.2	-53.8	-45.9	-41.0	-34.0	-20.9	-6.1	+9.7	-34.9
Diallyldichlorosilane	C ₆ H ₁₀ Cl ₂ Si	+9.5	34.8	47.4	61.3	76.4	86.3	99.7	119.4	142.0	165.3	
Diallyl sulfide	C ₆ H ₁₀ S	-9.5	+14.4	26.6	39.7	54.2	63.7	75.8	94.8	116.1	138.6	-83
Diisoamyl ether	C ₁₀ H ₂₂ O	18.6	44.3	57.0	70.7	86.3	96.0	109.6	129.0	150.3	173.4	
oxalate	C ₁₂ H ₂₂ O ₄	85.4	116.0	131.4	147.7	165.7	177.0	192.2	215.0	240.0	265.0	
sulfide	C ₁₀ H ₂₂ S	43.0	73.0	87.6	102.7	120.0	130.6	145.3	166.4	191.0	216.0	
Dibenzylamine	C ₁₄ H ₁₅ N	118.3	149.8	165.6	182.2	200.2	212.2	227.3	249.8	274.3	300.0	-26
Dibenzyl ketone (1,3-diphenyl-2-propanone)	C ₁₅ H ₁₄ O	125.5	159.8	177.6	195.7	216.6	229.4	246.6	272.3	301.7	330.5	34.5
1,4-Dibromobenzene	C ₆ HBr ₂	61.0	79.3	87.7	103.6	120.8	131.6	146.5	168.5	192.5	218.6	87.5
1,2-Dibromobutane	C ₄ H ₈ Br ₂	7.5	33.2	46.1	60.0	76.0	86.0	99.8	120.2	143.5	166.3	-64.5
dL-2,3-Dibromobutane	C ₄ H ₉ Br ₂	+5.0	30.0	41.6	56.4	72.0	82.0	95.3	115.7	138.0	160.5	
meso-2,3-Dibromobutane	C ₄ H ₉ Br ₂	+1.5	26.6	39.3	53.2	68.0	78.0	91.7	111.8	134.2	157.3	-34.5
1,2-Dibromodecane	C ₁₀ H ₂₀ Br ₂	95.7	123.6	137.3	151.0	167.4	177.5	190.2	209.6	229.8	250.4	
Di(2-bromoethyl) ether	C ₄ H ₈ Br ₂ O	47.7	75.3	85.5	103.6	119.8	130.0	144.0	165.0	188.0	212.5	
α,β-Dibromomaleic anhydride	C ₄ H ₂ Br ₂ O ₃	50.0	78.0	92.0	106.7	123.5	133.8	147.7	168.0	192.0	215.0	
1,2-Dibromo-2-methylpropane	C ₄ H ₈ Br ₂	-28.8	-3.0	+10.5	25.7	42.3	53.7	68.8	92.1	119.8	149.0	-70.3
1,3-Dibromo-2-methylpropane	C ₄ H ₈ Br ₂	14.0	40.0	53.0	67.5	83.5	93.7	107.4	117.8	150.6	174.6	
1,2-Dibromopentane	C ₅ H ₁₀ Br ₂	19.8	45.4	58.0	72.0	87.4	97.4	110.1	130.2	151.8	175.0	
1,2-Dibromopropane	C ₃ H ₆ Br ₂	-7.0	+17.3	29.4	42.3	57.2	66.4	78.7	97.8	118.5	141.6	-55.5
1,3-Dibromopropane	C ₃ H ₆ Br ₂	+9.7	35.4	48.0	62.1	77.8	87.8	101.3	121.7	144.1	167.5	-34.4
2,3-Dibromopropene	C ₃ H ₆ Br ₂	-6.0	+17.9	30.0	43.2	57.8	67.0	79.5	98.0	119.5	141.2	
2,3-Dibromo-1-propanol	C ₃ H ₆ Br ₂ O	57.0	84.5	98.2	113.5	129.8	140.0	153.0	173.8	196.0	219.0	
Diisobutylamine	C ₈ H ₁₉ N	-5.1	+18.4	30.6	43.7	57.8	67.0	79.2	97.6	118.0	139.5	-70
2,6-Ditert-butyl-4-cresol	C ₁₅ H ₂₄ O	85.8	116.2	131.0	147.0	164.1	175.2	190.0	212.8	237.6	262.5	
4,6-Ditert-butyl-2-cresol	C ₁₅ H ₂₄ O	86.2	117.3	132.4	149.0	167.4	179.0	194.0	217.5	243.4	269.3	
4,6-Ditert-butyl-3-cresol	C ₁₅ H ₂₄ O	103.7	135.2	150.0	167.0	185.3	196.1	211.0	233.0	257.1	282.0	
2,6-Ditert-butyl-4-ethylphenol	C ₁₆ H ₂₆ O	89.1	121.4	137.0	154.0	172.1	183.9	198.0	220.0	244.0	268.6	
4,6-Ditert-butyl-3-ethylphenol	C ₁₆ H ₂₆ O	111.5	142.6	157.4	174.0	192.3	204.4	218.0	241.7	264.6	290.0	
Diisobutyl oxalate	C ₁₀ H ₁₈ O ₄	63.2	91.2	105.3	120.3	137.5	147.8	161.8	183.5	205.8	229.5	
2,4-Ditert-butylphenol	C ₁₄ H ₂₂ O	84.5	115.4	130.0	146.0	164.3	175.8	190.0	212.5	237.0	260.8	
Dimethyl phthalate	C ₁₀ H ₂₂ O ₄	148.2	182.1	198.2	216.2	235.8	247.8	263.7	287.0	313.5	340.0	
sulfide	C ₈ H ₁₈ S	+21.7	51.8	66.4	80.5	96.0	105.8	118.6	138.0	159.0	182.0	-79.7
Diisobutyl d-tartrate	C ₁₂ H ₂₂ O ₆	117.8	151.8	169.0	188.0	208.5	221.6	239.5	264.7	294.0	324.0	73.5
Dicarvacryl-monoo-(6-chloro-2-xenyl) phosphate	C ₃₂ H ₃₄ ClO ₄ P	204.2	234.5	249.3	264.5	280.5	290.7	304.9	323.8	342.0	361.0	
Dicarvacryl-2-tolyl phosphate	C ₂₇ H ₃₀ O ₄ P	180.2	209.3	221.8	237.0	251.5	260.3	272.5	290.0	309.8	330.0	
Dichloroacetic acid	C ₂ H ₂ Cl ₂ O ₂	44.0	69.8	82.6	96.3	111.8	121.5	134.0	152.3	173.7	194.4	9.7
1,2-Dichlorobenzene	C ₆ H ₄ Cl ₂	20.0	46.0	59.1	73.4	89.4	99.5	112.9	133.4	155.8	179.0	-17.6
1,3-Dichlorobenzene	C ₆ H ₄ Cl ₂	12.1	39.0	52.0	66.2	82.0	92.2	105.0	125.9	149.0	173.0	-24.2
1,4-Dichlorobenzene	C ₆ H ₄ Cl ₂			54.8	69.2	84.8	95.2	108.4	128.3	150.2	173.9	53.0
1,2-Dichlorobutane	C ₄ H ₈ Cl ₂	-23.6	-0.3	+11.5	24.5	37.7	47.8	60.2	79.7	100.8	123.5	
2,3-Dichlorobutane	C ₄ H ₉ Cl ₂	-25.2	-3.0	+8.5	21.2	35.0	43.9	56.0	74.0	94.2	116.0	-80.4
1,2-Dichloro-1,2-difluoroethylene	C ₂ Cl ₂ F ₂	-82.0	-65.6	-57.3	-48.3	-38.2	-31.8	-23.0	-10.0	+5.0	20.9	-112
Dichlorodifluoromethane	CCl ₂ F ₂	-118.5	-104.6	-97.8	-90.1	-81.6	-76.1	-68.6	-57.0	-43.9	-29.8	
Dichlorodiphenyl silane	C ₁₂ H ₁₀ Cl ₂ Si	109.6	142.4	158.0	176.0	195.5	207.5	223.8	248.0	275.5	304.0	
Dichlorodipropyl ether	C ₆ H ₁₂ Cl ₂ O	29.6	55.2	68.2	82.2	97.3	106.9	119.7	139.0	159.8	182.7	
Di(2-chloroethoxy) methane	C ₅ H ₁₀ Cl ₂ O ₂	53.0	80.4	94.0	109.5	125.5	135.8	149.6	170.0	192.0	215.0	
Dichloroethoxymethylsilane	C ₅ H ₈ Cl ₂ O ₂ Si	-33.8	-12.1	-1.3	+11.3	24.4	32.6	44.1	61.0	80.3	100.6	
1,2-Dichloro-3-ethylbenzene	C ₈ H ₈ Cl ₂	46.0	75.0	90.0	105.9	123.8	135.0	149.8	172.0	197.0	222.1	-40.8
1,2-Dichloro-4-ethylbenzene	C ₈ H ₈ Cl ₂	47.0	77.2	92.3	109.6	127.5	139.0	153.3	176.0	201.7	226.6	-76.4
1,4-Dichloro-2-ethylbenzene	C ₈ H ₈ Cl ₂	38.5	68.0	83.2	99.8	118.0	129.0	144.0	166.2	191.5	216.3	-61.2
cis-1,2-Dichloroethylene	C ₂ H ₂ Cl ₂	-58.4	-39.2	-29.9	-19.4	-7.9	-0.5	+9.5	24.6	41.0	59.0	-80.5
trans-1,2-Dichloro ethylene	C ₂ H ₂ Cl ₂	-65.4	-47.2	-38.0	-28.0	-17.0	-10.0	-0.2	+14.3	30.8	47.8	-50.0
Di(2-chloroethyl) ether	C ₄ H ₈ Cl ₂ O	23.5	49.3	62.0	76.0	91.5	101.5	114.5	134.0	155.4	178.5	
Dichlorofluoromethane	CHCl ₂ F	-91.3	-75.5	-67.5	-58.6	-48.8	-42.6	-33.9	-20.9	-6.2	+8.9	-135
1,5-Dichlorohexamethyltrisiloxane	C ₆ H ₁₈ Cl ₂ O ₃ Si ₃	26.0	52.0	65.1	79.0	94.8	105.0	118.2	138.3	160.2	184.0	-53.0
Dichloromethylphenylsilane	C ₇ H ₈ Cl ₂ Si	35.7	63.5	77.4	92.4	109.5	120.0	134.2	155.5	180.2	205.5	
1,1-Dichloro-2-methylpropane	C ₄ H ₈ Cl ₂	-31.0	-8.4	+2.6	14.6	28.2	37.0	48.2	65.8	85.4	106.0	
1,2-Dichloro-2-methylpropane	C ₄ H ₈ Cl ₂	-25.8	-4.2	+6.7	18.7	32.0	40.2	51.7	68.9	87.8	108.0	
1,3-Dichloro-2-methylpropane	C ₄ H ₈ Cl ₂	-3.0	+20.6	32.0	44.8	58.6	67.5	78.8	96.1	115.4	135.0	
2,4-Dichlorophenol	C ₆ H ₄ Cl ₂ O	53.0	80.0	92.8	107.7	123.4	133.5	146.0	165.2	187.5	210.0	45.0
2,6-Dichlorophenol	C ₆ H ₄ Cl ₂ O	59.5	87.6	101.0	115.5	131.6	141.8	154.6	175.5	197.7	220.0	

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C	
			1	5	10	20	40	60	100	200	400		
Temperature, °C													
α,α -Dichlorophenylacetonitrile	$C_8H_5Cl_2N$	56.0	84.0	98.1	113.8	130.0	141.0	154.5	176.2	199.5	223.5		
Dichlorophenylarsine	$C_6H_5AsCl_2$	61.8	100.0	116.0	133.1	151.0	163.2	178.9	202.8	228.8	256.5		
1,2-Dichloropropane	$C_3H_6Cl_2$	-38.5	-17.0	-6.1	+6.0	19.4	28.0	39.4	57.0	76.0	96.8		
2,3-Dichlorostyrene	$C_8H_6Cl_2$	61.0	90.1	104.6	120.5	137.8	149.0	163.5	185.7	210.0	235.0		
2,4-Dichlorostyrene	$C_8H_6Cl_2$	53.5	82.2	97.4	111.8	129.2	140.0	153.8	176.0	200.0	225.0		
2,5-Dichlorostyrene	$C_8H_6Cl_2$	55.5	83.9	98.2	114.0	131.0	142.0	155.8	178.0	202.5	227.0		
2,6-Dichlorostyrene	$C_8H_6Cl_2$	47.8	75.7	90.0	105.5	122.4	133.3	147.6	169.0	193.5	217.0		
3,4-Dichlorostyrene	$C_8H_6Cl_2$	57.2	86.0	100.4	116.2	133.7	144.6	158.2	181.5	205.7	230.0		
3,5-Dichlorostyrene	$C_8H_6Cl_2$	53.5	82.2	97.4	111.8	129.2	140.0	153.8	176.0	200.0	225.0		
1,2-Dichlorotetraethylbenzene	$C_{14}H_{20}Cl_2$	105.6	138.7	155.0	172.5	192.2	204.8	220.7	245.6	272.8	302.0		
1,4-Dichlorotetraethylbenzene	$C_{14}H_{20}Cl_2$	91.7	126.1	143.8	162.0	183.2	195.8	212.0	238.5	265.8	296.5		
1,2-Dichloro-1,1,2,2-tetrafluoroethane	$C_2Cl_2F_4$	-95.4	-80.0	-72.3	-63.5	-53.7	-47.5	-39.1	-26.3	-12.0	+3.5	-94	
Dichloro-4-tolylsilane	$C_7H_5Cl_2Si$	46.2	71.7	84.2	97.8	113.2	122.6	135.5	153.5	175.2	196.3		
3,4-Dichloro- α,α -trifluorotoluene	$C_7H_3Cl_2F_3$	11.0	38.3	52.2	67.3	84.0	95.0	109.2	129.0	150.5	172.8	-12.1	
Dicyclopentadiene	$C_{10}H_8$	34.1	47.6	62.0	77.9	88.0	101.7	121.8	144.2	166.6	32.9		
Diethoxydimethylsilane	$C_6H_{16}O_2Si$	-19.1	+2.4	13.3	25.3	38.0	46.3	57.6	74.2	93.2	113.5		
Diethoxydiphenylsilane	$C_{16}H_{20}O_2Si$	111.5	142.8	157.6	174.3	193.2	205.0	220.0	243.8	259.7	296.0		
Diethyl adipate	$C_{10}H_{18}O_4$	74.0	106.6	123.0	138.3	154.6	165.8	179.0	198.2	219.1	240.0	-21	
Diethylamine	$C_4H_{11}N$		-33.0	-22.6	-11.3	-4.0	+6.0	21.0	38.0	55.5	-38.9		
N-Diethylaniline	$C_{10}H_{15}N$	49.7	78.0	91.9	107.2	123.6	133.8	147.3	168.2	192.4	215.5	-34.4	
Diethyl arsanilate	$C_{10}H_{16}As$	NO ₃	38.0	62.6	74.8	88.0	102.6	111.8	123.8	141.9	161.0	181.0	
1,2-Diethylbenzene	$C_{10}H_{14}$	22.3	48.7	62.0	76.4	92.5	102.6	116.2	136.7	159.0	183.5	-31.4	
1,3-Diethylbenzene	$C_{10}H_{14}$	20.7	46.8	59.9	74.5	90.4	100.7	114.4	134.8	156.9	181.1	-83.9	
1,4-Diethylbenzene	$C_{10}H_{14}$	20.7	47.1	60.3	74.7	91.1	101.3	115.3	136.1	159.0	183.8	-43.2	
Diethyl carbonate	$C_5H_{10}O_3$	-10.1	+12.3	23.8	36.0	49.5	57.9	69.7	86.5	105.8	125.8	-43	
cis-Diethyl citraconate	$C_9H_{14}O_4$	59.8	88.3	103.0	118.2	135.7	146.2	160.0	182.3	206.5	230.3		
Diethyl dioxosuccinate	$C_8H_{10}O_6$	70.0	98.0	112.0	126.8	143.8	153.7	167.7	188.0	210.8	233.5		
Diethylene glycol	$C_4H_{10}O_3$	91.8	120.0	133.8	148.0	164.3	174.0	187.5	207.0	226.5	244.8		
Diethyleneglycol-bis-chloroacetate	$C_8H_{12}Cl_2O_5$	148.3	180.0	195.8	212.0	229.0	239.5	252.0	271.5	291.8	313.0		
Diethylene glycol dimethyl ether													
Di(2-methoxyethyl) ether	$C_6H_{14}O_3$	13.0	37.6	50.0	63.0	77.5	86.8	99.5	118.0	138.5	159.8		
glycol ethyl ether	$C_6H_{14}O_3$	45.3	72.0	85.8	100.3	116.7	126.8	140.3	159.0	180.3	201.9		
Diethyl ether	$C_4H_{10}O$	-74.3	-56.9	-48.1	-38.5	27.7	-21.8	-11.5	+2.2	17.9	34.6	-116.3	
ethylmalonate	$C_9H_{16}O_4$	50.8	77.8	91.6	106.0	122.4	132.4	146.0	166.0	188.7	211.5		
fumarate	$C_8H_{12}O_4$	53.2	81.2	95.3	110.2	126.7	137.7	151.1	172.2	195.8	218.5	+0.6	
glutarate	$C_9H_{16}O_4$	65.6	94.7	109.7	125.4	142.8	153.2	167.8	189.5	212.8	237.0		
Diethylhexadecylamine	$C_{20}H_{43}N$	139.8	175.8	194.0	213.5	235.0	248.5	265.5	292.8	324.6	355.0		
Diethyl itaconate	$C_9H_{14}O_4$	51.3	80.2	95.2	111.0	128.2	139.9	154.3	177.5	203.1	227.9		
ketone (3-pentanone)	$C_5H_{10}O$	-12.7	+7.5	17.2	27.9	39.4	46.7	56.2	70.6	86.3	102.7	-42	
malate	$C_8H_{14}O_5$	80.7	110.4	125.3	141.2	157.8	169.0	183.9	205.3	229.5	253.4		
maleate	$C_8H_{12}O_4$	57.3	85.6	100.0	115.3	131.8	142.4	156.0	177.8	201.7	225.0		
malonate	$C_7H_{12}O_4$	40.0	67.5	81.3	95.9	113.3	123.0	136.2	155.5	176.8	198.9	-49.8	
mesaconate	$C_9H_{14}O_4$	62.8	91.0	105.3	120.3	137.3	147.9	161.6	183.2	205.8	229.0		
oxalate	$C_6H_{10}O_4$	47.4	71.8	83.8	96.8	110.6	119.7	130.8	147.9	166.2	185.7	-40.6	
phthalate	$C_{12}H_{16}O_4$	108.8	140.7	156.0	173.6	192.1	204.1	219.5	243.0	267.5	294.0		
sebacate	$C_{11}H_{26}O_4$	125.3	156.2	172.1	189.8	207.5	218.4	234.4	255.8	280.3	305.5	1.3	
2,5-Diethylstyrene	$C_{12}H_{16}$	49.7	78.4	92.6	105.8	125.8	136.8	151.0	173.2	198.0	223.0		
Diethyl succinate	$C_8H_{14}O_4$	54.6	83.0	96.6	111.7	127.8	138.2	151.1	171.7	193.8	216.5	-20.8	
isosuccinate	$C_8H_{14}O_4$	39.8	66.7	80.0	94.7	111.0	121.4	134.8	155.1	177.7	201.3		
sulfate	$C_4H_{10}O_5S$	47.0	74.0	87.7	102.1	118.0	128.6	142.5	162.5	185.5	209.5	-25.0	
sulfide	$C_4H_{10}S$	-39.6	-18.6	-8.0	+3.5	16.1	24.2	35.0	51.3	69.7	88.0	-99.5	
sulfite	$C_4H_{10}O_3S$	10.0	34.2	46.4	59.7	74.2	83.8	96.3	115.8	137.0	159.0		
d-Diethyl tartrate	$C_8H_{14}O_6$	102.0	133.0	148.0	164.2	182.3	194.0	208.5	230.4	254.8	280.0	17	
dl-Diethyl tartrate	$C_8H_{14}O_6$	100.0	131.7	147.2	163.8	181.7	193.2	208.0	230.0	254.3	280.0		
3,5-Diethyltoluene	$C_{11}H_{16}$	34.0	61.5	75.3	90.2	107.0	117.7	131.7	152.4	176.5	200.7		
Diethylzinc	$C_4H_{10}Zn$	-22.4	0.0	+11.7	24.2	38.0	47.2	59.1	77.0	97.3	118.0	-28	
1-Dihydrocarvone	$C_9H_{18}O$	46.6	75.5	90.0	106.0	123.7	134.7	149.7	171.8	197.0	223.0		
Dihydrocitronellol	$C_{10}H_{18}O$	68.0	91.7	103.0	115.0	127.6	136.7	145.9	160.2	176.8	193.5		
1,4-Dihydroxyanthraquinone	$C_{14}H_{12}O_4$	196.7	239.8	259.8	282.0	307.4	323.3	344.5	377.8	413.0	450.0	194	
Dimethylacetylene (2-butyne)	C_4H_6	-73.0	-57.9	-50.5	-42.5	-33.9	-27.8	-18.8	-5.0	+10.6	27.2	-32.5	
Dimethylamine	C_2H_7N	-87.7	-72.2	-64.6	-56.0	-46.7	-40.7	-32.6	-20.4	-7.1	+7.4	-96	
N,N-Dimethylaniline	$C_8H_{11}N$	29.5	56.3	70.0	84.8	101.6	111.9	125.8	146.5	169.2	193.1	+2.5	
Dimethyl arsanilate	$C_8H_{12}AsNO_3$	15.0	39.6	51.8	65.0	79.7	88.6	101.0	119.8	140.3	160.5		
Di(α -methylbenzyl) ether	$C_{16}H_{15}O$	96.7	128.3	144.0	160.3	179.6	191.5	206.8	229.7	254.8	281.0		
2,2-Dimethylbutane	C_6H_{14}	-69.3	-50.7	-41.5	-31.1	-19.5	-12.1	-2.0	+13.4	31.0	49.7	-99.8	
2,3-Dimethylbutane	C_6H_{14}	-63.6	-44.5	-34.9	-24.1	-12.4	-4.9	+5.4	21.1	39.0	58.0	-128.2	
Dimethyl citraconate	$C_7H_{10}O_4$	50.8	78.2	91.8	106.5	122.6	132.7	145.8	165.8	188.0	210.5		
1,1-Dimethylcyclohexane	C_8H_{16}	-24.4	-1.4	+10.3	23.0	37.3	45.7	57.9	76.2	97.2	119.5	-34	
cis-1,2-Dimethylcyclohexane	C_8H_{16}	-15.9	+7.3	18.4	31.1	45.3	54.4	66.8	85.6	107.0	129.7	-50.0	
trans-1,2-Dimethylcyclohexane	C_8H_{16}	-21.1	+1.7	13.0	25.6	39.7	48.7	61.0	79.6	100.9	123.4	-88.0	
trans-1,3-Dimethylcyclohexane	C_8H_{16}	-19.4	+3.4	14.9	27.4	41.4	50.4	62.5	81.0	102.1	124.4	-92.0	
cis-1,3-Dimethylcyclohexane	C_8H_{16}	-22.7	0.0	+11.2	23.6	37.5	46.4	58.5	76.9	97.8	120.1	-76.2	
cis-1,4-Dimethylcyclohexane	C_8H_{16}	-20.0	+3.2	14.5	27.1	41.1	50.1	62.3	80.8	101.9	124.3	-87.4	
trans-1,4-Dimethylcyclohexane	C_8H_{16}	-24.3	-1.7	+10.1	22.6	36.5	45.4	57.6	76.0	97.0	119.3	-36.9	

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
Temperature, °C												
Dimethyl ether	C ₂ H ₆ O	-115.7	-101.1	-93.3	-85.2	-76.2	-70.4	-62.7	-50.9	-37.8	-23.7	-138.5
2,2-Dimethylhexane	C ₈ H ₁₈	-29.7	-7.9	+3.1	15.0	28.2	36.7	48.2	65.7	85.6	106.8	
2,3-Dimethylhexane	C ₈ H ₁₈	-23.0	-1.1	+9.9	22.1	35.6	44.2	56.0	73.8	94.1	115.6	
2,4-Dimethylhexane	C ₈ H ₁₈	-26.9	-5.3	+5.2	17.2	30.5	39.0	50.6	68.1	88.2	109.4	-90.7
2,5-Dimethylhexane	C ₈ H ₁₈	-26.7	-5.5	+5.3	17.2	30.4	38.9	50.5	68.0	87.9	109.1	
3,3-Dimethylhexane	C ₈ H ₁₈	-25.8	-4.4	+6.1	18.2	31.7	40.4	52.5	70.0	90.4	112.0	
3,4-Dimethylhexane	C ₈ H ₁₈	-22.1	+0.2	11.3	23.5	37.1	45.8	57.7	75.6	96.0	117.7	
Dimethyl itaconate	C ₇ H ₁₀ O ₄	69.3	94.0	106.6	119.7	133.7	142.6	153.7	171.0	189.8	208.0	38
1-Dimethyl malate	C ₆ H ₁₀ O ₅	75.4	104.0	118.3	133.8	150.1	160.4	175.1	196.3	219.5	242.6	
Dimethyl maleate	C ₆ H ₈ O ₄	45.7	73.0	86.4	101.3	117.2	127.1	140.4	160.0	182.2	205.0	
malonate	C ₅ H ₈ O ₄	35.0	59.8	72.0	85.0	100.0	109.7	121.9	140.0	159.8	180.7	-62
<i>trans</i> -Dimethyl mesaconate	C ₇ H ₁₀ O ₄	46.8	74.0	87.8	102.1	118.0	127.8	141.5	161.0	183.5	206.0	
2,7-Dimethyloctane	C ₁₀ H ₂₂	+6.3	30.5	42.3	55.8	71.2	80.8	93.9	114.0	136.0	159.7	-52.8
Dimethyl oxalate	C ₄ H ₆ O ₄	20.0	44.0	56.0	69.4	83.6	92.8	104.8	123.3	143.3	163.3	
2,2-Dimethylpentane	C ₇ H ₁₆	-49.0	-28.7	-18.7	-7.5	+5.0	13.0	23.9	40.3	59.2	79.2	-123.7
2,3-Dimethylpentane	C ₇ H ₁₆	-42.0	-20.8	-10.3	+1.1	13.9	22.1	33.3	50.1	69.4	89.8	-135
2,4-Dimethylpentane	C ₇ H ₁₆	-48.0	-27.4	-17.1	-5.9	+6.5	14.5	25.4	41.8	60.6	80.5	-119.5
3,3-Dimethylpentane	C ₇ H ₁₆	-45.9	-25.0	-14.4	-2.9	+9.9	18.1	29.3	46.2	65.5	86.1	-135.0
2,3-Dimethylphenol (2,3-xylenol)	C ₈ H ₁₀ O	56.0	83.8	97.6	112.0	129.2	139.5	152.2	173.0	196.0	218.0	75
2,4-Dimethylphenol (2,4-xylenol)	C ₈ H ₁₀ O	51.8	78.0	91.3	105.0	121.5	131.0	143.0	161.5	184.2	211.5	25.5
2,5-Dimethylphenol (2,5-xylenol)	C ₈ H ₁₀ O	51.8	78.0	91.3	105.0	121.5	131.0	143.0	161.5	184.2	211.5	74.5
3,4-Dimethylphenol (3,4-xylenol)	C ₈ H ₁₀ O	66.2	93.8	107.7	122.0	138.0	148.0	161.0	181.5	203.6	225.2	62.5
3,5-Dimethylphenol (3,5-xylenol)	C ₈ H ₁₀ O	62.0	89.2	102.4	117.0	133.3	143.5	156.0	176.2	197.8	219.5	68
Dimethylphenylsilane	C ₈ H ₁₂ Si	+5.3	30.3	42.6	56.2	71.4	81.3	94.2	114.2	136.4	159.3	
Dimethyl phthalate	C ₁₀ H ₁₀ O ₄	100.3	131.8	147.6	164.0	182.8	194.0	210.0	232.7	257.8	283.7	
3,5-Dimethyl-1,2-pyrone	C ₇ H ₈ O ₂	78.6	107.6	122.0	136.4	152.7	163.8	177.5	198.0	221.0	245.0	51.5
4,6-Dimethylresorcinol	C ₈ H ₁₀ O ₂	49.0	76.8	90.7	105.8	122.5	133.2	147.3	167.8	192.0	215.0	
Dimethyl sebacate	C ₁₂ H ₂₂ O ₄	104.0	139.8	156.2	175.8	196.0	208.0	222.6	245.0	269.6	293.5	38
2,4-Dimethylstyrene	C ₁₀ H ₁₂	34.2	61.9	75.8	90.8	107.7	118.0	132.3	153.2	177.5	202.0	
2,5-Dimethylstyrene	C ₁₀ H ₁₂	29.0	55.9	69.0	84.0	100.2	110.7	124.7	145.6	168.7	193.0	
α,α-Dimethylsuccinic anhydride	C ₆ H ₈ O ₃	61.4	88.1	102.0	116.3	132.3	142.4	155.3	175.8	197.5	219.5	
Dimethyl sulfide	C ₂ H ₆ S	-75.6	-58.0	-49.2	-39.4	-28.4	-21.4	-12.0	+2.6	18.7	36.0	-83.2
d-Dimethyl tartrate	C ₆ H ₁₀ O ₆	102.1	133.2	148.2	164.3	182.4	193.8	208.8	230.5	255.0	280.0	61.5
dl-Dimethyl tartrate	C ₆ H ₁₀ O ₆	100.4	131.8	147.5	164.0	182.4	193.8	209.5	232.3	257.4	282.0	89
N,N-Dimethyl-2-toluidine	C ₉ H ₁₃ N	28.8	54.1	66.2	80.2	95.0	105.2	118.1	138.3	161.5	184.8	-61
N,N-Dimethyl-4-toluidine	C ₉ H ₁₃ N	50.1	74.3	86.7	100.0	116.3	126.4	140.3	161.6	185.4	209.5	
Di(nitrosomethyl) amine	C ₂ H ₅ N ₃ O ₂	+3.2	27.8	40.0	53.7	68.2	77.7	90.3	110.0	131.3	153.0	
Diosphenol	C ₁₀ H ₁₆ O ₂	66.7	95.4	109.0	124.0	141.2	151.3	165.6	186.2	209.5	232.0	
1,4-Dioxane	C ₄ H ₈ O ₂	-35.8	-12.8	-1.2	+12.0	25.2	33.8	45.1	62.3	81.8	101.1	10
Dipentene	C ₁₀ H ₁₆	14.0	40.4	53.8	68.2	84.3	94.6	108.3	128.2	150.5	174.6	
Diphenylamine	C ₁₂ H ₁₄ N	108.3	141.7	157.0	175.2	194.3	206.9	222.8	247.5	274.1	302.0	52.9
Diphenyl carbolin (benzhydrol)	C ₁₃ H ₁₂ O ₂	110.0	145.0	162.0	180.9	200.0	212.0	227.5	250.0	275.6	301.0	68.5
chlorophosphate	C ₁₂ H ₁₀ ClPO ₃	121.5	160.5	182.0	203.8	227.9	244.2	265.0	299.5	337.2	378.0	
disulfide	C ₁₂ H ₁₀ S ₂	131.6	164.0	180.0	197.0	214.8	226.2	241.3	262.6	285.8	310.0	61
1,2-Diphenylethane (dibenzyl)	C ₁₄ H ₁₄	86.8	119.8	136.0	153.7	173.7	186.0	202.8	227.8	255.0	284.0	51.5
Diphenyl ether	C ₁₂ H ₁₀ O	66.1	97.8	114.0	130.8	150.0	162.0	178.8	203.3	230.7	258.5	27
1,1-Diphenylethylene	C ₁₁ H ₁₂	87.4	119.6	135.0	151.8	170.8	183.4	198.6	222.8	249.8	277.0	
<i>trans</i> -Diphenylethyne	C ₁₄ H ₁₂	113.2	145.8	161.0	179.8	199.0	211.5	227.4	251.7	278.3	306.5	124
1,1-Diphenylhydrazine	C ₁₂ H ₁₂ N ₂	126.0	159.3	176.1	194.0	213.5	225.9	242.5	267.2	294.0	322.2	44
Diphenylmethane	C ₁₃ H ₁₂	76.0	107.4	122.8	139.8	157.8	170.2	186.3	210.7	237.5	264.5	26.5
Diphenyl sulfide	C ₁₂ H ₁₀ S	96.1	129.0	145.0	162.0	182.8	194.8	211.8	236.8	263.9	292.5	
Diphenyl-2-tolyl thiophosphate	C ₁₈ H ₁₇ O ₃ PS	159.7	179.8	201.6	215.5	230.6	240.4	252.5	270.3	290.0	310.0	
1,2-Dipropanoyethane	C ₅ H ₁₀ O ₂	-38.8	-10.3	+5.0	22.3	42.3	55.8	74.2	103.8	140.0	180.0	
1,2-Diisopropylbenzene	C ₁₂ H ₁₈	40.0	67.8	81.8	96.8	114.0	124.3	138.7	159.8	184.3	209.0	
1,3-Diisopropylbenzene	C ₁₂ H ₁₈	34.7	62.3	76.0	91.2	107.9	118.2	132.3	153.7	177.6	202.0	-105
Dipropylene glycol	C ₆ H ₁₄ O ₃	73.8	102.1	116.2	131.3	147.4	156.5	169.9	189.9	210.5	231.8	
Dipropylene glycol monobutyl ether	C ₁₀ H ₂₂ O ₃	64.7	92.0	106.0	120.4	136.3	146.3	159.8	180.0	203.8	227.0	
isopropyl ether	C ₆ H ₁₀ O ₃	46.0	72.8	86.2	100.8	117.0	126.8	140.3	160.0	183.1	205.6	
Di-n-propyl ether	C ₆ H ₁₄ O	-43.3	-22.3	-11.8	0.0	+13.2	21.6	33.0	50.3	69.5	89.5	-122
Diisopropyl ether	C ₆ H ₁₄ O	-57.0	-37.4	-27.4	-16.7	-4.5	+3.4	13.7	30.0	48.2	67.5	-60
Di-n-propyl ketone (4-heptanone)	C ₇ H ₁₄ O	23.0	44.4	55.0	66.2	78.1	85.8	96.0	111.2	127.3	143.7	-32.6
Di-n-propyl oxalate	C ₈ H ₁₄ O ₄	53.4	80.2	93.9	108.6	124.6	134.8	148.1	168.0	190.3	213.5	
Diisopropyl oxalate	C ₈ H ₁₄ O ₄	43.2	69.0	81.9	95.6	110.5	120.0	132.6	151.2	171.8	193.5	
Di-n-propyl succinate	C ₁₀ H ₁₈ O ₄	77.5	107.6	122.2	138.0	154.8	166.0	180.3	202.5	226.5	250.8	
Di-n-propyl dtartrate	C ₁₀ H ₁₈ O ₆	115.6	147.7	163.5	180.4	199.7	211.7	227.0	250.1	275.6	303.0	
Diisopropyl dtartrate	C ₁₀ H ₁₈ O ₆	103.7	133.7	148.2	164.0	181.8	192.6	207.3	228.2	251.8	275.0	
Divinyl acetylene (1,5-hexadiene-3-yne)	C ₆ H ₆	-45.1	-24.4	-14.0	-2.8	+10.0	18.1	29.5	46.0	64.4	84.0	
1,3-Divinylbenzene	C ₁₀ H ₁₀	32.7	60.0	73.8	88.7	105.5	116.0	130.0	151.4	175.2	199.5	-66.9
Docosane	C ₂₂ H ₄₆	157.8	195.4	213.0	233.5	254.5	268.3	286.0	314.2	343.5	376.0	44.5
n-Dodecane	C ₁₂ H ₂₆	47.8	75.8	90.0	104.6	121.7	132.1	146.2	167.2	191.0	216.2	-9.6
1-Dodecene	C ₁₂ H ₂₄	47.2	74.0	87.8	102.4	118.6	128.5	142.3	162.2	185.5	208.0	-31.5
n-Dodecyl alcohol	C ₁₂ H ₂₆ O	91.0	120.2	134.7	150.0	167.2	177.8	192.0	213.0	235.7	259.0	24
Dodecylamine	C ₁₂ H ₂₇ N	82.8	111.8	127.8	141.6	157.4	168.0	182.1	203.0	225.0	248.0	
Dodecytrimethylsilane	C ₁₅ H ₃₄ Si	91.2	122.1	137.7	153.8	172.1	184.2	199.5	222.0	248.0	273.0	
Elaidic acid	C ₁₈ H ₃₄ O ₂	171.3	206.7	223.5	242.3</							

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
Epichlorohydrin	C ₃ H ₅ ClO	-16.5	+5.6	16.6	29.0	42.0	50.6	62.0	79.3	98.0	117.9	-25.6
1,2-Epoxy-2-methylpropane	C ₄ H ₈ O	-69.0	-50.0	-40.3	-29.5	-17.3	-9.7	+1.2	17.5	36.0	55.5	
Erucic acid	C ₂₂ H ₄₂ O ₂	206.7	239.7	254.5	270.6	289.1	300.2	314.4	336.5	358.8	381.5	33.5
Estragole (<i>p</i> -methoxy allyl benzene)	C ₁₀ H ₁₂ O	52.6	80.0	93.7	108.4	124.6	135.2	148.5	168.7	192.0	215.0	
Ethane	C ₂ H ₆	-159.5	-148.5	-142.9	-136.7	-129.8	-125.4	-119.3	-110.2	-99.7	-88.6	-183.2
Ethoxydimethylphenylsilane	C ₁₁ H ₁₆ OSi	36.3	63.1	76.2	91.0	107.2	127.5	131.4	151.5	175.0	199.5	
Ethoxytrimethylsilane	C ₅ H ₁₄ OSi	-50.9	-31.0	-20.7	-9.8	+3.7	11.5	22.1	38.1	56.3	75.7	
Ethoxytriphenylsilane	C ₂₀ H ₂₀ OSi	167.0	198.2	213.5	230.0	247.0	258.3	273.5	295.0	319.5	344.0	
Ethyl acetate	C ₄ H ₈ O ₂	-43.4	-23.5	-13.5	-3.0	+9.1	16.6	27.0	42.0	59.3	77.1	-82.4
acetooacetate	C ₆ H ₁₀ O ₃	28.5	54.0	67.3	81.1	96.2	106.0	118.5	138.0	158.2	180.8	-45
Ethyldiacetylene (1-butyne)	C ₄ H ₆	-92.5	-76.7	-68.7	-59.9	-50.0	-43.4	-34.9	-21.6	-6.9	+8.7	-130
Ethyl acrylate	C ₅ H ₈ O ₂	-29.5	-8.7	+2.0	13.0	26.0	33.5	44.5	61.5	80.0	99.5	-71.2
α-Ethylacrylic acid	C ₅ H ₉ O ₂	47.0	70.7	82.0	94.4	108.1	116.7	127.5	144.0	160.7	179.2	
α-Ethylacrylonitrile	C ₅ H ₇ N	-29.0	-6.4	+5.0	17.7	31.8	40.6	53.0	71.6	92.2	114.0	
Ethyl alcohol (ethanol)	C ₂ H ₆ O	-31.3	-12.0	-2.3	+8.0	19.0	26.0	34.9	48.4	63.5	78.4	-112
Ethylamine	C ₂ H ₇ N	-82.3	-66.4	-58.3	-48.6	-39.8	-33.4	-25.1	-12.3	+2.0	16.6	-80.6
4-Ethylaniline	C ₈ H ₁₁ N	52.0	80.0	93.8	109.0	125.7	136.0	149.8	170.6	194.2	217.4	-4
<i>N</i> -Ethylaniline	C ₈ H ₁₁ N	38.5	66.4	80.6	96.0	113.2	123.6	137.3	156.9	180.8	204.0	-63.5
2-Ethylanisole	C ₉ H ₁₂ O	29.7	55.9	69.0	83.1	98.8	109.0	122.3	142.1	164.2	187.1	
3-Ethylanisole	C ₉ H ₁₂ O	33.7	60.3	73.9	88.5	104.8	115.5	129.2	149.7	172.8	196.5	
4-Ethylanisole	C ₉ H ₁₂ O	33.5	60.2	73.9	88.5	104.7	115.4	128.4	149.2	172.3	196.5	
Ethylbenzene	C ₈ H ₁₀	-9.8	+13.9	25.9	38.6	52.8	61.8	74.1	92.7	113.8	136.2	-94.9
Ethyl benzoate	C ₉ H ₁₀ O ₂	44.0	72.0	86.0	101.4	118.2	129.0	143.2	164.8	188.4	213.4	-34.6
benzoylacetate	C ₁₁ H ₁₂ O ₃	107.6	136.4	150.3	166.8	181.8	191.9	205.0	223.8	244.7	265.0	
bromide	C ₂ H ₅ Br	-74.3	-56.4	-47.5	-37.8	-26.7	-19.5	-10.0	+4.5	21.0	38.4	-117.8
α-bromoisobutyrate	C ₆ H ₁₁ BrO ₂	10.6	35.8	48.0	61.8	77.0	86.7	99.8	119.7	141.2	163.6	
<i>n</i> -butyrate	C ₆ H ₁₂ O ₂	-18.4	+4.0	15.3	27.8	41.5	50.1	62.0	79.8	100.0	121.0	-93.3
isobutyrate	C ₆ H ₁₂ O ₂	-24.3	-2.4	+8.4	20.6	33.8	42.3	53.5	71.0	90.0	110.0	-88.2
Ethylcamphoronic anhydride	C ₁₁ H ₁₆ O ₅	118.2	149.8	165.0	181.8	199.8	211.5	226.6	248.5	272.8	298.0	
Ethyl isocaproate	C ₈ H ₁₆ O ₂	11.0	35.8	48.0	61.7	76.3	85.8	98.4	117.8	139.2	160.4	
carbamate	C ₃ H ₇ NO ₂	65.8	77.8	91.0	105.6	114.8	126.2	144.2	164.0	184.0	194	52.5
carbanilate	C ₉ H ₁₁ NO ₂	107.8	131.8	143.7	155.5	168.8	177.3	187.9	203.8	220.0	237.0	
Ethylcetylamine	C ₁₈ H ₃₉ N	133.2	168.2	186.0	205.5	226.5	239.8	256.8	283.3	313.0	342.0	
Ethyl chloride	C ₂ H ₅ Cl	-89.8	-73.9	-65.8	-56.8	-47.0	-40.6	-32.0	-18.6	-3.9	+12.3	-139
chloroacetate	C ₄ H ₇ ClO ₂	+1.0	25.4	37.5	50.4	65.2	74.0	86.0	103.8	123.8	144.2	-26
chloroglyoxylate	C ₄ H ₅ ClO ₃	-5.1	+18.0	29.9	42.0	56.0	65.2	76.6	94.5	114.7	135.0	
α-chloropropionate	C ₅ H ₉ ClO ₂	+6.6	30.2	41.9	54.3	68.2	77.3	89.3	107.2	126.2	146.5	
trans-cinnamate	C ₁₁ H ₁₂ O ₂	87.6	108.5	134.0	150.3	169.2	181.2	196.0	219.3	245.0	271.0	12
3-Ethylcumene	C ₁₁ H ₁₆	28.3	55.5	68.8	83.6	99.9	110.2	124.3	145.4	168.2	193.0	
4-Ethylcumene	C ₁₁ H ₁₆	31.5	58.4	72.0	86.7	103.3	113.8	127.2	148.3	171.8	195.8	
Ethyl cyanoacetate	C ₅ H ₇ NO ₂	67.8	93.5	106.0	119.8	133.8	142.1	152.8	169.8	187.8	206.0	
Ethylcyclohexane	C ₈ H ₁₆	-14.5	+9.2	20.6	33.4	47.6	56.7	69.0	87.8	109.1	131.8	-111.3
Ethylocyclopentane	C ₇ H ₁₄	-32.2	-10.8	-0.1	+11.7	25.0	33.4	45.0	62.4	82.3	103.4	-138.6
Ethyl dichloroacetate	C ₄ H ₆ Cl ₂ O ₂	9.6	34.0	46.3	59.5	74.0	83.6	96.1	115.2	135.9	156.5	
<i>N,N</i> -diethylloxamate	C ₈ H ₁₅ NO ₃	76.0	106.3	121.7	137.7	154.4	166.0	180.3	202.8	226.5	252.0	
<i>N</i> -Ethylidiphenylamine	C ₁₄ H ₁₅ N	98.3	130.2	146.0	162.8	182.0	193.7	209.8	233.0	258.8	286.0	
Ethylene	C ₂ H ₄	-168.3	-158.3	-153.2	-147.6	-141.3	-137.3	-131.8	-123.4	-113.9	-103.7	-169
Ethylene-bis-(chloroacetate)	C ₆ H ₈ Cl ₂ O ₄	112.0	142.4	158.0	173.5	191.0	201.8	215.0	237.3	259.5	283.5	
Ethylene chlorohydrin (2-chloroethanol)	C ₂ H ₅ ClO	-4.0	+19.0	30.3	42.5	56.0	64.1	75.0	91.8	110.0	128.8	-69
diamine (1,2-ethanediamine)	C ₂ H ₈ N ₂	-11.0	+10.5	21.5	33.0	45.8	53.8	62.5	81.0	99.0	117.2	8.5
dibromide (1,2-dibromomethane)	C ₂ H ₂ Br ₂	-27.0	+4.7	18.6	32.7	48.0	57.9	70.4	89.8	110.1	131.5	10
dichloride (1,2-dichloroethane)	C ₂ H ₄ Cl ₂	-44.5	-24.0	-13.6	-2.4	+10.0	18.1	29.4	45.7	64.0	82.4	-35.3
glycol (1,2-ethanediol)	C ₂ H ₆ O ₂	53.0	79.7	92.1	105.8	120.0	129.5	141.8	158.5	178.5	197.3	-15.6
glycol diethyl ether (1,2-diethoxyethane)	C ₆ H ₁₄ O ₂	-33.5	-10.2	+1.6	14.7	29.7	39.0	51.8	71.8	94.1	119.5	
glycol dimethyl ether (1,2-dimethoxyethane)	C ₄ H ₁₀ O ₂	-48.0	-26.2	-15.3	-3.0	+10.7	19.7	31.8	50.0	70.8	93.0	
glycol monomethyl ether (2-methoxyethanol)	C ₃ H ₈ O ₂	-13.5	+10.2	22.0	34.3	47.8	56.4	68.0	85.3	104.3	124.4	
oxide	C ₂ H ₄ O	-89.7	-73.8	-65.7	-56.6	-46.9	-40.7	-32.1	-19.5	-4.9	+10.7	-111.3
Ethyl α-ethylacetacetate	C ₈ H ₁₄ O ₃	40.5	67.3	80.2	94.6	110.3	120.6	133.8	153.2	175.6	198.0	
fluoride	C ₂ H ₅ F	-117.0	-103.8	-97.7	-90.0	-81.8	-76.4	-69.3	-58.0	-45.5	-32.0	
formate	C ₂ H ₆ O ₂	-60.5	-42.2	-33.0	-22.7	-11.5	-4.3	-5.4	20.0	37.1	54.3	-79
2-furoate	C ₇ H ₈ O ₃	37.6	63.8	77.1	91.5	107.5	117.5	130.4	150.1	172.5	195.0	34
glycolate	C ₄ H ₈ O ₃	14.3	38.8	50.5	63.9	78.1	87.6	99.8	117.8	138.0	158.2	
3-Ethylhexane	C ₈ H ₁₈	-20.0	+2.1	12.8	25.0	38.5	47.1	58.9	76.7	97.0	118.5	
2-Ethylhexyl acrylate	C ₁₁ H ₂₀ O ₂	50.0	77.7	91.8	106.3	123.7	134.0	147.9	168.2	192.2	216.0	
Ethylidene chloride (1,1-dichloroethane)	C ₂ H ₄ Cl ₂	-60.7	-41.9	-32.3	-21.9	-10.2	-2.9	+7.2	22.4	39.8	57.4	-96.7
fluoride (1,1-difluoroethane)	C ₂ H ₄ F ₂	-112.5	-98.4	-91.7	-84.1	-75.8	-70.4	-63.2	-52.0	-39.5	-26.5	-117
Ethyl iodide	C ₂ H ₅ I	-54.4	-34.3	-24.3	-13.1	-0.9	+7.2	18.0	34.1	52.3	72.4	-105
Ethyl <i>L</i> -leucinate	C ₈ H ₁₇ NO ₂	27.8	57.3	72.1	88.0	106.0	117.8	131.8	149.8	167.3	184.0	
Ethyl levulinic	C ₇ H ₁₂ O ₃	47.3	74.0	87.3	101.8	117.7	127.6	141.3	160.2	183.0	206.2	
Ethyl mercaptan (ethanethiol)	C ₂ H ₆ S	-76.7	-59.1	-50.2	-40.7	-29.8	-22.4	-13.0	+1.5	17.7	35.0	-121
Ethyl methylcarbamate	C ₄ H ₉ NO ₂	26.5	51.0	63.2	76.1	91.0	100.0	112.0	130.0	149.8	170.0	
Ethyl methyl ether	C ₃ H ₈ O	-91.0	-75.6	-67.8	-59.1	-49.4	-43.3	-34.8	-22.0	-7.8	+7.5	

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg										Melting point, °C
			1	5	10	20	40	60	100	200	400	760	
Temperature, °C													
1-Ethynaphthalene	C ₁₂ H ₁₂	70.0	101.4	116.8	133.8	152.0	164.1	180.0	204.6	230.8	258.1	-27	
Ethyl α-naphthyl ketone (1-propionaphthone)	C ₁₃ H ₁₂ O	124.0	155.5	171.0	188.1	206.9	218.2	233.5	255.5	280.2	306.0		
Ethyl 3-nitrobenzoate	C ₈ H ₇ NO ₄	108.1	140.2	155.0	173.6	192.6	205.0	220.3	244.6	270.6	298.0	47	
3-Ethylpentane	C ₇ H ₁₆	-37.8	-17.0	-6.8	+4.7	17.5	25.7	36.9	53.8	73.0	93.5	-118.6	
4-Ethylphenetole	C ₁₀ H ₁₄ O	48.5	75.7	89.5	103.8	119.8	129.8	143.5	163.2	185.7	208.0		
2-Ethylphenol	C ₈ H ₁₀ O	46.2	73.4	87.0	101.5	117.9	127.9	141.8	161.6	184.5	207.5	-45	
3-Ethylphenol	C ₈ H ₁₀ O	60.0	86.8	100.2	114.5	130.0	139.8	152.0	171.8	193.3	214.0	-4	
4-Ethylphenol	C ₈ H ₁₀ O	59.3	86.5	100.2	115.0	131.3	141.7	154.2	175.0	197.4	219.0	46.5	
Ethyl phenyl ether (phenetole)	C ₈ H ₁₀ O	18.1	43.7	56.4	70.3	86.6	95.4	108.4	127.9	149.8	172.0	-30.2	
Ethyl propionate	C ₅ H ₁₀ O ₂	-28.0	-7.2	+3.4	14.3	27.2	35.1	45.2	61.7	79.8	99.1	-72.6	
Ethyl propyl ether	C ₅ H ₁₂ O	-64.3	-45.0	-35.0	-24.0	-12.0	-4.0	+6.8	23.3	41.6	61.7		
Ethyl salicylate	C ₉ H ₁₀ O ₃	61.2	90.0	104.2	119.3	136.7	147.6	161.5	183.7	207.0	231.5	1.3	
3-Ethylstyrene	C ₁₀ H ₁₂	28.3	55.0	68.3	82.8	99.2	109.6	123.2	144.0	167.2	191.5		
4-Ethylstyrene	C ₁₀ H ₁₂	26.0	52.7	66.3	80.8	97.3	107.6	121.5	142.0	165.0	189.0		
Ethyliodothiocyanate	C ₂ H ₅ NS	13.2	+10.6	22.8	36.1	50.8	59.8	71.9	90.0	110.1	131.0	-5.9	
2-Ethyltoluene	C ₉ H ₁₂	9.4	34.8	47.6	61.2	76.4	86.0	99.0	119.0	141.4	165.1		
3-Ethyltoluene	C ₉ H ₁₂	7.2	32.3	44.7	58.2	73.3	82.9	95.9	115.5	137.8	161.3	-95.5	
4-Ethyltoluene	C ₉ H ₁₂	7.6	32.7	44.9	58.5	73.6	83.2	96.3	116.1	136.4	162.0		
Ethyl trichloroacetate	C ₄ H ₅ Cl ₃ O ₂	20.7	45.5	57.7	70.6	85.5	94.4	107.4	125.8	146.0	167.0		
Ethytrimethylsilane	C ₅ H ₁₄ Si	-60.6	-41.4	-31.8	-21.0	-9.0	-1.2	+9.2	25.0	42.8	62.0		
Ethytrimethyltin	C ₅ H ₁₄ Sn	-30.0	-7.6	+3.8	16.1	30.0	38.4	50.0	67.3	87.6	108.8		
Ethyl isovalerate	C ₇ H ₁₄ O ₂	-6.1	+17.0	28.7	41.3	55.2	64.0	75.9	93.8	114.0	134.3	-99.3	
2-Ethyl-1,4-xylene	C ₁₀ H ₁₄	25.7	52.0	65.6	79.8	96.0	106.2	120.0	140.2	163.1	186.9		
4-Ethyl-1,3-xylene	C ₁₀ H ₁₄	26.3	53.0	66.4	80.6	97.2	107.4	121.2	141.8	164.4	188.4		
5-Ethyl-1,3-xylene	C ₁₀ H ₁₄	22.1	48.8	62.1	76.5	92.6	103.0	116.5	137.4	159.6	183.7		
Eugenol	C ₁₀ H ₁₂ O ₃	78.4	108.1	123.0	138.7	155.8	167.3	182.2	204.7	228.3	253.5		
iso-Eugenol	C ₁₀ H ₁₂ O ₂	86.3	117.0	132.4	149.0	167.0	178.2	194.0	217.2	242.3	267.5	-10	
Eugenol acetate	C ₁₂ H ₁₄ O ₃	101.6	132.3	148.0	164.2	183.0	194.0	209.7	232.5	257.4	282.0	295	
Fencholic acid	C ₁₀ H ₁₆ O ₂	101.7	128.7	142.3	155.8	171.8	181.5	194.0	215.0	237.8	264.1	19	
d-Fenchone	C ₁₀ H ₁₆ O	28.0	54.7	68.3	83.0	99.5	109.8	123.6	144.0	166.8	191.0	5	
dl-Fenchyl alcohol	C ₁₀ H ₁₈ O	45.8	70.3	82.1	95.6	110.8	120.2	132.3	150.0	173.2	201.0	35	
Fluorene	C ₁₃ H ₁₀	129.3	146.0	164.2	185.2	197.8	214.7	240.3	268.6	295.0	313		
Fluorobenzene	C ₆ H ₅ F	-43.4	-22.8	-12.4	-1.2	+11.5	19.6	30.4	47.2	65.7	84.7	-42.1	
2-Fluorotoluene	C ₇ H ₇ F	-24.2	-2.2	+8.9	21.4	34.7	43.7	55.3	73.0	92.8	114.0	-80	
3-Fluorotoluene	C ₇ H ₇ F	-22.4	-0.3	+11.0	23.4	37.0	45.8	57.5	75.4	95.4	116.0	-110.8	
4-Fluorotoluene	C ₇ H ₇ F	-21.8	+0.3	11.8	24.0	37.8	46.5	58.1	76.0	96.1	117.0		
Formaldehyde	CH ₂ O		-88.0	-79.6	-70.6	-65.0	-57.3	-46.0	-33.0	-19.5	-92		
Formamide	CH ₃ NO	70.5	96.3	109.5	122.5	137.5	147.0	157.5	175.5	193.5	210.5		
Formic acid	CH ₂ O ₂	-20.0	-5.0	+2.1	10.3	24.0	32.4	43.8	61.4	80.3	100.6	8.2	
trans-Fumaryl chloride	C ₄ H ₂ Cl ₂ O ₂	+15.0	38.5	51.8	65.0	79.5	89.0	101.0	120.0	140.0	160.0		
Furfural (2-furaldehyde)	C ₅ H ₈ O ₂	18.5	42.6	54.8	67.8	82.1	91.5	103.4	121.8	141.8	161.8		
Furfuryl alcohol	C ₅ H ₈ O ₂	31.8	56.0	68.0	81.0	95.7	104.0	115.9	133.1	151.8	170.0		
Geraniol	C ₁₀ H ₁₈ O	69.2	96.8	110.0	125.6	141.8	151.5	165.3	185.6	207.8	230.0		
Geranyl acetate	C ₁₂ H ₂₀ O ₂	73.5	102.7	117.9	133.0	150.0	160.3	175.2	196.3	219.8	243.3		
Geranyl n-butyrate	C ₁₄ H ₂₄ O ₃	96.8	125.2	139.0	153.8	170.1	180.2	193.8	214.0	235.0	257.4		
Geranyl isobutyrate	C ₁₁ H ₂₄ O ₂	90.9	119.6	133.0	147.9	164.0	174.0	187.7	207.6	228.5	251.0		
Geranyl formate	C ₁₁ H ₁₈ O ₂	61.8	90.3	104.3	119.8	136.2	147.2	160.7	182.6	205.8	230.0		
Glutaric acid	C ₅ H ₈ O ₄	155.5	183.8	196.0	210.5	226.3	235.5	247.0	265.0	283.5	303.0	97.5	
Glutaric anhydride	C ₅ H ₆ O ₃	100.8	133.3	149.5	166.0	185.5	196.2	212.5	236.5	261.0	287.0		
Glutaronitrile	C ₅ H ₆ N ₂	91.3	123.7	140.0	156.5	176.4	189.5	205.5	230.0	257.3	286.2		
Glutaryl chloride	C ₅ H ₆ Cl ₂ O ₂	56.1	84.0	97.8	112.3	128.3	139.1	151.8	172.4	195.3	217.0		
Glycerol	C ₃ H ₈ O ₃	125.5	153.8	167.2	182.2	198.0	208.0	220.1	240.0	263.0	290.0	17.9	
Glycerol dichlorohydrin (1,3-dichloro-2-propanol)	C ₃ H ₆ Cl ₂ O	28.0	52.2	64.7	78.0	93.0	102.0	114.8	133.3	153.5	174.3		
Glycol diacetate	C ₆ H ₁₀ O ₄	38.3	64.1	77.1	90.8	106.1	115.8	128.0	147.8	168.3	190.5	-31	
Glycolide (1,4-dioxane-2,6-dione)	C ₄ H ₄ O ₄	103.0	116.6	132.0	148.6	158.2	173.2	194.0	217.0	240.0	247		
Guaiacol (2-methoxyphenol)	C ₇ H ₈ O ₂	52.4	79.1	92.0	106.0	121.6	131.0	144.0	162.7	184.1	205.0	28.3	
Heneicosane	C ₂₃ H ₄₄	152.6	188.0	205.4	223.2	243.4	255.3	272.0	296.5	323.8	350.5	40.4	
Heptacosane	C ₂₇ H ₅₆	211.7	248.6	266.8	284.6	305.7	318.3	333.5	359.4	385.0	410.6	59.5	
Heptadecane	C ₁₇ H ₃₆	115.0	145.2	160.0	177.7	195.8	207.3	223.0	247.8	274.5	303.0	22.5	
Heptaldehyde (enanthaldehyde)	C ₇ H ₁₄ O	12.0	32.7	43.0	54.0	66.3	74.0	84.0	102.0	125.5	155.0	-42	
n-Heptane	C ₇ H ₁₆	-34.0	-12.7	-2.1	+9.5	22.3	30.6	41.8	58.7	78.0	98.4	-90.6	
Heptanoic acid (enanthic acid)	C ₇ H ₁₄ O ₂	78.0	101.3	113.2	125.6	139.5	148.5	160.0	179.5	199.6	221.5	-10	
1-Heptanol	C ₇ H ₁₆ O	42.4	64.3	74.7	85.8	99.8	108.0	119.5	136.6	155.6	175.8	34.6	
Heptanoyl chloride (enanthyl chloride)	C ₇ H ₁₃ ClO	34.2	54.6	64.6	75.0	86.4	93.5	102.7	116.3	130.7	145.0		
2-Heptene	C ₇ H ₁₄	-35.8	-14.1	-3.5	+8.3	21.5	30.0	41.3	58.6	78.1	98.5		
Heptylbenzene	C ₁₃ H ₃₀	64.0	94.6	110.0	126.0	144.0	154.8	170.2	193.3	217.8	244.0		
Heptyl cyanide (enanthonitrile)	C ₇ H ₁₃ N	21.0	47.8	61.6	76.3	92.6	103.0	116.8	137.7	160.0	184.6		
Hexachlorobenzene	C ₆ Cl ₆	114.4	149.3	166.4	185.7	206.0	219.0	235.5	258.5	283.5	309.4	230	
Hexachloroethane	C ₂ Cl ₆	32.7	49.8	73.5	87.6	102.3	112.0	124.2	143.1	163.8	185.6	186.6	
Hexacosane	C ₂₆ H ₅₄	204.0	240.0	257.4	275.8	295.2	307.8	323.2	348.4	374.6	399.8	56.6	
Hexadecane	C ₁₆ H ₃₄	105.3	135.2	149.8	164.7	181.3	193.2	208.5	231.7	258.3	287.5	18.5	
1-Hexadecene	C ₁₆ H ₃₂	101.6	131.7	146.2	162.0	178.8	190.8	205.3	226.8	250.0	274.0	4	
n-Hexadecyl alcohol (cetyl alcohol)	C ₁₆ H ₃₄ O	122.7	158.3	177.8	197.8	219.8	234.3	251.7	280.2	312.7	344.0	49.3	

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TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
<i>n</i> -Hexadecylamine (cetylamine)	C ₁₆ H ₃₃ N	123.6	157.8	176.0	195.7	215.7	228.8	245.8	272.2	300.4	330.0	
Hexaethylbenzene	C ₁₈ H ₃₀	134.3	150.3	168.0	187.7	199.7	216.0	241.7	268.5	298.3	130	
<i>n</i> -Hexane	C ₆ H ₁₄	-53.9	-34.5	-25.0	-14.1	-2.3	+5.4	15.8	31.6	49.6	68.7	-95.3
1-Hexanol	C ₆ H ₁₄ O	24.4	47.2	58.2	70.3	83.7	92.0	102.8	119.6	138.0	157.0	-51.6
2-Hexanol	C ₆ H ₁₄ O	14.6	34.8	45.0	55.9	67.9	76.0	87.3	103.7	121.8	139.9	
3-Hexanol	C ₆ H ₁₄ O	+2.5	25.7	36.7	49.0	62.2	70.7	81.8	98.3	117.0	135.5	
1-Hexene	C ₆ H ₁₂	-57.5	-38.0	-28.1	-17.2	-5.0	+2.8	13.0	29.0	46.8	66.0	-98.5
<i>n</i> -Hexyl levulinate	C ₁₁ H ₂₀ O ₃	90.0	120.0	134.7	150.2	167.8	179.0	193.6	215.7	241.0	266.8	
<i>n</i> -Hexyl phenyl ketone (enanthophenone)	C ₁₃ H ₁₈ O	100.0	130.3	145.5	161.0	178.9	189.8	204.2	225.0	248.3	271.3	
Hydrocinnamic acid	C ₉ H ₁₀ O ₂	102.2	133.5	148.7	165.0	183.3	194.0	209.0	230.8	255.0	279.8	48.5
Hydrogen cyanide (hydrocyanic acid)	CHN	-71.0	-55.3	-47.7	-39.7	-30.9	-25.1	-17.8	-5.3	+10.2	25.9	-13.2
Hydroquinone	C ₆ H ₆ O ₂	132.4	153.3	163.5	174.6	192.0	203.0	216.5	238.0	262.5	286.2	170.3
4-Hydroxybenzaldehyde	C ₇ H ₆ O ₂	121.2	153.2	169.7	186.8	206.0	217.5	233.5	256.8	282.6	310.0	115.5
α-Hydroxysobutyric acid	C ₄ H ₈ O ₃	73.5	98.5	110.5	123.8	138.0	146.4	157.7	175.2	193.8	212.0	79
α-Hydroxybutyronitrile	C ₅ H ₉ NO	41.0	65.8	77.8	90.7	104.8	113.9	125.0	142.0	159.8	178.8	
4-Hydroxy-3-methyl-2-butanone	C ₅ H ₁₀ O ₂	44.6	69.3	81.0	94.0	108.2	117.4	129.0	146.5	165.5	185.0	
4-Hydroxy-4-methyl-2-pentanone	C ₆ H ₁₂ O ₂	22.0	46.7	58.8	72.0	86.7	96.0	108.2	126.8	147.5	167.9	-47
3-Hydroxypropionitrile	C ₃ H ₅ NO	58.7	87.8	102.0	117.9	134.1	144.7	157.7	178.0	200.0	221.0	
Indene	C ₉ H ₈	16.4	44.3	58.5	73.9	90.7	100.8	114.7	135.6	157.8	181.6	-2
Iodobenzene	C ₆ H ₅ I	24.1	50.6	64.0	78.3	94.4	105.0	118.3	139.8	163.9	188.6	-28.5
Iodononane	C ₉ H ₁₉ I	70.0	96.2	109.0	123.0	138.1	147.7	159.8	179.0	199.3	219.5	
2-Iodotoluene	C ₇ H ₇ I	37.2	65.9	79.8	95.6	112.4	123.8	138.1	160.0	185.7	211.0	
α-Ionone	C ₁₃ H ₂₀ O	79.5	108.8	123.0	139.0	155.6	166.3	181.2	202.5	225.2	250.0	
Isoprene	C ₅ H ₈	-79.8	-62.3	-53.3	-43.5	-32.6	-25.4	-16.0	-1.2	+15.4	32.6	-146.7
Lauraldehyde	C ₁₀ H ₂₂ O	77.7	108.4	123.7	140.2	157.8	168.7	184.5	207.8	231.8	257.0	44.5
Lauric acid	C ₁₂ H ₂₂ O ₂	121.0	150.6	166.0	183.6	201.4	212.7	227.5	249.8	273.8	299.2	48
Levulinaldehyde	C ₅ H ₈ O ₂	28.1	54.9	68.0	82.7	98.3	108.4	121.8	142.0	164.0	187.0	
Levulinic acid	C ₅ H ₈ O ₃	102.0	128.1	141.8	154.1	169.5	178.0	190.2	208.3	227.4	245.8	33.5
<i>d</i> -Limonene	C ₁₀ H ₁₆	14.0	40.4	53.8	68.2	84.3	94.6	108.3	128.5	151.4	175.0	-96.9
Linalyl acetate	C ₁₁ H ₂₀ O ₂	55.4	82.5	96.0	111.4	127.7	138.1	151.8	173.3	196.2	220.0	
Maleic anhydride	C ₄ H ₂ O ₃	44.0	63.4	78.7	95.0	111.8	122.0	135.8	155.9	179.5	202.0	58
Menthane	C ₄ H ₁₀	+9.7	35.7	48.3	62.7	78.3	88.6	102.1	122.7	146.0	169.5	
1-Menthol	C ₁₀ H ₂₀ O	56.0	83.2	96.0	110.3	126.1	136.1	149.4	168.3	190.2	212.0	42.5
Menthyl acetate	C ₁₂ H ₂₂ O ₂	57.4	85.8	100.0	115.4	132.1	143.2	156.7	178.8	202.8	227.0	
benzoate	C ₁₇ H ₂₄ O ₂	123.2	154.2	170.0	186.3	204.3	215.8	230.4	253.2	277.1	301.0	54.5
formate	C ₁₁ H ₂₀ O ₂	47.3	75.8	90.0	105.8	123.0	133.8	148.0	169.8	194.2	219.0	
Mesityl oxide	C ₆ H ₁₀ O	-8.7	+14.1	26.0	37.9	51.7	60.4	72.1	90.0	109.8	130.0	-59
Methacrylic acid	C ₄ H ₆ O ₂	25.5	48.5	60.0	72.7	86.4	95.3	106.6	123.9	142.5	161.0	15
Methacrylonitrile	C ₄ H ₅ N	-44.5	-23.3	-12.5	-0.6	+12.8	21.5	32.8	50.0	70.3	90.3	
Methane	CH ₄	-205.9	-199.0	-195.5	-191.8	-187.7	-185.1	-181.4	-175.5	-168.8	-161.5	-182.5
Methanethiol	CH ₃ S	-90.7	-75.3	-67.5	-58.8	-49.2	-43.1	-34.8	-22.1	-7.9	+6.8	-121
Methoxyacetic acid	C ₃ H ₆ O ₃	52.5	79.3	92.0	106.5	122.0	131.8	144.5	163.5	184.2	204.0	
<i>N</i> -Methylacetanilide	C ₉ H ₁₁ NO	103.8	118.6	135.1	152.2	164.2	179.8	202.3	227.4	253.0	102	
Methyl acetate	C ₃ H ₆ O ₂	-57.2	-38.6	-29.3	-19.1	-7.9	-0.5	+9.4	24.0	40.0	57.8	-98.7
acetylene (propyne)	C ₃ H ₄	-111.0	-97.5	-90.5	-82.9	-74.3	-68.8	-61.3	-49.8	-37.2	-23.3	-102.7
acrylate	C ₄ H ₆ O ₂	-43.7	-23.6	-13.5	-2.7	+9.2	17.3	28.0	43.9	61.8	80.2	
alcohol (methanol)	CH ₄ O	-44.0	-25.3	-16.2	-6.0	+5.0	12.1	21.2	34.8	49.9	64.7	-97.8
Methylamine	CH ₃ N	-95.8	-81.3	-73.8	-65.9	-56.9	-51.3	-43.7	-32.4	-19.7	-6.3	-93.5
<i>N</i> -Methylaniline	C ₇ H ₉ N	36.0	62.8	76.2	90.5	106.0	115.8	129.8	149.3	172.0	195.5	-57
Methyl anthranilate	C ₈ H ₉ NO ₂	77.6	109.0	124.2	141.5	159.7	172.0	187.8	212.4	238.5	266.5	24
benzoate	C ₅ H ₈ O ₂	39.0	64.4	77.3	91.8	107.8	117.4	130.8	151.4	174.7	199.5	-12.5
2-Methylbenzothiazole	C ₈ H ₇ NS	70.0	97.5	111.2	125.5	141.2	150.4	163.9	183.2	204.5	225.5	15.4
α-Methylbenzyl alcohol	C ₈ H ₁₀ O	49.0	75.2	88.0	102.1	117.8	127.4	140.3	159.0	180.7	204.0	
Methyl bromide	CH ₃ Br	-96.3	-80.6	-72.8	-64.0	-54.2	-48.0	-39.4	-26.5	-11.9	+3.6	-93
2-Methyl-1-butene	C ₅ H ₁₀	-89.1	-72.8	-64.3	-54.8	-44.1	-37.3	-28.0	-13.8	+2.5	20.2	-135
2-Methyl-2-butene	C ₅ H ₁₀	-75.4	-57.0	-47.9	-37.9	-26.7	-19.4	-9.9	+4.9	21.6	38.5	-133
Methyl isobutyl carbinol (2-methyl-4-pentanol)	C ₆ H ₁₄ O	-0.3	+22.1	33.3	45.4	58.2	67.0	78.0	94.9	113.5	131.7	
<i>n</i> -butyl ketone (2-hexanone)	C ₆ H ₁₂ O	+7.7	28.8	38.8	50.0	62.0	69.8	79.8	94.3	111.0	127.5	-56.9
isobutyl ketone (4-methyl-2-pentanone)	C ₆ H ₁₂ O	-1.4	+19.7	30.0	40.8	52.8	60.4	70.4	85.6	102.0	119.0	-84.7
<i>n</i> -butyrate	C ₅ H ₁₀ O ₂	-26.8	-5.5	+5.0	16.7	29.6	37.4	48.0	64.3	83.1	102.3	
isobutyrate	C ₅ H ₁₀ O ₂	-34.1	-13.0	-2.9	+8.4	21.0	28.9	39.6	55.7	73.6	92.6	-84.7
caprate	C ₁₁ H ₂₂ O ₂	63.7	93.5	108.0	123.0	139.0	148.6	161.5	181.6	202.9	224.0	-18
caproate	C ₇ H ₁₄ O ₂	+5.0	30.0	42.0	55.4	70.0	79.7	91.4	109.8	129.8	150	
caprylate	C ₉ H ₁₈ O ₂	34.2	61.7	74.9	89.0	105.3	115.3	128.0	148.1	170.0	193.0	-40
chloride	CH ₃ Cl	-99.5	-92.4	-84.8	-76.0	-70.4	-63.0	-51.2	-38.0	-24.0	-97.7	
chloroacetate	C ₃ H ₅ ClO ₂	-2.9	19.0	30.0	41.5	54.5	63.0	73.5	90.5	109.5	130.3	-31.9
cinnamate	C ₉ H ₁₀ O ₂	77.4	108.1	123.0	140.0	157.9	170.0	185.8	209.6	235.0	263.0	33.4
α-Methylcinnamic acid	C ₁₀ H ₁₀ O ₂	125.7	155.0	169.8	185.2	201.8	212.0	224.8	245.0	266.8	288.0	
Methylcyclohexane	C ₇ H ₁₄	-35.9	-14.0	-3.2	+8.7	22.0	30.5	42.1	59.6	79.6	100.9	-126.4
Methylcyclopentane	C ₆ H ₁₂	-53.7	-33.8	-23.7	-12.8	-0.6	+7.2	17.9	34.0	52.3	71.8	-142.4
Methylcyclopropane	C ₄ H ₈	-96.0	-80.6	-72.8	-64.0	-54.2	-48.0	-39.3	-26.0	-11.3	+4.5	
Methyl <i>n</i> -decyl ketone (<i>n</i> -dodecan-2-one)	C ₁₂ H ₂₄ O	77.1	106.0	120.4	136.0	152.4	163.8	177.5	199.0	222.5	246.5	
dichloroacetate	C ₃ H ₄ Cl ₂ O ₂	3.2	26.7	38.1	50.7	64.7	73.6	85.4	103.2	122.6	143.0	
<i>N</i> -Methyldiphenylamine	C ₁₃ H ₁₃ N	103.5	134.0	149.7	165.8	184.0	195.4	210.1	232.8	257.0	282.0	-7.6

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm* (Continued)

Compound	Name	Formula	Pressure, mm Hg										Melting point, °C
			1	5	10	20	40	60	100	200	400	760	
Temperature, °C													
Methyl <i>n</i> -dodecyl ketone (2-tetradecanone)	C ₁₄ H ₂₈ O	99.3	130.0	145.5	161.3	179.8	191.4	206.0	228.2	253.3	278.0		
Methylene bromide (dibromomethane)	CH ₂ Br ₂	-35.1	-13.2	-2.4	+9.7	23.3	31.6	42.3	58.5	79.0	98.6	-52.8	
chloride (dichloromethane)	CH ₂ Cl ₂	-70.0	-52.1	-43.3	-33.4	-22.3	-15.7	-6.3	+8.0	24.1	40.7	-96.7	
Methyl ethyl ketone (2-butanone)	C ₄ H ₈ O	-48.3	-28.0	-17.7	-6.5	+6.0	14.0	25.0	41.6	60.0	79.6	-85.9	
2-Methyl-3-ethylpentane	C ₈ H ₁₈	-24.0	-1.8	+9.5	21.7	35.2	43.9	55.7	73.6	94.0	115.6	-114.5	
3-Methyl-3-ethylpentane	C ₈ H ₁₈	-23.9	-1.4	+9.9	22.3	36.2	45.0	57.1	75.3	96.2	118.3	-90	
Methyl fluoride	CH ₃ F	-147.3	-137.0	-131.6	-125.9	-119.1	-115.0	-109.0	-99.9	-89.5	-78.2		
formate	C ₂ H ₄ O ₂	-74.2	-57.0	-48.6	-39.2	-28.7	-21.9	-12.9	+0.8	16.0	32.0	-99.8	
α-Methylglutaric anhydride	C ₆ H ₈ O ₃	93.8	125.4	141.8	157.7	177.5	189.9	205.0	229.1	255.5	282.5		
Methyl glycolate	C ₃ H ₆ O ₃	+9.6	33.7	45.3	58.1	72.3	81.8	93.7	111.8	131.7	151.5		
2-Methylheptadecane	C ₁₈ H ₃₈	119.8	152.0	168.7	186.0	204.8	216.3	231.5	254.5	279.8	306.5		
2-Methylheptane	C ₈ H ₁₈	-21.0	+1.3	12.3	24.4	37.9	46.6	58.3	76.0	96.2	117.6	-109.5	
3-Methylheptane	C ₈ H ₁₈	-19.8	+2.6	13.3	25.4	38.9	47.6	59.4	77.1	97.4	118.9	-120.8	
4-Methylheptane	C ₈ H ₁₈	-20.4	+1.5	12.4	24.5	38.0	46.6	58.3	76.1	96.3	117.7	-121.1	
2-Methyl-2-heptene	C ₈ H ₁₆	-16.1	+6.7	17.8	30.4	44.0	52.8	64.6	82.3	102.2	122.5		
6-Methyl-3-hepten-2-ol	C ₈ H ₁₆ O	41.6	65.0	76.7	89.3	102.7	111.5	122.6	139.5	156.6	175.5		
6-Methyl-5-hepten-2-ol	C ₈ H ₁₆ O	41.9	66.0	77.8	90.4	104.0	112.8	123.8	140.0	156.6	174.3		
2-Methylhexane	C ₇ H ₁₆	-40.4	-19.5	-9.1	+2.3	14.9	23.0	34.1	50.8	69.8	90.0	-118.2	
3-Methylhexane	C ₇ H ₁₆	-39.0	-18.1	-7.8	+3.6	16.4	24.5	35.6	52.4	71.6	91.9		
Methyl iodide	CH ₃ I	-55.0	-45.8	-35.6	-24.2	-16.9	-7.0	+8.0	25.3	42.4	-64.4		5
laurate	C ₁₃ H ₂₆ O ₂	87.8	117.9	133.2	149.0	166.0	176.8	190.8					
levulinic	C ₆ H ₁₀ O ₃	39.8	66.4	79.7	93.7	109.5	119.3	133.0	153.4	175.8	197.7		
methacrylate	C ₅ H ₈ O ₂	-30.5	-10.0	+1.0	11.0	25.5	34.5	47.0	63.0	82.0	101.0		
myristate	C ₁₅ H ₃₀ O ₂	115.0	145.7	160.8	177.8	195.8	207.5	222.6	245.3	269.8	295.8	18.5	
α-naphthyl ketone (1-acetonaphthone)	C ₁₂ H ₁₀ O	115.6	146.3	161.5	178.4	196.8	208.6	223.8	246.7	270.5	295.5		
β-naphthyl ketone (2-acetonaphthone)	C ₁₂ H ₁₀ O	120.2	152.3	168.5	185.7	203.8	214.7	229.8	251.6	275.8	301.0	55.5	
<i>n</i> -nonyl ketone (undecan-2-one)	C ₁₁ H ₂₀ O	68.2	95.5	108.9	123.1	139.0	148.6	161.0	181.2	202.3	224.0	15	
palmitate	C ₁₇ H ₃₄ O ₂	134.3	166.8	184.3	202.0							30	
<i>n</i> -pentadecyl ketone (2-heptadecanone)	C ₁₇ H ₃₄ O	129.6	161.6	178.0	196.4	214.3	226.7	242.0	265.8	291.7	319.5		
2-Methylpentane	C ₆ H ₁₄	-60.9	-41.7	-32.1	-21.4	-9.7	-1.9	+8.1	24.1	41.6	60.3	-154	
3-Methylpentane	C ₆ H ₁₄	-59.0	-39.8	-30.1	-19.4	-7.3	+0.1	10.5	26.5	44.2	63.3	-118	
2-Methyl-1-pentanol	C ₆ H ₁₄ O	15.4	38.0	49.6	61.6	74.7	83.4	94.2	111.3	129.8	147.9		
2-Methyl-2-pentanol	C ₆ H ₁₄ O	-4.5	+16.8	27.6	38.8	51.3	58.8	69.2	85.0	102.6	121.2	-103	
Methyl <i>n</i> -pentyl ketone (2-heptanone)	C ₇ H ₁₄ O	19.3	43.6	55.5	67.7	81.2	89.8	100.0	116.1	133.2	150.2		
phenyl ether (anisole)	C ₇ H ₈ O	+5.4	30.0	42.2	55.8	70.7	80.1	93.0	112.3	133.8	155.5	-37.3	
2-Methylpropene	C ₄ H ₈	-105.1	-96.5	-81.9	-73.4	-63.8	-57.7	-49.3	-36.7	-22.2	-6.9	-140.3	
Methyl propionate	C ₄ H ₈ O ₂	-42.0	-21.5	-11.8	-1.0	+11.0	18.7	29.0	44.2	61.8	79.8	-87.5	
4-Methylpropiophenone	C ₁₀ H ₁₂ O	59.6	89.3	103.8	120.2	138.0	149.3	164.2	187.4	212.7	238.5		
2-Methylpropionyl bromide	C ₄ H ₇ BrO	13.5	38.4	50.6	64.1	79.4	88.8	101.6	120.5	141.7	163.0		
Methyl propyl ether	C ₄ H ₁₀ O	-72.2	-54.3	-45.4	-35.4	-24.3	-17.4	-8.1	+6.0	22.5	39.1		
<i>n</i> -propyl ketone (2-pentanone)	C ₅ H ₁₀ O	-12.0	+8.0	17.9	28.5	39.8	47.3	56.8	71.0	86.8	103.3	-77.8	
isopropyl ketone (3-Methyl-2-butanoine)	C ₅ H ₁₀ O	-19.9	-1.0	+8.3	18.3	29.6	36.2	45.5	59.0	73.8	88.9	-92	
2-Methylquinoline	C ₁₀ H ₉ N	75.3	104.0	119.0	134.0	150.8	161.7	176.2	197.8	211.7	246.5	-1	
Methyl salicylate	C ₈ H ₈ O ₃	54.0	81.6	95.3	110.0	126.2	136.7	150.0	172.6	197.5	223.2	-8.3	
α-Methyl styrene	C ₉ H ₁₀	7.4	34.0	47.1	61.8	77.8	88.3	102.2	121.8	143.0	165.4	-23.2	
4-Methyl styrene	C ₉ H ₁₀	16.0	42.0	55.1	69.2	85.0	95.0	108.6	128.7	151.2	175.0		
Methyl <i>n</i> -tetradecyl ketone (2-hexadecanone)	C ₁₆ H ₃₂ O	109.8	151.5	167.3	184.6	203.7	215.0	230.5	254.4	279.8	307.0		
thiocyanate	C ₂ H ₃ NS	-14.0	+9.8	21.6	34.5	49.0	58.1	70.4	89.8	110.8	132.9	-51	
isothiocyanate	C ₂ H ₃ NS	-34.7	-8.3	+5.4	20.4	38.2	47.5	59.3	77.5	97.8	119.0	35.5	
undecyl ketone (2-tridecanone)	C ₁₃ H ₂₆ O	86.8	117.0	131.8	147.8	165.7	176.6	191.5	214.0	238.3	262.5	28.5	
isovalerate	C ₆ H ₁₂ O ₂	-19.2	+2.9	14.0	26.4	39.8	48.2	59.8	77.3	96.7	116.7		
Monovinylacetylene (butenyne)	C ₄ H ₄	-93.2	-77.7	-70.0	-61.3	-51.7	-45.3	-37.1	-24.1	-10.1	+5.3		
Myrcene	C ₁₀ H ₁₆	14.5	40.0	53.2	67.0	82.6	92.6	106.0	126.0	148.3	171.5		
Myristaldehyde	C ₁₄ H ₂₈ O	99.0	132.0	148.3	166.2	186.0	198.3	214.5	240.4	267.9	297.8	23.5	
Myristic acid (tetradecanoic acid)	C ₁₄ H ₂₈ O ₂	142.0	174.1	190.8	207.6	223.5	237.2	250.5	272.3	294.6	318.0	57.5	
Naphthalene	C ₁₀ H ₈	52.6	74.2	85.8	101.7	119.3	130.2	145.5	167.7	193.2	217.9	80.2	
1-Naphthoic acid	C ₁₁ H ₈ O ₂	156.0	184.0	196.8	211.2	225.0	234.5	245.8	263.5	281.4	300.0	160.5	
2-Naphthoic acid	C ₁₁ H ₈ O ₂	160.8	189.7	202.8	216.9	231.5	241.3	252.7	270.3	289.5	308.5	184	
1-Naphthol	C ₁₀ H ₉ O	94.0	125.5	142.0	158.0	177.8	190.0	206.0	229.6	255.8	282.5	96	
2-Naphthol	C ₁₀ H ₉ O			128.6	145.5	161.8	181.7	193.7	209.8	234.0	260.6	288.0	122.5
1-Naphthylamine	C ₁₀ H ₉ N	104.3	137.7	153.8	171.6	191.5	203.8	220.0	244.9	272.2	300.8	50	
2-Naphthylamine	C ₁₀ H ₉ N	108.0	141.6	157.6	175.8	195.7	208.1	224.3	249.7	277.4	306.1	111.5	
Nicotine	C ₁₀ H ₁₄ N ₂	61.8	91.8	107.2	123.7	142.1	154.7	169.5	193.8	219.8	247.3		
2-Nitroaniline	C ₆ H ₅ N ₂ O ₂	104.0	135.7	150.4	167.7	186.0	197.8	213.0	236.3	260.0	284.5	71.5	
3-Nitroaniline	C ₆ H ₅ N ₂ O ₂	119.3	151.5	167.8	185.5	204.2	216.5	232.1	255.3	280.2	305.7	114	
4-Nitroaniline	C ₆ H ₅ N ₂ O ₂	142.4	177.6	194.4	213.2	234.2	245.9	261.8	284.5	310.2	336.0	146.5	
2-Nitrobenzaldehyde	C ₇ H ₅ NO ₃	85.8	117.7	133.4	150.0	168.8	180.7	196.2	220.0	246.8	273.5	40.9	
3-Nitrobenzaldehyde	C ₇ H ₅ NO ₃	96.2	127.4	142.8	159.0	177.7	189.5	204.3	227.4	252.1	278.3	58	
Nitrobenzene	C ₆ H ₅ NO ₂	44.4	71.6	84.9	99.3	115.4	125.8	139.9	161.2	185.8	210.6	+5.7	
Nitroethane	C ₂ H ₅ NO ₂	-21.0	+1.5	12.5	24.8	38.0	46.5	57.8	74.8	94.0	114.0	-90	
Nitroglycerin	C ₃ H ₅ NO ₉	127	167	188	210	235	251					11	
Nitromethane	CH ₃ NO ₂	-29.0	-7.9	+2.8	14.1	27.5	35.5	46.6	63.5	82.0	101.2	-29	
2-Nitrophenol	C ₆ H ₅ NO ₃	49.3	76.8	90.4	105.8	122.1	132.6	146.4	167.6	191.0	214.5	45	
2-Nitrophenyl acetate	C ₈ H ₇ NO ₄	100.0	128.0	142.0	155.8	172.8	181.7	194.1	213.0	233.5</td			

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
1-Nitropropane	C ₃ H ₇ NO ₂	-9.6	+13.5	25.3	37.9	51.8	60.5	72.3	90.2	110.6	131.6	-108
2-Nitropropane	C ₃ H ₇ NO ₂	-18.8	+4.1	15.8	28.2	41.8	50.3	62.0	80.0	99.8	120.3	-93
2-Nitrotoluene	C ₇ H ₇ NO ₂	50.0	79.1	93.8	109.6	126.3	137.6	151.5	173.7	197.7	222.3	-4.1
3-Nitrotoluene	C ₇ H ₇ NO ₂	50.2	81.0	96.0	112.8	130.7	142.5	156.9	180.3	206.8	231.9	15.5
4-Nitrotoluene	C ₇ H ₇ NO ₂	53.7	85.0	100.5	117.7	136.0	147.9	163.0	186.7	212.5	238.3	51.9
4-Nitro-1,3-xylene (4-nitro- <i>m</i> -xylene)	C ₈ H ₉ NO ₂	65.6	95.0	109.8	125.8	143.3	153.8	168.5	191.7	217.5	244.0	+2
Nonacosane	C ₂₉ H ₆₀	234.2	269.8	286.4	303.6	323.2	334.8	350.0	373.2	397.2	421.8	63.8
Nonadecane	C ₁₉ H ₄₀	133.2	166.3	183.5	200.8	220.0	232.8	248.0	271.8	299.8	330.0	32
<i>n</i> -Nonane	C ₉ H ₂₀	+1.4	25.8	38.0	51.2	66.0	75.5	88.1	107.5	128.2	150.8	-53.7
1-Nonanol	C ₉ H ₂₀ O	59.5	86.1	99.7	113.8	129.0	139.0	151.3	170.5	192.1	213.5	-5
2-Nonanone	C ₉ H ₁₈ O	32.1	59.0	72.3	87.2	103.4	113.8	127.4	148.2	171.2	195.0	-19
Octacosane	C ₂₈ H ₅₈	226.5	260.3	277.4	295.4	314.2	326.8	341.8	364.8	388.9	412.5	61.6
Octadecane	C ₁₈ H ₃₈	119.6	152.1	169.6	187.5	207.4	219.7	236.0	260.6	288.0	317.0	28
<i>n</i> -Octane	C ₈ H ₁₈	-14.0	+8.3	19.2	31.5	45.1	53.8	65.7	83.6	104.0	125.6	-56.8
<i>n</i> -Octanol (1-octanol)	C ₈ H ₁₈ O	54.0	76.5	88.3	101.0	115.2	123.8	135.2	152.0	173.8	195.2	-15.4
2-Octanone	C ₈ H ₁₆ O	23.6	48.4	60.9	74.3	89.8	99.0	111.7	130.4	151.0	172.9	-16
<i>n</i> -Octyl acrylate iodide (1-Iodooctane)	C ₁₁ H ₂₀ O ₂	58.5	87.7	102.0	117.8	135.6	145.6	159.1	180.2	204.0	227.0	
Oleic acid	C ₁₈ H ₃₄ O ₂	176.5	208.5	223.0	240.0	257.2	269.8	286.0	309.8	334.7	360.0	14
Palmitaldehyde	C ₁₆ H ₃₀ O	121.6	154.6	171.8	190.0	210.0	222.6	239.5	264.1	292.3	321.0	34
Palmitic acid	C ₁₆ H ₃₂ O ₂	153.6	188.1	205.8	223.8	244.4	256.0	271.5	298.7	326.0	353.8	64.0
Palmitonitrile	C ₁₆ H ₃₁ N	134.3	168.3	185.8	204.2	223.8	236.6	251.5	277.1	304.5	332.0	31
Pelargonic acid	C ₉ H ₁₈ O ₂	108.2	126.0	137.4	149.8	163.7	172.3	184.4	203.1	227.5	253.5	12.5
Pentachlorobenzene	C ₆ HCl ₅	98.6	129.7	144.3	160.0	178.5	190.1	205.5	227.0	251.6	276.0	85.5
Pentachloroethane	C ₂ HCl ₅	+1.0	27.2	39.8	53.9	69.9	80.0	93.5	114.0	137.2	160.5	-22
Pentachloroethylbenzene	C ₈ H ₅ Cl ₅	96.2	130.0	148.0	166.0	186.2	199.0	216.0	241.8	269.3	299.0	
Pentachlorophenol	C ₆ HCl ₅ O					192.2	211.2	223.4	239.6	261.8	285.0	309.3
Pentacosane	C ₂₅ H ₅₂	194.2	230.0	248.2	266.1	285.6	298.4	314.0	339.0	365.4	390.3	188.5
Pentadecane	C ₁₅ H ₃₂	91.6	121.0	135.4	150.2	167.7	178.4	194.0	216.1	242.8	270.5	10
1,3-Pentadiene	C ₅ H ₈	-71.8	-53.8	-45.0	-34.8	-23.4	-16.5	-6.7	+8.0	24.7	42.1	
1,4-Pentadiene	C ₅ H ₈	-83.5	-66.2	-57.1	-47.7	-37.0	-30.0	-20.6	-6.7	+8.3	26.1	
Pentaethylbenzene	C ₁₁ H ₂₆	86.0	120.0	135.8	152.4	171.9	184.2	200.0	224.1	250.2	277.0	
Pentaethylchlorobenzene	C ₁₆ H ₂₅ Cl	90.0	123.8	140.7	158.1	178.2	191.0	208.0	230.3	257.2	285.0	
<i>n</i> -Pentane	C ₅ H ₁₂	-76.6	-62.5	-50.1	-40.2	-29.2	-22.2	-12.6	+1.9	18.5	36.1	-129.7
iso-Pentane (2-methylbutane)	C ₅ H ₁₂	-82.9	-65.8	-57.0	-47.3	-36.5	-29.6	-20.2	-5.9	+10.5	27.8	-159.7
neo-Pentane (2,2-dimethylpropane)	C ₅ H ₁₂	-102.0	-85.4	-76.7	-67.2	-56.1	-49.0	-39.1	-23.7	-7.1	+9.5	-16.6
2,3,4-Pentanetriol	C ₅ H ₁₂ O ₃	155.0	189.3	204.5	220.5	239.6	249.8	263.5	284.5	307.0	327.2	
1-Pentene	C ₅ H ₁₀	-80.4	-63.3	-54.5	-46.0	-34.1	-27.1	-17.7	-3.4	+12.8	30.1	
α-Phellandrene	C ₁₀ H ₁₆	20.0	45.7	58.0	72.1	87.8	97.6	110.6	130.6	152.0	175.0	
Phenanthrene	C ₁₄ H ₁₀	118.2	154.3	173.0	193.7	215.8	229.9	249.0	277.1	308.0	340.2	99.5
Phenethyl alcohol (phenyl cellosolve)	C ₈ H ₁₀ O ₂	58.2	85.9	100.0	114.8	130.5	141.2	154.0	175.0	197.5	219.5	
2-Phenetidine	C ₈ H ₁₁ NO	67.0	94.7	108.6	123.7	139.9	149.8	163.5	184.0	207.0	228.0	
Phenol	C ₆ H ₆ O	40.1	62.5	73.8	86.0	100.1	108.4	121.4	139.0	160.0	181.9	40.6
2-Phenoxyethanol	C ₈ H ₁₀ O ₂	78.0	106.6	121.2	136.0	152.2	163.2	176.5	197.6	221.0	245.3	11.6
2-Phenoxyethyl acetate	C ₁₀ H ₁₂ O ₃	82.6	113.5	128.0	144.5	162.3	174.0	189.2	211.3	235.0	259.7	-6.7
Phenyl acetate	C ₈ H ₈ O ₂	38.2	64.8	78.0	92.3	108.1	118.1	131.6	151.2	173.5	195.9	
Phenylacetic acid	C ₈ H ₈ O ₂	97.0	127.0	141.3	156.0	173.6	184.5	198.2	219.5	243.0	265.5	76.5
Phenylacetomitrile	C ₈ H ₇ N	60.0	89.0	103.5	119.4	136.3	147.7	161.8	184.1	208.5	233.5	-23.8
Phenylacetyl chloride	C ₈ H ₇ ClO	48.0	75.3	89.0	103.6	119.8	129.8	143.5	163.8	186.0	210.0	
Phenyl benzoate	C ₁₃ H ₁₀ O ₂	106.8	141.5	157.8	177.0	197.6	210.8	227.8	254.0	283.5	314.0	70.5
4-Phenyl-3-buten-2-one	C ₉ H ₁₀ O	81.7	112.2	127.4	143.8	161.3	172.6	187.8	211.0	235.4	261.0	41.5
Phenyl isocyanate isocyanide	C ₇ H ₅ N	10.6	36.0	48.5	62.5	77.7	87.7	100.6	120.8	142.7	165.6	
Phenylcyclohexane	C ₁₂ H ₁₆	67.5	96.5	111.3	126.4	144.0	154.2	169.3	191.3	214.6	240.0	+7.5
Phenyl dichlorophosphate	C ₆ H ₅ Cl ₂ O ₂ P	66.7	95.9	110.0	125.9	143.4	153.6	168.0	189.8	213.0	239.5	
<i>m</i> -Phenylenediamine (1,3-phenylenediamine)	C ₆ H ₈ N ₂	99.8	131.2	147.0	163.8	182.5	194.0	209.9	233.0	259.0	285.5	62.8
Phenylglyoxal	C ₆ H ₆ O ₂	75.0	87.8	100.7	115.5	124.2	136.2	153.8	173.5	193.5	213.5	73
Phenylhydrazine	C ₆ H ₈ N ₂	71.8	101.6	115.8	131.5	148.2	158.7	173.5	195.4	218.2	243.5	19.5
<i>N</i> -Phenyliminodioethanol	C ₁₀ H ₁₅ NO ₂	145.0	179.2	195.8	213.4	233.0	245.3	260.6	284.5	311.3	337.8	
1-Phenyl-1,3-pentanedione	C ₉ H ₁₂ O ₂	98.0	128.5	144.0	159.9	178.0	189.8	204.5	226.7	251.2	276.5	
2-Phenylphenol	C ₁₂ H ₁₀ O	100.0	131.6	146.2	163.3	180.3	192.2	205.9	227.9	251.8	275.0	56.5
4-Phenylphenol	C ₁₂ H ₁₀ O					176.2	193.8	213.0	240.9	263.2	285.5	308.0
3-Phenyl-1-propanol	C ₉ H ₁₂ O	74.7	102.4	116.0	131.2	147.4	156.8	170.3	191.2	212.8	235.0	
Phenyl isothiocyanate	C ₇ H ₅ NS	47.2	75.6	89.8	115.5	122.5	133.3	147.7	169.6	194.0	218.5	-21.0
Phorone	C ₉ H ₁₄ O	42.0	68.3	81.5	95.6	111.3	121.4	134.0	153.5	175.3	197.2	28
iso-Phorone	C ₉ H ₁₄ O	38.0	66.7	81.2	96.8	114.5	125.6	140.6	163.3	188.7	215.2	
Phosgene (carbonyl chloride)	CCl ₂ O	-92.9	-77.0	-69.3	-60.3	-50.3	-44.0	-35.6	-22.3	-7.6	+8.3	-104
Phthalic anhydride	C ₈ H ₄ O ₃	96.5	121.3	134.0	151.7	172.0	185.3	202.3	228.0	256.8	284.5	130.8
Phthalide	C ₈ H ₆ O ₂	95.5	127.7	144.0	161.3	181.0	193.5	210.0	234.5	261.8	290.0	73
Phthaloyl chloride	C ₈ H ₄ Cl ₂ O ₂	86.3	118.3	134.2	151.0	170.0	182.2	197.8	222.0	248.3	275.8	88.5
2-Picoline	C ₆ H ₇ N	-11.1	+12.6	24.4	37.4	51.2	59.9	71.4	89.0	105.4	128.8	-70
Pimelic acid	C ₁₂ H ₁₂ O ₄	163.4	196.2	212.0	229.3	247.0	258.2	272.0	294.5	318.5	342.1	103
α-Pinene	C ₁₀ H ₁₆	-1.0	+24.6	37.3	51.4	66.8	76.8	90.1	110.2	132.3	155.0	-55
β-Pinene	C ₁₀ H ₁₆	+4.2	30.0	42.3	58.1	71.5	81.2	94.0	114.1	136.1	158.3	

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
Temperature, °C												
Piperidine	C ₅ H ₁₁ N		-7.0	+3.9	15.8	29.2	37.7	49.0	66.2	85.7	106.0	-9
Piperonal	C ₈ H ₆ O ₃	87.0	117.4	132.0	148.0	165.7	177.0	191.7	214.3	238.5	263.0	37
Propane	C ₃ H ₈	-128.9	-115.4	-108.5	-100.9	-92.4	-87.0	-79.6	-68.4	-55.6	-42.1	-187.1
Propenylbenzene	C ₉ H ₁₀	17.5	43.8	57.0	71.5	87.7	97.8	111.7	132.0	154.7	179.0	-30.1
Propionamide	C ₃ H ₇ NO	65.0	91.0	105.0	119.0	134.8	144.3	156.0	174.2	194.0	213.0	79
Propionic acid anhydride	C ₄ H ₆ O ₂	4.6	28.0	39.7	52.0	65.8	74.1	85.8	102.5	122.0	141.1	-22
Propionitrile	C ₃ H ₅ N	-35.0	-13.6	-3.0	+8.8	22.0	30.1	41.4	58.2	77.7	97.1	-91.9
Propiophenone	C ₉ H ₁₀ O	50.0	77.9	92.2	107.6	124.3	135.0	149.3	170.2	194.2	218.0	21
n-Propyl acetate	C ₅ H ₁₀ O ₂	-26.7	-5.4	+5.0	16.0	28.8	37.0	47.8	64.0	82.0	101.8	-92.5
iso-Propyl acetate	C ₅ H ₁₀ O ₂	-38.3	-17.4	-7.2	+4.2	17.0	25.1	35.7	51.7	69.8	89.0	
n-Propyl alcohol (1-propanol)	C ₃ H ₈ O	-15.0	+5.0	14.7	25.3	36.4	43.5	52.8	66.8	82.0	97.8	-127
iso-Propyl alcohol (2-propanol)	C ₃ H ₈ O	-26.1	-7.0	+2.4	12.7	23.8	30.5	39.5	53.0	67.8	82.5	-85.8
n-Propylamine	C ₃ H ₉ N	-64.4	-46.3	-37.2	-27.1	-16.0	-9.0	+0.5	15.0	31.5	48.5	-83
Propylbenzene	C ₉ H ₁₂	6.3	31.3	43.4	56.8	71.6	81.1	94.0	113.5	135.7	159.2	-99.5
Propyl benzoate	C ₁₀ H ₁₂ O ₂	54.6	83.8	98.0	114.3	131.8	143.3	157.4	180.1	205.2	231.0	-51.6
n-Propyl bromide (1-bromopropane)	C ₃ H ₇ Br	-53.0	-33.4	-23.3	-12.4	-0.3	+7.5	18.0	34.0	52.0	71.0	-109.9
iso-Propyl bromide (2-bromopropane)	C ₃ H ₇ Br	-61.8	-42.5	-32.8	-22.0	-10.1	-2.5	+8.0	23.8	41.5	60.0	-89.0
n-Propyl n-butyrate isobutyrate	C ₇ H ₁₄ O ₂	-1.6	+22.1	34.0	47.0	61.5	70.3	82.6	101.0	121.7	142.7	-95.2
iso-Propyl isobutyrate	C ₇ H ₁₄ O ₂	-6.2	+16.8	28.3	40.6	54.3	63.0	73.9	91.8	112.0	133.9	
Propyl carbamate	C ₄ H ₉ NO ₂	-16.3	+5.8	17.0	29.0	42.4	51.4	62.3	80.2	100.0	120.5	
n-Propyl chloride (1-chloropropane)	C ₃ H ₇ Cl	-68.3	-50.0	-41.0	-31.0	-19.5	-12.1	-2.5	+12.2	29.4	46.4	-122.8
iso-Propyl chloride (2-chloropropane)	C ₃ H ₇ Cl	-78.8	-61.1	-52.0	-42.0	-31.0	-23.5	-13.7	+1.3	18.1	36.5	-117
iso-Propyl chloroacetate	C ₅ H ₉ ClO ₂	+3.8	28.1	40.2	53.9	68.7	78.0	90.3	108.8	128.0	148.6	
Propyl chloroglyoxylate	C ₅ H ₇ ClO ₃	9.7	32.3	43.5	55.6	68.8	77.2	88.0	104.7	123.0	150.0	
Propylene	C ₃ H ₆	-131.9	-120.7	-112.1	-104.7	-96.5	-91.3	-84.1	-73.3	-60.9	-47.7	-185
Propylene glycol (1,2-Propanediol)	C ₃ H ₈ O ₂	45.5	70.8	83.2	96.4	111.2	119.9	132.0	149.7	168.1	188.2	
Propylene oxide	C ₃ H ₆ O	-75.0	-57.8	-49.0	-39.3	-28.4	-21.3	-12.0	+2.1	17.8	34.5	-112.1
n-Propyl formate	C ₄ H ₈ O ₂	-43.0	-22.7	-12.6	-1.7	+10.8	18.8	29.5	45.3	62.6	81.3	-92.9
iso-Propyl formate	C ₄ H ₈ O ₂	-52.0	-32.7	-22.7	-12.1	-0.2	+7.5	17.8	33.6	50.5	68.3	
4,4'-iso-Propylidenebisphenol	C ₁₅ H ₁₆ O ₂	193.0	224.2	240.8	255.5	273.0	282.9	297.0	317.5	339.0	360.5	
n-Propyl iodide (1-iodopropane)	C ₃ H ₇ I	-36.0	-13.5	-2.4	+10.0	23.6	32.1	43.8	61.8	81.8	102.5	-98.8
iso-Propyl iodide (2-iodopropane)	C ₃ H ₇ I	-43.3	-22.1	-11.7	0.0	+13.2	21.6	32.8	50.0	69.5	89.5	-90
n-Propyl levulinic acid	C ₈ H ₁₄ O ₃	59.7	86.3	99.9	114.0	130.1	140.6	154.0	175.6	198.0	221.2	
iso-Propyl levulinic acid	C ₈ H ₁₄ O ₃	48.0	74.5	88.0	102.4	118.1	127.8	141.8	161.6	185.2	208.2	
Propyl mercaptan (1-propanethiol)	C ₃ H ₈ S	-56.0	-36.3	-26.3	-15.4	-3.2	+4.6	15.3	31.5	49.2	67.4	-112
2-iso-Propynaphthalene	C ₁₃ H ₁₄	76.0	107.9	123.4	140.3	159.0	171.4	187.6	211.8	238.5	266.0	
iso-Propyl β-naphthyl ketone (2-isobutryl naphthone)	C ₁₄ H ₁₄ O	133.2	165.4	181.0	197.7	215.6	227.0	242.3	264.0	288.2	313.0	
2-iso-Propylphenol	C ₉ H ₁₂ O	56.6	83.8	97.0	111.7	127.5	137.7	150.3	170.1	192.6	214.5	15.5
3-iso-Propylphenol	C ₉ H ₁₂ O	62.0	90.3	104.1	119.8	136.2	146.6	160.2	182.0	205.0	228.0	26
4-iso-Propylphenol	C ₉ H ₁₂ O	67.0	94.7	108.0	123.4	139.8	149.7	163.3	184.0	206.1	228.2	61
Propyl propionate	C ₆ H ₁₂ O ₂	-14.2	+8.0	19.4	31.6	45.0	53.8	65.2	82.7	102.0	122.4	-76
4-iso-Propylstyrene	C ₁₁ H ₁₄	34.7	62.3	76.0	91.2	108.0	118.4	132.8	153.9	178.0	202.5	
Propyl isovalerate	C ₈ H ₁₆ O ₂	+8.0	32.8	45.1	58.0	72.8	82.3	95.0	113.9	135.0	155.9	
Pulegone	C ₁₀ H ₁₆ O	58.3	82.5	94.0	106.8	121.7	130.2	143.1	162.5	189.8	221.0	
Pyridine	C ₅ H ₅ N	-18.9	+2.5	13.2	24.8	38.0	46.8	57.8	75.0	95.6	115.4	-42
Pyrocatechol	C ₆ H ₆ O ₂		104.0	118.3	134.0	150.6	161.7	176.0	197.7	221.5	245.5	105
Pyrocaltechol diacetate (1,2-phenylene diacetate)	C ₁₀ H ₁₀ O ₄	98.0	129.8	145.7	161.8	179.8	191.6	206.5	228.7	253.3	278.0	
Pyrogallol	C ₆ H ₆ O ₃		151.7	167.7	185.3	204.2	216.3	232.0	255.3	281.5	309.0	133
Pyrotartaric anhydride	C ₅ H ₆ O ₃	69.7	99.7	114.2	130.0	147.8	158.6	173.8	196.1	221.0	247.4	
Pyruvic acid	C ₃ H ₄ O ₃	21.4	45.8	57.9	70.8	85.3	94.1	106.5	124.7	144.7	165.0	13.6
Quinoline	C ₉ H ₇ N	59.7	89.6	103.8	119.8	136.7	148.1	163.2	186.2	212.3	237.7	-15
iso-Quinoline	C ₉ H ₇ N	63.5	92.7	107.8	123.7	141.6	152.0	167.6	190.0	214.5	240.5	24.6
Resorcinol	C ₆ H ₆ O ₂	108.4	138.0	152.1	168.0	185.3	195.8	209.8	230.8	253.4	276.5	110.7
Safrole	C ₁₀ H ₁₀ O ₂	63.8	93.0	107.6	123.0	140.1	150.3	165.1	186.2	210.0	233.0	11.2
Salicylaldehyde	C ₇ H ₆ O ₂	33.0	60.1	73.8	88.7	105.2	115.7	129.4	150.0	173.7	196.5	-7
Salicylic acid	C ₇ H ₆ O ₃	113.7	136.0	146.2	156.8	172.2	182.0	193.4	210.0	230.5	256.0	159
Sebacic acid	C ₁₀ H ₁₈ O ₄	183.0	215.7	232.0	250.0	268.2	279.8	294.5	313.2	332.8	352.3	134.5
Selenophene	C ₄ H ₄ Se	-39.0	-16.0	-4.0	+9.1	24.1	33.8	47.0	66.7	89.8	114.3	
Skatole	C ₉ H ₉ N	95.0	124.2	139.6	154.3	171.9	183.6	197.4	218.8	242.5	266.2	95
Stearaldehyde	C ₁₈ H ₃₆ O	140.0	174.6	192.1	210.6	230.8	244.2	260.0	285.0	313.8	342.5	63.5
Stearic acid	C ₁₈ H ₃₆ O ₂	173.7	209.0	225.0	243.4	263.3	275.5	291.0	316.5	343.0	370.0	69.3
Stearyl alcohol (1-octadecanol)	C ₁₈ H ₃₆ O	150.3	185.6	202.0	220.0	240.4	252.7	269.4	293.5	320.3	349.5	58.5
Styrene	C ₈ H ₈	-7.0	+18.0	30.8	44.6	59.8	69.5	82.0	101.3	122.5	145.2	-30.6
Styrene dibromide [(1,2-dibromoethyl)benzene]	C ₈ H ₈ Br ₂	86.0	115.6	129.8	145.2	161.8	172.2	186.3	207.8	230.0	254.0	
Suberic acid	C ₈ H ₁₄ O ₄	172.8	205.5	219.5	238.2	254.6	265.4	279.8	300.5	322.8	345.5	142
Succinic anhydride	C ₄ H ₄ O ₃	92.0	115.0	128.2	145.3	163.0	174.0	189.0	212.0	237.0	261.0	119.6
Succinimide	C ₄ H ₅ NO ₂	115.0	143.2	157.0	174.0	192.0	203.0	217.4	240.0	263.5	287.5	125.5
Succinyl chloride	C ₄ H ₄ Cl ₂ O ₂	39.0	65.0	78.0	91.8	107.5	117.2	130.0	149.3	170.0	192.5	17
α-Terpineol	C ₁₀ H ₁₈ O	52.8	80.4	94.3	109.8	126.0	136.3	150.1	171.2	194.3	217.5	35
Terpenoline	C ₁₀ H ₁₆	32.3	58.0	70.6	84.8	100.0	109.8	122.7	142.0	163.5	185.0	

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Continued)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
1,1,1,2-Tetrabromoethane	C ₂ H ₂ Br ₄	58.0	83.3	95.7	108.5	123.2	132.0	144.0	161.5	181.0	200.0	
1,1,2,2-Tetrabromoethane	C ₂ H ₂ Br ₄	65.0	95.5	110.0	126.0	144.0	155.1	170.0	192.5	217.5	243.5	
Tetraisobutylene	C ₁₆ H ₃₂	63.8	93.7	108.5	124.5	142.2	152.6	167.5	190.0	214.6	240.0	
Tetracosane	C ₂₄ H ₅₀	183.8	219.6	237.6	255.3	276.3	288.4	305.2	330.5	358.0	386.4	51.1
1,2,3,4-Tetrachlorobenzene	C ₆ H ₂ Cl ₄	68.5	99.6	114.7	131.2	149.2	160.0	175.7	198.0	225.5	254.0	46.5
1,2,3,5-Tetrachlorobenzene	C ₆ H ₂ Cl ₄	58.2	89.0	104.1	121.6	140.0	152.0	168.0	193.7	220.0	246.0	54.5
1,2,4,5-Tetrachlorobenzene	C ₆ H ₂ Cl ₄					146.0	157.7	173.5	196.0	220.5	245.0	139
1,1,2,2-Tetrachloro-1,2-difluoroethane	C ₂ Cl ₄ F ₂	-37.5	-16.0	-5.0	+6.7	19.8	28.1	38.6	55.0	73.1	92.0	26.5
1,1,1,2-Tetrachloroethane	C ₂ H ₂ Cl ₄	-16.3	+7.4	19.3	32.1	46.7	56.0	68.0	87.2	108.2	130.5	-68.7
1,1,2,2-Tetrachloroethane	C ₂ H ₂ Cl ₄	-3.8	+20.7	33.0	46.2	60.8	70.0	83.2	102.2	124.0	145.9	-36
1,2,3,5-Tetrachloro-4-ethylbenzene	C ₈ H ₆ Cl ₄	77.0	110.0	126.0	143.7	162.1	175.0	191.6	215.3	243.0	270.0	
Tetrachloroethylene	C ₂ Cl ₄	-20.6	+2.4	13.8	26.3	40.1	49.2	61.3	79.8	100.0	120.8	-19.0
2,3,4,6-Tetrachlorophenol	C ₆ H ₂ Cl ₄ O	100.0	130.3	145.3	161.0	179.1	190.0	205.2	227.2	250.4	275.0	69.5
3,4,5,6-Tetrachloro-1,2-xylene	C ₈ H ₆ Cl ₄	94.4	125.0	140.3	156.0	174.2	185.8	200.5	223.0	248.3	273.5	
Tetradecane	C ₁₄ H ₃₀	76.4	106.0	120.7	135.6	152.7	164.0	178.5	201.8	226.8	252.5	5.5
Tetradecylamine	C ₁₄ H ₃₁ N	102.6	135.8	152.0	170.0	189.0	200.2	215.7	239.8	264.6	291.2	
Tetradecytrimethylsilane	C ₁₇ H ₃₈ Si	120.0	150.7	166.2	183.5	201.5	213.3	227.8	250.0	275.0	300.0	
Tetraethoxysilane	C ₈ H ₃₀ O ₂ Si	16.0	40.3	52.6	65.8	81.1	90.7	103.6	123.5	146.2	168.5	
1,2,3,4-Tetraethylbenzene	C ₁₄ H ₂₂	65.7	96.2	111.6	127.7	145.8	156.7	172.4	196.0	221.4	248.0	11.6
Tetraethylene glycol	C ₈ H ₁₈ O ₅	153.9	183.7	197.1	212.3	228.0	237.8	250.0	268.4	288.0	307.8	
Tetraethylene glycol chlorohydrin	C ₈ H ₁₇ ClO ₄	110.1	141.8	156.1	172.6	190.0	200.5	214.7	236.5	258.2	281.5	
Tetraethyllead	C ₈ H ₂₀ Pb	38.4	63.6	74.8	88.0	102.4	111.7	123.8	142.0	161.8	183.0	-136
Tetraethylsilane	C ₈ H ₂₀ Si	-1.0	+23.9	36.3	50.0	65.3	74.8	88.0	108.0	130.2	153.0	
Tetralin	C ₁₀ H ₁₂	38.0	65.3	79.0	93.8	110.4	121.3	135.3	157.2	181.8	207.2	-31.0
1,2,3,4-Tetramethylbenzene	C ₁₀ H ₁₄	42.6	68.7	81.8	95.8	111.5	121.8	135.7	155.7	180.0	204.4	-6.2
1,2,3,5-Tetramethylbenzene	C ₁₀ H ₁₄	40.6	65.8	77.8	91.0	105.8	115.4	128.3	149.9	173.7	197.9	-24.0
1,2,4,5-Tetramethylbenzene	C ₁₀ H ₁₄	45.0	65.0	74.6	88.0	104.2	114.8	128.1	149.5	172.1	195.9	79.5
2,2,3,3-Tetramethylbutane	C ₈ H ₁₈	-17.4	+3.2	13.5	24.6	36.8	44.5	54.8	70.2	87.4	106.3	-102.2
Tetramethylene dibromide (1,4-dibromobutane)	C ₄ H ₈ Br ₂	32.0	58.8	72.4	87.6	104.0	115.1	128.7	149.8	173.8	197.5	-20
Tetramethyllead	C ₄ H ₁₂ Pb	-29.0	-6.8	+4.4	16.6	30.3	39.2	50.8	68.8	89.0	110.0	-27.5
Tetramethyltin	C ₄ H ₁₂ Sn	-51.3	-31.0	-20.6	-9.3	+3.5	11.7	22.8	39.8	58.5	78.0	
Tetrapropylene glycol monoisopropyl ether	C ₁₅ H ₃₂ O ₅	116.6	147.8	163.0	179.8	197.7	209.0	223.3	245.0	268.3	292.7	
Thioacetic acid (mercaptoacetic acid)	C ₂ H ₆ OS ₂	60.0	87.7	101.5	115.8	131.8	142.0	154.0				-16.5
Thiodiglycol (2,2'-thiodiethanol)	C ₄ H ₁₀ OS ₂	42.0	96.0	128.0	165.0	210.0	240.5	285				
Thiophene	C ₄ H ₄ S	-40.7	-20.8	-10.9	0.0	+12.5	20.1	30.5	46.5	64.7	84.4	-38.3
Thiophenol (benzenethiol)	C ₆ H ₆ S	18.6	43.7	56.0	69.7	84.2	93.9	106.6	125.8	146.7	168.0	
α-Thujone	C ₁₀ H ₁₆ O	38.3	65.7	79.3	93.7	110.0	120.2	134.0	154.2	177.8	201.0	
Thymol	C ₁₀ H ₁₄ O	64.3	92.8	107.4	122.6	139.8	149.8	164.1	185.5	209.2	231.8	51.5
Tiglaldehyde	C ₅ H ₈ O	-25.0	-1.6	+10.0	23.2	37.0	45.8	57.7	75.4	95.5	116.4	
Tiglic acid	C ₅ H ₈ O ₂	52.0	77.8	90.2	103.8	119.0	127.8	140.5	158.0	179.2	198.5	64.5
Tiglonitrile	C ₅ H ₇ N	-25.5	-2.4	+9.2	22.1	36.7	46.0	58.2	77.8	99.7	122.0	
Toluene	C ₇ H ₈	-26.7	-4.4	+6.4	18.4	31.8	40.3	51.9	69.5	89.5	110.6	-95.0
Toluene-2,4-diamine	C ₇ H ₁₀ N ₂	106.5	137.2	151.7	167.9	185.7	196.2	211.5	232.8	256.0	280.0	99
2-Toluidic nitrile (2-tolunitrile)	C ₈ H ₇ N	36.7	64.0	77.9	93.0	110.0	120.8	135.0	156.0	180.0	205.2	-13
4-Toluidic nitrile (4-tolunitrile)	C ₈ H ₇ N	42.5	71.3	85.8	101.7	109.5	130.0	145.2	167.3	193.0	217.6	29.5
2-Toluidine	C ₇ H ₉ N	44.0	69.3	81.4	95.1	110.0	119.8	133.0	153.0	176.2	199.7	-16.3
3-Toluidine	C ₇ H ₉ N	41.0	68.0	82.0	96.7	113.5	123.8	136.7	157.6	180.6	203.3	-31.5
4-Toluidine	C ₇ H ₉ N	42.0	68.2	81.8	95.8	111.5	121.5	133.7	154.0	176.9	200.4	44.5
2-Tolyl isocyanide	C ₈ H ₇ N	25.2	51.0	64.0	78.2	94.0	104.0	117.7	137.8	159.9	183.5	
4-Tolylhydrazine	C ₇ H ₁₀ N ₂	82.4	110.0	123.8	138.6	154.1	165.0	178.0	198.0	219.5	242.0	65.5
Tri bromoacetaldehyde	C ₂ HBr ₃ O	18.5	45.0	58.0	72.1	87.8	97.5	110.2	130.0	151.6	174.0	
1,1,2-Tribromobutane	C ₄ H ₇ Br ₃	45.0	73.5	87.8	103.2	120.2	131.6	146.0	167.8	192.0	216.2	
1,2,2-Tribromobutane	C ₄ H ₇ Br ₃	41.0	69.0	83.2	98.6	116.0	127.0	141.8	163.5	188.0	213.8	
2,2,3-Tribromobutane	C ₄ H ₇ Br ₃	38.2	66.0	79.8	94.6	111.8	122.2	136.3	157.8	182.2	206.5	
1,1,2-Tribromobutane	C ₄ H ₇ Br ₃	32.6	58.0	70.6	84.2	100.0	110.0	123.5	143.5	165.4	188.4	-26
1,2,3-Tribromopropane	C ₃ H ₅ Br ₃	47.5	75.8	90.0	105.8	122.8	134.0	148.0	170.0	195.0	220.0	16.5
Triisobutylamine	C ₉ H ₂₇ N	32.3	57.4	69.8	83.0	97.8	107.3	119.7	138.0	157.8	179.0	-22
Triisobutylene	C ₁₂ H ₂₄	18.0	44.0	56.5	70.0	86.7	96.7	110.0	130.2	153.0	179.0	
2,4,6-Triterbutylphenol	C ₁₅ H ₃₀ O	95.2	126.1	142.0	158.0	177.4	188.0	203.0	226.2	250.6	276.3	
Trichloroacetic acid	C ₂ Cl ₃ O ₂	51.0	76.0	88.2	101.8	116.3	125.9	137.8	155.4	175.2	195.6	57
Trichloroacetic anhydride	C ₂ Cl ₃ O ₃	56.2	85.3	99.6	114.3	131.2	141.8	155.2	176.2	199.8	223.0	
Trichloroacetyl bromide	C ₂ BrCl ₃ O	-7.4	+16.7	29.3	42.1	57.2	66.7	79.5	98.4	120.2	143.0	
2,4,6-Trichloroaniline	C ₆ H ₄ Cl ₃ N	134.0	157.8	170.0	182.6	195.8	204.5	214.6	229.8	246.4	262.0	78
1,2,3-Trichlorobenzene	C ₆ H ₃ Cl ₃	40.0	70.0	85.6	101.8	119.8	131.5	146.0	168.2	193.5	218.5	52.5
1,2,4-Trichlorobenzene	C ₆ H ₃ Cl ₃	38.4	67.3	81.7	97.2	114.8	125.7	140.0	162.0	187.7	213.0	17
1,3,5-Trichlorobenzene	C ₆ H ₃ Cl ₃	63.8	78.0	93.7	110.8	121.8	136.0	157.7	183.0	208.4	208.4	63.5
1,2,3-Trichlorobutane	C ₄ H ₇ Cl ₃	+0.5	27.2	40.0	55.0	71.5	82.0	96.2	118.0	143.0	169.0	
1,1,1-Trichloroethane	C ₂ H ₃ Cl ₃	-52.0	-32.0	-21.9	-10.8	+1.6	9.5	20.0	36.2	54.6	74.1	-30.6
1,1,2-Trichloroethane	C ₂ H ₃ Cl ₃	-24.0	-2.0	+8.3	21.6	35.2	44.0	55.7	73.3	93.0	113.9	-36.7
Trichloroethylene	C ₂ HCl ₃	-43.8	-22.8	-12.4	-1.0	+11.9	20.0	31.4	48.0	67.0	86.7	-73
Trichlorofluoromethane	CCl ₃ F	-84.3	-67.6	-59.0	-49.7	-39.0	-32.3	-23.0	-9.1	+6.8	23.7	
2,4,5-Trichlorophenol	C ₆ H ₃ Cl ₃ O	72.0	102.1	117.3	134.0	151.5	162.5	178.0	201.5	226.5	251.8	62
2,4,6-Trichlorophenol	C ₆ H ₃ Cl ₃ O	76.5	105.9	120.2	135.8	152.2	163.5	177.8	199.0	222.5	246.0	68.5

TABLE 2-8 Vapor Pressures of Organic Compounds, up to 1 atm (Concluded)

Compound	Name	Formula	Pressure, mm Hg									Melting point, °C
			1	5	10	20	40	60	100	200	400	
Temperature, °C												
Tri-2-chlorophenylthiophosphate	C ₁₈ H ₁₂ Cl ₃ O ₃ PS	C ₁₈ H ₁₂ Cl ₃ O ₃ PS	188.2	217.2	231.2	246.7	261.7	271.5	283.8	302.8	322.0	341.3
1,1,1-Trichloropropane	C ₃ H ₅ Cl ₃	C ₃ H ₅ Cl ₃	-28.8	-7.0	+4.2	16.2	29.9	38.3	50.0	67.7	87.5	108.2
1,2,3-Trichloropropane	C ₃ H ₅ Cl ₃	C ₃ H ₅ Cl ₃	+9.0	33.7	46.0	59.3	74.0	83.6	96.1	115.6	137.0	158.0
1,1,2-Trichloro-1,2,2-trifluoroethane	C ₂ Cl ₃ F ₃	C ₂ Cl ₃ F ₃	-68.0	-49.4	-40.3	-30.0	-18.5	-11.2	-1.7	+13.5	30.2	47.6
Tricosane	C ₂₃ H ₄₈	C ₂₃ H ₄₈	170.0	206.3	223.0	242.0	261.3	273.8	289.8	313.5	339.8	366.5
Tridecane	C ₁₃ H ₂₈	C ₁₃ H ₂₈	59.4	98.3	104.0	120.2	137.7	148.2	162.5	185.0	209.4	234.0
Tridecanoic acid	C ₁₃ H ₂₆ O ₃	C ₁₃ H ₂₆ O ₃	137.8	166.3	181.0	195.8	212.4	222.0	236.0	255.2	276.5	299.0
Triethoxymethylsilane	C ₇ H ₁₈ O ₃ Si	C ₇ H ₁₈ O ₃ Si	-1.5	+22.8	34.6	47.2	61.7	70.4	82.7	101.0	121.8	143.5
Triethoxyphenylsilane	C ₁₂ H ₂₀ O ₃ Si	C ₁₂ H ₂₀ O ₃ Si	71.0	98.8	112.6	127.2	143.5	153.2	167.5	188.0	210.5	233.5
1,2,4-Triethylbenzene	C ₁₂ H ₁₈	C ₁₂ H ₁₈	46.0	74.2	88.5	104.0	121.7	132.2	146.8	168.3	193.7	218.0
1,3,4-Triethylbenzene	C ₁₂ H ₁₈	C ₁₂ H ₁₈	47.9	76.0	90.2	105.8	122.6	133.4	147.7	168.3	193.2	217.5
Triethylborine	C ₆ H ₁₅ B	C ₆ H ₁₅ B		-148.0	-140.6	-131.4	-125.2	-116.0	-101.0	-81.0	-56.2	
Triethyl camphorone citrate	C ₁₅ H ₂₆ O ₆	C ₁₅ H ₂₆ O ₆	150.2	166.0	183.6	201.8	213.5	228.6	250.8	276.0	301.0	135
C ₁₂ H ₂₀ O ₇	C ₁₂ H ₂₀ O ₇	C ₁₂ H ₂₀ O ₇	107.0	138.7	144.0	171.1	190.4	202.5	217.8	242.2	267.5	294.0
Triethylene glycol	C ₆ H ₁₄ O ₄	C ₆ H ₁₄ O ₄	114.0	144.0	158.1	174.0	191.3	201.5	214.6	235.2	256.6	278.3
Triethylheptylsilane	C ₁₃ H ₂₈ Si	C ₁₃ H ₂₈ Si	70.0	99.8	114.6	130.3	148.0	158.2	174.0	196.0	221.0	247.0
Triethyloctylsilane	C ₁₄ H ₃₀ Si	C ₁₄ H ₃₀ Si	73.7	104.8	120.6	137.7	155.7	168.0	184.3	208.0	235.0	262.0
Triethyl orthoformate phosphate	C ₇ H ₁₆ O ₃	C ₇ H ₁₆ O ₃ P	+5.5	29.2	40.5	53.4	67.5	76.0	88.0	106.0	125.7	146.0
C ₆ H ₁₅ O ₃ P	C ₆ H ₁₅ O ₃ P	C ₆ H ₁₅ O ₃ P	39.6	67.8	82.1	97.8	115.7	126.3	141.6	163.7	187.0	211.0
Triethylthallium	C ₆ H ₁₅ Tl	C ₆ H ₁₅ Tl	+9.3	37.6	51.7	67.7	85.4	95.7	112.1	136.0	163.5	192.1
Trifluorophenylsilane	C ₆ H ₅ F ₃ Si	C ₆ H ₅ F ₃ Si	-31.0	-9.7	+0.8	12.3	25.4	33.2	44.2	60.1	78.7	98.3
Trimethylallyl phosphate	C ₁₂ H ₂₁ PO ₄	C ₁₂ H ₂₁ PO ₄	93.7	131.0	149.8	169.8	192.0	207.0	225.7	255.0	288.5	324.0
2,3,5-Trimethylacetophenone	C ₁₁ H ₁₄ O	C ₁₁ H ₁₄ O	79.0	108.0	122.3	137.5	154.2	165.7	179.7	201.3	224.3	247.5
Trimethylamine	C ₃ H ₉ N	C ₃ H ₉ N	-97.1	-81.7	-73.8	-65.0	-55.2	-48.8	-40.3	-27.0	-12.5	+2.9
2,4,5-Trimethylaniline	C ₉ H ₁₃ N	C ₉ H ₁₃ N	68.4	95.9	109.0	123.7	139.8	149.5	162.0	182.3	203.7	234.5
1,2,3-Trimethylbenzene	C ₉ H ₁₂	C ₉ H ₁₂	16.8	42.9	55.9	69.9	85.4	95.3	108.8	129.0	152.0	176.1
1,2,4-Trimethylbenzene	C ₉ H ₁₂	C ₉ H ₁₂	13.6	38.3	50.7	64.5	79.8	89.5	102.8	122.7	145.4	169.2
1,3,5-Trimethylbenzene	C ₉ H ₁₂	C ₉ H ₁₂	9.6	34.7	47.4	61.0	76.1	85.8	98.9	118.6	141.0	164.7
2,2,3-Trimethylbutane	C ₇ H ₁₆	C ₇ H ₁₆		-18.8	-7.5	+5.2	13.3	24.4	41.2	60.4	80.9	-25.0
Trimethyl citrate	C ₉ H ₁₄ O ₇	C ₉ H ₁₄ O ₇	106.2	146.2	160.4	177.2	194.2	205.5	219.6	241.3	264.2	287.0
Trimethylene glycol (1,3-propanediol)	C ₃ H ₈ O ₂	C ₃ H ₈ O ₂	59.4	87.2	100.6	115.5	131.0	141.1	153.4	172.8	193.8	214.2
1,2,4-Trimethyl-5-ethylbenzene	C ₁₁ H ₁₆	C ₁₁ H ₁₆	43.7	71.2	84.6	99.7	106.0	126.3	140.3	160.3	184.5	208.1
1,3,5-Trimethyl-2-ethylbenzene	C ₁₁ H ₁₆	C ₁₁ H ₁₆	38.8	67.0	80.5	96.0	113.2	123.8	137.9	158.4	183.5	208.0
2,2,3-Trimethylpentane	C ₈ H ₁₈	C ₈ H ₁₈	-29.0	-7.1	+3.9	16.0	29.5	38.1	49.9	67.8	88.2	109.8
2,2,4-Trimethylpentane	C ₈ H ₁₈	C ₈ H ₁₈	-36.5	-15.0	-4.3	+7.5	20.7	29.1	40.7	58.1	78.0	99.2
2,3,3-Trimethylpentane	C ₈ H ₁₈	C ₈ H ₁₈	-25.8	-3.9	+6.9	19.2	33.0	41.8	53.8	72.0	92.7	114.8
2,3,4-Trimethylpentane	C ₈ H ₁₈	C ₈ H ₁₈	-26.3	-4.1	+7.1	19.3	32.9	41.6	53.4	71.3	91.8	113.5
2,2,4-Trimethyl-3-pentanone	C ₈ H ₁₆ O	C ₈ H ₁₆ O	14.7	36.0	46.4	57.6	69.8	77.3	87.6	102.2	118.4	135.0
Trimethyl phosphate	C ₃ H ₉ O ₄ P	C ₃ H ₉ O ₄ P	26.0	53.7	67.8	83.0	100.0	110.0	124.0	145.0	167.8	192.7
2,4,5-Trimethylstyrene	C ₁₁ H ₁₄	C ₁₁ H ₁₄	48.1	77.0	91.6	107.1	124.2	135.5	149.8	171.8	196.1	221.2
2,4,6-Trimethylstyrene	C ₁₁ H ₁₄	C ₁₁ H ₁₄	37.5	65.7	79.7	94.8	111.8	122.3	136.8	157.8	182.3	207.0
Trimethylsuccinic anhydride	C ₇ H ₁₀ O ₃	C ₇ H ₁₀ O ₃	53.5	82.6	97.4	113.8	131.0	142.2	156.5	179.8	205.5	231.0
Triphenylmethane	C ₁₉ H ₁₆	C ₁₉ H ₁₆	169.7	188.4	197.0	206.8	215.5	221.2	228.4	239.7	249.8	259.2
Triphenylphosphate	C ₁₈ H ₁₅ O ₄ P	C ₁₈ H ₁₅ O ₄ P	193.5	230.4	249.8	269.7	290.3	305.2	322.5	349.8	379.2	413.5
Tripropylene glycol	C ₈ H ₂₀ O ₄	C ₈ H ₂₀ O ₄	96.0	125.7	140.5	155.8	173.7	184.6	199.0	220.2	244.3	267.2
Tripropylene glycol monobutyl ether	C ₁₃ H ₂₈ O ₄	C ₁₃ H ₂₈ O ₄	101.5	131.6	147.0	161.8	179.8	190.2	204.4	224.4	247.0	269.5
Tripropylene glycol monoisopropyl ether	C ₁₂ H ₂₆ O ₄	C ₁₂ H ₂₆ O ₄	82.4	112.4	127.3	143.7	161.4	173.2	187.8	209.7	232.8	256.6
Trityl phosphate	C ₂₁ H ₃₁ O ₄ P	C ₂₁ H ₃₁ O ₄ P	154.6	184.2	198.0	213.2	229.7	239.8	252.2	271.8	292.7	313.0
Undecane	C ₁₁ H ₂₄	C ₁₁ H ₂₄	32.7	59.7	73.9	85.6	104.4	115.2	128.1	149.3	171.9	195.8
Undecanoic acid	C ₁₁ H ₂₂ O ₂	C ₁₁ H ₂₂ O ₂	101.4	133.1	149.0	166.0	185.6	197.2	212.5	237.8	262.8	290.0
10-Decenoic acid	C ₁₁ H ₂₂ O ₂	C ₁₁ H ₂₂ O ₂	114.0	142.8	156.3	172.0	188.7	199.5	213.5	232.8	254.0	275.0
Undecan-2-ol	C ₁₁ H ₂₄ O	C ₁₁ H ₂₄ O	71.1	99.0	112.8	127.5	143.7	153.7	167.2	187.7	209.8	232.0
n-Valeric acid	C ₅ H ₁₀ O ₂	C ₅ H ₁₀ O ₂	42.2	67.7	79.8	93.1	107.8	116.6	128.3	146.0	165.0	184.4
iso-Valeric acid	C ₅ H ₁₀ O ₂	C ₅ H ₁₀ O ₂	34.5	59.6	71.3	84.0	98.0	107.3	118.9	136.2	155.2	175.1
γ-Valerolactone	C ₅ H ₈ O ₂	C ₅ H ₈ O ₂	37.5	65.8	79.8	95.2	101.9	122.4	136.5	157.7	182.3	207.5
Valeronitrile	C ₅ H ₉ N	C ₅ H ₉ N	-6.0	+18.1	30.0	43.3	57.8	66.9	78.6	97.7	118.7	140.8
Vanillin	C ₈ H ₈ O ₃	C ₈ H ₈ O ₃	107.0	138.4	154.0	170.5	188.7	199.8	214.5	237.3	260.0	285.0
Vinyl acetate	C ₄ H ₆ O ₂	C ₄ H ₆ O ₂	-48.0	-28.0	-18.0	-7.0	+5.3	13.0	23.3	38.4	55.5	72.5
2-Vinylanisole	C ₉ H ₁₀ O	C ₉ H ₁₀ O	41.9	68.0	81.0	94.7	110.0	119.8	132.3	151.0	172.1	194.0
3-Vinylanisole	C ₉ H ₁₀ O	C ₉ H ₁₀ O	43.4	69.9	83.0	97.2	112.5	122.3	135.3	154.0	175.8	197.5
4-Vinylanisole	C ₉ H ₁₀ O	C ₉ H ₁₀ O	45.2	72.0	85.7	100.0	116.0	126.1	139.7	159.0	182.0	204.5
Vinyl chloride (1-chloroethylene) cyanide (acrylonitrile) fluoride (1-fluoroethylene)	C ₂ H ₃ Cl	C ₂ H ₃ Cl	-105.6	-90.8	-83.7	-75.7	-66.8	-61.1	-53.2	-41.3	-28.0	-13.8
Vinyldiene chloride (1,1-dichloroethylene)	C ₂ H ₂ Cl ₂	C ₂ H ₂ Cl ₂	-149.3	-138.0	-132.2	-125.4	-118.0	-113.0	-106.2	-95.4	-84.0	-72.2
4-Vinylphenetole	C ₁₀ H ₁₂ O	C ₁₀ H ₁₂ O	64.0	91.7	105.6	120.3	136.3	146.4	159.8	180.0	202.8	225.0
2-Xenyl dichlorophosphate	C ₁₂ H ₈ Cl ₂ PO	C ₁₂ H ₈ Cl ₂ PO	138.2	171.1	187.0	205.0	223.8	236.0	251.5	275.3	301.5	328.5
2,4-Xylyldehyde	C ₉ H ₁₀ O	C ₉ H ₁₀ O	59.0	85.9	99.0	114.0	129.7	139.8	152.2	172.3	194.1	21

VAPOR PRESSURES OF SOLUTIONS

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$^{\circ}\text{F} = ^{\circ}\text{C} + 32.$$

To convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

To convert cubic feet to cubic meters, multiply by 0.02832.
To convert bars to pounds-force per square inch, multiply by 14.504.

To convert bars to kilopascals, multiply by 1×10^5 .

TABLE 2-9 Partial Pressures of Water over Aqueous Solutions of HCl*

$\log_{10} p_{\text{mm}} = A - B/T$, (T in K), which, however, agrees only approximately with the table. The table is more nearly correct.
Partial pressure of H_2O , mmHg, $^{\circ}\text{C}$

% HCl	A	B	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	60°	70°	80°	90°	100°	110°
6	8.99156	2282	4.18	6.04	8.45	11.7	15.9	21.8	29.1	39.4	50.6	66.2	86.0	139	220	333	492	715	
10	8.99864	2295	3.84	5.52	7.70	10.7	14.6	20.0	26.8	35.5	47.0	61.5	80.0	130	204	310	463	677	960
14	8.97075	2300	3.39	4.91	6.95	9.65	13.1	18.0	24.1	31.9	42.1	55.3	72.0	116	185	273	425	625	892
18	8.98014	2323	2.87	4.21	5.92	8.26	11.3	15.4	20.6	27.5	36.4	47.9	62.5	102	162	248	374	550	783
20	8.97877	2334	2.62	3.83	5.40	7.50	10.3	14.1	19.0	25.1	33.3	43.6	57.0	93.5	150	230	345	510	729
22	9.02708	2363	2.33	3.40	4.82	6.75	9.30	12.6	17.1	22.8	30.2	39.8	52.0	85.6	138	211	317	467	670
24	8.96022	2356	2.05	3.04	4.31	6.03	8.30	11.4	15.4	20.4	27.1	35.7	46.7	77.0	124	194	290	426	611
26	9.01511	2390	1.76	2.60	3.71	5.21	7.21	9.95	13.5	18.0	24.0	31.7	41.5	69.0	112	173	261	387	555
28	8.97611	2395	1.50	2.24	3.21	4.54	6.32	8.75	11.8	15.8	21.1	27.9	36.5	60.7	99.0	154	234	349	499
30	9.00117	2422	1.26	1.90	2.73	3.88	5.41	7.52	10.2	13.7	18.4	24.3	32.0	53.5	87.5	136	207	310	444
32	9.03317	2453	1.04	1.57	2.27	3.25	4.55	6.37	8.70	11.7	15.7	21.0	27.7	46.5	76.5	120	184	275	396
34	9.07143	2487	0.85	1.29	1.87	2.70	3.81	5.35	7.32	9.95	13.5	18.1	24.0	40.5	66.5	104	161	243	355
36	9.11815	2526	0.68	1.03	1.50	2.19	3.10	4.41	6.08	8.33	11.4	15.4	20.4	34.8	57.0	90.0	140	212	311
38	9.20783	2579	0.53	0.81	1.20	1.75	2.51	3.60	5.03	6.92	9.52	13.0	17.4	29.6	49.1	77.5	120	182	266
40	9.33923	2647	0.41	0.63	0.94	1.37	2.00	2.88	4.09	5.68	7.85	10.7	14.5	25.0	42.1	67.3	105	158	230
42	9.44953	2709	0.31	0.48	0.72	1.06	1.56	2.30	3.28	4.60	6.45	8.90	12.1	21.2	35.8	57.2	89.2	135	195

*Accuracy, ca. 2 percent for solutions of 15 to 30 percent HCl between 0 and 100°; for solutions of > 30 percent HCl the accuracy is ca. 5 percent at the lower temperatures and ca. 15 percent at the higher temperatures. Below 15 percent HCl, the accuracy is ca. 5 percent at the lower temperatures and higher strengths to ca. 15 to 20 percent at the lower strengths and perhaps 15 to 20 percent at the higher temperatures and lower strengths.

TABLE 2-10 Partial Pressures of HCl over Aqueous Solutions of HCl*

$\log_{10} p_{\text{mm}} = A - B/T$, (T in K), which, however, agrees only approximately with the table. The table is more nearly correct. mmHg, $^{\circ}\text{C}$

% HCl	A	B	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	60°	70°	80°	90°	100°	110°	
2	11.8037	4736	.0009	.0000117	.0000036	.00000117	.0000023	.0000044	.0000084	.0000151	.0000275	.000047	.000083	.000140	.000380	.00100	.00245	.0058	.0132	.0280
4	11.6400	4471	.0000018	.0000036	.0000069	.000131	.00024	.00044	.00077	.00134	.0023	.00385	.0064	.0165	.0405	.095	.21	.46	.93	
6	11.2144	4202	.000066	.000125	.000234	.000425	.00076	.00131	.00225	.0038	.0062	.0102	.0163	.040	.094	.206	.44	.92	1.78	
8	11.0406	4042	.000118	.000323	.000583	.00104	.00178	.0031	.00515	.0085	.0136	.022	.0344	.081	.183	.39	.82	1.64	3.10	
10	10.9311	3908	.00042	.00075	.00134	.00232	.00395	.0067	.0111	.0178	.0282	.045	.069	.157	.35	.73	1.48	2.9	5.4	
12	10.7900	3765	.00099	.00175	.00305	.0052	.0088	.0145	.0234	.037	.058	.091	.136	.305	.66	1.34	2.65	5.1	9.3	
14	10.6954	3636	.0024	.00415	.0071	.0118	.0196	.0316	.050	.078	.121	.185	.275	.60	1.25	2.50	4.8	9.0	16.0	
16	10.6261	3516	.0056	.0095	.016	.0265	.0428	.0685	.106	.163	.247	.375	.55	1.17	2.40	4.66	8.8	16.1	28	
18	10.4957	3376	.0135	.0225	.037	.060	.095	.148	.228	.345	.515	.77	1.11	2.3	4.55	8.6	15.7	28	48	
20	10.3833	3245	.0316	.052	.084	.132	.205	.32	.48	.72	1.06	1.55	2.21	4.4	8.5	15.6	28.1	49	83	
22	10.3172	3125	.0734	.119	.187	.294	.45	.68	1.02	1.50	2.18	3.14	4.42	8.6	16.3	29.3	52	90	146	
24	10.2185	2995	.175	.277	.43	.66	1.00	1.49	2.17	3.14	4.5	6.4	8.9	16.9	31.0	54.5	94	157	253	
26	10.1303	2870	.41	.64	.98	1.47	2.17	3.20	4.56	6.50	9.2	12.7	17.5	32.5	58.5	100	169	276	436	
28	10.0115	2732	1.0	1.52	2.27	3.36	4.90	7.05	9.90	13.8	19.1	26.4	35.7	64	112	188	309	493	760	
30	9.8763	2593	2.4	3.57	5.23	7.60	10.6	15.1	21.0	28.6	39.4	53	71	124	208	340	542	845		
32	9.7523	2457	5.7	8.3	11.8	16.8	23.5	32.5	44.5	60.0	81	107	141	238	390	623	970			
34	9.6061	2316	13.1	18.8	26.4	36.8	50.5	68.5	92	122	161	211	273	450	720					
36	9.5262	2229	29.0	41.0	56.4	78	105.5	142	188	246	322	416	535	860						
38	9.4670	2094	63.0	87.0	117	158	210	277	360	465	598	758	955							
40	9.2156	1939	130	176	233	307	399	515	627	830										
42	8.9925	1800	253	332	430	560	709	900												
44	8.8621	1681	510	655	840															
46			940																	

*Accuracy, ca. 2 percent for solutions of 15 to 30 percent HCl between 0 and 100°; for solutions of > 30 percent HCl the accuracy is ca. 5 percent at the lower temperatures and ca. 15 percent at the higher temperatures. Below 15 percent HCl, the accuracy is ca. 5 percent at the lower temperatures and higher strengths to ca. 15 to 20 percent at the lower strengths and perhaps 15 to 20 percent at the higher temperatures and lower strengths.

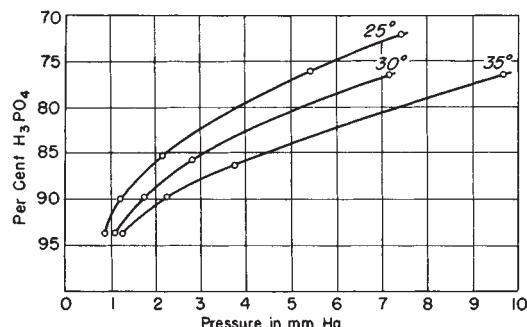


FIG. 2-1 Vapor pressures of H_3PO_4 aqueous: partial pressure of H_2O vapor. (Courtesy of Victor Chemical Works, Stauffer Chemical Company; measurements by W. H. Woodstock.)

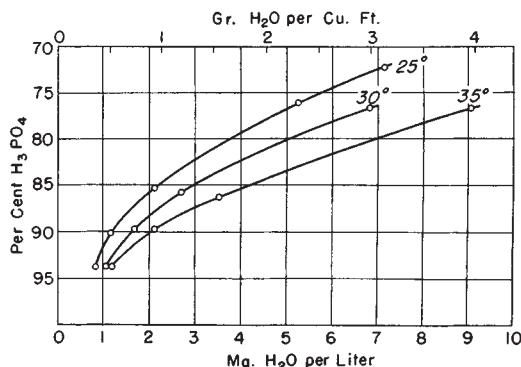


FIG. 2-2 Vapor pressures of H_3PO_4 aqueous: weight of H_2O in saturated air. (Courtesy of Victor Chemical Works, Stauffer Chemical Company; measurements by W. H. Woodstock.)

TABLE 2-11 Partial Pressures of H_2O and SO_2 over Aqueous Solutions of Sulfur Dioxide*

Partial pressures of H_2O and SO_2 , mmHg, °C

g SO_2 / 100 g H_2O	Temperature, °C								
	0	10	20	30	40	50	60	90	120
0.01	0.02	0.04	0.07	0.12	0.19	0.29	0.43	1.21	2.82
0.05	0.38	0.66	1.07	1.68	2.53	3.69	5.24	12.9	27.0
0.10	1.15	1.91	3.03	4.62	6.80	9.71	13.5	31.7	63.9
0.15	2.10	3.44	5.37	8.07	11.7	16.5	22.7	52.2	104
0.20	3.17	5.13	7.93	11.8	17.0	23.8	32.6	73.7	145
0.25	4.34	6.93	10.6	15.7	22.5	31.4	42.8	95.8	186
0.30	5.57	8.84	13.5	19.8	28.2	39.2	53.3	118	229
0.40	8.17	12.8	19.4	28.3	40.1	55.3	74.7	164	316
0.50	10.9	17.0	25.6	37.1	52.3	72.0	96.8	211	404
1.00	25.8	39.5	58.4	83.7	117	159	212	454	856
2.00	58.6	88.5	129	183	253	342	453	955	
3.00	93.2	139	202	285	393	530	700		
4.00	129	192	277	389	535	720			
5.00	165	245	353	496	679				
6.00	202	299	430	602	824				
8.00	275	407	585	818					
10.00	351	517	741						
15.00	542	796							
20.00	735								

*Extracted with permission from *J. Chem Eng. Data* 8, 1963: 333–336. Copyright 1963 American Chemical Society.

2-78 PHYSICAL AND CHEMICAL DATA

TABLE 2-12 Water Partial Pressure, bar, over Aqueous Sulfuric Acid Solutions*
Weight percent, H₂SO₄

°C	10.0	20.0	30.0	40.0	50.0	60.0	70.0	75.0	80.0	85.0
0	.582E-02	.534E-02	.448E-02	.326E-02	.193E-02	.836E-03	.207E-03	.747E-04	.197E-04	.343E-05
10	.117E-01	.107E-01	.909E-02	.670E-02	.405E-02	.180E-02	.467E-03	.175E-03	.490E-04	.952E-05
20	.223E-01	.205E-01	.174E-01	.130E-01	.802E-02	.367E-02	.995E-03	.388E-03	.115E-04	.245E-04
30	.404E-01	.373E-01	.319E-01	.241E-01	.151E-01	.710E-02	.201E-02	.811E-03	.253E-03	.589E-04
40	.703E-01	.649E-01	.558E-01	.427E-01	.272E-01	.131E-01	.387E-02	.162E-02	.531E-03	.133E-03
50	.117	.109	.939E-01	.725E-01	.470E-01	.232E-01	.715E-02	.309E-02	.106E-02	.286E-03
60	.189	.175	.152	.119	.782E-01	.395E-01	.127E-01	.565E-02	.204E-02	.584E-03
70	.296	.275	.239	.188	.126	.651E-01	.217E-01	.997E-02	.376E-02	.114E-02
80	.449	.417	.365	.290	.196	.104	.360E-01	.170E-01	.668E-02	.213E-02
90	.664	.617	.542	.434	.298	.161	.578E-01	.281E-01	.115E-01	.383E-02
100	.957	.891	.786	.634	.441	.244	.905E-01	.452E-01	.192E-01	.666E-02
110	1.349	1.258	1.113	.904	.638	.360	.138	.708E-01	.312E-01	.112E-01
120	1.863	1.740	1.544	1.264	.903	.519	.206	.108	.493E-01	.183E-01
130	2.524	2.361	2.101	1.732	1.253	.734	.301	.162	.760E-01	.291E-01
140	3.361	3.149	2.810	2.333	1.708	1.020	.481	.236	.115	.451E-01
150	4.404	4.132	3.697	3.090	2.289	1.392	.605	.339	.170	.682E-01
160	5.685	5.342	4.793	4.031	3.021	1.870	.837	.478	.246	.101
170	7.236	6.810	6.127	5.185	3.930	2.475	1.138	.662	.350	.147
180	9.093	8.571	7.731	6.584	5.045	3.233	1.525	.902	.489	.208
190	11.289	10.658	9.640	8.259	6.397	4.169	2.017	1.212	.673	.291
200	13.861	13.107	11.887	10.245	8.020	5.312	2.632	1.606	.913	.401
210	16.841	15.951	14.505	12.576	9.948	6.696	3.395	2.101	1.220	.542
220	20.264	19.225	17.529	15.287	12.217	8.354	4.331	2.714	1.609	.724
230	24.160	22.960	20.992	18.414	14.864	10.322	5.466	3.467	2.096	.952
240	28.561	27.188	24.927	21.992	17.929	12.641	6.831	4.381	2.699	1.237
250	33.494	31.939	29.364	26.056	21.452	15.351	8.458	5.480	3.435	1.587
260	38.984	37.240	34.334	30.642	25.472	18.496	10.382	6.788	4.326	2.012
270	45.055	43.116	39.865	35.784	30.030	22.121	12.640	8.333	5.395	2.525
280	51.726	49.590	45.984	41.514	35.168	26.274	15.269	10.142	6.663	3.136
290	59.015	56.681	52.715	47.865	40.926	31.003	18.311	12.242	8.155	3.857
300	66.934	64.407	60.081	54.868	47.346	36.360	21.808	14.665	9.897	4.701
310	75.495	72.781	68.100	62.553	54.470	42.395	25.804	17.438	11.912	5.680
320	84.705	81.816	76.792	70.947	62.337	49.164	30.343	20.591	14.227	6.806
330	94.567	91.518	86.172	80.077	70.988	56.721	35.473	24.153	16.867	8.093
340	105.083	101.894	96.252	89.969	80.463	65.123	41.240	28.154	19.855	9.551
350	116.251	112.946	107.043	100.646	90.802	74.426	47.692	32.622	23.217	11.193

*Vermeulen, Dong, Robinson, Nguyen, and Gmitro, AIChE meeting, Anaheim, Calif., 1982; and private communication from Prof. Theodore Vermeulen, Chemical Engineering Dept., University of California, Berkeley.

TABLE 2-12 Water Partial Pressure, bar, over Aqueous Sulfuric Acid Solutions (Concluded)
Weight percent, H₂SO₄

°C	90.0	92.0	94.0	96.0	97.0	98.0	98.5	99.0	99.5	100.0
0	.518E-06	.242E-06	.107E-06	.401E-07	.218E-07	.980E-08	.569E-08	.268E-08	.775E-09	.196E-09
10	.159E-05	.762E-06	.344E-06	.130E-06	.713E-07	.323E-07	.188E-07	.888E-08	.258E-08	.655E-09
20	.448E-05	.220E-05	.101E-05	.390E-06	.215E-06	.978E-07	.572E-07	.271E-07	.789E-08	.201E-08
30	.117E-04	.587E-05	.275E-05	.108E-05	.598E-06	.275E-06	.161E-06	.766E-07	.224E-07	.575E-08
40	.285E-04	.146E-04	.696E-05	.278E-05	.155E-05	.720E-06	.424E-06	.202E-06	.595E-07	.153E-07
50	.652E-04	.341E-04	.166E-04	.672E-05	.379E-05	.177E-05	.105E-05	.503E-06	.149E-06	.384E-07
60	.141E-03	.754E-04	.372E-04	.154E-04	.875E-05	.413E-05	.245E-05	.118E-05	.350E-06	.910E-07
70	.290E-03	.158E-03	.795E-04	.334E-04	.192E-04	.912E-05	.544E-05	.263E-05	.784E-06	.205E-06
80	.569E-03	.316E-03	.162E-03	.691E-04	.400E-04	.192E-04	.115E-04	.559E-05	.168E-05	.439E-06
90	.107E-02	.606E-03	.315E-03	.137E-03	.801E-04	.388E-04	.234E-04	.114E-04	.343E-05	.903E-06
100	.194E-02	.112E-02	.590E-03	.261E-03	.154E-03	.752E-04	.455E-04	.223E-04	.674E-05	.178E-05
110	.338E-02	.198E-02	.107E-02	.479E-03	.285E-03	.141E-03	.855E-04	.420E-04	.128E-04	.339E-05
120	.571E-02	.341E-02	.186E-02	.851E-03	.511E-03	.254E-03	.155E-03	.766E-04	.233E-04	.623E-05
130	.938E-02	.569E-02	.315E-02	.146E-02	.886E-03	.445E-03	.278E-03	.135E-03	.414E-04	.111E-04
140	.150E-01	.923E-02	.519E-02	.245E-02	.149E-02	.757E-03	.467E-03	.232E-03	.711E-04	.191E-04
150	.233E-01	.146E-01	.832E-02	.399E-02	.245E-02	.125E-02	.776E-03	.387E-03	.119E-03	.321E-04
160	.354E-01	.225E-01	.130E-01	.633E-02	.393E-02	.202E-02	.126E-02	.629E-03	.194E-03	.526E-04
170	.526E-01	.340E-01	.199E-01	.983E-02	.614E-02	.319E-02	.199E-02	.999E-03	.309E-03	.840E-04
180	.766E-01	.502E-01	.298E-01	.149E-01	.941E-02	.492E-02	.309E-02	.155E-02	.482E-03	.131E-03
190	.110	.729E-01	.438E-01	.222E-01	.141E-01	.744E-02	.469E-02	.236E-02	.735E-03	.201E-03
200	.154	.104	.631E-01	.325E-01	.208E-01	.110E-01	.698E-02	.352E-02	.110E-02	.300E-03
210	.213	.146	.894E-01	.467E-01	.300E-01	.161E-01	.102E-01	.516E-02	.161E-02	.442E-03
220	.290	.201	.125	.660E-01	.427E-01	.230E-01	.147E-01	.743E-02	.232E-02	.635E-03
230	.389	.273	.171	.918E-01	.598E-01	.325E-01	.208E-01	.105E-01	.329E-02	.906E-03
240	.514	.366	.232	.126	.825E-01	.451E-01	.290E-01	.147E-01	.460E-02	.127E-02
250	.673	.485	.310	.170	.112	.618E-01	.398E-01	.202E-01	.633E-02	.174E-02
260	.870	.635	.409	.227	.151	.835E-01	.540E-01	.274E-01	.858E-02	.237E-02
270	1.112	.822	.534	.300	.200	.111	.723E-01	.366E-01	.115E-01	.317E-02
280	1.407	1.052	.689	.391	.263	.147	.957E-01	.485E-01	.152E-01	.420E-02
290	1.763	1.335	.880	.505	.341	.192	.125	.634E-01	.199E-01	.548E-02
300	2.190	1.676	1.112	.646	.437	.248	.162	.820E-01	.257E-01	.708E-02
310	2.696	2.088	1.394	.817	.556	.316	.208	.105	.328E-01	.905E-02
320	3.292	2.578	1.732	1.025	.701	.400	.264	.133	.415E-01	.114E-01
330	3.990	3.159	2.133	1.274	.875	.502	.331	.167	.520E-01	.143E-01
340	4.801	3.843	2.608	1.571	1.083	.624	.413	.208	.646E-01	.178E-01
350	5.738	4.641	3.164	1.922	1.331	.770	.511	.256	.795E-01	.218E-01

TABLE 2-13 Sulfur Trioxide Partial Pressure, bar, over Aqueous Sulfuric Acid Solutions*
Weight percent, H₂SO₄

°C	10.0	20.0	30.0	40.0	50.0	60.0	70.0	75.0	80.0	85.0
0	.644E-29	.103E-27	.205E-26	.688E-25	.368E-23	.341E-21	.784E-19	.174E-17	.531E-16	.229E-14
10	.149E-27	.223E-26	.395E-25	.113E-23	.522E-22	.415E-20	.796E-18	.158E-16	.417E-15	.141E-13
20	.278E-26	.394E-25	.626E-24	.156E-22	.621E-21	.426E-19	.685E-17	.121E-15	.280E-14	.767E-13
30	.426E-25	.577E-24	.832E-23	.181E-21	.630E-20	.376E-18	.509E-16	.808E-15	.164E-13	.371E-12
40	.549E-24	.714E-23	.941E-22	.181E-20	.555E-19	.288E-17	.331E-15	.473E-14	.851E-13	.162E-11
50	.602E-23	.757E-22	.921E-21	.158E-19	.429E-18	.195E-16	.191E-14	.246E-13	.395E-12	.643E-11
60	.573E-22	.699E-21	.789E-20	.122E-18	.294E-17	.118E-15	.985E-14	.116E-12	.165E-11	.234E-10
70	.477E-21	.567E-20	.599E-19	.843E-18	.181E-16	.643E-15	.461E-13	.492E-12	.634E-11	.791E-10
80	.352E-20	.410E-19	.408E-18	.524E-17	.101E-15	.319E-14	.197E-12	.192E-11	.223E-10	.249E-09
90	.233E-19	.266E-18	.250E-17	.296E-16	.516E-15	.145E-13	.775E-12	.693E-11	.731E-10	.734E-09
100	.139E-18	.157E-17	.140E-16	.153E-15	.242E-14	.606E-13	.283E-11	.232E-10	.223E-09	.204E-08
110	.756E-18	.844E-17	.719E-16	.730E-15	.105E-13	.236E-12	.961E-11	.729E-10	.641E-09	.538E-08
120	.377E-17	.418E-16	.340E-15	.323E-14	.424E-13	.858E-12	.307E-10	.215E-09	.174E-08	.135E-07
130	.174E-16	.191E-15	.150E-14	.133E-13	.160E-12	.293E-11	.922E-10	.601E-09	.446E-08	.324E-07
140	.743E-16	.815E-15	.615E-14	.517E-13	.569E-12	.943E-11	.262E-09	.159E-08	.109E-07	.745E-07
150	.297E-15	.325E-14	.237E-13	.188E-12	.191E-11	.287E-10	.710E-09	.403E-08	.256E-07	.165E-06
160	.111E-14	.122E-13	.862E-13	.649E-12	.605E-11	.833E-10	.183E-08	.974E-08	.575E-07	.351E-06
170	.393E-14	.430E-13	.296E-12	.212E-11	.184E-10	.231E-09	.453E-08	.226E-07	.125E-06	.725E-06
180	.131E-13	.144E-12	.967E-12	.622E-11	.532E-10	.610E-09	.107E-07	.505E-07	.260E-06	.145E-05
190	.415E-13	.458E-12	.301E-11	.197E-10	.147E-09	.155E-08	.246E-07	.109E-06	.527E-06	.282E-05
200	.125E-12	.139E-11	.893E-11	.561E-10	.391E-09	.379E-08	.542E-07	.228E-06	.103E-05	.534E-05
210	.362E-12	.404E-11	.254E-10	.154E-09	.100E-08	.894E-08	.116E-06	.462E-06	.198E-05	.986E-05
220	.100E-11	.112E-10	.695E-10	.405E-09	.246E-08	.204E-07	.240E-06	.911E-06	.368E-05	.175E-04
230	.265E-11	.301E-10	.183E-09	.103E-08	.587E-08	.450E-07	.482E-06	.175E-05	.668E-05	.314E-04
240	.678E-11	.777E-10	.465E-09	.253E-08	.135E-07	.965E-07	.944E-06	.328E-05	.119E-04	.543E-04
250	.167E-10	.193E-09	.114E-08	.602E-08	.303E-07	.201E-06	.180E-05	.600E-05	.206E-04	.923E-04
260	.399E-10	.466E-09	.272E-08	.139E-07	.660E-07	.408E-06	.336E-05	.108E-04	.352E-04	.154E-03
270	.920E-10	.109E-08	.628E-08	.312E-07	.140E-06	.807E-06	.612E-05	.189E-04	.590E-04	.253E-03
280	.206E-09	.247E-08	.141E-07	.683E-07	.288E-06	.156E-05	.109E-04	.326E-04	.973E-04	.408E-03
290	.449E-09	.545E-08	.308E-07	.145E-06	.580E-06	.295E-05	.191E-04	.553E-04	.158E-03	.649E-03
300	.953E-09	.117E-07	.657E-07	.302E-06	.114E-05	.546E-05	.329E-04	.921E-04	.253E-03	.102E-02
310	.197E-08	.245E-07	.136E-06	.614E-06	.220E-05	.990E-05	.556E-04	.151E-03	.398E-03	.155E-02
320	.397E-08	.502E-07	.277E-06	.122E-05	.414E-05	.176E-04	.923E-04	.245E-03	.621E-03	.242E-02
330	.782E-08	.100E-06	.551E-06	.237E-05	.766E-05	.308E-04	.151E-03	.391E-03	.956E-03	.367E-02
340	.151E-07	.196E-06	.107E-05	.452E-05	.139E-04	.529E-04	.243E-03	.617E-03	.145E-02	.550E-02
350	.285E-07	.376E-06	.204E-05	.846E-05	.246E-04	.893E-04	.387E-03	.963E-03	.219E-02	.815E-02

*Vermeulen, Dong, Robinson, Nguyen, and Gmitro, AIChE meeting, Anaheim, Calif., 1982; and private communication from Prof. Theodore Vermeulen, Chemical Engineering Dept., University of California, Berkeley.

TABLE 2-13 Sulfur Trioxide Partial Pressure, bar, over Aqueous Sulfuric Acid Solutions (Concluded)
Weight percent, H₂SO₄

°C	90.0	92.0	94.0	96.0	97.0	98.0	98.5	99.0	99.5	100.0
0	.671E-13	.216E-12	.677E-12	.240E-11	.500E-11	.124E-10	.224E-10	.502E-10	.182E-09	.755E-09
10	.345E-12	.107E-11	.326E-11	.114E-10	.234E-10	.578E-10	.104E-09	.232E-09	.839E-09	.347E-08
20	.159E-11	.475E-11	.141E-10	.482E-10	.986E-10	.241E-09	.433E-09	.961E-09	.346E-08	.142E-07
30	.664E-11	.192E-10	.557E-10	.186E-09	.376E-09	.911E-09	.163E-08	.360E-08	.129E-07	.528E-07
40	.254E-10	.709E-10	.201E-09	.655E-09	.131E-08	.315E-08	.562E-08	.123E-07	.440E-07	.179E-06
50	.897E-10	.242E-09	.669E-09	.214E-08	.424E-08	.101E-07	.179E-07	.391E-07	.139E-06	.560E-06
60	.294E-09	.771E-09	.207E-08	.647E-08	.127E-07	.299E-07	.528E-07	.115E-06	.405E-06	.163E-05
70	.904E-09	.230E-08	.602E-08	.184E-07	.357E-07	.833E-07	.146E-06	.316E-06	.111E-05	.444E-05
80	.261E-08	.643E-08	.165E-07	.492E-07	.946E-07	.218E-06	.381E-06	.820E-06	.286E-05	.114E-04
90	.712E-08	.171E-07	.426E-07	.124E-06	.237E-06	.541E-06	.940E-06	.201E-05	.698E-05	.276E-04
100	.184E-07	.430E-07	.105E-06	.300E-06	.565E-06	.127E-05	.220E-05	.470E-05	.162E-04	.638E-04
110	.456E-07	.103E-06	.247E-06	.689E-06	.128E-05	.287E-05	.494E-05	.105E-04	.359E-04	.141E-03
120	.108E-06	.238E-06	.555E-06	.152E-05	.280E-05	.619E-05	.106E-04	.224E-04	.764E-04	.298E-03
130	.244E-06	.526E-06	.120E-05	.321E-05	.586E-05	.128E-04	.219E-04	.459E-04	.156E-03	.606E-03
140	.533E-06	.112E-05	.250E-05	.656E-05	.118E-04	.257E-04	.435E-04	.910E-04	.308E-03	.119E-02
150	.112E-05	.230E-05	.504E-05	.129E-04	.231E-04	.497E-04	.837E-04	.174E-03	.588E-03	.226E-02
160	.229E-05	.459E-05	.983E-05	.247E-04	.438E-04	.932E-04	.156E-03	.324E-03	.109E-02	.416E-02
170	.453E-05	.886E-05	.186E-04	.459E-04	.806E-04	.170E-03	.283E-03	.586E-03	.196E-02	.746E-02
180	.870E-05	.166E-04	.343E-04	.829E-04	.144E-03	.301E-03	.499E-03	.103E-02	.343E-02	.130E-01
190	.163E-04	.304E-04	.615E-04	.146E-03	.252E-03	.520E-03	.859E-03	.177E-02	.587E-02	.222E-01
200	.297E-04	.543E-04	.108E-03	.251E-03	.429E-03	.878E-03	.144E-02	.296E-02	.981E-02	.370E-01
210	.528E-04	.946E-04	.185E-03	.422E-03	.714E-03	.145E-02	.237E-02	.486E-02	.161E-01	.603E-01
220	.919E-04	.161E-03	.309E-03	.694E-03	.117E-02	.235E-02	.383E-02	.781E-02	.258E-01	.965E-01
230	.157E-03	.269E-03	.508E-03	.112E-02	.187E-02	.373E-02	.605E-02	.123E-01	.405E-01	.152
240	.261E-03	.441E-03	.819E-03	.178E-02	.293E-02	.582E-02	.939E-02	.191E-01	.627E-01	.234
250	.428E-03	.708E-03	.130E-02	.276E-02	.453E-02	.891E-02	.143E-01	.291E-01	.955E-01	.356
260	.690E-03	.112E-02	.202E-02	.423E-02	.688E-02	.134E-01	.215E-01	.437E-01	.143	.532
270	.109E-02	.174E-02	.309E-02	.638E-02	.103E-01	.200E-01	.319E-01	.646E-01	.212	.786
280	.170E-02	.266E-02	.466E-02	.948E-02	.152E-01	.293E-01	.465E-01	.943E-01	.309	.1.144
290	.261E-02	.401E-02	.694E-02	.139E-01	.221E-01	.423E-01	.670E-01	.136	.444	.1.646
300	.395E-02	.595E-02	.102E-01	.201E-01	.318E-01	.604E-01	.953E-01	.193	.632	.2.339
310	.589E-02	.873E-02	.148E-01	.287E-01	.451E-01	.852E-01	.134	.272	.889	.3.289
320	.868E-02	.126E-01	.211E-01	.405E-01	.632E-01	.119	.186	.378	.1.236	.4.575
330	.126E-01	.181E-01	.299E-01	.565E-01	.877E-01	.164	.256	.520	.1.703	.6.303
340	.181E-01	.255E-01	.418E-01	.780E-01	.120	.224	.348	.708	.2.323	.8.603
350	.258E-01	.357E-01	.578E-01	.107	.164	.303	.470	.956	.3.142	.11.640

TABLE 2-14 Sulfuric Acid Partial Pressure, bar, over Aqueous Sulfuric Acid*

°C	Weight Percent, H ₂ SO ₄									
	10.0	20.0	30.0	40.0	50.0	60.0	70.0	75.0	80.0	85.0
0	.576E-21	.843E-20	.141E-18	.344E-17	.109E-15	.438E-14	.249E-12	.200E-11	.161E-10	.121E-09
10	.634E-20	.874E-19	.131E-17	.276E-16	.769E-15	.273E-13	.135E-11	.101E-10	.743E-10	.490E-09
20	.588E-19	.769E-18	.104E-16	.193E-15	.474E-14	.149E-12	.649E-11	.447E-10	.305E-09	.179E-08
30	.468E-18	.584E-17	.721E-16	.119E-14	.259E-13	.725E-12	.278E-10	.178E-09	.113E-08	.594E-08
40	.324E-17	.389E-16	.441E-15	.649E-14	.127E-12	.317E-11	.108E-09	.643E-09	.379E-08	.181E-07
50	.197E-16	.229E-15	.241E-14	.320E-13	.562E-12	.126E-10	.380E-09	.212E-08	.117E-07	.513E-07
60	.107E-15	.121E-14	.119E-13	.144E-12	.228E-11	.462E-10	.124E-08	.646E-08	.334E-07	.135E-06
70	.526E-15	.581E-14	.535E-13	.592E-12	.851E-11	.156E-09	.373E-08	.183E-07	.888E-07	.336E-06
80	.235E-14	.254E-13	.221E-12	.225E-11	.295E-10	.492E-09	.105E-07	.485E-07	.222E-06	.786E-06
90	.960E-14	.102E-12	.844E-12	.798E-11	.956E-10	.145E-08	.279E-07	.121E-06	.522E-06	.175E-05
100	.353E-13	.381E-12	.300E-11	.264E-10	.291E-09	.402E-08	.698E-07	.287E-06	.117E-05	.371E-05
110	.127E-12	.132E-11	.997E-11	.824E-10	.835E-09	.106E-07	.166E-06	.644E-06	.249E-05	.752E-05
120	.418E-12	.432E-11	.312E-10	.243E-09	.227E-08	.264E-07	.375E-06	.135E-05	.508E-05	.147E-04
130	.129E-11	.132E-10	.924E-10	.678E-09	.589E-08	.631E-07	.814E-06	.285E-05	.995E-05	.277E-04
140	.375E-11	.385E-10	.259E-09	.181E-08	.146E-07	.144E-06	.169E-05	.565E-05	.188E-04	.503E-04
150	.103E-10	.106E-09	.694E-09	.460E-08	.346E-07	.316E-06	.340E-05	.105E-04	.343E-04	.889E-04
160	.272E-10	.279E-09	.178E-08	.112E-07	.789E-07	.670E-06	.659E-05	.200E-04	.608E-04	.152E-03
170	.682E-10	.702E-09	.436E-08	.264E-07	.174E-06	.137E-05	.124E-04	.359E-04	.104E-03	.255E-03
180	.164E-09	.170E-08	.103E-07	.599E-07	.369E-06	.271E-05	.225E-04	.627E-04	.175E-03	.416E-03
190	.378E-09	.394E-08	.234E-07	.131E-06	.760E-06	.521E-05	.400E-04	.107E-03	.286E-03	.663E-03
200	.842E-09	.883E-08	.514E-07	.278E-06	.152E-05	.975E-05	.691E-04	.177E-03	.457E-03	.104E-02
210	.181E-08	.191E-07	.109E-06	.573E-06	.295E-05	.178E-04	.117E-03	.288E-03	.715E-03	.159E-02
220	.376E-08	.401E-07	.226E-06	.115E-05	.559E-05	.316E-04	.193E-03	.459E-03	.110E-02	.239E-02
230	.758E-08	.817E-07	.455E-06	.224E-05	.103E-04	.549E-04	.311E-03	.717E-03	.166E-02	.354E-02
240	.148E-07	.162E-06	.889E-06	.427E-05	.186E-04	.935E-04	.494E-03	.110E-02	.245E-02	.515E-02
250	.283E-07	.312E-06	.170E-05	.793E-05	.329E-04	.156E-03	.770E-03	.166E-02	.358E-02	.740E-02
260	.526E-07	.588E-06	.316E-05	.144E-04	.569E-04	.255E-03	.118E-02	.247E-02	.516E-02	.105E-01
270	.954E-07	.108E-05	.577E-05	.257E-04	.965E-04	.411E-03	.178E-02	.362E-02	.733E-02	.147E-01
280	.169E-06	.194E-05	.103E-04	.450E-04	.161E-03	.650E-03	.265E-02	.524E-02	.103E-01	.203E-01
290	.294E-06	.342E-05	.180E-04	.771E-04	.263E-03	.101E-02	.389E-02	.750E-02	.143E-01	.278E-01
300	.500E-06	.591E-05	.309E-04	.130E-03	.424E-03	.156E-02	.563E-02	.106E-01	.196E-01	.376E-01
310	.834E-06	.100E-04	.522E-04	.215E-03	.672E-03	.236E-02	.805E-02	.148E-01	.266E-01	.504E-01
320	.137E-05	.167E-04	.865E-04	.352E-03	.105E-02	.352E-02	.114E-01	.205E-01	.359E-01	.670E-01
330	.220E-05	.273E-04	.141E-03	.565E-03	.162E-02	.519E-02	.159E-01	.281E-01	.480E-01	.883E-01
340	.349E-05	.440E-04	.227E-03	.895E-03	.246E-02	.757E-02	.221E-01	.382E-01	.636E-01	.116
350	.544E-05	.698E-04	.360E-03	.140E-02	.369E-02	.109E-01	.303E-01	.516E-01	.836E-01	.150
°C	Weight percent, H ₂ SO ₄									
	90.0	92.0	94.0	96.0	97.0	98.0	98.5	99.0	99.5	100.0
0	.534E-09	.803E-09	.112E-08	.148E-08	.167E-08	.187E-08	.196E-08	.206E-08	.217E-08	.228E-08
10	.200E-08	.296E-08	.409E-08	.540E-08	.609E-08	.679E-08	.714E-08	.750E-08	.788E-08	.827E-08
20	.677E-08	.993E-08	.136E-07	.179E-07	.201E-07	.224E-07	.236E-07	.247E-07	.260E-07	.273E-07
30	.211E-07	.306E-07	.415E-07	.543E-07	.611E-07	.680E-07	.714E-07	.749E-07	.786E-07	.824E-07
40	.607E-07	.870E-07	.117E-06	.153E-06	.171E-06	.191E-06	.200E-06	.210E-06	.220E-06	.230E-06
50	.163E-06	.231E-06	.309E-06	.400E-06	.449E-06	.498E-06	.523E-06	.548E-06	.574E-06	.600E-06
60	.411E-06	.575E-06	.765E-06	.958E-06	.110E-05	.122E-05	.128E-05	.134E-05	.140E-05	.147E-05
70	.976E-06	.135E-05	.179E-05	.229E-05	.256E-05	.283E-05	.297E-05	.310E-05	.325E-05	.339E-05
80	.220E-05	.302E-05	.396E-05	.504E-05	.562E-05	.622E-05	.652E-05	.681E-05	.712E-05	.743E-05
90	.473E-05	.642E-05	.835E-05	.106E-04	.118E-04	.130E-04	.136E-04	.143E-04	.149E-04	.155E-04
100	.973E-05	.131E-04	.169E-04	.213E-04	.237E-04	.261E-04	.274E-04	.285E-04	.298E-04	.310E-04
110	.192E-04	.256E-04	.328E-04	.412E-04	.457E-04	.503E-04	.527E-04	.549E-04	.572E-04	.595E-04
120	.366E-04	.482E-04	.614E-04	.767E-04	.849E-04	.935E-04	.977E-04	.102E-03	.106E-03	.110E-03
130	.672E-04	.879E-04	.111E-03	.138E-03	.153E-03	.168E-03	.175E-03	.182E-03	.190E-03	.197E-03
140	.120E-03	.155E-03	.195E-03	.241E-03	.266E-03	.292E-03	.304E-03	.316E-03	.329E-03	.341E-03
150	.207E-03	.266E-03	.332E-03	.408E-03	.449E-03	.493E-03	.514E-03	.534E-03	.554E-03	.574E-03
160	.348E-03	.444E-03	.550E-03	.673E-03	.740E-03	.810E-03	.844E-03	.876E-03	.909E-03	.941E-03
170	.572E-03	.723E-03	.889E-03	.108E-02	.119E-02	.130E-02	.135E-02	.140E-02	.145E-02	.150E-02
180	.917E-03	.115E-02	.140E-02	.170E-02	.186E-02	.204E-02	.212E-02	.220E-02	.227E-02	.235E-02
190	.144E-02	.179E-02	.217E-02	.262E-02	.286E-02	.312E-02	.325E-02	.336E-02	.348E-02	.359E-02
200	.221E-02	.273E-02	.329E-02	.395E-02	.431E-02	.470E-02	.488E-02	.505E-02	.522E-02	.538E-02
210	.333E-02	.408E-02	.490E-02	.558E-02	.637E-02	.693E-02	.720E-02	.744E-02	.768E-02	.791E-02
220	.494E-02	.601E-02	.715E-02	.850E-02	.924E-02	.1000E-01	.104E-01	.108E-01	.111E-01	.114E-01
230	.719E-02	.869E-02	.103E-01	.122E-01	.132E-01	.143E-01	.149E-01	.153E-01	.158E-01	.162E-01
240	.103E-01	.124E-01	.146E-01	.171E-01	.186E-01	.201E-01	.209E-01	.215E-01	.221E-01	.227E-01
250	.146E-01	.174E-01	.203E-01	.238E-01	.257E-01	.278E-01	.289E-01	.297E-01	.305E-01	.314E-01
260	.203E-01	.240E-01	.279E-01	.326E-01	.352E-01	.380E-01	.394E-01	.405E-01	.416E-01	.427E-01
270	.279E-01	.329E-01	.380E-01	.441E-01	.475E-01	.513E-01	.531E-01	.545E-01	.560E-01	.574E-01
280	.380E-01	.444E-01	.510E-01	.589E-01	.633E-01	.683E-01	.706E-01	.725E-01	.744E-01	.762E-01
290	.510E-01	.592E-01	.676E-01	.778E-01	.835E-01	.900E-01	.930E-01	.954E-01	.978E-01	.100
300	.678E-01	.782E-01	.888E-01	.102	.109	.117	.121	.124	.127	.130
310	.892E-01	.102	.115	.132	.141	.151	.156	.160	.164	.167
320	.116	.132	.149	.169	.180	.193	.199	.204	.209	.213
330	.150	.170	.190	.214	.228	.245	.252	.258	.263	.269
340	.192	.216	.240	.270	.287	.307	.317	.328	.330	.386
350	.243	.272	.301	.337	.358	.383	.394	.402	.410	.417

*Vermeulen, Dong, Robinson, Nguyen, and Gmitro, AIChE meeting, Anaheim, CA, 1982; and private communication from Prof. Theodore Vermeulen, Chemical Engineering Dept., University of California, Berkeley.

TABLE 2-15 Total Pressure, bar, of Aqueous Sulfuric Acid Solutions*

°C	Weight percent, H ₂ SO ₄									
	10.0	20.0	30.0	40.0	50.0	60.0	70.0	75.0	80.0	85.0
0	.582E-02	.534E-02	.448E-02	.326E-02	.193E-02	.836E-03	.207E-03	.747E-04	.197E-04	.343E-05
10	.117E-01	.107E-01	.909E-02	.670E-02	.405E-02	.180E-02	.467E-03	.175E-03	.490E-04	.952E-05
20	.223E-01	.205E-01	.174E-01	.130E-01	.802E-02	.367E-02	.995E-03	.388E-03	.115E-03	.245E-04
30	.404E-01	.373E-01	.319E-01	.241E-01	.151E-01	.710E-02	.201E-02	.811E-03	.253E-03	.589E-04
40	.703E-01	.649E-01	.558E-01	.427E-01	.272E-01	.131E-01	.387E-02	.162E-02	.531E-03	.134E-03
50	.117	.109	.939E-01	.725E-01	.470E-01	.232E-01	.715E-02	.309E-02	.106E-02	.286E-03
60	.189	.175	.152	.119	.782E-01	.395E-01	.127E-01	.565E-02	.204E-02	.584E-03
70	.296	.275	.239	.188	.126	.651E-01	.217E-01	.997E-01	.376E-02	.114E-02
80	.449	.417	.365	.290	.196	.104	.360E-01	.170E-01	.668E-02	.213E-02
90	.664	.617	.542	.434	.298	.161	.578E-01	.281E-01	.115E-01	.383E-02
100	.957	.891	.786	.634	.441	.244	.905E-01	.452E-01	.192E-01	.666E-02
110	1.349	1.258	1.113	.904	.638	.360	.138	.708E-01	.312E-01	.112E-01
120	1.863	1.740	1.544	1.264	.903	.519	.206	.108	.493E-01	.183E-01
130	2.524	2.361	2.101	1.732	1.253	.734	.301	.162	.760E-01	.291E-01
140	3.361	3.149	2.810	2.333	1.708	1.020	.431	.236	.115	.451E-01
150	4.404	4.132	3.697	3.090	2.289	1.392	.605	.339	.170	.683E-01
160	5.685	5.342	4.793	4.031	3.021	1.870	.837	.478	.246	.101
170	7.236	6.810	6.127	5.185	3.930	2.475	1.138	.662	.350	.147
180	9.093	8.571	7.731	6.584	5.045	3.233	1.525	.902	.489	.209
190	11.289	10.658	9.640	8.259	6.397	4.169	2.017	1.212	.673	.292
200	13.861	13.107	11.887	10.245	8.020	5.312	2.633	1.606	.913	.402
210	16.841	15.951	14.505	12.576	9.948	6.696	3.396	2.101	1.221	.544
220	20.264	19.225	17.529	15.287	12.217	8.354	4.331	2.715	1.610	.726
230	24.160	22.960	20.992	18.414	14.864	10.322	5.466	3.468	2.098	.956
240	28.561	27.188	24.927	21.992	17.929	12.641	6.832	4.382	2.701	1.242
250	33.494	31.939	29.364	26.056	21.452	15.351	8.459	5.481	3.439	1.594
260	38.984	37.240	34.334	30.642	25.472	18.496	10.384	6.791	4.332	2.023
270	45.055	43.116	39.865	35.784	30.030	22.122	12.642	8.337	5.402	2.540
280	51.726	49.590	45.984	41.514	35.168	26.275	15.272	10.147	6.673	3.157
290	59.015	56.681	52.715	47.866	40.926	31.004	18.315	12.250	8.170	3.886
300	66.934	64.407	60.081	54.869	47.347	36.361	21.814	14.675	9.916	4.740
310	75.495	72.781	68.101	62.553	54.470	42.398	25.812	17.453	11.939	5.732
320	84.705	81.816	76.792	70.947	62.338	49.168	30.355	20.611	14.264	6.876
330	94.567	91.518	86.172	80.078	70.990	56.727	35.489	24.182	16.916	8.185
340	105.083	101.894	96.252	89.970	80.466	65.130	41.262	28.193	19.920	9.672
350	116.251	112.947	107.043	100.647	90.806	74.437	47.723	32.674	23.303	11.351
°C	Weight percent, H ₂ SO ₄									
	90.0	92.0	94.0	96.0	97.0	98.0	98.5	99.0	99.5	100.0
0	.518E-06	.243E-06	.109E-06	.416E-07	.235E-07	.117E-07	.768E-08	.479E-08	.313E-08	.323E-08
10	.159E-05	.765E-06	.348E-06	.136E-06	.774E-07	.391E-07	.261E-07	.166E-07	.113E-07	.124E-07
20	.449E-05	.221E-05	.102E-05	.407E-06	.235E-06	.121E-06	.812E-07	.528E-07	.373E-07	.435E-07
30	.117E-04	.590E-05	.279E-05	.113E-05	.659E-06	.344E-06	.234E-06	.155E-06	.114E-06	.141E-06
40	.385E-04	.147E-04	.708E-05	.293E-05	.173E-05	.914E-06	.630E-06	.425E-06	.323E-06	.425E-06
50	.653E-04	.344E-04	.169E-04	.712E-05	.425E-05	.228E-05	.159E-05	.109E-05	.861E-06	.120E-05
60	.141E-03	.759E-04	.350E-04	.164E-04	.957E-05	.538E-05	.379E-05	.264E-05	.216E-05	.319E-05
70	.291E-03	.159E-03	.813E-04	.357E-04	.218E-04	.120E-04	.856E-05	.605E-05	.514E-05	.804E-05
80	.571E-03	.319E-03	.166E-03	.742E-04	.458E-04	.257E-04	.184E-04	.132E-04	.117E-04	.193E-04
90	.107E-02	.612E-03	.324E-03	.148E-03	.921E-04	.524E-04	.390E-04	.277E-04	.253E-04	.441E-04
100	.195E-02	.113E-02	.607E-03	.283E-03	.178E-03	.103E-03	.751E-04	.555E-04	.527E-04	.966E-04
110	.340E-02	.201E-02	.110E-02	.521E-03	.332E-03	.194E-03	.143E-03	.107E-03	.106E-03	.204E-03
120	.575E-02	.346E-02	.192E-02	.929E-03	.598E-03	.354E-03	.263E-03	.201E-03	.206E-03	.414E-03
130	.944E-02	.578E-02	.327E-02	.161E-02	.104E-02	.626E-03	.470E-03	.363E-03	.387E-03	.314E-03
140	.151E-01	.939E-02	.539E-02	.270E-02	.177E-02	.107E-02	.815E-03	.639E-03	.708E-03	.155E-02
150	.235E-01	.149E-01	.866E-02	.441E-02	.293E-02	.180E-02	.137E-02	.109E-02	.126E-02	.257E-02
160	.357E-01	.230E-01	.136E-01	.703E-02	.471E-02	.293E-02	.226E-02	.183E-02	.219E-02	.516E-02
170	.532E-01	.347E-01	.208E-01	.110E-01	.741E-02	.466E-02	.363E-02	.299E-02	.372E-02	.905E-02
180	.775E-01	.514E-01	.312E-01	.167E-01	.114E-01	.726E-02	.571E-02	.478E-02	.619E-02	.155E-01
190	.111	.747E-01	.460E-01	.250E-01	.172E-01	.111E-01	.880E-02	.749E-02	.101E-01	.260E-01
200	.156	.107	.665E-01	.367E-01	.255E-01	.166E-01	.133E-01	.115E-01	.161E-01	.427E-01
210	.216	.150	.944E-01	.530E-01	.371E-01	.245E-01	.198E-01	.175E-01	.253E-01	.657E-01
220	.295	.207	.132	.752E-01	.531E-01	.354E-01	.289E-01	.260E-01	.392E-01	.109
230	.396	.282	.182	.105	.749E-01	.505E-01	.417E-01	.382E-01	.596E-01	.169
240	.525	.379	.247	.145	.104	.710E-01	.592E-01	.553E-01	.895E-01	.258
250	.688	.503	.331	.197	.143	.985E-01	.830E-01	.790E-01	.132	.389
260	.881	.660	.439	.264	.193	.135	.115	.112	.193	.577
270	1.141	.856	.575	.351	.258	.153	.157	.156	.279	.846
280	1.447	1.099	.744	.460	.341	.245	.213	.215	.398	1.225
290	1.817	1.398	.954	.597	.446	.324	.285	.295	.562	1.751
300	2.261	1.761	1.211	.767	.578	.425	.379	.399	.785	2.476
310	2.791	2.199	1.524	.977	.742	.553	.498	.536	1.085	3.465
320	3.417	2.723	1.901	1.234	.944	.713	.649	.714	1.486	4.800
330	4.153	3.347	2.353	1.545	1.191	.911	.840	.944	2.018	6.586
340	5.011	4.084	2.889	1.919	1.491	1.156	1.078	1.239	2.718	8.957
350	6.006	4.949	3.523	2.366	1.852	1.456	1.374	1.614	3.631	12.079

*Vermeulen, Dong, Robinson, Nguyen, and Gmitro, AIChE meeting, Anaheim, Calif., 1982; and private communication from Prof. Theodore Vermeulen, Chemical Engineering Dept., University of California, Berkeley.

2-84 PHYSICAL AND CHEMICAL DATA

TABLE 2-16 Partial Pressures of HNO₃ and H₂O over Aqueous Solutions of HNO₃

mmHg

Percentages are weight % HNO₃ in solution.

°C	20%		25%		30%		35%		40%		45%		50%	
	HNO ₃	H ₂ O												
0		4.1		3.8		3.6		3.3		3.0		2.6		2.1
5		5.7		5.4		5.0		4.6		4.2		3.6		3.0
10		8.0		7.6		7.1		6.5		5.8		5.0		4.2
15		10.9		10.3		9.7		8.9		8.0	0.10	6.9	.18	5.8
20		15.2		14.2		13.2		12.0		10.8	.15	9.4	.27	7.9
25		20.6		19.2		17.8		16.2	0.12	14.6	.23	12.7	.39	10.7
30		27.6		25.7		23.8	0.09	21.7	.17	19.5	.33	16.9	.56	14.4
35		36.5		33.8		31.1	.13	28.3	.25	25.5	.48	22.3	.80	19.0
40		47.5		44	0.11	41	.20	37.7	.36	33.5	.68	29.3	1.13	25.0
45		62	0.09	57.5	.17	53	.28	48	.52	43	.96	38.0	1.57	32.5
50		80	.13	75	.25	69	.42	63	.75	56	1.35	49.5	2.18	42.5
55	0.09	100	.18	94	.35	87	.59	79	1.04	71	1.83	62.5	2.95	54
60	.13	128	.28	121	.51	113	.85	102	1.48	90	2.54	80	4.05	70
65	.19	162	.40	151	.71	140	1.18	127	2.05	114	3.47	100	5.46	88
70	.27	200	.54	187	1.00	174	1.63	159	2.80	143	4.65	126	7.25	110
75	.38	250	.77	234	1.38	217	2.26	198	3.80	178	6.20	158	9.6	138
80	.53	307	1.05	287	1.87	267	3.07	243	5.10	218	8.15	195	12.5	170
85	.74	378	1.44	352	2.53	325	4.15	297	6.83	268	10.7	240	16.3	211
90	1.01	458	1.95	426	3.38	393	5.50	359	9.0	325	13.7	292	20.9	258
95	1.37	555	2.62	517	4.53	478	7.32	436	11.7	394	17.8	355	26.8	315
100	1.87	675	3.50	628	6.05	580	9.7	530	15.5	480	23.0	430	34.2	383
105	2.50	800	4.65	745	7.90	690	12.7	631	20.0	573	29.2	520	43.0	463
110							16.5	755	25.7	688	37.0	625	54.5	560
115									32.5	810	46	740	67	665
120												84		785
°C	55%		60%		65%		70%		80%		90%		100%	
	HNO ₃	H ₂ O												
0		1.8	0.19	1.5	0.41	1.3	0.79	1.1	2		5.5		11	
5	0.14	2.5	.28	2.1	.60	1.8	1.12	1.6	3		8		15	
10	.21	3.5	.41	3.0	.86	2.6	1.58	2.2	4		11		22	
15	.31	4.9	.59	4.1	1.21	3.5	2.18	3.0	6		15		30	
20	.45	6.7	.84	5.6	1.68	4.9	3.00	4.1	8		20		42	
25	.66	9.1	1.21	7.7	2.32	6.6	4.10	5.5	10.5		3.2		57	
30	.93	12.2	1.66	10.3	3.17	8.8	5.50	7.4	14		4		1.3	
35	1.30	16.1	2.28	13.6	4.26	11.6	7.30	9.8	18.5		5.5		102	
40	1.82	21.3	3.10	18.1	5.70	15.5	9.65	12.8	24.5		7		2.4	
45	2.50	28.0	4.20	23.7	7.55	20.0	12.6	16.7	32		9.5		170	
50	3.41	36.3	5.68	31	10.0	26.0	16.5	21.8	41		12		103	
55	4.54	46	7.45	39	12.8	33.0	21.0	27.3	52		15		5	
60	6.15	60	9.9	51	16.8	43.0	27.1	35.3	67		20		157	
65	8.18	76	13.0	64	21.7	54.5	34.5	44.5	85		25		192	
70	10.7	95	16.8	81	27.5	68	43.3	56	106		31		232	
75	13.9	120	21.8	102	35.0	86	54.5	70	130		38		282	
80	18.0	148	27.5	126	43.5	106	67.5	86	158		48		338	
85	23.0	182	34.8	156	54.5	131	83	107	192		60		405	
90	29.4	223	43.7	192	67.5	160	103	130	230		73		480	
95	37.3	272	55.0	233	83.5	195	125	158	278		89		570	
100	47	331	69.5	285	103	238	152	192	330		108		675	
105	58.5	400	84.5	345	124	288	183	231	392		129		790	
110	73	485	103	417	152	345	221	278	465		155			
115	90	575	126	495	181	410	262	330	545		185			
120	110	685	156	590	218	490	312	393	640		219			
125			187	700	260	580	372	469						

TABLE 2-17 Partial Pressures of H_2O and HBr over Aqueous Solutions of HBr at 20 to 55°C

% HBr	mmHg							
	20°C		25°C		50°C		55°C	
HBr	HBr	H_2O	HBr	H_2O	HBr	H_2O	HBr	H_2O
32			0.0016					
34			.0022					
36			.0033					
38			.0061					
40			.011					
42			.023					
44			.048					
46			.10					
48	0.09	6.2	.13	8.2	1.3	30.2	2.0	38
50	.23	4.5	.37	6.1	3.2	24.3	4.6	31
52	.71	3.3	1.1	4.5	7.2	19.3	10.2	25
54	2.2	2.4	3.2	3.3	17	16.0	23.0	21
56	6.8	1.7	9.3	2.4	40	13.3	51	18
58	21	1.3	27	1.9	91	10.4	115	14
60						260		11.4

TABLE 2-20 Total Vapor Pressures of Aqueous Solutions of CH_3COOH

°C	Percentages of weight % acetic acid in the solution mmHg		
	25%	50%	75%
20	16.3	15.7	15.3
25	22.1	21.4	20.8
30	29.6	28.8	27.8
35	39.4	38.3	36.6
40	51.7	50.2	48.1
45	67.0	65.0	62.0
50	87.2	85.0	80.1
55	110	107	102
60	141	138	130
65	178	172	162
70	223	216	203
75	277	269	251
80	342	331	310
85	419	407	376
90	510	497	458
95	618	602	550
100	743	725	666

TABLE 2-18 Partial Pressures of HI over Aqueous Solutions of HI at 25°C

% HI	mmHg						
	4	46	48	50	52	54	56
P_{HI}	0.00064	0.0010	0.0022	0.0050	0.013	0.035	0.10

TABLE 2-19 Vapor Pressures of the System: Water-Sulfuric Acid-Nitric Acid

For these data reference must be made to the graphs of *International Critical Tables*, vol. 3, pp. 306-308.

TABLE 2-21 Partial Pressures of H_2O over Aqueous Solutions of NH_3^*

Pressures are in pounds per square inch absolute

$t, ^\circ F$	Molar concentration of ammonia in the solutions in percentages (Weight concentration of ammonia in the solution in percentages)																			
	0 (0)	5 (4.74)	10 (9.50)	15 (14.29)	20 (19.10)	25 (23.94)	30 (28.81)	35 (33.71)	40 (38.64)	45 (43.59)	50 (48.57)	55 (53.58)	60 (58.62)	65 (63.69)	70 (68.79)	75 (73.91)	80 (79.07)	85 (84.26)	90 (89.47)	95 (94.72)
32	0.09	0.084	0.079	0.074	0.070	0.065	0.060	0.056	0.051	0.047	0.042	0.038	0.034	0.030	0.025	0.021	0.017	0.013	0.008	0.004
40	.12	.115	.108	.101	.095	.089	.083	.076	.070	.064	.058	.052	.046	.040	.035	.029	.023	.015	.012	.006
50	.18	.17	.16	.15	.14	.13	.12	.11	.10	.094	.085	.076	.068	.059	.051	.042	.034	.025	.017	.008
60	.26	.24	.23	.21	.20	.19	.17	.16	.15	.13	.12	.11	.097	.085	.073	.061	.049	.037	.024	.012
70	.36	.34	.32	.30	.28	.26	.25	.23	.21	.19	.17	.15	.14	.12	.10	.086	.069	.052	.034	.017
80	.51	.48	.45	.42	.40	.37	.34	.32	.29	.27	.24	.22	.19	.17	.14	.12	.096	.072	.048	.024
90	.70	.66	.63	.58	.55	.51	.47	.44	.40	.37	.33	.30	.26	.23	.20	.16	.13	.10	.066	.033
100	.95	.90	.85	.79	.74	.69	.64	.59	.55	.50	.45	.41	.36	.31	.27	.22	.18	.13	.090	.045
110	1.27	1.20	1.14	1.07	1.00	.93	.86	.80	.73	.67	.60	.54	.48	.42	.36	.30	.24	.18	.120	.061
120	1.69	1.60	1.51	1.42	1.33	1.24	1.15	1.06	.97	.89	.80	.72	.64	.56	.48	.40	.32	.24	.160	.081
130	2.22	2.10	1.98	1.86	1.74	1.62	1.51	1.39	1.28	1.17	1.05	.95	.84	.74	.63	.53	.42	.32	.210	.100
140	2.89	2.73	2.57	2.42	2.26	2.11	1.96	1.81	1.66	1.52	1.37	1.23	1.10	.96	.82	.69	.55	.41	.270	.140
150	3.72	3.51	3.31	3.11	2.91	2.72	2.52	2.33	2.14	1.95	1.76	1.59	1.41	1.24	1.06	.88	.71	.53	.350	.180
160	4.74	4.48	4.22	3.97	3.71	3.46	3.22	2.97	2.73	2.49	2.25	2.02	1.80	1.58	1.35	1.12	.90	.67	.450	.220
170	5.99	5.66	5.34	5.02	4.70	4.38	4.07	3.75	3.45	3.15	2.84	2.56	2.28	1.99	1.71	1.42	1.13	1.85	.570	.300
180	7.51	7.10	6.69	6.30	5.89	5.49	5.10	4.71	4.33	3.94	3.57	3.21	2.85	2.50	2.14	1.77	1.42	1.06		
190	9.34	8.83	8.32	7.82	7.32	6.83	6.34	5.86	5.38	4.91	4.44	3.99	3.55	3.10	2.65					
200	11.53	10.90	10.27	9.65	9.04	8.43	7.83	7.23	6.64	6.06	5.48	4.93	4.38	3.81						
210	14.12	13.35	12.58	11.82	11.07	10.32	9.59	8.86	8.13	7.42	6.71	6.04	5.34							
220	17.19	16.25	15.32	14.39	13.48	12.57	11.67	10.78	9.90	9.03	8.17	7.31								
230	20.78	19.64	18.51	17.40	16.29	15.19	14.11	13.03	11.97	10.91	9.87									
240	24.97	23.60	22.25	20.91	19.58	18.26	16.95	15.66	14.38	13.12	11.86									
250	29.83	28.20	26.58	25.00	23.39	21.82	20.25	18.71	17.18	15.67										

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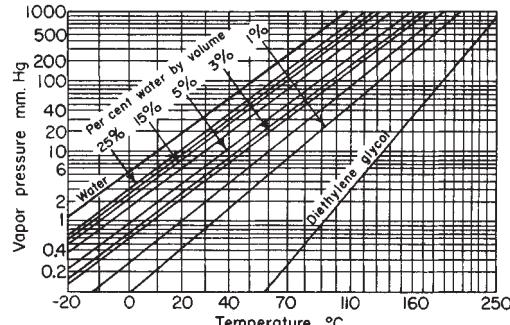


FIG. 2-3 Vapor pressure of aqueous diethylene glycol solutions. (Courtesy of Carbide and Carbon Chemicals Corp.)

TABLE 2-22 Mole Percentages of H₂O over Aqueous Solutions of NH₃*

t, °F	Molar concentration of ammonia in the solutions in percentages (Weight concentration of ammonia in the solutions in percentages)																				
	0 (0)	5 (4.74)	10 (9.50)	15 (14.29)	20 (19.10)	25 (23.94)	30 (28.81)	35 (33.71)	40 (38.64)	45 (43.59)	50 (48.57)	55 (53.58)	60 (58.62)	65 (63.69)	70 (68.79)	75 (73.91)	80 (79.07)	85 (84.26)	90 (89.47)	95 (94.72)	100 (100.00)
32	100	24.3	13.2	7.63	4.43	2.50	1.43	0.856	0.514	0.335	0.216	0.151	0.109	0.0816	0.0585	0.0457	0.0345	0.0249	0.0146	0.00689	0.00
40	100	25.3	14.1	8.15	4.73	2.74	1.59	.943	.581	.372	.248	.172	.124	.0914	.0706	.0533	.0395	.0243	.0185	.00879	
50	100	26.6	15.2	9.09	5.24	3.03	1.78	1.060	.652	.434	.290	.202	.148	.1095	.0838	.0630	.0477	.0332	.0215	.00959	
60	100	27.9	16.2	9.50	5.69	3.42	1.97	1.210	.777	.481	.331	.238	.172	.1290	.0986	.0754	.0566	.0406	.0251	.01125	
70	100	29.1	17.4	10.30	6.14	3.65	2.27	1.390	.873	.569	.383	.266	.205	.1510	.112	.0882	.0656	.0474	.0296	.0135	
80	100	31.6	18.5	11.20	6.89	4.08	2.45	1.550	.978	.659	.444	.323	.230	.1750	.130	.103	.0772	.0528	.0351	.0167	
90	100	32.7	20.0	12.00	7.40	4.47	2.73	1.730	1.100	.742	.505	.366	.267	.2020	.157	.115	.0884	.0647	.0408	.0194	
100	100	34.4	21.0	12.90	7.92	4.85	3.00	1.890	1.250	.834	.574	.420	.307	.2290	.179	.135	.104	.0714	.0473	.0226	
110	100	35.9	22.2	13.80	8.59	5.29	3.30	2.110	1.370	.932	.644	.466	.347	.2640	.208	.157	.118	.0846	.0540	.0262	
120	100	37.5	23.4	14.70	9.22	5.75	3.63	2.320	1.520	1.044	.714	.529	.395	.3020	.233	.180	.135	.0970	.0619	.0300	
130	100	39.0	24.5	15.60	9.85	6.18	3.95	2.550	1.690	1.160	.811	.596	.444	.3430	.263	.205	.154	.1117	.0703	.0339	
140	100	40.7	25.8	16.50	10.50	6.69	4.28	2.790	1.860	1.286	.906	.663	.501	.3540	.297	.232	.175	.124	.0786	.0385	
150	100	42.3	27.1	17.50	11.20	7.19	4.63	3.080	2.040	1.410	1.004	.741	.558	.4320	.334	.257	.197	.140	.0892	.0439	
160	100	44.1	28.3	18.40	11.90	7.69	5.01	3.300	2.230	1.550	1.110	.818	.617	.4800	.372	.287	.218	.154	.1005	.0499	
170	100	45.6	29.6	19.40	12.70	8.22	5.38	3.580	2.430	1.700	1.220	.904	.689	.5300	.414	.320	.242	.174	.112	.0567	
180	100	47.3	30.9	20.40	13.40	8.76	5.78	3.870	2.640	1.850	1.340	.994	.756	.5860	.456	.352	.268	.192			
190	100	48.7	32.2	21.40	14.10	9.31	6.18	4.160	2.860	2.020	1.460	1.087	.830	.6420	.501						
200	100	50.4	33.4	22.30	14.90	9.88	6.59	4.470	3.080	2.190	1.580	1.187	.907	.7010							
210	100	52.1	34.7	23.40	15.70	10.45	7.03	4.780	3.310	2.360	1.720	1.272	.983								
220	100	53.7	36.1	24.40	16.40	11.05	7.48	5.100	3.560	2.540	1.860	1.390									
230	100	55.2	37.3	25.40	17.30	11.63	7.91	5.440	3.810	2.730	2.000										
240	100	56.8	38.6	26.50	18.00	12.24	8.36	5.780	4.060	2.920	2.150										
250	100	58.4	39.8	27.50	18.80	12.88	8.82	6.120	4.340	3.120											

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TABLE 2-23 Partial Pressures of NH₃ over Aqueous Solutions of NH₃*
 Pressures are in pounds per square inch absolute

t, °F (4.74)	Molal concentration of ammonia in the solutions in percentages (Weight concentration of ammonia in the solutions in percentages)																		
	5 (9.50)	10 (14.29)	15 (19.10)	20 (23.94)	25 (28.81)	30 (33.71)	35 (38.64)	40 (43.59)	45 (48.57)	50 (53.58)	55 (58.62)	60 (63.69)	65 (68.79)	70 (73.91)	75 (79.07)	80 (84.26)	85 (89.47)	90 (94.72)	
32	0.26	0.52	0.90	1.51	2.67	4.27	6.54	8.93	14.13	19.36	25.12	31.13	36.74	42.69	45.92	49.26	52.13	54.89	58.01
40	.33	.66	1.14	1.92	3.16	5.13	7.98	11.98	17.14	23.33	30.15	37.15	43.69	49.56	54.40	58.31	61.62	64.77	68.31
50	.47	.89	1.50	2.53	4.16	6.63	10.24	15.24	21.56	29.17	37.46	45.86	53.79	60.82	66.63	71.26	75.22	79.05	83.40
60	.62	1.19	2.00	3.21	5.36	8.48	13.06	19.15	26.92	36.14	46.12	56.22	65.81	73.99	80.90	86.44	91.04	95.67	100.65
70	.83	1.52	2.60	4.28	6.87	10.76	16.33	23.84	33.20	44.25	56.29	68.32	79.42	89.26	97.42	104.01	109.55	114.83	120.61
80	1.04	1.98	3.34	5.45	8.69	13.52	20.29	29.40	40.69	53.84	67.97	82.36	95.52	107.06	116.42	124.20	130.57	136.35	143.70
90	1.36	2.52	4.25	6.88	10.89	16.76	25.04	35.94	49.45	64.99	81.61	98.35	113.79	127.22	138.18	147.02	154.46	161.74	169.73
100	1.72	3.20	5.34	8.60	13.53	20.68	30.57	43.57	59.49	77.85	97.27	116.81	134.70	150.23	162.94	173.22	181.97	190.13	199.17
110	2.14	4.00	6.65	10.64	16.65	25.21	37.01	52.43	71.20	92.59	115.16	137.62	158.42	176.18	190.85	203.02	212.71	222.22	232.79
120	2.67	4.95	8.21	13.09	20.30	30.54	44.56	62.62	84.44	109.40	135.48	161.44	185.14	205.81	222.28	236.05	247.14	258.24	270.02
130	3.28	6.09	10.05	15.93	24.58	36.74	53.16	74.27	99.69	128.45	158.45	188.16	215.14	238.70	257.87	272.88	286.08	298.46	311.80
140	3.97	7.41	12.21	19.23	29.43	43.77	62.97	87.53	116.72	149.93	184.17	218.18	248.70	275.33	297.12	314.45	328.99	342.93	358.46
150	4.78	8.92	14.70	23.09	35.09	51.91	74.28	102.51	136.15	173.64	212.91	251.24	286.00	316.24	340.82	360.39	376.57	392.45	409.62
160	5.68	10.70	17.57	27.45	41.56	61.03	86.91	119.37	157.71	200.45	244.98	288.38	327.82	361.75	389.08	411.30	429.73	447.35	466.38
170	6.75	12.67	20.85	32.41	48.89	71.48	101.09	138.30	181.95	230.36	280.54	329.42	373.61	411.59	442.28	466.67	487.85	507.63	528.50
180	7.90	14.96	24.56	38.13	57.19	83.07	116.97	159.37	208.66	263.43	319.89	374.25	424.10	466.26	500.63	528.08	551.24		
190	9.23	17.55	28.78	44.49	66.49	96.22	134.89	182.72	238.39	299.86	363.11	424.15	479.40						
200	10.70	20.45	33.49	51.58	76.90	110.85	154.58	208.56	270.94	340.02	410.17	478.62	539.79						
210	12.26	23.68	38.76	59.65	88.48	126.83	176.24	236.97	307.08	383.99	462.36	537.56							
220	14.02	27.15	44.61	68.43	101.24	144.74	200.46	268.30	346.07	431.43	518.19								
230	15.95	31.09	51.06	78.14	115.45	164.17	226.67	302.53	389.29	483.53									
240	17.92	35.40	58.00	89.02	130.94	185.79	255.26	339.72	435.78	540.44									
250	20.12	40.09	65.74	100.69	147.66	209.37	286.89	380.42	486.73										

*Wilson, *Univ. Ill., Eng. Expt. Sta. Bull.* 146.

TABLE 2-24 Total Vapor Pressures of Aqueous Solutions of NH₃*

Pressures are in pounds per square inch absolute

t, °F	Molal concentration of ammonia in the solutions in percentages (Weight concentration of ammonia in the solutions in percentages)																				
	0 (0)	5 (4.74)	10 (9.50)	15 (14.29)	20 (19.10)	25 (23.94)	30 (28.81)	35 (33.71)	40 (38.64)	45 (43.59)	50 (48.57)	55 (53.58)	60 (58.62)	65 (63.69)	70 (68.79)	75 (73.91)	80 (79.07)	85 (84.26)	90 (89.47)	95 (94.72)	100 (100.00)
32	0.09	0.34	0.60	0.97	1.58	2.60	4.20	6.54	9.93	14.18	19.40	25.16	31.16	36.77	42.72	45.94	49.28	52.14	54.90	58.01	62.29
40	.12	.45	.77	1.24	2.01	3.25	5.21	8.06	12.05	17.20	23.39	30.20	37.20	43.73	49.60	54.43	58.33	61.64	64.78	68.32	73.32
50	.18	.64	1.05	1.65	2.67	4.29	6.75	10.35	15.34	21.65	29.26	37.54	45.93	53.85	60.87	66.67	71.29	75.25	79.07	83.41	89.19
60	.26	.86	1.42	2.21	3.51	5.55	8.65	13.22	19.30	27.05	36.26	46.23	56.32	65.90	74.06	80.96	86.49	91.08	95.69	100.66	107.6
70	.36	1.17	1.84	2.90	4.56	7.13	11.01	16.56	24.05	33.39	44.42	56.44	68.46	79.54	89.36	97.51	104.08	109.60	114.86	120.63	128.8
80	.51	1.52	2.43	3.76	5.85	9.06	13.86	20.61	29.69	40.96	54.08	68.19	82.55	95.69	107.20	116.54	124.30	130.64	136.40	143.72	153.0
90	.70	2.02	3.15	4.83	7.43	11.40	17.23	25.48	36.34	49.82	65.32	81.91	98.61	114.02	127.42	138.34	147.15	154.56	161.81	169.76	180.6
100	.95	2.62	4.05	6.13	9.34	14.22	21.32	31.16	44.12	59.99	78.30	97.68	117.17	135.01	150.50	163.16	173.40	182.10	190.22	199.22	211.9
110	1.27	3.34	5.14	7.72	11.64	17.58	26.07	37.81	53.16	71.87	93.19	115.7	138.10	158.84	176.54	191.15	203.26	212.89	222.34	232.85	247.0
120	1.69	4.27	6.46	9.63	14.42	21.54	31.69	45.62	63.59	85.33	110.2	136.2	162.08	185.70	206.29	222.68	236.37	247.38	258.40	270.1	286.4
130	2.22	5.38	8.07	11.91	17.67	26.20	38.25	54.55	75.55	100.86	129.5	159.0	189.00	215.88	239.33	258.40	273.3	286.4	298.67	311.9	330.3
140	2.89	6.70	9.98	14.63	21.49	31.54	45.73	64.78	89.19	118.24	151.3	185.4	219.28	249.66	276.15	297.81	315.0	329.4	343.2	358.6	379.1
150	3.72	8.29	12.23	17.81	26.00	37.81	54.43	76.61	104.65	138.1	175.4	214.5	252.65	287.24	317.3	341.7	361.1	377.1	392.8	409.8	432.2
160	4.74	10.16	14.92	21.54	31.16	45.02	64.25	89.88	122.10	160.2	202.7	247.0	290.18	329.4	363.1	390.2	412.2	430.4	447.8	466.6	492.8
170	5.99	12.41	18.01	25.87	37.11	53.27	75.55	104.84	141.75	185.1	233.2	283.1	331.7	375.6	413.3	443.7	467.8	488.7	508.2	528.8	558.4
180	7.51	15.00	21.65	30.86	44.02	62.68	88.17	121.68	163.7	212.6	267.0	323.1	377.1	426.6	468.4	502.4	529.5	552.3			
190	9.34	18.06	25.87	36.60	51.81	73.32	102.56	140.75	188.1	243.3	304.3	367.1	427.7	482.5	528.8						
200	11.53	21.60	30.72	43.14	60.62	85.33	118.68	161.81	215.2	277.0	345.5	415.1	483.0	543.6							
210	14.12	25.61	36.26	50.58	70.72	98.80	136.42	185.10	245.1	314.5	390.7	468.4	542.9								
220	17.19	30.27	42.47	59.00	81.91	113.81	156.41	211.24	278.2	355.1	439.6	525.5									
230	20.78	35.59	49.60	68.46	94.43	130.64	178.28	239.70	314.5	400.2	493.4										
240	24.97	41.52	57.65	78.91	108.60	149.20	202.74	270.92	354.1	448.9	552.3										
250	29.83	48.32	66.67	90.74	124.08	169.48	229.62	305.60	397.6	502.4											

*Wilson, *Univ. Ill. Eng. Expt. Sta. Bull.* 146.

TABLE 2-25 Partial Pressures of H₂O over Aqueous Solutions of Sodium Carbonate

t, °C	%Na ₂ CO ₃						
	0	5	10	15	20	25	30
0	4.5	4.5					
10	9.2	9.0	8.8				
20	17.5	17.2	16.8	16.3			
30	31.8	31.2	30.4	29.6	28.8	27.8	26.4
40	55.3	54.2	53.0	57.6	50.2	48.4	46.1
50	92.5	90.7	88.7	86.5	84.1	81.2	77.5
60	149.5	146.5	143.5	139.9	136.1	131.6	125.7
70	239.8	235	230.5	225	219	211.5	202.5
80	355.5	348	342	334	325	315	301
90	526.0	516	506	494	482	467	447
100	760.0	746	731	715	697	676	648

TABLE 2-26 Partial Pressures of H₂O and CH₃OH over Aqueous Solutions of Methyl Alcohol*

Mole fraction CH ₃ OH	39.9°C		Mole fraction CH ₃ OH	59.4°C	
	P _{H₂O} , mmHg	P _{CH₃OH} , mmHg		P _{H₂O} , mmHg	P _{CH₃OH} , mmHg
0	54.7	0	0	145.4	0
14.99	39.2	66.1	22.17	106.9	210.1
17.85	38.5	75.5	27.40	102.2	240.2
21.07	37.2	85.2	33.24	96.6	272.1
27.31	35.8	100.6	39.80	91.7	301.9
31.06	34.9	108.8	47.08	84.8	335.6
40.1	32.8	127.7	55.5	76.9	373.7
47.0	31.5	141.6	69.2	57.8	439.4
55.8	27.3	158.4	78.5	43.8	486.6
68.9	20.7	186.6	85.9	30.1	526.9
86.0	10.1	225.2	100.0	0	609.3
100.0	0	260.7			

⁹International Critical Tables, vol. 3, McGraw-Hill, p. 290.

TABLE 2-27 Partial Pressures of H₂O over Aqueous Solutions of Sodium Hydroxide

WATER-VAPOR CONTENT OF GASES

CHART FOR GASES AT HIGH PRESSURES

The accompanying figure is useful in determining the water-vapor content of air at high pressure in contact with liquid water.

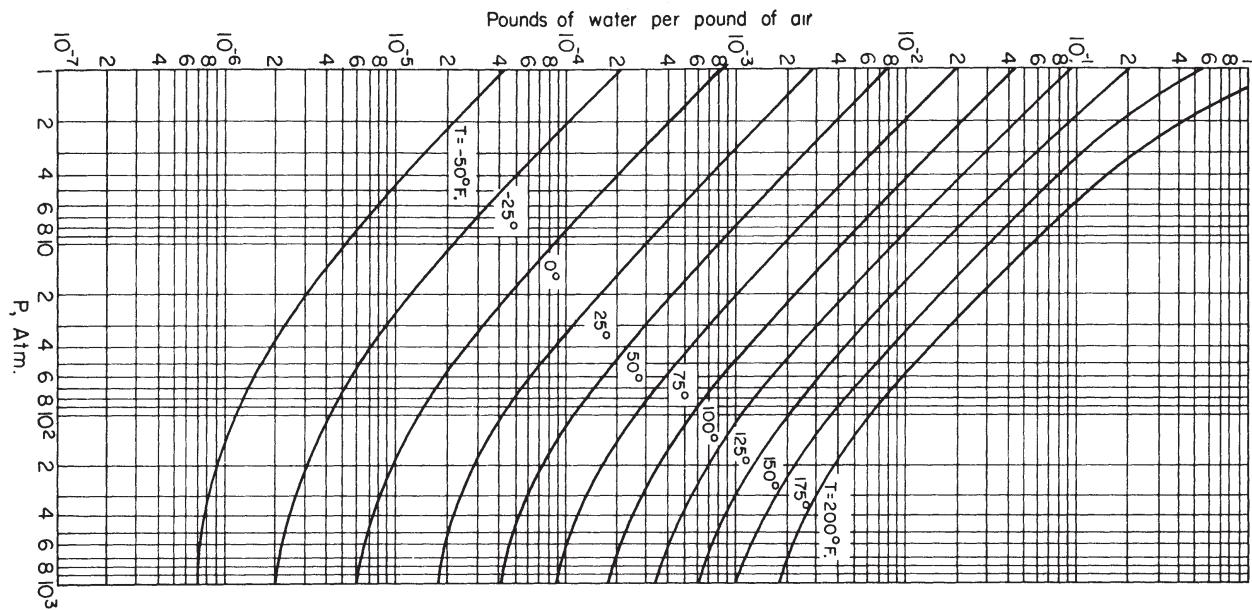


FIG. 2-4 Water content of air, ${}^{\circ}\text{C} = ({}^{\circ}\text{F} - 32) \times \frac{5}{9}$. (*Landsbaum, Dadds, and Stutzman*. Reprinted from vol. 47, January 1955 issue of Ind. Eng. Chem. [p. 192]. Copyright 1955 by the American Chemical Society and reproduced by permission of the copyright owner.)

DENSITIES OF PURE SUBSTANCES

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$^{\circ}\text{F} = \% ^{\circ}\text{C} + 32.$$

To convert kilograms per cubic meter to pounds per cubic foot, multiply by 0.06243.

TABLE 2-28 Density (kg/m^3) of Water from 0 to 100°C*

$t, ^{\circ}\text{C}$	$\rho, \text{kg}/\text{m}^3$									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	999.839	999.846	999.852	999.859	999.865	999.871	999.877	999.882	999.888	999.893
1	999.898	999.903	999.908	999.913	999.917	999.921	999.925	999.929	999.933	999.936
2	999.940	999.943	999.946	999.949	999.952	999.954	999.956	999.959	999.961	999.962
3	999.964	999.966	999.967	999.968	999.969	999.970	999.971	999.972	999.972	999.972
4	999.972	999.972	999.972	999.971	999.971	999.970	999.969	999.968	999.967	999.965
5	999.964	999.962	999.960	999.958	999.956	999.954	999.951	999.949	999.946	999.943
6	999.940	999.937	999.934	999.930	999.926	999.923	999.919	999.915	999.910	999.906
7	999.901	999.897	999.892	999.887	999.882	999.877	999.871	999.866	999.860	999.854
8	999.848	999.842	999.836	999.829	999.823	999.816	999.809	999.802	999.795	999.788
9	999.781	999.773	999.765	999.758	999.750	999.742	999.734	999.725	999.717	999.708
10	999.699	999.691	999.682	999.672	999.663	999.654	999.644	999.635	999.625	999.615
11	999.605	999.595	999.584	999.574	999.563	999.553	999.542	999.531	999.520	999.509
12	999.497	999.486	999.474	999.462	999.451	999.439	999.426	999.414	999.402	999.389
13	999.377	999.364	999.351	999.338	999.325	999.312	999.299	999.285	999.272	999.258
14	999.244	999.230	999.216	999.202	999.188	999.173	999.159	999.144	999.129	999.114
15	999.099	999.084	999.069	999.054	999.038	999.022	999.007	998.991	998.975	998.958
16	998.943	998.926	998.910	998.894	998.877	998.860	998.843	998.826	998.809	998.792
17	998.775	998.757	998.740	998.722	998.704	998.686	998.668	998.650	998.632	998.614
18	998.595	998.577	998.558	998.539	998.520	998.502	998.482	998.463	998.444	998.425
19	998.405	998.385	998.366	998.346	998.326	998.306	998.286	998.265	998.245	998.224
20	998.204	998.183	998.162	998.141	998.120	998.099	998.078	998.057	998.035	998.014
21	997.992	997.971	997.949	997.927	997.905	997.883	997.860	997.838	997.816	997.793
22	997.770	997.747	997.725	997.702	997.679	997.656	997.632	997.609	997.585	997.562
23	997.538	997.515	997.491	997.467	997.443	997.419	997.394	997.370	997.345	997.321
24	997.296	997.272	997.247	997.222	997.197	997.172	997.146	997.121	997.096	997.070
25	997.045	997.019	996.993	996.967	996.941	996.915	996.889	996.863	996.836	996.810
26	996.783	996.757	996.730	996.703	996.676	996.649	996.622	996.595	996.568	996.540
27	996.513	996.485	996.458	996.430	996.402	996.374	996.346	996.318	996.290	996.262
28	996.233	996.205	996.176	996.148	996.119	996.090	996.061	996.032	996.003	995.974
29	995.945	995.915	995.886	995.856	995.827	995.797	995.767	995.737	995.707	995.677
30	995.647	995.617	995.586	995.556	995.526	995.495	995.464	995.433	995.403	995.372
31	995.341	995.310	995.278	995.247	995.216	995.184	995.153	995.121	995.090	995.058
32	995.026	994.997	994.962	994.930	994.898	994.865	994.833	994.801	994.768	994.735
33	994.703	994.670	994.637	994.604	994.571	994.538	994.505	994.472	994.438	994.405
34	994.371	994.338	994.304	994.270	994.236	994.202	994.168	994.134	994.100	994.066
35	994.032	993.997	993.963	993.928	993.893	993.859	993.824	993.789	993.754	993.719
36	993.684	993.648	993.613	993.578	993.543	993.507	993.471	993.436	993.400	993.364
37	993.328	993.292	993.256	993.220	993.184	993.148	993.111	993.075	993.038	993.002
38	992.965	992.928	992.891	992.855	992.818	992.780	992.743	992.706	992.669	992.631
39	992.594	992.557	992.519	992.481	992.444	992.406	992.368	992.330	992.292	992.254
40	992.215	992.177	992.139	992.100	992.062	992.023	991.985	991.946	991.907	992.868
41	991.830	991.791	991.751	991.712	992.673	991.634	991.594	991.555	991.515	991.476
42	991.436	991.396	991.357	991.317	991.277	991.237	991.197	991.157	991.116	991.076
43	991.036	990.995	990.955	990.914	990.873	990.833	990.792	990.751	990.710	990.669
44	990.628	990.587	990.546	990.504	990.463	990.421	990.380	990.338	990.297	990.255
45	990.213	990.171	990.129	990.087	990.045	990.003	989.961	989.919	989.876	989.834
46	989.792	989.749	989.706	989.664	989.621	989.578	989.535	989.492	989.449	989.406
47	989.363	989.320	989.276	989.233	989.190	989.146	989.103	989.059	989.015	988.971
48	988.928	988.884	988.840	988.796	988.752	988.707	988.663	988.619	988.574	988.530
49	988.485	988.441	988.396	988.352	988.307	988.262	988.217	988.172	988.127	988.082

*From "Water: Density at Atmospheric Pressure and Temperatures from 0 to 100°C," *Tables of Standard Handbook Data*, Standartov, Moscow, 1978. To conserve space, only a few tables of density values are given. The reader is reminded that density values may be found as the reciprocal of the specific volume values tabulated in the "Thermodynamic Properties: Tables" subsection.

2-92 PHYSICAL AND CHEMICAL DATA

TABLE 2-28 Density (kg/m^3) of Water from 0 to 100°C (Concluded)

TABLE 2-29 Density (kg/m^3) of Mercury from 0 to 350°C*

t °C	Density, kg/m^3									
	0	1	2	3	4	5	6	7	8	9
0	13595.08	13592.61	13590.14	13587.68	13585.21	13582.75	13580.29	13577.82	13575.36	13572.90
10	13570.44	13567.98	13565.52	13563.06	13560.60	13558.14	13555.69	13553.23	13550.78	13548.32
20	13545.87	13543.41	13540.96	13538.51	13536.06	13533.61	13531.16	13528.71	13526.26	13523.81
30	13521.36	13518.91	13516.47	13514.02	13511.58	13509.13	13506.69	13504.25	13501.80	13499.36
40	13496.92	13494.48	13492.04	13489.60	13487.16	13484.72	13482.29	13479.85	13477.41	13474.98
50	13472.54	13470.11	13467.67	13465.24	13462.81	13460.38	13457.94	13455.51	13453.08	13450.65
60	13448.22	13445.80	13443.37	13440.94	13438.51	13436.09	13433.66	13431.23	13428.81	13426.39
70	13423.96	13421.54	13419.12	13416.69	13414.27	13411.85	13409.43	13407.01	13404.59	13402.17
80	13399.75	13397.34	13394.92	13392.50	13390.08	13387.67	13385.25	13382.84	13380.42	13378.01
90	13375.59	13373.18	13370.77	13368.36	13365.94	13363.53	13361.12	13358.71	13356.30	13353.89
100	13351.5	13349.1	13346.7	13344.3	13341.9	13339.4	13337.0	13334.6	13332.2	13329.8
110	13327.4	13325.0	13322.6	13320.2	13317.8	13315.4	13313.0	13310.6	13308.2	13305.8
120	13303.4	13301.0	13298.6	13296.2	13293.8	13291.4	13288.9	13286.6	13284.2	13281.8
130	13279.4	13277.0	13274.6	13272.2	13269.8	13267.4	13265.0	13262.6	13260.2	13257.8
140	13255.4	13253.0	13250.6	13248.2	13245.8	13243.4	13241.0	13238.7	13236.3	13233.9
150	13231.5	13229.1	13226.7	13224.3	13221.9	13219.5	13217.1	13214.7	13212.4	13210.0
160	13207.6	13205.2	13202.8	13200.4	13198.0	13195.6	13193.2	13190.8	13188.5	13186.1
170	13183.7	13181.3	13178.9	13176.5	13174.1	13171.7	13169.4	13167.0	13164.6	13162.2
180	13159.8	13157.4	13155.0	13152.6	13150.3	13147.9	13145.5	13143.1	13140.7	13138.3
190	13136.0	13133.6	13131.2	13128.3	13126.4	13124.0	13121.7	13119.3	13116.9	13114.5
200	13112.1	13109.7	13107.4	13105.0	13102.6	13100.2	13097.8	13095.4	13093.1	13090.7
210	13088.3	13085.9	13083.5	13081.1	13078.8	13076.4	13074.0	13071.6	13069.2	13066.8
220	13064.5	13062.1	13059.7	13057.3	13054.9	13052.6	13050.2	13047.8	13045.4	13043.0
230	13040.6	13038.3	13035.9	13033.5	13031.1	13028.7	13026.4	13024.0	13021.6	13019.2
240	13016.8	13014.5	13012.1	13009.7	13007.3	13004.9	13002.5	13000.2	12997.8	12995.4
250	12993.0	12990.6	12988.3	12985.9	12983.5	12981.1	12978.7	12976.3	12974.0	12971.6
260	12969.2	12966.8	12964.4	12962.0	12959.7	12957.3	12954.9	12952.5	12950.1	12947.7
270	12945.4	12943.0	12940.6	12938.2	12935.8	12933.4	12931.1	12928.7	12926.3	12923.9
280	12921.5	12919.1	12916.7	12914.4	12912.0	12909.6	12907.2	12904.8	12902.4	12900.0
290	12897.7	12895.3	12892.9	12890.5	12888.1	12885.7	12883.3	12880.9	12878.5	12876.2
300	12873.8	12871.4	12869.0	12866.6	12864.2	12861.8	12859.4	12857.0	12854.6	12852.2
310	12849.9	12847.5	12845.1	12842.7	12840.3	12837.9	12835.5	12833.1	12830.7	12828.3
320	12825.9	12823.5	12821.1	12818.7	12816.3	12813.9	12811.5	12809.1	12806.7	12804.3
330	12801.9	12799.5	12797.1	12794.7	12792.3	12789.9	12787.5	12785.1	12782.7	12780.2
340	12777.8	12775.4	12773.0	12770.6	12768.2	12765.8	12763.4	12761.0	12758.6	12756.1
350	12753.7									

*From "Mercury—Density and Thermal Expansion at Atmospheric Pressure and Temperatures from 0 to 350°C," *Tables of Standard Handbook Data*, Standartov, Moscow, 1978. The density values obtainable from those cited for the specific volume of the saturated liquid in the "Thermodynamic Properties" subsection show minor differences. No attempt was made to adjust either set.

TABLE 2-30 Densities of Inorganic and Organic Liquids

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T _{min} , K	Density at T _{min}	T _{max} , K	Density at T _{max}
1	Methane	CH ₄	74828	16.043	2.9214	0.28976	190.56	0.28881	90.69	28.18	190.56	10.082
2	Ethane	C ₂ H ₆	74840	30.070	1.9122	0.27937	305.32	0.29187	90.35	21.64	305.32	6.845
3	Propane	C ₃ H ₈	74986	44.097	1.3757	0.27453	369.83	0.29359	85.47	16.583	369.83	5.011
4	<i>n</i> -Butane	C ₄ H ₁₀	106978	58.123	1.0677	0.27188	425.12	0.28688	134.86	12.62	425.12	3.927
5	<i>n</i> -Pentane	C ₅ H ₁₂	109660	72.150	0.84947	0.26726	469.7	0.27789	143.42	10.474	469.7	3.178
6	<i>n</i> -Hexane	C ₆ H ₁₄	110543	86.177	0.70824	0.26411	507.6	0.27537	177.83	8.747	507.6	2.682
7	<i>n</i> -Heptane	C ₇ H ₁₆	142825	100.204	0.61259	0.26211	540.2	0.28141	182.57	7.6998	540.2	2.337
8	<i>n</i> -Octane	C ₈ H ₁₈	111659	114.231	0.53731	0.26115	568.7	0.28034	216.38	6.6558	568.7	2.058
9	<i>n</i> -Nonane	C ₉ H ₂₀	111842	128.258	0.48387	0.26147	594.6	0.28281	219.66	6.007	594.6	1.851
10	<i>n</i> -Decane	C ₁₀ H ₂₂	124185	142.285	0.42831	0.25745	617.7	0.28912	243.51	5.3811	617.7	1.664
11	<i>n</i> -Undecane	C ₁₁ H ₂₄	1120214	156.312	0.39	0.25678	639	0.2913	247.57	4.9362	639	1.519
12	<i>n</i> -Dodecane	C ₁₂ H ₂₆	112403	170.338	0.35541	0.25511	658	0.29368	263.57	4.5132	658	1.393
13	<i>n</i> -Tridecane	C ₁₃ H ₂₈	629505	184.365	0.3216	0.2504	675	0.3071	267.76	4.2035	675	1.284
14	<i>n</i> -Tetradecane	C ₁₄ H ₃₀	629594	198.392	0.30545	0.2535	693	0.30538	279.01	3.8924	693	1.205
15	<i>n</i> -Pentadecane	C ₁₅ H ₃₂	629629	212.419	0.28445	0.25269	708	0.30786	283.07	3.6471	708	1.126
16	<i>n</i> -Hexadecane	C ₁₆ H ₃₄	544763	226.446	0.26807	0.25287	723	0.31143	291.31	3.4187	723	1.060
17	<i>n</i> -Heptadecane	C ₁₇ H ₃₆	629787	240.473	0.2545	0.254	736	0.31072	295.13	3.2241	736	1.002
18	<i>n</i> -Octadecane	C ₁₈ H ₃₈	593453	254.500	0.23864	0.25272	747	0.31104	301.31	3.0466	747	0.944
19	<i>n</i> -Nonadecane	C ₁₉ H ₄₀	629925	268.527	0.22451	0.25133	758	0.3133	305.04	2.8933	758	0.893
20	<i>n</i> -Eicosane	C ₂₀ H ₄₂	112958	282.553	0.21624	0.25287	768	0.31613	309.58	2.7496	768	0.855
21	2-Methylpropane	C ₄ H ₁₀	75285	58.123	1.0463	0.27294	408.14	0.27301	113.54	12.575	408.14	3.833
22	2-Methylbutane	C ₅ H ₁₂	78784	72.150	0.9079	0.2761	460.43	0.28673	113.25	10.776	460.43	3.288
23	2,3-Dimethylbutane	C ₆ H ₁₄	79298	86.177	0.76929	0.27524	499.98	0.27691	145.19	9.0343	499.98	2.795
24	2-Methylpentane	C ₆ H ₁₄	107835	86.177	0.73335	0.2687	497.5	0.28361	119.55	9.2041	497.5	2.729
25	2,3-Dimethylpentane	C ₇ H ₁₆	565593	100.204	0.7229	0.28614	537.35	0.2713	160.00	7.8746	537.35	2.526
26	2,3,3-Trimethylpentane	C ₈ H ₁₈	560214	114.231	0.6028	0.27446	573.5	0.2741	172.22	7.0934	573.5	2.196
27	2,2,4-Trimethylpentane	C ₈ H ₁₈	540841	114.231	0.5886	0.27373	543.96	0.2846	165.78	6.9163	543.96	2.150
28	Ethylene	C ₂ H ₄	74851	28.054	2.0961	0.27657	282.34	0.29147	104.00	23.326	282.34	7.579
29	Propylene	C ₃ H ₆	115071	42.081	1.4094	0.26465	365.57	0.295	87.89	18.143	365.57	5.326
30	1-Butene	C ₄ H ₈	106989	56.108	1.0972	0.2649	419.95	0.29043	87.80	14.326	419.95	4.142
31	<i>cis</i> -2-Butene	C ₄ H ₈	590181	56.108	1.1609	0.27104	435.58	0.2816	134.26	13.895	435.58	4.283
32	<i>trans</i> -2-Butene	C ₄ H ₈	624646	56.108	1.1426	0.27095	428.63	0.2854	167.62	13.1	428.63	4.217
33	1-Pentene	C ₅ H ₁₀	109671	70.134	0.9038	0.26648	464.78	0.2905	107.93	11.543	464.78	3.392
34	1-Hexene	C ₆ H ₁₂	592416	84.161	0.7389	0.26147	504.03	0.2902	133.39	9.6388	504.03	2.826
35	1-Heptene	C ₇ H ₁₄	592767	98.188	0.63734	0.26319	537.29	0.27375	154.27	8.1759	537.29	2.422
36	1-Octene	C ₈ H ₁₆	111660	112.215	0.5871	0.27005	566.65	0.27187	171.45	7.1247	566.65	2.174
37	1-Nonene	C ₉ H ₁₈	124118	126.242	0.4945	0.26108	593.25	0.27319	191.78	6.333	593.25	1.894
38	1-Decene	C ₁₀ H ₂₀	872059	140.269	0.44244	0.25838	616.4	0.28411	206.89	5.7131	616.4	1.712
39	2-Methylpropene	C ₄ H ₈	115117	56.108	1.1454	0.2725	417.9	0.28186	132.81	13.506	417.9	4.203
40	2-Methyl-1-butene	C ₅ H ₁₀	563462	70.134	0.91619	0.26752	465	0.28164	135.58	11.332	465	3.425
41	2-Methyl-2-butene	C ₅ H ₁₀	513359	70.134	0.93322	0.27251	471	0.26031	139.39	11.218	471	3.425
42	1,2-Butadiene	C ₄ H ₆	590192	54.092	1.187	0.26114	452	0.3065	136.95	15.123	452	4.546
43	1,3-Butadiene	C ₄ H ₆	106990	54.092	1.2384	0.2725	425.17	0.28813	164.25	14.061	425.17	4.545
44	2-Methyl-1,3-butadiene ¹	C ₅ H ₈	78795	68.119	0.95673	0.26488	484	0.28571	127.27	12.205	484	3.612
45	Acetylene	C ₂ H ₂	74862	26.038	2.4091	0.27223	308.32	0.28477	192.40	23.692	308.32	8.850
46	Methylacetylene	C ₃ H ₄	74997	40.065	1.6056	0.26448	402.39	0.279	170.45	19.027	402.39	6.082
47	Dimethylacetylene	C ₄ H ₆	503173	54.092	1.1717	0.25895	473.2	0.27289	240.91	13.767	473.2	4.525
48	3-Methyl-1-butyne	C ₅ H ₈	598232	68.119	0.94575	0.26008	463.2	0.30807	183.45	11.519	463.2	3.636
49	1-Pentyne	C ₅ H ₈	627190	68.119	0.8491	0.2352	481.2	0.353	167.45	12.532	481.2	3.610
50	2-Pentyne	C ₅ H ₈	627214	68.119	0.92099	0.25419	519	0.31077	163.83	12.24	519	3.623
51	1-Hexyne	C ₆ H ₁₀	693027	82.145	0.84427	0.27185	516.2	0.2771	141.25	10.23	516.2	3.106
52	2-Hexyne	C ₆ H ₁₀	764352	82.145	0.76277	0.25248	549	0.31611	183.65	10.133	549	3.021
53	3-Hexyne ¹	C ₆ H ₁₀	928494	82.145	0.78045	0.26065	544	0.28571	170.05	10.021	544	2.994

54	1-Heptyne	C ₇ H ₁₂	628717	96.172	0.67366	0.26003	559	0.29804	192.22	8.4987	559	2.591
55	1-Octyne	C ₈ H ₁₄	629050	110.199	0.59229	0.26118	585	0.29357	193.55	7.478	585	2.268
56	Vinylacetylene ³	C ₄ H ₄	689974	52.076	1.2703	0.26041	454	0.297	173.15	15.664	454	4.878
57	Cyclopentane	C ₅ H ₁₀	287923	70.134	1.124	0.28559	511.76	0.2506	179.28	11.883	511.76	3.895
58	Methylcyclopentane	C ₆ H ₁₂	96377	84.161	0.84798	0.27042	532.79	0.28276	130.73	10.492	532.79	3.136
59	Ethylcyclopentane	C ₇ H ₁₄	1640897	98.188	0.7193	0.26936	569.52	0.2777	134.71	9.018	569.52	2.670
60	Cyclohexane	C ₆ H ₁₂	110827	84.161	0.8908	0.27396	553.58	0.2851	279.69	9.3797	553.58	3.252
61	Methylcyclohexane	C ₇ H ₁₄	108872	98.188	0.735	0.27041	572.19	0.2927	146.58	9.018	572.19	2.718
62	1,1-Dimethyl-cyclohexane	C ₈ H ₁₆	590669	112.215	0.55873	0.25143	591.15	0.27758	239.66	7.3417	591.15	2.222
63	Ethylcyclohexane	C ₈ H ₁₆	1678917	112.215	0.61587	0.26477	609.15	0.28054	161.84	7.8679	609.15	2.326
64	Cyclopentene	C ₅ H ₈	142290	68.119	1.1035	0.27035	507	0.28699	138.13	13.47	507	4.082
65	1-Methylcyclopentene	C ₆ H ₁₀	693890	82.145	0.88824	0.26914	542	0.27874	146.62	10.98	542	3.300
66	Cyclohexene	C ₆ H ₁₀	110838	82.145	0.92997	0.27056	560.4	0.28943	169.67	11.16	560.4	3.437
67	Benzene	C ₆ H ₆	71432	78.114	1.0162	0.2655	562.16	0.28212	278.68	11.421	562.16	3.828
68	Toluene	C ₇ H ₈	108883	92.141	0.8488	0.26655	591.8	0.2878	178.18	10.495	591.8	3.184
69	<i>o</i> -Xylene	C ₈ H ₁₀	95476	106.167	0.69883	0.26113	630.33	0.27429	247.98	8.6285	630.33	2.676
70	<i>m</i> -Xylene	C ₈ H ₁₀	108383	106.167	0.69555	0.26204	617.05	0.27602	225.30	8.6505	617.05	2.654
71	<i>p</i> -Xylene	C ₈ H ₁₀	106423	106.167	0.6816	0.25963	616.23	0.2768	286.41	8.1616	616.23	2.625
72	Ethylbenzene	C ₈ H ₁₀	100414	106.167	0.6952	0.26037	617.2	0.2844	178.15	9.0568	617.2	2.670
73	Propylbenzene	C ₉ H ₁₂	103651	120.194	0.57695	0.25395	638.32	0.283	183.15	7.8942	638.32	2.272
74	1,2,4-Trimethylbenzene	C ₉ H ₁₂	95636	120.194	0.60394	0.25955	649.13	0.27716	229.33	7.6895	649.13	2.327
75	Isopropylbenzene	C ₉ H ₁₂	98828	120.194	0.604	0.25912	631.1	0.2914	177.14	7.9496	631.1	2.331
76	1,3,5-Trimethylbenzene	C ₉ H ₁₂	108678	120.194	0.59879	0.25916	637.36	0.27968	228.42	7.6154	637.36	2.311
77	<i>p</i> -Isopropyltoluene	C ₁₀ H ₁₄	99876	134.221	0.51036	0.25383	653.15	0.28816	205.25	6.8779	653.15	2.011
78	Naphthalene ⁶	C ₁₀ H ₈	91203	128.174	0.61674	0.25473	748.35	0.27355	333.15	7.7543	748.35	2.421
79	Biphenyl	C ₁₂ H ₁₀	92524	154.211	0.5039	0.25273	789.26	0.281	342.20	6.4395	789.26	1.994
80	Styrene	C ₈ H ₈	100425	104.152	0.7397	0.2603	636	0.3009	242.54	9.1088	636	2.842
81	<i>m</i> -Terphenyl	C ₁₈ H ₁₄	92068	230.309	0.30826	0.23669	924.85	0.29678	360.00	4.5223	924.85	1.302
82	Methanol	CH ₄ O	67561	32.042	2.288	0.2685	512.64	0.2453	175.47	27.912	512.64	8.521
83	Ethanol	C ₂ H ₆ O	64175	46.069	1.648	0.27627	513.92	0.2331	159.05	19.413	513.92	5.965
84	1-Propanol	C ₃ H ₈ O	71238	60.096	1.235	0.27136	536.78	0.24	146.95	15.231	536.78	4.551
85	1-Butanol	C ₄ H ₁₀ O	71363	74.123	0.965	0.2666	563.05	0.24419	184.51	12.016	563.05	3.620
86	2-Butanol	C ₄ H ₁₀ O	78922	74.123	0.966	0.26064	536.05	0.2746	158.45	12.57	536.05	3.706
87	2-Propanol	C ₃ H ₈ O	67630	60.096	1.24	0.27342	508.3	0.2353	185.28	14.547	508.3	4.535
88	2-Methyl-2-propanol	C ₄ H ₁₀ O	75650	74.123	0.9212	0.2544	506.21	0.276	298.97	10.555	506.21	3.621
89	1-Pentanol	C ₅ H ₁₂ O	71410	88.150	0.8164	0.2673	586.15	0.2506	195.56	10.057	586.15	3.054
90	2-Methyl-1-butanol	C ₅ H ₁₂ O	137326	88.150	0.82046	0.26829	565	0.2322	203.00	10.017	565	3.058
91	3-Methyl-1-butanol	C ₅ H ₁₂ O	123513	88.150	0.837	0.27375	577.2	0.22951	155.95	10.204	577.2	3.058
92	1-Hexanol	C ₆ H ₁₄ O	11273	102.177	0.70617	0.26901	611.35	0.2479	228.55	8.4506	611.35	2.625
93	1-Heptanol	C ₇ H ₁₆ O	111706	116.203	0.60481	0.2632	631.9	0.273	239.15	7.421	631.9	2.298
94	Cyclohexanol	C ₆ H ₁₂ O	108930	100.161	0.8243	0.26546	650	0.2848	296.60	9.4693	650	3.105
95	Ethylene glycol	C ₂ H ₆ O ₂	107211	62.068	1.3151	0.25125	719.7	0.2187	260.15	18.31	719.7	5.234
96	1,2-Propylene glycol	C ₃ H ₈ O ₂	57556	76.095	1.0923	0.26106	626	0.20459	213.15	14.363	626	4.184
97	Phenol	C ₆ H ₆ O	108952	94.113	1.3798	0.31598	694.25	0.32768	314.06	11.244	694.25	4.367
98	<i>o</i> -Cresol	C ₇ H ₈ O	95487	108.140	1.0861	0.30624	697.55	0.30587	304.19	9.5751	697.55	3.547
99	<i>m</i> -Cresol	C ₇ H ₈ O	108394	108.140	0.9061	0.28268	705.85	0.2707	285.39	9.6115	705.85	3.205
100	<i>p</i> -Cresol	C ₇ H ₈ O	106445	108.140	1.1503	0.31861	704.65	0.30104	307.93	9.4494	704.65	3.610
101	Dimethyl ether	C ₂ H ₆ O	115106	46.069	1.5693	0.2679	400.1	0.2882	131.65	18.95	400.1	5.858
102	Methyl ethyl ether	C ₃ H ₈ O	540670	60.096	1.2635	0.27878	437.8	0.2744	160.00	13.995	437.8	4.532
103	Methyl- <i>n</i> -propyl ether	C ₄ H ₁₀ O	557175	74.123	1.0124	0.27942	476.3	0.2555	133.97	11.696	476.3	3.623
104	Methyl- <i>isopropyl</i> ether	C ₄ H ₁₀ O	598538	74.123	1.0318	0.28478	464.5	0.2444	127.93	11.568	464.5	3.623
105	Methyl- <i>n</i> -butyl ether	C ₅ H ₁₂ O	628284	88.150	0.8281	0.27245	510	0.2827	157.48	9.8068	510	3.040
106	Methyl isobutyl ether ¹	C ₅ H ₁₂ O	625445	88.150	0.8252	0.27282	497	0.2857	150.00	9.7673	497	3.025
107	Methyl tert-butyl ether	C ₅ H ₁₂ O	1634044	88.150	0.82157	0.27032	497.1	0.2829	164.55	9.7682	497.1	3.039
108	Diethyl ether	C ₄ H ₁₀ O	60297	74.123	0.9554	0.26847	466.7	0.2814	156.85	11.487	466.7	3.559

TABLE 2-30 Densities of Inorganic and Organic Liquids (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T _{min} , K	Density at T _{min}	T _{max} , K	Density at T _{max}
109	Ethyl propyl ether	C ₅ H ₁₂ O	628320	88.150	0.7908	0.266	500.23	0.292	145.65	9.8474	500.23	2.973
110	Ethyl isopropyl ether	C ₆ H ₁₂ O	625547	88.150	0.82049	0.26994	489	0.30381	140.00	9.9117	489	3.040
111	Methyl phenyl ether	C ₇ H ₈ O	100663	108.140	0.77488	0.26114	645.6	0.28234	235.65	9.6675	645.6	2.967
112	Diphenyl ether	C ₁₂ H ₁₀ O	101848	170.211	0.52133	0.26218	766.8	0.31033	300.03	6.2648	766.8	1.988
113	Formaldehyde ³	CH ₂ O	50000	30.026	1.9415	0.22309	408	0.28571	181.15	30.945	408	8.703
114	Acetaldehyde	C ₂ H ₄ O	75070	44.053	1.6994	0.26167	466	0.2913	150.15	21.499	466	6.494
115	1-Propanal	C ₃ H ₆ O	123386	58.080	1.296	0.26439	504.4	0.29471	170.00	15.929	504.4	4.902
116	1-Butanal	C ₄ H ₈ O	123728	72.107	1.0361	0.26731	537.2	0.28397	176.75	12.589	537.2	3.876
117	1-Pentanal	C ₅ H ₁₀ O	110623	86.134	0.83871	0.26252	566.1	0.29444	182.00	10.534	566.1	3.195
118	1-Hexanal	C ₆ H ₁₂ O	66251	100.161	0.71899	0.26531	591	0.27628	217.15	8.7243	591	2.710
119	1-Heptanal	C ₇ H ₁₄ O	111717	114.188	0.62649	0.26376	617	0.29221	229.80	7.6002	617	2.375
120	1-Octanal	C ₈ H ₁₆ O	124130	128.214	0.56833	0.26939	638.1	0.26975	246.00	6.6637	638.1	2.110
121	1-Nonanal	C ₉ H ₁₈ O	124196	142.241	0.49587	0.26135	658	0.30736	255.15	6.0165	658	1.897
122	1-Decanal	C ₁₀ H ₂₀ O	112312	156.268	0.46802	0.27146	674.2	0.26869	267.15	5.3834	674.2	1.724
123	Acetone	C ₃ H ₆ O	67641	58.080	1.2332	0.25886	508.2	0.2913	178.45	15.683	508.2	4.764
124	Methyl ethyl ketone	C ₄ H ₈ O	78933	72.107	0.93767	0.25035	535.5	0.29964	186.48	12.663	535.5	3.745
125	2-Pentanone	C ₅ H ₁₀ O	107879	86.134	0.90411	0.27207	561.08	0.30669	196.29	10.398	561.08	3.323
126	Methyl isopropyl ketone ¹	C ₅ H ₁₀ O	563804	86.134	0.8374	0.26204	553	0.2857	181.15	10.565	553	3.196
127	2-Hexanone	C ₆ H ₁₂ O	591786	100.161	0.70659	0.26073	587.05	0.2963	217.35	8.7505	587.05	2.710
128	Methyl isobutyl ketone	C ₆ H ₁₂ O	108101	100.161	0.71791	0.26491	571.4	0.28544	189.15	8.8579	571.4	2.710
129	3-Methyl-2-pentanone ¹	C ₆ H ₁₂ O	565617	100.161	0.6969	0.2587	573	0.2857	167.15	9.1722	573	2.694
130	3-Pentanone	C ₅ H ₁₀ O	96220	86.134	0.71811	0.24129	560.95	0.27996	234.18	10.102	560.95	2.976
131	Ethyl isopropyl ketone	C ₆ H ₁₂ O	565695	100.161	0.66469	0.24527	567	0.34305	200.00	9.0933	567	2.710
132	Diisopropyl ketone	C ₈ H ₁₄ O	565800	114.188	0.56213	0.23385	576	0.2618	204.81	8.7779	576	2.404
133	Cyclohexanone	C ₆ H ₁₀ O	108941	98.145	0.8663	0.26941	653	0.2977	242.00	10.081	653	3.216
134	Methyl phenyl ketone	C ₈ H ₈ O	98862	120.151	0.64417	0.24863	709.5	0.28661	292.81	8.5581	709.5	2.591
135	Formic acid	CH ₂ O ₂	64186	46.026	1.938	0.24225	588	0.24435	281.45	26.806	588	8.000
136	Acetic acid	C ₂ H ₄ O ₂	64197	60.053	1.4486	0.25892	591.95	0.2529	289.81	17.492	591.95	5.595
137	Propionic acid	C ₃ H ₆ O ₂	79094	74.079	1.1041	0.25659	600.81	0.26874	252.45	13.933	600.81	4.303
138	n-Butyric acid	C ₄ H ₈ O ₂	107926	88.106	0.89213	0.25938	615.7	0.24909	267.95	11.087	615.7	3.440
139	Isobutyric acid	C ₄ H ₈ O ₂	79312	88.106	0.88575	0.25736	605	0.26265	227.15	11.42	605	3.442
140	Benzoic acid ¹	C ₇ H ₆ O ₂	65850	122.123	0.71587	0.24812	751	0.2857	395.45	8.8935	751	2.885
141	Acetic anhydride	C ₄ H ₆ O ₃	108247	102.090	0.86852	0.25187	606	0.31172	200.15	11.643	606	3.448
142	Methyl formate	C ₂ H ₄ O ₂	107313	60.053	1.525	0.2634	487.2	0.2806	174.15	18.811	487.2	5.790
143	Methyl acetate	C ₃ H ₆ O ₂	79209	74.079	1.13	0.2593	506.55	0.2764	175.15	14.475	506.55	4.358
144	Methyl propionate	C ₃ H ₈ O ₂	554121	88.106	0.9147	0.2594	530.6	0.2774	185.65	11.678	530.6	3.526
145	Methyl n-butyrate	C ₅ H ₁₀ O ₂	623427	102.133	0.76983	0.26173	554.5	0.26879	187.35	9.7638	554.5	2.941
146	Ethyl formate	C ₃ H ₆ O ₂	109944	74.079	1.1343	0.26168	508.4	0.2791	193.55	14.006	508.4	4.335
147	Ethyl acetate	C ₄ H ₈ O ₂	141786	88.106	0.8996	0.25856	523.3	0.278	189.60	11.478	523.3	3.479
148	Ethyl propionate	C ₅ H ₁₀ O ₂	105373	102.133	0.7405	0.25563	546	0.2795	199.25	9.6317	546	2.897
149	Ethyl n-butyrate	C ₆ H ₁₂ O ₂	105544	116.160	0.63566	0.25613	571	0.27829	175.15	8.4912	571	2.482
150	n-Propyl formate	C ₄ H ₈ O ₂	110747	88.106	0.915	0.26134	538	0.28	180.25	11.59	538	3.501
151	n-Propyl acetate	C ₅ H ₁₀ O ₂	109604	102.133	0.73041	0.25456	549.73	0.27666	178.15	9.7941	549.73	2.869
152	n-Butyl acetate	C ₆ H ₁₂ O ₂	123864	116.160	0.669	0.26028	579.15	0.309	199.65	8.3747	579.15	2.570
153	Methyl benzoate	C ₇ H ₆ O ₂	93583	136.150	0.53944	0.23519	693	0.2676	260.75	8.2133	693	2.294
154	Ethyl benzoate	C ₈ H ₁₀ O ₂	93890	150.177	0.4883	0.23878	698	0.28487	238.45	7.2924	698	2.045
155	Vinyl acetate	C ₄ H ₆ O ₂	108054	86.090	0.9591	0.2593	519.13	0.27448	180.35	12.287	519.13	3.699
156	Methylamine	CH ₃ N	74895	31.057	1.39	0.21405	430.05	0.2275	179.69	25.378	430.05	6.494
157	Dimethylamine	C ₂ H ₇ N	124403	45.084	1.5436	0.27784	437.2	0.2572	180.96	16.964	437.2	5.556
158	Trimethylamine	C ₃ H ₉ N	75503	59.111	1.0116	0.25683	433.25	0.2696	156.08	13.144	433.25	3.939
159	Ethylamine	C ₂ H ₇ N	75047	45.084	1.1477	0.23182	456.15	0.26053	192.15	17.588	456.15	4.951
160	Diethylamine	C ₄ H ₁₁ N	109897	73.138	0.85379	0.25675	496.6	0.27027	223.35	10.575	496.6	3.325

161	Triethylamine	C ₆ H ₁₅ N	121448	101.192	0.7035	0.27386	535.15	0.2872	158.45	8.2843	535.15	2.569
162	<i>n</i> -Propylamine	C ₃ H ₉ N	107108	59.111	0.9195	0.23878	496.95	0.2461	188.36	13.764	496.95	3.851
163	di- <i>n</i> -Propylamine	C ₆ H ₁₅ N	142847	101.192	0.659	0.26428	550	0.2766	210.15	7.9929	550	2.494
164	Isopropylamine	C ₃ H ₉ N	75310	59.111	1.2801	0.2828	471.85	0.2972	177.95	13.561	471.85	4.527
165	Diisopropylamine	C ₆ H ₁₅ N	108189	101.192	0.6181	0.25786	523.1	0.271	176.85	8.0541	523.1	2.397
166	Aniline	C ₆ H ₅ N	62533	93.128	1.0405	0.2807	699	0.29236	267.13	11.176	699	3.707
167	<i>N</i> -Methylaniline	C ₇ H ₉ N	100618	107.155	0.6527	0.24324	701.55	0.25374	216.15	9.7244	701.55	2.683
168	<i>N,N</i> -Dimethylaniline	C ₈ H ₁₁ N	121697	121.182	0.4923	0.22868	687.15	0.2335	275.60	7.9705	687.15	2.153
169	Ethylene oxide	C ₂ H ₄ O	75218	44.053	1.836	0.26024	469.15	0.2696	160.65	23.477	469.15	7.055
170	Furan	C ₄ H ₄ O	110009	68.075	1.1339	0.24741	490.15	0.2612	187.55	15.702	490.15	4.583
171	Thiophene	C ₄ H ₄ S	110021	84.142	1.2875	0.28195	579.35	0.3077	234.94	13.431	579.35	4.566
172	Pyridine	C ₅ H ₅ N	110861	79.101	0.9815	0.24957	619.95	0.29295	231.51	13.193	619.95	3.933
173	Formamide ⁵	CH ₃ NO	75127	45.041	1.2486	0.20352	771	0.25178	275.60	25.488	771	6.135
174	<i>N,N</i> -Dimethyl-formamide	C ₃ H ₇ NO	68122	73.095	0.89615	0.23478	649.6	0.28091	212.72	13.954	649.6	3.817
175	Acetamide	C ₂ H ₅ NO	60355	59.068	1.016	0.21845	761	0.26116	353.33	16.936	761	4.651
176	<i>N</i> -Methylacetamide	C ₃ H ₇ NO	79163	73.095	0.88268	0.23568	718	0.27379	301.15	13.012	718	3.745
177	Acetonitrile	C ₃ H ₃ N	75058	41.053	1.3064	0.22597	545.5	0.28678	229.32	20.628	545.5	5.781
178	Propionitrile	C ₃ H ₅ N	107120	55.079	1.0224	0.23452	564.4	0.2804	180.26	16.027	564.4	4.360
179	<i>n</i> -Butyronitrile	C ₄ H ₇ N	109740	69.106	0.87533	0.24331	582.25	0.28586	161.25	13.047	582.25	3.598
180	Benzonitrile	C ₇ H ₅ N	100470	103.123	0.73136	0.24793	699.35	0.2841	260.40	10.009	699.35	2.950
181	Methyl mercaptan	CH ₃ S	74931	48.109	1.9323	0.28018	469.95	0.28523	150.18	21.564	469.95	6.897
182	Ethyl mercaptan	C ₂ H ₅ S	75081	62.136	1.3047	0.2694	499.15	0.27866	125.26	16.242	499.15	4.843
183	<i>n</i> -Propyl mercaptan	C ₃ H ₈ S	107039	76.163	1.0714	0.27214	536.6	0.29481	159.95	12.716	536.6	3.937
184	<i>n</i> -Butyl mercaptan	C ₄ H ₁₀ S	109795	90.189	0.89458	0.27463	570.1	0.28512	157.46	10.585	570.1	3.257
185	Isobutyl mercaptan	C ₄ H ₁₀ S	513440	90.189	0.88801	0.27262	559	0.29522	128.31	10.851	559	3.257
186	<i>sec</i> -Butyl mercaptan	C ₄ H ₁₀ S	513531	90.189	0.89137	0.27365	554	0.2953	133.02	10.761	554	3.257
187	Dimethyl sulfide	C ₂ H ₆ S	75183	62.136	1.4029	0.27991	503.04	0.2741	174.88	15.556	503.04	5.012
188	Methyl ethyl sulfide	C ₂ H ₅ S	624895	76.163	1.067	0.27101	533	0.29363	167.23	12.672	533	3.937
189	Diethyl sulfide	C ₄ H ₁₀ S	352932	90.189	0.82413	0.26333	557.15	0.27445	169.20	10.476	557.15	3.130
190	Fluoromethane	CH ₃ F	593533	34.033	2.1854	0.24725	317.42	0.27558	131.35	29.526	317.42	8.839
191	Chloromethane	CH ₃ Cl	74873	50.488	1.817	0.25877	416.25	0.2833	175.43	22.347	416.25	7.022
192	Trichloromethane	CHCl ₃	67663	119.377	1.0841	0.2581	536.4	0.2741	209.63	13.702	536.4	4.200
193	Tetrachloromethane	CCl ₄	56235	153.822	0.99835	0.274	556.35	0.287	250.33	10.843	556.35	3.644
194	Bromomethane	CH ₃ Br	74839	94.939	1.6762	0.26141	467	0.28402	179.47	20.64	467	6.412
195	Fluoroethane	C ₂ H ₂ F	353366	48.060	1.6525	0.27099	375.31	0.2442	129.95	19.785	375.31	6.098
196	Chloroethane	C ₂ H ₅ Cl	75003	64.514	2.176	0.3377	460.35	0.3361	134.80	16.934	460.35	6.444
197	Bromoethane	C ₂ H ₅ Br	74964	108.966	1.1908	0.25595	503.8	0.29152	154.55	15.833	503.8	4.653
198	1-Chloropropane	C ₃ H ₇ Cl	540545	78.541	1.087	0.26832	503.15	0.28055	150.35	13.328	503.15	4.051
199	2-Chloropropane	C ₃ H ₇ Cl	75296	78.541	1.1202	0.27669	489	0.27646	155.97	12.855	489	4.049
200	1,1-Dichloropropane ¹	C ₃ H ₆ Cl ₂	78999	112.986	0.91064	0.26561	560	0.28571	200.00	11.03	560	3.429
201	1,2-Dichloropropane	C ₃ H ₆ Cl ₂	78875	112.986	0.89833	0.26142	572	0.2868	172.71	11.526	572	3.436
202	Vinyl chloride	C ₂ H ₃ Cl	75014	62.499	1.5115	0.2707	432	0.2716	119.36	18.481	432	5.584
203	Fluorobenzene	C ₆ H ₅ F	462066	96.104	1.0146	0.27277	560.09	0.28291	230.94	11.374	560.09	3.720
204	Chlorobenzene	C ₆ H ₅ Cl	108907	112.558	0.8711	0.26805	632.35	0.2799	227.95	10.385	632.35	3.250
205	Bromobenzene	C ₆ H ₅ Br	108861	157.010	0.8226	0.26632	670.15	0.2821	242.43	9.9087	670.15	3.089
206	Air		132259100	28.951	2.8963	0.26733	132.45	0.27341	59.15	33.279	132.45	10.834
207	Hydrogen	H ₂	1333740	2.016	5.414	0.34893	33.19	0.2706	13.95	38.487	33.19	15.516
208	Helium-4 ⁴	He	7440597	4.003	7.2475	0.41865	5.2	0.24096	2.20	37.115	5.2	17.312
209	Neon	Ne	7440019	20.180	7.3718	0.3067	44.4	0.2786	24.56	61.796	44.4	24.036
210	Argon	Ar	7440371	39.948	3.8469	0.2881	150.86	0.29783	83.78	35.491	150.86	13.353
211	Fluorine	F ₂	7782414	37.997	4.2895	0.28587	144.12	0.28776	53.48	44.888	144.12	15.005
212	Chlorine	Cl ₂	7782505	70.905	2.23	0.27645	417.15	0.2926	172.12	24.242	417.15	8.067
213	Bromine	Br ₂	7726956	159.808	2.1872	0.29527	584.15	0.3295	265.85	20.109	584.15	7.408
214	Oxygen	O ₂	7782447	31.999	3.9143	0.28772	154.58	0.2924	54.35	40.77	154.58	13.605
215	Nitrogen	N ₂	7727379	28.014	3.2091	0.2861	126.2	0.2966	63.15	31.063	126.2	11.217
216	Ammonia	NH ₃	7664417	17.031	3.5383	0.25443	405.65	0.2888	195.41	43.141	405.65	13.907
217	Hydrazine	N ₂ H ₄	302012	32.045	1.0516	0.16613	653.15	0.1898	274.69	31.934	653.15	6.330

TABLE 2-30 Densities of Inorganic and Organic Liquids (Concluded)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	C1	C2	C3	C4	T _{min} , K	Density at T _{min}	T _{max} , K	Density at T _{max}
218	Nitrous oxide	N ₂ O	10024972	44.013	2.781	0.27244	309.57	0.2882	182.30	27.928	309.57	10.208
219	Nitric oxide	NO	10102439	30.006	5.246	0.3044	180.15	0.242	109.50	44.487	180.15	17.234
220	Cyanogen	C ₂ N ₂	460195	52.036	1.0761	0.20984	400.15	0.20635	245.25	18.513	400.15	5.128
221	Carbon monoxide	CO	630080	28.010	2.897	0.27532	132.92	0.2813	68.15	30.18	132.92	10.522
222	Carbon dioxide	CO ₂	124389	44.010	2.768	0.26212	304.21	0.2908	216.58	26.828	304.21	10.560
223	Carbon disulfide	CS ₂	75150	76.143	1.7968	0.28749	552	0.3226	161.11	19.064	552	6.250
224	Hydrogen fluoride	HF	7664393	20.006	2.5635	0.1766	461.15	0.3733	189.79	60.203	461.15	14.516
225	Hydrogen chloride	HCl	7647010	36.461	3.342	0.2729	324.65	0.3217	158.97	34.854	324.65	12.246
226	Hydrogen bromide ¹	HBr	10035106	80.912	2.832	0.2832	363.15	0.28571	185.15	27.985	363.15	10.000
227	Hydrogen cyanide	HCN	74908	27.026	1.3413	0.18589	456.65	0.28206	259.83	27.202	456.65	7.216
228	Hydrogen sulfide	H ₂ S	7783064	34.082	2.7672	0.27369	373.53	0.29015	187.68	29.13	373.53	10.111
229	Sulfur dioxide	SO ₂	7446095	64.065	2.106	0.25842	430.75	0.2895	197.67	25.298	430.75	8.150
230	Sulfur trioxide	SO ₃	7446119	80.064	1.4969	0.19013	490.85	0.4359	289.95	24.241	490.85	7.873
231	Water ⁷	H ₂ O	7732185	18.015	5.459	0.30542	647.13	0.081	273.16	55.583	333.15	54.703

All substances are listed in alphabetical order in Table 2-6a. Compiled from Daubert, T. E., R. P. Danner, H. M. Sibul, and C. C. Stebbins, DIPPR Data Compilation of Pure Compound Properties, Project 801 Sponsor Release, July, 1993, Design Institute for Physical Property Data, AIChE, New York, NY; and from Thermodynamics Research Center, "Selected Values of Properties of Hydrocarbons and Related Compounds," Thermodynamics Research Center Hydrocarbon Project, Texas A&M University, College Station, Texas (extant 1994).

Temperatures are in kelvins. Liquid densities are in kmol/m³. Density formulas: kmol/m³ × (mol. wt./1E+03) = g/cm³; kmol/m³ × (mol. wt./1.601846E+01) = lb/ft³.

The liquid density equation is $C_1/C_2^{[1 + (1 - T/C_0)^{C_1}]}$ unless otherwise noted.

¹ The modified Rackett equation, density = $(P_c/RT_c)/ZRA^{1 + [1 - (T/T_c)]^{2/7}}$, was used. See Spencer, C. F., and R. P. Danner, "Improved Equation for Prediction of Saturated Liquid Density," *J. Chem. Eng. Data* **17**, 236 (1972).

² Decomposes violently on heating. Forms explosive peroxides with air or oxygen. Polymerizes under pressure and heat.

³ For the hypothetical pure liquid.

⁴ Exhibits superfluid properties below 2.2 K.

⁵ Coefficients are hypothetical above the decomposition temperature.

⁶ Lower limit is for the undercooled liquid.

⁷ For the temperature range 333.15 to 403.15 K, use the coefficients: $C_1 = 4.9669E+00$, $C_2 = 2.7788E-01$, $C_3 = 6.4713E+02$, $C_4 = 1.8740E-01$. For the temperature range 403.15 to 647.13 K, use $C_1 = 4.3910E+00$, $C_2 = 2.4870E-01$, $C_3 = 6.4713E+02$, $C_4 = 2.5340E-01$.

DENSITIES OF AQUEOUS INORGANIC SOLUTIONS

UNITS AND UNITS CONVERSIONS

Densities are given in grams per cubic centimeter. To convert to pounds per cubic foot, multiply by 62.43. °F = % °C + 32.

ADDITIONAL REFERENCES

For more detailed data on densities see *International Critical Tables*: tabular index, vol. 3, p. 1; abrasives, vol. 2, p. 87; air, moist, vol. 1, p. 71; building stones, vol. 2, p. 52; clays, vol. 2, p. 56; coals, vol. 2, p. 135; compounds, vol. 1, pp. 106, 176, 313, 341; elements, vol. 1, pp. 102, 340; fibers, vol. 2, p. 237; gases and vapors, vol. 3, pp. 3, 345; glass, vol. 2, p. 93; liquids and vitreous solids, vol. 3, p. 22; vol. 1, pp. 102, 340; vol. 2, pp. 456, 463; vol. 3, pp. 20, 35; liquid coolants and saturated

vapors are available from WADC-TR-59-598, 1959; plastics are collected in the *Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co.: solid helium, neon, argon, fluorine, and methane data are given by Johnson (ed.), WADD-TR-60-56, 1960; temperatures of maximum solubility, vol. 3, p. 107; metals, vol. 2, p. 463; oils, fats, and waxes, vol. 2, p. 201; orthobaric, vol. 3, pp. 202, 228, 237, 244; petroleums, vol. 2, pp. 137, 144; plastics, vol. 2, p. 296; porcelains, vol. 2, pp. 68, 75; refrigerating brines, vol. 2, p. 327; rubber, vol. 2, pp. 255, 259; soaps, vol. 5, p. 447; metallic solid solutions, vol. 2, p. 358; solids, vol. 3, pp. 43, 45; vol. 2, p. 456; vol. 3, p. 21; solutions and mixtures, vol. 3, pp. 17, 51, 95, 104, 107, 111, 125, 130; woods, vol. 2, p. 1. Also see the *Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., 40th ed., etc.

TABLE 2-31 Aluminum Sulfate [Al₂(SO₄)₃]

%	d ₄ ¹⁵	%	d ₄ ¹⁵
1	1.0093	16	1.1770
2	1.0195	20	1.2272
4	1.0404	24	1.2803
8	1.0837	26	1.3079
12	1.1293		

TABLE 2-32 Ammonia (NH₃)

%	-15°C	-10°C	-5°C	0°C	5°C	10°C	20°C	25°C	%	d ₄ ¹⁵
1	0.9943	0.9954	0.9959	0.9958	0.9955	0.9939	0.993	32	0.889	
2	.9906	.9915	.9919	.9917	.9913	.9895	.988	36	.877	
4	.9834	.9840	.9842	.9837	.9832	.9811	.980	40	.865	
8	0.970	.9701	.9695	.9686	.9677	.9651	.964	45	.849	
12	.958	.9576	.9571	.9561	.9548	.9534	.9501	.948	50	.832
16	.947	.9461	.9450	.9435	.9420	.9402	.9362	.934	60	.796
20		.9353	.9335	.9316	.9296	.9275	.9229		70	.755
24		.9249	.9226	.9202	.9179	.9155	.9101		80	.711
28		.9150	.9122	.9094	.9067	.9040	.8980		90	.665
30		.9101	.9070	.9040	.9012	.8983	.8920		100	.618

TABLE 2-33 Ammonium Acetate* (CH₃COONH₄)

%	d ₄ ²⁵	%	d ₄ ¹²
1	0.9992	1	1.0051
2	1.0013	2	1.0108
4	1.0055	4	1.0223
8	1.0136	8	1.0463
12	1.0216	12	1.0715
16	1.0294	16	1.0981
20	1.0368	20	1.1263
24	1.0439		
28	1.0507		
30	1.0540		
35	1.0618		
40	1.0691		
45	1.0760		

*For data at 16°C for 3(1)52 percent see Atack *Handbook of Chemical Data*, p. 33, Reinhold, New York, 1957.

TABLE 2-34 Ammonium Bichromate [(NH₄)₂Cr₂O₇]

%	d ₄ ¹²
1	1.0051
2	1.0108
4	1.0223
8	1.0463
12	1.0715
16	1.0981
20	1.1263

TABLE 2-35 Ammonium Chloride (NH₄Cl)

%	0°C	10°C	20°C	30°C	50°C	80°C	100°C
1	1.0033	1.0029	1.0013	0.9987	0.9910	0.9749	0.9617
2	1.0067	1.0062	1.0045	1.0018	.9940	.9780	.9651
4	1.0135	1.0126	1.0107	1.0077	.9999	.9842	.9718
8	1.0266	1.0251	1.0227	1.0195	1.0116	.9963	.9849
12	1.0391	1.0370	1.0344	1.0310	1.0231	1.0081	.9975
16	1.0510	1.0485	1.0457	1.0422	1.0343	1.0198	1.0096
20	1.0625	1.0596	1.0567	1.0532	1.0454	1.0312	1.0213
24	1.0736	1.0705	1.0674	1.0641	1.0564	1.0426	1.0327

TABLE 2-36 Ammonium Chromate [(NH₄)₂CrO₄]

%	°C	d ₄ ¹
3.80	20	1.0219
10.52	13	1.0627
19.75	13.7	1.1189
28.04	19.6	1.1707

TABLE 2-37 Ammonium Nitrate (NH₄NO₃)

%	0°C	10°C	25°C	40°C	60°C	80°C
1.0	1.0043	1.0039	1.0011	0.9961	0.9870	0.9755
2.0	1.0088	1.0082	1.0051	1.0000	.9908	.9793
4.0	1.0178	1.0168	1.0132	1.0079	.9985	.9869
8.0	1.0358	1.0340	1.0297	1.0238	1.0142	1.0024
12.0	1.0539	1.0515	1.0464	1.0400	1.0301	1.0181
16.0	1.0721	1.0691	1.0633	1.0565	1.0462	1.0342
20.0	1.0905	1.0870	1.0806	1.0734	1.0627	1.0506
24.0	1.1090	1.1051	1.0982	1.0907	1.0796	1.0673
28.0	1.1277	1.1234	1.1161	1.1082	1.0968	1.0844
30.0	1.1371	1.1327	1.1252	1.1171	1.1055	1.0931
40.0	1.1862	1.1810	1.1727	1.1640	1.1515	1.1385
50.0	1.2380	1.2320	1.2229	1.2136	1.2006	1.1868

TABLE 2-38 Ammonium Sulfate [(NH₄)₂SO₄]

%	0°C	20°C	40°C	80°C	100°C
1	1.0061	1.0041	0.9980	0.9777	0.9644
2	1.0124	1.0101	1.0039	.9836	.9705
4	1.0248	1.0220	1.0155	.9953	.9826
8	1.0495	1.0456	1.0387	1.0187	1.0066
12	1.0740	1.0691	1.0619	1.0421	1.0303
16	1.0980	1.0924	1.0849	1.0653	1.0539
20	1.1215	1.1154	1.1077	1.0883	1.0772
24	1.1448	1.1383	1.1304	1.1111	1.1003
28	1.1677	1.1609	1.1529	1.1338	1.1232
35	1.2072	1.2800	1.1919	1.1731	1.1629
40	1.2350	1.2277	1.2196	1.2011	1.1910
50	1.2899	1.2825	1.2745	1.2568	1.2466

TABLE 2-39 Arsenic Acid (H₃A₃O₄)

%	d ₄ ⁵	%	d ₄ ⁵
1	1.0057	20	1.1447
2	1.0124	30	1.2331
6	1.0398	40	1.3370
10	1.0681	50	1.4602
16	1.1128	60	1.6070
		70	1.7811

2-100 PHYSICAL AND CHEMICAL DATA

TABLE 2-40 Barium Chloride (BaCl_2)

%	0°C	20°C	40°C	60°C	80°C	100°C
2	1.0181	1.0159	1.0096	1.0004	0.9890	0.9755
4	1.0368	1.0341	1.0275	1.0181	1.0066	.9931
8	1.0760	1.0721	1.0648	1.0551	1.0434	1.0299
12	1.1178	1.1128	1.1047	1.0948	1.0827	1.0692
16	1.1627	1.1564	1.1478	1.1373	1.1249	1.1113
20	1.2105	1.2031	1.1938	1.1828	1.1702	1.1563
24		1.2531	1.2430	1.2316	1.2186	1.2045
26		1.2793	1.2688	1.2571	1.2440	1.2298

TABLE 2-41 Cadmium Nitrate [$\text{Cd}(\text{NO}_3)_2$]

%	d_4^{18}	%	d_4^{18}
2	1.0154	20	1.1904
4	1.0326	25	1.2488
8	1.0683	30	1.3124
12	1.1061	40	1.4590
16	1.1468	50	1.6356

TABLE 2-42 Calcium Chloride (CaCl_2)

%	-5°C	0°C	20°C	30°C	40°C	60°C	80°C	100°C	120°C*	140°C
2	1.0171	1.0148	1.0120	1.0084	0.9994	0.9881	0.9748	0.9596	0.9428	
4	1.0346	1.0316	1.0286	1.0249	1.0158	1.0046	.9915	.9765	.9601	
8	1.0708	1.0703	1.0659	1.0626	1.0586	1.0492	1.0382	1.0257	1.0111	.9954
12	1.1083	1.1072	1.1015	1.0978	1.0937	1.0840	1.0730	1.0610	1.0466	1.0317
16	1.1471	1.1454	1.1386	1.1345	1.1301	1.1202	1.1092	1.0973	1.0835	1.0691
20	1.1874	1.1853	1.1775	1.1730	1.1684	1.1581	1.1471	1.1352	1.1219	1.1080
25		1.2376	1.2284	1.2236	1.2186	1.2079	1.1965	1.1846		
30		1.2922	1.2816	1.2764	1.2709	1.2597	1.2478	1.2359		
35			1.3373	1.3316	1.3255	1.3137	1.3013	1.2893		
40				1.3957	1.3895	1.3826	1.3700	1.3571	1.3450	

*Corrected to atmospheric pressure.

TABLE 2-43 Calcium Hydroxide ($\text{Ca}(\text{OH})_2$)

%	d_4^{15}	d_4^{25}
0.05	0.99979	0.99773
.10	1.00044	.99838
.15	1.00110	.99904

TABLE 2-44 Calcium Hypochlorite* (CaOCl_2)

% total salt	d_4^{15}
2	1.0169
4	1.0345
6	1.0520
8	1.0697
10	1.0876
12	1.1060

* $\text{CaOCl}_2 = 89.15\%$
 $\text{CaCl}_2 = 7.31\%$
 $\text{Ca}(\text{ClO}_3)_2 = 0.26\%$
 $\text{Ca}(\text{OH})_2 = 2.92\%$.

TABLE 2-45 Calcium Nitrate ($\text{Ca}(\text{NO}_3)_2$)

%	6°C	18°C	25°C	30°C
2°	1.0157	1.0137	1.0120	1.0105
4	1.0316	1.0291	1.0272	1.0256
8	1.0641	1.0608	1.0585	1.0565
12	1.0979	1.0937	1.0911	1.0887
16	1.1330	1.1279	1.1250	1.1224
20	1.1694	1.1636	1.1602	1.1575
25	1.2168	1.2106	1.2065	1.2032
30		1.260		
35		1.311		
40		1.365		
45		1.422		
68°		1.747	1.741	1.736

*Supercooled tetrahydrate (m.p. 41.4°C).

TABLE 2-46 Chromic Acid (CrO_3)

%	d_4^5	%	d_4^{15}
1	1.006	20	1.163
2	1.014	26	1.220
6	1.045	30	1.260
10	1.076	40	1.371
16	1.127	50	1.505
		60	1.663

TABLE 2-47 Chromium Chloride (CrCl_3)

% Violet	d_4^{18}		Equilibrium mixture of violet and green
	Green		
1	1.0076	1.0071	1.0075
2	1.0166	1.0157	1.0165
4	1.0349	1.0332	1.0347
8	1.0724	1.0691	1.0722
12	1.1114	1.1065	1.1111
14	1.1316		

TABLE 2-48 Copper Nitrate ($\text{Cu}(\text{NO}_3)_2$)

%	d_4^{20}	%	d_4^{20}
1	1.007	12	1.107
2	1.015	16	1.147
4	1.032	20	1.189
8	1.069	25	1.248

TABLE 2-49 Copper Sulfate (CuSO_4)

%	0°C	20°C	40°C
1	1.0104	1.0086	1.0024
4	1.0429	1.0401	1.0332
8	1.0887	1.084	1.0764
12	1.1379	1.1308	1.1222
16		1.180	
18		1.206	

TABLE 2-50 Cuprous Chloride (Cu_2Cl_2)

%	0°C	20°C	40°C
1	1.0095	1.0072	1.002
4	1.0387	1.036	1.0305
8	1.0788	1.0754	1.0682
12	1.1208	1.1165	1.107
16	1.1653	1.1595	1.151
20	1.2121	1.2052	1.1953

TABLE 2-51 Ferric Chloride (FeCl_3)

%	0°C	10°C	20°C	30°C
1	1.0086	1.0084	1.0068	1.0040
2	1.0174	1.0168	1.0152	1.0122
4	1.0347	1.0341	1.0324	1.0292
8	1.0703	1.0692	1.0669	1.0636
12	1.1088	1.1071	1.1040	1.1006
16	1.1475	1.1449	1.1418	1.1386
20	1.1870	1.1847	1.1820	1.1786
25	1.2400	1.2380	1.2340	1.2290
30	1.2970	1.2950	1.2910	1.2850
35	1.3605	1.3580	1.3530	1.3475
40	1.4280	1.4235	1.4175	1.4115
45		1.4920	1.4850	
50		1.5610	1.5510	

TABLE 2-52 Ferric Sulfate [$\text{Fe}_2(\text{SO}_4)_3$]

%	$d_4^{17.5}$
1	1.0072
2	1.0157
4	1.0327
8	1.0670
12	1.1028
16	1.1409
20	1.1811
30	1.3073
40	1.4487
50	1.6127
60	1.7983

TABLE 2-54 Ferrous Sulfate (FeSO_4)

%	15°C	18°C	20°C
0.2		1.00068	1.0002
0.4		1.00275	1.0022
0.8		1.00645	1.0062
1.0	1.0090	1.0085	1.0082
4.0	1.0380	1.0375	
8.0	1.0790	1.0785	
12.0	1.1235	1.1220	
16.0	1.1690	1.1675	
20.0	1.2150	1.2135	

TABLE 2-56 Hydrogen Cyanide (HCN)

%	d_4^{15}
1	0.998
2	.996
4	.993
8	.984
12	.971
16	.956
82	.752
90	.724
100	.691

TABLE 2-57 Hydrogen Chloride (HCl)

%	-5°C	0°C	10°C	20°C	40°C	60°C	80°C	100°C
1	1.0048	1.0052	1.0048	1.0032	0.9970	0.9881	0.9768	0.9636
2	1.0104	1.0106	1.0100	1.0082	1.0019	0.9930	0.9819	0.9688
4	1.0213	1.0213	1.0202	1.0181	1.0116	1.0026	0.9919	0.9791
6	1.0321	1.0319	1.0303	1.0279	1.0211	1.0121	1.0016	0.9892
8	1.0428	1.0423	1.0403	1.0376	1.0305	1.0215	1.0111	.9992
10	1.0536	1.0528	1.0504	1.0474	1.0400	1.0310	1.0206	1.0090
12	1.0645	1.0634	1.0607	1.0574	1.0497	1.0406	1.0302	1.0188
14	1.0754	1.0741	1.0711	1.0675	1.0594	1.0502	1.0398	1.0286
16	1.0864	1.0849	1.0815	1.0776	1.0692	1.0598	1.0494	1.0383
18	1.0975	1.0958	1.0920	1.0878	1.0790	1.0694	1.0590	1.0479
20	1.1087	1.1067	1.1025	1.0980	1.0888	1.0790	1.0685	1.0574
22	1.1200	1.1177	1.1131	1.1083	1.0986	1.0886	1.0780	1.0668
24	1.1314	1.1287	1.1238	1.1187	1.1085	1.0982	1.0874	1.0761
26	1.1426	1.1396	1.1344	1.1290	1.1183	1.1076	1.0967	1.0853
28	1.1537	1.1505	1.1449	1.1392	1.1280	1.1169	1.1058	1.0942
30	1.1648	1.1613	1.1553	1.1493	1.1376	1.1260	1.1149	1.1030
32				1.1593				
34				1.1691				
36				1.1789				
38				1.1885				
40				1.1980				

TABLE 2-53 Ferric Nitrate [$\text{Fe}(\text{NO}_3)_3$]

%	d_4^{18}
1	1.0065
2	1.0144
4	1.0304
8	1.0636
12	1.0989
16	1.1359
20	1.1748
25	1.2281

TABLE 2-58 Hydrogen Fluoride (HF)

%	d_4^{20}	d_4^l
5	1.020	1.017
10	1.040	1.035
20	1.080	1.070
30	1.119	1.101
40	1.159	1.130
50	1.198	1.155
60	1.235	
70	1.258	
80	1.259	
90	1.178	
95	1.089	
100	1.0005	

TABLE 2-59 Hydrogen Peroxide (H_2O_2)

%	d_4^{18}	%	d_4^{18}
1	1.0022	26	1.0959
2	1.0058	28	1.1040
4	1.0131	30	1.1122
6	1.0204	35	1.1327
8	1.0277	40	1.1536
10	1.0351	45	1.1749
12	1.0425	50	1.1966
14	1.0499	55	1.2188
16	1.0574	60	1.2416
18	1.0649	70	1.2897
20	1.0725	80	1.3406
22	1.0802	90	1.3931
24	1.0880	100	1.4465

TABLE 2-55 Hydrogen Bromide (HBr)

%	d_4^l	d_4^{10}	d_4^{25}
1.0	1.0073	1.0068	1.0041
2.0	1.0146	1.0139	1.0111
4.0	1.0295	1.0285	1.0255
6.0	1.0448	1.0435	1.0402
8.0	1.0604	1.0589	1.0552
10.0	1.0764	1.0747	1.0707
12.0	1.0928	1.0910	1.0867
14.0	1.1097	1.1078	1.1032
16.0	1.1272	1.1251	1.1202
18.0	1.1453	1.1430	1.1377
20.0	1.1640	1.1615	1.1557
22.0	1.1832	1.1806	1.1743
24.0	1.2030	1.2003	1.1935
26.0	1.2235	1.2206	1.2134
28.0	1.2446	1.2415	1.2340
30.0	1.2663	1.2630	1.2552
40.0	1.3877	1.3838	1.3736
50.0	1.5305	1.5257	1.5127

TABLE 2-60 Hydrofluosilic Acid (H_2SiF_6)

%	$d_4^{17.5}$	%	$d_4^{17.5}$
1	1.0080	16	1.1373
2	1.0161	20	1.1748
4	1.0324	25	1.2235
8	1.0661	30	1.2742
12	1.1011	34	1.3162

TABLE 2-61 Magnesium Chloride (MgCl_2)

%	0°C	20°C	30°C	40°C	60°C	80°C	100°C
2	1.0210	1.0186	1.0158	1.0123	1.0081	1.0032	0.9916
4	1.0423	1.0392	1.0362	1.0326	1.0283	1.0234	1.0118
8	1.0858	1.0816	1.0782	1.0743	1.0700	1.0650	1.0534
12	1.1309	1.1256	1.1220	1.1179	1.1135	1.1083	1.0968
16	1.1777	1.1717	1.1679	1.1637	1.1592		
20	1.2264	1.2198	1.2159	1.2117	1.2072		
26	1.3032	1.2961	1.2922	1.2879	1.2836		

TABLE 2-63 Nickel Chloride (NiCl_2)

%	d_4^{18}
1	1.0082
2	1.0179
4	1.0375
8	1.0785
12	1.1217
16	1.1674
20	1.2163
30	1.353

TABLE 2-64 Nickel Nitrate [$\text{Ni}(\text{NO}_3)_2$]

%	d_4^{20}
1	1.0065
2	1.0150
4	1.0325
8	1.0688
12	1.1070
16	1.1480
20	1.191
30	1.311
35	1.377

TABLE 2-65 Nickel Sulfate (NiSO_4)

%	d_4^{18}
1	1.0091
2	1.0198
4	1.0415
8	1.0552
12	1.1325
16	1.1825
18	1.2090

2-102 PHYSICAL AND CHEMICAL DATA

TABLE 2-66 Nitric Acid (HNO_3)

%	0°C	5°C	10°C	15°C	20°C	25°C	30°C	40°C	50°C	60°C	80°C	100°C
1	1.0058	1.00572	1.00534	1.00464	1.00364	1.00241	1.0009	0.9973	0.9931	0.9882	0.9767	0.9632
2	1.0117	1.01149	1.01099	1.01018	1.00909	1.00778	1.0061	1.0025	.9982	.9932	.9816	.9681
3	1.0176	1.01730	1.01668	1.01576	1.01457	1.01318	1.0114	1.0077	1.0033	.9982	.9865	.9730
4	1.0236	1.02315	1.02240	1.02137	1.02008	1.01861	1.0168	1.0129	1.0084	1.0033	.9915	.9779
5	1.0296	1.02904	1.02816	1.02702	1.02563	1.02408	1.0222	1.0182	1.0136	1.0084	.9965	.9829
6	1.0357	1.03497	1.03397	1.03272	1.03122	1.02958	1.0277	1.0235	1.0188	1.0136	1.0015	.9879
7	1.0418	1.0410	1.0399	1.0385	1.0369	1.0352	1.0333	1.0289	1.0241	1.0188	1.0066	.9929
8	1.0480	1.0471	1.0458	1.0443	1.0427	1.0409	1.0389	1.0344	1.0295	1.0241	1.0117	.9980
9	1.0543	1.0532	1.0518	1.0502	1.0485	1.0466	1.0446	1.0399	1.0349	1.0294	1.0169	1.0032
10	1.0606	1.0594	1.0578	1.0561	1.0543	1.0523	1.0503	1.0455	1.0403	1.0347	1.0221	1.0083
11	1.0669	1.0656	1.0639	1.0621	1.0602	1.0581	1.0560	1.0511	1.0458	1.0401	1.0273	1.0134
12	1.0733	1.0718	1.0700	1.0681	1.0661	1.0640	1.0618	1.0567	1.0513	1.0455	1.0326	1.0186
13	1.0797	1.0781	1.0762	1.0742	1.0721	1.0699	1.0676	1.0624	1.0568	1.0509	1.0379	1.0238
14	1.0862	1.0845	1.0824	1.0803	1.0781	1.0758	1.0735	1.0681	1.0624	1.0564	1.0432	1.0289
15	1.0927	1.0909	1.0887	1.0865	1.0842	1.0818	1.0794	1.0739	1.0680	1.0619	1.0485	1.0341
16	1.0992	1.0973	1.0950	1.0927	1.0903	1.0879	1.0854	1.0797	1.0737	1.0675	1.0538	1.0393
17	1.1057	1.1038	1.1014	1.0989	1.0964	1.0940	1.0914	1.0855	1.0794	1.0731	1.0592	1.0444
18	1.1123	1.1103	1.1078	1.1052	1.1026	1.1001	1.0974	1.0913	1.0851	1.0787	1.0646	1.0496
19	1.1189	1.1168	1.1142	1.1115	1.1088	1.1062	1.1034	1.0972	1.0908	1.0843	1.0700	1.0547
20	1.1255	1.1234	1.1206	1.1178	1.1150	1.1123	1.1094	1.1031	1.0966	1.0899	1.0754	1.0598
21	1.1322	1.1300	1.1271	1.1242	1.1213	1.1185	1.1155	1.1090	1.1024	1.0956	1.0808	1.0650
22	1.1389	1.1366	1.1336	1.1306	1.1276	1.1247	1.1217	1.1150	1.1083	1.1013	1.0862	1.0701
23	1.1457	1.1433	1.1402	1.1371	1.1340	1.1310	1.1280	1.1210	1.1142	1.1070	1.0917	1.0753
24	1.1525	1.1501	1.1469	1.1437	1.1404	1.1374	1.1343	1.1271	1.1201	1.1127	1.0972	1.0805
25	1.1594	1.1569	1.1536	1.1503	1.1469	1.1438	1.1406	1.1332	1.1260	1.1185	1.1027	1.0857
26	1.1663	1.1638	1.1603	1.1569	1.1534	1.1502	1.1469	1.1394	1.1320	1.1244	1.1083	1.0910
27	1.1733	1.1707	1.1670	1.1635	1.1600	1.1566	1.1533	1.1456	1.1381	1.1303	1.1139	1.0963
28	1.1803	1.1777	1.1738	1.1702	1.1666	1.1631	1.1597	1.1519	1.1442	1.1362	1.1195	1.1016
29	1.1874	1.1847	1.1807	1.1770	1.1733	1.1697	1.1662	1.1582	1.1503	1.1422	1.1251	1.1069
30	1.1945	1.1917	1.1876	1.1838	1.1800	1.1763	1.1727	1.1645	1.1564	1.1482	1.1307	1.1122
31	1.2016	1.1988	1.1945	1.1906	1.1867	1.1829	1.1792	1.1708	1.1625	1.1542	1.1363	1.1175
32	1.2088	1.2059	1.2014	1.1974	1.1934	1.1896	1.1857	1.1772	1.1687	1.1602	1.1419	1.1228
33	1.2160	1.2131	1.2084	1.2043	1.2002	1.1963	1.1922	1.1836	1.1749	1.1662	1.1476	1.1281
34	1.2233	1.2203	1.2155	1.2113	1.2071	1.2030	1.1988	1.1901	1.1812	1.1723	1.1533	1.1335
35	1.2306	1.2275	1.2227	1.2183	1.2140	1.2098	1.2055	1.1966	1.1876	1.1784	1.1591	1.1390
36	1.2375	1.2344	1.2294	1.2249	1.2205	1.2163	1.2119	1.2028	1.1936	1.1842	1.1645	1.1440
37	1.2444	1.2412	1.2361	1.2315	1.2270	1.2227	1.2182	1.2089	1.1995	1.1899	1.1699	1.1490
38	1.2513	1.2479	1.2428	1.2381	1.2335	1.2291	1.2245	1.2150	1.2054	1.1956	1.1752	1.1540
39	1.2581	1.2546	1.2494	1.2446	1.2399	1.2354	1.2308	1.2210	1.2112	1.2013	1.1805	1.1589
40	1.2649	1.2613	1.2560	1.2511	1.2463	1.2417	1.2370	1.2270	1.2170	1.2069	1.1858	1.1638
41	1.2717	1.2680	1.2626	1.2576	1.2527	1.2480	1.2432	1.2330	1.2229	1.2126	1.1911	1.1687
42	1.2786	1.2747	1.2692	1.2641	1.2591	1.2543	1.2494	1.2390	1.2287	1.2182	1.1963	1.1735
43	1.2854	1.2814	1.2758	1.2706	1.2655	1.2606	1.2556	1.2450	1.2345	1.2238	1.2015	1.1783
44	1.2922	1.2880	1.2824	1.2771	1.2719	1.2669	1.2618	1.2510	1.2403	1.2294	1.2067	1.1831
45	1.2990	1.2947	1.2890	1.2836	1.2783	1.2732	1.2680	1.2570	1.2461	1.2350	1.2119	1.1879
46	1.3058	1.3014	1.2955	1.2901	1.2847	1.2795	1.2742	1.2630	1.2519	1.2406	1.2171	1.1927
47	1.3126	1.3080	1.3021	1.2966	1.2911	1.2858	1.2804	1.2690	1.2577	1.2462	1.2223	1.1976
48	1.3194	1.3147	1.3087	1.3031	1.2975	1.2921	1.2867	1.2750	1.2635	1.2518	1.2275	1.2024
49	1.3263	1.3214	1.3153	1.3096	1.3040	1.2984	1.2929	1.2811	1.2693	1.2575	1.2328	1.2073
50	1.3327	1.3277	1.3215	1.3157	1.3100	1.3043	1.2987	1.2867	1.2748	1.2628	1.2377	1.2118
51	1.3391	1.3339	1.3277	1.3218	1.3160	1.3102	1.3045	1.2923	1.2802	1.2680	1.2425	1.2163
52	1.3454	1.3401	1.3338	1.3278	1.3219	1.3160	1.3102	1.2978	1.2856	1.2731	1.2473	1.2208
53	1.3517	1.3462	1.3399	1.3338	1.3278	1.3218	1.3159	1.3033	1.2909	1.2782	1.2521	1.2252
54	1.3579	1.3523	1.3459	1.3397	1.3336	1.3275	1.3215	1.3087	1.2961	1.2833	1.2568	1.2296
55	1.3640	1.3583	1.3518	1.3455	1.3393	1.3331	1.3270	1.3141	1.3013	1.2883	1.2615	1.2339
56	1.3700	1.3642	1.3576	1.3512	1.3449	1.3386	1.3324	1.3194	1.3064	1.2932	1.2661	1.2382
57	1.3759	1.3700	1.3634	1.3569	1.3505	1.3441	1.3377	1.3246	1.3114	1.2981	1.2706	1.2424
58	1.3818	1.3757	1.3691	1.3625	1.3560	1.3495	1.3430	1.3298	1.3164	1.3029	1.2751	1.2466
59	1.3875	1.3813	1.3747	1.3680	1.3614	1.3548	1.3482	1.3348	1.3213	1.3077	1.2795	1.2507
60	1.3931	1.3868	1.3801	1.3734	1.3667	1.3600	1.3533	1.3398	1.3261	1.3124	1.2839	1.2547
61	1.3986	1.3922	1.3855	1.3787	1.3719	1.3651	1.3583	1.3447	1.3308	1.3169	1.2881	1.2587
62	1.4039	1.3975	1.3907	1.3838	1.3769	1.3700	1.3632	1.3494	1.3354	1.3213	1.2922	1.2625
63	1.4091	1.4027	1.3958	1.3888	1.3818	1.3748	1.3679	1.3540	1.3398	1.3255	1.2962	1.2661
64		1.4078	1.4007	1.3936	1.3866	1.3795	1.3725					

TABLE 2-66 Nitric Acid (HNO_3) (Concluded)

%	0°C	5°C	10°C	15°C	20°C	25°C	30°C	40°C	50°C	60°C	80°C	100°C
65		1.4128	1.4055	1.3984	1.3913	1.3841	1.3770					
66		1.4177	1.4103	1.4031	1.3959	1.3887	1.3814					
67		1.4224	1.4150	1.4077	1.4004	1.3932	1.3857					
68		1.4271	1.4196	1.4122	1.4048	1.3976	1.3900					
69		1.4317	1.4241	1.4166	1.4091	1.4019	1.3942					
70		1.4362	1.4285	1.4210	1.4134	1.4061	1.3983					
71		1.4406	1.4328	1.4252	1.4176	1.4102	1.4023					
72		1.4449	1.4371	1.4294	1.4218	1.4142	1.4063					
73		1.4491	1.4413	1.4335	1.4258	1.4182	1.4103					
74		1.4532	1.4454	1.4376	1.4298	1.4221	1.4142					
75		1.4573	1.4494	1.4415	1.4337	1.4259	1.4180					
76		1.4613	1.4533	1.4454	1.4375	1.4296	1.4217					
77		1.4652	1.4572	1.4492	1.4413	1.4333	1.4253					
78		1.4690	1.4610	1.4529	1.4450	1.4369	1.4288					
79		1.4727	1.4647	1.4565	1.4486	1.4404	1.4323					
80		1.4764	1.4683	1.4601	1.4521	1.4439	1.4357					
81		1.4800	1.4718	1.4636	1.4555	1.4473	1.4391					
82		1.4835	1.4753	1.4670	1.4589	1.4507	1.4424					
83		1.4869	1.4787	1.4704	1.4622	1.4540	1.4456					
84		1.4903	1.4820	1.4737	1.4655	1.4572	1.4487					
85		1.4936	1.4852	1.4769	1.4686	1.4603	1.4518					
86		1.4968	1.4883	1.4799	1.4716	1.4633	1.4548					
87		1.4999	1.4913	1.4829	1.4745	1.4662	1.4577					
88		1.5029	1.4942	1.4858	1.4773	1.4690	1.4605					
89		1.5058	1.4970	1.4885	1.4800	1.4716	1.4631					
90		1.5085	1.4997	1.4911	1.4826	1.4741	1.4656					
91		1.5111	1.5023	1.4936	1.4850	1.4766	1.4681					
92		1.5136	1.5048	1.4960	1.4873	1.4789	1.4704					
93		1.5156	1.5068	1.4979	1.4892	1.4807	1.4722					
94		1.5177	1.5088	1.4999	1.4912	1.4826	1.4741					
95		1.5198	1.5109	1.5019	1.4932	1.4846	1.4761					
96		1.5220	1.5130	1.5040	1.4952	1.4867	1.4781					
97		1.5244	1.5152	1.5062	1.4974	1.4889	1.4802					
98		1.5278	1.5187	1.5096	1.5008	1.4922	1.4835					
99		1.5327	1.5235	1.5144	1.5056	1.4969	1.4881					
100		1.5402	1.5310	1.5217	1.5129	1.5040	1.4952					

TABLE 2-67 Perchloric Acid (HClO_4)

%	d_4^{15}	d_4^{20}	d_4^{25}	d_4^{30}	%	d_4^{15}	d_4^{20}	d_4^{30}
1	1.0050		1.0020	0.9933	28	1.1900	1.1851	1.1645
2	1.0109		1.0070	0.9986	30	1.2067	1.2013	1.1800
4	1.0228		1.0169	0.9906	32	1.2239	1.2183	1.1960
6	1.0348		1.0270	1.0205	34	1.2418	1.2359	1.2130
8	1.0471		1.0372	1.0320	36	1.2603	1.2542	1.2310
10	1.0597		1.0475	1.0440	38	1.2794	1.2732	1.2490
12	1.0726		1.0560	40	1.2991	1.2927	1.2680	
14	1.0589		1.0680	45	1.3521	1.3450	1.3180	
16	1.0995		1.0810	50	1.4103	1.4018	1.3730	
18	1.1135		1.0940	55	1.4733	1.4636	1.4320	
20	1.1279		1.1070	60	1.5389	1.5298	1.4950	
22	1.1428		1.1205	65	1.6059	1.5986	1.5620	
24	1.1581		1.1345	70	1.6736	1.6680	1.6290	
26	1.1738	1.1697		1.1490				

TABLE 2-69 Potassium Bicarbonate (KHCO_3)

°C	1%	2%	4%	6%	8%	10%
0	1.0066	1.0134	1.0270			
10	1.0064	1.0132	1.0268			
15	1.0058	1.0125	1.0260	1.0396	1.0534	1.0674
20	1.0049	1.0117	1.0252			
30	1.0024	1.0092	1.0228			
40	0.9990	1.0058	1.0195			
50	0.9949	1.0017	1.0154			
60	0.9901	0.9969	1.0106			
80	0.9786	0.9855	0.9993			
100	0.9653	0.9722	0.9860			

TABLE 2-68 Phosphoric Acid (H_3PO_4)

°C	2%	6%	14%	20%	26%	35%	50%	75%	100%
0	1.0113	1.0339	1.0811	1.1192					
10	1.0109	1.0330	1.0792	1.1167	1.1567	1.221	1.341		
20	1.0092	1.0309	1.0764	1.1134	1.1529	1.216	1.335	1.579	1.870
30	1.0065	1.0279	1.0728	1.1094	1.1484	1.211	1.329	1.572	1.862
40	1.0029	1.0241	1.0685	1.1048					

TABLE 2-70 Potassium Bromide (KBr)

%	d_4^{20}
1	1.0054
2	1.0127
6	1.0426
12	1.0903
20	1.1601
30	1.2593
40	1.3746

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TABLE 2-71 Potassium Carbonate (K_2CO_3)

%	0°C	10°C	20°C	40°C	60°C	80°C	100°C
1	1.0094	1.0089	1.0072	1.0010	0.9919	0.9803	0.9670
2	1.0189	1.0182	1.0163	1.0098	1.0005	.9889	.9756
4	1.0381	1.0369	1.0345	1.0276	1.0180	1.0063	.9951
8	1.0768	1.0746	1.0715	1.0640	1.0538	1.0418	1.0291
12	1.1160	1.1131	1.1096	1.1013	1.0906	1.0786	1.0663
16	1.1562	1.1530	1.1490	1.1399	1.1290	1.1170	1.1049
20	1.1977	1.1941	1.1898	1.1801	1.1690	1.1570	1.1451
24	1.2405	1.2366	1.2320	1.2219	1.2106	1.1986	1.1869
28	1.2846	1.2804	1.2756	1.2652	1.2538	1.2418	1.2301
30	1.3071	1.3028	1.2979	1.2873	1.2759	1.2640	1.2522
35	1.3646	1.3600	1.3548	1.3440	1.3324	1.3206	1.3089
40	1.4244	1.4195	1.4141	1.4029	1.3913	1.3795	1.3678
45	1.4867	1.4815	1.4759	1.4644	1.4528	1.4408	1.4290
50	1.5517	1.5462	1.5404	1.5285	1.5169	1.5048	1.4928

TABLE 2-72 Potassium Chromate (K_2CrO_4)

%	d_4^{15}	d_4^{18}
1	1.0073	1.0066
2	1.0155	1.0147
4	1.0321	1.0311
8	1.0659	1.0647
12	1.1009	1.0999
16		1.1366
20		1.1748
24		1.2147
28		1.2566
30		1.2784

TABLE 2-73 Potassium Chlorate ($KClO_3$)

°C	1%	2%	3%	4%
0	1.0061	1.0124	1.0189	1.0256
10	1.0059	1.0122	1.0187	1.0254
20	1.0045	1.0109	1.0174	1.0241
30	1.0020	1.0085	1.0151	1.0218
40	0.9986	1.0051	1.0116	1.0183
60	0.9895	0.9959	1.0024	1.0091
80	0.9781	0.9845	0.9910	0.9977
100	0.9646	0.9709	0.9774	0.9840

TABLE 2-74 Potassium Chloride (KCl)

%	0°C	20°C	25°C	40°C	60°C	80°C	100°C
1.0	1.00661	1.00462	1.00342	0.99847	0.9894	0.9780	0.9646
2.0	1.01335	1.01103	1.00977	1.00471	.9956	.9842	.9708
4.0	1.02690	1.02391	1.02255	1.01727	1.0080	.9966	.9634
8.0	1.05431	1.05003	1.04847	1.04278	1.0333	1.0219	1.0888
12.0	1.08222	1.07679	1.07506	1.06897	1.0592	1.0478	1.0350
16.0	1.11068	1.10434	1.10245	1.09600	1.0861	1.0746	1.0619
20.0	1.13973	1.13280	1.13072	1.12399	1.1138	1.1024	1.0897
24.0		1.16226	1.15995	1.15299	1.1425	1.1311	1.1185
28.0				1.18304	1.1723	1.1609	1.1483
%	110°C	120°C	130°C	140°C			
3.79	0.9733	0.9663	0.9583	0.9502			
7.45	.9978	.9899	.9827	.9745			
13.62	1.0388	1.0313	1.0238	1.0159			

TABLE 2-75 Potassium Chrome Alum [$K_2Cr_2(SO_4)_4$]

%	d_4^{15}
1	1.007
2	1.016
6	1.052
10	1.089
14	1.129
20	1.193
30	1.315
40	1.456
50	1.615

TABLE 2-76 Potassium Hydroxide (KOH)

%	d_4^{15}
1.0	1.0083
2.0	1.0175
4.0	1.0359
6.0	1.0544
8.0	1.0730
10.0	1.0918
15.0	1.1396
20.0	1.1884
25.0	1.2387
30.0	1.2905
35.0	1.3440
40.0	1.3991
45.0	1.4558
50.0	1.5143
51.7	1.5355 (sat'd. soln.)

TABLE 2-77 Potassium Nitrate (KNO_3)

%	0°C	10°C	20°C	40°C	60°C	80°C	100°C
1	1.00654	1.00615	1.00447	0.99825	0.9890	0.9776	0.9641
2	1.01326	1.01262	1.01075	1.00430	.9949	.9834	.9699
4	1.02677	1.02566	1.02344	1.01652	1.0068	.9951	.9816
8	1.05419	1.05226	1.04940	1.04152	1.0313	1.0192	1.0056
12	1.08221	1.07963	1.07620	1.06740	1.0567	1.0442	1.0304
16				1.01039	1.09432	1.0831	1.0562
20				1.13261	1.12240	1.1106	1.0974
24				1.16233	1.15175	1.1391	1.1256

TABLE 2-78 Potassium Dichromate ($K_2Cr_2O_7$)

%	d_4^{20}
1	1.0052
2	1.0122
4	1.0264
6	1.0408
8	1.0554
10	1.0703

TABLE 2-79 Potassium Sulfate (K_2SO_4)

%	d_4^{20}
1	1.0063
2	1.0145
4	1.0310
6	1.0477
8	1.0646
10	1.0817

TABLE 2-80 Potassium Sulfite (K_2SO_3)

%	d_4^{15}
1	1.0073
2	1.0155
4	1.0322
8	1.0667
12	1.1026
16	1.1402
20	1.1793
24	1.2197
26	1.2404

TABLE 2-81 Sodium Acetate ($NaC_2H_3O_2$)

%	d_4^{20}
1	1.0033
2	1.0084
4	1.0186
8	1.0392
12	1.0598
18	1.0807
20	1.1021
26	1.1351
28	1.1462

TABLE 2-82 Sodium Arsenate (Na_3AsO_4)

%	d_4^{17}
1	1.0097
2	1.0207
4	1.0431
8	1.0892
10	1.1130
12	1.1373

TABLE 2-83 Sodium Bichromate ($Na_2Cr_2O_7$)

%	d_4^{15}
1	1.006
2	1.013
4	1.027
8	1.056
12	1.084
16	1.112
20	1.140
24	1.166
28	1.193
30	1.207
35	1.244
40	1.279
45	1.312
50	1.342

TABLE 2-84 Sodium Bromide (NaBr)

%	d_4^{17}
1	1.0060
2	1.0139
4	1.0298
8	1.0631
10	1.0803
12	1.0981
20	1.1745
30	1.2841
40	1.4138

TABLE 2-85 Sodium Formate (HCOONa)

%	d_4^{25}
1	1.003
2	1.009
4	1.022
8	1.048
12	1.074
16	1.100
20	1.127
24	1.155
28	1.184
30	1.199
35	1.236
40	1.274

TABLE 2-86 Sodium Carbonate (Na_2CO_3)

%	0°C	10°C	20°C	30°C	40°C	60°C	80°C	100°C
1	1.0109	1.0103	1.0086	1.0058	1.0022	0.9929	0.9814	0.9683
2	1.0219	1.0210	1.0190	1.0159	1.0122	1.0027	.9910	.9782
4	1.0439	1.0423	1.0398	1.0363	1.0323	1.0223	1.0105	.9980
8	1.0878	1.0850	1.0816	1.0775	1.0732	1.0625	1.0503	1.0380
12	1.1319	1.1284	1.1244	1.1200	1.1150	1.1039	1.0914	1.0787
14	1.1543	1.1506	1.1463	1.1417	1.1365	1.1251	1.1125	1.0996
16			1.1636					
18			1.1859					
20			1.2086					
24			1.2552					
28			1.3031					
30			1.3274					

TABLE 2-87 Sodium Chlorate (NaClO_3)

%	d_4^{18}	%	d_4^{18}
1	1.0053	18	1.1288
2	1.0121	20	1.1449
4	1.0258	22	1.1614
6	1.0397	24	1.1782
8	1.0538	26	1.1953
10	1.0681	28	1.2128
12	1.0827	30	1.2307
14	1.0977	32	1.2491
16	1.1131	34	1.2680

TABLE 2-88 Sodium Chloride (NaCl)

%	0°C	10°C	25°C	40°C	60°C	80°C	100°C
1	1.00747	1.00707	1.00409	0.99908	0.9900	0.9785	0.9651
2	1.01509	1.01442	1.01112	1.00593	.9967	.9852	.9719
4	1.03038	1.02920	1.02530	1.01977	1.0103	.9988	.9855
8	1.06121	1.05907	1.05412	1.04798	1.0381	1.0264	1.0134
12	1.09244	1.08946	1.08365	1.07699	1.0667	1.0549	1.0420
16	1.12419	1.12056	1.11401	1.10688	1.0962	1.0842	1.0713
20	1.15663	1.15254	1.14533	1.13774	1.1268	1.1146	1.1017
24	1.18999	1.18557	1.17776	1.16971	1.1584	1.1463	1.1331
26	1.20709	1.20254	1.19443	1.18614	1.1747	1.1626	1.1492

TABLE 2-89 Sodium Chromate (Na_2CrO_4)

%	d_4^{18}
1	1.0074
2	1.0164
4	1.0344
8	1.0718
12	1.1110
16	1.1518
20	1.1942
24	1.2383
26	1.2611

TABLE 2-90 Sodium Hydroxide (NaOH)

%	0°C	15°C	20°C	40°C	60°C	80°C	100°C
1	1.0124	1.01065	1.0095	1.0033	0.9941	0.9824	0.9693
2	1.0244	1.02198	1.0207	1.0139	1.0045	.9929	.9797
4	1.0482	1.04441	1.0428	1.0352	1.0254	1.0139	1.0009
8	1.0943	1.08887	1.0869	1.0780	1.0676	1.0560	1.0432
12	1.1399	1.13327	1.1309	1.1210	1.1101	1.0983	1.0855
16	1.1761	1.1751	1.1645	1.1531	1.1408	1.1277	
20	1.2296	1.22183	1.2191	1.2079	1.1960	1.1833	1.1700
24	1.2741	1.26582	1.2629	1.2512	1.2388	1.2259	1.2124
28	1.3182	1.3094	1.3064	1.2942	1.2814	1.2682	1.2546
32	1.3614	1.3520	1.3490	1.3362	1.3232	1.3097	1.2960
36	1.4030	1.3933	1.3900	1.3768	1.3634	1.3498	1.3360
40	1.4435	1.4334	1.4300	1.4164	1.4027	1.3889	1.3750
44	1.4825	1.4720	1.4685	1.4545	1.4405	1.4266	1.4127
48	1.5210	1.5102	1.5065	1.4922	1.4781	1.4641	1.4503
50	1.5400	1.5290	1.5253	1.5109	1.4967	1.4827	1.4690

TABLE 2-91 Sodium Nitrate (NaNO_3)

%	0°C	20°C	40°C	60°C	80°C	100°C
1	1.0071	1.0049	0.9986	0.9894	0.9779	0.9644
2	1.0144	1.0117	1.0050	.9956	.9840	.9704
4	1.0290	1.0254	1.0180	1.0082	.9964	.9826
8	1.0587	1.0532	1.0447	1.0340	1.0218	1.0078
12	1.0891	1.0819	1.0724	1.0609	1.0481	1.0340
16	1.1203	1.1118	1.1013	1.0892	1.0757	1.0614
20	1.1526	1.1429	1.1314	1.1187	1.1048	1.0901
24	1.1860	1.1752	1.1629	1.1496	1.1351	1.1200
28	1.2204	1.2085	1.1955	1.1816	1.1667	1.1513
30	1.2380	1.2256	1.2122	1.1980	1.1830	1.1674
35	1.2834	1.2701	1.2560	1.2413	1.2258	1.2100
40	1.3316	1.3175	1.3027	1.2875	1.2715	1.2555
45		1.3683	1.3528	1.3371	1.3206	1.3044

TABLE 2-92 Sodium Nitrite (NaNO_2)

%	d_4^{15}
1	1.0058
2	1.0125
4	1.0260
8	1.0535
12	1.0816
16	1.1103
20	1.1394

TABLE 2-93 Sodium Silicates

Formula	Concentration, %												
	1	2	4	8	10	14	20	24	30	36	40	45	50
$\text{Na}_2\text{O}/3.9\text{SiO}_2$	1.006	1.014	1.030	1.063	1.080	1.116	1.172	1.211	1.275				
$\text{Na}_2\text{O}/3.36\text{SiO}_2$	1.006	1.014	1.030	1.065	1.083	1.120	1.179	1.222	1.290	1.365			
$\text{Na}_2\text{O}/2.40\text{SiO}_2$	1.007	1.016	1.034	1.071	1.090	1.130			1.309	1.387	1.445		
$\text{Na}_2\text{O}/2.44\text{SiO}_2$									1.321	1.397	1.450	1.520	1.594
$\text{Na}_2\text{O}/2.06\text{SiO}_2$	1.007	1.016	1.035	1.073	1.093	1.134	1.200	1.247	1.337	1.424			
$\text{Na}_2\text{O}/1.69\text{SiO}_2$	1.007	1.017	1.036	1.077	1.098	1.141	1.210	1.259					

TABLE 2-94 Sodium Sulfate (Na_2SO_4)

%	0°C	20°C	30°C	40°C	60°C	80°C	100°C
1	1.0094	1.0073	1.0046	1.0010	0.9919	0.9805	0.9671
2	1.0189	1.0164	1.0135	1.0098	1.0007	.9892	.9758
4	1.0381	1.0348	1.0315	1.0276	1.0184	1.0068	.9934
8	1.0773	1.0724	1.0682	1.0639	1.0544	1.0426	1.0292
12	1.1174	1.1109	1.1062	1.1015	1.0915	1.0795	1.0661
16	1.1585	1.1586	1.1456	1.1406	1.1299	1.1176	1.1042
20	1.2008	1.1915	1.1865	1.1813	1.1696	1.1569	
24	1.2443	1.2336	1.2292	1.2237			

TABLE 2-95 Sodium Sulfide (Na_2S)

%	d_4^{18}
1	1.0098
2	1.0211
4	1.0440
8	1.0907
12	1.1388
16	1.1885
18	1.2140

TABLE 2-96 Sodium Sulfite (Na_2SO_3)

%	d_4^{19}
1	1.0078
2	1.0172
4	1.0363
8	1.0751
12	1.1146
16	1.1549
18	1.1755

TABLE 2-97 Sodium Thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$)

%	d_4^{20}
1	1.0065
2	1.0148
4	1.0315
8	1.0654
12	1.1003
16	1.1365
20	1.1740
24	1.2128
28	1.2532
30	1.2739
35	1.3273
40	1.3827

TABLE 2-98 Sodium Thiosulfate Pentahydrate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$)

%	d_4^{19}
1	1.0052
2	1.0105
4	1.0211
8	1.0423
12	1.0639
16	1.0863
20	1.1087
24	1.1322
28	1.1558
30	1.1676
40	1.2297
50	1.2954

TABLE 2-99 Stannic Chloride (SnCl_4)

%	d_4^{15}
1	1.007
2	1.015
4	1.031
8	1.064
12	1.099
16	1.135
20	1.173
24	1.212
28	1.255
30	1.278
35	1.337
40	1.403
45	1.475
50	1.555
55	1.644
60	1.742
65	1.851
70	1.971

TABLE 2-100 Stannous Chloride (SnCl_2)

%	d_4^{15}
1	1.0068
2	1.0146
4	1.0306
8	1.0638
12	1.0986
16	1.1353
20	1.1743
24	1.2159
28	1.2603
30	1.2837
35	1.3461
40	1.4145
45	1.4897
50	1.5729
55	1.6656
60	1.7695
65	1.8865

TABLE 2-101 Sulfuric Acid (H_2SO_4)

%	0°C	10°C	15°C	20°C	25°C	30°C	40°C	50°C	60°C	80°C	100°C
1	1.0074	1.0068	1.0060	1.0051	1.0038	1.0022	0.9986	0.9944	0.9895	0.9779	0.9645
2	1.0147	1.0138	1.0129	1.0118	1.0104	1.0087	1.0050	1.0006	.9956	.9839	.9705
3	1.0219	1.0206	1.0197	1.0184	1.0169	1.0152	1.0113	1.0067	1.0017	.9900	.9766
4	1.0291	1.0275	1.0264	1.0250	1.0234	1.0216	1.0176	1.0129	1.0078	.9961	.9827
5	1.0364	1.0344	1.0332	1.0317	1.0300	1.0281	1.0240	1.0192	1.0140	1.0022	.9888
6	1.0437	1.0414	1.0400	1.0385	1.0367	1.0347	1.0305	1.0256	1.0203	1.0084	.9950
7	1.0511	1.0485	1.0469	1.0453	1.0434	1.0414	1.0371	1.0321	1.0266	1.0146	1.0013
8	1.0585	1.0556	1.0539	1.0522	1.0502	1.0481	1.0437	1.0386	1.0330	1.0209	1.0076
9	1.0660	1.0628	1.0610	1.0591	1.0571	1.0549	1.0503	1.0451	1.0395	1.0273	1.0140
10	1.0735	1.0700	1.0681	1.0661	1.0640	1.0617	1.0570	1.0517	1.0460	1.0338	1.0204
11	1.0810	1.0773	1.0753	1.0731	1.0710	1.0686	1.0637	1.0584	1.0526	1.0403	1.0269
12	1.0886	1.0846	1.0825	1.0802	1.0780	1.0756	1.0705	1.0651	1.0593	1.0469	1.0335
13	1.0962	1.0920	1.0898	1.0874	1.0851	1.0826	1.0774	1.0719	1.0661	1.0536	1.0402
14	1.1039	1.0994	1.0971	1.0947	1.0922	1.0897	1.0844	1.0788	1.0729	1.0603	1.0469
15	1.1116	1.1069	1.1045	1.1020	1.0994	1.0968	1.0914	1.0857	1.0798	1.0671	1.0537
16	1.1194	1.1145	1.1120	1.1094	1.1067	1.1040	1.0985	1.0927	1.0868	1.0740	1.0605
17	1.1272	1.1221	1.1195	1.1168	1.1141	1.1113	1.1057	1.0998	1.0938	1.0809	1.0674
18	1.1351	1.1298	1.1271	1.1243	1.1215	1.1187	1.1129	1.1070	1.1009	1.0879	1.0744
19	1.1430	1.1375	1.1347	1.1318	1.1290	1.1261	1.1202	1.1142	1.1081	1.0950	1.0814
20	1.1510	1.1453	1.1424	1.1394	1.1365	1.1335	1.1275	1.1215	1.1153	1.1021	1.0885
21	1.1590	1.1531	1.1501	1.1471	1.1441	1.1410	1.1349	1.1288	1.1226	1.1093	1.0957
22	1.1670	1.1609	1.1579	1.1548	1.1517	1.1486	1.1424	1.1362	1.1299	1.1166	1.1029
23	1.1751	1.1688	1.1657	1.1626	1.1594	1.1563	1.1500	1.1437	1.1373	1.1239	1.1102
24	1.1832	1.1768	1.1736	1.1704	1.1672	1.1640	1.1576	1.1512	1.1448	1.1313	1.1176
25	1.1914	1.1848	1.1816	1.1783	1.1750	1.1718	1.1653	1.1588	1.1523	1.1388	1.1250
26	1.1996	1.1929	1.1896	1.1862	1.1829	1.1796	1.1730	1.1665	1.1599	1.1463	1.1325
27	1.2078	1.2010	1.1976	1.1942	1.1909	1.1875	1.1808	1.1742	1.1676	1.1539	1.1400
28	1.2160	1.2091	1.2057	1.2023	1.1989	1.1955	1.1887	1.1820	1.1753	1.1616	1.1476
29	1.2243	1.2173	1.2138	1.2104	1.2069	1.2035	1.1966	1.1898	1.1831	1.1693	1.1553
30	1.2326	1.2255	1.2220	1.2185	1.2150	1.2115	1.2046	1.1977	1.1909	1.1771	1.1630
31	1.2409	1.2338	1.2302	1.2267	1.2232	1.2196	1.2126	1.2057	1.1988	1.1849	1.1708
32	1.2493	1.2421	1.2385	1.2349	1.2314	1.2278	1.2207	1.2137	1.2068	1.1928	1.1787
33	1.2577	1.2504	1.2468	1.2432	1.2396	1.2360	1.2289	1.2218	1.2148	1.2008	1.1866
34	1.2661	1.2588	1.2552	1.2515	1.2479	1.2443	1.2371	1.2300	1.2229	1.2088	1.1946
35	1.2746	1.2672	1.2636	1.2599	1.2563	1.2526	1.2454	1.2383	1.2311	1.2169	1.2027
36	1.2831	1.2757	1.2720	1.2684	1.2647	1.2610	1.2538	1.2466	1.2394	1.2251	1.2109
37	1.2917	1.2843	1.2805	1.2769	1.2732	1.2695	1.2622	1.2550	1.2477	1.2334	1.2192
38	1.3004	1.2929	1.2891	1.2855	1.2818	1.2780	1.2707	1.2635	1.2561	1.2418	1.2276
39	1.3091	1.3016	1.2978	1.2941	1.2904	1.2866	1.2793	1.2720	1.2646	1.2503	1.2361
40	1.3179	1.3103	1.3065	1.3028	1.2991	1.2953	1.2880	1.2806	1.2732	1.2589	1.2446
41	1.3268	1.3191	1.3153	1.3116	1.3079	1.3041	1.2967	1.2893	1.2819	1.2675	1.2532
42	1.3357	1.3280	1.3242	1.3205	1.3167	1.3129	1.3055	1.2981	1.2907	1.2762	1.2619
43	1.3447	1.3370	1.3332	1.3294	1.3256	1.3218	1.3144	1.3070	1.2996	1.2850	1.2707
44	1.3538	1.3461	1.3423	1.3384	1.3346	1.3308	1.3234	1.3160	1.3086	1.2939	1.2796
45	1.3630	1.3553	1.3515	1.3476	1.3437	1.3399	1.3325	1.3251	1.3177	1.3029	1.2886
46	1.3724	1.3646	1.3608	1.3569	1.3530	1.3492	1.3417	1.3343	1.3269	1.3120	1.2976
47	1.3819	1.3740	1.3702	1.3663	1.3624	1.3586	1.3510	1.3435	1.3362	1.3212	1.3067
48	1.3915	1.3835	1.3797	1.3758	1.3719	1.3680	1.3604	1.3528	1.3455	1.3305	1.3159
49	1.4012	1.3931	1.3893	1.3854	1.3814	1.3775	1.3699	1.3623	1.3549	1.3399	1.3253
50	1.4110	1.4029	1.3990	1.3951	1.3911	1.3872	1.3795	1.3719	1.3644	1.3494	1.3348
51	1.4209	1.4128	1.4088	1.4049	1.4009	1.3970	1.3893	1.3816	1.3740	1.3590	1.3444
52	1.4310	1.4228	1.4188	1.4148	1.4109	1.4069	1.3991	1.3914	1.3837	1.3687	1.3540
53	1.4412	1.4329	1.4289	1.4248	1.4209	1.4169	1.4091	1.4013	1.3936	1.3785	1.3637
54	1.4515	1.4431	1.4391	1.4350	1.4310	1.4270	1.4191	1.4113	1.4036	1.3884	1.3735
55	1.4619	1.4535	1.4494	1.4453	1.4412	1.4372	1.4293	1.4214	1.4137	1.3984	1.3834
56	1.4724	1.4640	1.4598	1.4557	1.4516	1.4475	1.4396	1.4317	1.4239	1.4085	1.3934
57	1.4830	1.4746	1.4703	1.4662	1.4621	1.4580	1.4500	1.4420	1.4342	1.4187	1.4035
58	1.4937	1.4852	1.4809	1.4768	1.4726	1.4685	1.4604	1.4524	1.4446	1.4290	1.4137
59	1.5045	1.4959	1.4916	1.4875	1.4832	1.4791	1.4709	1.4629	1.4551	1.4393	1.4240
60	1.5154	1.5067	1.5024	1.4983	1.4940	1.4898	1.4816	1.4735	1.4656	1.4497	1.4344
61	1.5264	1.5177	1.5133	1.5091	1.5048	1.5006	1.4923	1.4842	1.4762	1.4602	1.4449
62	1.5375	1.5287	1.5243	1.5200	1.5157	1.5115	1.5031	1.4950	1.4869	1.4708	1.4554
63	1.5487	1.5398	1.5354	1.5310	1.5267	1.5225	1.5140	1.5058	1.4977	1.4815	1.4660
64	1.5600	1.5510	1.5465	1.5421	1.5378	1.5335	1.5250	1.5167	1.5086	1.4923	1.4766

2-108 PHYSICAL AND CHEMICAL DATA

TABLE 2-101 Sulfuric Acid (H_2SO_4) (Concluded)

%	0°C	10°C	15°C	20°C	25°C	30°C	40°C	50°C	60°C	80°C	100°C
65	1.5714	1.5623	1.5578	1.5533	1.5490	1.5446	1.5361	1.5277	1.5195	1.5031	1.4873
66	1.5828	1.5736	1.5691	1.5646	1.5602	1.5558	1.5472	1.5388	1.5305	1.5140	1.4981
67	1.5943	1.5850	1.5805	1.5760	1.5715	1.5671	1.5584	1.5499	1.5416	1.5249	1.5089
68	1.6059	1.5965	1.5920	1.5874	1.5829	1.5785	1.5697	1.5611	1.5528	1.5359	1.5198
69	1.6176	1.6081	1.6035	1.5989	1.5944	1.5899	1.5811	1.5724	1.5640	1.5470	1.5307
70	1.6293	1.6198	1.6151	1.6105	1.6059	1.6014	1.5925	1.5838	1.5753	1.5582	1.5417
71	1.6411	1.6315	1.6268	1.6221	1.6175	1.6130	1.6040	1.5952	1.5867	1.5694	1.5527
72	1.6529	1.6433	1.6385	1.6338	1.6292	1.6246	1.6155	1.6067	1.5981	1.5806	1.5637
73	1.6648	1.6551	1.6503	1.6456	1.6409	1.6363	1.6271	1.6182	1.6095	1.5919	1.5747
74	1.6768	1.6670	1.6622	1.6574	1.6526	1.6480	1.6387	1.6297	1.6209	1.6031	1.5857
75	1.6888	1.6789	1.6740	1.6692	1.6644	1.6597	1.6503	1.6412	1.6322	1.6142	1.5966
76	1.7008	1.6908	1.6858	1.6810	1.6761	1.6713	1.6619	1.6526	1.6435	1.6252	1.6074
77	1.7128	1.7026	1.6976	1.6927	1.6878	1.6829	1.6734	1.6640	1.6547	1.6361	1.6181
78	1.7247	1.7144	1.7093	1.7043	1.6994	1.6944	1.6847	1.6751	1.6657	1.6469	1.6286
79	1.7365	1.7261	1.7209	1.7158	1.7108	1.7058	1.6959	1.6862	1.6766	1.6575	1.6390
80	1.7482	1.7376	1.7323	1.7272	1.7221	1.7170	1.7069	1.6971	1.6873	1.6680	1.6493
81	1.7597	1.7489	1.7435	1.7383	1.7331	1.7279	1.7177	1.7077	1.6978	1.6782	1.6594
82	1.7709	1.7599	1.7544	1.7491	1.7437	1.7385	1.7281	1.7180	1.7080	1.6882	1.6692
83	1.7815	1.7704	1.7649	1.7594	1.7540	1.7487	1.7382	1.7279	1.7179	1.6979	1.6787
84	1.7916	1.7804	1.7748	1.7693	1.7639	1.7585	1.7479	1.7375	1.7274	1.7072	1.6878
85	1.8009	1.7897	1.7841	1.7786	1.7732	1.7678	1.7571	1.7466	1.7364	1.7161	1.6966
86	1.8095	1.7983	1.7927	1.7872	1.7818	1.7763	1.7657	1.7552	1.7449	1.7245	1.7050
87	1.8173	1.8061	1.8006	1.7951	1.7897	1.7842	1.7736	1.7632	1.7529	1.7324	1.7129
88	1.8243	1.8132	1.8077	1.8022	1.7968	1.7914	1.7809	1.7705	1.7602	1.7397	1.7202
89	1.8306	1.8195	1.8141	1.8087	1.8033	1.7979	1.7874	1.7770	1.7669	1.7464	1.7269
90	1.8361	1.8252	1.8198	1.8144	1.8091	1.8038	1.7933	1.7829	1.7729	1.7525	1.7331
91	1.8410	1.8302	1.8248	1.8195	1.8142	1.8090	1.7986	1.7883	1.7783	1.7581	1.7388
92	1.8453	1.8346	1.8293	1.8240	1.8188	1.8136	1.8033	1.7932	1.7832	1.7633	1.7439
93	1.8490	1.8384	1.8331	1.8279	1.8227	1.8176	1.8074	1.7974	1.7876	1.7681	1.7485
94	1.8520	1.8415	1.8363	1.8312	1.8260	1.8210	1.8109	1.8011	1.7914		
95	1.8544	1.8439	1.8388	1.8337	1.8286	1.8236	1.8137	1.8040	1.7944		
96	1.8560	1.8457	1.8406	1.8355	1.8305	1.8255	1.8157	1.8060	1.7965		
97	1.8569	1.8466	1.8414	1.8364	1.8314	1.8264	1.8166	1.8071	1.7977		
98	1.8567	1.8463	1.8411	1.8361	1.8310	1.8261	1.8163	1.8068	1.7976		
99	1.8551	1.8445	1.8393	1.8342	1.8292	1.8242	1.8145	1.8050	1.7958		
100	1.8517	1.8409	1.8357	1.8305	1.8255	1.8205	1.8107	1.8013	1.7922		

%	$d_4^{9.96}$	%	$d_4^{13.00}$	$d_4^{8.00}$
0.005	1.000 0140	0.05	0.999 810	0.999 028
.01	1.000 0576	.1	1.000 185	.999 400
.02	1.000 1434	.2	1.000 912	1.000 119
.03	1.000 2276	.3	1.001 623	1.000 820
.04	1.000 3104	.4	1.002 326	1.001 512
.05	1.000 3920	.5	1.003 023	1.002 197
.06	1.000 4726	.6	1.003 716	1.002 877
.07	1.000 5523	.8	1.005 090	1.004 227
.08	1.000 6313	1.0	1.006 452	1.005 570
.09	1.000 7098	1.2	1.007 807	1.006 909
.10	1.000 7880	1.4	1.009 159	1.008 247
.15	1.001 1732	1.6	1.010 510	1.009 583
.20	1.001 5514	1.8	1.011 860	1.010 918
.25	1.001 9254	2.0	1.013 209	1.012 252
.30	1.002 2961	2.2	1.014 557	1.013 586
.35	1.002 6639	2.4	1.015 904	1.014 919
.40	1.003 0292			
.45	1.003 3923			
.50	1.003 7534			

TABLE 2-102 Zinc Bromide ($ZnBr_2$)

%	0°C	20°C	40°C	60°C	80°C	100°C
2	1.0188	1.0167	1.0102	1.0008	0.9890	0.9751
4	1.0381	1.0354	1.0285	1.0187	1.0065	0.9921
8	1.0777	1.0738	1.0660	1.0554	1.0422	1.0270
12	1.1186	1.1135	1.1046	1.0932	1.0789	1.0629
16	1.1609	1.1544	1.1445	1.1320	1.1169	1.1000
20	1.2043	1.1965	1.1855	1.1720	1.1560	1.1382
30	1.3288	1.3170	1.3030	1.2868	1.2688	1.2489
40	1.477	1.462	1.445	1.427	1.406	1.385
50	1.661	1.643	1.623	1.602	1.579	1.555
60	1.891	1.869	1.845	1.822	1.797	1.771
65	2.026	2.002	1.976	1.951	1.924	1.898

TABLE 2-103 Zinc Chloride ($ZnCl_2$)

%	0°C	20°C	40°C	60°C	80°C	100°C
2	1.0192	1.0167	1.0099	1.0003	0.9882	0.9739
4	1.0384	1.0350	1.0274	1.0172	1.0044	.9894
8	1.0769	1.0715	1.0624	1.0508	1.0369	1.0211
12	1.1159	1.1085	1.0980	1.0853	1.0704	1.0541
16	1.1558	1.1468	1.1350	1.1212	1.1055	1.0888
20	1.1970	1.1866	1.1736	1.1590	1.1428	1.1255
30	1.3062	1.2928	1.2778	1.2614	1.2438	1.2252
40	1.4329	1.4173	1.4003	1.3824	1.3637	1.3441
50	1.5860	1.5681	1.5495	1.5300	1.5097	1.4892
60		1.749				
70		1.962				

TABLE 2-104 Zinc Nitrate [$Zn(NO_3)_2$]

%	18°C	%	18°C
2	1.0154	18	1.1652
4	1.0322	20	1.1865
6	1.0496	25	1.2427
8	1.0675	30	1.3029
10	1.0859	35	1.3678
12	1.1048	40	1.4378
14	1.1244	45	1.5134
16	1.1445	50	1.5944

TABLE 2-105 Zinc Sulfate ($ZnSO_4$)

%	20°C
2	1.019
4	1.0403
6	1.0620
8	1.0842
10	1.1071
12	1.1308
14	1.1553
16	1.1806

DENSITIES OF AQUEOUS ORGANIC SOLUTIONS***UNITS AND UNITS CONVERSIONS**

Unless otherwise noted, densities are given in grams per cubic centimeter. To convert to pounds per cubic foot, multiply by 62.43.

$$^{\circ}\text{F} = \frac{\%}{5} \text{ }^{\circ}\text{C} + 32$$

From *International Critical Tables*, vol. 3, pp. 115–129. All compositions are in weight percent in vacuo. All density values are $d_i^v = \text{g/mL}$ in vacuo.

*For gasoline and aircraft fuels see Hibbard, NACA Res. Mem. E56I21 (declassified 1958).

TABLE 2-106 Formic Acid ($HCOOH$)

%	0°C	15°C	20°C	30°C	%	0°C	15°C	20°C	30°C	%	0°C	15°C	20°C	30°C	
0	0.9999	0.9991	0.9982	0.9957	25	1.0706	1.0627	1.0609	1.0540	50	1.1349	1.1225	1.1207	1.1098	
1	1.0028	1.0019	1.0019	0.9980	26	1.0733	1.0652	1.0633	1.0564	51	1.1374	1.1248	1.1223	1.1120	
2	1.0059	1.0045	1.0044	1.0004	27	1.0760	1.0678	1.0656	1.0587	52	1.1399	1.1271	1.1244	1.1142	
3	1.0090	1.0072	1.0070	1.0028	28	1.0787	1.0702	1.0681	1.0609	53	1.1424	1.1294	1.1269	1.1164	
4	1.0120	1.0100	1.0093	1.0053	29	1.0813	1.0726	1.0705	1.0632	54	1.1448	1.1318	1.1295	1.1186	
5	1.0150	1.0124	1.0115	1.0075	30	1.0839	1.0750	1.0729	1.0654	55	1.1472	1.1341	1.1320	1.1208	
6	1.0179	1.0151	1.0141	1.0101	31	1.0866	1.0774	1.0753	1.0676	56	1.1497	1.1365	1.1342	1.1230	
7	1.0207	1.0177	1.0170	1.0125	32	1.0891	1.0798	1.0777	1.0699	57	1.1523	1.1388	1.1361	1.1253	
8	1.0237	1.0204	1.0196	1.0149	33	1.0916	1.0821	1.0800	1.0721	58	1.1548	1.1411	1.1381	1.1274	
9	1.0266	1.0230	1.0221	1.0173	34	1.0941	1.0844	1.0823	1.0743	59	1.1573	1.1434	1.1401	1.1295	
10	1.0295	1.0256	1.0246	1.0197	35	1.0966	1.0867	1.0847	1.0766	60	1.1597	1.1458	1.1424	1.1317	
11	1.0324	1.0281	1.0271	1.0221	36	1.0993	1.0892	1.0871	1.0788	61	1.1621	1.1481	1.1448	1.1338	
12	1.0351	1.0306	1.0296	1.0244	37	1.1018	1.0916	1.0895	1.0810	62	1.1645	1.1504	1.1473	1.1360	
13	1.0379	1.0330	1.0321	1.0267	38	1.1043	1.0940	1.0919	1.0832	63	1.1669	1.1526	1.1493	1.1382	
14	1.0407	1.0355	1.0345	1.0290	39	1.1069	1.0964	1.0940	1.0854	64	1.1694	1.1549	1.1517	1.1403	
15	1.0435	1.0380	1.0370	1.0313	40	1.1095	1.0988	1.0963	1.0876	65	1.1718	1.1572	1.1543	1.1425	
16	1.0463	1.0405	1.0393	1.0336	41	1.1122	1.1012	1.0990	1.0898	66	1.1742	1.1595	1.1565	1.1446	
17	1.0491	1.0430	1.0417	1.0358	42	1.1148	1.1036	1.1015	1.0920	67	1.1766	1.1618	1.1584	1.1467	
18	1.0518	1.0455	1.0441	1.0381	43	1.1174	1.1060	1.1038	1.0943	68	1.1790	1.1640	1.1604	1.1489	
19	1.0545	1.0480	1.0464	1.0404	44	1.1199	1.1084	1.1062	1.0965	69	1.1813	1.1663	1.1628	1.1510	
20	1.0571	1.0505	1.0488	1.0427	45	1.1224	1.1109	1.1085	1.0987	70	1.1835	1.1685	1.1655	1.1531	
21	1.0598	1.0532	1.0512	1.0451	46	1.1249	1.1133	1.1108	1.1009	71	1.1858	1.1707	1.1677	1.1552	
22	1.0625	1.0556	1.0537	1.0473	47	1.1274	1.1156	1.1130	1.1031	72	1.1882	1.1729	1.1702	1.1573	
23	1.0652	1.0580	1.0561	1.0496	48	1.1299	1.1179	1.1157	1.1053	73	1.1906	1.1751	1.1728	1.1595	
24	1.0679	1.0604	1.0585	1.0518	49	1.1324	1.1202	1.1185	1.1076	74	1.1929	1.1773	1.1752	1.1615	
											99	1.2441	1.2257	1.2202	1.2073
											100	1.2456	1.2273	1.2212	1.2073

2-110 PHYSICAL AND CHEMICAL DATA

TABLE 2-107 Acetic Acid (CH_3COOH)

%	0°C	10°C	15°C	20°C	25°C	30°C	40°C	%	0°C	10°C	15°C	20°C	25°C	30°C	40°C
0	0.9999	0.9997	0.9991	0.9982	0.9971	0.9957	0.9922	50	1.0729	1.0654	1.0613	1.0575	1.0534	1.0492	1.0408
1	1.0016	1.0013	1.0006	.9996	.9987	.9971	.9934	51	1.0738	1.0663	1.0622	1.0582	1.0542	1.0499	1.0414
2	1.0033	1.0029	1.0021	1.0012	1.0000	.9984	.9946	52	1.0748	1.0671	1.0629	1.0590	1.0549	1.0506	1.0421
3	1.0051	1.0044	1.0036	1.0025	1.0013	.9997	.9958	53	1.0757	1.0679	1.0637	1.0597	1.0555	1.0512	1.0427
4	1.0070	1.0060	1.0051	1.0040	1.0027	1.0011	.9970	54	1.0765	1.0687	1.0644	1.0604	1.0562	1.0518	1.0432
5	1.0088	1.0076	1.0066	1.0055	1.0041	1.0024	.9982	55	1.0774	1.0694	1.0651	1.0611	1.0568	1.0525	1.0438
6	1.0106	1.0092	1.0081	1.0069	1.0055	1.0037	.9994	56	1.0782	1.0701	1.0658	1.0618	1.0574	1.0531	1.0443
7	1.0124	1.0108	1.0096	1.0083	1.0068	1.0050	1.0006	57	1.0790	1.0708	1.0665	1.0624	1.0580	1.0536	1.0448
8	1.0142	1.0124	1.0111	1.0097	1.0081	1.0063	1.0018	58	1.0798	1.0715	1.0672	1.0631	1.0586	1.0542	1.0453
9	1.0159	1.0140	1.0126	1.0111	1.0094	1.0076	1.0030	59	1.0805	1.0722	1.0678	1.0637	1.0592	1.0547	1.0458
10	1.0177	1.0156	1.0141	1.0125	1.0107	1.0089	1.0042	60	1.0813	1.0728	1.0684	1.0642	1.0597	1.0552	1.0462
11	1.0194	1.0171	1.0155	1.0139	1.0120	1.0102	1.0054	61	1.0820	1.0734	1.0690	1.0648	1.0602	1.0557	1.0466
12	1.0211	1.0187	1.0170	1.0154	1.0133	1.0115	1.0065	62	1.0826	1.0740	1.0696	1.0653	1.0607	1.0562	1.0470
13	1.0228	1.0202	1.0184	1.0168	1.0146	1.0127	1.0077	63	1.0833	1.0746	1.0701	1.0658	1.0612	1.0566	1.0473
14	1.0245	1.0217	1.0199	1.0182	1.0159	1.0139	1.0088	64	1.0838	1.0752	1.0706	1.0662	1.0616	1.0571	1.0477
15	1.0262	1.0232	1.0213	1.0195	1.0172	1.0151	1.0099	65	1.0844	1.0757	1.0711	1.0666	1.0621	1.0575	1.0480
16	1.0278	1.0247	1.0227	1.0209	1.0185	1.0163	1.0110	66	1.0850	1.0762	1.0716	1.0671	1.0624	1.0578	1.0483
17	1.0295	1.0262	1.0241	1.0223	1.0198	1.0175	1.0121	67	1.0856	1.0767	1.0720	1.0675	1.0628	1.0582	1.0486
18	1.0311	1.0276	1.0255	1.0236	1.0210	1.0187	1.0132	68	1.0860	1.0771	1.0725	1.0678	1.0631	1.0585	1.0489
19	1.0327	1.0291	1.0269	1.0250	1.0223	1.0198	1.0142	69	1.0865	1.0775	1.0729	1.0682	1.0634	1.0588	1.0491
20	1.0343	1.0305	1.0283	1.0263	1.0235	1.0210	1.0153	70	1.0869	1.0779	1.0732	1.0685	1.0637	1.0590	1.0493
21	1.0358	1.0319	1.0297	1.0276	1.0248	1.0222	1.0164	71	1.0874	1.0783	1.0736	1.0687	1.0640	1.0592	1.0495
22	1.0374	1.0333	1.0310	1.0288	1.0260	1.0233	1.0174	72	1.0877	1.0786	1.0738	1.0690	1.0642	1.0594	1.0496
23	1.0389	1.0347	1.0323	1.0301	1.0272	1.0244	1.0185	73	1.0881	1.0789	1.0741	1.0693	1.0644	1.0595	1.0497
24	1.0404	1.0361	1.0336	1.0313	1.0283	1.0256	1.0195	74	1.0884	1.0792	1.0743	1.0694	1.0645	1.0596	1.0498
25	1.0419	1.0375	1.0349	1.0326	1.0295	1.0267	1.0205	75	1.0887	1.0794	1.0745	1.0696	1.0647	1.0597	1.0499
26	1.0434	1.0388	1.0362	1.0338	1.0307	1.0278	1.0215	76	1.0889	1.0796	1.0746	1.0698	1.0648	1.0598	1.0499
27	1.0449	1.0401	1.0374	1.0349	1.0318	1.0289	1.0225	77	1.0891	1.0797	1.0747	1.0699	1.0648	1.0598	1.0499
28	1.0463	1.0414	1.0386	1.0361	1.0329	1.0299	1.0234	78	1.0893	1.0798	1.0747	1.0700	1.0648	1.0598	1.0498
29	1.0477	1.0427	1.0399	1.0372	1.0340	1.0310	1.0244	79	1.0894	1.0798	1.0747	1.0700	1.0648	1.0597	1.0497
30	1.0491	1.0440	1.0411	1.0384	1.0350	1.0320	1.0253	80	1.0895	1.0798	1.0747	1.0700	1.0647	1.0596	1.0495
31	1.0505	1.0453	1.0423	1.0395	1.0361	1.0330	1.0262	81	1.0895	1.0797	1.0745	1.0699	1.0646	1.0594	1.0493
32	1.0519	1.0465	1.0435	1.0406	1.0372	1.0341	1.0272	82	1.0895	1.0796	1.0743	1.0698	1.0644	1.0592	1.0490
33	1.0532	1.0477	1.0446	1.0417	1.0382	1.0351	1.0281	83	1.0895	1.0795	1.0741	1.0696	1.0642	1.0589	1.0487
34	1.0545	1.0489	1.0458	1.0428	1.0392	1.0361	1.0289	84	1.0893	1.0793	1.0738	1.0693	1.0638	1.0585	1.0483
35	1.0558	1.0501	1.0469	1.0438	1.0402	1.0371	1.0298	85	1.0891	1.0790	1.0735	1.0689	1.0635	1.0582	1.0479
36	1.0571	1.0513	1.0480	1.0449	1.0412	1.0380	1.0306	86	1.0887	1.0787	1.0731	1.0685	1.0630	1.0576	1.0473
37	1.0584	1.0524	1.0491	1.0459	1.0422	1.0390	1.0314	87	1.0883	1.0783	1.0726	1.0680	1.0626	1.0571	1.0467
38	1.0596	1.0535	1.0501	1.0469	1.0432	1.0399	1.0322	88	1.0877	1.0778	1.0721	1.0675	1.0620	1.0564	1.0460
39	1.0608	1.0546	1.0512	1.0479	1.0441	1.0408	1.0330	89	1.0872	1.0773	1.0715	1.0668	1.0613	1.0557	1.0453
40	1.0621	1.0557	1.0522	1.0488	1.0450	1.0416	1.0338	90	1.0865	1.0766	1.0708	1.0661	1.0605	1.0549	1.0445
41	1.0633	1.0568	1.0532	1.0498	1.0460	1.0425	1.0346	91	1.0857	1.0758	1.0700	1.0652	1.0597	1.0541	1.0436
42	1.0644	1.0578	1.0542	1.0507	1.0469	1.0433	1.0353	92	1.0848	1.0749	1.0690	1.0643	1.0587	1.0530	1.0426
43	1.0656	1.0588	1.0551	1.0516	1.0477	1.0441	1.0361	93	1.0838	1.0739	1.0680	1.0632	1.0577	1.0518	1.0414
44	1.0667	1.0598	1.0561	1.0525	1.0486	1.0449	1.0368	94	1.0826	1.0727	1.0667	1.0619	1.0564	1.0506	1.0401
45	1.0679	1.0608	1.0570	1.0534	1.0495	1.0456	1.0375	95	1.0813	1.0714	1.0652	1.0605	1.0551	1.0491	1.0386
46	1.0689	1.0618	1.0579	1.0542	1.0503	1.0464	1.0382	96	1.0798	1.0632	1.0588	1.0535	1.0473	1.0368	
47	1.0699	1.0627	1.0588	1.0551	1.0511	1.0471	1.0389	97	1.0780	1.0611	1.0570	1.0516	1.0454	1.0348	
48	1.0709	1.0636	1.0597	1.0559	1.0518	1.0479	1.0395	98	1.0759	1.0590	1.0549	1.0495	1.0431	1.0325	
49	1.0720	1.0645	1.0605	1.0567	1.0526	1.0486	1.0402	99	1.0730	1.0567	1.0524	1.0468	1.0407	1.0299	
								100	1.0697	1.0545	1.0498	1.0440	1.0380	1.0271	

TABLE 2-108 Oxalic Acid ($\text{H}_2\text{C}_2\text{O}_4$)

%	$d_4^{17.5}$	%	$d_4^{17.5}$
1	1.0035	8	1.0280
2	1.0070	10	1.0350
4	1.0140	12	1.0420

TABLE 2-109 Methyl Alcohol (CH_3OH)*

%	0°C	10°C	15.56°C	20°C	15°C	%	0°C	10°C	15.56°C	20°C	15°C	%	0°C	10°C	15.56°C	20°C	15°C
0	0.9999	0.9997	0.9990	0.9982	0.99913	35	0.9534	0.9484	0.9456	0.9433	0.94570	70	0.8869	0.8794	0.8748	0.8715	0.87507
1	.9981	.9980	.9973	.9965	.99727	36	.9520	.9469	.9440	.9416	.94404	71	.8847	.8770	.8726	.8690	.87271
2	.9963	.9962	.9955	.9948	.99543	37	.9505	.9453	.9422	.9398	.94237	72	.8824	.8747	.8702	.8665	.87033
3	.9946	.9945	.9938	.9931	.99370	38	.9490	.9437	.9405	.9381	.94067	73	.8801	.8724	.8678	.8641	.86792
4	.9930	.9929	.9921	.9914	.99198	39	.9475	.9420	.9387	.9363	.93894	74	.8778	.8699	.8653	.8616	.86546
5	.9914	.9912	.9904	.9896	.99029	40	.9459	.9403	.9369	.9345	.93720	75	.8754	.8676	.8629	.8592	.86300
6	.9899	.9896	.9889	.9880	.98864	41	.9443	.9387	.9351	.9327	.93543	76	.8729	.8651	.8604	.8567	.86051
7	.9884	.9881	.9872	.9863	.98701	42	.9427	.9370	.9333	.9309	.93365	77	.8705	.8626	.8579	.8542	.85801
8	.9870	.9865	.9857	.9847	.98547	43	.9411	.9352	.9315	.9290	.93185	78	.8680	.8602	.8554	.8518	.85551
9	.9856	.9849	.9841	.9831	.98394	44	.9395	.9334	.9297	.9272	.93001	79	.8657	.8577	.8529	.8494	.85300
10	.9842	.9834	.9826	.9815	.98241	45	.9377	.9316	.9279	.9252	.92815	80	.8634	.8551	.8503	.8469	.85048
11	.9829	.9820	.9811	.9799	.98093	46	.9360	.9298	.9261	.9234	.92627	81	.8610	.8527	.8478	.8446	.84794
12	.9816	.9805	.9796	.9784	.97945	47	.9342	.9279	.9242	.9214	.92436	82	.8585	.8501	.8452	.8420	.84536
13	.9804	.9791	.9781	.9768	.97802	48	.9324	.9260	.9223	.9196	.92242	83	.8560	.8475	.8426	.8394	.84274
14	.9792	.9778	.9766	.9754	.97660	49	.9306	.9240	.9204	.9176	.92048	84	.8535	.8449	.8400	.8366	.84009
15	.9780	.9764	.9752	.9740	.97518	50	.9287	.9221	.9185	.9156	.91852	85	.8510	.8422	.8374	.8340	.83742
16	.9769	.9751	.9738	.9725	.97377	51	.9269	.9202	.9166	.9135	.91653	86	.8483	.8394	.8347	.8314	.83475
17	.9758	.9739	.9723	.9710	.97237	52	.9250	.9152	.9146	.9114	.91451	87	.8456	.8367	.8320	.8286	.83207
18	.9747	.9726	.9709	.9696	.97096	53	.9230	.9162	.9126	.9094	.91248	88	.8428	.8340	.8294	.8258	.82937
19	.9736	.9713	.9695	.9681	.96955	54	.9211	.9142	.9106	.9073	.91044	89	.8400	.8314	.8267	.8230	.82667
20	.9725	.9700	.9680	.9666	.96814	55	.9191	.9122	.9086	.9052	.90839	90	.8374	.8287	.8239	.8202	.82396
21	.9714	.9687	.9666	.9651	.96673	56	.9172	.9101	.9065	.9032	.90631	91	.8347	.8261	.8212	.8174	.82124
22	.9702	.9673	.9652	.9636	.96533	57	.9151	.9080	.9045	.9010	.90421	92	.8320	.8234	.8185	.8146	.81849
23	.9690	.9660	.9638	.9622	.96392	58	.9131	.9060	.9024	.8988	.90210	93	.8293	.8208	.8157	.8118	.81568
24	.9678	.9646	.9624	.9607	.96251	59	.9111	.9039	.9002	.8968	.89996	94	.8266	.8180	.8129	.8090	.81285
25	.9666	.9632	.9609	.9592	.96108	60	.9090	.9018	.8980	.8946	.89781	95	.8240	.8152	.8101	.8062	.80999
26	.9654	.9618	.9595	.9576	.95963	61	.9068	.8998	.8958	.8924	.89563	96	.8212	.8124	.8073	.8034	.80713
27	.9642	.9604	.9580	.9562	.95817	62	.9046	.8977	.8936	.8902	.89341	97	.8186	.8096	.8045	.8005	.80428
28	.9629	.9590	.9565	.9546	.95668	63	.9024	.8955	.8913	.8879	.89117	98	.8158	.8068	.8016	.7976	.80143
29	.9616	.9575	.9550	.9531	.95518	64	.9002	.8933	.8890	.8856	.88890	99	.8130	.8040	.7987	.7948	.79859
30	.9604	.9560	.9535	.9515	.95366	65	.8980	.8911	.8867	.8834	.88662	100	.8102	.8009	.7959	.7917	.79577
31	.9590	.9546	.9521	.9499	.95213	66	.8958	.8888	.8844	.8811	.88433						
32	.9576	.9531	.9505	.9483	.95056	67	.8935	.8865	.8820	.8787	.88203						
33	.9563	.9516	.9489	.9466	.94896	68	.8913	.8842	.8797	.8763	.87971						
34	.9549	.9500	.9473	.9450	.94734	69	.8891	.8818	.8771	.8738	.87739						

* It should be noted that the values for 100 percent do not agree with some data available elsewhere, e.g., *American Institute of Physics Handbook*, McGraw-Hill, New York, 1957. Also, see Atack, *Handbook of Chemical Data*, Reinhold, New York, 1957.

2-112 PHYSICAL AND CHEMICAL DATA

TABLE 2-110 Ethyl Alcohol (C_2H_5OH)*

%	10°C	15°C	20°C	25°C	30°C	35°C	40°C	%	10°C	15°C	20°C	25°C	30°C	35°C	40°C
0	0.99973	0.99913	0.99823	0.99708	0.99568	0.99406	0.99225	50	0.92126	0.91776	0.91384	0.90985	0.90580	0.90168	0.89750
1	785	725	636	520	379	217	034	51	.91943	555	160	760	353	.89940	519
2	602	542	453	336	194	031	.98846	52	723	333	.90936	534	125	710	288
3	426	365	275	157	014	.98849	663	53	502	110	711	307	.89896	479	056
4	258	195	103	.98984	.98839	672	485	54	279	.90885	485	079	667	248	.88823
5	098	032	.98938	817	670	501	311	55	055	659	258	.89850	437	016	589
6	.98946	.98877	780	656	507	335	142	56	.90831	433	031	621	206	.88784	356
7	801	729	627	500	347	172	.97975	57	607	207	.89803	392	.88975	552	122
8	660	584	478	346	189	009	808	58	381	.89980	574	162	744	319	.87888
9	524	442	331	193	031	.97846	641	59	154	752	344	.88931	512	085	653
10	393	304	187	043	.97875	685	475	60	.89927	523	113	699	278	.87851	417
11	267	171	047	.97897	723	527	312	61	698	293	.88882	446	044	615	180
12	145	041	.97910	753	573	371	150	62	468	062	650	233	.87809	379	.86943
13	026	.97914	775	611	424	216	.96989	63	237	.88830	417	.87998	574	142	705
14	.97911	790	643	472	278	063	829	64	006	597	183	763	337	.86905	466
15	800	669	514	334	133	.96911	670	65	.88774	364	.87948	527	100	667	227
16	692	552	387	199	.96990	760	512	66	541	130	713	291	.86863	429	.85987
17	583	433	259	062	844	607	352	67	308	.87895	477	054	625	190	747
18	473	313	129	.96923	697	452	189	68	074	660	241	.86817	387	.85950	407
19	363	191	.96997	782	547	294	023	69	.87839	424	004	579	148	710	266
20	252	068	864	639	395	134	.95856	70	602	187	.86766	340	.85908	470	025
21	139	.96944	729	495	242	.95973	687	71	365	.86949	527	100	667	228	.84783
22	024	818	592	348	087	809	516	72	127	710	287	.85859	426	.84986	540
23	.96907	689	453	199	.95929	643	343	73	.86888	470	047	618	184	743	297
24	787	558	312	048	769	476	168	74	648	229	.85806	376	.84941	500	053
25	665	424	168	.95895	607	306	.94991	75	408	.85988	564	134	698	257	.83809
26	539	287	020	738	442	133	810	76	168	747	322	.84891	455	013	564
27	406	144	.95867	576	272	.94955	625	77	.85927	505	079	647	211	.83768	319
28	268	.95996	710	410	098	774	438	78	685	262	.84835	403	.83966	523	074
29	125	844	548	241	.94922	590	248	79	442	018	590	158	720	277	.82827
30	.95977	686	382	067	741	403	055	80	197	.84772	344	.83911	473	029	578
31	823	524	212	.94890	557	214	.93860	81	.84950	525	096	664	224	.82780	329
32	665	357	038	709	370	021	662	82	702	277	.83848	415	.82974	530	079
33	502	186	.94860	525	180	.93825	461	83	453	028	599	164	724	279	.81828
34	334	011	679	337	.93986	626	257	84	203	.83777	348	.82913	473	027	576
35	162	.94832	494	146	790	425	051	85	.83951	525	095	660	220	.81774	322
36	.94986	650	306	.93952	591	221	.92843	86	697	271	.82840	405	.81965	519	067
37	805	464	114	756	390	016	634	87	441	014	583	148	708	262	.80811
38	620	273	.93919	556	186	.92808	422	88	181	.82754	323	.81888	448	003	552
39	431	079	720	353	.92979	597	208	89	.82919	492	062	626	186	.80742	291
40	238	.93882	518	148	770	385	.91992	90	654	227	.81797	362	.80922	478	028
41	042	682	314	.92940	558	170	774	91	386	.81959	529	094	655	211	.79761
42	.93842	478	107	729	344	.91952	554	92	114	688	257	.80823	384	.79941	491
43	639	271	.92897	516	128	733	332	93	.81839	413	.80983	549	111	669	220
44	433	062	685	301	.91910	513	108	94	561	134	705	272	.79835	393	.78947
45	226	.92852	472	085	692	291	.90884	95	278	.80852	424	.79991	555	114	670
46	017	640	257	.91868	472	069	660	96	.80991	566	138	706	271	.78831	388
47	.92806	426	041	649	250	.90845	434	97	698	274	.79846	415	.78981	542	100
48	593	211	.91823	429	028	621	207	98	399	.79975	547	117	684	247	.77806
49	379	.91995	604	208	.90805	396	.89979	99	094	670	243	.78814	382	.77946	507
								100	.79784	360	.78934	506	075	641	203

*For data from -78° to 78° C, see p. 2-142, Table 2N-5, *American Institute of Physics Handbook*, McGraw-Hill, New York, 1957.

TABLE 2-111 Densities of Mixtures of C₂H₅OH and H₂O at 20°C

g/mL

% alcohol by weight	Tenths of %										% alcohol by weight	Tenths of %									
	0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
0	0.99823	804	785	766	748	729	710	692	673	655	50	0.91384	361	339	317	295	272	250	228	206	183
1	636	618	599	581	562	544	525	507	489	471	51	160	138	116	093	071	049	026	004	0981	*959
2	453	435	417	399	381	363	345	327	310	292	52	.90936	914	891	869	846	824	801	779	756	734
3	275	257	240	222	205	188	171	154	137	120	53	711	689	666	644	621	598	576	553	531	508
4	103	087	070	053	037	020	003	*987	*971	*954	54	485	463	440	417	395	372	349	327	304	281
5	.98938	922	906	890	874	859	843	827	811	796	55	258	236	213	190	167	145	122	099	076	054
6	780	765	749	734	718	703	688	673	658	642	56	031	008	*955	*962	*939	*917	*894	*871	*848	*825
7	627	612	597	582	567	553	538	523	508	493	57	.89803	780	757	734	711	688	665	643	620	597
8	478	463	449	434	419	404	389	374	360	345	58	574	551	528	505	482	459	436	413	390	367
9	331	316	301	287	273	258	244	229	215	201	59	344	321	298	275	252	229	206	183	160	137
10	187	172	158	144	130	117	103	089	075	061	60	113	090	067	044	021	*998	*975	*951	*928	*905
11	047	033	019	006	*992	*978	*964	*951	*937	*923	61	.88882	859	836	812	789	766	743	720	696	673
12	.97910	896	883	869	855	842	828	815	801	788	62	650	626	603	580	557	533	510	487	463	440
13	775	761	748	735	722	709	696	683	670	657	63	417	393	370	347	323	300	277	253	230	206
14	643	630	617	604	591	578	565	552	539	526	64	183	160	136	113	089	066	042	019	*995	*972
15	514	501	488	475	462	450	438	425	412	400	65	.87948	925	901	878	854	831	807	784	760	737
16	387	374	361	349	336	323	310	297	284	272	66	713	689	666	642	619	595	572	548	524	501
17	259	246	233	220	207	194	181	168	155	142	67	477	454	430	406	383	359	336	312	288	265
18	129	116	103	089	076	063	050	037	024	010	68	241	218	194	170	147	123	099	075	052	028
19	.96997	984	971	957	944	931	917	904	891	877	69	004	*981	*957	*933	*909	*885	*862	*838	*814	*790
20	864	850	837	823	810	796	783	769	756	742	70	.86766	742	718	694	671	647	623	599	575	551
21	729	716	702	688	675	661	647	634	620	606	71	527	503	479	455	431	407	383	359	335	311
22	592	578	564	551	537	523	509	495	481	467	72	287	263	239	215	191	167	143	119	095	071
23	453	439	425	411	396	382	368	354	340	326	73	047	022	*998	*974	*950	*926	*902	*878	*854	*830
24	312	297	283	269	254	240	225	211	196	182	74	.85806	781	757	733	709	685	661	636	612	588
25	168	153	139	124	109	094	080	065	050	035	75	564	540	515	491	467	443	419	394	370	346
26	020	005	*990	*975	*959	*944	*929	*914	*898	*883	76	322	297	273	249	225	200	176	152	128	103
27	.95867	851	836	820	805	789	773	757	742	726	77	079	055	031	006	*982	*958	*933	*909	*884	*860
28	710	694	678	662	646	630	613	597	581	565	78	.84835	811	787	762	738	713	689	664	640	615
29	548	532	516	499	483	466	450	433	416	400	79	590	566	541	517	492	467	443	418	393	369
30	382	365	349	332	315	298	281	264	247	230	80	344	319	294	270	245	220	196	171	146	121
31	212	195	178	161	143	126	108	091	074	056	81	096	072	047	022	*997	*972	*947	*923	*898	*873
32	038	020	003	*985	*967	*950	*932	*914	*896	*878	82	.83848	823	798	773	748	723	698	674	649	624
33	.94860	842	824	806	788	770	752	734	715	697	83	599	574	549	523	498	473	448	423	398	373
34	679	660	642	624	605	587	568	550	531	512	84	348	323	297	272	247	222	196	171	146	120
35	494	475	456	438	419	400	382	363	344	325	85	095	070	044	019	*994	*968	*943	*917	*892	*866
36	306	287	268	249	230	211	192	172	153	134	86	.82840	815	789	763	738	712	686	660	635	609
37	114	095	075	056	036	017	*997	*978	*958	*939	87	583	557	531	505	479	453	427	401	375	349
38	.93919	899	879	859	840	820	800	780	760	740	88	323	297	271	245	219	193	167	140	114	088
39	720	700	680	660	640	620	599	579	559	539	89	062	035	009	*983	*956	*930	*903	*877	*850	*824
40	518	498	478	458	437	417	396	376	356	335	90	.81797	770	744	717	690	664	637	610	583	556
41	314	294	273	253	232	212	191	170	149	129	91	529	502	475	448	421	394	366	339	312	285
42	107	086	065	044	023	002	*981	*960	*939	*918	92	257	230	203	175	148	120	093	066	038	010
43	.92897	876	855	834	812	791	770	749	728	707	93	.80983	955	928	900	872	844	817	789	761	733
44	685	664	642	621	600	579	557	536	515	493	94	705	677	649	621	593	565	537	509	480	452
45	472	450	429	408	386	365	343	322	300	279	95	424	395	367	338	310	281	253	224	195	166
46	257	236	214	193	171	150	128	106	085	063	96	138	109	080	051	022	*993	*963	*934	*905	*875
47	041	019	*997	*976	*954	*932	*910	*889	*867	*845	97	.79846	816	787	757	727	698	668	638	608	578
48	.91823	801	780	758	736	714	692	670	648	626	98	547	517	487	456	426	396	365	335	305	274
49	604	582	560	538	516	494	472	450	428	406	99	243	213	182	151	120	089	059	028	*997	*966
										100	.78934										

*Indicates change in the first two decimal places.

2-114 PHYSICAL AND CHEMICAL DATA

TABLE 2-112 Specific Gravity ($60^{\circ}/60^{\circ}\text{F}$ [$(15.56^{\circ}/15.56^{\circ}\text{C})$]) of Mixtures by Volume of $\text{C}_2\text{H}_5\text{OH}$ and H_2O

% alcohol by volume at 60°F	Tenths of %										% alcohol by volume at 60°F	Tenths of %											
	0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9		
0	1.00000	*985	*970	*955	*940	*925	*910	*895	*880	865	50	0.93426	407	387	368	348	328	309	289	270	250		
1	0.99850	835	820	806	791	776	761	747	732	717	51	230	210	190	171	151	131	111	091	071	051		
2	703	688	674	659	645	630	616	602	587	573	52	031	011	*991	*971	*951	*931	*911	*890	*870	*850		
3	559	545	531	516	502	488	474	460	446	432	53	.92830	810	789	769	749	728	708	688	667	647		
4	419	405	391	378	364	350	336	323	309	296	54	626	605	585	564	544	523	502	482	461	440		
5	282	269	255	242	228	215	202	189	176	163	55	419	398	377	357	336	315	294	273	252	231		
6	150	137	124	111	098	085	073	060	047	035	56	210	189	168	147	126	105	084	062	041	020		
7	022	009	*997	*984	*972	*960	*947	*935	*923	*911	57	.91999	978	956	935	914	892	871	849	827	806		
8	.98899	887	875	863	851	838	826	814	803	791	58	784	762	741	719	697	675	653	631	610	588		
9	779	767	755	743	731	720	708	696	684	672	59	565	543	521	499	477	455	433	410	388	366		
10	661	649	637	625	614	602	590	579	567	556	60	344	322	299	277	255	232	210	188	165	143		
11	544	532	521	509	498	487	475	464	452	441	61	120	097	075	052	030	007	*984	*962	*939	*916		
12	430	419	408	396	385	374	363	352	341	330	62	.90893	870	847	825	802	779	756	733	710	687		
13	319	308	297	286	275	264	254	243	232	221	63	664	641	618	595	572	549	526	503	480	457		
14	210	200	190	179	168	157	147	136	125	115	64	434	411	388	365	341	318	295	272	249	225		
15	104	093	083	072	062	051	040	030	019	009	65	202	179	155	132	108	085	061	038	014	*991		
16	.97998	988	977	967	956	946	936	925	915	905	66	.89967	943	920	896	872	848	825	801	777	753		
17	895	885	875	864	854	844	834	824	814	804	67	729	705	681	657	633	609	585	561	537	513		
18	794	784	774	764	754	744	734	724	714	704	68	489	465	441	416	392	368	343	319	295	270		
19	694	684	674	664	654	645	635	625	615	605	69	245	220	196	171	147	122	098	073	048	024		
20	596	586	576	566	556	546	536	526	516	506	70	.88999	974	950	925	900	875	850	825	801	776		
21	496	486	476	466	456	446	436	425	415	405	71	751	725	700	675	650	625	600	574	549	524		
22	395	385	375	365	354	344	334	324	313	303	72	499	474	448	423	397	372	346	321	296	270		
23	293	283	272	262	252	241	231	221	210	200	73	244	218	193	167	141	116	090	064	039	013		
24	189	179	168	158	147	137	126	116	105	095	74	.87987	961	935	910	884	858	832	806	780	754		
25	.084	073	063	052	042	031	020	010	*999	*988	75	728	702	676	650	623	597	571	545	518	492		
26	.96978	967	957	946	935	924	914	903	892	881	76	465	439	412	386	359	332	306	279	252	226		
27	870	859	848	837	826	815	804	793	782	771	77	199	172	145	118	092	065	038	011	*984	*957		
28	760	749	738	727	715	704	693	682	671	659	78	.86929	902	875	847	820	793	766	738	711	684		
29	648	637	625	614	603	591	580	568	557	546	79	656	629	601	574	546	518	491	463	435	408		
30	534	522	511	499	488	476	464	453	441	429	80	380	352	324	296	269	241	213	185	157	129		
31	418	406	394	382	370	358	346	334	321	309	81	100	072	044	015	*987	*959	*931	*902	*874	*846		
32	296	284	271	259	246	234	221	209	196	183	82	.85817	789	760	732	703	674	646	617	588	560		
33	170	157	144	132	119	106	093	080	067	054	83	531	502	473	444	415	386	357	328	299	270		
34	041	028	015	002	*988	*975	*962	*948	*935	*921	84	240	211	181	152	122	093	063	033	004	*974		
35	.95908	894	881	867	854	840	826	812	798	784	85	.84944	914	884	854	824	794	764	734	703	673		
36	770	756	742	728	714	700	685	671	657	643	86	642	612	581	551	520	490	459	428	398	367		
37	628	614	599	585	570	556	541	526	512	497	87	336	305	274	243	212	181	150	119	088	056		
38	482	467	452	437	423	408	393	378	362	347	88	025	*994	*962	*930	*899	*867	*835	*803	*771	*739		
39	332	317	302	286	271	256	240	225	209	194	89	.83707	675	643	610	578	545	513	480	447	415		
40	178	162	147	131	115	100	084	068	052	036	90	392	349	315	282	249	216	183	150	116	083		
41	020	004	*988	*972	*956	*940	*923	*907	*891	*875	91	049	015	*981	*947	*913	*879	*845	*810	*776	*741		
42	.94858	842	825	809	792	776	759	743	726	710	92	.82705	670	635	600	565	529	494	458	423	387		
43	693	676	660	643	626	609	592	575	558	541	93	351	315	279	243	206	170	133	096	059	022		
44	524	507	490	473	455	438	421	403	386	369	94	.81984	947	909	871	834	796	757	719	681	642		
45	351	334	316	298	281	263	245	228	210	192	95	603	564	525	486	446	407	367	327	287	247		
46	174	156	138	120	102	084	066	048	030	011	96	206	165	125	084	042	001	*960	*918	*876	*834		
47	.93993	975	956	938	920	901	883	864	845	827	97	.80792	750	707	664	620	577	533	489	445	401		
48	808	789	771	752	733	714	695	676	657	638	98	.79566	311	265	219	173	127	080	033	*955	*937		
49	619	600	581	562	543	523	504	485	465	446	99	.79889	841	792	743	693	643	593	543	492	441		
											100	389											

*Indicates change in first two decimal places.

TABLE 2-113 *n*-Propyl Alcohol (C_3H_7OH)

%	0°C	15°C	30°C	%	0°C	15°C	30°C												
0	0.9999	0.9991	0.9957	20	0.9789	0.9723	0.9643	40	0.9430	0.9331	0.9226	60	0.9033	0.8922	0.8807	80	0.8634	0.8516	0.8394
1	.9982	.9974	.9940	21	.9776	.9705	.9622	41	.9411	.9310	.9205	61	.9013	.8902	.8786	81	.8614	.8496	.8373
2	.9967	.9960	.9924	22	.9763	.9688	.9602	42	.9391	.9290	.9184	62	.8994	.8882	.8766	82	.8594	.8475	.8352
3	.9952	.9944	.9908	23	.9748	.9670	.9583	43	.9371	.9269	.9164	63	.8974	.8861	.8745	83	.8574	.8454	.8332
4	.9939	.9929	.9893	24	.9733	.9651	.9563	44	.9352	.9248	.9143	64	.8954	.8841	.8724	84	.8554	.8434	.8311
5	.9926	.9915	.9877	25	.9717	.9633	.9543	45	.9332	.9228	.9122	65	.8934	.8820	.8703	85	.8534	.8413	.8290
6	.9914	.9902	.9862	26	.9700	.9614	.9522	46	.9311	.9207	.9100	66	.8913	.8800	.8682	86	.8513	.8393	.8269
7	.9904	.9890	.9848	27	.9682	.9594	.9501	47	.9291	.9186	.9079	67	.8894	.8779	.8662	87	.8492	.8372	.8248
8	.9894	.9877	.9834	28	.9664	.9576	.9481	48	.9272	.9165	.9057	68	.8874	.8759	.8641	88	.8471	.8351	.8227
9	.9883	.9864	.9819	29	.9646	.9556	.9460	49	.9252	.9145	.9036	69	.8854	.8739	.8620	89	.8450	.8330	.8206
10	.9874	.9852	.9804	30	.9627	.9535	.9439	50	.9232	.9124	.9015	70	.8835	.8719	.8600	90	.8429	.8308	.8185
11	.9865	.9840	.9790	31	.9608	.9516	.9418	51	.9213	.9104	.8994	71	.8815	.8700	.8580	91	.8408	.8287	.8164
12	.9857	.9828	.9775	32	.9589	.9495	.9396	52	.9192	.9084	.8973	72	.8795	.8680	.8559	92	.8387	.8266	.8142
13	.9849	.9817	.9760	33	.9570	.9474	.9375	53	.9173	.9064	.8952	73	.8776	.8659	.8539	93	.8364	.8244	.8120
14	.9841	.9806	.9746	34	.9550	.9454	.9354	54	.9153	.9044	.8931	74	.8756	.8639	.8518	94	.8342	.8221	.8098
15	.9833	.9793	.9730	35	.9530	.9434	.9333	55	.9132	.9023	.8911	75	.8736	.8618	.8497	95	.8320	.8199	.8077
16	.9825	.9780	.9714	36	.9511	.9413	.9312	56	.9112	.9003	.8890	76	.8716	.8598	.8477	96	.8296	.8176	.8054
17	.9817	.9768	.9698	37	.9491	.9392	.9289	57	.9093	.8983	.8869	77	.8695	.8577	.8456	97	.8272	.8153	.8031
18	.9808	.9752	.9680	38	.9471	.9372	.9269	58	.9073	.8963	.8849	78	.8675	.8556	.8435	98	.8248	.8128	.8008
19	.9800	.9739	.9661	39	.9450	.9351	.9247	59	.9053	.8942	.8828	79	.8655	.8536	.8414	99	.8222	.8104	.7984
																100	.8194	.8077	.7958

TABLE 2-114 Isopropyl Alcohol (C_3H_7OH)

%	0°C	15°C°	15°C°	20°C	30°C	%	0°C	15°C°	15°C°	20°C	30°C	%	0°C	15°C°	15°C°	20°C	30°C		
0	0.9999	0.9991	0.99913	0.9982	0.9957	35	0.9557			0.9446	0.9419	0.9338	70	0.8761	0.8639	0.86346	0.8584	0.8511	
1	.9980	.9973	.9972	.9962	.9939	36	.9536			.9424	.9399	.9315	71	.8738	.8615	.8611	.8560	.8487	
2	.9962	.9956	.9954	.9944	.9921	37	.9514			.9401	.9377	.9292	72	.8714	.8592	.8588	.8537	.8464	
3	.9946	.9938	.9936	.9926	.9904	38	.9493			.9379	.9355	.9269	73	.8691	.8568	.8564	.8513	.8440	
4	.9930	.9922	.9920	.9909	.9887	39	.9472			.9356	.9333	.9246	74	.8668	.8545	.8541	.8489	.8416	
5	.9916	.9906	.9904	.9893	.9871	40	.9450			.93333	.9310	.9224	75	.8644	.8521	.8517	.8464	.8392	
6	.9902	.9892	.9890	.9877	.9855	41	.9428			.9311	.9287	.9201	76	.8621	.8497	.8493	.8439	.8368	
7	.9890	.9878	.9875	.9862	.9839	42	.9406			.9288	.9264	.9177	77	.8598	.8474	.8470	.8415	.8344	
8	.9878	.9864	.9862	.9847	.9824	43	.9384			.9266	.9239	.9154	78	.8575	.8450	.8446	.8391	.8321	
9	.9866	.9851	.9849	.9833	.9809	44	.9361			.9243	.9215	.9130	79	.8551	.8426	.8422	.8366	.8297	
10	.9856	.9838	.98362	.9820	.9794	45	.9338			.9220	.9191	.9106	80	.8528	.8403	.83979	.8342	.8273	
11	.9846	.9826	.9824	.9808	.9778	46	.9315			.9197	.9165	.9082	81	.8503	.8379	.8374	.8317	.8248	
12	.9838	.9813	.9812	.9797	.9764	47	.9292			.9174	.9141	.9059	82	.8479	.8355	.8350	.8292	.8224	
13	.9829	.9802	.9800	.9786	.9750	48	.9270			.9150	.9117	.9036	83	.8456	.8331	.8326	.8268	.8200	
14	.9821	.9790	.9788	.9776	.9735	49	.9247			.9127	.9093	.9013	84	.8432	.8307	.8302	.8243	.8175	
15	.9814	.9779	.9777	.9765	.9720	50	.9224			.91043	.9069	.8990	85	.8408	.8282	.8278	.8219	.8151	
16	.9806	.9768	.9765	.9754	.9705	51	.9201			.9081	.9044	.8966	86	.8384	.8259	.8254	.8194	.8127	
17	.9799	.9756	.9753	.9743	.9690	52	.9178			.9058	.9020	.8943	87	.8360	.8234	.8229	.8169	.8201	
18	.9792	.9745	.9741	.9731	.9675	53	.9155			.9035	.8996	.8919	88	.8336	.8209	.8205	.8145	.8078	
19	.9784	.9730	.9728	.9717	.9658	54	.9132			.9011	.8971	.8895	89	.8311	.8184	.8180	.8120	.8053	
20	.9777	.9719	.97158	.9703	.9642	55	.9109			.8988	.8946	.8871	90	.8287	.8161	.81553	.8096	.8029	
21	.9768	.9704	.9703	.9688	.9624	56	.9086			.8964	.8921	.8847	91	.8262	.8136	.8130	.8072	.8004	
22	.9759	.9690	.9689	.9669	.9606	57	.9063			.8940	.8896	.8823	92	.8237	.8110	.8104	.8047	.7979	
23	.9749	.9675	.9674	.9651	.9587	58	.9040			.8917	.8874	.8800	93	.8212	.8085	.8079	.8023	.7954	
24	.9739	.9660	.9659	.9634	.9569	59	.9017			.8893	.8850	.8777	94	.8186	.8060	.8052	.7998	.7929	
25	.9727	.9643	.9642	.9615	.9549	60	.8994			.88690	.8825	.8752	95	.8160	.8034	.8026	.7973	.7904	
26	.9714	.9626	.9624	.9597	.9529	61	.8970			.8845	.8800	.8728	96	.8133	.8008	.7999	.7949	.7878	
27	.9699	.9608	.9605	.9577	.9509	62	.8947			.8829	.8821	.8776	97	.8106	.7981	.7972	.7925	.7852	
28	.9684	.9590	.9586	.9558	.9488	63	.8924			.8805	.8798	.8751	98	.8078	.7954	.7945	.7901	.7826	
29	.9669	.9570	.9568	.9540	.9467	64	.8901			.8781	.8775	.8727	99	.8048	.7926	.7918	.7877	.7799	
30	.9652	.9551	.95493	.9520	.9446	65	.8878			.8757	.8752	.8702	100	.8631	.8016	.7896	.78913	.7854	.7770
31	.9634	.9530	.9500	.9426	.8854	66	.8854			.8733	.8728	.8679		.8607					
32	.9615	.9510	.9481	.9405	.8831	67	.8807			.8710	.8705	.8656		.8583					
33	.9596	.9489	.9460	.9383	.8807	68	.8686			.8652	.8632	.8559							
34	.9577	.9468	.9440	.9361	.8784	69	.8662			.8658	.8609	.8535							

*Two different observers; see *International Critical Tables*, vol. 3, p. 120.

TABLE 2-115 Glycerol*

Glycerol, %	Density					Glycerol, %	Density					Glycerol, %	Density				
	15°C	15.5°C	20°C	25°C	30°C		15°C	15.5°C	20°C	25°C	30°C		15°C	15.5°C	20°C	25°C	30°C
100	1.26415	1.26381	1.26108	1.15802	1.25495	65	1.17030	1.17000	1.16750	1.16475	1.16195	30	1.07455	1.07435	1.07270	1.07070	1.06855
99	1.26160	1.26125	1.25850	1.25545	1.25235	64	1.16755	1.16725	1.16475	1.16200	1.15925	29	1.07195	1.07175	1.07010	1.06815	1.06605
98	1.25900	1.25865	1.25590	1.25290	1.24975	63	1.16480	1.16445	1.16205	1.15925	1.15650	28	1.06935	1.06915	1.06755	1.06560	1.06355
97	1.25645	1.25610	1.25335	1.25030	1.24710	62	1.16200	1.16170	1.15930	1.15655	1.15375	27	1.06670	1.06655	1.06495	1.06305	1.06105
96	1.25385	1.25350	1.25080	1.24770	1.24450	61	1.15925	1.15895	1.15655	1.15380	1.15100	26	1.06410	1.06390	1.06240	1.06055	1.05855
95	1.25130	1.25095	1.24825	1.24515	1.24190	60	1.15650	1.15615	1.15380	1.15105	1.14830	25	1.06150	1.06130	1.05980	1.05800	1.05605
94	1.24865	1.24830	1.24560	1.24250	1.23930	59	1.15370	1.15340	1.15105	1.14835	1.14555	24	1.05885	1.05870	1.05720	1.05545	1.05350
93	1.24600	1.24565	1.24300	1.23985	1.23670	58	1.15095	1.15065	1.14830	1.14560	1.14285	23	1.05625	1.05610	1.05465	1.05290	1.05100
92	1.24340	1.24305	1.24035	1.23725	1.23410	57	1.14815	1.14785	1.14555	1.14285	1.14010	22	1.05365	1.05350	1.05205	1.05035	1.04850
91	1.24075	1.24040	1.23770	1.23460	1.23150	56	1.14535	1.14510	1.14280	1.14015	1.13740	21	1.05100	1.05090	1.04950	1.04780	1.04600
90	1.23810	1.23775	1.23510	1.23200	1.22890	55	1.14260	1.14230	1.14005	1.13740	1.13470	20	1.04840	1.04825	1.04690	1.04525	1.04350
89	1.23545	1.23510	1.23245	1.22935	1.22625	54	1.13980	1.13955	1.13730	1.13465	1.13195	19	1.04590	1.04575	1.04440	1.04280	1.04105
88	1.23280	1.23245	1.22975	1.22665	1.22360	53	1.13705	1.13680	1.13455	1.13195	1.12925	18	1.04335	1.04325	1.04195	1.04035	1.03860
87	1.23015	1.22980	1.22710	1.22400	1.22095	52	1.13425	1.13400	1.13180	1.12920	1.12650	17	1.04085	1.04075	1.03945	1.03790	1.03615
86	1.22750	1.22710	1.22445	1.22135	1.21830	51	1.13150	1.13125	1.12905	1.12650	1.12380	16	1.03835	1.03825	1.03695	1.03545	1.03370
85	1.22485	1.22445	1.22180	1.21870	1.21565	50	1.12870	1.12845	1.12630	1.12375	1.12110	15	1.03580	1.03570	1.03450	1.03300	1.03130
84	1.22220	1.22180	1.21915	1.21605	1.21300	49	1.12600	1.12575	1.12360	1.12110	1.11845	14	1.03330	1.03320	1.03200	1.03055	1.02885
83	1.21955	1.21915	1.21650	1.21340	1.21035	48	1.12325	1.12305	1.12090	1.11840	1.11580	13	1.03080	1.03070	1.02955	1.02805	1.02640
82	1.21690	1.21650	1.21380	1.21075	1.20770	47	1.12055	1.12030	1.11820	1.11575	1.11320	12	1.02830	1.02820	1.02705	1.02560	1.02395
81	1.21425	1.21385	1.21115	1.20810	1.20505	46	1.11780	1.11760	1.11550	1.11310	1.11055	11	1.02575	1.02565	1.02455	1.02315	1.02150
80	1.21160	1.21120	1.20850	1.20545	1.20240	45	1.11510	1.11490	1.11280	1.11040	1.10795	10	1.02325	1.02315	1.02210	1.02070	1.01905
79	1.20855	1.20845	1.20575	1.20275	1.19970	44	1.11235	1.11215	1.11010	1.10775	1.10530	9	1.02085	1.02075	1.01970	1.01835	1.01670
78	1.20610	1.20570	1.20305	1.20005	1.19705	43	1.10960	1.10945	1.10740	1.10510	1.10265	8	1.01840	1.01835	1.01730	1.01600	1.01440
77	1.20335	1.20300	1.19735	1.19435	1.19170	42	1.10690	1.10670	1.10470	1.10240	1.10005	7	1.01600	1.01590	1.01495	1.01360	1.01205
76	1.20060	1.20025	1.19760	1.19465	1.19170	41	1.10415	1.10400	1.10200	1.09975	1.09740	6	1.01360	1.01350	1.01255	1.01125	1.00970
75	1.19785	1.19750	1.19485	1.19195	1.18900	40	1.10145	1.10130	1.09930	1.09710	1.09475	5	1.01120	1.01110	1.01015	1.00890	1.00735
74	1.19510	1.19480	1.19215	1.18925	1.18635	39	1.09875	1.09860	1.09665	1.09445	1.09215	4	1.00875	1.00870	1.00780	1.00655	1.00505
73	1.19235	1.19205	1.18940	1.18650	1.18365	38	1.09605	1.09590	1.09400	1.09180	1.08955	3	1.00635	1.00630	1.00540	1.00415	1.00270
72	1.18965	1.18930	1.18670	1.18380	1.18100	37	1.09340	1.09320	1.09135	1.08915	1.08690	2	1.00395	1.00385	1.00300	1.00180	1.00035
71	1.18690	1.18655	1.18395	1.18110	1.17830	36	1.09070	1.09050	1.08865	1.08655	1.08430	1	1.00155	1.00145	1.00060	0.99945	0.99800
70	1.18415	1.18385	1.18125	1.17840	1.17565	35	1.08800	1.08780	1.08600	1.08390	1.08165	0	0.99913	0.99905	0.99823	0.99708	0.99568
69	1.18135	1.18105	1.17850	1.17565	1.17290	34	1.08530	1.08515	1.08335	1.08125	1.07905						
68	1.17860	1.17830	1.17575	1.17295	1.17020	33	1.08265	1.08245	1.08070	1.07860	1.07645						
67	1.17585	1.17555	1.17300	1.17020	1.16745	32	1.07995	1.07975	1.07800	1.07600	1.07380						
66	1.17305	1.17275	1.17025	1.16745	1.16470	31	1.07725	1.07705	1.07535	1.07335	1.07120						

*Bosart and Snoddy, *Ind. Eng. Chem.*, **20**, (1928): 1378.TABLE 2-116 Hydrazine (N_2H_4)

%	d_4^{l5}	%	d_4^{l5}
1	1.0002	30	1.0305
2	1.0013	40	1.038
4	1.0034	50	1.044
8	1.0077	60	1.047
12	1.0121	70	1.046
16	1.0164	80	1.040
20	1.0207	90	1.030
24	1.0248	100	1.011
28	1.0286		

TABLE 2-117 Densities of Aqueous Solutions of Miscellaneous Organic Compounds*

d (resp., d_w , d) = density of the solution (resp., water; resp., the pure liquid solute) in g/mL; p_s (resp., p_w) = wt % of solute (resp., water) in the solution; range = range of applicability of the equation.

Name	Formula	$t, ^\circ\text{C}$	Section A	$d = d_w + Ap_s + Bp_s^2 + Cp_s^3$	A	B	C
			Range, p_s				
Acetaldehyde	$\text{C}_2\text{H}_4\text{O}$	18	0– 30	+0.0255	-0.016		
Acetamide	$\text{C}_2\text{H}_5\text{NO}$	15	0– 6	+0.0639	+0.0171		
		0	0–100	-0.0856	-0.0449		
		4	0–100	-0.07648	-0.01193	+0.0272	
Acetone	$\text{C}_3\text{H}_6\text{O}$	15	0–100	-0.01009	-0.09682	-0.0624	
		20	0–100	-0.021233	-0.03529	-0.05327	
		25	0–100	-0.031171	-0.0904	-0.056	
Acetonitrile	$\text{C}_2\text{H}_3\text{N}$	15	0– 16	-0.021175	-0.02024		
Allyl alcohol	$\text{C}_3\text{H}_6\text{O}$	0	0– 89	-0.03729	-0.01232	+0.02984	
Benzenepentacarboxylic acid	$\text{C}_{11}\text{H}_4\text{O}_{10}$	25	0– 0.6	+0.02515	-0.0117		
Butyl alcohol (<i>n</i> -)	$\text{C}_4\text{H}_{10}\text{O}$	20	0– 7.9	-0.01651	+0.0285		
Butyric acid (<i>n</i> -)	$\text{C}_4\text{H}_8\text{O}_2$	18	0– 10	+0.0414	+0.0131		
		25	0– 62	+0.05135	-0.0166	+0.011	
Chloral hydrate	$\text{C}_2\text{H}_3\text{Cl}_3\text{O}_2$	15	0– 70	+0.04489	+0.02502	-0.01291	
		30	0– 90	+0.04455	+0.02198	+0.04366	
Chloroacetic acid	$\text{C}_2\text{H}_3\text{ClO}_2$	20	0– 32	+0.03648	+0.0302		
Citric acid (hydrate)	$\text{C}_6\text{H}_8\text{O}_7 + \text{H}_2\text{O}$	18	0– 50	+0.03824	+0.01141	+0.017	
Dichloroacetic acid	$\text{C}_2\text{H}_2\text{Cl}_2\text{O}_2$	20	0– 30	+0.04427	+0.0537	+0.07534	
		25	0– 97	+0.04427	+0.0537	+0.07534	
Diethylamine hydrochloride	$\text{C}_4\text{H}_{12}\text{ClN}$	21	0– 36	+0.034	+0.076		
Ethylamine hydrochloride	$\text{C}_2\text{H}_5\text{ClN}$	21	0– 65	+0.01193	-0.0307	-0.047	
Ethylene glycol	$\text{C}_2\text{H}_6\text{O}_2$	0	0–100	+0.02483	+0.02992	-0.05248	
		15	0– 6	+0.02133	-0.0108		
Ethyl ether	$\text{C}_4\text{H}_{10}\text{O}$	20	0– 5	-0.0221	+0.048		
tartrate	$\text{C}_8\text{H}_{14}\text{O}_6$	15	0– 95	+0.02367	+0.0358	-0.06005	
Formaldehyde	CH_2O	15	0– 40	+0.02518	-0.0658	+0.0542	
Formamide	CH_3NO	25	22– 96	+0.021217	+0.03199	-0.02529	
Furfural	$\text{C}_5\text{H}_4\text{O}_2$	20	0– 8	+0.01827	+0.0366		
Isoamyl alcohol	$\text{C}_5\text{H}_{12}\text{O}$	20	0– 2.5	+0.01664	+0.021		
Isobutyl alcohol	$\text{C}_4\text{H}_{10}\text{O}$	15	0– 8	+0.0155	+0.03		
		20	0– 8	-0.0146	+0.056		
Isobutyric acid	$\text{C}_4\text{H}_8\text{O}_2$	15	0– 9	+0.0169	+0.038		
		18	0– 9	+0.052			
		25	0– 12	+0.045			
Isovaleric acid	$\text{C}_5\text{H}_{10}\text{O}_2$	25	0– 5	+0.0253	-0.0282		
Lactic acid	$\text{C}_3\text{H}_6\text{O}$	25	0– 9	+0.0231	+0.0186		
Maleic acid	$\text{C}_4\text{H}_4\text{O}_4$	25	0– 40	+0.0234	+0.0575		
Malic acid	$\text{C}_4\text{H}_6\text{O}_5$	20	0– 40	+0.03933	+0.0957		
Malonic acid	$\text{C}_3\text{H}_4\text{O}_4$	20	0– 40	+0.03736	+0.0175		
Methyl acetate	$\text{C}_3\text{H}_6\text{O}_2$	20	0– 20	+0.0389	+0.01066		
glucoside (α -)	$\text{C}_7\text{H}_{14}\text{O}_6$	0	26– 51	+0.03336	+0.0996	+0.01544	
Nicotine	$\text{C}_{10}\text{H}_{14}\text{N}_2$	20	0– 60	+0.03151	+0.0975	+0.0978	
Nitrophenol (<i>p</i> -)	$\text{C}_6\text{H}_5\text{NO}_3$	15	0– 1.5	+0.03216	+0.0454	-0.0687	
		0	0– 4	+0.05898	-0.03185	+0.041	
Oxalic acid	$\text{C}_2\text{H}_2\text{O}_4$	15	0– 4	+0.0494	-0.058		
		20	0– 4	+0.05264	-0.01996	+0.0254	
		25	0– 4	+0.05108	-0.01607	+0.0208	
Phenol	$\text{C}_6\text{H}_6\text{O}$	15	0– 5	+0.02111	-0.0283		
Phenylglycolic acid	$\text{C}_8\text{H}_8\text{O}_3$	25	0– 11	+0.0462	-0.086		
Picoline (α -)	$\text{C}_6\text{H}_7\text{N}$	25	0– 70	+0.0207	+0.023		
(β -)	$\text{C}_6\text{H}_7\text{N}$	25	0– 60	-0.0386	-0.01405	-0.04167	
Propionic acid	$\text{C}_3\text{H}_6\text{O}_2$	18	0– 10	+0.095	-0.0172		
		25	0– 40	+0.09245	-0.099	+0.0361	
Pyridine	$\text{C}_5\text{H}_5\text{N}$	25	0– 60	+0.0229	-0.0204	-0.028	
Resorcinol	$\text{C}_6\text{H}_6\text{O}_2$	18	0– 52	+0.0201	+0.0519	-0.019	
Succinic acid	$\text{C}_4\text{H}_6\text{O}_4$	25	0– 5.5	+0.0304			
Tartaric acid (<i>d</i> , <i>l</i> , or <i>dl</i>)	$\text{C}_4\text{H}_6\text{O}_6$	15	0– 15	+0.04482	+0.0485		
		17.5	0– 50	+0.04455	+0.0485		
		20	0– 50	+0.04432	+0.04837		
		30	0– 50	+0.04335	+0.0485		
		40	0– 50	+0.04265	+0.0485		
		50	0– 50	+0.04205	+0.0485		
		60	0– 50	+0.04155	+0.0485		

*From "International Critical Tables," vol. 3, pp. 111–114.

TABLE 2-117 Densities of Aqueous Solutions of Miscellaneous Organic Compounds (Concluded)

Section A $d = d_w + Ap_s + Bp_s^2 + Cp_s^3$ (Cont.)						
Name	Formula	$t, ^\circ\text{C}$	Range, p_s	A	B	C
Tetraethyl ammonium chloride	C ₈ H ₂₀ ClN	21	0– 63	+0.031884	+0.056	+0.0122
Thiourea	CH ₄ N ₂ S	15	0– 7	+0.02995	+0.0374	
Trichloroacetic acid	C ₂ HCl ₃ O ₂	{ 12.5 20 25	0– 61 10– 30 0– 94	+0.02499 +0.05053 +0.02051	+0.04153 +0.01387 +0.056119	+0.01038
Triethylamine hydrochloride	C ₆ H ₁₆ ClN	21	0– 54	+0.06	+0.0558	-0.069
Trimethyl carbinol	C ₄ H ₁₀ O	{ 20 25	0–100 0–100	-0.0117 -0.021286	-0.041908 -0.04176	+0.0957 +0.0887
Urea	CH ₄ N ₂ O	{ 14.8 18 20 25	0– 12 0– 51 0– 35 0– 10	+0.03213 +0.02718 +0.02702 +0.02728	+0.04802 +0.01552 +0.03712 +0.041817	+0.01216 +0.02573 -0.02285 +0.01379
Urethane	C ₃ H ₇ NO ₂	20	0– 56	+0.02178	-0.0245	-0.03437
Valeric acid (<i>n</i> -)	C ₅ H ₁₀ O ₂	25	0– 3	+0.0334	-0.0427	
Section B $d = d_s + Ap_w + Bp_w^2 + Cp_w^3$						
Name	Formula	d_s	$t, ^\circ\text{C}$	Range, p_w	A	B
Butyl alcohol (<i>n</i> -)	C ₄ H ₁₀ O	0.8097	20	0–20	+0.02103	-0.04113
Butyric acid (<i>n</i> -)	C ₄ H ₈ O ₂	0.9534	25	0–38	+0.021854	-0.02314
Ethyl ether	C ₄ H ₁₀ O	0.7077	25	0– 1.1	+0.034	+0.036
Isobutyl alcohol	C ₄ H ₁₀ O	{ 0.8170 0.8055	0	0–14 0–16	+0.02437 +0.0224	-0.04285 -0.0129
Isobutyric acid	C ₄ H ₈ O ₂	0.9425	26	0–80	+0.01808	-0.02358
Nicotine	C ₁₀ H ₁₄ N ₂	1.0093	20	0–40	+0.02199	-0.0331
Picoline (α -) (β -)	C ₆ H ₇ N	0.9404	25	0–30	+0.02715	-0.0393
Pyridine	C ₅ H ₅ N	0.9515	25	0–40	+0.021925	-0.0352
Trimethyl carbinol	C ₄ H ₁₀ O	0.9776	25	0–40	+0.031157	-0.0536
		0.7856	20	0–20	+0.02287	+0.0275
Section C $d_t = d_o + At + Bt^2$						
Name	Formula	p_s	d_o	Range, $^\circ\text{C}$	A	B
Allyl alcohol	C ₃ H ₆ O	76.60	0.9122	0–45	-0.038	-0.027
Butyl alcohol (<i>n</i> -)	C ₄ H ₁₀ O	80.95	0.8614	0–43	-0.037292	-0.075
Chloral hydrate	C ₂ H ₃ Cl ₃ O ₂	{ 2.00 10.00 5.00	1.0094 1.0476 1.0150	7–80 7–80 15–80	-0.02597 -0.07955 -0.032103	-0.04313 -0.04253 -0.02544
Ethyl tartrate	C ₇ H ₁₄ O ₆	{ 10.00 25.00	1.0270 1.0665	15–80 15–80	-0.032116 -0.03401	-0.02929 -0.023
Furfural	C ₅ H ₄ O ₂	{ 4.62 5.69 6.56 9.34	1.0125 1.0140 1.0155 1.0055	22–74 22–74 22–74 11–73	-0.03221 -0.03211 -0.03171	-0.0268 -0.0290 -0.03615
Pyridine	C ₅ H ₅ N	{ 21.20 29.50 40.40	1.0115 1.0145 1.0182	14–73 12–72 9–74	-0.0378 -0.0463 -0.03605	-0.0248 -0.0235 -0.0167

DENSITIES OF MISCELLANEOUS MATERIALS

TABLE 2-118 Approximate Specific Gravities and Densities of Miscellaneous Solids and Liquids*

Water at 4°C and normal atmospheric pressure taken as unity. For more detailed data on any material, see the section dealing with the properties of that material.

Substance	Sp. gr.	Aver. weight lb/ft ³	Substance	Sp. gr.	Aver. weight lb/ft ³	Substance	Sp. gr.	Aver. weight lb/ft ³
Metals, Alloys, Ores			Timber, Air-dry			Dry Rubble Masonry		
Aluminum, cast-hammered bronze	2.55–2.80 7.7	165 481	Apple, black	0.66–0.74 0.55	44 34	Granite, syenite, gneiss	1.9–2.3	130
Brass, cast-rolled	8.4–8.7	534	white	0.64–0.71	42	Limestone, marble	1.9–2.1	125
Bronze, 7.9 to 14% Sn phosphor	7.4–8.9 8.88	509 554	Birch, sweet, yellow	0.71–0.72	44	Sandstone, bluestone	1.8–1.9	110
Copper, cast-rolled ore, pyrites	8.8–8.95 4.1–4.3	556 262	Cedar, white, red	0.35	22	Brick Masonry		
German silver	8.58	536	Cherry, wild red	0.43	27	Hard brick	1.8–2.3	128
Gold, cast-hammered coin (U.S.)	19.25–19.35 17.18–17.2	1205 1073	Chestnut	0.48	30	Medium brick	1.6–2.0	112
Iridium	21.78–22.42	1383	Cypress	0.45–0.48	29	Soft brick	1.4–1.9	103
Iron, gray cast cast, pig wrought spiegeleisen	7.03–7.13 7.2 7.6–7.9 7.5	442 450 485 468	Elm, white	0.56	35	Sand-lime brick	1.4–2.2	112
ferro-silicon ore, hematite ore, limonite ore, magnetite slag	6.7–7.3 5.2 3.6–4.0 4.9–5.2 2.5–3.0	437 325 237 315 172	Fir, Douglas balsam	0.48–0.55 0.40	32 25	Concrete Masonry		
Lead ore, galena	11.34 7.3–7.6	710 465	Hemlock	0.45–0.50	29	Cement, stone, sand slag, etc.	2.2–2.4 1.9–2.3	144 130
Manganese ore, pyrolusite	7.42	475	Hickory	0.74–0.80	48	cinder, etc.	1.5–1.7	100
Mercury	3.7–4.6	259	Locust	0.67–0.77	45	Various Building Materials		
Monel metal, rolled Nickel	8.97 8.9	555 537	Mahogany	0.56–0.85	44	Ashes, cinders	0.64–0.72	40–45
Platinum, cast-hammered Silver, cast-hammered	21.5 10.4–10.6	1330 656	Maple, sugar white	0.68 0.53	43 33	Cement, Portland, loose	1.5	94
Steel, cold-drawn machine tool	7.83 7.80 7.70–7.73	489 487 481	Oak, chestnut live red, black	0.74 0.87 0.64–0.71	46 54 42	Lime, gypsum, loose Mortar, lime, set Portland cement	0.85–1.00 1.4–1.9 2.08–2.25	53–64 103 94–135
Tin, cast-hammered cassiterite	7.2–7.5	459	Southern white	0.61–0.67	38–42	Portland cement	3.1–3.2	196
Tungsten	6.4–7.0	418		0.43	27	Slags, bank slag bank screenings machine slag slag sand	1.1–1.2 1.5–1.9 1.5 0.8–0.9	67–72 98–117 96 49–55
Zinc, cast-rolled blonde	19.22 6.9–7.2 3.9–4.2	1200 440 253	Various Liquids			Earth, etc., Excavated		
Various Solids			Alcohol, ethyl (100%) methyl (100%) Acid, muriatic, 40% nitric, 91% sulfuric, 87%	0.789 0.796 1.20 1.50 1.80	49 50 75 94 112	Clay, dry damp plastic and gravel, dry Earth, dry, loose dry, packed moist, loose moist, packed mud, flowing mud, packed Riprap, limestone	1.0 1.76 1.6 1.2 1.5 1.3 1.6 1.7 1.8 1.3–1.4	63 110 100 76 95 78 96 108 115 80–85
Cereals, oats, bulk barley, bulk corn, rye, bulk wheat, bulk	0.51 0.62 0.73 0.77	26 39 45 48	Chloroform	1.500	95	Riprap, sandstone Riprap, shale Sand, gravel, dry, loose gravel, dry, packed gravel, wet	1.4 1.7 1.4–1.7 1.6–1.9	90 105 90–105 100–120
Cork	0.22–0.26	15	Ether	0.736	46	Excavations in Water		
Cotton, flax, hemp Fats	1.47–1.50 0.90–0.97	93 58	Lye, soda, 66%	1.70	106	Clay River mud Sand or gravel and clay	1.28 1.44 0.96	80 90 60
Flour, loose pressed	0.40–0.50 0.70–0.80	28 47	Oils, vegetable mineral, lubricants	0.91–0.94 0.88–0.94	58 57	Soil Stone riprap	1.00 1.12 1.00	65 70 65
Glass, common plate or crown crystal dint	2.40–2.80 2.45–2.72 2.90–3.00 3.2–4.7	162 161 184 247	Turpentine	0.861–0.867	54	Minerals		
Hay and straw, bales Leather	0.32 0.86–1.02	20 59	Water, 4°C max. density 100°C	1.0 0.9584	62.428 59.830	Asbestos Barytes Basalt Bauxite Bluestone	2.1–2.8 4.50 2.7–3.2 2.55 2.5–2.6	153 281 184 159 159
Paper Potatoes, piled Rubber, caoutchouc goods	0.70–1.15 0.67 0.92–0.96 1.0–2.0	58 44 59 94	ice snow, fresh fallen	0.88–0.92 0.125	56 8	Borax Chalk Clay, marl Dolomite Feldspar, orthoclase	1.7–1.8 1.8–2.8 1.8–2.6 2.9 2.5–2.7	109 143 137 181 162
Salt, granulated, piled Saltpeter Starch Sulfur Wool	0.77 1.07 1.53 1.93–2.07 1.32	48 67 96 125 82	Rubble Masonry Bluestone Granite, syenite, gneiss Limestone Marble Sandstone	2.2–2.5 2.2–2.5 2.3–2.6 2.0–2.7 2.3–2.7 1.9–2.5	147 153 153 147 156 137	Gneiss Granite Greenstone, trap Gypsum, alabaster Hornblende Limestone Marble Magnesite Phosphate rock, apatite Porphyry	2.7–2.9 2.6–2.7 2.8–3.2 2.3–2.8 3.0 2.1–2.86 2.6–2.86 3.0 3.2 2.6–2.9	175 165 187 159 187 155 170 187 200 172

*From Marks, *Mechanical Engineers' Handbook*, McGraw-Hill.

2-120 PHYSICAL AND CHEMICAL DATA

TABLE 2-118 Approximate Specific Gravities and Densities of Miscellaneous Solids and Liquids (Concluded)

Water at 4°C and normal atmospheric pressure taken as unity. For more detailed data on any material, see the section dealing with the properties of that material.

Substance	Sp. gr.	Aver. weight lb/ft ³	Substance	Sp. gr.	Aver. weight lb/ft ³	Substance	Sp. gr.	Aver. weight lb/ft ³
Minerals (Cont.)			Bituminous Substances			Bituminous Substances (Cont.)		
Pumice, natural	0.37–0.90	40	Asphaltum	1.1–1.5	81	Petroleum	0.87	54
Quartz, flint	2.5–2.8	165	Coal, anthracite	1.4–1.8	97	refined (kerosene)	0.78–0.82	50
Sandstone	2.0–2.6	143	bituminous	1.2–1.5	84	benzine	0.73–0.75	46
Serpentine	2.7–2.8	171	lignite	1.1–1.4	78	gasoline	0.70–0.75	45
Shale, slate	2.6–2.9	172	peat, turf, dry	0.65–0.85	47	Pitch	1.07–1.15	69
Soapstone, talc	2.6–2.8	169	charcoal, pine	0.28–0.44	23	Tar, bituminous	1.20	75
Syenite	2.6–2.7	165	charcoal, oak	0.47–0.57	33			
Stone, Quarried, Piled			coke	1.0–1.4	75	Coal and Coke, Piled		
Basalt, granite, gneiss	1.5	96	Graphite	1.64–2.7	135	Coal, anthracite	0.75–0.93	47–58
Greensfone, hornblende	1.7	107	Paraffin	0.87–0.91	56	bituminous, lignite	0.64–0.87	40–54
Limestone, marble, quartz	1.5	95				peat, turf	0.32–0.42	20–26
Sandstone	1.3	82				charcoal	0.16–0.23	10–14
Shale	1.5	92				coke	0.37–0.51	23–32

NOTE: To convert pounds per cubic foot to kilograms per cubic meter, multiply by 16.02. °F = % °C + 32.

TABLE 2-119 Density (kg/m³) of Selected Elements as a Function of Temperature

Temperature, K°	Element symbol												
	Al	Bef	Cr	Cu	Au	Ir	Fe	Pb	Mo	Ni	Pt	Ag	Zn†
50	2736	3650	7160	9019	19,490	22,600	7910	11,570	10,260	8960	21,570	10,620	7280
100	2732	3640	7155	9009	19,460	22,580	7900	11,520	10,260	8950	21,550	10,600	7260
150	2726	3630	7150	8992	19,420	22,560	7890	11,470	10,250	8940	21,530	10,575	7230
200	2719	3620	7145	8973	19,380	22,540	7880	11,430	10,250	8930	21,500	10,550	7200
250	2710	3610	7140	8951	19,340	22,520	7870	11,380	10,250	8910	21,470	10,520	7170
300	2701	3600	7135	8930	19,300	22,500	7860	11,330	10,240	8900	21,450	10,490	7135
400	2681	3580	7120	8885	19,210	22,450	7830	11,230	10,220	8860	21,380	10,430	7070
500	2661	3555	7110	8837	19,130	22,410	7800	11,130	10,210	8820	21,330	10,360	7000
600	2639	3530	7080	8787	19,040	22,360	7760	11,010	10,190	8780	21,270	10,300	6935
800	2591		7040	8686	18,860	22,250	7690	10,430	10,160	8690	21,140	10,160	6430
1000	2365	—	7000	8568	18,660	22,140	7650	10,190	10,120	8610	21,010	10,010	6260
1200	2305	—	6945	8458	18,440	22,030	7620	9,940	10,080	8510	20,870	9,850	
1400	2255	—	6890	7920	17,230	21,920	7520		10,040	8410	20,720	9,170	
1600		—	6760	7750	16,950	21,790	7420		10,000	8320	20,570	8,980	
1800		—	6700	7600		21,660	7320		9,950	7690	20,400		
2000		—		7460		21,510	7030		9,900	7450	20,220		

NOTE: Above the horizontal line the condensed phase is solid; below the line, it is liquid.

°R = % K.

†Polycrystalline form tabulated. Similar tables for an additional 45 elements appear in the *Handbook of Heat Transfer*, 2d ed., McGraw-Hill, New York, 1984.

SOLUBILITIES

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$^{\circ}\text{F} = \% ^{\circ}\text{C} + 32.$$

To convert cubic centimeters to cubic feet, multiply by 3.532×10^{-5} .

To convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

To convert grams per liter to pounds per cubic foot, multiply by 6.243×10^{-2} .

TABLE 2-120 Solubilities of Inorganic Compounds in Water at Various Temperatures*

This table shows the amount of anhydrous substance that is soluble in 100 g of water at the temperature in degrees Celsius as indicated; when the name is followed by †, the value is expressed in grams of substance in 100 cm³ of saturated solution. Solid phase gives the hydrated form in equilibrium with the saturated solution.

	Substance	Formula	Solid phase	0°C	10°C	20°C	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C	
1	Aluminum chloride sulfate	AlCl ₃ Al ₂ (SO ₄) ₃	6H ₂ O 18H ₂ O	31.2	33.5	36.4 7.74	40.4 10.94	46.1 14.88	52.2 20.10	59.2 26.70	66.1 116.8	73.0 126	80.8 135.6	89.0 145.6	1
3	Ammonium aluminum sulfate bicarbonate	(NH ₄) ₂ Al ₂ (SO ₄) ₄ NH ₄ HCO ₃	24H ₂ O	2.1	4.99	7.74	21	27						109.7 ¹⁵⁰	3
5	bromide	NH ₄ Br		11.9	15.8	21									4
6	chloride	NH ₄ Cl		60.6	68	75.5									6
7	chloroplatinate	(NH ₄) ₂ PtCl ₆		29.4	33.3	37.2									7
8	chromate	(NH ₄) ₂ CrO ₄				0.7									8
9	chromium sulfate	(NH ₄) ₂ Cr ₂ (SO ₄) ₄	24H ₂ O				10.78 ²⁵⁰								9
10	dichromate	(NH ₄) ₂ Cr ₂ O ₇						47.17							10
11	dihydrogen phosphate	NH ₄ H ₂ PO ₄					190 ^{14.50}	260 ³¹⁰							11
12	hydrogen phosphate	(NH ₄) ₂ HPO ₄					131 ¹⁵								12
13	iodide	NH ₄ I		154.2	163.2	172.3	181.4	190.5	199.6	208.9	218.7	228.8		250.3	13
14	magnesium phosphate	NH ₄ MgPO ₄	6H ₂ O	0.023		0.052		0.036	0.030	0.040	0.016	0.019			14
15	manganese phosphate	NH ₄ MnPO ₄	7H ₂ O			0		0	0	0	0.005	0.007			15
16	nitrate	NH ₄ NO ₃		118.3		192	241.8	297.0	344.0	421.0	499.0	580.0	740.0	871.0	16
17	oxalate	(NH ₄) ₂ C ₂ O ₄	1H ₂ O	2.2	3.1	4.4	5.9	8.0	10.3						17
18	perchlorate†	NH ₄ ClO ₄ †		11.56		20.85		30.58							18
19	persulfate	(NH ₄) ₂ S ₂ O ₈		58.2											19
20	sulfate	(NH ₄) ₂ SO ₄		70.6	73.0	75.4	78.0	81.0							20
21	thiocyanate	NH ₄ CNS		119.8	144	170	207.7								21
22	vanadate (meta)	NH ₄ VO ₃				0.48	0.84	1.32	1.78			3.05			22
23	Antimonous fluoride sulfide	SbF ₃ Sb ₂ S ₃		384.7		444.7	563.6								23
25	Arsenic oxide	As ₂ O ₅		59.5	62.1	65.8	69.5	71.2							25
26	Arsenious sulfide	As ₂ S ₃		5.17×10 ⁻⁵ at 18°											26
27	Barium acetate	Ba(C ₂ H ₃ O ₂) ₂	3H ₂ O	59	63	71									27
28	acetate	Ba(C ₂ H ₃ O ₂) ₂	1H ₂ O				75	79	77	74	74			75	28
29	carbonate	BaCO ₃			0.0016 ⁵⁰	0.0022 ¹⁵⁰	0.0024 at 24.2°								29
30	chlorate	Ba(ClO ₃) ₂	1H ₂ O	20.34	26.95	33.80	41.70	49.61	66.81	84.84					30
31	chloride	BaCl ₂	2H ₂ O	31.6	33.3	35.7	38.2	40.7	43.6	46.4	49.4	52.4			31
32	chromate	BaCrO ₄		0.0002	0.00028	0.00037	0.00046								32
33	hydroxide	Ba(OH) ₂	8H ₂ O	1.67	2.48	3.89	5.59	8.22	13.12	20.94					33
34	iodide	BaI ₂	6H ₂ O	170.2	185.7	203.1	219.6								34
35	iodide	BaI ₂	2H ₂ O					231.9		247.3		261.0			35
36	nitrate	Ba(NO ₃) ₂		5.0	7.0	9.2	11.6	14.2	17.1	20.3					36
37	nitrite	Ba(NO ₂) ₂	1H ₂ O			67.5									37
38	oxalate	BaC ₂ O ₄			0.0016 ⁵⁰	0.0022 ¹⁵⁰	0.0024 at 24.2°								38
39	perchlorate	Ba(ClO ₄) ₂	3H ₂ O	205.8		289.1		358.7	426.3	495.2					39
40	sulfate	BaSO ₄		1.15×10 ⁻⁴	2.0×10 ⁻⁴	2.4×10 ⁻⁴	2.85×10 ⁻⁴								40
41	Beryllium sulfate	BeSO ₄	6H ₂ O				52		60.67						41
42	sulfate	BeSO ₄	4H ₂ O				43.78	46.74		62					42
43	sulfate	BeSO ₄	2H ₂ O								83	100			43
44	Boric acid	H ₃ BO ₃		2.66	3.57	5.04	6.60	8.72	11.54	14.81	16.73	23.75	30.38	40.25	44
45	Boron oxide	B ₂ O ₃		1.1	1.5	2.2		4.0		6.2		9.5			45
46	Bromine	Br ₂		4.22	3.4	3.20	3.13								46
47	Cadmium chloride	CdCl ₂	4H ₂ O	97.59	125.1		132.1								47
48	chloride	CdCl ₂	2/4H ₂ O	90.01		135.1	134.5 1.7 ¹⁵⁰	135.3							48
49	chloride	CdCl ₂	1H ₂ O												49
50	cyanide	Cd(CN) ₂													50
51	hydroxide	Cd(OH) ₂						2.6×10 ⁻⁴ at 25°							51
52	sulfate	CdSO ₄		76.48	76.00	76.60		78.54		83.68		140.4			52
53	Calcium acetate	Ca(C ₂ H ₃ O ₂) ₂	2H ₂ O	37.4	36.0	34.7	33.8	33.2		32.7	33.5				53
54	acetate	Ca(C ₂ H ₃ O ₂) ₂	1H ₂ O								31.1	29.7			54

*By N. A. Lange. Abridged from "Table of Solubilities of Inorganic Compounds in Water at Various Temperatures" in Lange, *Handbook of Chemistry*, 10th ed., McGraw-Hill, New York, 1961. For tables of the solubility of gases in water at various temperatures, Atack (*Handbook of Chemical Data*, Reinhold, New York, 1957) gives values at closer temperature intervals, usually 1 or 5°C, than are tabulated here. For materials marked by †, additional data are given in tables subsequent to this one. For the solubility of various hydrocarbons in water at high pressures see *J. Chem. Eng. Data*, **4**, 212 (1959).

TABLE 2-120 Solubilities of Inorganic Compounds in Water at Various Temperatures (Continued)

	Substance	Formula	Solid phase	0°C	10°C	20°C	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C
1	Calcium bicarbonate chloride	$\text{Ca}(\text{HCO}_3)_2$ CaCl_2	$6\text{H}_2\text{O}$ $2\text{H}_2\text{O}$	16.15 59.5	65.0 74.5	16.60 102	0.0016 ¹⁸⁰ 0.0017 ²⁶⁰	0.141 0.128	17.05 0.116	17.50 0.106	141.7 0.094	147.0 0.085	152.7 0.077	159 159
3	chloride	CaCl_2	$2\text{H}_2\text{O}$							136.8				2
4	fluoride	CaF_2												3
5	hydroxide	$\text{Ca}(\text{OH})_2$												4
6	nitrate	$\text{Ca}(\text{NO}_3)_2$	$4\text{H}_2\text{O}$	0.185 102.0	0.176 115.3	0.165 129.3	0.153 152.6	0.141 195.9	0.128 237.5	0.116 281.5				5
7	nitrate	$\text{Ca}(\text{NO}_3)_2$	$3\text{H}_2\text{O}$											6
8	nitrate	$\text{Ca}(\text{NO}_3)_2$				76.68						358.7		7
9	nitrite	$\text{Ca}(\text{NO}_2)_2$	$4\text{H}_2\text{O}$											8
10	nitrite	$\text{Ca}(\text{NO}_2)_2$	$2\text{H}_2\text{O}$	42.07										9
11	oxalate	CaC_2O_4					6.7×10^{-4} at 13°	6.8×10^{-4} at 25°	9.5×10^{-4} at 50°	14×10^{-4} at 95°				10
12	sulfate	CaSO_4	$2\text{H}_2\text{O}$	0.1759	0.1928	0.2090	0.2097	0.2047	0.1966				0.1619	12
13	Carbon dioxide, 760 mm ‡	CO_2		0.3346	0.2318	0.1688	0.1257	0.0973	0.0761	0.0576			0	13
14	monoxide, 760 mm ‡	CO		0.0044	0.0035	0.0028	0.0024	0.0021	0.0018	0.0015	0.0013	0.0010	0.0006	14
15	Cesium chloride	CsCl		161.4	174.7	186.5	197.3	208.0	218.5	229.7	239.5	250.0	260.1	15
16	nitrate	CsNO_3		9.33	14.9	23.0	33.9	47.2	64.4	83.8	107.0	134.0	163.0	16
17	sulfate	Cs_2SO_4		167.1	173.1	178.7	184.1	189.9	194.9	199.9	205.0	210.3	214.9	17
18	Chlorine, 760 mm ‡	Cl_2		1.46	0.980	0.716	0.562	0.451	0.386	0.324	0.274	0.219	0	18
19	Chromic anhydride	CrO_3		164.9				174.0	182.1				217.5	19
20	Cuprio chloride	CuCl_2	$2\text{H}_2\text{O}$	70.7	73.76	77.0	80.34	83.8	87.44	91.2				20
21	nitrate	$\text{Cu}(\text{NO}_3)_2$	$6\text{H}_2\text{O}$	81.8	95.28	125.1								21
22	nitrate	$\text{Cu}(\text{NO}_3)_2$	$3\text{H}_2\text{O}$					159.8		178.8		207.8		22
23	sulfate	CuSO_4	$5\text{H}_2\text{O}$	14.3	17.4	20.7	25	28.5	33.3	40		55		23
24	sulfide	CuS				3.3×10^{-5} at 18°								24
25	Cuprous chloride	CuCl				1.52 ²⁵⁰								25
26	Ferric chloride	FeCl_3		74.4	81.9	91.8						525.8		26
27	Ferrous chloride	FeCl_2	$4\text{H}_2\text{O}$		64.5		73.0	77.3	82.5	88.7		100		27
28	chloride	FeCl_2										105.3	105.8	28
29	nitrate	$\text{Fe}(\text{NO}_3)_2$	$6\text{H}_2\text{O}$	71.02		83.8								29
30	sulfate	FeSO_4	$7\text{H}_2\text{O}$	15.65	20.51	26.5	32.9	40.2	48.6					30
31	sulfate	FeSO_4	$1\text{H}_2\text{O}$							165.6				31
32	Hydrobromic acid, 760 mm	HBr		221.2	210.3	198				171.5				32
33	Hydrochloric acid, 760 mm	HCl		82.3			67.3	63.3	59.6	56.1				33
34	Iodine	I_2				0.029	0.04	0.056	0.078					34
35	Lead acetate	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$	$3\text{H}_2\text{O}$			55.04 ²⁵⁰								35
36	bromide	PbBr_2		0.4554		0.85	1.15	1.53	1.94	2.36				36
37	carbonate	PbCO_3				0.00011								37
38	chloride	PbCl_2		0.6728		0.99	1.20	1.45	1.70	1.98				38
39	chromate	PbCrO_4				7 $\times 10^{-6}$								39
40	fluoride	PbF_2		0.060		0.064	0.068							40
41	nitrate	$\text{Pb}(\text{NO}_3)_2$		38.8	48.3	56.5	66	75	85	95		115		41
42	sulfate	PbSO_4		0.0028	0.0035	0.0041	0.0049	0.0056						42
43	Magnesium bromide	MgBr_2	$6\text{H}_2\text{O}$	91.0	94.5	96.5	99.2	101.6	104.1	107.5		113.7		43
44	chloride	MgCl_2	$6\text{H}_2\text{O}$	52.8	53.5	54.5		57.5		61.0		66.0		44
45	hydroxide	$\text{Mg}(\text{OH})_2$				0.0009 ¹⁸⁰								45
46	nitrate	$\text{Mg}(\text{NO}_3)_2$	$6\text{H}_2\text{O}$	66.55				84.74						46
47	sulfate	MgSO_4	$7\text{H}_2\text{O}$		30.9	35.5	40.8	45.6						47
48	sulfate	MgSO_4	$6\text{H}_2\text{O}$	40.8	42.2	44.5	45.3		50.4	53.5	59.5	64.2	69.0	48
49	sulfate	MgSO_4	$1\text{H}_2\text{O}$									62.9		49
50	Manganous sulfate	MnSO_4	$7\text{H}_2\text{O}$	53.23	60.01									50
51	sulfate	MnSO_4	$5\text{H}_2\text{O}$		59.5	62.9	67.76							51
52	sulfate	MnSO_4	$4\text{H}_2\text{O}$			64.5	66.44	68.8	72.6					52
53	sulfate	MnSO_4	$1\text{H}_2\text{O}$						58.17	55.0	52.0	48.0	42.5	53
54	Mercurous chloride	HgCl		0.00014		0.0002		0.0007						54
55	Molybdic oxide	MoO_3	$2\text{H}_2\text{O}$			0.138	0.264	0.476	0.687	1.206	2.055			55
56	Nickel chloride	NiCl_2	$6\text{H}_2\text{O}$	53.9	59.5	64.2	68.9	73.3	78.3	82.2	85.2			56
57	nitrate	$\text{Ni}(\text{NO}_3)_2$	$6\text{H}_2\text{O}$	79.58		96.31		122.2						57
58	nitrate	$\text{Ni}(\text{NO}_3)_2$	$3\text{H}_2\text{O}$							163.1	169.1		235.1	58
59	sulfate	NiSO_4	$7\text{H}_2\text{O}$	27.22	32		42.46							59
60	sulfate	NiSO_4	$6\text{H}_2\text{O}$					0.00440	50.15	54.80	59.44	63.17		60
61	Nitric oxide, 760 mm	NO		0.00984	0.00757	0.00618	0.00517		0.00440	0.00376	0.00267	0.00199	0.00114	61
62	Nitrous oxide	N_2O			0.1705	0.1211							0	62

1	Potassium acetate	KC ₂ H ₃ O ₂	1½H ₂ O	216.7	233.9	255.6	283.8	323.3	337.3	350	364.8	380.1	396.3	1
2	acetate	KC ₂ H ₃ O ₂	½H ₂ O											2
3	alum	K ₂ SO ₄ ·Al ₂ (SO ₄) ₃	24H ₂ O	3.0	4.0	5.9	8.39	11.70	17.00	24.75	40.0	71.0	109.0	3
4	bicarbonate	KHCO ₃		22.4	27.7	33.2	39.1	45.4		60.0				4
5	bisulfate	KHSO ₄				51.4		67.3						5
6	bitartrate	KHC ₄ H ₄ O ₆		36.3		0.53	0.90	1.32	1.83	2.46		4.6		6
7	carbonate	K ₂ CO ₃	2H ₂ O	0.32	0.40							121.6		5
8	chlorate	KClO ₃		105.5	108	110.5	113.7	116.9	121.2	126.8	133.1	139.8	147.5	7
9	chloride	KCl		3.3	5	7.4	10.5	14	19.3	24.5		38.5		8
10	chromate	K ₂ CrO ₄		27.6	31.0	34.0	37.0	40.0	42.6	45.5	48.3	51.1	54.0	9
11	dichromate	K ₂ Cr ₂ O ₇		58.2	60.0	61.7	63.4	65.2	66.8	68.6	70.4	72.1	73.9	10
12	ferricyanide	K ₃ Fe(CN) ₆		5	7	12	20	26	34	43	52	61	70	11
13	hydroxide	KOH	2H ₂ O	31	36	43	50	60		66			82.6 ¹⁰⁴	12
14	hydroxide	KOH	1H ₂ O	97	103	112	126							13
15	nitrate	KNO ₃		13.3	20.9	31.6	45.8	63.9	85.5	110.0	138	169	202	14
16	nitrite	KNO ₂		278.8		298.4		334.9					246	15
17	perchlorate	KClO ₄		0.75	1.05	1.80	2.6	4.4	6.5	9	11.8	14.8	18	17
18	permanganate	KMnO ₄		2.83	4.4	6.4	9.0	12.56	16.89	22.2			412.8	16
19	persulfate†	K ₂ S ₂ O ₈ †	†	1.62	2.60	4.49	7.19	9.89						19
20	sulfate	K ₂ SO ₄		7.35	9.22	11.11	12.97	14.76	16.50	18.17	19.75	21.4	22.8	20
21	thiocyanate	KCNS		177.0		217.5								21
22	Silver cyanide	AgCN				2.2 × 10 ⁻⁵								22
23	nitrate	AgNO ₃		122	170	222	300	376	455	525		669	952	23
24	sulfate	Ag ₂ SO ₄		0.573	0.695	0.796	0.888	0.979	1.08	1.15	1.22	1.30	1.36	24
25	Sodium acetate	NaC ₂ H ₃ O ₂	3H ₂ O	36.3	40.8	46.5	54.5	65.5	83	139				25
26	acetate	NaC ₂ H ₃ O ₂		119	121	123.5	126	129.5	134	139.5	146	153	161	26
27	bicarbonate	NaHCO ₃		6.9	8.15	9.6	11.1	12.7	14.45	16.4				27
28	carbonate	Na ₂ CO ₃	10H ₂ O	7	12.5	21.5	38.8							28
29	carbonate	Na ₂ CO ₃	1H ₂ O				50.5	48.5	46.4			45.8		29
30	chlorate	NaClO ₃		79	89	101	113	126	140	155	172	189	230	30
31	chloride	NaCl		35.7	35.8	36.0	36.3	36.6	37.0	37.3	37.8	38.4	39.0	31
32	chromate	Na ₂ CrO ₄	10H ₂ O	31.70	50.17	88.7		88.7	95.96	104	114.6			32
33	chromate	Na ₂ CrO ₄	4H ₂ O											33
34	chromate	Na ₂ CrO ₄										123.0	124.8	34
35	dichromate	Na ₂ Cr ₂ O ₇	2H ₂ O	163.0		177.8			244.8			316.7	376.2	35
36	dichromate	Na ₂ Cr ₂ O ₇											426.3	36
37	dihydrogen phosphate	NaH ₂ PO ₄	2H ₂ O	57.9	69.9	85.2	106.5	138.2						37
38	dihydrogen phosphate	NaH ₂ PO ₄	1H ₂ O						158.6					38
39	dihydrogen phosphate	NaH ₂ PO ₄								179.3	190.3	207.3	225.3	39
40	hydrogen arsenate	Na ₃ HAsO ₄	12H ₂ O	7.3	15.5	26.5	37	47		65		85		40
41	hydrogen phosphate	Na ₂ HPO ₄	12H ₂ O	1.67	3.6	7.7	20.8							41
42	hydrogen phosphate	Na ₂ HPO ₄	7H ₂ O				51.8							42
43	hydrogen phosphate	Na ₂ HPO ₄	2H ₂ O							80.2	82.9	88.1	92.4	43
44	hydrogen phosphate	Na ₂ HPO ₄												44
45	hydroxide	NaOH	4H ₂ O	42										45
46	hydroxide	NaOH	3½H ₂ O		51.5									46
47	hydroxide	NaOH	1H ₂ O			109	119	129	145	174				47
48	hydroxide	NaOH										313	347	48
49	nitrate	NaNO ₃		73	80	88	96	104	114	124		148		49
50	nitrite	NaNO ₂		72.1	78.0	84.5	91.6	98.4	104.1			132.6		50
51	oxalate	Na ₂ C ₂ O ₄				3.7							6.33	51
52	phosphate, tri-	Na ₃ PO ₄	12H ₂ O	1.5	4.1	11	20	31	43	55		81		52
53	pyrophosphate	Na ₂ P ₂ O ₇	10H ₂ O	3.16	3.95	6.23	9.95	13.50	17.45	21.83		30.04		53
54	sulfate	Na ₂ SO ₄	10H ₂ O	5.0	9.0	19.4	40.8							54
55	sulfate	Na ₂ SO ₄	7H ₂ O	19.5	30	44								55
56	sulfate	Na ₂ SO ₄						48.8	46.7	45.3		43.7		56
57	sulfide	Na ₂ S	9H ₂ O		15.42	18.8	22.5	28.5						57
58	sulfide	Na ₂ S	5½H ₂ O						39.82	42.69	45.73	51.40	59.23	58
59	sulfide	Na ₂ S	6H ₂ O						36.4	39.1	43.31	49.14	57.28	59
60	sulfite	Na ₂ SO ₃	7H ₂ O	13.9	20	26.9	36		28	28.2	28.8		28.3	60
61	sulfite	Na ₂ SO ₃								10.5	20.3			61
62	tetraborate	Na ₄ B ₄ O ₇	10H ₂ O	1.3	1.6	2.7	3.9					24.4	31.5	62
63	tetraborate	Na ₂ B ₄ O ₇	5H ₂ O											63
64	vanadate (meta)	NaVO ₃	2H ₂ O			15.3 ²⁵⁰		30.2			68.4		41	64

TABLE 2-120 Solubilities of Inorganic Compounds in Water at Various Temperatures (Concluded)

	Substance	Formula	Solid phase	0°C	10°C	20°C	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C
1	Sodium vanadate (meta)	NaVO ₃				21.10 ²⁵⁰								1
2	Stannous chloride	SnCl ₂		83.9		269.8 ¹⁵⁰								2
3	sulfate	SnSO ₄				19								3
4	Strontium acetate	Sr(C ₂ H ₃ O ₂) ₂	4H ₂ O	36.9	43.61									4
5	acetate	Sr(C ₂ H ₃ O ₂) ₂	½H ₂ O		42.95	41.6	39.5		37.35		36.24	36.10		5
6	chloride	SrCl ₂	6H ₂ O	43.5	47.7	52.9	58.7	65.3	72.4	81.8	85.9	90.5		6
7	chloride	SrCl ₂	2H ₂ O										100.8	7
8	nitrate	Sr(NO ₃) ₂	1H ₂ O	52.7		64.0				83.8	97.2			8
9	nitrate	Sr(NO ₃) ₂	4H ₂ O	40.1		70.5							130.4	9
10	nitrate	Sr(NO ₃) ₂					88.6	90.1		93.8	96	98	100	10
11	sulfate	SrSO ₄		0.0113			0.0114	0.0114						11
12	Sulfur dioxide, 760 mm †	SO ₂		22.83	16.21	11.29	7.81	5.41	4.5					12
13	Thallium sulfate	Tl ₂ SO ₄		2.70	3.70	4.87	6.16			9.21	10.92	12.74	14.61	13
14	Thorium sulfate	Th(SO ₄) ₂	9H ₂ O	0.74	0.98	1.38	1.995	2.998	5.22					14
15	sulfate	Th(SO ₄) ₂	8H ₂ O	1.0	1.25	1.62								15
16	sulfate	Th(SO ₄) ₂	6H ₂ O	1.50		1.90	2.45				6.64			16
17	sulfate	Th(SO ₄) ₂	4H ₂ O					4.04	2.54	1.63	1.09			17
18	Zinc chlorate	ZnClO ₃	6H ₂ O	145.0	152.5									18
19	chlorate	ZnClO ₃	4H ₂ O			200.3	209.2	223.2	273.1					19
20	nitrate	Zn(NO ₃) ₂	6H ₂ O	94.78		118.3								20
21	nitrate	Zn(NO ₃) ₂	3H ₂ O					206.9						21
22	sulfate	ZnSO ₄	7H ₂ O	41.9	47	54.4				70.1	76.8			22
23	sulfate	ZnSO ₄	6H ₂ O											23
24	sulfate	ZnSO ₄	1H ₂ O								86.6	83.7	80.8	24

2-124

The H in solubility tables (2-121 to 2-144) is the proportionality constant for the expression of Henry's law, $p = Hx$, where x = mole fraction of the solute in the liquid phase; p = partial pressure of the solute in the gas phase, expressed in atmospheres; and H = a proportionality constant expressed in units of atmospheres of solute pressure in the gas phase per unit concentration of the solute in the liquid phase. (The unit of concentration of the solute in the liquid phase is moles solute per mole solution.)

TABLE 2-121 Acetylene (C_2H_2)

$t, ^\circ C$	0	5	10	15	20	25	30
$10^{-3} \times H^\circ$	0.72	0.84	0.96	1.08	1.21	1.33	1.46

International Critical Tables, vol. 3, p. 260, McGraw-Hill, 1928.

$^\circ H$. See footnote for Table 2-122.

TABLE 2-122 Air

$t, ^\circ C$	0	5	10	15	20	25	30	35
$10^{-4} \times H^\circ$	4.32	4.88	5.49	6.07	6.64	7.20	7.71	8.23

$t, ^\circ C$	40	45	50	60	70	80	90	100
$10^{-4} \times H^\circ$	8.70	9.11	9.46	10.1	10.5	10.7	10.8	10.7

International Critical Tables, vol. 3, p. 257.

$^\circ H$ is calculated from the absorption coefficients of O_2 and N_2 , taking into consideration the correction for constant argon content.

TABLE 2-123 Ammonia (NH_3)

Weight NH_3 per 100 weights H_2O	Partial pressure of NH_3 , mm. Hg							
	0°C	10°C	20°C	25°C	30°C	40°C	50°C	60°C
100	947							
90	785							
80	636	987	1450		3300			
70	500	780	1170		2760			
60	380	600	945		2130			
50	275	439	686		1520			
40	190	301	470		719	1065		
30	119	190	298		454	692		
25	89.5	144	227		352	534	825	
20	64	103.5	166		260	395	596	834
15	42.7	70.1	114		179	273	405	583
10	25.1	41.8	69.6		110	167	247	361
7.5	17.7	29.9	50.0		79.7	120	179	261
5	11.2	19.1	31.7		51.0	76.5	115	165
4		16.1	24.9		40.1	60.8	91.1	129.2
3		11.3	18.2	23.5	29.6	45	67.1	94.3
2.5			15.0	19.4	24.4	(37.6) ^o	(55.7)	77.0
2			12.0	15.3	19.3	(30.0)	(44.5)	61.0
1.6				12.0	15.3	(24.1)	(35.5)	48.7
1.2					9.1	(18.3)	(26.7)	36.3
1.0					7.4	(15.4)	(22.2)	30.2
0.5					3.4			

^oExtrapolated values.

TABLE 2-124 Ammonia (NH_3)—Low Pressures

Weight NH_3 per 100 weights H_2O	0.105	0.244	0.32	0.38	0.576	0.751	1.02
Partial pressure NH_3 , mm. Hg, at 25°C	0.791	1.83	2.41	2.89	4.41	5.80	7.96
Weight NH_3 per 100 weights H_2O	1.31	1.53	1.71	1.98	2.11	2.58	2.75
Partial pressure NH_3 , mm. Hg, at 25°C	10.31	11.91	13.46	15.75	16.94	20.86	22.38

"Landolt-Börnstein Physikalische-chemische Tabellen," Eg. I, p. 303, 1927. Phase-equilibrium data for the binary system NH_3 - H_2O are given by Clifford and Hunter, *J. Phys. Chem.*, **37**, 101 (1933).

TABLE 2-125 Carbon Dioxide (CO_2)

Total pressure, atm	Weight of CO_2 per 100 weights of H_2O°								
	12°C	18°C	25°C	31.04°C	35°C	40°C	50°C	75°C	100°C
25	3.86		2.80	2.56	2.30	1.92	1.35	1.06	
50	7.03	6.33	5.38	4.77	4.39	4.02	3.41	2.49	2.01
75	7.18	6.69	6.17	5.80	5.51	5.10	4.45	3.37	2.82
100	7.27	6.72	6.28	5.97	5.76	5.50	5.07	4.07	3.49
150	7.59	7.07		6.25	6.03	5.81	5.47	4.86	4.49
200				6.48	6.29	6.28	5.76	5.27	5.08
300	7.86	7.35	7.54	7.27	7.06	6.89	6.58	6.30	5.84
400	8.12	7.77		7.65	7.51	7.26	7.58	7.43	7.61
500									
700									

^oIn the original, concentration is expressed in cubic centimeters of CO_2 (reduced to 0°C and 1 atm) dissolved in 1 g of water.

TABLE 2-126 Carbon Monoxide (CO)

Partial pressure of CO , mm Hg	10 ⁻⁴ $\times H$	
	17.7°C	19.0°C
900	4.77	4.88
2000	4.77	4.91
3000	4.77	4.93
4000	4.78	4.95
5000	4.80	4.97
6000	4.82	4.98
7000	4.86	5.02
8000	4.88	5.08

International Critical Tables, vol. 3, p. 260.

TABLE 2-127 Carbonyl Sulfide (CO_3)

t °C	0	5	10	15	20	25	30
$10^{-3} \times H$	0.92	1.17	1.48	1.82	2.19	2.59	3.04

International Critical Tables, vol. 3, p. 261.

TABLE 2-128 Chlorine (Cl_2)

Partial pressure of Cl_2 , mm Hg	Solubility, g of Cl_2 per liter					
	0°C	10°C	20°C	30°C	40°C	50°C
5	0.488	0.451	0.438	0.424	0.412	0.398
10	.679	.603	.575	.553	.532	.512
30	1.221	1.024	.937	.873	.821	.781
50	1.717	1.354	1.210	1.106	1.025	.962
100	2.79	2.08	1.773	1.573	1.424	1.313
150	3.81	2.73	2.27	1.966	1.754	1.599
200	4.78	3.35	2.74	2.34	2.05	1.856
250	5.71	3.95	3.19	2.69	2.34	2.09
300		4.54	3.63	3.03	2.61	2.31
350		5.13	4.06	3.35	2.86	2.53
400		5.71	4.48	3.69	3.11	2.74
450		6.26	4.88	3.98	3.36	2.94
500		6.85	5.29	4.30	3.61	3.14
550		7.39	5.71	4.60	3.84	3.33
600		7.97	6.12	4.91	4.08	3.52
650		8.52	6.52	5.21	4.32	3.71
700		9.09	6.90	5.50	4.54	3.89
750		9.65	7.29	5.80	4.77	4.07
800		10.21	7.69	6.08	4.99	4.27
900			8.46	6.68	5.44	4.62
1000			9.27	7.27	5.89	4.97
1200	Cl ₂ :8H ₂ O ₂ separates	10.84	8.42	6.81	5.67	
1500		13.23	10.14	8.05	6.70	
2000		17.07	13.02	10.22	8.38	
2500		21.0	15.84	12.32	10.03	
3000			18.73	14.47	11.70	
3500			21.7	16.62	13.38	
4000			24.7	18.84	15.04	
4500			27.7	20.7	16.75	
5000			30.8	23.3	18.46	

Partial pressure of Cl_2 , mm Hg	Solubility, g of Cl_2 per liter					
	60°C	70°C	80°C	90°C	100°C	110°C
5	0.383	0.369	0.351	0.339	0.326	0.316
10	.492	.470	.447	.431	.415	.402
30	.743	.704	.671	.642	.627	.598
50	.912	.863	.815	.781	.747	.722
100	1.228	1.149	1.085	1.034	.987	.950
150	1.482	1.382	1.294	1.227	1.174	1.137
200	1.706	1.580	1.479	1.396	1.333	1.276
250	1.914	1.764	1.642	1.553	1.480	1.413
300	2.10	1.932	1.793	1.700	1.610	1.542
350	2.28	2.10	1.940	1.831	1.736	1.661
400	2.47	2.25	2.08	1.965	1.854	1.773
450	2.64	2.41	2.22	2.09	1.972	1.880
500	2.80	2.55	2.35	2.21	2.08	1.986
550	2.97	2.69	2.47	2.32	2.19	2.09
600	3.13	2.83	2.59	2.43	2.29	2.19
650	3.29	2.97	2.72	2.55	2.41	2.28
700	3.44	3.10	2.84	2.66	2.50	2.37
750	3.59	3.23	2.96	2.76	2.60	2.47
800	3.75	3.37	3.08	2.87	2.69	2.56
900	4.04	3.63	3.30	3.08	2.89	2.74
1000	4.36	3.88	3.53	3.28	3.07	2.91
1200	4.92	4.37	3.95	3.67	3.43	3.25
1500	5.76	5.09	4.58	4.23	3.95	3.74
2000	7.14	6.26	5.63	5.17	4.78	4.49
2500	8.48	7.40	6.61	6.05	5.59	5.25
3000	9.83	8.52	7.54	6.92	6.38	5.97
3500	11.22	9.65	8.53	7.79	7.16	6.72
4000	12.54	10.76	9.52	8.65	7.94	7.42
4500	13.88	11.91	10.46	9.49	8.72	8.13
5000	15.26	13.01	11.42	10.35	9.48	8.84

TABLE 2-129 Chlorine Dioxide (ClO_2)

Vol % of ClO_2 in gas phase	Weight of ClO_2 , grams per liter of solution						
	0°C	5°C	10°C	15°C	20°C	30°C	40°C
1	2.00	1.50	1.25	1.00	0.90	0.60	0.46
3	6.00	4.7	3.85	3.20	2.70	1.95	1.30
5	10.0	7.8	6.30	5.25	4.30	3.20	2.25
7	14.0	10.9	8.95	7.35	6.15	4.40	3.20
10	20.0	15.5	12.8	10.5	8.80	6.30	4.50
11		17.0	14.0	11.7	9.70	7.00	5.00
12		18.6	15.3	12.8	10.55	7.50	5.45
13		20.3	16.6	13.8	11.5	8.20	5.85
14			18.0	14.9	12.3	8.80	6.35
15			19.2	16.0	13.2	9.50	6.80
16			20.3	17.0	14.2	10.1	7.20

Ishi, *Chem. Eng. (Japan)*, **22**, 153 (1958).**TABLE 2-130 Ethane (C_2H_6)**

t, °C	0	5	10	15	20	25	30	35
$10^{-4} \times H$	1.26	1.55	1.89	2.26	2.63	3.02	3.42	3.83
t, °C	40	45	50	60	70	80	90	100
$10^{-4} \times H$	4.23	4.63	5.00	5.65	6.23	6.61	6.87	6.92

International Critical Tables, vol. 3, p. 261.**TABLE 2-131 Ethylene (C_2H_4)**

t, °C	0	5	10	15	20	25	30
$10^{-3} \times H$	5.52	6.53	7.68	8.95	10.2	11.4	12.7

International Critical Tables, vol. 3, p. 260.**TABLE 2-132 Helium (He)**

t, °C	0	10	20	30	40	50
$10^{-4} \times H$	12.9	12.6	12.5	12.4	12.1	11.5

See also Pray, Schweickert, and Minnich, *Ind. Eng. Chem.*, **44**, 1146 (1952).**TABLE 2-133 Hydrogen (H_2)—Temperature**

t, °C	0	5	10	15	20	25	30	35
$10^{-4} \times H$	5.79	6.08	6.36	6.61	6.83	7.07	7.29	7.42

International Critical Tables, vol. 3, p. 256.See also Pray, Schweickert, and Minnich, *Ind. Eng. Chem.*, **44**, 1146 (1952).

TABLE 2-134 Hydrogen (H_2)—Pressure

Partial pressure H_2 , mm Hg	$10^{-4} \times H$	
	19.5°C	23°C
900	7.42	7.75
1100	7.42	7.76
2000	7.43	7.77
3000	7.47	7.81
4000	7.56	7.89
5000	7.70	8.00
6000	7.87	8.16
7000	8.17	8.41
8200		
8250		

International Critical Tables, vol. 3, p. 256.

TABLE 2-135 Hydrogen Chloride (HCl)

Weights of HCl per 100 weights of H_2O	Partial pressure of HCl, mm Hg			
	0°C	10°C	20°C	30°C
78.6	510	840	399	627
66.7	130	233	105.5	188
56.3	29.0	56.4	23.5	44.5
47.0	5.7	11.8	4.90	9.90
38.9	1.0	2.27	1.00	2.17
31.6	0.175	0.43	0.205	0.48
25.0	.0316	.084	.0428	.106
19.05	.0056	.016	.0088	.0234
13.64	.00099	.00305	.00178	.00515
8.70	.000118	.000553	.00024	.00077
4.17	.000018	.000069	.000044	.000151
2.04		.0000117		
Weights of HCl per 100 weights of H_2O	Partial pressure of HCl, mm Hg			
	50°C	80°C	110°C	
78.6				
66.7				
56.3	535			
47.0	141	623		
38.9	35.7	188	760	
31.6	8.9	54.5	253	
25.0	2.21	15.6	83	
19.05	0.55	4.66	28	
13.64	.136	1.34	9.3	
8.70	.0344	0.39	3.10	
4.17	.0064	.095	0.93	
2.04	.00140	.0245	.280	

Enthalpy and phase-equilibrium data for the binary system HCl-H₂O are given by Van Nuys, *Trans. Am. Inst. Chem. Engrs.*, **39**, 663 (1943).

TABLE 2-136 Hydrogen Sulfide (H_2S)

t, °C	0	5	10	15	20	25	30	35
$10^{-2} \times H$	2.68	3.15	3.67	4.23	4.83	5.45	6.09	6.76
t, °C	40	45	50	60	70	80	90	100
$10^{-2} \times H$	7.45	8.14	8.84	10.3	11.9	13.5	14.4	14.8

International Critical Tables, vol. 3, p. 259.

TABLE 2-137 Methane (CH_4)

t, °C	0	5	10	15	20	25	30	35
$10^{-4} \times H$	2.24	2.59	2.97	3.37	3.76	4.13	4.49	4.86
t, °C	40	45	50	60	70	80	90	100
$10^{-4} \times H$	5.20	5.51	5.77	6.26	6.66	6.82	6.92	7.01

International Critical Tables, vol. 3, p. 260.

TABLE 2-138 Nitrogen (N_2)—Temperature*

t, °C	0	5	10	15	20	25	30	35
$10^{-4} \times H$	5.29	5.97	6.68	7.38	8.04	8.65	9.24	9.85
t, °C	40	45	50	60	70	80	90	100
$10^{-4} \times H$	10.4	10.9	11.3	12.0	12.5	12.6	12.6	12.6

* International Critical Tables, vol. 3, p. 256. See also Pray, Schweickert, and Minnich, *Ind. Eng. Chem.*, **44**, 1146 (1952).

Atmospheric nitrogen = 98.815 vol. % N_2 + 1.185 vol. % A.

TABLE 2-139 Nitrogen (N_2)—Pressure

Partial pressure of N_2 , mm Hg	$10^{-4} \times H$	
	19.4°C	24.9°C
900	8.24	9.08
2000	8.32	9.15
3000	8.41	9.25
4000	8.49	9.38
5000	8.59	9.49
6000	8.74	9.62
7000	8.86	9.75
8100	9.04	
8200		9.91

See also Goodman and Kruse [Ind. Eng. Chem., **23**, 401 (1931)] for values up to 169°C and 300 atm.

TABLE 2-140 Oxygen (O_2)—Temperature

t, °C	0	5	10	15	20	25	30	35
$10^{-4} \times H$	2.55	2.91	3.27	3.64	4.01	4.38	4.75	5.07
t, °C	40	45	50	60	70	80	90	100
$10^{-4} \times H$	5.35	5.63	5.88	6.29	6.63	6.87	6.99	7.01

International Critical Tables, vol. 3, p. 257. Pray, Schweickert, and Minnich [Ind. Eng. Chem., **44**, 1146 (1952)] give $H = 4.46 \times 10^{-4}$ at 25°C and other values up to 343°C.

TABLE 2-141 Oxygen (O_2)—Pressure

Partial pressure of O_2 , mm Hg	$10^{-4} \times H$	
	23°C	25.9°C
800		4.79
900	4.58	
2000	4.59	4.80
3000	4.60	4.83
4000	4.68	4.88
5000	4.73	4.92
6000	4.80	4.98
7000	4.88	5.05
8150	4.98	
8200		5.16

International Critical Tables, vol. 3, p. 257. See also Trans. Am. Soc. Mech. Engrs., **76**, 69 (1954) for solubility of O_2 for 100°F < T < 650°F, 300 < P < 2000 lb/in².

TABLE 2-142 Ozone (O_3)

$t, ^\circ C$	0	5	10	15	20	25	30	35	40	50
$10^{-3} \times H$	1.94	2.18	2.48	2.88	3.76	4.57	5.98	8.18	12.0	27.4

International Critical Tables, vol. 3, p. 257.

TABLE 2-143 Propylene (C_3H_6)

$t, ^\circ C$	2	6	10	14	18
$10^{-3} \times H$	3.04	3.84	4.46	5.06	5.69

International Critical Tables, vol. 3, p. 260.

TABLE 2-144 Partial Vapor Pressure of Sulfur Dioxide over Water, mm Hg

g SO_2 / 100 g H_2O	Temperature, $^\circ C$								
	0	10	20	30	40	50	60	90	120
0.01	0.02	0.04	0.07	0.12	0.19	0.29	0.43	1.21	2.82
0.05	0.38	0.66	1.07	1.68	2.53	3.69	5.24	12.9	27.0
0.10	1.15	1.91	3.03	4.62	6.80	9.71	13.5	31.7	63.9
0.15	2.10	3.44	5.37	8.07	11.7	16.5	22.7	52.2	104
0.20	3.17	5.13	7.93	11.8	17.0	23.8	32.6	73.7	145
0.25	4.34	6.93	10.6	15.7	22.5	31.4	42.8	95.8	186
0.30	5.57	8.84	13.5	19.8	28.2	39.2	53.3	118	229
0.40	8.17	12.8	19.4	28.3	40.1	55.3	74.7	164	316
0.50	10.9	17.0	25.6	37.1	52.3	72.0	96.8	211	404
1.00	25.8	39.5	58.4	83.7	117	159	212	454	856
2.00	58.6	88.5	129	183	253	342	453	955	
3.00	93.2	139	202	285	393	530	700		
4.00	129	192	277	389	535	720			
5.00	165	245	353	496	679				
6.00	202	299	430	602	824				
8.00	275	407	585	818					
10.00	351	517	741						
15.00	542	796							
20.00	735								

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THERMAL EXPANSION

UNITS CONVERSIONS

For this subsection, the following units conversion is applicable:

$$^{\circ}\text{F} = \frac{9}{5} ^{\circ}\text{C} + 32.$$

ADDITIONAL REFERENCES

The tables given under this subject are reprinted by permission from the *Smithsonian Tables*. For more detailed data on thermal expansion, see *International Critical Tables*: tabular index, vol. 3, p. 1; abrasives, vol. 2, p. 87; alloys, vol. 2, p. 463; building stones, vol. 2, p. 54; carbons, vol. 2, p. 303; elements, vol. 1, p. 102; enamels, vol. 2, p. 115; glass, vol.

2, p. 93; metals, vol. 2, p. 459; petroleums, vol. 2, p. 145; porcelains, vol. 2, pp. 70, 78; refractory materials, vol. 2, p. 83; solid insulators, vol. 2, p. 310.

THERMAL EXPANSION OF GASES

No tables of the coefficients of thermal expansion of gases are given in this edition. The coefficient at constant pressure, $1/v(\partial v/\partial T)_p$, for an ideal gas is merely the reciprocal of the absolute temperature. For a real gas or liquid, both it and the coefficient at constant volume, $1/p(\partial p/\partial T)_v$, should be calculated either from the equation of state or from tabulated PVT data.

TABLE 2-145 Linear Expansion of the Solid Elements*

C is the true expansion coefficient at the given temperature; M is the mean coefficient between given temperatures; where one temperature is given, the true coefficient at that temperature is indicated; α and β are coefficients in formula $l_t = l_0(1 + \alpha t + \beta t^2)$; l_0 is length at 0°C (unless otherwise indicated, when, if x is the reference temperature, $l_t = l_x[1 + \alpha(t - t_x) + \beta(t - t_x)^2]$; l_t is length at t °C).

Element	Temp. °C	$C \times 10^4$	Temp. range, °C	$M \times 10^4$	Temp. range, °C	$\alpha \times 10^4$	$\beta \times 10^6$
Aluminum	20	0.224	100	0.235	0, 500	0.22	0.009
Aluminum	300	0.284	500	0.311			
Antimony	20	0.136	20	0.080±			
Arsenic	20	0.05					
Bismuth	20	0.014	20	0.103±			
Cadmium	0	0.54	-180, -140	0.59	20, 100	0.526	
Cadmium	0	0.20±	-180, -140	0.117±	20, 100	0.214±	
Carbon, diamond	50	0.012					
graphite	50	0.06					
Chromium			20, 100	0.068	20, 500	0.086	
Cobalt	20	0.123			6, 121	0.121	0.0064
Copper	20	0.162	100	0.166	0, 625	0.161	0.0040
Copper	200	0.170	300	0.175			
Gold	20	0.140	17, 100	0.143	0, 520	0.142	0.0022
Gold			-191, 17	0.132			
Indium	40	0.417					
Iodine			-190, 17	0.837			
Iridium	20	0.065			0, 80	0.0636	0.0032
Iridium					1070, 1720	0.0679	0.0011
Iron, soft	40	0.1210	0, 100	0.11			
cast	20	0.118			0, 750	0.1158	0.0053
wrought	20	0.119			0, 750	0.1170	0.0053
steel	20	0.114			0, 750	0.1118	0.0053
Lead (99.9)			20, 100	0.291	100, 240	0.269	0.011
	100	0.291	20, 200	0.300			
	280	0.343					
Magnesium	20	0.254	-100, +20	0.240	+20, 500	0.2480	0.0096
			20, 100	0.260			
Manganese	20	0.233	0, 100	0.228			
			-190, 0	0.159	20, 300	0.216	0.0121
Molybdenum†	20	0.053	0, 100	0.052	-142, 19	0.0515	0.0057
			25, 100	0.049	19, +305	0.0501	0.0014
			25, 500	0.055			
Nickel	20	0.126	0, 100	0.130	-190, +20	0.1308	0.0166
					+20, +300	0.1236	0.0066
					500, 1000	0.1346	0.0033
Osmium	40	0.066					
Palladium	20	0.1173			-190, +100	0.1152	0.00517
					0, 1000	0.1167	0.0022
Platinum	20	0.0887			-190, -100	0.0875	0.00314
	20	0.0893			0, +80	0.0890	0.00121
					0, 1000	0.0887	0.00132
Potassium			0, 50	0.83			
Rhodium	40	0.0850	6, 21	0.0876	-75, -112	0.0746	
Ruthenium	40	0.0963					
Selenium	0	0.439	0, 100	0.660			
Silicon	40	0.0763	-3, +18	0.0249	-75, -67	0.0182	
Silver	20	0.1846	0, 100	0.197	0, 875	0.1827	0.00479
	20	0.195			20, 500	0.1939	0.00295
Sodium			-190, -17	0.622	0, 50	0.72	
Steel, 36.4Ni			20, 260	0.031	260, 500	0.144	
			20, 340	0.055	340, 500	0.136	
Tantalum†	20	0.065	-78, 0	0.059	20, 400	0.0646	0.0009
			0, 100	0.0655			
Tellurium	20	0.016	20	0.272±			
Thallium	40	0.302					
Tin	20	0.214			8, 95	0.2033	0.0263
	20	0.305	20	0.154±			
Tungsten†	27	0.0444	0, 100	0.045	-105, +502	0.0428	0.00058
Zinc	20‡	0.643	-140, -100	0.656	+0, 400	0.354	0.010
	20‡	0.125±	+20, 100	0.639			
	20	0.358	+20, 100	0.141±			

*Smithsonian Tables. For more complete tabulations see Table 142, *Smithsonian Physical Tables*, 9th ed., 1954; *Handbook of Chemistry and Physics*, 40th ed., pp. 2239-2245. Chemical Rubber Publishing Co.; Goldsmith, and Waterman, WADC-TR-58-476, 1959; Johnson (ed.), WADD-TR-60-56, 1960, etc.

†Molybdenum, 300° to 2500°C; $l_t = l_{300}[1 + 5.00 \times 10^{-6}(t - 300) + 10.5 \times 10^{-10}(t - 300)^2]$

Tantalum, 300° to 2800°C; $l_t = l_{300}[1 + 6.60 \times 10^{-6}(t - 300) + 5.2 \times 10^{-10}(t - 300)^2]$

Tungsten, 300° to 2700°C; $l_t = l_{300}[1 + 4.44 \times 10^{-6}(t - 300) + 4.5 \times 10^{-10}(t - 300)^2]$

Beryllium, 20° to 100°C; 12.3×10^{-6} per °C.

Columbium, 0° to 100°C; 7.2×10^{-6} per °C.

Tantalum, 20° to 100°C; 6.6×10^{-6} per °C.

‡Two errors in the data of zinc have been corrected. These values were taken from Grüneisen and Goens, *Z. Physik.*, **29**, 141 (1924).

TABLE 2-146 Linear Expansion of Miscellaneous Substances*

The coefficient of cubical expansion may be taken as three times the linear coefficient. In the following table, t is the temperature or range of temperature, and C , the coefficient of expansion.

Substance	$t^{\circ}\text{C}$	$C \times 10^4$	Substance	$t^{\circ}\text{C}$	$C \times 10^4$	Substance	$t^{\circ}\text{C}$	$C \times 10^4$
Amber	0–30	0.50	Jena thermometer 59 ^{III}	0–100	0.058	Topas:		
	0–9	0.61	Jena thermometer 59 ^{III}	-191 to +16	0.424	Parallel to lesser horizontal axis	0–100	0.0832
Bakelite, bleached	20–60	0.22	Gutta percha	20	1.983	Parallel to greater horizontal axis	0–100	0.0836
Brass:			Ice	-20 to -1	0.51	Parallel to vertical axis	0–100	0.0472
Cast	0–100	0.1875	Iceland spar:			Tourmaline:		
Wire	0–100	0.1930	Parallel to axis	0–80	0.2631	Parallel to longitudinal axis	0–100	0.0937
Wire	0–100	0.1783 to 0.193	Perpendicular to axis	0–80	0.0544	Parallel to horizontal axis	0–100	0.0773
71.5 Cu + 27.7 Zn +			Lead tin (solder) 2 Pb			Type metal	16.6–254	0.1952
0.3 Sn + 0.5 Pb	40	0.1859	+ 1 Sn	0–100	0.2508	Vulcanite	0–18	0.6360
71 Cu + 29 Zn	0–100	0.1906	Limestone	25–100	0.09	Wedgwood ware	0–100	0.0890
Bronze:			Magnalium	12–39	0.238	Wood:		
3 Cu + 1 Sn	16.6–100	0.1844	Manganin			Parallel to fiber:		
3 Cu + 1 Sn	16.6–350	0.2116	Marble	15–100	0.117	Ash	0–100	0.0951
3 Cu + 1 Sn	16.6–957	0.1737	Monel metal	25–100	0.14	Beech	2.34	0.0257
86.3 Cu + 9.7 Sn + 4 Zn	40	0.1782	Paraffin	25–600	0.16	Chestnut	2.34	0.0649
97.6 Cu + [hard	0–80	0.1713	Paraffin	0–16	1.0662	Elm	2.34	0.0565
2.2 Sn + [soft	0–80	0.1708	Paraffin	16–38	1.3030	Mahogany	2.34	0.0361
0.2 P			Quartz:	38–49	4.7707	Maple	2.34	0.0638
Caoutchouc		0.657 to 0.686	Platinum-iridium, 10 Pt	40	0.0884	Oak	2.34	0.0492
Caoutchouc	16.7–25.3	0.770	+ 1 Ir			Pine	2.34	0.0541
Celluloid	20–70	1.00	Platinum-silver, 1 Pt +			Walnut	2.34	0.0658
Constantan	4–29	0.1523	2 Ag	0–100	0.1523	Across the fiber:		
Duralumin, 94Al	20–100	0.23	Porcelain	20–790	0.0413	Beech	2.34	0.614
	20–300	0.25	Porcelain Bayeux	1000–1400	0.0553	Chestnut	2.34	0.325
Ebonite	25.3–35.4	0.842	Quartz:			Elm	2.34	0.443
Fluorspar, CaF ₂	0–100	0.1950	Parallel to axis	0–80	0.0797	Mahogany	2.34	0.404
German silver	0–100	0.1836	Parallel to axis	-190 to + 16	0.0521	Maple	2.34	0.484
Gold-platinum, 2 Au + 1 Pt	0–100	0.1523	Perpend. to axis	0–80	0.1337	Oak	2.34	0.544
Gold-copper, 2 Au + 1 Cu	0–100	0.1552	Quartz glass	-190 to + 16	-0.0026	Pine	2.34	0.341
Glass:			Quartz glass	16 to 500	0.0057	Walnut	2.34	0.484
Tube	0–100	0.0833	Quartz glass	16 to 1000	0.0058	Wax white	10–26	2.300
Tube	0–100	0.0828	Rock salt	40	0.4040	Wax white	26–31	3.120
Plate	0–100	0.0891	Rubber, hard	0	0.691	Wax white	31–43	4.860
Crown (mean)	0–100	0.0897	Rubber, hard	-160	0.300	Wax white	43–57	15.227
Crown (mean)	50–60	0.0954	Speculum metal	0–100	0.1933			
Flint	50–60	0.0788	Steel, 0.14 C, 34.5 Ni	25–100	0.037			
Jena ther-	16 ^{III}	0–100		25–600	0.136			
mometer normal]		0.081						

*Smithsonian Tables. For a more complete tabulation see Tables 143, 144. Smithsonian Physical Tables, 9th ed., 1954, also reprinted in American Institute of Physics Handbook, McGraw-Hill, New York, 1957; Handbook of Chemistry and Physics, 40th ed., pp. 2239–2245, Chemical Rubber Publishing Co. For data on many solids prior to 1926, see Gruneisen, *Handbuch der Physik*, vol. 10, pp. 1–52, 1926, translation available as N.A.S.A. RE 2-18-59W, 1959. For eight plastic solids below 300 K, see Scott, *Cryogenic Engineering*, p. 331, Van Nostrand, Princeton, NJ, 1959. For 11 other materials to 300 K, see Scott, *loc. cit.*, p. 333. For quartz and silica, see Cook, *Brit. J. Appl. Phys.*, 7, 285 (1956).

TABLE 2-147 Cubical Expansion of Liquids*

If V_0 is the volume at 0° , then at t° the expansion formula is $V_t = V_0(1 + \alpha t + \beta t^2 + \gamma t^3)$. The table gives values of α , β , and γ , and of C , the true coefficient of cubical expansion at 20° for some liquids and solutions. The temperature range of the observation is Δt . Values for the coefficient of cubical expansion of liquids can be derived from the tables of specific volumes of the saturated liquid given as a function of temperature later in this section.

Liquid	Range	$\alpha \times 10^3$	$\beta \times 10^6$	$\gamma \times 10^8$	$C \times 10^8$ at 20°
Acetic acid	16–107	1.0630	0.12636	1.0876	1.071
Acetone	0–54	1.3240	3.8090	-0.87983	1.487
Alcohol:					
Amyl	-15–80	0.9001	0.6573	1.18458	0.902
Ethyl, 30% by volume	18–39	0.2928	10.790	-11.87	
Ethyl, 50% by volume	0–39	0.7450	1.85	0.730	
Ethyl, 99.3% by volume	27–46	1.012	2.20		1.12
Ethyl, 500 atm. pressure	0–40	0.866			
Ethyl, 3000 atm. pressure	0–40	0.524			
Methyl	0–61	1.1342	1.3635	0.8741	1.199
Benzene	11–81	1.17626	1.27776	0.80648	1.237
Bromine	0–59	1.06218	1.87714	-0.30854	1.132
Calcium chloride:					
5.8% solution	18–25	0.07878	4.2742		0.250
40.9% solution	17–24	0.42383	0.8571		0.458
Carbon disulfide	-34–60	1.13980	1.37065	1.91225	1.218
500 atm. pressure	0–50	0.940			
3000 atm. pressure	0–50	0.581			
Carbon tetrachloride	0–76	1.18384	0.89881	1.35135	1.236
Chloroform	0–63	1.10715	4.66473	-1.74328	1.273
Ether	-15–38	1.51324	2.35918	4.00512	1.656
Glycerin		0.4853	0.4895		0.505
Hydrochloric acid, 33.2% solution	0–33	0.4460	0.215		0.455
Mercury	0–100	0.18182	0.0078		0.18186
Olive oil		0.6821	1.1405	-0.539	0.721
Pentane	0–33	1.4646	3.09319	1.6084	1.608
Potassium chloride, 24.3% solution	16–25	0.2695	2.080		0.353
Phenol	36–157	0.8340	0.10732	0.4446	1.090
Petroleum, 0.8467 density	24–120	0.8994	1.396		0.955
Sodium chloride, 20.6% solution	0–29	0.3640	1.237		0.414
Sodium sulfate, 24% solution	11–40	0.3599	1.258		0.410
Sulfuric acid:					
10.9% solution	0–30	0.2835	2.580		0.387
100.0%	0–30	0.5758	-0.432		0.558
Turpentine	-9–106	0.9003	1.9595	-0.44998	0.973
Water	0–33	-0.06427	8.5053	-6.7900	0.207

*Smithsonian Tables, Table 269. For a detailed discussion of mercury data, see Cook, *Brit. J. Appl. Phys.*, **7**, 285 (1956). For data on nitrogen and argon, see Johnson (ed.), WADD-TR-60-56, 1960.

Bromoform¹ 7.7–50°C.

$$V_t = 0.34204[1 + 0.00090411(t - 7.7) + 0.0000006766(t - 7.7)^2]$$

0.34204 in the specific volume of bromoform at 7.7°C.

Glycerin² -62 to 0°C.

$$\bar{V}_t = V_0(1 + 4.83 \times 10^{-4}t - 0.49 \times 10^{-6}t^2)$$

0–80°C.

$$V_t = V_0(1 + 4.83 \times 10^{-4}t + 0.49 \times 10^{-6}t^2)$$

Mercury³ 0–300°C.

$$V_t = V_0[1 + 10^{-8}(18153.8t + 0.7548t^2 + 0.001533t^3 + 0.00000536t^4)]$$

¹ Sherman and Sherman, *J. Am. Chem. Soc.*, **50**, 1119 (1928). (An obvious error in their equation has been corrected.)

² Samsoen, *Ann. phys.*, (10) **9**, 91 (1928).

³ Harlow, *Phil. Mag.*, (7) **7**, 674 (1929).

TABLE 2-148 Cubical Expansion of Solids*

If v_2 and v_1 are the volumes at t_2 and t_1 , respectively, then $v_2 = v_1(1 + C\Delta t)$, C being the coefficient of cubical expansion and Δt the temperature interval. Where only a single temperature is stated, C represents the true coefficient of cubical expansion at that temperature.

Substance	t or Δt	$C \times 10^4$
Antimony	0–100	0.3167
Beryl	0–100	0.0105
Bismuth	0–100	0.3948
Copper [†]	0–100	0.4998
Diamond	40	0.0354
Emerald	40	0.0168
Galena	0–100	0.558
Glass, common tube	0–100	0.276
hard	0–100	0.214
Jena, borosilicate 59 III	20–100	0.156
pure silica	0–80	0.0129
Gold	0–100	0.4411
Ice	-20 to -1	1.1250
Iron	0–100	0.3550
Lead [†]	0–100	0.8399
Paraffin	20	5.88
Platinum	0–100	0.265
Porcelain, Berlin	20	0.0814
chloride	0–100	1.094
nitrate	0–100	1.967
sulfate	20	1.0754
Quartz	0–100	0.3840
Rock salt	50–60	1.2120
Rubber	20	4.87
Silver	0–100	0.5831
Sodium	20	2.13
Stearic acid	33.8–45.4	8.1
Sulfur, native	13.2–50.3	2.23
Tin	0–100	0.6889
Zinc [†]	0–100	0.8928

*Smithsonian Tables, Table 268.

†See additional data below.

Aluminum¹ 100–530°C.

$$V = V_0(1 + 2.16 \times 10^{-5}t + 0.95 \times 10^{-8}t^2)$$

Cadmium¹ 130–270°C.

$$V = V_0(1 + 8.04 \times 10^{-5}t + 5.9 \times 10^{-8}t^2)$$

Copper¹ 110–300°C.

$$V = V_0(1 + 1.62 \times 10^{-5}t + 0.20 \times 10^{-8}t^2)$$

Colophony² 0–34°C.

$$V = V_0(1 + 2.21 \times 10^{-4}t + 0.31 \times 10^{-6}t^2)$$

34–150°C.

$$V = V_{34}[1 + 7.40 \times 10^{-4}(t - 34) + 5.91 \times 10^{-6}(t - 34)^2]$$

Lead¹ 100–280°C.

$$V = V_0(1 + 1.60 \times 10^{-5}t + 3.2 \times 10^{-8}t^2)$$

Shellac² 0–46°C.

$$V = V_0(1 + 2.73 \times 10^{-4}t + 0.39 \times 10^{-6}t^2)$$

46–100°C.

$$V = V_{46}[1 + 13.10 \times 10^{-4}(t - 46) + 0.62 \times 10^{-6}(t - 46)^2]$$

Silica (vitreous)³ 0–300°C.

$$V_t = V_0[1 + 10^{-8}(93.6t + 0.7776t^2 - 0.003315t^3 + 0.000005244t^4)]$$

Sugar (cane, amorphous)³ 0–67°C.

$$\bar{V}_t = V_0(1 + 2.34 \times 10^{-4}t + 0.14 \times 10^{-6}t^2)$$

67–160°C.

$$V_t = V_{67}[1 + 5.02 \times 10^{-4}(t - 67) + 0.43 \times 10^{-6}(t - 67)^2]$$

Zinc¹ 120–360°C.

$$V_t = V_0(1 + 8.50 \times 10^{-5}t + 3.9 \times 10^{-8}t^2)$$

1 Uffelmann, *Phil. Mag.*, (7) **10**, 633 (1930).

² Samsoen, *Ann. phys.*, (10) **9**, 83 (1928).

³ Harlow, *Phil. Mag.*, (7) **7**, 674 (1929).

JOULE-THOMSON EFFECT

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

To convert the Joule-Thomson coefficient, μ , in degrees Celsius per atmosphere to degrees Fahrenheit per atmosphere, multiply by 1.8.

$$^{\circ}\text{F} = \frac{9}{5} ^{\circ}\text{C} + 32; ^{\circ}\text{R} = \frac{9}{5} \text{ K}$$

To convert bars to pounds-force per square inch, multiply by 14.504; to convert bars to kilopascals, multiply by 1×10^5 .

TABLE 2-149 Additional References Available for the Joule-Thomson Coefficient

Gas	Pressure range, atm				Temp. range, °C			Unclassified
	0–10	10–50	50–200	>200	<0	0–300	>300	
Air	12, 15, 16 19, 35	12, 15, 19 35	15, 19, 35		19, 35	12, 15, 16 19, 35		3, 4, 18
Ammonia	28					28		2, 3
Argon	39	39	39		39	39		
Benzene	31	31	31			31		
Butane	26	26				26		
Carbon dioxide	7, 8, 28 37	7, 8, 37	7, 8, 37		7, 8, 37	7, 8, 9, 10 37		
Carbon monoxide	17	17			17	17		
Deuterium		22, 24, 25 1°	22, 24, 24 25		1° 22, 24, 25			
Dowtherm A	46	46				46	46	
Ethane	45	45				45		
Ethylene						9, 10		
Helium	1, 38	1, 38	38		1, 38	38		
Hydrogen	24, 30	22, 24, 25 30	24, 30		22, 24, 25 30	24		48
Methane		6	6			6		
Mixtures						9, 11		
Natural gas			33	33	33	33		
Nitrogen	13, 28, 40	13, 40	13, 40	13	13, 40	9, 10, 13 28, 40 9, 10	13	19
Nitrous oxide								
Pentane	26, 34, 44	34	34			26, 34, 44		
Propane	41	43				43		
Steam	28, 29, 42	29, 42, 47	42, 47			28, 29, 42 45	29, 42, 47	29, 47

*See also 14 (generalized chart); 18 (review, to 1919); 20–22; 23 (review, to 1948); 27 (review, to 1905); 32, 36, 41, 50.

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TABLE 2-150 Approximate Inversion-Curve Locus in Reduced Coordinates ($T_r = T/T_c$; $P_r = P/P_c$)^a

P_r	0	0.5	1	1.5	2	2.5	3	4
T_{rl}	0.782	0.800	0.818	0.838	0.859	0.880	0.903	0.953
T_{ru}	4.984	4.916	4.847	4.777	4.706	4.633	4.550	4.401
P_r	5	6	7	8	9	10	11	11.79
T_{rl}	1.01	1.08	1.16	1.25	1.35	1.50	1.73	2.24
T_{ru}	4.23	4.06	3.88	3.68	3.45	3.18	2.86	2.24

^aCalculated from the best three-constant equation recommended by Miller, *Ind. Eng. Chem. Fundam.*, **9**, 585 (1970). T_{rl} refers to the lower curve, and T_{ru} , to the upper curve.

TABLE 2-151 Joule-Thomson Data for Air*

P , atm	t , °C											
	-150	-100	-75	-50	-25	0	25	50	75	100	150	200
1	0.5895	0.4795	0.3910	0.3225	0.2745	0.2320	0.1956	0.1614	0.1355	0.0961	0.0645	0.0409
20	.5700	.4555	.3690	.3010	.2580	.2173	.1830	.1508	.1258	.0883	.0580	.0356
60	0.0450	.4820	.3835	.3195	.2610	.2200	.1852	.1571	.1293	.1062	.0732	.0453
100	.0185	.2775	.2880	.2505	.2130	.1820	.1550	.1310	.1087	.0884	.0600	.0165
140	-.0070	.1360	.1855	.1825	.1650	.1450	.1249	.1070	.0889	.0726	.0482	.0250
180	-.0255	.0655	.1136	.1270	.1240	.1100	.0959	.0829	.0707	.0580	.0376	.0174
200	-.0330	.0440	.0855	.1065	.1090	.0950						

*Free of water and CO₂. Extracted from Table 261, *Smithsonian Physical Tables*, 9th rev. ed., Washington, DC, 1954. These data are corrected from earlier publications. μ in °C/atm.

TABLE 2-152 Approximate Inversion-Curve Locus for Air

P , bar	0	25	50	75	100	125	150	175	200	225
T_L , K	(112) ^a	114	117	120	124	128	132	137	143	149
T_U , K	653	641	629	617	606	594	582	568	555	541
P , bar	250	275	300	325	350	375	400	425	432	
T_L , K	156	164	173	184	197	212	230	265	300	
T_U , K	526	509	491	470	445	417	386	345	300	

^aHypothetical low-pressure limit.

TABLE 2-153 Joule-Thomson Data for Argon*

t , °C	Pressure, atm						
	1	20	60	100	140	180	200
-150	1.812			-0.0025	-0.0277	-0.0403	-0.0595
-125	1.112	1.102		.1250	.0415	.0090	-.0100
-100	0.8605	0.8485		.6900	.2820	.1137	.0560
-75	.7100	.6895		.5910	.4225	.2480	.1537
-50	.5960	.5720		.4963	.3970	.2840	.2037
-25	.5045	.4805		.4210	.3460	.2763	.2140
0	.4307	.4080		.3600	.3010	.2505	.2050
25	.3720	.3490		.3077	.2628	.2213	.1890
50	.3220	.3015		.2650	.2297	.1947	.1700
75	.2695	.2557		.2285	.1993	.1710	.1505
100	.2413	.2277		.1975	.1715	.1490	.1320
125	.2105	.1980		.1707	.1480	.1300	.1153
150	.1845	.1720		.1485	.1285	.1123	.0998
200	.1377	.1280		.1102	.0950	.0823	.0715
250	.0980	.0910		.0785	.0665	.0555	.0485
300	.0643	.0607		.0530	.0445	.0370	.0276

*Extracted from Table 263, *Smithsonian Physical Tables*, 9th rev. ed., Washington, DC, 1954. These data are corrected from an earlier publication. μ in °C/atm.

TABLE 2-154 Approximate Inversion-Curve Locus for Argon

P , bar	0	25	50	75	100	125	150	175	200	225
T_L , K	94	97	101	105	109	113	118	123	128	134
T_U , K	765	755	744	736	726	716	705	694	683	671
P , bar	250	275	300	325	350	375	400	425	450	475
T_L , K	141	148	158	170	183	201	222	248	288	375
T_U , K	657	643	627	610	591	569	544	515	478	375

TABLE 2-155 Joule-Thomson Data for Carbon Dioxide*

t , °C	Pressure, atm							
	1	20	60	73	100	140	180	200
-75		-0.0200	-0.0200	-0.0232	-0.0228	-0.0240	-0.0250	-0.0290
-50	2.4130	-.0140	-.0150	-.0165	-.0160	-.0183	-.0228	-.0248
0	1.2900	1.4020	.0370	.0310	.0215	.0115	.0085	.0045
50	0.8950	.8950	.8800	.8225	.5570	.1720	.1025	.0930
100	.6490	.6375	.6080	.5920	.5405	.4320	.3000	.2555
125	.5600	.5450	.5160	.5068	.4750	.4130	.3230	.2915
150	.4890	.4695	.4430	.4380	.4155	.3760	.3102	.2910
200	.3770	.3575	.3400	.3325	.3150	.2890	.2600	.2455
250	.3075	.2885	.2625	.2565	.2420	.2235	.2045	.1975
300	.2650	.2425	.2080	.2002	.1872	.1700	.1540	.1505

*Extracted from Table 266, *Smithsonian Physical Tables*, 9th rev. ed., Washington, DC, 1954. These data are corrected from an earlier publication. μ in °C/atm.

TABLE 2-156 Approximate Inversion-Curve Locus for Carbon Dioxide*

P , bar	50	100	150	200	250	300	350	400	450
T_L , K	243	251	258	266	272	283	293	302	312
T_U , K	1290	1261	1233	1205	1175	1146	1111	1076	1045
P , bar	500	550	600	650	700	750	800	850	884
T_L , K	325	338	351	365	383	403	441	496	608
T_U , K	1015	983	950	914	878	840	796	739	608

*Interpolated from Vukalovich and Altunin's interpolation of data of Price, *Ind. Eng. Chem.*, **47**, 1691 (1955). T_L = lower inversion temperature, and T_U = upper inversion temperature.

TABLE 2-157 Approximate Inversion-Curve Locus for Deuterium

P , bar	0	25	50	75	100	125	150	175	194
T_L , K	(31)*	34	38	43	49	56	65	77	108
T_U , K	216	202	189	178	168	157	146	131	108

*Hypothetical low-pressure limit.

TABLE 2-158 Approximate Inversion-Curve Locus for Ethane

P , bar	0	25	50	75	100	125	150	175	200	225
T_L , K		249	255	262	269	275	282	290	297	306
P , bar	250	275	300	325	350	375	400	425	450	475
T_L , K	315	325	335	345	357	370	383	398	415	432
P , bar	500	525	550	575	600					
T_L , K	453	477	505	545	626					

TABLE 2-159 Joule-Thomson Data for Helium*

T , K	160	180	200	220	240	260	280	300
μ	-0.0574	-0.0587	-0.0594	-0.0601	-0.0608	-0.0614	-0.0619	-0.0625
T , K	320	340	360	380	400	420	440	460
μ	-0.0629	-0.0634	-0.0637	-0.0640	-0.0643	-0.0645	-0.0645	-0.0643
T , K	480	500	520	540	560	580	600	
μ	-0.0640	-0.0636	-0.0630	-0.0622	-0.0611	-0.0587	-0.0540	

*Interpolated and converted from data in Table 262, *Smithsonian Physical Tables*, 9th rev. ed., Washington, DC, 1954. These data are corrected from those in an earlier publication. μ is in $^{\circ}\text{C}/\text{atm}$. Below about 200 atm, little change in the coefficient with pressure occurs.

TABLE 2-160 Approximate Inversion-Curve Locus for Normal Hydrogen

P , bar	0	25	50	75	100	125	150	164
T_L , K	(28) ^a	32	38	44	52	61	73	92
T_U , K	202	193	183	171	157	141	119	92

^aHypothetical low-pressure limit.

TABLE 2-161 Approximate Inversion-Curve Locus for Methane

P , bar	25	50	75	100	125	150	175	200	225	250	275	300
T_L , K		161	166	172	176	182	189	195	202	209	217	225
P , bar	325	350	375	400	425	450	475	500	525	554		
T_L , K	234	243	254	265	277	292	309	331	365	400		
T_U , K							505	474	437	400		

TABLE 2-162 Joule-Thomson Data for Nitrogen*

t , $^{\circ}\text{C}$	Pressure, atm							
	1	20	33.5	60	100	140	180	200
-150	1.2659	1.1246	0.1704	0.0601	0.0202	-0.0056	-0.0211	-0.0284
-125	0.8557	0.7948	.7025	.4940	.1314	.0498	.0167	.0032
-100	.6490	.5958	.5494	.4506	.2754	.1373	.0765	.0587
-75	.5033	.4671	.4318	.3712	.2682	.1735	.1026	.0800
-50	.3968	.3734	.3467	.3059	.2332	.1676	.1120	.0906
-25	.3224	.3013	.2854	.2528	.2001	.1506	.1101	.0932
0	.2656	.2494	.2377	.2088	.1679	.1316	.1015	.0891
25	.2217	.2060	.1961	.1729	.1400	.1105	.0874	.0779
50	.1855	.1709	.1621	.1449	.1164	.0915	.0732	.0666
75	.1555	.1421	.1336	.1191	.0941	.0740	.0583	.0543
100	.1292	.1173	.1100	.0975	.0768	.0582	.0462	.0419
125	.1070	.0973	.0904	.0786	.0621	.0459	.0347	.0326
150	.0868	.0776	.0734	.0628	.0482	.0348	.0248	.0228
200	.0558	.0472	.0430	.0372	.0262	.0168	.0094	.0070
250	.0331	.0256	.0230	.0160	.0071	.0009	-.0037	-.0058
300	.0140	.0096	.0050	-.0013	-.0075	-.0129	-.0160	-.0171

*Extracted from Table 264, *Smithsonian Physical Tables*, 9th rev. ed., Washington, DC, 1954. These data are corrected from an earlier publication. μ in $^{\circ}\text{C}/\text{atm}$.

TABLE 2-163 Approximate Inversion-Curve Locus for Propane

P , bar	0	25	50	75	100	125	150	175	200	225	250	275
T_L , K	(296) ^a	303	311	318	327	336	345	355	365	374	389	403
P , bar	300	325	350	375	400	425	450	475	500	525	541	
T_U , K	418	435	452	473	495	521	551	586	628	686	780	

^aHypothetical low-pressure limit.

CRITICAL CONSTANTS

ADDITIONAL REFERENCES

Other data and estimation techniques for the elements are contained in Gates and Thodos, *Am. Inst. Chem. Eng. J.*, **6** (1960):50–54; and Ohse and von Tippelskirch, *High Temperatures—High Pressures*, **9**

(1977):367–385. For inorganic substances see Mathews, *Chem. Rev.*, **72** (1972):71–100; for organics see Kudchaker, Alami, and Zwolinski, *Chem. Rev.*, **68** (1968):659–735; and for fluorocarbons see *Advances in Fluorine Chemistry*, App. B, Butterworth, Washington, 1963, pp. 173–175.

TABLE 2-164 Critical Constants and Acentric Factors of Inorganic and Organic Compounds

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T_c , K	$P_c \times 10^{-6}$ Pa	V_c , m ³ /Kmol	Z_c	Acentric factor
1	Methane	CH ₄	74828	16.043	190.564	4.59	0.099	0.286	0.011
2	Ethane	C ₂ H ₆	74840	30.070	305.32	4.85	0.146	0.279	0.098
3	Propane	C ₃ H ₈	74986	44.097	369.83	4.21	0.200	0.273	0.149
4	n-Butane	C ₄ H ₁₀	106978	58.123	425.12	3.77	0.255	0.272	0.197
5	n-Pentane	C ₅ H ₁₂	109660	72.150	469.7	3.36	0.315	0.271	0.251
6	n-Hexane	C ₆ H ₁₄	110543	86.177	507.6	3.04	0.373	0.269	0.304
7	n-Heptane	C ₇ H ₁₆	142825	100.204	540.2	2.72	0.428	0.259	0.346
8	n-Octane	C ₈ H ₁₈	111659	114.231	568.7	2.47	0.486	0.254	0.396
9	n-Nonane	C ₉ H ₂₀	111842	128.258	594.6	2.31	0.540	0.252	0.446
10	n-Decane	C ₁₀ H ₂₂	124185	142.285	617.7	2.09	0.601	0.245	0.488
11	n-Undecane	C ₁₁ H ₂₄	1120214	156.312	639	1.95	0.658	0.242	0.530
12	n-Dodecane	C ₁₂ H ₂₆	112403	170.338	658	1.82	0.718	0.239	0.577
13	n-Tridecane	C ₁₃ H ₂₈	629505	184.365	675	1.68	0.779	0.233	0.617
14	n-Tetradecane	C ₁₄ H ₃₀	629594	198.392	693	1.57	0.830	0.226	0.643
15	n-Pentadecane	C ₁₅ H ₃₂	629629	212.419	708	1.47	0.888	0.222	0.685
16	n-Hexadecane	C ₁₆ H ₃₄	544763	226.446	723	1.41	0.943	0.221	0.721
17	n-Heptadecane	C ₁₇ H ₃₆	629787	240.473	736	1.34	0.998	0.219	0.771
18	n-Octadecane	C ₁₈ H ₃₈	593453	254.500	747	1.26	1.059	0.214	0.806
19	n-Nonadecane	C ₁₉ H ₄₀	629925	268.527	758	1.21	1.119	0.215	0.851
20	n-Eicosane	C ₂₀ H ₄₂	112958	282.553	768	1.17	1.169	0.215	0.912
21	2-Methylpropane	C ₄ H ₁₀	75285	58.123	408.14	3.62	0.261	0.278	0.177
22	2-Methylbutane	C ₅ H ₁₂	78784	72.150	460.43	3.37	0.304	0.268	0.226
23	2,3-Dimethylbutane	C ₆ H ₁₄	79298	86.177	499.98	3.13	0.358	0.269	0.246
24	2-Methylpentane	C ₆ H ₁₄	107835	86.177	497.5	3.02	0.366	0.267	0.279
25	2,3-Dimethylpentane	C ₇ H ₁₆	565593	100.204	537.35	2.88	0.396	0.255	0.292
26	2,3,3-Trimethylpentane	C ₈ H ₁₈	560214	114.231	573.5	2.81	0.455	0.268	0.289
27	2,2,4-Trimethylpentane	C ₈ H ₁₈	540841	114.231	543.96	2.56	0.465	0.264	0.301
28	Ethylene	C ₂ H ₄	74851	28.054	282.34	5.03	0.132	0.283	0.086
29	Propylene	C ₃ H ₆	115071	42.081	365.57	4.63	0.188	0.286	0.137
30	1-Butene	C ₄ H ₈	106989	56.108	419.95	4.04	0.241	0.279	0.190
31	cis-2-Butene	C ₄ H ₈	590181	56.108	435.58	4.24	0.233	0.273	0.204
32	trans-2-Butene	C ₄ H ₈	624646	56.108	428.63	4.08	0.237	0.272	0.216
33	1-Pentene	C ₅ H ₁₀	109671	70.134	464.78	3.56	0.295	0.271	0.236
34	1-Hexene	C ₆ H ₁₂	592416	84.161	504.03	3.14	0.354	0.265	0.280
35	1-Heptene	C ₇ H ₁₄	592767	98.188	537.29	2.82	0.413	0.261	0.330
36	1-Octene	C ₈ H ₁₆	111660	112.215	566.65	2.57	0.460	0.251	0.377
37	1-Nonene	C ₉ H ₁₈	124118	126.242	593.25	2.33	0.528	0.249	0.417
38	1-Decene	C ₁₀ H ₂₀	872059	140.269	616.4	2.21	0.584	0.252	0.478
39	2-Methylpropene	C ₄ H ₈	115117	56.108	417.9	3.98	0.238	0.272	0.192
40	2-Methyl-1-butene	C ₅ H ₁₀	563462	70.134	465	3.45	0.292	0.261	0.237
41	2-Methyl-2-butene	C ₅ H ₁₀	513359	70.134	471	3.38	0.292	0.252	0.272
42	1,2-Butadiene	C ₄ H ₆	590192	54.092	452	4.36	0.220	0.255	0.166
43	1,3-Butadiene	C ₄ H ₆	106990	54.092	425.17	4.30	0.220	0.268	0.192
44	2-Methyl-1,3-butadiene	C ₅ H ₈	78795	68.119	484	3.85	0.277	0.265	0.158
45	Acetylene	C ₂ H ₂	74862	26.038	308.32	6.15	0.113	0.271	0.188
46	Methylacetylene	C ₃ H ₄	74997	40.065	402.39	5.62	0.164	0.276	0.216
47	Dimethylacetylene	C ₄ H ₆	503173	54.092	473.2	4.87	0.221	0.274	0.239
48	3-Methyl-1-butyne	C ₅ H ₈	598232	68.119	463.2	4.20	0.275	0.300	0.308
49	1-Pentyne	C ₅ H ₈	627190	68.119	481.2	4.17	0.277	0.289	0.290
50	2-Pentyne	C ₅ H ₈	627214	68.119	519	4.02	0.276	0.257	0.174
51	1-Hexyne	C ₆ H ₁₀	693027	82.145	516.2	3.64	0.322	0.273	0.335
52	2-Hexyne	C ₆ H ₁₀	764352	82.145	549	3.53	0.331	0.256	0.221
53	3-Hexyne	C ₆ H ₁₀	928494	82.145	544	3.54	0.334	0.261	0.219
54	1-Heptyne	C ₇ H ₁₂	628717	96.172	559	3.13	0.386	0.260	0.272
55	1-Octyne	C ₈ H ₁₄	629050	110.199	585	2.82	0.441	0.256	0.323
56	Vinylacetylene	C ₄ H ₄	689974	52.076	454	4.89	0.205	0.265	0.109

TABLE 2-164 Critical Constants and Acentric Factors of Inorganic and Organic Compounds (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T _c , K	P _c × 1E-06 Pa	V _c , m ³ /Kmol	Z _c	Acentric factor
57	Cyclopentane	C ₅ H ₁₀	287923	70.134	511.76	4.50	0.257	0.272	0.196
58	Methylcyclopentane	C ₆ H ₁₂	96377	84.161	532.79	3.78	0.319	0.272	0.230
59	Ethylcyclopentane	C ₇ H ₁₄	1640897	98.188	569.52	3.40	0.374	0.269	0.271
60	Cyclohexane	C ₆ H ₁₂	110827	84.161	553.58	4.10	0.308	0.274	0.212
61	Methylcyclohexane	C ₇ H ₁₄	108872	98.188	572.19	3.48	0.368	0.269	0.236
62	1,1-Dimethylcyclohexane	C ₈ H ₁₆	590669	112.215	591.15	2.94	0.450	0.269	0.233
63	Ethylcyclohexane	C ₈ H ₁₆	1678917	112.215	609.15	3.04	0.430	0.258	0.246
64	Cyclopentene	C ₅ H ₈	142290	68.119	507	4.81	0.245	0.279	0.196
65	1-Methylcyclopentene	C ₆ H ₁₀	693890	82.145	542	4.13	0.303	0.278	0.232
66	Cyclohexene	C ₆ H ₁₀	110838	82.145	560.4	4.39	0.291	0.274	0.216
67	Benzene	C ₆ H ₆	71432	78.114	562.16	4.88	0.261	0.273	0.209
68	Toluene	C ₇ H ₈	108883	92.141	591.8	4.10	0.314	0.262	0.262
69	<i>o</i> -Xylene	C ₈ H ₁₀	95476	106.167	630.33	3.74	0.374	0.267	0.311
70	<i>m</i> -Xylene	C ₈ H ₁₀	108383	106.167	617.05	3.53	0.377	0.259	0.325
71	<i>p</i> -Xylene	C ₈ H ₁₀	106423	106.167	616.23	3.50	0.381	0.260	0.320
72	Ethylbenzene	C ₈ H ₁₀	100414	106.167	617.2	3.60	0.375	0.263	0.301
73	Propylbenzene	C ₉ H ₁₂	103651	120.194	638.32	3.20	0.440	0.265	0.344
74	1,2,4-Trimethylbenzene	C ₉ H ₁₂	95636	120.194	649.13	3.25	0.430	0.259	0.380
75	Isopropylbenzene	C ₉ H ₁₂	98828	120.194	631.1	3.18	0.429	0.260	0.322
76	1,3,5-Trimethylbenzene	C ₉ H ₁₂	108678	120.194	637.36	3.11	0.433	0.254	0.397
77	<i>p</i> -Isopropyltoluene	C ₁₀ H ₁₄	99876	134.221	653.15	2.80	0.497	0.256	0.366
78	Naphthalene	C ₁₀ H ₈	91203	128.174	748.35	3.99	0.413	0.265	0.296
79	Biphenyl	C ₁₂ H ₁₀	92524	154.211	789.26	3.86	0.502	0.295	0.367
80	Styrene	C ₈ H ₈	100425	104.152	636	3.82	0.352	0.254	0.295
81	<i>m</i> -Terphenyl	C ₁₈ H ₁₄	92068	230.309	924.85	3.53	0.768	0.352	0.561
82	Methanol	CH ₄ O	67561	32.042	512.64	8.14	0.117	0.224	0.566
83	Ethanol	C ₂ H ₆ O	64175	46.069	513.92	6.12	0.168	0.240	0.643
84	1-Propanol	C ₃ H ₈ O	71238	60.096	536.78	5.12	0.220	0.252	0.617
85	1-Butanol	C ₄ H ₁₀ O	71363	74.123	563.05	4.34	0.276	0.256	0.585
86	2-Butanol	C ₄ H ₁₀ O	78922	74.123	536.05	4.20	0.270	0.254	0.574
87	2-Propanol	C ₃ H ₈ O	67630	60.096	508.3	4.79	0.221	0.250	0.670
88	2-Methyl-2-propanol	C ₄ H ₁₀ O	75650	74.123	506.21	3.99	0.276	0.262	0.613
89	1-Pentanol	C ₅ H ₁₂ O	71410	88.150	586.15	3.87	0.327	0.260	0.592
90	2-Methyl-1-butanol	C ₅ H ₁₂ O	137326	88.150	565	3.87	0.327	0.270	0.678
91	3-Methyl-1-butanol	C ₅ H ₁₂ O	123513	88.150	577.2	3.90	0.327	0.266	0.586
92	1-Hexanol	C ₆ H ₁₄ O	111273	102.177	611.35	3.46	0.381	0.259	0.572
93	1-Heptanol	C ₇ H ₁₆ O	111706	116.203	631.9	3.18	0.435	0.263	0.592
94	Cyclohexanol	C ₆ H ₁₂ O	108930	100.161	650	4.25	0.322	0.253	0.371
95	Ethylene glycol	C ₂ H ₆ O ₂	107211	62.068	719.7	7.71	0.191	0.246	0.487
96	1,2-Propylene glycol	C ₃ H ₈ O ₂	57556	76.095	626	6.04	0.239	0.277	1.102
97	Phenol	C ₆ H ₆ O	108952	94.113	694.25	6.06	0.229	0.240	0.438
98	<i>o</i> -Cresol	C ₇ H ₈ O	95487	108.140	697.55	5.06	0.282	0.246	0.438
99	<i>m</i> -Cresol	C ₇ H ₈ O	108394	108.140	705.85	4.52	0.312	0.240	0.444
100	<i>p</i> -Cresol	C ₇ H ₈ O	106445	108.140	704.65	5.15	0.277	0.244	0.507
101	Dimethyl ether	C ₂ H ₆ O	115106	46.069	400.1	5.27	0.171	0.271	0.192
102	Methyl ethyl ether	C ₃ H ₈ O	540670	60.096	437.8	4.47	0.221	0.271	0.229
103	Methyl n-propyl ether	C ₄ H ₁₀ O	557175	74.123	476.3	3.77	0.276	0.263	0.264
104	Methyl isopropyl ether	C ₄ H ₁₀ O	598538	74.123	464.5	3.89	0.276	0.278	0.280
105	Methyl n-butyl ether	C ₅ H ₁₂ O	628284	88.150	510	3.31	0.329	0.257	0.335
106	Methyl isobutyl ether	C ₅ H ₁₂ O	625445	88.150	497	3.41	0.331	0.273	0.310
107	Methyl tert-butyl ether	C ₅ H ₁₂ O	1634044	88.150	497.1	3.41	0.329	0.272	0.264
108	Diethyl ether	C ₄ H ₁₀ O	60297	74.123	466.7	3.64	0.281	0.264	0.281
109	Ethyl propyl ether	C ₅ H ₁₂ O	628320	88.150	500.23	3.37	0.336	0.273	0.347
110	Ethyl isopropyl ether	C ₅ H ₁₂ O	625547	88.150	489	3.41	0.329	0.276	0.306
111	Methyl phenyl ether	C ₇ H ₈ O	100663	108.140	645.6	4.27	0.337	0.268	0.353
112	Diphenyl ether	C ₁₂ H ₁₀ O	101848	170.211	766.8	3.10	0.503	0.244	0.441
113	Formaldehyde	CH ₂ O	50000	30.026	408	6.59	0.115	0.223	0.282
114	Acetaldehyde	C ₂ H ₄ O	75070	44.053	466	5.57	0.154	0.221	0.292
115	1-Propanal	C ₃ H ₆ O	123386	58.080	504.4	4.92	0.204	0.239	0.256
116	1-Butanal	C ₄ H ₈ O	123728	72.107	537.2	4.32	0.258	0.250	0.278
117	1-Pentanal	C ₅ H ₁₀ O	110623	86.134	566.1	3.97	0.313	0.264	0.347
118	1-Hexanal	C ₆ H ₁₂ O	66251	100.161	591	3.46	0.369	0.260	0.387
119	1-Heptanal	C ₇ H ₁₄ O	111717	114.188	617	3.18	0.421	0.261	0.427
120	1-Octanal	C ₈ H ₁₆ O	124130	128.214	638.1	2.97	0.474	0.265	0.474
121	1-Nonanal	C ₉ H ₁₈ O	124196	142.241	658	2.74	0.527	0.264	0.514
122	1-Decanal	C ₁₀ H ₂₀ O	112312	156.268	674.2	2.60	0.580	0.269	0.582

TABLE 2-164 Critical Constants and Acentric Factors of Inorganic and Organic Compounds (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T _c , K	P _c × 1E-06 Pa	V _c , m ³ /Kmol	Z _c	Acentric factor
123	Acetone	C ₃ H ₆ O	67641	58.080	508.2	4.71	0.210	0.234	0.307
124	Methyl ethyl ketone	C ₄ H ₈ O	78933	72.107	535.5	4.12	0.267	0.247	0.320
125	2-Pentanone	C ₅ H ₁₀ O	107879	86.134	561.08	3.71	0.301	0.239	0.345
126	Methyl isopropyl ketone	C ₅ H ₁₀ O	563804	86.134	553	3.84	0.313	0.261	0.349
127	2-Hexanone	C ₆ H ₁₂ O	591786	100.161	587.05	3.31	0.369	0.250	0.395
128	Methyl isobutyl ketone	C ₆ H ₁₂ O	108101	100.161	571.4	3.27	0.369	0.254	0.389
129	3-Methyl-2-pentanone	C ₆ H ₁₂ O	565617	100.161	573	3.32	0.371	0.259	0.386
130	3-Pentanone	C ₅ H ₁₀ O	96220	86.134	560.95	3.70	0.336	0.267	0.340
131	Ethyl isopropyl ketone	C ₆ H ₁₂ O	565695	100.161	567	3.34	0.369	0.262	0.394
132	Diisopropyl ketone	C ₇ H ₁₄ O	565800	114.188	576	3.06	0.416	0.266	0.411
133	Cyclohexanone	C ₆ H ₁₀ O	108941	98.145	653	4.01	0.311	0.230	0.308
134	Methyl phenyl ketone	C ₈ H ₈ O	98862	120.151	709.5	3.85	0.386	0.252	0.365
135	Formic acid	CH ₂ O ₂	64186	46.026	588	5.81	0.125	0.148	0.317
136	Acetic acid	C ₂ H ₄ O ₂	64197	60.053	591.95	5.74	0.179	0.208	0.463
137	Propionic acid	C ₃ H ₆ O ₂	79094	74.079	600.81	4.61	0.232	0.214	0.574
138	n-Butyric acid	C ₄ H ₈ O ₂	107926	88.106	615.7	4.07	0.291	0.231	0.682
139	Isobutyric acid	C ₄ H ₈ O ₂	79312	88.106	605	3.68	0.291	0.213	0.612
140	Benzoic acid	C ₇ H ₆ O ₂	65850	122.123	751	4.47	0.347	0.248	0.603
141	Acetic anhydride	C ₄ H ₆ O ₃	108247	102.090	606	3.97	0.290	0.229	0.450
142	Methyl formate	C ₂ H ₄ O ₂	107313	60.053	487.2	5.98	0.173	0.255	0.254
143	Methyl acetate	C ₃ H ₆ O ₂	79209	74.079	506.55	4.69	0.229	0.256	0.326
144	Methyl propionate	C ₄ H ₈ O ₂	554121	88.106	530.6	4.03	0.284	0.259	0.349
145	Methyl n-butyrate	C ₅ H ₁₀ O ₂	623427	102.133	554.5	3.48	0.340	0.257	0.378
146	Ethyl formate	C ₃ H ₆ O ₂	109944	74.079	508.4	4.71	0.231	0.257	0.282
147	Ethyl acetate	C ₄ H ₈ O ₂	141786	88.106	523.3	3.85	0.287	0.254	0.363
148	Ethyl propionate	C ₅ H ₁₀ O ₂	105373	102.133	546	3.34	0.345	0.254	0.391
149	Ethyl n-butyrate	C ₆ H ₁₂ O ₂	105544	116.160	571	2.94	0.403	0.249	0.399
150	n-Propyl formate	C ₄ H ₈ O ₂	110747	88.106	538	4.03	0.286	0.257	0.310
151	n-Propyl acetate	C ₅ H ₁₀ O ₂	109604	102.133	549.73	3.37	0.349	0.257	0.390
152	n-Butyl acetate	C ₆ H ₁₂ O ₂	123864	116.160	579.15	3.11	0.389	0.251	0.410
153	Methyl benzoate	C ₈ H ₈ O ₂	93583	136.150	693	3.59	0.436	0.272	0.421
154	Ethyl benzoate	C ₉ H ₁₀ O ₂	93890	150.177	698	3.22	0.489	0.271	0.477
155	Vinyl acetate	C ₄ H ₆ O ₂	108054	86.090	519.13	3.93	0.270	0.246	0.348
156	Methylamine	CH ₃ N	74895	31.057	430.05	7.41	0.154	0.319	0.279
157	Dimethylamine	C ₂ H ₇ N	124403	45.084	437.2	5.26	0.180	0.260	0.293
158	Trimethylamine	C ₃ H ₉ N	75503	59.111	433.25	4.10	0.254	0.289	0.210
159	Ethylamine	C ₂ H ₇ N	75047	45.084	456.15	5.59	0.202	0.298	0.283
160	Diethylamine	C ₄ H ₁₁ N	109897	73.138	496.6	3.67	0.301	0.268	0.300
161	Triethylamine	C ₆ H ₁₅ N	121448	101.192	535.15	3.04	0.389	0.266	0.316
162	n-Propylamine	C ₃ H ₉ N	107108	59.111	496.95	4.74	0.260	0.298	0.280
163	di-n-Propylamine	C ₆ H ₁₅ N	142847	101.192	550	3.11	0.401	0.273	0.446
164	Isopropylamine	C ₃ H ₉ N	75310	59.111	471.85	4.54	0.221	0.256	0.276
165	Diisopropylamine	C ₆ H ₁₅ N	108189	101.192	523.1	3.20	0.417	0.307	0.388
166	Aniline	C ₆ H ₇ N	62533	93.128	699	5.35	0.270	0.248	0.381
167	N-Methylaniline	C ₇ H ₉ N	100618	107.155	701.55	5.19	0.373	0.332	0.480
168	N,N-Dimethylaniline	C ₈ H ₁₁ N	121697	121.182	687.15	3.63	0.465	0.295	0.403
169	Ethylene oxide	C ₂ H ₄ O	75218	44.053	469.15	7.26	0.142	0.264	0.201
170	Furan	C ₄ H ₄ O	110009	68.075	490.15	5.55	0.218	0.297	0.205
171	Thiophene	C ₄ H ₄ S	110021	84.142	579.35	5.71	0.219	0.260	0.195
172	Pyridine	C ₅ H ₅ N	110861	79.101	619.95	5.64	0.254	0.278	0.239
173	Formamide	CH ₃ NO	75127	45.041	771	7.75	0.163	0.197	0.410
174	N,N-Dimethylformamide	C ₃ H ₇ NO	68122	73.095	649.6	4.37	0.262	0.212	0.312
175	Acetamide	C ₂ H ₅ NO	60355	59.068	761	6.57	0.215	0.223	0.419
176	N-Methylacetamide	C ₃ H ₇ NO	79163	73.095	718	5.00	0.267	0.224	0.437
177	Acetonitrile	C ₂ H ₃ N	75058	41.053	545.5	4.85	0.173	0.185	0.340
178	Propionitrile	C ₃ H ₅ N	107120	55.079	564.4	4.19	0.229	0.205	0.325
179	n-Butyronitrile	C ₄ H ₇ N	109740	69.106	582.25	3.79	0.278	0.217	0.371
180	Benzonitrile	C ₇ H ₅ N	100470	103.123	699.35	4.21	0.339	0.245	0.352
181	Methyl mercaptan	CH ₃ S	74931	48.109	469.95	7.23	0.145	0.268	0.158
182	Ethyl mercaptan	C ₂ H ₆ S	75081	62.136	499.15	5.49	0.206	0.273	0.188
183	n-Propyl mercaptan	C ₃ H ₈ S	107039	76.163	536.6	4.63	0.254	0.263	0.232
184	n-Butyl mercaptan	C ₄ H ₁₀ S	109795	90.189	570.1	3.97	0.307	0.257	0.272
185	Isobutyl mercaptan	C ₄ H ₁₀ S	513440	90.189	559	4.06	0.307	0.268	0.253
186	sec-Butyl mercaptan	C ₄ H ₁₀ S	513531	90.189	554	4.06	0.307	0.271	0.251
187	Dimethyl sulfide	C ₂ H ₆ S	75183	62.136	503.04	5.53	0.200	0.264	0.194
188	Methyl ethyl sulfide	C ₃ H ₈ S	624895	76.163	533	4.26	0.254	0.244	0.209
189	Diethyl sulfide	C ₄ H ₁₀ S	352932	90.189	557.15	3.96	0.320	0.273	0.294

TABLE 2-164 Critical Constants and Acentric Factors of Inorganic and Organic Compounds (Concluded)

Cmpd. no.	Name	Formula	CAS no.	Mol. wt.	T_c , K	$P_c \times 10^{-6}$ Pa	V_c , m^3/kmol	Z_c	Acentric factor
190	Fluoromethane	CH_3F	593533	34.033	317.42	5.88	0.113	0.252	0.198
191	Chloromethane	CH_3Cl	74873	50.488	416.25	6.69	0.142	0.275	0.154
192	Trichloromethane	CHCl_3	67663	119.377	536.4	5.55	0.238	0.296	0.228
193	Tetrachloromethane	CCl_4	56235	153.822	556.35	4.54	0.274	0.270	0.191
194	Bromomethane	CH_3Br	74839	94.939	467	8.00	0.156	0.321	0.192
195	Fluoroethane	$\text{C}_2\text{H}_5\text{F}$	353366	48.060	375.31	5.01	0.164	0.263	0.218
196	Chloroethane	$\text{C}_2\text{H}_5\text{Cl}$	75003	64.514	460.35	5.46	0.155	0.221	0.206
197	Bromoethane	$\text{C}_2\text{H}_5\text{Br}$	74964	108.966	503.8	6.29	0.215	0.323	0.259
198	1-Chloropropane	$\text{C}_3\text{H}_7\text{Cl}$	540545	78.541	503.15	4.58	0.247	0.270	0.228
199	2-Chloropropane	$\text{C}_3\text{H}_7\text{Cl}$	75296	78.541	489	4.51	0.247	0.274	0.196
200	1,1-Dichloropropane	$\text{C}_3\text{H}_6\text{Cl}_2$	78999	112.986	560	4.24	0.292	0.266	0.253
201	1,2-Dichloropropane	$\text{C}_3\text{H}_6\text{Cl}_2$	78875	112.986	572	4.23	0.291	0.259	0.256
202	Vinyl chloride	$\text{C}_2\text{H}_3\text{Cl}$	75014	62.499	432	5.75	0.179	0.287	0.106
203	Fluorobenzene	$\text{C}_6\text{H}_5\text{F}$	462066	96.104	560.09	4.54	0.269	0.262	0.247
204	Chlorobenzene	$\text{C}_6\text{H}_5\text{Cl}$	108907	112.558	632.35	4.53	0.308	0.265	0.251
205	Bromobenzene	$\text{C}_6\text{H}_5\text{Br}$	108861	157.010	670.15	4.52	0.324	0.263	0.251
206	Air		132259100	28.951	132.45	3.79	0.092	0.318	0.000
207	Hydrogen	H_2	1333740	2.016	33.19	1.32	0.064	0.307	-0.215
208	Helium-4	He	7440597	4.003	5.2	0.23	0.058	0.305	-0.388
209	Neon	Ne	7440019	20.180	44.4	2.67	0.042	0.300	-0.038
210	Argon	Ar	7440371	39.948	150.86	4.90	0.075	0.292	0.000
211	Fluorine	F_2	7782414	37.997	144.12	5.17	0.067	0.287	0.053
212	Chlorine	Cl_2	7782505	70.905	417.15	7.79	0.124	0.279	0.073
213	Bromine	Br_2	7726956	159.808	584.15	10.28	0.135	0.286	0.128
214	Oxygen	O_2	7782447	31.999	154.58	5.02	0.074	0.287	0.020
215	Nitrogen	N_2	7727379	28.014	126.2	3.39	0.089	0.288	0.037
216	Ammonia	NH_3	7664417	17.031	405.65	11.30	0.072	0.241	0.253
217	Hydrazine	N_2H_4	302012	32.045	653.15	14.73	0.158	0.429	0.315
218	Nitrous oxide	N_2O	10024972	44.013	309.57	7.28	0.098	0.277	0.143
219	Nitric oxide	NO	10102439	30.006	180.15	6.52	0.058	0.252	0.585
220	Cyanogen	C_2N_2	460195	52.036	400.15	5.94	0.195	0.348	0.276
221	Carbon monoxide	CO	630080	28.010	132.92	3.49	0.095	0.300	0.048
222	Carbon dioxide	CO_2	124389	44.010	304.21	7.39	0.095	0.277	0.224
223	Carbon disulfide	CS_2	75150	76.143	552	8.04	0.160	0.280	0.118
224	Hydrogen fluoride	HF	7664393	20.006	461.15	6.49	0.069	0.117	0.383
225	Hydrogen chloride	HCl	7647010	36.461	324.65	8.36	0.082	0.253	0.134
226	Hydrogen bromide	HBr	10035106	80.912	363.15	8.46	0.100	0.280	0.069
227	Hydrogen cyanide	HCN	74908	27.026	456.65	5.35	0.139	0.195	0.407
228	Hydrogen sulfide	H_2S	7783064	34.082	373.53	9.00	0.099	0.287	0.096
229	Sulfur dioxide	SO_2	7446095	64.065	430.75	7.86	0.123	0.269	0.244
230	Sulfur trioxide	SO_3	7446119	80.064	490.85	8.19	0.127	0.255	0.423
231	Water	H_2O	7732185	18.015	647.13	21.94	0.056	0.228	0.343

All substances are listed in alphabetical order in Table 2-6a.

Compiled from Daubert, T. E., R. P. Danner, H. M. Sibul, and C. C. Stebbins, DIPPR Data Compilation of Pure Compound Properties, Project 801 Sponsor Release, July, 1993, Design Institute for Physical Property Data, AIChE, New York, NY; and from Ambrose, D. "Vapour-Liquid Critical Properties", Report Chem 107, National Physical Laboratory, Teddington, UK, October, 1979.

In order to ensure thermodynamic consistency, in almost all cases these properties are calculated from T_c and the vapor pressure and liquid density correlation coefficients listed in those tables. This means that there will be slight differences between the values listed here and those in the DIPPR tables. Most of the differences are less than 1%, and almost all the rest are less than the estimated accuracy of the quantity in question.

The atomic weights used, taken from *J. Phys. Chem. Ref. Data* 22(6), 1993, are C = 12.011, H = 1.00794, O = 15.9994, N = 14.00674, S = 32.066, F = 18.9984, Cl = 35.4527, Br = 79.904, and I = 126.90447.

The value of the gas constant, R , used here is 8314.51 J/(kmol·K), as given by E. R. Cohen and B. N. Taylor in *J. Phys. Chem. Ref. Data* 17, 1988. K = 273.15 °C; $1.8 \times K - 459.67 = {}^\circ\text{F}$; Pa × 9.869233E-06 = atm; Pa × 1.450377E-04 = psia j ; $\text{m}^3/\text{kmol} \times (1E + 03/\text{mol. wt.}) = \text{cm}^3/\text{g}$; $\text{m}^3/\text{kmol} \times (1.601846E + 01/\text{mol wt}) = \text{ft}^3/\text{lb}$.

COMPRESSIBILITIES

INTRODUCTION

The increasing ranges of pressure and temperature of interest to technology for an ever-increasing number of substances would necessitate additional tables in this subsection as well as in the subsection "Thermodynamic Properties." Space restrictions preclude this. Hence, in the present revision, an attempt was made to update the fluid-compressibility tables for selected fluids and to omit tables for other fluids. The reader is thus referred to the fourth edition for tables on miscellaneous gases at 0°C, acetylene, ammonia, ethane, ethylene, hydrogen-nitrogen mixtures, and methyl chloride. The reader is also

reminded that compressibilities can be calculated from the pressure—volume (or density)—temperature tables of the subsection "Thermodynamic Properties."

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$^{\circ}\text{R} = \% \text{ K}$$

To convert bars to pounds-force per cubic inch, multiply by 14.504.

To convert bars to kilopascals, multiply by 1×10^5 .

TABLE 2-165 Compressibility Factors for Air*

Temp., K	Pressure, bar													
	1	5	10	20	40	60	80	100	150	200	250	300	400	500
75	0.0052	0.0260	0.0519	0.1036	0.2063	0.3082	0.4094	0.5099	0.7581	1.0025				
80		0.0250	0.0499	0.0995	0.1981	0.2958	0.3927	0.4887	0.7258	0.9588	1.1931	1.4139		
90	0.9764	0.0236	0.0471	0.0940	0.1866	0.2781	0.3686	0.4581	0.6779	0.8929	1.1098	1.3110	1.7161	2.1105
100	0.9797	0.8872	0.0453	0.0900	0.1782	0.2635	0.3498	0.4337	0.6386	0.8377	1.0395	1.2227	1.5937	1.9536
120	0.9880	0.9373	0.8660	0.6730	0.1778	0.2557	0.3371	0.4132	0.5964	0.7720	0.9530	1.1076	1.5091	1.7366
140	0.9927	0.9614	0.9205	0.8297	0.5556	0.3313	0.3737	0.4340	0.5909	0.7699	0.9114	1.0393	1.3202	1.5903
160	0.9951	0.9748	0.9489	0.8954	0.7803	0.6603	0.5696	0.5489	0.6340	0.7564	0.8840	1.0105	1.2585	1.4970
180	0.9967	0.9832	0.9660	0.9314	0.8625	0.7977	0.7432	0.7084	0.7180	0.7986	0.9000	1.0068	1.2232	1.4361
200	0.9978	0.9886	0.9767	0.9539	0.9100	0.8701	0.8374	0.8142	0.8061	0.8549	0.9311	1.0185	1.2054	1.3944
250	0.9992	0.9957	0.9911	0.9822	0.9671	0.9549	0.9463	0.9411	0.9450	0.9713	1.0152	1.0702	1.1990	1.3392
300	0.9999	0.9987	0.9974	0.9950	0.9917	0.9901	0.9903	0.9930	1.0074	1.0326	1.0669	1.1089	1.2073	1.3163
350	1.0000	1.0002	1.0004	1.0014	1.0038	1.0075	1.0121	1.0183	1.0377	1.0635	1.0947	1.1303	1.2116	1.3015
400	1.0002	1.0012	1.0025	1.0046	1.0100	1.0159	1.0229	1.0312	1.0533	1.0795	1.1087	1.1411	1.2117	1.2890
450	1.0003	1.0016	1.0034	1.0063	1.0133	1.0210	1.0287	1.0374	1.0614	1.0913	1.1183	1.1463	1.2090	1.2778
500	1.0003	1.0020	1.0034	1.0074	1.0151	1.0234	1.0323	1.0410	1.0650	1.0913	1.1183	1.1463	1.2051	1.2667
600	1.0004	1.0022	1.0039	1.0081	1.0164	1.0253	1.0340	1.0434	1.0678	1.0920	1.1172	1.1427	1.1947	1.2475
800	1.0004	1.0020	1.0038	1.0077	1.0157	1.0240	1.0321	1.0408	1.0621	1.0844	1.1061	1.1283	1.1720	1.2150
1000	1.0004	1.0018	1.0037	1.0068	1.0142	1.0215	1.0290	1.0365	1.0556	1.0744	1.0948	1.1131	1.1515	1.1889

*Calculated from values of pressure, volume (or density), and temperature in Vasserman, Kazavchinskii, and Rabinovich, *Thermophysical Properties of Air and Air Components*, Moscow, Nauka, 1966, and NBS-NSF Trans. TT 70-50095, 1971; and Vasserman and Rabinovich, *Thermophysical Properties of Liquid Air and Its Components*, Moscow, 1968, and NBS-NSF Trans. 69-55092, 1970.

TABLE 2-166 Compressibility Factors for Argon*

Temp., K	Pressure, bar											
	1	5	10	20	40	60	80	100	200	300	400	500
100	0.9773	0.0183	0.0366	0.0729	0.1449	0.2162	0.2867	0.3567	0.6975	1.0267	1.3470	1.6932
150	0.9932	0.9647	0.9273	0.8447	0.6101	0.2249	0.2781	0.3324	0.5934	0.8387	1.0732	1.2995
200	0.9972	0.9857	0.9713	0.9419	0.8810	0.8208	0.7624	0.7121	0.6570	0.8360	1.0051	1.1982
250	0.9988	0.9935	0.9869	0.9741	0.9494	0.9263	0.9056	0.8877	0.8590	0.9207	1.0262	1.1479
300	0.9995	0.9969	0.9941	0.9884	0.9777	0.9686	0.9611	0.9552	0.9533	0.9950	1.0673	1.1786
400	1.0001	0.9997	0.9998	0.9999	1.0004	1.0018	1.0031	1.0056	1.0280	1.0656	1.1157	1.1976
500	1.0002	1.0007	1.0012	1.0034	1.0071	1.0113	1.0154	1.0205	1.0501	1.0874	1.1301	1.1997
600	1.0003	1.0012	1.0025	1.0046	1.0094	1.0143	1.0198	1.0250	1.0553	1.0904	1.1291	1.1933
800	1.0003	1.0012	1.0023	1.0050	1.0102	1.0151	1.0205	1.0258	1.0532	1.0830	1.1147	1.1707
1000	1.0002	1.0013	1.0022	1.0050	1.0096	1.0142	1.0193	1.0239	1.0484	1.0736	1.0999	1.1497

*Calculated from PVT values tabulated in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standard Press, Moscow, 1976. This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

TABLE 2-167 Compressibility Factors for Carbon Dioxide*

Temp., °C	Pressure, bar											
	1	5	10	20	40	60	80	100	200	300	400	500
0	0.9933	0.9658	0.9294	0.8496								
50	0.9964	0.9805	0.9607	0.9195	0.8300	0.7264	0.5981	0.4239				
100	0.9977	0.9883	0.9764	0.9524	0.9034	0.8533	0.8022	0.7514	0.5891	0.6420		
150	0.9985	0.9927	0.9853	0.9705	0.9416	0.9131	0.8854	0.8590	0.7651	0.7623	0.8235	0.9098
200	0.9991	0.9953	0.9908	0.9818	0.9640	0.9473	0.9313	0.9170	0.8649	0.8619	0.8995	0.9621
250	0.9994	0.9971	0.9943	0.9886	0.9783	0.9684	0.9593	0.9511	0.9253	0.9294	0.9508	1.0096
300	0.9996	0.9982	0.9967	0.9936	0.9875	0.9822	0.9773	0.9733	0.9640	0.9746	1.0030	1.0464
350	0.9998	0.9991	0.9983	0.9964	0.9938	0.9914	0.9896	0.9882	0.9895	1.0053	1.0340	1.0734
400	0.9999	0.9997	0.9994	0.9989	0.9982	0.9979	0.9979	0.9984	1.0073	1.0266	1.0559	1.0928
450	1.0000	1.0000	1.0003	1.0005	1.0013	1.0023	1.0038	1.0056	1.0070	1.0412	1.0709	1.1067
500	1.0000	1.0004	1.0008	1.0015	1.0035	1.0056	1.0079	1.0107	1.0282	1.0522	1.0820	1.1165
600	1.0000	1.0007	1.0013	1.0030	1.0062	1.0093	1.0129	1.0168	1.0386	1.0648	1.0948	1.1277
700	1.0003	1.0010	1.0017	1.0036	1.0073	1.0161	1.0155	1.0198	1.0436	1.0707	1.1000	1.1318
800	1.0002	1.0009	1.0019	1.0040	1.0082	1.0122	1.0168	1.0212	1.0458	1.0731	1.1016	1.1324
900	1.0002	1.0009	1.0020	1.0041	1.0083	1.0128	1.0171	1.0221	1.0463	1.0726	1.1012	1.1303
1000	1.0002	1.0009	1.0021	1.0042	1.0084	1.0128	1.0172	1.0218	1.0460	1.0725	1.0725	1.1274

*Calculated from density-pressure-temperature data in Vulakovitch and Altunin, *Thermophysical Properties of Carbon Dioxide*, Atomizdat, Moscow, 1965, and Collet's, London, 1968, translation.

TABLE 2-168 Compressibility Factors for Carbon Monoxide*

Temp., K	Pressure, atm						
	1	4	7	10	40	70	100
200	0.9973	0.9893	0.9813	0.9734			
250	0.9989	0.9957	0.9926	0.9896	0.9632		
300	0.9997	0.9987	0.9977	0.9968	0.9907	0.9896	0.9935
350	1.0000	1.0002	1.0003	1.0005	1.0042	1.0112	1.0216
400	1.0002	1.0010	1.0017	1.0025	1.0042	1.0112	1.0216
450	1.0003	1.0014	1.0025	1.0035	1.0152	1.0285	1.0433
500	1.0004	1.0016	1.0029	1.0041	1.0172	1.0314	1.0469
600	1.0005	1.0018	1.0032	1.0045	1.0186	1.0332	1.0485
700	1.0005	1.0018	1.0032	1.0045	1.0183	1.0325	1.0470
800	1.0004	1.0017	1.0030	1.0044	1.0175	1.0309	1.0445
900	1.0004	1.0017	1.0029	1.0041	1.0166	1.0291	1.0418
1000	1.0004	1.0016	1.0027	1.0039	1.0156	1.0273	1.0391
1500	1.0003	1.0012	1.0021	1.0029	1.0115	1.0200	1.0286
2000	1.0002	1.0009	1.0016	1.0022	1.0088	1.0155	1.0221
2500	1.0002	1.0007	1.0013	1.0018	1.0071	1.0124	1.0178
3000	1.0002	1.0006	1.0010	1.0015	1.0059	1.0104	1.0148

*From Hilsenrath *et al.*, N.B.S. Circ. 564, 1955. Some of the above values have been rounded to four decimal places. Values at 10-K increments below 1000 K and at 50 K increments for higher temperatures appear in the original, also for pressures below atmospheric.

TABLE 2-169 Compressibility Factors for Ethanol

Temp., K	Pressure, bar								
	0.1	0.5	1.013	10	20	50	100	250	500
300	0.0022	0.0023	0.0024	0.0229	0.0458	0.114	0.228	0.565	1.11
350				0.0215	0.0411	0.107	0.208	0.509	1.03
400	0.999	0.993	0.986	0.0204	0.0408	0.101	0.201	0.490	0.95
450	1.000	0.997	0.991	0.908		0.101	0.198	0.472	0.898
500	1.000	0.997	0.994	0.941	0.874	0.122	0.214	0.473	0.868
600	1.000	0.998	0.997	0.972	0.943		0.672	0.470	0.868
700	1.000	0.999	0.999	0.985	0.971	0.948	0.902	0.760	0.921
800	1.000	1.000	0.999	0.992	0.984	0.973	0.953	0.890	0.988
900	1.000	1.000	1.000	0.996	0.992	0.988	0.981	0.962	1.04
1000	1.000	1.000	1.000	0.998	0.997	0.993	0.990	1.002	1.08

Rounded and interpolated from Thermodynamics Research Center tables, Texas A&M University.

TABLE 2-170 Compressibility Factors for Ethylene

Pressure, bar	Temperature, K								
	110	150	200	250	300	350	400	450	500
1	0.0047	0.0038	0.9808	0.9902	0.9944	0.9966	0.9979	0.9986	0.9991
5	0.0237	0.0189	0.0162	0.9495	0.9717	0.9828	0.9894	0.9935	0.9959
10	0.0472	0.0378	0.0323	0.8946	0.9425	0.9659	0.9785	0.9867	0.9919
15	0.0710	0.0566	0.0484	0.8320	0.9121	0.9479	0.9679	0.9749	0.9876
20	0.0946	0.0754	0.0644	0.7578	0.8804	0.9299	0.9574	0.9734	0.9833
30	0.1418	0.1129	0.0963	0.0950	0.8122	0.8936	0.9357	0.9603	0.9754
40	0.1889	0.1504	0.1280	0.1251	0.7342	0.8560	0.9144	0.9477	0.9677
60	0.2831	0.2251	0.1910	0.1838	0.5235	0.7791	0.8730	0.9231	0.9541
80	0.3767	0.2994	0.2533	0.2410	0.3302	0.7023	0.9056	0.9009	0.9428
100	0.4702	0.3734	0.3150	0.2968	0.3480	0.6359	0.9220	0.8825	0.9321
150	0.7030	0.5567	0.4671	0.4324	0.4528	0.5842	0.7483	0.8523	0.9167
200	0.9337	0.7382	0.6161	0.5630	0.5641	0.6347	0.7499	0.8494	0.9184
250	1.1636	0.9179	0.7630	0.6904	0.6740	0.7110	0.7895	0.8710	0.9343
300	1.3917	1.0960	0.9075	0.8148	0.7816	0.7969	0.8479	0.9095	0.9631
400	1.8441	1.4475	1.1910	1.0565	0.9909	0.9726	0.9849	1.0142	1.0450
500	solid	1.7934	1.4679	1.2908	1.1932	1.1468	1.1304	1.1341	1.1436

Calculated from Jacobsen, R.T., M. Jahangiri, et al., *Ethylene*, Blackwell Sci. Publs., Oxford, 1988 (299 pp.).

TABLE 2-171 Compressibility Factors for Normal Hydrogen*

Temp., K	Pressure, bar											
	1	10	20	40	60	80	100	200	400	600	800	1000
20	0.0169	0.1680	0.3302	0.6430	0.9434	1.2346	1.5166	2.844				
40	0.9848	0.8340	0.6311	0.5240	0.6627	0.8118	0.9590	1.650	2.878	3.993	5.034	6.019
60	0.9955	0.9562	0.9169	0.8608	0.8498	0.8832	0.9432	1.347	2.158	2.902	3.598	4.263
80	0.9986	0.9776	0.9763	0.9655	0.9676	0.9842	1.0138	1.257	1.834	2.389	2.907	3.404
100	0.9998	0.9979	0.9976	1.0022	1.0133	1.0280	1.0528	1.225	1.659	2.095	2.512	2.902
200	1.0007	1.0066	1.0134	1.0275	1.0422	1.0575	1.0734	1.163	1.355	1.555	1.753	1.936
300	1.0005	1.0059	1.0117	1.0236	1.0357	1.0479	1.0603	1.124	1.253	1.383	1.510	1.636
400	1.0004	1.0048	1.0096	1.0192	1.0289	1.0386	1.0484	1.098	1.196	1.293	1.388	1.481
500	1.0004	1.0040	1.0080	1.0160	1.0240	1.0320	1.0400	1.080	1.159	1.236	1.311	1.355
600	1.0003	1.0034	1.0068	1.0136	1.0204	1.0272	1.0340	1.068	1.133	1.197	1.259	1.320
800	1.0002	1.0026	1.0052	1.0104	1.0156	1.0208	1.0259	1.051	1.100	1.147	1.193	1.237
1000	1.0002	1.0021	1.0042	1.0084	1.0126	1.0168	1.0209	1.041	1.080	1.117	1.153	1.187
2000	1.0009	1.0013	1.0023	1.0044	1.0065	1.0086	1.0107	1.021	1.040	1.057	1.073	1.088

*Calculated from PVT tables of McCarty, Hord, and Roder, NBS Monogr. 168, 1981.

TABLE 2-172 Compressibility Factors for KLEA 60

Temp., K	Pressure, bar									
	1	5	10	15	20	25	30	Z_{sat}	P_{sat}	
250	0.9687								0.9494	2.08
260	0.9780								0.9315	3.11
270	0.9803								0.9098	4.49
280	0.9824	0.9099							0.8839	6.30
290	0.9848	0.9199							0.8538	8.62
300	0.9867	0.9284	0.8459						0.8175	11.55
310	0.9872	0.9359	0.8637	0.7800					0.7756	15.19
320	0.9884	0.9425	0.8790	0.8066					0.7261	19.66
330	0.9894	0.9484	0.8908	0.8299	0.7577	0.6700			0.6666	25.10
340	0.9905	0.9537	0.9026	0.8488	0.7888	0.7184	0.6305			
350	0.9920	0.9582	0.9139	0.8663	0.8145	0.7570	0.6908			
Z_{sat}	0.9712	0.9022	0.8361	0.7777	0.7224	0.6677	0.6118			
T_{sat}	234.0	273.1	295.0	309.5	320.7	329.8	337.6			

Converted and interpolated from "Thermodynamic Properties of KLEA 60," British units, © ICI Chemicals and Polymers, 1993 (20 pp.). Reproduced by permission. KLEA 60 is R32/125/134a (20/40/40 wt %).

TABLE 2-173 Compressibility Factors for KLEA 61

Temp., K	Pressure, bar								
	1	5	10	15	20	25	30	Z _{sat}	P _{sat}
250	0.9746							0.9381	2.46
260	0.9773							0.9172	3.63
270	0.9798							0.8920	5.18
280	0.9787	0.9067						0.8622	7.19
290	0.9838	0.9185						0.8272	9.75
300	0.9854	0.9270	0.8431					0.7868	12.21
310	0.9868	0.9348	0.8615	0.7755				0.7377	16.88
320	0.9881	0.9416	0.8772	0.8042	0.7148			0.6801	21.68
330	0.9892	0.9481	0.8909	0.8280	0.7518	0.6659		0.6087	27.50
340	0.9903	0.9529	0.9027	0.8484	0.7934	0.7174	0.6312		
350	0.9917	0.9577	0.9131	0.8653	0.8134	0.7565	0.6916		
Z _{sat}	0.9686	0.8944	0.8237	0.7602	0.7003	0.6399	0.5780		
T _{sat}	230.0	269.0	290.9	305.5	316.7	325.9	333.7		

Converted and interpolated from "Thermodynamic Properties of KLEA 61," British units, © ICI Chemicals and Polymers, 1993 (23 pp.). Reproduced by permission. KLEA 61 is R32/125/134a (10/70/20 wt %).

TABLE 2-174 Compressibility Factors for KLEA 66

Temp., K	Pressure, bar								
	1	5	10	15	20	25	30	Z _{sat}	P _{sat}
250	0.974							0.9541	1.89
260	0.9772							0.9374	2.84
270	0.9796							0.9172	4.12
280	0.9838	0.9089						0.8931	5.81
290	0.9858	0.9209						0.8645	7.98
300	0.9872	0.9287	0.8461					0.8328	10.73
310	0.9883	0.9359	0.8663					0.7920	14.15
320	0.9896	0.9431	0.8786	0.8056				0.7462	18.37
330	0.9907	0.9490	0.8910	0.8292	0.7551			0.6918	23.50
340	0.9917	0.9540	0.9035	0.8492	0.7878	0.7147		0.6255	29.73
350	0.9926	0.9588	0.9137	0.8659	0.8127	0.7542	0.6843		
Z _{sat}	0.9719	0.9044	0.8397	0.7827	0.7289	0.6759	0.6220		
T _{sat}	236.1	275.5	297.6	312.1	323.5	332.6	340.4		

Converted and interpolated from "Thermodynamic properties of KLEA 66," British units, © ICI Chemicals and Polymers, 1993 (20 pp.). Reproduced by permission. KLEA 66 is R32/125/134a (23/25/52 wt %).

TABLE 2-175 Compressibility Factors for Krypton*

Temp., K	Pressure, bar											
	1	5	10	20	40	60	80	100	200	300	400	500
150	0.9837	0.9155	0.0310	0.0618	0.1227	0.1829	0.2423	0.3012	0.5875	0.8636	1.1315	1.3932
200	0.9933	0.9648	0.9278	0.8459	0.6039	0.1870	0.2393	0.2903	0.5313	0.7568	0.9730	1.1820
250	0.9966	0.9841	0.9635	0.9265	0.8468	0.7605	0.6680	0.5810	0.5785	0.7461	0.9197	1.0891
300	0.9982	0.9899	0.9800	0.9595	0.9197	0.8807	0.8437	0.8097	0.7337	0.7954	0.9302	1.0627
350	0.9989	0.9949	0.9897	0.9793	0.9522	0.9415	0.9250	0.9110	0.8774	0.8992	0.9799	1.0664
400	0.9993	0.9967	0.9933	0.9867	0.9746	0.9635	0.9539	0.9459	0.9323	0.9570	1.0150	1.0910
450	0.9998	0.9985	0.9969	0.9939	0.9886	0.9838	0.9800	0.9774	0.9663	1.0011	1.0543	1.1142
500	0.9998	0.9992	0.9984	0.9970	0.9942	0.9921	0.9910	0.9906	1.0019	1.0311	1.0732	1.1258
600	1.0000	1.0003	1.0005	1.0012	1.0025	1.0043	1.0064	1.0091	1.0301	1.0618	1.1000	1.1431
800	1.0002	1.0010	1.0020	1.0041	1.0079	1.0122	1.0170	1.0214	1.0475	1.0779	1.1112	1.1147
1000	1.0002	1.0013	1.0023	1.0045	1.0091	1.0135	1.0184	1.0230	1.0486	1.0767	1.1063	1.1369

*Calculated from PVT values tabulated in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

2-144 PHYSICAL AND CHEMICAL DATA
TABLE 2-176 Compressibility Factors for Methane (R50)*

Temp., K	Pressure, bar											
	1	5	10	20	40	60	80	100	200	300	400	500
150	0.9854	0.9225	0.8275	0.0714	0.1411	0.2093	0.2763	0.3423	0.6599	0.9623	1.2537	1.5363
200	0.9936	0.9676	0.9339	0.8599	0.6784	0.3559	0.3172	0.3618	0.6141	0.8568	1.0887	1.3122
250	0.9965	0.9838	0.9680	0.9352	0.8682	0.8020	0.7386	0.6854	0.6899	0.8554	1.0359	1.2155
300	0.9983	0.9915	0.9830	0.9667	0.9343	0.9047	0.8783	0.8556	0.8280	0.9154	1.0432	1.1829
350	0.9991	0.9954	0.9911	0.9825	0.9662	0.9520	0.9401	0.9306	0.9227	0.9800	1.0723	1.1804
400	0.9995	0.9977	0.9953	0.9912	0.9835	0.9772	0.9726	0.9696	0.9779	1.0245	1.0986	1.1859
450	0.9997	0.9989	0.9979	0.9963	0.9935	0.9917	0.9911	0.9916	1.0098	1.0528	1.1152	1.1899
500	0.9999	0.9997	0.9995	0.9995	0.9996	1.0005	1.0022	1.0048	1.0285	1.0699	1.1248	1.1899
600	1.0000	1.0009	1.0020	1.0039	1.0081	1.0125	1.0171	1.0217	1.0540	1.0969	1.1470	1.2019
800	1.0003	1.0017	1.0034	1.0068	1.0130	1.0197	1.0263	1.0330	1.0678	1.1068	1.1496	1.1951
1000	1.0004	1.0014	1.0035	1.0071	1.0141	1.0207	1.0274	1.0342	1.0678	1.1033	1.1400	1.1790

*Calculated from PVT values tabulated in Goodwin, NBS Tech. Note 653, 1974, for temperatures up to 500 K, and from PVT values tabulated in Zhuravlev. *Thermophysical Properties of Gaseous and Liquid Methane*, Standartov, Moscow, 1969, and NBS-NSF transl. TT 70-50097, 1970.

TABLE 2-177 Compressibility Factors for Methanol

Temp., K	Pressure, bar												
	0.1	0.5	1.0133	10	20	50	100	150	200	250	300	400	500
200	0.0002	0.0011	0.0022	0.0219	0.0438	0.1091	0.2174	0.3250	0.4319	0.5381	0.6437	0.8531	1.6030
250	0.0002	0.0009	0.0019	0.0185	0.0370	0.0923	0.1837	0.2743	0.3643	0.4535	0.5422	0.7176	0.8909
300	0.9792	0.0008	0.0017	0.0164	0.0327	0.0813	0.1617	0.2413	0.3201	0.3981	0.4755	0.6284	0.7791
350	0.9844	0.9713	0.9551	0.0150	0.0298	0.0742	0.1473	0.2193	0.2904	0.3606	0.4301	0.5671	0.7016
400	0.9872	0.9795	0.9722	0.0142	0.0283	0.0702	0.1386	0.2056	0.2714	0.3362	0.4000	0.5253	0.6478
450	0.9890	0.9835	0.9792	0.9145	0.7989	0.0701	0.1366	0.2007	0.2629	0.3238	0.3834	0.4997	0.6128
500	0.9903	0.9859	0.9828	0.9525	0.9081	0.6799	0.1505	0.2110	0.2699	0.3271	0.3829	0.4912	0.5959
600	0.9922	0.9889	0.9867	0.9756	0.9643	0.9042	0.7629	0.6275	0.5255	0.4921	0.5010	0.5606	0.6358
700	0.9934	0.9907	0.9889	0.9816	0.9778	0.9541	0.8932	0.8392	0.8027	0.7797	0.7675	0.7713	0.7993
800	0.9964	0.9920	0.9904	0.9838	0.9818	0.9711	0.9411	0.9156	0.9025	0.8994	0.9026	0.9205	0.9485

Goodwin, R.D., *J. Phys. Chem. Ref. Data*, **16** (4), 799, 1987.

TABLE 2-178 Compressibility Factors for Neon*

Temp., K	Pressure, bar											
	1	5	10	20	40	60	80	100	200	300	400	500
50	0.9913	0.9472	0.9083	0.8013	0.3810	0.4398	0.4984	0.5850	0.9864	1.3659	1.7289	2.0794
100	0.9993	0.9970	0.9949	0.9913	0.9854	0.9245	0.9864	0.9930	1.0796	1.2197	1.3796	1.5473
150	1.0002	1.0017	1.0036	1.0078	1.0162	1.0262	1.0375	1.0497	1.1236	1.2131	1.3113	1.4150
200	1.0003	1.0023	1.0049	1.0100	1.0204	1.0318	1.0427	1.0551	1.1191	1.1909	1.2655	1.3422
250	1.0001	1.0022	1.0045	1.0097	1.0198	1.0295	1.0403	1.0502	1.1057	1.1633	1.2223	1.2822
300	1.0000	1.0020	1.0041	1.0091	1.0181	1.0277	1.0369	1.0469	1.0961	1.1476	1.1997	1.2520
400	1.0000	1.0017	1.0036	1.0074	1.0151	1.0216	1.0301	1.0376	1.0771	1.1172	1.1575	1.1981
500	1.0000	1.0014	1.0029	1.0058	1.0124	1.0188	1.0252	1.0316	1.0641	1.0963	1.1291	1.1621
600	1.0000	1.0012	1.0024	1.0049	1.0107	1.0160	1.0214	1.0267	1.0542	1.0814	1.1091	1.1369
800	1.0000	1.0009	1.0018	1.0043	1.0081	1.0123	1.0163	1.0206	1.0413	1.0622	1.0829	1.1039
1000	1.0000	1.0007	1.0014	1.0034	1.0068	1.0098	1.0132	1.0165	1.0330	1.0500	1.0670	1.0836

*Calculated from PVT values tabulated in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

TABLE 2-179 Compressibility Factors for Nitrogen*

Temp., K	Pressure, bar											
	1	5	10	20	40	60	80	100	200	300	400	500
70	0.0057	0.0287	0.0573	0.1143	0.2277	0.3400	0.4516	0.5623	1.1044	1.6308	Solid	Solid
80	0.9593	0.0264	0.0528	0.1053	0.2093	0.3122	0.4140	0.5148	1.0061	1.4797	1.9396	2.3879
90	0.9722	0.0251	0.0500	0.0996	0.1975	0.2938	0.3888	0.4826	0.9362	1.3700	1.7890	2.1962
100	0.9798	0.8910	0.0487	0.0966	0.1905	0.2823	0.3720	0.4605	0.8840	1.2852	1.6707	2.0441
120	0.9883	0.9397	0.8732	0.7059	0.1975	0.2822	0.3641	0.4438	0.8188	1.1684	1.5015	1.8223
140	0.9927	0.9635	0.9253	0.8433	0.6376	0.4251	0.4278	0.4799	0.7942	1.0996	1.3920	1.6726
160	0.9952	0.9766	0.9529	0.9042	0.8031	0.7017	0.6304	0.6134	0.8107	1.0708	1.3275	1.5762
180	0.9967	0.9846	0.9690	0.9381	0.8782	0.8125	0.7784	0.7530	0.8550	1.0669	1.2893	1.5105
200	0.9978	0.9897	0.9791	0.9592	0.9212	0.8882	0.8621	0.8455	0.9067	1.0760	1.2683	1.4631
250	0.9992	0.9960	0.9924	0.9857	0.9741	0.9655	0.9604	0.9589	1.0048	1.1143	1.2501	1.3962
300	0.9998	0.9990	0.9983	0.9971	0.9964	0.9973	1.0000	1.0052	1.0559	1.1422	1.2480	1.3629
350	1.0001	1.0007	1.0011	1.0029	1.0069	1.0125	1.0189	1.0271	1.0810	1.1560	1.2445	1.3405
400	1.0002	1.0011	1.0024	1.0057	1.0125	1.0199	1.0283	1.0377	1.0926	1.1609	1.2382	1.3216
450	1.0003	1.0018	1.0033	1.0073	1.0153	1.0238	1.0332	1.0430	1.0973	1.1606	1.2303	1.3043
500	1.0004	1.0020	1.0040	1.0081	1.0167	1.0257	1.0350	1.0451	1.0984	1.1575	1.2213	1.2881
600	1.0004	1.0021	1.0040	1.0084	1.0173	1.0263	1.0355	1.0450	1.0951	1.1540	1.2028	1.2657
800	1.0004	1.0017	1.0036	1.0074	1.0157	1.0237	1.0320	1.0402	1.0832	1.1264	1.1701	1.2140
1000	1.0003	1.0015	1.0034	1.0067	1.0136	1.0205	1.0275	1.0347	1.0714	1.1078	1.1449	1.1814

*Computed from pressure-volume-temperature tables in the Vasserman monographs referenced under Table 2-165.

TABLE 2-180 Compressibility Factors for Oxygen*

Temp., K	Pressure, bar											
	1	5	10	20	40	60	80	100	200	300	400	500
75	0.0043	0.0213	0.0425	0.0849	0.1693	0.2533	0.3368	0.4200	0.8301	1.2322	1.6278	2.0175
80	0.0041	0.0203	0.0406	0.0811	0.1616	0.2418	0.3214	0.4007	0.7912	1.1738	1.5495	1.9196
90	0.0038	0.0188	0.0376	0.0750	0.1494	0.2233	0.2966	0.3696	0.7281	1.0780	1.4211	1.7580
100	0.9757	0.0177	0.0354	0.0705	0.1404	0.2096	0.2783	0.3464	0.6798	1.0040	1.3206	1.6309
120	0.9855	0.9246	0.8367	0.0660	0.1302	0.1935	0.2558	0.3173	0.6148	0.8999	1.1762	1.4456
140	0.9911	0.9535	0.9034	0.7852	0.1334	0.1940	0.2527	0.3099	0.5815	0.8374	1.0832	1.3214
160	0.9939	0.9697	0.9379	0.8689	0.6991	0.3725	0.2969	0.3378	0.5766	0.8058	1.0249	1.2364
180	0.9960	0.9793	0.9579	0.9134	0.8167	0.7696	0.5954	0.5106	0.6043	0.8025	0.9990	1.1888
200	0.9970	0.9853	0.9705	0.9399	0.8768	0.8140	0.7534	0.6997	0.6720	0.8204	0.9907	1.1623
250	0.9987	0.9938	0.9870	0.9736	0.9477	0.9237	0.9030	0.8858	0.8563	0.9172	1.0222	1.1431
300	0.9994	0.9968	0.9941	0.9884	0.9771	0.9676	0.9597	0.9542	0.9560	0.9972	1.0689	1.1572
350	0.9998	0.9990	0.9979	0.9961	0.9919	0.9890	0.9870	0.9870	1.0049	1.0451	1.1023	1.1722
400	1.0000	1.0000	1.0000	1.0000	1.0003	1.0011	1.0022	1.0045	1.0305	1.0718	1.1227	1.1816
450	1.0002	1.0007	1.0015	1.0024	1.0048	1.0074	1.0106	1.0152	1.0445	1.0859	1.1334	1.1859
500	1.0002	1.0011	1.0022	1.0038	1.0075	1.0115	1.0161	1.0207	1.0523	1.0927	1.1380	1.1866
600	1.0003	1.0014	1.0024	1.0052	1.0102	1.0153	1.0207	1.0266	1.0582	1.0961	1.1374	1.1803
800	1.0003	1.0014	1.0026	1.0055	1.0109	1.0164	1.0219	1.0271	1.0565	1.0888	1.1231	1.1582
1000	1.0003	1.0013	1.0026	1.0053	1.0101	1.0149	1.0198	1.0253	1.0507	1.0783	1.1072	1.1369

*Calculated from pressure-volume-temperature tables in the Vasserman monographs listed under Table 2-165.

TABLE 2-181 Compressibility Factors for Refrigerant 32*

Temp., K	Pressure, bar										
	1	5	10	15	20	25	30	40	50	Z _{sat}	P _{sat}
230	0.9656									0.9453	1.54
240	0.9711									0.9278	2.40
250	0.9755									0.9062	3.60
260	0.9791	0.8865								0.8811	5.22
270	0.9819	0.9036								0.8522	7.34
280	0.9844	0.9180	0.8210							0.8194	10.07
290	0.9864	0.9285	0.8476							0.7822	13.51
300	0.9880	0.9376	0.8686	0.7899						0.7401	17.76
310	0.9894	0.9453	0.8358	0.8197	0.7439					0.6922	22.95
320	0.9904	0.9518	0.8998	0.8436	0.7812	0.7089				0.6370	29.21
330	0.9914	0.9573	0.9118	0.8628	0.8102	0.7518	0.6851			0.5719	36.72
340	0.9923	0.9619	0.9203	0.8790	0.8338	0.7846	0.7316	0.6021		0.4905	45.66
350	0.9932	0.9655	0.9296	0.8932	0.8534	0.8115	0.7671	0.6675	0.5312	0.3702	56.35
Z _{sat}	0.9595	0.8843	0.8202	0.7670	0.7191	0.6722	0.6303	0.5427	0.4467		
T _{sat}	221.2	258.8	279.8	293.8	304.6	313.5	321.1	333.9	344.3		

*Converted and interpolated from British units shown in *Thermodynamic properties of KLEA 32*, ICI Chemicals and Polymers, 1993. Reproduced by permission.

2-146 PHYSICAL AND CHEMICAL DATA
TABLE 2-182 Compressibility Factors for Refrigerant 123

Temp., °C	Pressure, bar												
	1	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	Z _{sat}	Psat
40	0.9639											0.9427	1.54
50	0.9682											0.9294	2.13
60	0.9717	0.9248										0.9134	2.96
70	0.9745	0.9327										0.8950	3.78
80	0.9766	0.9401										0.8727	4.90
100	0.9804	0.9501	0.9197	0.8355								0.8262	7.87
120	0.9839	0.9591	0.9146	0.8667	0.8140							0.7640	12.01
140	0.9861	0.9650	0.9282	0.8915	0.8503	0.8023	0.7479	0.6916				0.6890	17.59
160	0.9886	0.9714	0.9406	0.9077	0.8747	0.8398	0.8026	0.7600	0.7134	0.6553		0.5820	24.92
180	0.9908	0.9762	0.9518	0.9254	0.8970	0.8709	0.8402	0.8072	0.7712	0.7346	0.6841	0.3926	34.54
200	0.9924	0.9806	0.9602	0.9388	0.9174	0.8931	0.8688	0.8422	0.8163	0.7882	0.7539	—	—
225	0.9938	0.9846	0.9692	0.9526	0.9378	0.9170	0.8972	0.8800	0.8566	0.8401	0.8157	—	—
250	0.9954	0.9885	0.9	0.9651	0.9528	0.9382	0.9229	0.9101	0.8930	0.8771	0.8581	—	—
Z _{sat}	0.9575	0.9210	0.9730	0.8292	0.7947	0.7654	0.7229	0.7110	0.6564	0.6206	0.5821	—	—
T	27.5	55.4	80.8	97.9	111.1	122.0	131.4	139.7	147.2	154.0	160.2	—	—

Dashes indicate inaccessible states; blanks indicate no available data.

TABLE 2-183 Compressibility Factors for Refrigerant 124

Temp., °C	Pressure, bar												
	1	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	Z _{sat}	Psat
-20												0.9562	0.72
-10												0.9431	1.10
0	0.9573											0.9284	1.63
10	0.9641											0.9243	2.34
20	0.9693											0.8920	3.27
30	0.9736	0.9313										0.8828	4.45
40	0.9675	0.9396	0.8728									0.8427	5.93
50	0.9798	0.9473	0.8889	0.8229								0.8151	7.75
60	0.9820	0.9534	0.9017	0.8462								0.7803	9.96
80	0.9854	0.9633	0.9226	0.8820	0.8366		0.7251					0.7024	15.74
100	0.9880	0.9700	0.9370	0.9040	0.8710	0.8314	0.7918	0.7463	0.6950	0.6380		0.5955	23.75
120	0.9899	0.9749	0.9478	0.9206	0.8935	0.8634	0.8329	0.8022	0.7682	0.7285	0.6878	0.3912	34.70
140	0.9917	0.9794	0.9575	0.9357	0.9138	0.8884	0.8641	0.8391	0.8105	0.7896	0.7647		
160		0.9825	0.9645	0.9464	0.9247	0.9061	0.8868	0.8644	0.8489	0.8285	0.7868		
180			0.9690	0.9536	0.9382	0.9213	0.9056	0.8857	0.8634	0.8574	0.8379		
200				0.9601	0.9471	0.9338	0.9211	0.9042	0.8951	0.8783	0.8647		
225					0.9589	0.9488	0.9391	0.9223	0.9160	0.9040	0.8947		
250					0.9650	0.9573	0.9443	0.9412	0.9333	0.9252	0.9174		
Z _{sat}	0.9468	0.9071	0.8605	0.8185	0.7830	0.7488	0.7157	0.6825	0.6484	0.6279	0.5788		
T	-12.4	11.9	34.0	48.7	60.2	69.6	77.8	85.0	91.4	96.3	102.6		

Dashes indicate inaccessible states; blanks indicate no available data.

TABLE 2-184 Compressibility Factors for Refrigerant 134a

Temp., °C	Pressure, bar												
	1	5	10	15	20	25	30	40	50	Z _{sat}	Psat		
-10	0.9622											0.9316	2.005
0	0.9710											0.9119	2.926
10	0.9752											0.8888	4.144
20	0.9778	0.8819										0.8621	5.716
30	0.9817	0.8973										0.8314	7.701
40	0.9839	0.9098	0.8005									0.7963	10.17
50	0.9857	0.9206	0.8280									0.7560	13.18
60	0.9872	0.9296	0.8449	0.7361								0.7098	16.82
70	0.9886	0.9376	0.8678	0.7917	0.6853							0.6562	21.17
80	0.9897	0.9442	0.8828	0.8137	0.7327	0.6290						0.5911	26.38
90	0.9908	0.9495	0.8954	0.8390	0.7682	0.6860	0.5832					0.5054	32.45
100	0.9916	0.9543	0.9062	0.8555	0.7965	0.7335	0.6557					0.3462	39.72
110	0.9920	0.9592	0.9151	0.8630	0.8144	0.7630	0.7046	0.5732	0.4530			—	—
120	0.9924	0.9638	0.9235	0.8802	0.8386	0.7915	0.7418	0.6249	0.4885			—	—
130	0.9927	0.9673	0.9308	0.8949	0.8553	0.8165	0.7716	0.6771	0.5645			—	—
140	0.9929	0.9691	0.9370	0.9040	0.8694	0.8350	0.7964	0.7169	0.6303			—	—
150	0.9931	0.9727	0.9428	0.8877	0.8817	0.8495	0.8173	0.7489	0.6783			—	—
sat.	0.9567	0.8741	0.7989	0.7017	0.6704	0.6094	0.5415	0.4442	—			—	—
sat. T	-26.37	15.74	39.39	55.23	67.49	77.57	86.20	100.35	—			—	—

Dashes indicate inaccessible states; blanks indicate no available data.

TABLE 2-185 Compressibility Factors for Water Substance (fps units)*

Pressure, lb/in ² abs.	Temp., °F																		
	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
10	0.9965	0.9989	0.9992	0.9995	0.9999	0.9999	0.9999	1.0000	1.0000	1.0001	1.0006	1.0012	1.0024	1.0053	1.0084	1.0145	1.0211	1.0332	
15	0.9943	0.9972	0.9986	0.9993	0.9997	0.9998	0.9999	0.9999	1.0000	1.0000	1.0001	1.0004	1.0012	1.0022	1.0042	1.0072	1.0124	1.0188	1.0295
20	0.9930	0.9970	0.9981	0.9991	0.9995	0.9996	0.9998	0.9999	1.0000	1.0000	1.0001	1.0003	1.0011	1.0020	1.0036	1.0065	1.0112	1.0173	1.0269
40	0.9861	0.9940	0.9967	0.9981	0.9990	0.9994	0.9996	0.9998	0.9999	1.0001	1.0003	1.0010	1.0018	1.0028	1.0054	1.0090	1.0139	1.0214	
60	0.9788	0.9910	0.9951	0.9973	0.9984	0.9991	0.9994	0.9997	0.9999	1.0001	1.0003	1.0009	1.0018	1.0024	1.0048	1.0080	1.0120	1.0186	
80	0.9714	0.9878	0.9935	0.9963	0.9979	0.9987	0.9992	0.9996	0.9998	0.9999	1.0001	1.0003	1.0008	1.0016	1.0023	1.0044	1.0073	1.0108	1.0170
100	0.9469	0.9848	0.9919	0.9954	0.9974	0.9985	0.9990	0.9995	0.9998	0.9999	1.0001	1.0004	1.0007	1.0015	1.0022	1.0042	1.0067	1.0099	1.0157
150	0.9435	0.9770	0.9879	0.9931	0.9960	0.9976	0.9985	0.9993	0.9997	0.9998	1.0001	1.0004	1.0006	1.0014	1.0021	1.0039	1.0059	1.0087	1.0137
200	0.9216	0.9690	0.9839	0.9908	0.9947	0.9968	0.9980	0.9991	0.9996	0.9998	1.0001	1.0005	1.0007	1.0015	1.0021	1.0037	1.0055	1.0080	1.0126
400		0.9356	0.9675	0.9817	0.9893	0.9935	0.9960	0.9982	0.9992	0.9998	1.0002	1.0007	1.0011	1.0017	1.0023	1.0033	1.0049	1.0070	1.0105
600		0.8989	0.9509	0.9725	0.9839	0.9904	0.9942	0.9973	0.9988	0.9997	1.0002	1.0008	1.0014	1.0019	1.0026	1.0034	1.0048	1.0066	1.0097
800		0.8586	0.9336	0.9633	0.9790	0.9872	0.9925	0.9964	0.9985	0.9996	1.0003	1.0010	1.0016	1.0022	1.0029	1.0036	1.0049	1.0065	1.0094
1,000		0.8138	0.9162	0.9540	0.9733	0.9841	0.9905	0.9955	0.9981	0.9994	1.0004	1.0012	1.0019	1.0025	1.0032	1.0039	1.0052	1.0066	1.0092
1,500		0.6702	0.8695	0.9305	0.9600	0.9764	0.9859	0.9932	0.9971	0.9992	1.0007	1.0017	1.0026	1.0033	1.0040	1.0048	1.0059	1.0072	1.0096
2,000		0.8188	0.9067	0.9468	0.9687	0.9813	0.9900	0.9958	0.9990	1.0010	1.0023	1.0034	1.0042	1.0049	1.0058	1.0068	1.0082	1.0104	
4,000		0.5608	0.8060	0.8942	0.9392	0.9647	0.9836	0.9930	0.9989	1.0024	1.0050	1.0069	1.0082	1.0093	1.0106	1.0118	1.0132	1.0149	
6,000			0.7042	0.8442	0.9121	0.9497	0.9771	0.9907	0.9991	1.0048	1.0081	1.0110	1.0128	1.0139	1.0152	1.0165	1.0179	1.0195	
8,000				0.6185	0.8003	0.8883	0.9371	0.9714	0.9895	1.0004	1.0075	1.0118	1.0152	1.0172	1.0188	1.0204	1.0216	1.0229	1.0242
10,000					0.5699	0.7657	0.8693	0.9274	0.9668	0.9890	1.0025	1.0105	1.0158	1.0196	1.0220	1.0240	1.0258	1.0271	1.0284

* Calculated by P. E. Liley from various steam tables for the lower temperatures and from Paper B-11 by P. H. Kesselman and Yu. I. Blank, 7th. Int. Conf. Properties of Steam, Tokyo, 1968, for the higher temperatures.

TABLE 2-186 Compressibility Factors of Water Substance (SI units)*

Temperature, K	Pressure, bar																				
	1	5	10	15	20	25	30	40	50	60	80	100	150	200	250	300	400	500	600	800	1000
400	0.990	0.003	0.006	0.009	0.012	0.014	0.017	0.023	0.029	0.035	0.046	0.058	0.086	0.114	0.143	0.171	0.227	0.282	0.336	0.445	0.552
450	0.993	0.003	0.006	0.009	0.012	0.014	0.016	0.022	0.027	0.033	0.043	0.054	0.080	0.107	0.134	0.159	0.206	0.255	0.304	0.402	0.498
500	0.996	0.980	0.958	0.930	0.901	0.878	0.016	0.021	0.026	0.031	0.042	0.052	0.077	0.102	0.127	0.152	0.201	0.249	0.297	0.390	0.482
550	0.997	0.985	0.969	0.956	0.939	0.922	0.904	0.865	0.822	0.773	0.042	0.052	0.077	0.102	0.126	0.150	0.181	0.198	0.289	0.378	0.464
600	0.998	0.990	0.979	0.970	0.961	0.948	0.935	0.910	0.885	0.858	0.798	0.726	0.082	0.107	0.131	0.155	0.201	0.246	0.290	0.375	0.457
650	0.999	0.992	0.984	0.977	0.968	0.959	0.958	0.937	0.919	0.902	0.864	0.824	0.702	0.514	0.177	0.183	0.221	0.260	0.303	0.383	0.460
700	1.000	0.994	0.988	0.984	0.976	0.967	0.966	0.952	0.941	0.929	0.900	0.876	0.800	0.716	0.618	0.503	0.326	0.316	0.340	0.406	0.476
750	1.000	0.996	0.991	0.988	0.981	0.975	0.971	0.961	0.955	0.945	0.927	0.907	0.856	0.801	0.743	0.682	0.557	0.465	0.435	0.456	0.509
800	1.000	0.997	0.993	0.991	0.985	0.982	0.976	0.970	0.966	0.957	0.945	0.929	0.892	0.853	0.813	0.773	0.693	0.620	0.568	0.538	0.561
850	1.000	0.997	0.995	0.992	0.989	0.984	0.981	0.977	0.973	0.967	0.957	0.946	0.917	0.889	0.860	0.831	0.775	0.715	0.679	0.631	0.629
900	1.000	0.998	0.997	0.993	0.992	0.989	0.986	0.982	0.979	0.974	0.965	0.958	0.936	0.915	0.893	0.872	0.830	0.792	0.760	0.714	0.700
950	1.000	0.998	0.997	0.994	0.994	0.993	0.991	0.985	0.983	0.980	0.973	0.967	0.950	0.933	0.916	0.901	0.867	0.839	0.816	0.780	0.761
1000	1.000	0.999	0.998	0.995	0.995	0.994	0.993	0.990	0.987	0.985	0.978	0.973	0.960	0.948	0.935	0.923	0.900	0.878	0.859	0.831	0.816
1200	1.000	1.000	0.999	0.998	0.998	0.997	0.997	0.995	0.994	0.994	0.992	0.990	0.986	0.982	0.975	0.968	0.961	0.957	0.949	0.942	0.937
1400	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.998	0.998	0.998	0.997	0.996	0.995	0.995	0.994	0.993	0.992	0.994	0.996	0.998
1600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.001	1.002	1.002	1.004	1.006	1.009	1.012	1.015	1.020
1800	1.001	1.001	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.001	1.002	1.003	1.003	1.004	1.005	1.008	1.011	1.014	1.017	1.021	1.031
2000	1.003	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.003	1.003	1.004	1.004	1.006	1.008	1.011	1.014	1.018	1.021	1.032	1.043

*Calculated by P. E. Liley from various steam tables for the lower temperatures and from Pap. B-11 by P. H. Kesselman and Yu. I. Blank, 7th Internal Conference on the Properties of Steam, Tokyo, 1968, for the higher temperatures.

TABLE 2-187 Compressibility Factors for Xenon*

Temperature, K	Pressure, bar											
	1	5	10	20	40	60	80	100	200	300	400	500
200	0.9831	0.9088	0.0293	0.0584	0.1162	0.1733	0.2300	0.2861	0.5601	0.8253	1.0833	1.3356
250	0.9911	0.9545	0.9052	0.7887	0.1114	0.1642	0.2158	0.2663	0.5074	0.7355	0.9546	1.1670
300	0.9949	0.9736	0.9465	0.8885	0.7517	0.5492	0.2794	0.3016	0.5021	0.6997	0.8886	1.0707
350	0.9967	0.9834	0.9669	0.9322	0.8473	0.7840	0.7039	0.6249	0.5645	0.7124	0.8706	1.0269
400	0.9977	0.9892	0.9183	0.9562	0.9128	0.8696	0.8278	0.7888	0.6916	0.7642	0.8850	1.0148
450	0.9989	0.9928	0.9856	0.9714	0.9429	0.9163	0.8911	0.8679	0.7335	0.8331	0.9187	1.0224
500	0.9982	0.9951	0.9902	0.9810	0.9623	0.9452	0.9293	0.9156	0.8774	0.8953	0.9572	1.0412
600	0.9996	0.9979	0.9957	0.9917	0.9841	0.9772	0.9715	0.9667	0.9596	0.9791	1.0211	1.0799
800	1.0000	0.9998	1.0002	1.0004	1.0012	1.0020	1.0034	1.0054	1.0213	1.0476	1.0818	1.1222
1000	1.0000	1.0004	1.0015	1.0031	1.0144	1.0101	1.0133	1.0172	1.0394	1.0669	1.0979	1.1331

*Calculated from PVT values tabulated in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

TABLE 2-188 Compressibilities of Liquids*

At the constant temperature T , the compressibility $\beta = (1/\bar{V}_0)(d\bar{V}/dT)$. In general as P increases, β decreases rapidly at first and then slowly; the change of β with T is large at low pressures but very small at pressures above 1000 to 2000 megabars. 1 megabar = 0.987 atm. = 10^6 dynes/cm² based upon the older usage, 1 bar = 1 dyne/cm². The use of the bar as a pressure unit is not encouraged.

Substance	Temp., °C	Pres- sure, mega- bars	Compress- ibility per megabar $\beta \times 10^6$	Substance	Temp., °C	Pres- sure, mega- bars	Compress- ibility per megabar $\beta \times 10^6$	Substance	Temp., °C	Pres- sure, mega- bars	Compress- ibility per megabar $\beta \times 10^6$
Acetone	14	23	111	Ethyl acetate	20	400	75	Methyl alcohol	15	23	103
Acetone	20	500	61	alcohol	14	23	100	alcohol	20	200	95
Acetone	20	1,000	52	alcohol	20	500	63	alcohol	20	400	80
Acetone	40	12,000	9	alcohol	20	1,000	54	alcohol	20	500	65
Amyl alcohol	14	23	88	alcohol	20	12,000	8	alcohol	20	1,000	54
alcohol, iso.	20	200	84	bromide	20	200	100	alcohol	20	12,000	8
alcohol, iso.	20	400	70	bromide	20	400	82	Nitric acid	0	17	32
alcohol, <i>n</i>	20	500	61	bromide	20	500	70	Oils:			
alcohol, <i>n</i>	20	1,000	46	bromide	20	1,000	54	Almond	15	5	53
alcohol, <i>n</i>	20	12,000	8	bromide	20	12,000	8	Castor	15	5	46
alcohol, <i>n</i>	40	12,000	8	chloride	15	23	151	Linseed	15	5	51
Benzene	17	5	89	chloride	20	500	102	Olive	15	5	55
Benzene	20	200	77	chloride	20	1,000	66	Rapeseed	20		59
Benzene	20	400	67	chloride	20	12,000	8	Phosphorus trichloride	10	250	71
Bromine	20	200	56	ether	25	23	188	trichloride	20	500	63
Bromine	20	400	51	ether	20	500	84	trichloride	20	1,000	47
Butyl alcohol, iso.	18	8	97	ether	20	1,000	61	Propyl alcohol (<i>n</i>)	20	200	77
alcohol, iso.	20	200	81	ether	20	12,000	10	alcohol (<i>n</i>)	20	400	67
alcohol, iso.	20	400	64	iodide	20	200	81	alcohol (<i>n?</i>)	20	500	65
alcohol, iso.	20	500	56	iodide	20	400	69	alcohol (<i>n?</i>)	20	1,000	47
alcohol, iso.	20	1,000	46	iodide	20	500	64	alcohol (<i>n?</i>)	20	12,000	7
alcohol, iso.	20	12,000	8	iodide	20	1,000	50	Toluene	20	200	74
Carbon bisulfide	16	21	86	iodide	20	12,000	8	Toluene	20	400	64
bisulfide	20	500	57	Gallium	30	300	3.97	Turpentine	20		74
bisulfide	20	1,000	48	Glycerol	15	5	22	Water	20	13	49
bisulfide	20	12,000	6	Hexane	20	200	117	Water	20	200	43
tetrachloride	20	200	86	Hexane	20	400	91	Water	20	400	41
tetrachloride	20	400	73	Kerosene	20	500	55	Water	20	500	39
Chloroform	20	200	83	Kerosene	20	1,000	45	Water	20	500	38
Chloroform	20	400	70	Kerosene	20	12,000	8	Water	40	500	33
Dichloroethylsulfide	32	1,000	34	Mercury	20	300	3.95	Water	40	1,000	9
Dichloroethylsulfide	32	2,000	24	Mercury	22	500	3.97	Water	40	12,000	69
Ethyl acetate	13	23	103	Mercury	22	1,000	3.91	Xylene, meta	20	200	69
acetate	20	200	90	Mercury	22	12,000	2.37	meta	20	400	60

*Smithsonian Tables, Table 106.

Scott (*Cryogenic Engineering*, Van Nostrand, Princeton, NJ, 1959) gives data for liquid nitrogen (p. 283), oxygen (p. 276), and hydrogen (p. 303). For a convenient index to the high-pressure work of Bridgman, see *American Institute of Physics Handbook*, p. 2-163, McGraw-Hill, New York, 1957.

TABLE 2-189 Compressibilities of Solids

Many data on the compressibility of solids obtained prior to 1926 are contained in Gruneisen, *Handbuch der Physik*, vol. 10, Springer, Berlin, 1926, pp. 1–52; also available as translation, NASA RE 2-18-59W, 1959. See also Tables 271, 273, 276, 278, and other material in *Smithsonian Physical Tables*, 9th ed., 1954. For a review of high-pressure work to 1946, see Bridgman, *Rev. Mod. Phys.*, **18**, 1 (1946).

LATENT HEATS

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$^{\circ}\text{F} = \frac{5}{9} ^{\circ}\text{C} + 32.$$

To convert calories per gram-mole to British thermal units per

pound-mole, multiply by 1.799; to convert calories per gram to British thermal units per pound, multiply by 1.799.

To convert millimeters of mercury to pounds-force per square inch, multiply by 1.934×10^{-2} .

TABLE 2-190 Heats of Fusion and Vaporization of the Elements and Inorganic Compounds*

Unless stated otherwise, the values have been taken from the compilations by K. K. Kelley on "Heats of Fusion of Inorganic Compounds," U.S. Bur. Mines Bull. 393 (1936), and "The Free Energies of Vaporization and Vapor Pressures of Inorganic Substances," U.S. Bur. Mines Bull. 383 (1935).

Substance	mp, °C	Heat of fusion, ^{a,b} cal/mole	bp at 1 atm, °C	Heat of vaporization, ^{a,b} cal/mole	Substance	mp, °C	Heat of fusion, ^{a,b} cal/mole	bp at 1 atm, °C	Heat of vaporization, ^{a,b} cal/mole
Aluminum					Carbon (<i>Cont.</i>)				
Al	660.0	2,550	2057	61,020	CNF			-72.8	5,780 ^c
Al ₂ Br ₆	97.5	5,420	256.4	10,920	CNI			141	13,980 ^c
Al ₂ Cl ₆	192.5	16,960	180.2 ^c	26,750 ^c	CO	-205.0	200	-191.5	1,444
AlF ₃ ·3NaF	1000	16,380			CO ₂	-57.5	1,900	-78.4 ^c	6,030 ^{c,r}
Al ₃ I ₆	191.0	7,960	385.5	15,360	CO ₃	-138.8	1,129 ^k	-50.2	4,423 ^k
Al ₂ O ₃	2045	(26,000)	3000		COCl ₂			8.0	5,990
Antimony					CS ₂	-112.0	1,049 ^l		
Sb	630.5	4,770	1440	46,670	Cerium				
SbBr ₃	97	3,510			Ce	775	2,120		
SbCl ₃	73.4	3,030	219	10,360	Cesium				
SbCl ₅	4	2,400	172 ^d	11,570	Cs	28.4	500	690	16,320
Sb ₄ O ₆	655	(27,000)	1425	17,820	CsBr			1300	35,990
Sb ₂ S ₆	546	11,200			CsCl	642	3,600	1300	35,690
Argon					CsF	715	(2,450)	1251	34,330
A	-189.3	290	-185.8	1,590	CsI			1280	35,930
Arsenic					CsNO ₃	407	3,250		
As	814	(6,620)	610 ^c	31,000 ^c	Chlorine				
AsBr ₃	31	2,810			Cl ₂	-101.0	1,531 ^m	-34.1	4,878 ^m
AsCl ₃	-16	2,420	122	7,570	ClF			-101	
AsF ₅	-80.7	2,800	-52.8	4,980	ClF ₃			11.3	5,890
As ₄ O ₆	313	8,000	457.2	14,300	Cl ₂ O			2.0	6,280
Barium					ClO ₂			10.9	7,100
Ba	704	(1,400) ^e	1638	35,670	ClO ₂ ⁷			79	8,480
BaBr ₂	847	6,000			Chromium				
BaCl ₂	960	5,370			Cr	1550	3,930	2475	
BaF ₂	1287	3,000			CrO ₂ Cl ₂			117	8,250
Ba(NO ₃) ₂	595	(5,980)			Cobalt				
Ba ₃ (PO ₄) ₂	1730	18,600			Co	1490	3,660		
BaSO ₄	1350	9,700			CoCl ₂	727	7,390	1050	27,170
Beryllium					Copper				
Be	1280	2,500 ^e			Cu	1083.0	3,110	2595	72,810
Bismuth					Cu ₂ Br ₃			1355	16,310
Bi	271.3	2,505	1420		Cu ₂ Cl ₂	430	4,890	1490	11,920
BiBr ₃			461	18,020	Cu ₂ (CN) ₂	473	(5,400)	1336	15,940
BiCl ₃	224	2,600	441	17,350	Cu ₂ O	1230	(13,400)		
Bi ₂ O ₃	817	6,800			CuO	1447	2,820		
Bi ₂ S ₃	747	8,900			Cu ₂ S	1127	5,500		
Boron					Fluorine				
BBR ₃			91.3	7,300	F ₂	-223		-188.2	1,640
BCl ₃			12.5	5,680	F ₂ O			-144.8	2,650
BF ₃	-128	480	-100.9	4,620	Gallium				
B ₂ H ₆	-165.5		-92.4	3,685	Ga	29.8	1,336	2071	
B ₃ H ₁₀	-119.8		16	6,470	Germanium				
B ₃ H ₉	-46.9		58	7,700	Ge	959	(8,300)		
B ₃ H ₁₁			67	8,500	GeH ₄	-165		-89.1	3,580
B ₁₀ H ₁₄	99.7	7,800	f	11,600	Ge ₂ H ₆	-109		31.4	5,900
B ₂ H ₅ Br	-104		16	6,230	Ge ₃ H ₈	-105.6		110.6	7,550
B ₃ N ₄ H ₆	-58		50.4	7,670	GeHCl ₃	-71		75 ^e	8,000
Bromine					GeBr ₄	26.1		189	8,560
Br ₂	-7.2	2,580	58.0	7,420	GeCl ₄	-49.5		84	7,030
BrF ₅	-61.3	1,355	40.4	7,470	Ge(CH ₃) ₄	-88		44	6,460
Cadmium					Gold				
Cd	320.9	1,460	765	23,870	Au	1063.0	3,030	2966	81,800
CdBr ₂	568	(5,000)			Helium				
CdCl ₂	568	5,300	967	29,860	He	-271.4		-268.4	22
CdF ₂	1110	(5,400)			Hydrogen				
CdI ₂	387	3,660	796	25,400	H ₂	-259.2	28	-252.7	216
CdO				53,820 ^c	HBr	-86.9	575	-66.7	4,210
CdSO ₄	1000	4,790	1559 ^e		HCl	-114.2	476	-85.0	3,860
Calcium					HCN	-13.2	2,009	25.7	6,027 ⁱ
Ca	851	2,230	1487	36,580	HF	-83.0	1,094	33.3	7,460
CaBr ₂	730	4,180			(HF) ₆			51.2	5,020
CaCO ₃	1282	(12,700)			HI	-50.8	686		
CaCl ₂	782	6,100			H ₂ O	0.0	1,436	100.0	9,729 ^{h,q}
CaF ₂	1392	4,100			H ₂ O (D ₂ O)	3.8	1,501 ⁱ	101.4	9,945 ^{oq}
Ca(NO ₃) ₂	561	5,120			H ₂ O ₂	-2	2,520 ^e	158	10,270
CaO	2707	(12,240)			HNO ₃	-47	600		
CaO-Al ₂ O ₃ -2SiO ₂	1550	29,400			H ₃ PO ₂	17.4	2,310		
CaO-MgO-2SiO ₂	1392	(18,200)			H ₃ PO ₃	74	3,070		
CaO-SiO ₂	1512	13,400			H ₃ PO ₄	42.4	2,520		
CaSO ₄	1297	6,700			H ₄ P ₂ O ₆	55	8,300		
Carbon					H ₂ S	-55.5	568 ^e	-60.3	4,463 ^t
C (graphite)	3600	11,000 ^e			H ₂ S ₂	-87.6	1,805		
CBR ₄	90	1,050			H ₂ SO ₄	10.5	2,360		
CCl ₄	-24.0	644	77	7,280	H ₂ Se			-41.3	4,880
CF ₄			-127.9	3,110	H ₂ SeO ₄	58	3,450		
CH ₄	-182.5	224	-161.4	2,040	H ₂ Te	-48.9	1,670	-2.2	5,650
C ₂ N ₂	-27.8	1,938 ^e	-21.1	5,576 ^u	Indium				
CNBr	52			11,010 ^c	In	156.4	781		
CNCl	-5	2,240	13	6,300					

*See also subsection "Thermodynamic Properties."

2-152 PHYSICAL AND CHEMICAL DATA

TABLE 2-190 Heats of Fusion and Vaporization of the Elements and Inorganic Compounds (Continued)

Substance	mp, °C	Heat of fusion, ^{a,b} cal/mole	bp at 1 atm, °C	Heat of vaporization, ^{a,b} cal/mole	Substance	mp, °C	Heat of fusion, ^{a,b} cal/mole	bp at 1 atm, °C	Heat of vaporization, ^{a,b} cal/mole
Iodine					Palladium				
I ₂	113.0	3,650	183	10,390	Pd	1554	4,120		
ICl(α)	17.2	2,660			Phosphorus				
ICl(β)	13.9	2,270			P ₄ (yellow)	44.2	615	280	12,520
IF ₇			4 ^c	7,460 ^c	P ₄ (violet)			417 ^c	25,600 ^c
					P ₄ (black)			453 ^c	33,100
Iron					PCl ₃				
Fe	1530	3,560	2735	84,600	PH ₃	-133.8	270 ^c	74.2	7,280
FeCl ₂	677	7,800	1026	30,210	P ₄ O ₆	23.8	3,360	-87.7	3,489 ^v
Fe ₂ Cl ₆	304	20,590	319	12,040	P ₂ O ₁₀ (α)	569	17,080	174	10,380
Fe(CO) ₅	-21	3,250	105	9,000	P ₂ O ₁₀ (β)			591	20,670
FeO	1380	(7,700)			POCl ₃	1.1	3,110	358 ^c	
FeS	1195	5,000			P ₂ S ₃			105.1	8,380
Krypton					Platinum				
Kr	-157	360 ^c	152.9	2,310 ^c	Pt	1773.5	4,700	(4400)	(107,000)
Lead					Potassium				
Pb	327.4	1,224	1744	42,060	K	63.5	574	776	18,920
PbBr ₂	488	4,290	914	27,700	KBO ₂	947			
PbCl ₂	498	5,650	954	29,600	KBr	742	5,000	1383	37,060
PbF ₂	824	1,560	1293	38,300	KCl	770	6,410	1407	38,840
PbI ₂	412	5,970	872	24,850	KCN	623	(3,500)		
PbMoO ₄	1065	(25,800)			KCNS	179	2,250		
PbO	890	2,820	1472	51,310	K ₂ CO ₃	897	7,800		
PbS	1114	4,150	1281	(50,000)	K ₂ CrO ₄	954	6,920		
PbSO ₄	1087	9,600			K ₂ Cr ₂ O ₇	398	8,770		
PbWO ₄	1123	(15,200)			KF	857	6,500		
Lithium					KI	682	4,100	1324	34,690
Li	179	1,100	1372	32,250	K ₂ MoO ₄	922	(4,000)		
LiBO ₂	845	(5,570)			KNO ₃	338	2,840		
LiBr	552	2,900	1310	35,420	KOH	360	(2,000)	1327	30,850
LiCl	614	3,200	1382	35,960	KPO ₃	817	2,110		
LiF	847	(2,360)	1681	50,970	K ₃ PO ₄	1340	8,900		
LiI	440	(1,420)	1171	40,770	K ₃ P ₂ O ₇	1092	14,000		
LiOH	462	2,480			K ₂ SO ₄	1074	8,100		
Li ₂ MoO ₄	705	4,200			K ₂ TiO ₃	810	(10,600)		
Li ₂ NO ₃	1177	7,210			K ₂ WO ₄	927	(4,400)		
Li ₂ SiO ₃	1249	7,430			Praseodymium				
Li ₂ SO ₄	857	3,040			Pr	932	2,700		
Li ₂ WO ₄	742	(6,700)			Radon				
Magnesium					Rn	-71		-61.8	4,010
Mg	650	2,160	1107	32,520	Rhenium				
MgBr ₂	711	8,300			Re	(3000)			
MgCl ₂	712	8,100	1418	32,690	Re ₂ O ₇	296	15,340	362.4	18,060
MgF ₂	1221	5,900			Re ₂ O ₈	147	3,800		
MgO	2642	18,500			Rubidium				
Mg ₂ (PO ₄) ₂	1184	(11,300)			Rb	39.1	525	679	18,110
MgSiO ₃	1524	14,700			RbBr	677	3,700	1352	37,120
MgSO ₄	1127	3,500			RbCl	717	4,400	1381	36,920
MgZn ₂	589	(8,270)			RbF	833	4,130	1408	39,510
Manganese					RbI	638	2,990	1304	35,960
Mn	1220	3,450	2152	55,150	RbNO ₃	305	1,340		
MnCl ₂	650	7,340	1190	29,630	Selenium				
MnSiO ₃	1274	(8,200)			Se ₂	217	1,220	753	25,490
MnTiO ₃	1404	(7,960)			Se ₆			736	20,600
Mercury					SeF ₆			-45.8 ^c	6,350 ^c
Hg	-38.9	557	361	13,980	SeO ₂			317 ^c	20,900
HgBr ₂	241	3,960	319	14,080	SeOCl ₂	10	1,010	168	
HgCl ₂	277	4,150	304	14,080	Silicon				
HgI ₂	250	4,500	354	14,260	Si	1427	9,470	2290	
HgSO ₄	850	(1,440)			SiCl ₄	-67.6	1,845	56.8	6,860
Molybdenum					Si ₂ Cl ₆	-1		139	
Mo	2622	(6,660)	(4800)	(128,000)	Si ₃ Cl ₈			211.4	12,340
MoF ₆	17	2,500	36	6,000	(SiCl ₃) ₂ O	-33		135.6	8,820
MoO ₃	745	(2,500)	1151		SiF ₄			-94.8 ^c	6,130 ^c
Neon					Si ₂ F ₆	-18.5	3,900	-18.9 ^c	10,400 ^c
Ne	-248.5	77	-246.0	440 ^c	SiF ₃ Cl	-138		-70.1	4,460
Nickel					SiF ₂ Cl ₂	-144		-31.5	5,080
Ni	1455	4,200	2730	87,300	SiH ₄	-185		-111.6	2,960
NiCl ₂					Si ₂ H ₆	-132.5		-14.3	5,110
Ni(CO) ₄					Si ₃ H ₈	-117		53.1	6,780
Ni ₂ S	645	(2,980)		42.5	Si ₄ H ₁₀	-93.5		100	8,890
Ni ₃ S ₂	790	5,800			SiH ₃ Br	-93.8		2.4	5,650
Nitrogen					SiH ₂ Br ₂	-70.0		70.5	6,840
N ₂	-210.0	172	-195.8	1,336	SiHCl ₃	-126.5		31.8	6,360
NF ₃					(SiH ₃) ₂ N	-105.6		48.7	6,850
NH ₃	-77.7	1,352 ^a	-33.4	3,000	(SiH ₃) ₂ O	-144		-15.4	5,350
NH ₄ CNS	146	(4,700)		5,581 ^a	SiO ₂ (quartz)	1470	3,400		
NH ₄ NO ₃	169.6	1,460			SiO ₂ (cristobalite)	1700	2,100		
N ₂ O	-90.8	1,563	-88.5	3,950	Silver				
NO	-163.6	550	-151.7	3,307	Ag	960.5	2,700	2212	60,720
N ₂ O ₄	-13	5,540	30	7,040	AgBr	430	2,180		
N ₂ O ₅					AgCl	455	3,155	1564	42,520
NOCl					AgCN	350	2,750		
Osmium					AgI	557	2,250	1506	34,450
OsF ₆					AgNO ₃	209	2,755		
OsO ₄ (yellow)	56	4,060	47.4	6,840	Ag ₂ S	842	3,360		
OsO ₄ (white)	42	2,340	130	9,450	Ag ₂ SO ₄	657	(4,300)		
Oxygen					Sodium				
O ₂	-218.9	106	-183.0	1,629	Na	97.7	630	914	23,120
O ₃			-111	2,880	NaBO ₂	966	8,660		

TABLE 2-190 Heats of Fusion and Vaporization of the Elements and Inorganic Compounds (Concluded)

Substance	mp, °C	Heat of fusion, ^{a,b} cal/mole	bp at 1 atm, °C	Heat of vaporization, ^{a,b} cal/mole	Substance	mp, °C	Heat of fusion, ^{a,b} cal/mole	bp at 1 atm, °C	Heat of vaporization, ^{a,b} cal/mole
Sodium (<i>Cont.</i>)					Thallium				
NaBr	747	6,140	1392	37,950	Tl	302.5	1,030	1457	38,810
NaCl	800	7,220	1465	40,810	TlBr	460	5,990	819	23,800
NaClO ₃	255	5,290			TlCl	427	4,260	807	24,420
NaCN	562	(4,400)	1500	37,280	Tl ₂ CO ₃	273	4,400		
NaCNS	323	4,450			TlI	440	3,125	823	25,030
Na ₂ CO ₃	854	7,000			TlNO ₃	207	2,290		
NaF	992	7,000	1704	53,260	Tl ₂ S	449	3,000		
NaI	662	5,240			Tl ₂ SO ₄	632	5,500		
Na ₂ MoO ₄	687	3,600			Tin				
NaNO ₃	310	3,760			Sn ₄	231.8	1,720	2270	68,000
NaOH	322	2,000	1378		SnBr ₂	232	(1,700)		
½Na ₂ O·½Al ₂ O ₃ ·3SiO ₂	1107	13,150			SnBr ₄	30	3,000		
NaPO ₃	988	(5,000)			SnCl ₂	247	3,050	623	20,740
Na ₃ P ₂ O ₇	970	(13,700)			SnCl ₄	-33.2	2,190	113	8,330
Na ₂ S	920	(1,200)			Sn(CH ₃) ₄			78.3	7,320
Na ₂ SiO ₃	1087	10,300			SnH ₄	-149.8		-52.3	4,420
Na ₂ Si ₂ O ₅	884	8,460			SnI ₄	143.5	(4,300)		
Na ₂ SO ₄	884	5,830			Titanium				
Na ₂ WO ₄	702	5,800			TiBr ₄	38.2	(2,060)		
Strontium					TiCl ₄	-23	2,240		
Sr	757	2,190	1384	33,610	TiO ₂	1825	(11,400)	136	8,350
SrBr ₂	643	4,780			Tungsten				
SrCl ₂	872	4,100			W	3390	(8,400)	(5900)	(176,000)
SrF ₂	1400	4,260			WF ₆	-0.4	1,800	17.3	6,350
Sr ₃ (PO ₄) ₂	1770	18,500			Uranium				
Sulfur					UF ₆			55.1 ^c	9,990 ^c
S (rhombic)	112.8		444.6	2,200	Xenon				
S (monoclinic)	119.2				Xe	-111.5	740	-108.0	3,110
S ₂ Cl ₂			138	8,720	Zinc				
SF ₆			-63.5 ^c	5,600 ^c	Zn	419.5	1,595	907	27,430
SO ₂	-75.5	1,769 ^p	-5.0	5,960 ^p	ZnCl ₂	283	(5,500)	732	28,710
SO ₃ (α)	17	2,060	44.8	10,190	Zn(C ₂ H ₅) ₂			118	8,960
SO ₃ (β)	32.4	2,890			ZnO	1975	4,470		
SO ₃ (γ)	62.2	6,310			ZnS	1645	(9,000)		
SOBr ₂			139.5	9,920	Zirconium				
SOCl ₂			75.4	7,600	ZrBr ₄			357 ^c	25,800 ^c
SO ₂ Cl ₂			69.2	7,760	ZrCl ₄			311 ^c	25,290 ^c
Tellurium					ZrI ₄			431 ^c	29,030 ^c
Te	453	3,230	1090		ZrO ₂	2715	20,800		
TeCl ₄			392						
TeF ₆			-38.6 ^c	16,830					
				6,700 ^c					

^aValues in parentheses are uncertain.^bFor the freezing point or the normal boiling point unless otherwise stated.^cSublimation.^dDecomposes at about 75°C; value obtained by extrapolation.^eBichowsky and Rossini, "Thermochemistry of the Chemical Substances," Reinhold, New York (1936).^fDecomposes before the normal boiling point is reached.^gDecomposes at about 40°C; value obtained by extrapolation.^hSee also pp. 2-304 through 2-307 on steam table.ⁱGiauque and Ruehrwein, *J. Am. Chem. Soc.*, **61** (1939): 2626.^jGiauque and Egan, *J. Chem. Phys.*, **5** (1937): 45.^kKemp and Giauque, *J. Am. Chem. Soc.*, **59** (1937): 79.^lBrown and Manov, *J. Am. Chem. Soc.*, **59** (1937): 500.^mGiauque and Powell, *J. Am. Chem. Soc.*, **61** (1939): 1970.ⁿOverstreet and Giauque, *J. Am. Chem. Soc.* **59** (1937): 254.^oStephenson and Giauque, *J. Chem. Phys.*, **5** (1937): 149.^pGiauque and Stephenson, *J. Am. Chem. Soc.*, **60** (1938): 1389.^qOsborne, Stimson, and Ginnings, *Bur. Standards J. Research*, **23**, 197 (1939): 261.^rMiles and Menzies, *J. Am. Chem. Soc.*, **58** (1936): 1067.^sLong and Kemp, *J. Am. Chem. Soc.*, **58** (1936): 1829.^tGiauque and Blue, *J. Am. Chem. Soc.*, **58** (1936): 831.^uRuehrwein and Giauque, *J. Am. Chem. Soc.*, **61** (1939): 2940.**TABLE 2-191 Heats of Fusion of Miscellaneous Materials**

Material	mp, °C	Heat of fusion, cal/g
Alloys		
30.5 Pb + 69.5 Sn	183	17
36.9 Pb + 63.1 Sn	179	15.5
63.7 Pb + 36.3 Sn	177.5	11.6
77.8 Pb + 22.2 Sn	176.5	9.54
1 Pb + 9 Sn	236	28
24 Pb + 27.3 Sn + 48.7 Bi	98.8	6.85
25.8 Pb + 14.7 Sn + 52.4 Bi + 7 Cd	75.5	8.4
Silicates		
Anorthite (CaAl ₂ Si ₂ O ₈)		100
Orthoclase (KAlSi ₃ O ₈)		100
Microcline (KAlSi ₃ O ₈)		83
Wollastonite (CaSiO ₃)		100
Malacolite (Ca ₂ MgSi ₂ O ₁₂)		94
Diopside (CaMgSi ₂ O ₆)		100
Olivine (Mg ₂ SiO ₄)		130
Fayalite (Fe ₂ SiO ₄)		85
Spermaceti	43.9	37.0
Wax (bees')	61.8	42.3

TABLE 2-192 Heats of Fusion of Organic Compounds

The values for the hydrocarbons are from the tables of the American Petroleum Institute Research Project 44 at the National Bureau of Standards, with some from Parks and Huffman, *Ind. Eng. Chem.*, **23**, 1138 (1931).

The values for the nonhydrocarbon compounds were recalculated from data in *International Critical Tables*, vol. 5.

Hydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g	Hydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g
Paraffins				Aromatics—(Cont.)			
Methane	CH ₄	-182.48	14.03	1-Methyl-3-ethylbenzene	C ₉ H ₁₂	-95.55	15.14
Ethane	C ₂ H ₆	-183.23	22.712	1-Methyl-4-ethylbenzene	C ₉ H ₁₂	-62.350	25.29
Propane	C ₃ H ₈	-187.65	19.100	1,2,3-Trimethylbenzene	C ₉ H ₁₂	-25.375	16.64
<i>n</i> -Butane	C ₄ H ₁₀	-138.33	19.167	1,2,4-Trimethylbenzene	C ₉ H ₁₂	-43.80	24.54
2-Methylpropane	C ₄ H ₁₀	-159.60	18.668	1,3,5-Trimethylbenzene	C ₉ H ₁₂	-44.720	18.97
<i>n</i> -Pentane	C ₅ H ₁₂	-129.723	27.874	Naphthalene	C ₁₀ H ₈	+80.0	36.0
2-Methylbutane	C ₅ H ₁₂	-159.890	17.076	Camphene	C ₁₀ H ₁₂	+51	57
2,2-Dimethylpropane	C ₅ H ₁₂	-16.6	10.786	Durene	C ₁₀ H ₁₄	+79.3	37.4
<i>n</i> -Hexane	C ₆ H ₁₄	-95.320	36.138	Isodurene	C ₁₀ H ₁₄	-24.0	23.0
2-Methylpentane	C ₆ H ₁₄	-153.680	17.407	Prehnitene	C ₁₀ H ₁₄	-7.7	20.0
2,2-Dimethylbutane	C ₆ H ₁₄	-99.73	1.607	<i>p</i> -Cymene	C ₁₀ H ₁₄	-68.9	17.1
2,3-Dimethylbutane	C ₆ H ₁₄	-128.41	2.251	<i>n</i> -Butyl benzene	C ₁₀ H ₁₄	-88.5	19.5
<i>n</i> -Heptane	C ₇ H ₁₆	-90.595	33.513	<i>tert</i> -Butyl benzene	C ₁₀ H ₁₄	-58.1	14.9
2-Methylhexane	C ₇ H ₁₆	-118.270	21.158	β-Methyl naphthalene	C ₁₁ H ₁₀	+34.1	20.1
3-Ethylpentane	C ₇ H ₁₆	-118.593	22.555	Diphenyl	C ₁₂ H ₁₀	+68.6	28.8
2,2-Dimethylpentane	C ₇ H ₁₆	-123.790	13.982	Hexamethyl benzene	C ₁₂ H ₁₈	+165.5	30.4
2,4-Dimethylpentane	C ₇ H ₁₆	-119.230	15.968	Diphenyl methane	C ₁₃ H ₁₂	+25.2	26.4
3,3-Dimethylpentane	C ₇ H ₁₆	-134.46	16.856	Anthracene	C ₁₄ H ₁₀	+216.5	38.7
2,2,3-Trimethylbutane	C ₇ H ₁₆	-24.96	5.250	Phenanthrene	C ₁₄ H ₁₀	+96.3	25.0
<i>n</i> -Octane	C ₈ H ₁₈	-56.798	43.169	Toluene	C ₁₄ H ₁₀	+60	28.7
2-Methylheptane	C ₈ H ₁₈	-109.04	21.458	Stilbene	C ₁₄ H ₁₂	+124	40.0
3-Methylpentane	C ₈ H ₁₈	-120.50	23.795	Dibenzil	C ₁₄ H ₁₄	+51.4	30.7
4-Methylheptane	C ₈ H ₁₈	-120.955	22.692	Triphenyl methane	C ₁₉ H ₁₆	+92.1	21.1
2,2-Dimethylhexane	C ₈ H ₁₈	-121.18	24.226	Alkyl cyclohexanes			
2,5-Dimethylhexane	C ₈ H ₁₈	-91.200	26.903	Cyclohexane	C ₆ H ₁₂	+6.67	7.569
3,3-Dimethylhexane	C ₈ H ₁₈	-126.10	14.9	Methylcyclohexane	C ₇ H ₁₄	-126.58	16.429
2-Methyl-3-ethylpentane	C ₈ H ₁₈	-114.960	23.690	Alkyl cyclopentanes			
3-Methyl-3-ethylpentane	C ₈ H ₁₈	-90.870	22.657	Cyclopentane	C ₅ H ₁₀	-93.80	2.068
2,2,3-Trimethylpentane	C ₈ H ₁₈	-112.27	18.061	Methylcyclopentane	C ₆ H ₁₂	-142.445	19.68
2,2,4-Trimethylpentane	C ₈ H ₁₈	-107.365	19.278	Ethylcyclopentane	C ₇ H ₁₄	-138.435	11.10
2,3,3-Trimethylpentane	C ₈ H ₁₈	-100.70	3.204	1,1-Dimethylcyclopentane	C ₉ H ₁₄	-69.73	3.36
2,3,4-Trimethylpentane	C ₈ H ₁₈	-109.210	19.392	cis-1,2-Dimethylcyclopentane	C ₉ H ₁₄	-53.85	3.87
2,2,3,3-Tetramethylbutane	C ₈ H ₁₈	+100.69	14.900	trans-1,2-Dimethylcyclopentane	C ₉ H ₁₄	-117.57	15.68
<i>n</i> -Nonane	C ₉ H ₂₀	-53.9	41.2	trans-1,3-Dimethylcyclopentane	C ₉ H ₁₄	-133.680	17.93
<i>n</i> -Decane	C ₁₀ H ₂₂	-30.0	48.3	Monolefins			
<i>n</i> -Undecane	C ₁₁ H ₂₄	-25.9	34.1	Ethene (Ethylene)	C ₂ H ₄	-169.15	28.547
<i>n</i> -Dodecane	C ₁₂ H ₂₆	-9.6	51.3	Propene (Propylene)	C ₃ H ₆	-185.25	17.054
Eicosane	C ₂₀ H ₄₂	+36.4	52.0	1-Butene	C ₄ H ₈	-185.35	16.393
Pentacosane	C ₂₅ H ₅₂	+53.3	53.6	cis-2-Butene	C ₄ H ₈	-138.91	31.135
Triteriacacontane	C ₃₃ H ₆₈	+71.1	54.0	trans-2-Butene	C ₄ H ₈	-105.55	41.564
Aromatics				2-Methylpropene (isobutene)	C ₄ H ₈	-140.35	25.265
Benzene	C ₆ H ₆	+5.533	30.100	1-Pentene	C ₅ H ₁₀	-165.27	16.82
Methylbenzene (Toluene)	C ₇ H ₈	-94.991	17.171	cis-2-pentene	C ₅ H ₁₀	-151.363	24.239
Ethylbenzene	C ₈ H ₁₀	-94.950	20.629	trans-2-pentene	C ₆ H ₁₀	-140.235	26.536
<i>o</i> -Xylene	C ₈ H ₁₀	-25.187	30.614	2-Methyl-1-butene	C ₆ H ₁₀	-137.560	26.879
<i>m</i> -Xylene	C ₈ H ₁₀	-47.872	26.045	3-Methyl-1-butene	C ₆ H ₁₀	-168.500	18.009
<i>p</i> -Xylene	C ₈ H ₁₀	+13.263	38.526	2-Methyl-2-butene	C ₅ H ₁₀	-133.780	25.738
<i>n</i> -Propylbenzene	C ₉ H ₁₂	-99.500	16.97	Acetylenes			
Isopropylbenzene	C ₉ H ₁₂	-96.028	19.22	Acetylene	C ₂ H ₂	-81.5	23.04
1-Methyl-2-ethylbenzene	C ₉ H ₁₂	-80.833	21.13	2-Butyne (dimethylacetylene)	C ₄ H ₆	-132.23	40.808

Nonhydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g	Nonhydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g
Acetic acid	C ₂ H ₄ O ₂	16.7	46.68	Butyl alcohol (<i>n</i> -)	C ₄ H ₁₀ O	-89.2	29.93
Acetone	C ₃ H ₆ O	-95.5	23.42	(<i>t</i> -)	C ₄ H ₉ O	25.4	21.88
Acrylic acid	C ₃ H ₄ O ₂	12.3	37.03	Butyric acid (<i>n</i> -)	C ₄ H ₈ O ₂	-5.7	30.04
Allō-cinnamic acid	C ₉ H ₈ O ₂	68	27.35	Caprylic acid (<i>n</i> -)	C ₁₀ H ₂₀ O ₂	31.99	38.87
Aminobenzoic acid (<i>o</i> -)	C ₇ H ₇ NO ₂	145	35.48	Caprylic acid (<i>n</i> -)	C ₈ H ₁₆ O ₂	16.3	35.40
(<i>m</i> -)	C ₇ H ₇ NO ₂	179.5	38.03	Carbazole	C ₁₂ H ₉ N	243	42.05
(<i>p</i> -)	C ₇ H ₇ NO ₂	188.5	36.46	Carbon tetrachloride	CCl ₄	-22.8	41.57
Amyl alcohol	C ₅ H ₁₂ O	-78.9	26.65	Carboxime (<i>d</i> -)	C ₁₀ H ₁₅ NO	71.5	23.29
Anethole	C ₁₀ H ₁₂ O	22.5	25.80	(<i>l</i> -)	C ₁₀ H ₁₅ NO	71	23.41
Aniline	C ₆ H ₅ NH ₂	-6.3	27.09	(<i>dl</i> -)	C ₁₀ H ₁₅ NO	91	24.61
Anthraquinone	C ₁₄ H ₈ O ₂	284.8	37.48	Cetyl alcohol	C ₁₆ H ₃₀ O	49.27	33.80
Apiol	C ₁₂ H ₁₀ O ₄	29.5	25.80	Chloroacetic acid (<i>α</i> -)	C ₂ H ₃ ClO ₂	61.2	31.06
Azobenzene	C ₁₂ H ₁₀ N ₂	67.1	28.91	(<i>β</i> -)	C ₂ H ₃ ClO ₂	56	35.12
Azoxybenzene	C ₁₂ H ₁₀ N ₂ O	36	21.62	Chloral alcoholate	C ₄ H ₇ Cl ₂ O ₂	9	24.03
Benzil	C ₁₄ H ₁₀ O ₂	95.2	22.15	hydrate	C ₂ H ₃ Cl ₂ O ₂	47.4	33.18
Benzoic acid	C ₆ H ₅ CO ₂	122.45	33.90	Chloroaniline (<i>p</i> -)	C ₆ H ₅ ClN	71	37.15
Benzophenone	C ₁₃ H ₁₀ O	47.85	23.53	Chlorobenzoic acid (<i>o</i> -)	C ₇ H ₇ ClO ₂	140.2	39.30
Benzylaniline	C ₁₃ H ₁₃ N	32.37	21.86	(<i>m</i> -)	C ₇ H ₇ ClO ₂	154.25	36.41
Bromocamphor	C ₁₀ H ₈ Br ₂ O	78	41.57	(<i>p</i> -)	C ₇ H ₇ ClO ₂	239.7	49.21
Bromo-chlorobenzene (<i>o</i> -)	C ₆ H ₅ BrCl	-12.6	15.41	Chloronitrobenzene (<i>m</i> -)	C ₆ H ₅ ClNO ₂	44.4	29.38
(<i>m</i> -)	C ₆ H ₄ BrCl	-21.2	15.29	(<i>p</i> -)	C ₆ H ₅ ClNO ₂	83.5	31.51
(<i>p</i> -)	C ₆ H ₄ BrCl	64.6	23.41	Cinnamic acid	C ₉ H ₈ O ₂	133	36.50
Bromoiodobenzene (<i>o</i> -)	C ₆ H ₅ BrI	21	12.18	anhydride	C ₁₈ H ₁₄ O ₃	48	28.14
(<i>m</i> -)	C ₆ H ₄ BrI	9.3	10.27	Cresol (<i>p</i> -)	C ₇ H ₈ O	34.6	26.28
(<i>p</i> -)	C ₆ H ₄ BrI	90.1	16.60	Crotonic acid (<i>α</i> -)	C ₄ H ₆ O ₂	72	25.32
Bromol hydrate	C ₆ H ₅ Br ₂ O ₂	46	16.90	(<i>cis</i> -)	C ₄ H ₆ O ₂	71.2	34.90
Bromophenol (<i>p</i> -)	C ₆ H ₅ BrO ₂	63.5	20.50	Cyanamide	CH ₂ N ₂	44	49.81
Bromotoluene (<i>p</i> -)	C ₇ H ₇ Br	28	20.86	Cyclohexanol	C ₆ H ₁₂ O	25.46	4.19

TABLE 2-192 Heats of Fusion of Organic Compounds (Concluded)

Nonhydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g	Nonhydrocarbon compounds	Formula	mp, °C	Heat of fusion, cal/g
Dibromobenzene (<i>o</i> -)	C ₆ H ₄ Br ₂	1.8	12.78	Naphthol (α -)	C ₁₀ H ₈ O	95.0	38.94
(<i>m</i> -)	C ₆ H ₄ Br ₂	-6.9	13.38	(β -)	C ₁₀ H ₈ O	120.6	31.30
(<i>p</i> -)	C ₆ H ₄ Br ₂	86	20.55	Naphthylamine (α -)	C ₁₀ H ₉ N	50	22.34
Dibromophenol (2, 4-)	C ₆ H ₄ Br ₂ O	12	13.97	Nitroaniline (<i>o</i> -)	C ₆ H ₅ NO ₂	71.2	27.88
Dichloroacetic acid	C ₂ H ₂ Cl ₂ O ₂	-4(?)	14.21	(<i>m</i> -)	C ₆ H ₅ NO ₂	114.0	40.97
Dichlorobenzene (<i>o</i> -)	C ₆ H ₄ Cl ₂	-16.7	21.02	(ρ -)	C ₆ H ₅ NO ₂	147.3	36.46
(<i>m</i> -)	C ₆ H ₄ Cl ₂	-24.8	20.55	Nitrobenzene	C ₆ H ₅ NO ₂	5.85	22.52
(<i>p</i> -)	C ₆ H ₄ Cl ₂	53.13	29.67	Nitrobenzoic acid (<i>o</i> -)	C ₇ H ₅ NO ₄	145.8	40.06
Dihydroxybenzene (<i>o</i> -)	C ₆ H ₆ O ₂	104.3	49.40	(<i>m</i> -)	C ₇ H ₅ NO ₄	141.1	27.59
(<i>m</i> -)	C ₆ H ₆ O ₂	109.65	46.20	(ρ -)	C ₇ H ₅ NO ₄	239.2	52.80
(<i>p</i> -)	C ₆ H ₆ O ₂	172.3	58.77	Nitronaphthalene	C ₁₀ H ₇ NO ₂	56.7	25.44
Di-iodobenzene (<i>o</i> -)	C ₆ H ₄ I ₂	23.4	10.15	Nitrophenol (<i>o</i> -)	C ₆ H ₅ NO ₃	45.13	26.76
(<i>m</i> -)	C ₆ H ₄ I ₂	34.2	11.54				
(<i>p</i> -)	C ₆ H ₄ I ₂	129	16.20	Palmitic acid	C ₁₆ H ₃₂ O ₂	61.82	39.18
Dimethyl tartrate (<i>dl</i> -)	C ₆ H ₁₀ O ₆	87	35.12	Paraldehyde	C ₆ H ₁₂ O ₃	10.5	25.02
(<i>d</i> -)	C ₆ H ₁₀ O ₆	49	21.50	Pelargic acid (<i>n</i> -) (β -)	C ₉ H ₁₆ O ₂		39.04
pyrone	C ₄ H ₆ O ₂	132	56.14	Pelargonic acid (<i>n</i> -) (α -)	C ₉ H ₁₆ O ₂	12.35	30.63
Dinitrobenzene (<i>o</i> -)	C ₆ H ₄ N ₂ O ₄	116.93	32.25	Phenol	C ₆ H ₆ O	40.92	29.03
(<i>m</i> -)	C ₆ H ₄ N ₂ O ₄	89.7	24.70	Phenylacetic acid	C ₈ H ₈ O ₂	76.7	25.44
(<i>p</i> -)	C ₆ H ₄ N ₂ O ₄	173.5	39.99	Phenylhydrazine	C ₆ H ₅ N ₂	19.6	36.31
Dinitrotoluene (2, 4-)	C ₇ H ₆ N ₂ O ₄	70.14	26.40	Propyl ether (<i>n</i>)	C ₆ H ₁₁ O	-126.1	20.66
Dioxane	C ₄ H ₈ O ₂	11.0	34.85				
Diphenyl amine	C ₁₂ H ₁₁ N	52.98	25.23	Quinone	C ₆ H ₄ O ₂	115.7	40.85
Elaidic acid	C ₁₈ H ₃₂ O ₂	44.4	52.08	Stearic acid	C ₁₈ H ₃₀ O ₂	68.82	47.54
Ethyl acetate	C ₄ H ₈ O ₂	83.8	28.43	Succinic anhydride	C ₄ H ₆ O ₃	119	48.74
alcohol	C ₂ H ₆ O	-114.4	25.76	Succinonitrile	C ₄ H ₄ N ₂	54.5	11.71
Ethylened bromide	C ₂ H ₄ Br ₂	10.012	13.52	Tetrachloroxylene (<i>o</i> -)	C ₈ H ₆ Cl ₄	86	21.02
Ethyl ether	C ₄ H ₁₀ O	-116.3	23.54	(<i>p</i> -)	C ₈ H ₆ Cl ₄	95	22.10
Formic acid	CH ₂ O ₂	8.40	58.89	Thiophene	C ₄ H ₆ S	-39.4	14.11
Glutaric acid	C ₆ H ₈ O ₄	97.5	37.39	Thiosianamine	C ₄ H ₅ N ₂ S	77	33.45
Glycerol	C ₃ H ₈ O ₃	18.07	47.49	Thymol	C ₁₀ H ₁₄ O	51.5	27.47
Glycol, ethylene	C ₂ H ₆ O ₂	-11.5	43.26	Toluic acid (<i>o</i> -)	C ₈ H ₈ O ₂	103.7	35.40
Hydrazo benzene	C ₁₂ H ₁₂ N ₂	134	22.89	(<i>m</i> -)	C ₈ H ₈ O ₂	105.75	27.59
Hydrocinnamic acid	C ₉ H ₁₀ O ₂	48	28.14	(<i>p</i> -)	C ₈ H ₈ O ₂	179.6	39.90
Hydroxyacetanilide	C ₈ H ₉ NO ₂	91.3	33.59	Toluidine (<i>p</i> -)	C ₇ H ₉ N	43.3	39.90
Iodotoluene (<i>p</i> -)	C ₇ H ₇ I	34	18.75	Tribromophenol (2, 4, 6-)	C ₆ H ₃ Br ₃ O	93	13.38
Isopropyl alcohol	C ₃ H ₈ O	-88.5	21.08	Trichloroacetic acid	C ₂ HCl ₃ O ₂	57.5	8.60
ether	C ₆ H ₁₄ O	-86.8	25.79	Trimitroglycerol	C ₃ H ₅ N ₃ O ₉	12.3	23.02
Lauric acid (<i>n</i> -)	C ₁₂ H ₂₄ O ₂	43.22	43.72	Trinitrotoluene (2, 4, 6-)	C ₇ H ₅ N ₃ O ₆	80.83	22.34
Levulinic acid	C ₅ H ₈ O ₃	33	18.97	Tristearin	C ₅₇ H ₁₁₀ O ₆	70.8, 54.5	45.63
Menthol (<i>l</i> -) (α)	C ₁₀ H ₂₀ O	43.5	18.63	Undecylic acid (<i>o</i> -) (<i>n</i> -)	C ₁₁ H ₂₂ O ₂	28.25	32.20
Methyl alcohol	CH ₄ O	-97.8	23.7	(β -) (<i>n</i> -)	C ₁₁ H ₂₂ O ₂		42.91
Myristic acid	C ₁₄ H ₂₈ O ₂	53.86	47.49	Urethane	C ₃ H ₇ NO ₂	48.7	40.85
Methyl cinnamate	C ₁₀ H ₁₆ O ₂	36	26.53	Veratrol	C ₈ H ₁₀ O ₂	22.5	27.45
fumarate	C ₆ H ₈ O ₄	102	57.93	Xylene dibromide (<i>o</i> -)	C ₈ H ₈ Br ₂	95	24.25
oxalate	C ₄ H ₂ O ₄	54.35	42.64	(<i>m</i> -)	C ₈ H ₈ Br ₂	77	21.45
phenylpropionate	C ₁₀ H ₁₄ O ₂	18	22.86	dichloride (<i>o</i> -)	C ₈ H ₈ Cl ₂	55	29.03
succinate	C ₆ H ₁₀ O ₄	19.5	35.72	(<i>m</i> -)	C ₈ H ₈ Cl ₂	34	26.64
				(<i>p</i> -)	C ₈ H ₈ Cl ₂	100	32.73

TABLE 2-193 Heats of Vaporization of Inorganic and Organic Compounds

Cmpd. no.	Name	Formula	CAS no.	Mol wt	C1 × 1E-07	C2	C3	C4	T _{min} , K	ΔH _v at T _{min} × 1E-07	T _{max} , K	ΔH _v at T _{max}
1	Methane	CH ₄	74828	16.043	1.0194	0.26087	-0.14694	0.22154	90.69	0.8724	190.56	0
2	Ethane	C ₂ H ₆	74840	30.070	2.1091	0.60646	-0.55492	0.32799	90.35	1.7879	305.32	0
3	Propane	C ₃ H ₈	74986	44.097	2.9209	0.78237	-0.77319	0.39246	85.47	2.4787	369.83	0
4	n-Butane	C ₄ H ₁₀	106978	58.123	3.6238	0.8337	-0.82274	0.39613	134.86	2.8684	425.12	0
5	n-Pentane	C ₅ H ₁₂	109660	72.150	3.9109	0.38681	0	0	143.42	3.3968	469.7	0
6	n-Hexane	C ₆ H ₁₄	110543	86.177	4.4544	0.39002	0	0	177.83	3.7647	507.6	0
7	n-Heptane	C ₇ H ₁₆	142825	100.204	5.0014	0.38795	0	0	182.57	4.2619	540.2	0
8	n-Octane	C ₈ H ₁₈	111659	114.231	5.5180	0.38467	0	0	216.38	4.5898	568.7	0
9	n-Nonane	C ₉ H ₂₀	111842	128.258	6.0370	0.38522	0	0	219.66	5.0545	594.6	0
10	n-Decane	C ₁₀ H ₂₂	124185	142.285	6.6126	0.39797	0	0	243.51	5.4168	617.7	0
11	n-Undecane	C ₁₁ H ₂₄	1120214	156.312	7.2284	0.40607	0	0	247.57	5.9240	639	0
12	n-Dodecane	C ₁₂ H ₂₆	112403	170.338	7.7337	0.40681	0	0	263.57	6.2802	658	0
13	n-Tridecane	C ₁₃ H ₂₈	629505	184.365	8.4339	0.4257	0	0	267.76	6.8015	675	0
14	n-Tetradecane	C ₁₄ H ₃₀	629594	198.392	9.0539	0.44467	0	0	279.01	7.2002	693	0
15	n-Pentadecane	C ₁₅ H ₃₂	629629	212.419	9.6741	0.45399	0	0	283.07	7.6728	708	0
16	n-Hexadecane	C ₁₆ H ₃₄	544763	226.446	10.1560	0.45726	0	0	291.31	8.0225	723	0
17	n-Heptadecane	C ₁₇ H ₃₆	629787	240.473	10.4730	0.4374	0	0	295.13	8.3699	736	0
18	n-Octadecane	C ₁₈ H ₃₈	593453	254.500	10.9690	0.44327	0	0	301.31	8.7246	747	0
19	n-Nonadecane	C ₁₉ H ₄₀	629925	268.527	11.6740	0.45865	0	0	305.04	9.2185	758	0
20	n-Eicosane	C ₂₀ H ₄₂	112958	282.553	12.8600	0.50351	0.32986	-0.42184	309.58	9.5933	768	0
21	2-Methylpropane	C ₄ H ₁₀	75295	58.123	3.1667	0.3855	0	0	113.54	2.7927	408.14	0
22	2-Methylbutane	C ₅ H ₁₂	78784	72.150	3.7700	0.3952	0	0	113.25	3.3720	460.43	0
23	2,3-Dimethylbutane	C ₆ H ₁₄	79298	86.177	4.1404	0.38124	0	0	145.19	3.6328	499.98	0
24	2-Methylpentane	C ₅ H ₁₄	107835	86.177	4.2780	0.384	0	0	119.55	3.8495	497.5	0
25	2,3-Dimethylpentane	C ₇ H ₁₆	565593	100.204	4.6536	0.37579	0	0	160	4.0747	537.35	0
26	2,3,3-Trimethylpentane	C ₉ H ₁₈	560214	114.231	4.9910	0.383	0	0	172.22	4.3530	573.5	0
27	2,2,4-Trimethylpentane	C ₈ H ₁₈	540841	114.231	4.7721	0.37992	0	0	165.78	4.1565	543.96	0
28	Ethylene	C ₂ H ₄	74851	28.054		0.3746	0	0	104	1.6025	282.34	0
29	Propylene	C ₃ H ₆	115071	42.081	2.8694	0.8375	-0.9216	0.5012	87.89	2.4031	365.57	0
30	1-Butene	C ₄ H ₈	106989	56.108	3.2300	0.3747	0	0	87.8	2.9582	419.95	0
31	cis-2-Butene	C ₄ H ₈	590181	56.108	3.4190	0.3754	0	0	134.26	2.9773	435.58	0
32	trans-2-Butene	C ₄ H ₈	624646	56.108	3.3320	0.3736	0	0	167.62	2.7684	428.63	0
33	1-Pentene	C ₅ H ₁₀	109671	70.134	3.7740	0.37647	0	0	107.93	3.4166	464.78	0
34	1-Hexene	C ₆ H ₁₂	592416	84.161	4.3236	0.3788	0	0	133.39	3.8483	504.03	0
35	1-Heptene	C ₇ H ₁₄	592767	98.188	4.8120	0.3685	0	0	154.27	4.2478	537.29	0
36	1-Octene	C ₈ H ₁₆	111660	112.215	5.3980	0.3835	0	0	171.45	4.7013	566.65	0
37	1-Nonene	C ₉ H ₁₈	124118	126.242	5.9940	0.3953	0	0	191.78	5.1366	593.25	0
38	1-Decene	C ₁₀ H ₂₀	872059	140.269	6.4898	0.39187	0	0	206.89	5.5289	616.4	0
39	2-Methylpropene	C ₄ H ₈	115117	56.108	3.2720	0.383	0	0	132.81	2.8262	417.9	0
40	2-Methyl-1-butene	C ₅ H ₁₀	563462	70.134	3.9091	0.39866	0	0	135.58	3.4072	465	0
41	2-Methyl-2-butene	C ₅ H ₁₀	513359	70.134	3.9121	0.3634	0	0	139.39	3.4437	471	0
42	1,2-Butadiene	C ₄ H ₆	590192	54.092	3.5220	0.395	0	0	136.95	3.0540	452	0
43	1,3-Butadiene	C ₄ H ₆	106990	54.092	3.2580	0.373	0	0	164.25	2.7155	425.17	0
44	2-Methyl-1,3-butadiene	C ₅ H ₈	78795	68.119	3.9310	0.425	0	0	127.27	3.4529	484	0
45	Acetylene	C ₂ H ₂	74862	26.038	2.3795	0.375	0	0	192.4	1.6488	308.32	0
46	Methylacetylene	C ₃ H ₄	74997	40.065	3.2775	0.3997	0	0	170.45	2.6297	402.39	0
47	Dimethylacetylene	C ₄ H ₆	503173	54.092	3.8560	0.3737	0	0	240.91	2.9557	473.2	0
48	3-Methyl-1-butyne	C ₅ H ₈	598232	68.119	3.7920	0.3565	0	0	183.45	3.1681	463.2	0
49	1-Pentyne	C ₅ H ₈	627190	68.119	3.9540	0.3512	0	0	167.45	3.4025	481.2	0
50	2-Pentyne	C ₅ H ₈	627214	68.119	4.4158	0.44347	0	0	163.83	3.7321	519	0
51	1-Hexyne	C ₆ H ₁₀	693027	82.145	4.5740	0.3698	0	0	141.25	4.0640	516.2	0
52	2-Hexyne	C ₆ H ₁₀	764352	82.145	4.9110	0.4392	0	0	183.65	4.1067	549	0

53	3-Hexyne	C ₆ H ₁₀	928494	82.145	4.8080	0.436	0	0	170.05	4.0831	544	0
54	1-Heptyne	C ₇ H ₁₂	628717	96.172	5.0514	0.41163	0	0	192.22	4.2470	559	0
55	1-Octyne	C ₈ H ₁₄	629050	110.199	5.6306	0.4148	0	0	193.55	4.7663	585	0
56	Vinylacetylene ¹	C ₄ H ₄	689974	52.076	3.6490	0.4	0.043	0	173.15	2.9876	454	0
57	Cyclopentane	C ₅ H ₁₀	287923	70.134	3.8900	0.361	0	0	179.28	3.3292	511.76	0
58	Methylcyclopentane	C ₆ H ₁₂	96377	84.161	4.3600	0.38531	0	0	130.73	3.9118	532.79	0
59	Ethylcyclopentane	C ₇ H ₁₄	1640897	98.188	4.8288	0.37809	0	0	134.71	4.3604	569.52	0
60	Cyclohexane	C ₆ H ₁₂	110827	84.161	4.4940	0.3974	0	0	279.69	3.3977	553.58	0
61	Methylcyclohexane	C ₇ H ₁₄	108872	98.188	4.7534	0.39461	0	0	146.58	4.2295	572.19	0
62	1,1-Dimethylcyclohexane	C ₈ H ₁₆	590669	112.215	5.0402	0.4036	0	0	239.66	4.0862	591.15	0
63	Ethylcyclohexane	C ₇ H ₁₆	1678917	112.215	5.3832	0.41763	0	0	161.84	4.7318	609.15	0
64	Cyclopentene	C ₅ H ₈	142290	68.119	3.8107	0.3543	0	0	138.13	3.4046	507	0
65	1-Methylcyclopentene	C ₆ H ₁₀	693890	82.145	4.3541	0.36805	0	0	146.62	3.8769	542	0
66	Cyclohexene	C ₆ H ₁₀	110838	82.145	4.4405	0.37479	0	0	169.67	3.8791	560.4	0
67	Benzene	C ₆ H ₆	71432	78.114	4.7500	0.45238	0.0534	-0.1181	278.68	3.4909	562.16	0
68	Toluene	C ₇ H ₈	108883	92.141	5.0144	0.359	0	0	178.18	4.3670	591.8	0
69	<i>o</i> -Xylene	C ₈ H ₁₀	95476	106.167	5.5330	0.377	0	0	247.98	4.5826	630.33	0
70	<i>m</i> -Xylene	C ₈ H ₁₀	108383	106.167	5.4600	0.3726	0	0	225.3	4.6097	617.05	0
71	<i>p</i> -Xylene	C ₈ H ₁₀	106423	106.167	5.3740	0.3656	0	0	286.41	4.2761	616.23	0
72	Ethylbenzene	C ₈ H ₁₀	100414	106.167	5.4640	0.392	0	0	178.15	4.7811	617.2	0
73	Propylbenzene	C ₉ H ₁₂	103651	120.194	5.7663	0.3956	-8.9129E-03	0	215.03	5.0574	574.54	2.4695E+07
74	1,2,4-Trimethylbenzene	C ₉ H ₁₂	95636	120.194	5.9126	0.35632	0	0	229.33	5.0621	649.13	0
75	Isopropylbenzene	C ₉ H ₁₂	98828	120.194	5.7950	0.3956	0	0	177.14	5.0869	631.1	0
76	1,3,5-Trimethylbenzene	C ₉ H ₁₂	108678	120.194	6.0380	0.37999	0	0	228.42	5.1010	637.36	0
77	<i>p</i> -Isopropyltoluene	C ₁₀ H ₁₄	99876	134.221	6.3314	0.40289	0	0	205.25	5.4387	653.15	0
78	Naphthalene	C ₁₀ H ₈	91203	128.174	7.0510	0.4612	0	0	353.43	5.2508	748.35	0
79	Biphenyl	C ₁₂ H ₁₀	92524	154.211	7.5736	0.3975	0	0	342.2	6.0420	789.26	0
80	Styrene	C ₈ H ₈	100425	104.152	5.7260	0.4055	0	0	242.54	4.7128	636	0
81	<i>m</i> -Terphenyl	C ₁₈ H ₁₄	92068	230.309	10.1230	0.3767	0	0	360	8.4070	924.85	0
82	Methanol	CH ₄ O	67561	32.042	5.2390	0.3682	0	0	175.47	4.4900	512.64	0
83	Ethanol	C ₂ H ₆ O	64175	46.069	5.6900	0.3359	0	0	159.05	5.0245	513.92	0
84	1-Propanol	C ₃ H ₈ O	71238	60.096	6.3300	0.3575	0	0	146.95	5.6460	536.78	0
85	1-Butanol	C ₄ H ₁₀ O	71363	74.123	6.7390	0.173	0.2915	0	184.51	6.0575	563.05	0
86	2-Butanol	C ₄ H ₁₀ O	78922	74.123	7.2560	0.4774	0	0	158.45	6.1383	536.05	0
87	2-Propanol	C ₃ H ₈ O	67630	60.096	6.3080	0.3921	0	0	185.28	5.2807	508.3	0
88	2-Methyl-2-propanol	C ₄ H ₁₀ O	75650	74.123	7.7320	0.5645	0	0	298.97	4.6703	506.21	0
89	1-Pentanol	C ₅ H ₁₂ O	71410	88.150	8.3100	0.511	0	0	195.56	6.7533	586.15	0
90	2-Methyl-1-butanol	C ₅ H ₁₂ O	137326	88.150	7.7839	0.45313	0	0	203	6.3619	565	0
91	3-Methyl-1-butanol	C ₅ H ₁₂ O	123513	88.150	8.0815	0.50185	0	0	155.95	6.8999	577.2	0
92	1-Hexanol	C ₆ H ₁₄ O	111273	102.177	8.5980	0.513	0	0	228.55	6.7623	611.35	0
93	1-Heptanol	C ₇ H ₁₆ O	111706	116.203	9.6900	0.572	0	0	239.15	7.3822	631.9	0
94	Cyclohexanol	C ₆ H ₁₂ O	108930	100.161	9.2440	0.64825	0	0	296.6	6.2273	650	0
95	Ethylene glycol	C ₂ H ₆ O ₂	107211	62.068	8.2900	0.4266	0	0	260.15	6.8461	719.7	0
96	1,2-Propylene glycol	C ₃ H ₈ O ₂	57556	76.095	8.0700	0.295	0	0	213.15	7.1374	626	0
97	Phenol	C ₆ H ₆ O	108952	94.113	7.3060	0.4246	0	0	314.06	5.6577	694.25	0
98	<i>o</i> -Cresol	C ₇ H ₈ O	95487	108.140	7.1979	0.40317	0	0	304.19	5.7135	697.55	0
99	<i>m</i> -Cresol	C ₇ H ₈ O	108394	108.140	8.0082	0.45314	0	0	285.39	6.3326	705.85	0
100	<i>p</i> -Cresol	C ₇ H ₈ O	106445	108.140	8.4942	0.50234	0	0	307.93	6.3649	704.65	0
101	Dimethyl ether	C ₂ H ₆ O	115106	46.069	2.9940	0.3505	0	0	131.65	2.6032	400.1	0
102	Methyl ethyl ether	C ₃ H ₈ O	540670	60.096	3.5300	0.376	0	0	160	2.9751	437.8	0
103	Methyl <i>n</i> -propyl ether	C ₄ H ₁₀ O	557175	74.123	3.9795	0.3729	0	0	133.97	3.5184	476.3	0
104	Methyl isopropyl ether	C ₄ H ₁₀ O	598538	74.123	3.9305	0.3711	0	0	127.93	3.4876	464.5	0
105	Methyl- <i>n</i> -butyl ether	C ₅ H ₁₂ O	628284	88.150	4.5328	0.3824	0	0	157.48	3.9358	510	0
106	Methyl isobutyl ether	C ₅ H ₁₂ O	625445	88.150	4.2678	0.37995	0	0	150	3.7232	497	0
107	Methyl tert-butyl ether	C ₅ H ₁₂ O	1634044	88.150	4.2024	0.37826	0	0	164.55	3.6096	497.1	0

TABLE 2-193 Heats of Vaporization of Inorganic and Organic Compounds (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol wt	C1 × 1E-07	C2	C3	C4	T _{min} , K	ΔH _v at T _{min} × 1E-07	T _{max} , K	ΔH _v at T _{max}
108	Diethyl ether	C ₄ H ₁₀ O	60297	74.123	4.0600	0.3568	0	0	156.85	3.4651	466.7	0
109	Ethyl propyl ether	C ₅ H ₁₂ O	628320	88.150	5.4380	0.60624	0	0	145.65	4.4140	500.23	0
110	Ethyl isopropyl ether	C ₅ H ₁₂ O	625547	88.150	4.2580	0.37221	0	0	140	3.7556	489	0
111	Methyl phenyl ether	C ₇ H ₈ O	100663	108.140	5.8662	0.37127	0	0	235.65	4.9560	645.6	0
112	Diphenyl ether	C ₁₂ H ₁₀ O	101848	170.211	6.8243	0.30877	0	0	300.03	5.8546	766.8	0
113	Formaldehyde	CH ₂ O	50000	30.026	3.0760	0.2954	0	0	181.15	2.5863	408	0
114	Acetaldehyde	C ₂ H ₄ O	75070	44.053	4.6070	0.62	0	0	150.15	3.6199	466	0
115	1-Propanal	C ₃ H ₆ O	123386	58.080	4.1492	0.36751	0	0	170	3.5675	504.4	0
116	1-Butanal	C ₄ H ₈ O	123728	72.107	4.6403	0.3549	0	0	176.75	3.9797	537.2	0
117	1-Pentanal	C ₅ H ₁₀ O	110623	86.134	5.1478	0.37541	0	0	182	4.4502	566.1	0
118	1-Hexanal	C ₆ H ₁₂ O	66251	100.161	5.6661	0.38533	0	0	217.15	4.7495	591	0
119	1-Heptanal	C ₇ H ₁₄ O	111717	114.188	6.1299	0.37999	0	0	229.8	5.1353	617	0
120	1-Octanal	C ₈ H ₁₆ O	124130	128.214	6.8347	0.41039	0	0	246	5.5966	638.1	0
121	1-Nonanal	C ₉ H ₁₈ O	124196	142.241	7.3363	0.41735	0	0	255.15	5.9779	658	0
122	1-Decanal	C ₁₀ H ₂₀ O	112312	156.268	7.9073	0.4129	0	0	267.15	6.4201	674.2	0
123	Acetone	C ₃ H ₆ O	67641	58.080	4.2150	0.3397	0	0	178.45	3.6390	508.2	0
124	Methyl ethyl ketone	C ₃ H ₆ O	78933	72.107	4.6220	0.355	0	0	186.48	3.9704	535.5	0
125	2-Pentanone	C ₅ H ₁₀ O	107879	86.134	5.1740	0.39422	0	0	196.29	4.3663	561.08	0
126	Methyl isopropyl ketone	C ₅ H ₈ O	563804	86.134	5.1400	0.3858	0	0	250	4.0753	553	0
127	2-Hexanone	C ₆ H ₁₂ O	591786	100.161	5.6770	0.3817	0	0	217.35	4.7584	587.05	0
128	Methyl isobutyl ketone	C ₆ H ₁₂ O	108101	100.161	5.4000	0.383	0	0	189.15	4.6294	571.4	0
129	3-Methyl-2-pentanone	C ₆ H ₁₂ O	565617	100.161	5.1130	0.3395	0	0	167.15	4.5480	573	0
130	3-Pentanone	C ₅ H ₁₀ O	96220	86.134	5.2359	0.40465	0	0	234.18	4.2075	560.95	0
131	Ethyl isopropyl ketone	C ₆ H ₁₂ O	565695	100.161	5.3880	0.40616	0	0	200	4.5154	567	0
132	Diisopropyl ketone	C ₇ H ₁₄ O	565800	114.188	5.5980	0.3774	0	0	204.81	4.7426	576	0
133	Cyclohexanone	C ₆ H ₁₀ O	108941	98.145	5.5500	0.3538	0	0	242	4.7114	653	0
134	Methyl phenyl ketone	C ₈ H ₈ O	98862	120.151	6.6104	0.37425	0	0	292.81	5.4166	709.5	0
135	Formic acid	CH ₂ O ₂	64186	46.026	2.3700	1.999	-5.1503	3.331	281.45	1.9532	588	0
136	Acetic acid	C ₂ H ₄ O ₂	64197	60.053	2.0265	0.11911	-1.3487	1.4227	289.81	2.3185	591.95	0
137	Propionic acid	C ₃ H ₆ O ₂	79094	74.079	2.7290	0.06954	-1.0423	1.1152	252.45	2.9964	600.81	0
138	n-Butyric acid	C ₄ H ₈ O ₂	107926	88.106	7.4996	2.333	-3.8644	2.016	267.95	4.1566	615.7	0
139	Isobutyric acid	C ₄ H ₈ O ₂	79312	88.106	4.4967	1.1615	-2.4573	1.5823	227.15	3.6179	605	0
140	Benzoic acid ²	C ₇ H ₆ O ₂	65850	122.123	10.1900	0.478	0	0	395.45	7.1277	751	0
141	Acetic anhydride	C ₄ H ₆ O ₃	108247	102.090	6.3520	0.3986	0	0	200.15	5.4139	606	0
142	Methyl formate	C ₂ H ₄ O ₂	107313	60.053	4.1030	0.3825	0	0	174.15	3.4644	487.2	0
143	Methyl acetate	C ₃ H ₆ O ₂	79209	74.079	4.4920	0.3685	0	0	175.15	3.8418	506.55	0
144	Methyl propionate	C ₄ H ₈ O ₂	554121	88.106	5.0080	0.3959	0	0	185.65	4.2231	530.6	0
145	Methyl n-butyrate	C ₅ H ₁₀ O ₂	623427	102.133	5.3781	0.39523	0	0	187.35	4.5694	554.5	0
146	Ethyl formate	C ₃ H ₆ O ₂	109944	74.079	4.5909	0.4123	0	0	193.55	3.7679	508.4	0
147	Ethyl acetate	C ₄ H ₈ O ₂	141786	88.106	4.9330	0.3847	0	0	189.6	4.1490	523.3	0
148	Ethyl propionate	C ₅ H ₁₀ O ₂	105373	102.133	5.3325	0.401	0	0	199.25	4.4449	546	0
149	Ethyl n-butyrate	C ₆ H ₁₂ O ₂	105544	116.160	5.6419	0.37985	0	0	175.15	4.9090	571	0
150	n-Propyl formate	C ₄ H ₈ O ₂	110747	88.106	4.9687	0.4025	0	0	180.25	4.2162	538	0
151	n-Propyl acetate	C ₅ H ₁₀ O ₂	109604	102.133	5.4327	0.407	0	0	178.15	4.6322	549.73	0
152	n-Butyl acetate	C ₆ H ₁₂ O ₂	123864	116.160	5.7800	0.3935	0	0	199.65	4.8943	579.15	0
153	Methyl benzoate	C ₉ H ₈ O ₂	935583	136.150	6.9650	0.4061	0	0	260.75	5.7500	693	0
154	Ethyl benzoate	C ₉ H ₁₀ O ₂	93890	150.177	6.3400	0.2911	0	0	238.45	5.6137	698	0
155	Vinyl acetate	C ₄ H ₆ O ₂	108054	86.090	4.7700	0.3765	0	0	180.35	4.0619	519.13	0
156	Methylamine	CH ₅ N	74895	31.057	3.8580	0.404	0	0	179.69	3.1006	430.05	0
157	Dimethylamine	C ₂ H ₅ N	124403	45.084	4.0900	0.42005	0	0	180.96	3.2678	437.2	0
158	Trimethylamine	C ₃ H ₉ N	75503	59.111	3.3050	0.354	0	0	156.08	2.8216	433.25	0

159	Ethylamine	C ₂ H ₇ N	75047	45.084	4.2750	0.5857	-0.332	0.169	192.15	3.2955	456.15	0
160	Diethylamine	C ₄ H ₁₁ N	109897	73.138	4.6133	0.42628	0	0	223.35	3.5761	496.6	0
161	Triethylamine	C ₆ H ₁₅ N	121448	101.192	4.6640	0.3663	0	0	158.45	4.1011	535.15	0
162	<i>n</i> -Propylamine	C ₃ H ₉ N	107108	59.111	4.4488	0.39494	0	0	188.36	3.6857	496.95	0
163	di- <i>n</i> -Propylamine	C ₆ H ₁₅ N	142847	101.192	5.4280	0.3665	0	0	210.15	4.5500	550	0
164	Isopropylamine	C ₃ H ₉ N	75310	59.111	4.4041	0.43325	0	0	177.95	3.5874	471.85	0
165	Diisopropylamine	C ₆ H ₁₃ N	108189	101.192	5.0070	0.4362	0	0	176.85	4.1823	523.1	0
166	Aniline	C ₆ H ₇ N	62533	93.128	7.1950	0.458	0	0	267.13	5.7710	699	0
167	<i>N</i> -Methylaniline	C ₇ H ₉ N	100618	107.155	6.3860	0.3104	0	0	216.15	5.6961	701.55	0
168	<i>N,N</i> -Dimethylaniline	C ₈ H ₁₁ N	121697	121.182	6.7900	0.4053	0	0	275.6	5.5162	687.15	0
169	Ethylene oxide	C ₂ H ₄ O	75218	44.053	3.6652	0.37878	0	0	160.65	3.1271	469.15	0
170	Furan	C ₄ H ₄ O	110009	68.075	4.0050	0.3995	0	0	196.29	3.2647	490.15	0
171	Thiophene	C ₄ H ₈ S	110021	84.142	4.5793	0.38557	0	0	234.94	3.7472	579.35	0
172	Pyridine	C ₅ H ₅ N	110861	79.101	5.1740	0.38865	0	0	231.51	4.3144	619.95	0
173	Formamide ³	CH ₃ NO	75127	45.041	7.3580	0.3564	0	0	275.7	6.2844	771	0
174	<i>N,N</i> -Dimethylformamide	C ₃ H ₇ NO	68122	73.095	5.9217	0.37996	0	0	212.72	5.0931	649.6	0
175	Acetamide	C ₂ H ₅ NO	60355	59.068	8.1070	0.42	0	0	353.15	6.2386	761	0
176	<i>N</i> -Methylacetamide	C ₃ H ₇ NO	79163	73.095	7.3402	0.38974	0	0	301.15	5.9384	718	0
177	Acetonitrile	C ₃ H ₃ N	75058	41.053	4.3511	0.34765	0	0	229.32	3.5996	545.5	0
178	Propionitrile	C ₃ H ₅ N	107120	55.079	4.9348	0.41873	0	0	180.26	4.2005	564.4	0
179	<i>n</i> -Butyronitrile	C ₄ H ₇ N	109740	69.106	5.2200	0.165	0.6692	-0.539	161.25	4.7223	582.25	0
180	Benzonitrile	C ₇ H ₅ N	100470	103.123	6.2615	0.35427	0	0	260.4	5.3091	699.35	0
181	Methyl mercaptan	CH ₃ S	74931	48.109	3.4448	0.37427	0	0	150.18	2.9825	469.95	0
182	Ethyl mercaptan	C ₂ H ₆ S	75081	62.136	3.8440	0.37534	0	0	125.26	3.4489	499.15	0
183	<i>n</i> -Propyl mercaptan	C ₃ H ₇ S	107039	76.163	4.4782	0.41073	0	0	159.95	3.8723	536.6	0
184	<i>n</i> -Butyl mercaptan	C ₄ H ₁₀ S	109795	90.189	4.9702	0.41199	0	0	157.46	4.3505	570.1	0
185	Isobutyl mercaptan	C ₄ H ₉ S	513440	90.189	4.7420	0.40535	0	0	128.31	4.2664	559	0
186	sec-Butyl mercaptan	C ₄ H ₉ S	513531	90.189	4.6432	0.399	0	0	133.02	4.1614	554	0
187	Dimethyl sulfide	C ₂ H ₆ S	75183	62.136	3.8690	0.3694	0	0	174.88	3.3042	503.04	0
188	Methyl ethyl sulfide	C ₃ H ₈ S	624895	76.163	4.4740	0.4097	0	0	167.23	3.8344	533	0
189	Diethyl sulfide	C ₄ H ₁₀ S	352932	90.189	4.7182	0.3643	0	0	169.2	4.1353	557.15	0
190	Fluoromethane	CH ₃ F	593533	34.033	2.4708	0.37014	0	0	131.35	2.0276	317.42	0
191	Chloromethane	CH ₃ Cl	74873	50.488	2.9745	0.353	0	0	175.43	2.4520	416.25	0
192	Trichloromethane	CHCl ₃	67663	119.377	4.1860	0.3584	0	0	209.63	3.5047	536.4	0
193	Tetrachloromethane	CCl ₄	56235	153.822	4.3252	0.37688	0	0	250.33	3.4528	556.35	0
194	Bromomethane	CH ₃ Br	74839	94.939	3.1690	0.3015	0	0	179.47	2.7379	467	0
195	Fluoroethane	C ₂ H ₅ F	353366	48.060	2.7617	0.32162	0	0	129.95	2.4089	375.31	0
196	Chloroethane	C ₂ H ₅ Cl	75003	64.514	3.5240	0.3652	0	0	134.8	3.1052	460.35	0
197	Bromoethane	C ₂ H ₅ Br	74964	108.966	3.9004	0.38012	0	0	154.55	3.3933	503.8	0
198	1-Chloropropane	C ₃ H ₇ Cl	540545	78.541	3.9890	0.37956	0	0	150.35	3.4862	503.15	0
199	2-Chloropropane	C ₃ H ₇ Cl	75296	78.541	3.8871	0.38043	0	0	155.97	3.3586	489	0
200	1,1-Dichloropropane	C ₃ H ₆ Cl ₂	78999	112.986	4.7740	0.39204	0	0	200	4.0147	560	0
201	1,2-Dichloropropane	C ₃ H ₆ Cl ₂	78875	112.986	4.6750	0.36529	0	0	172.71	4.0997	572	0
202	Vinyl chloride	C ₂ H ₃ Cl	75014	62.499	3.4125	0.4513	0	0	119.36	2.9491	432	0
203	Fluorobenzene	C ₆ H ₅ F	462066	96.104	4.5820	0.3717	0	0	230.94	3.7605	560.09	0
204	Chlorobenzene	C ₆ H ₅ Cl	108907	112.558	5.1480	0.36614	0	0	227.95	4.3707	632.35	0
205	Bromobenzene	C ₆ H ₅ Br	108861	157.010	5.5520	0.37694	0	0	242.43	4.6875	670.15	0
206	Air		132259100	28.951	0.8474	0.3822	0	0	59.15	0.6759	132.45	0
207	Hydrogen	H ₂	1333740	2.016	0.1013	0.698	-1.817	1.447	13.95	0.0913	33.19	0
208	Helium-4	He	7440597	4.003	0.0125	1.3038	-2.6954	1.7098	2.2	0.0097	5.2	0
209	Neon	Ne	7440019	20.180	0.2389	0.3494	0	0	24.56	0.1803	44.4	0
210	Argon	Ar	7440371	39.948	0.8731	0.3526	0	0	83.78	0.6561	150.86	0
211	Fluorine	F ₂	7782414	37.997	0.8876	0.34072	0	0	53.48	0.7578	144.12	0
212	Chlorine	Cl ₂	7782505	70.905	3.0680	0.8458	-0.9001	0.453	172.12	2.2878	417.15	0
213	Bromine	Br ₂	7726956	159.808	4.0000	0.351	0	0	265.85	3.2323	584.15	0

TABLE 2-193 Heats of Vaporization of Inorganic and Organic Compounds (Concluded)

Cmpd. no.	Name	Formula	CAS no.	Mol wt	C1 × 1E-07	C2	C3	C4	T _{min} , K	ΔH _v at T _{min} × 1E-07	T _{max} , K	ΔH _v at T _{max}
214	Oxygen	O ₂	7782447	31.999	0.9008	0.4542	-0.4096	0.3183	54.36	0.7742	154.58	0
215	Nitrogen	N ₂	7727379	28.014	0.7491	0.40406	-0.317	0.27343	63.15	0.6024	126.2	0
216	Ammonia	NH ₃	7664417	17.031	3.1523	0.3914	-0.2289	0.2309	195.41	2.5298	405.65	0
217	Hydrazine	N ₂ H ₄	302012	32.045	5.9794	0.9424	-1.398	0.8862	274.69	4.5238	653.15	0
218	Nitrous oxide	N ₂ O	10024972	44.013	2.3215	0.384	0	0	182.3	1.6502	309.57	0
219	Nitric oxide	NO	10102439	30.006	2.1310	0.4056	0	0	109.5	1.4578	180.15	0
220	Cyanogen	C ₂ N ₂	460195	52.036	3.3840	0.3707	0	0	245.25	2.3803	400.15	0
221	Carbon monoxide	CO	630080	28.010	0.8585	0.4921	-0.326	0.2231	68.13	0.6517	132.5	915280
222	Carbon dioxide	CO ₂	124389	44.010	2.1730	0.382	-0.4339	0.42213	216.58	1.5202	304.21	0
223	Carbon disulfide	CS ₂	75150	76.143	3.4960	0.2986	0	0	161.11	3.1537	552	0
224	Hydrogen fluoride	HF	7664393	20.006	13.4510	13.36	-23.383	10.785	277.56	0.7104	461.15	0
225	Hydrogen chloride	HCl	7647010	36.461	2.2093	0.3466	0	0	158.97	1.7498	324.65	0
226	Hydrogen bromide	HBr	10035106	80.912	2.4850	0.39	0	0	185.15	1.8817	363.15	0
227	Hydrogen cyanide ²	HCN	74908	27.026	3.3490	0.2053	0	0	259.83	2.8176	456.65	0
228	Hydrogen sulfide	H ₂ S	7783064	34.082	2.5676	0.37358	0	0	187.68	1.9782	373.53	0
229	Sulfur dioxide	SO ₂	7446095	64.065	3.6760	0.4	0	0	197.67	2.8753	430.75	0
230	Sulfur trioxide	SO ₃	7446119	80.064	7.3370	0.5647	0	0	289.95	4.4303	490.85	0
231	Water	H ₂ O	7732185	18.015	5.2053	0.3199	-0.212	0.25795	273.16	4.4733	647.13	0

All substances are listed in alphabetical order in Table 2-6a.

Compiled from Daubert, T. E., R. P. Danner, H. M. Sibul, and C. C. Stebbins, DIPPR Data Compilation of Pure Compound Properties, Project 801 Sponsor Release, July, 1993, Design Institute for Physical Property Data, AIChE, New York, NY; and from Thermodynamics Research Center, "Selected Values of Properties of Hydrocarbons and Related Compounds," Thermodynamics Research Center Hydrocarbon Project, Texas A&M University, College Station, Texas (extant 1994).

Temperatures are expressed in kelvins; heats of vaporization, in J/kmol.

J/kmol × 2.390E-04 = cal/gmol; J/kmol × 4.302106E-04 = Btu/lbmol.

The heat of vaporization equation used is $\Delta H_v = C1 \times (1 - T_r)^{C2 + C3 \times T_r + C4 \times T_r^2}$. T_r is the reduced temperature, T/T_c .¹ Coefficients are hypothetical; compound decomposes violently on heating.² For the monomer.³ Equation coefficients are hypothetical above the decomposition temperature.

SPECIFIC HEATS OF PURE COMPOUNDS

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$\begin{aligned}^{\circ}\text{F} &= \frac{9}{5}^{\circ}\text{C} + 32 \\^{\circ}\text{F} &= 1.8\text{ K}\end{aligned}$$

To convert calories per gram-kelvin to British thermal units per pound-degree Rankine, multiply by 1.0; to convert calories per gram-mole-kelvin to British thermal units per pound-mole-degree Rankine, multiply by 1.0.

To convert kilojoules per kilogram-kelvin to British thermal units per pound-degree Rankine, multiply by 0.2388.

ADDITIONAL REFERENCES

Additional data are contained in the subsection "Thermodynamic Properties." Data on water are also contained in that subsection. Additional tables for water are found in Eng. Sci. Data Item 68008, 251 Regent Street, London, England, which contains about 5000 values from 1 to 1000 bar, 0 to 1500°C.

TABLE 2-194 Heat Capacities of the Elements and Inorganic Compounds*

Substance	State†	Heat capacity at constant pressure (T = K; 0°C = 273.1 K), cal/deg mol	Range of temperature, K	Uncertainty, %
Aluminum ¹				
Al	c	4.80 + 0.00322T	273–931	1
	l	7.00	931–1273	5
AlBr ₃	c	18.74 + 0.01866T	273–370	3
	l	29.5	370–407	5
AlCl ₃	c	13.25 + 0.02800T	273–465	3
	l	31.2	465–504	3
AlCl ₃ ·6H ₂ O	c	76	288–327	?
AlF ₃	c	19.3	288–326	?
AlF ₃ ·3½H ₂ O	c	50.5	288–326	?
AlF ₃ ·3NaF	c	38.63 + 0.04760T – 449200/T ²	273–1273	2
	l	142	1273–1373	?
AlI ₃	c	16.88 + 0.02266T	273–464	3
	l	28.8	464–480	5
Al ₂ O ₃	c	22.08 + 0.008971T – 522500/T ²	273–1973	3
Al ₂ O ₃ ·SiO ₂	c, sillimanite	40.79 + 0.004763T – 992800/T ²	273–1573	3
	c, disthene	41.81 + 0.005283T – 1211000/T ²	273–1673	2
	c, andalusite	43.96 + 0.001923T – 1086000/T ²	273–1573	3
3Al ₂ O ₃ ·2SiO ₂	c, mullite	59.65 + 0.0670T	273–576	5
4Al ₂ O ₃ ·3SiO ₂	c	113.2 + 0.0652T	273–575	3
Al ₂ (SO ₄) ₃	c	63.5	273–373	?
Al ₂ (SO ₄) ₃ ·18H ₂ O	c	235	288–325	?
Antimony				
Sb	c	5.51 + 0.00178T	273–903	2
	l	7.15	903–1273	5
SbBr ₃	c	17.2 + 0.0293T	273–370	?
SbCl ₃	c	10.3 + 0.0511T	273–346	?
Sb ₂ O ₃	c	19.1 + 0.0171T	273–929	?
Sb ₂ O ₄	c	22.6 + 0.0162T	273–1198	?
Sb ₂ S ₃	c	24.2 + 0.0132T	273–821	?
Argon ²				
A	g	4.97	All	0
Arsenic				
As	c	5.17 + 0.00234T	273–1168	5
AsCl ₃	l	31.9	286–371	?
As ₂ O ₃	c	8.37 + 0.0486T	273–548	?
As ₂ S ₃	c	25.8	293–373	?
Barium				
BaCl ₂	c	17.0 + 0.00334T	273–1198	?
BaCl ₂ ·H ₂ O	c	28.2	273–307	?
BaCl ₂ ·2H ₂ O	c	37.3	273–307	?
Ba(ClO ₃) ₂ ·H ₂ O	c	51	289–320	?
BaCO ₃	c, α	17.26 + 0.0131T	273–1083	5
	c, β	30.0	1083–1255	15
BaMoO ₄	c	34	273–297	?
Ba(NO ₃) ₂	c	39.8	285–371	?
BaSO ₄	c	21.35 + 0.0141T	273–1323	5
Beryllium ^{3,4}				
Be	c	4.698 + 0.001555T – 121000/T ²	273–1173	1
BeO	c	8.69 + 0.00365T – 313000/T ²	273–1175	5
BeO·Al ₂ O ₃	c	25.4	273–373	?
BeSO ₄	c	20.8	273–373	?

*From Kelley, U.S. Bur. Mines Bull. 371, 1934. For a revision see Kelley, U.S. Bur. Mines Bull. 477, 1948. Data for many elements and compounds are given by Johnson (ed.), WADD-TR-60-56, 1960, for cryogenic temperatures. Tabulated data for gases can be obtained from many of the references cited in the "Thermodynamic Properties" subsection and other tables in this section, Thinh, Duran, et al., *Hydrocarbon Process.*, **50**, 98 (January 1971), review previous equation fits and give newer fits for 408 hydrocarbons and related compounds. Later publications include Duran, Thinh, et al., *Hydrocarbon Process.*, **55**, 153 (August 1976); Thompson, *J. Chem. Eng. Data*, **22**(4), 431 (1977); and Passut and Danner, *Ind. Eng. Chem. Process Des. Dev.*, **11**, 543 (1972); **13**, 193 (1974).

†The symbols in this column have the following meaning: c, crystal; l, liquid; g, gas; gls, glass.

TABLE 2-194 Heat Capacities of the Elements and Inorganic Compounds (Continued)

Substance	State†	Heat capacity at constant pressure ($T = \text{K}$; $0^\circ\text{C} = 273.1 \text{ K}$), cal/deg mol	Range of temperature, K	Uncertainty, %
Bismuth ⁴				
Bi	c	$5.38 + 0.00260T$	273–544	3
	l	7.60	544–1273	3
Bi ₂ O ₃	c	$23.27 + 0.01105T$	273–777	2
Bi ₂ S ₃	c	30.4	284–372	?
Boron				
B	c	$1.54 + 0.00440T$	273–1174	5
B ₂ O ₃	gls	$5.14 + 0.0320T$	273–513	3
	gls	30.4	513–623	3
BN	c	$1.61 + 0.00400T$	273–1173	5
Bromine				
Br ₂	g	9.00	300–2000	5
Cadmium				
Cd	c	$5.46 + 0.002466T$	273–594	1
	l	7.13	594–973	5
CdO	c	$9.65 + 0.00208T$	273–2086	?
CdS	c	$12.9 + 0.00090T$	273–1273	?
CdSO ₄ ·8H ₂ O	c	51.3	293	?
Calcium				
Ca	c	$5.31 + 0.00333T$	273–673	2
	c	$6.29 + 0.00140T$	673–873	2
CaCl ₂	c	$16.9 + 0.00386T$	273–1055	?
CaCO ₃	c	$19.68 + 0.01189T - 307600/T^2$	273–1033	3
CaF ₂	c	$14.7 + 0.00380T$	273–1651	?
CaMg(CO ₃) ₂	c	40.1	299–372	?
CaMoO ₄	c	33	273–297	?
CaO	c	$10.00 + 0.00484T - 108000/T^2$	273–1173	2
Ca(OH) ₂	c	21.4	276–373	?
CaO·Al ₂ O ₃ ·2SiO ₂	c, anorthite	$63.13 + 0.01500T - 1537000/T^2$	273–1673	1
	gls	$67.41 + 0.01048T - 1874000/T^2$	273–973	1
CaO·MgO·2SiO ₂	c, diopside	$54.46 + 0.005746T - 1500000/T^2$	273–1573	1
	gls	$51.68 + 0.009724T - 1308000/T^2$	273–973	1
CaO·SiO ₂	c, wollastonite	$27.95 + 0.002056T - 745600/T^2$	273–1573	1
	c, pseudowollastonite	$25.48 + 0.004132T - 488100/T^2$	273–1673	1
	gls	$23.16 + 0.009672T - 487100/T^2$	273–973	1
CaP ₂ O ₆	c	39.5	287–371	?
CaSO ₄	c	$18.52 + 0.02197T - 156800/T^2$	273–1373	5
CaSO ₄ ·2H ₂ O	c	46.8	282–373	?
CaWO ₄	c	27.9	292–322	?
Carbon ⁵				
C	c, graphite	$2.673 + 0.002611T - 116900/T^2$	273–1373	2
	c, diamond	$2.162 + 0.003059T - 130300/T^2$	273–1313	3
CH ₄	g	$5.34 + 0.0115T$	273–1200	2
CO ⁶	g	$6.60 + 0.00120T$	273–2500	1½
CO ₂	g	$10.34 + 0.00274T - 195500/T^2$	273–1200	1½
CS ₂	l	18.4	293	?
Cerium				
Ce	c	$5.88 + 0.00123T$	273–908	?
CeO ₂	c	15.1	273–373	?
Ce ₂ (MoO ₄) ₃	c	96	273–297	?
Ce ₂ (SO ₄) ₃	c	66.4	273–373	?
Ce ₂ (SO ₄) ₃ ·5H ₂ O	c	131.6	273–319	?
Cesium				
Cs	c	$1.96 + 0.0182T$	273–301	3
	l	8.00	302	3
	g	4.97	All	0
CsBr	c	$12.6 + 0.00259T$	273–909	?
CsCl	c	$11.7 + 0.00309T$	273–752	?
CsF	c	$11.3 + 0.00285T$	273–957	?
CsI	c	$11.6 + 0.00268T$	273–894	?
Chlorine				
Cl ₂	g	$8.28 + 0.00056T$	273–2000	1½
Chromium ⁴				
Cr	c	$4.84 + 0.00295T$	273–1823	5
	l	9.70	1823–1923	10
CrCl ₃	c	23	286–319	?
Cr ₂ O ₃	c	$26.0 + 0.00400T$	273–2263	?
CrSb	c	$12.3 + 0.00120T$	273–1383	?
Cr ₂ Sb ₃	c	$19.2 + 0.00184T$	273–949	?
Cr ₂ (SO ₄) ₃	c	67.4	273–373	?
Cobalt ⁴				
Co	c	$5.12 + 0.00333T$	273–1763	5
	l	8.40	1763–1873	5
CoAs ₂ ·CoS ₂	c	32.9	283–373	?
CoSb	c	$11.7 + 0.00156T$	273–1464	?
Co ₂ Sn	c	$15.83 + 0.00950T$	273–903	2
CoS	c	$10.6 + 0.00251T$	273–1373	?
CoSO ₄ ·7H ₂ O	c	96	286–303	?

TABLE 2-194 Heat Capacities of the Elements and Inorganic Compounds (Continued)

Substance	State†	Heat capacity at constant pressure (T = K; 0°C = 273.1 K), cal/deg mol	Range of temperature, K	Uncertainty, %
Copper ⁷				
Cu	c	5.44 + 0.001462T	273–1357	1
	l	7.50	1357–1573	3
CuAl	c	9.88 + 0.00500T	273–733	2
CuAl ₂	c	16.78 + 0.00366T	273–773	2
Cu ₃ Al	c	19.61 + 0.01054T	273–775	2
CuI	c	12.1 + 0.00286T	273–675	?
Cu ₂	c	20.1	274–328	?
CuO	c	10.87 + 0.003576T – 150600/T ²	273–810	2
CuO·SiO ₂ ·H ₂ O	c	29	293–323	?
CuS	c	10.6 + 0.00264T	273–1273	?
Cu ₂ S	c, α	9.38 + 0.0312T	273–376	3
	c, β	20.9	376–1173	2
CuS·FeS	c	24	292–321	?
Cu ₂ Sb	c	13.73 + 0.01350T	273–573	2
Cu ₂ Sb	c	21.79 + 0.00900T	273–693	2
Cu ₂ Se	c, α	20.85	273–383	5
	c, β	20.35	383–488	5
Cu ₃ Si	c	20.3 + 0.00587T	273–1135	?
CuSO ₄	c	24.1	282	?
CuSO ₄ ·H ₂ O	c	31.3	282	?
CuSO ₄ ·3H ₂ O	c	49.0	282	?
CuSO ₄ ·5H ₂ O	c	67.2	282	?
Fluorine ⁸				
F ₂	g	6.50 + 0.00100T	300–3000	5
Gallium				
Ga ₂ O ₃	c	18.2 + 0.0252T	273–923	?
Ga ₂ (SO ₄) ₃	c	62.4	273–373	?
Germanium ⁴				
Ge	c			
Gold				
Au	c	5.61 + 0.00144T	273–1336	2
	l	7.00	1336–1573	5
AuSb ₂	c, α	17.12 + 0.00465T	273–628	1
	c, βγ	11.47 + 0.01756T	628–713	?
Helium ⁹				
He	g	4.97	All	0
Hydrogen ¹⁰				
H	g	4.97	All	0
H ₂	g	6.62 + 0.00081T	273–2500	2
HBr	g	6.80 + 0.00084T	273–2000	2
HCl	g	6.70 + 0.00084T	273–2000	1½
HI	g	6.93 + 0.00083T	273–2000	2
H ₂ O	l	See Tables 2-355 through 2-357		
		8.22 + 0.00015T + 0.00000134T ²	300–2500	?
H ₂ S	g	7.20 + 0.00360T	300–600	8
H ₂ S ₂ O ₇	c	27	281	?
	l	58	308	?
Indium				
In	c			
Iodine				
I ₂	g	9.00	300–2000	5
Iridium				
Ir	c	5.50 + 0.00148T	273–1873	1
Iron ⁴				
Fe	c, α	4.13 + 0.00638T	273–1041	3
	c, β	6.12 + 0.00336T	1041–1179	3
	c, γ	8.40	1179–1674	5
	c, δ	10.0	1674–1803	5
	l	8.15	1803–1873	5
FeAs ₂	c	17.8	283–373	?
Fe ₃ C	c	25.17 + 0.00223T	273–1173	10
FeCO ₃	c	22.7	293–368	?
FeO	c	12.62 + 0.001492T – 76200/T ²	273–1173	2
Fe ₂ O ₃	c	24.72 + 0.016047 – 423400/T ²	273–1097	2
Fe ₃ O ₄	c	41.17 + 0.01882T – 979500/T ²	273–1065	2
Fe ₃ O ₄ ·3H ₂ O	c	47.8	286–373	?
FeS	c, α	2.03 + 0.0390T	273–411	5
	c, β	12.05 + 0.00273T	411–1468	3
FeS ₂	c	10.7 + 0.01336T	273–773	?
FeSi	c	10.54 + 0.00458T	273–903	2
Fe ₂ SiO ₄	c	33.57 + 0.01907T – 879700/T ²	273–1161	2
FeSO ₄	c	22	293–373	?
Fe ₂ (SO ₄) ₃	c	66.2	273–373	?
FeSO ₄ ·4H ₂ O	c	63.6	282	?
FeSO ₄ ·7H ₂ O	c	96	291–319	?
Krypton				
Kr	g	4.97	All	0

TABLE 2-194 Heat Capacities of the Elements and Inorganic Compounds (Continued)

Substance	State†	Heat capacity at constant pressure ($T = \text{K}$; $0^\circ\text{C} = 273.1 \text{ K}$), cal/deg mol	Range of temperature, K	Uncertainty, %
Lanthanum				
La	c	$5.91 + 0.00100T$	273–1009	?
La ₂ O ₃	c	$22.6 + 0.00544T$	273–2273	?
La ₂ (MoO ₄) ₃	c	86	273–307	?
La ₂ (SO ₄) ₃	c	66.9	273–373	?
La ₂ (SO ₄) ₃ ·9H ₂ O	c	152	273–319	?
Lead ⁴				
Pb	c	$5.77 + 0.00202T$	273–600	2
	l	6.8	600–1273	5
Pb ₃ (AsO ₄) ₂	c	65.5	286–370	?
PbB ₂ O ₄	c	26.5	288–371	?
PbB ₄ O ₇	c	41.4	289–371	?
PbBr ₂	c	$18.13 + 0.00310T$	273–761	2
	l	27.4	761–860	10
PbCl ₂	c	$15.88 + 0.00835T$	273–771	2
	l	27.2	771–851	10
2PbCl ₂ ·NH ₄ Cl	c	53.1	293	?
PbCO ₃	c	21.1	286–320	?
PbCrO ₄	c	29.1	292–323	?
PbF ₂	c	$16.5 + 0.00412T$	273–1091	?
PbI ₂	c	$18.66 + 0.00293T$	273–648	2
	l	32.3	648–776	20
PbMoO ₄	c	30.4	292–322	?
Pb(NO ₃) ₂	c	36.4	286–320	?
PbO	c	$10.33 + 0.00318T$	273–544	2
PbO ₂	c	$12.7 + 0.00780T$	273–?	?
Pb ₂ P ₂ O ₇	c	48.3	284–371	?
PbS	c	$10.63 + 0.00401T$	273–873	3
PbSO ₄	c	26.4	293–372	?
PbS ₂ O ₃	c	29	293–373	?
PbWO ₄	c	35	273–297	?
Lithium				
Li	c	$0.68 + 0.0180T$	273–459	10
	g	4.97	All	0
LiBr	c	$11.5 + 0.00302T$	273–825	?
LiBr·H ₂ O	c	22.6	278–318	?
LiCl	c	$11.0 + 0.00339T$	273–887	?
LiCl·H ₂ O	c	23.6	279–360	?
LiF	c	$8.20 + 0.00520T$	273–1117	?
LiI	c	$12.5 + 0.00208T$	273–723	?
LiI·H ₂ O	c	23.6	277–359	?
LiI·2H ₂ O	c	32.9	277–345	?
LiI·3H ₂ O	c	43.2	277–347	?
LiNO ₃	c	$9.17 + 0.0360T$	273–523	5
	l	26.8	523–575	5
Magnesium ⁴				
Mg	c	$6.20 + 0.00133T - 67800/T^2$	273–923	1
	l	7.4	923–1048	10
MgAg	c	$10.58 + 0.00412T$	273–905	2
MgAl ₃	c	$34.4 + 0.0198T$	273–736	?
MgAu	c	$11.3 + 0.00189T$	273–1433	?
Mg ₂ Au	c	$16.2 + 0.00451T$	273–1073	?
Mg ₂ Au	c	$21.2 + 0.00614T$	273–1103	?
MgCl ₂	c	$17.3 + 0.00377T$	273–991	?
MgCl ₂ ·6H ₂ O	c	77.1	292–342	?
MgCO ₃	c	16.9	290	?
MgCu ₂	c	$14.96 + 0.00776T$	273–903	3
Mg ₂ Cu	c	$15.5 + 0.00652T$	273–843	?
MgNi ₂	c	$15.87 + 0.00692T$	273–903	2
MgO	c	$10.86 + 0.001197T - 208700/T^2$	273–2073	2
MgO·Al ₂ O ₃	c	28	288–319	?
MgO·SiO ₂	c, amphibole	$25.60 + 0.004380T - 674200/T^2$	273–1373	1
	c, pyroxene	$23.35 + 0.008062T - 558800/T^2$	273–773	1
	glas	$23.30 + 0.007734T - 542000/T^2$	273–973	1
6MgO·MgCl ₂ ·8B ₂ O ₃	c, α	58.7 + 0.408T	273–538	5
	c, β	$107.2 + 0.2876T$	538–623	5
Mg(OH) ₂	c	18.2	292–323	?
Mg ₃ Sb ₂	c	$28.2 + 0.00560T$	273–1234	?
Mg ₂ Si	c	$15.4 + 0.00415T$	273–1343	?
MgSO ₄	c	26.7	296–372	?
MgSO ₄ ·H ₂ O	c	33	282	?
MgSO ₄ ·6H ₂ O	c	80	282	?
MgSO ₄ ·7H ₂ O	c	89	291–319	?

TABLE 2-194 Heat Capacities of the Elements and Inorganic Compounds (Continued)

Substance	State†	Heat capacity at constant pressure ($T = \text{K}$, $0^\circ\text{C} = 273.1 \text{ K}$), cal/deg mol	Range of temperature, K	Uncertainty, %
Manganese				
Mn	c, α	$3.76 + 0.00747T$	273–1108	5
	c, β	$5.06 + 0.00395T$	1108–1317	5
	c, γ	$4.80 + 0.00422T$	1317–1493	5
	l	11.0	1493–1673	10
MnCl ₂	c	$16.2 + 0.00520T$	273–923	?
MnCO ₃	c	$7.79 + 0.0421T + 0.0000090T^2$	273–773	?
MnO	c	$7.43 + 0.01038T - 0.00000362T^2$	273–1923	?
Mn ₂ O ₃	c	$10.33 + 0.0530T - 0.00002577T^2$	273–1173	?
Mn ₃ O ₄	c	$19.25 + 0.0538T - 0.00002097T^2$	273–1773	?
MnO ₂	c	$1.92 + 0.0471T - 0.00002977T^2$	273–773	?
Mn ₂ O ₃ ·H ₂ O	c	31	291–322	?
MnS	c	$10.21 + 0.00656T - 0.00000242T^2$	273–1883	?
MnSO ₄	c	27.5	293–373	?
MnSO ₄ ·5H ₂ O	c	78	290–319	?
Mercury ¹¹				
Hg	l	6.61	273–630	1
	g	4.97	All	0
Hg ₂	g	9.00	300–2000	5
HgCl	c	$11.05 + 0.00370T$	273–798	?
HgCl ₂	c	$15.3 + 0.0103T$	273–553	?
Hg(CN) ₂	c	25	285–319	?
HgI	c	$11.4 + 0.00461T$	273–563	?
HgI ₂	c, α	$17.4 + 0.004001T$	273–403	3
	c, β	20.2	403–523	3
HgO	c	11.5	278–371	?
HgS	c	$10.9 + 0.00365T$	273–853	?
Hg ₂ SO ₄	c	31.0	273–307	?
Molybdenum				
Mo	c	$5.69 + 0.00188T - 50300/T^2$	273–1773	5
MoO ₃	c	$15.1 + 0.0121T$	273–1068	?
MoS ₂	c	$19.7 + 0.00315T$	273–729	?
Neon ¹²				
Ne	g	4.97	All	0
Nickel ¹⁴				
Ni	c, α	$4.26 + 0.00640T$	273–626	2
	c, β	$6.99 + 0.000905T$	626–1725	5
	l	8.55	1725–1903	10
NiO	c	$11.3 + 0.00215T$	273–1273	?
NiS	c	$9.25 + 0.00640T$	273–597	3
Ni ₂ Si	c	$15.8 + 0.00329T$	273–1582	?
NiSi	c	$10.0 + 0.00312T$	273–1273	?
Ni ₃ Sn	c	$20.78 + 0.0102T$	273–904	2
NiSO ₄	c	33.4	293–373	?
NiSO ₄ ·6H ₂ O	c	82	291–325	?
NiTe	c	$11.00 + 0.00433T$	273–700	2
Nitrogen ¹³				
N ₂	g	$6.50 + 0.00100T$	300–3000	3
NH ₃	g	$6.70 + 0.00630T$	300–800	1½
NH ₄ Br	c	22.8	274–328	?
NH ₄ Cl	c, α	$9.80 + 0.0368T$	273–457	5
	c, β	$5.0 + 0.0340T$	457–523	5
NH ₄ I	c	17.8	273–328	?
NH ₄ NO ₃	c	31.8	273–293	?
(NH ₄) ₂ SO ₄	c	51.6	275–328	?
NO	g	$8.05 + 0.000233T - 156300/T^2$	300–5000	2
Osmium				
Os	c	$5.686 + 0.000875T$	273–1877	1
Oxygen ¹⁴				
O ₂	g	$8.27 + 0.000258T - 187700/T^2$	300–5000	1
Palladium				
Pd	c	$5.41 + 0.00184T$	273–1822	2
Phosphorus				
P	c, yellow	5.50	273–317	5
	c, red	$0.21 + 0.0180T$	273–472	10
	l	6.6	317–373	10
PCl ₃	l	28.7	284–371	?
P ₄ O ₁₀	c	$15.72 + 0.1092T$	273–631	2
	g	73.6	631–1371	3
Platinum ⁴				
Pt	c	$5.92 + 0.00116T$	273–1873	1
Potassium				
K	c	$5.24 + 0.00555T$	273–336	5
	l	7.7	336–373	5

TABLE 2-194 Heat Capacities of the Elements and Inorganic Compounds (Continued)

Substance	State†	Heat capacity at constant pressure ($T = \text{K}$; $0^\circ\text{C} = 273.1 \text{ K}$), cal/deg mol	Range of temperature, K	Uncertainty, %
Potassium—(Cont.)				
K	g	4.97	All	0
K ₂	g	9.00	300–2000	5
KAsO ₃	c	25.3	290–372	?
KBO ₂	c	$12.6 + 0.0126T$	273–1220	?
K ₂ B ₄ O ₇	c	51.3	290–372	?
KBr	c	$11.49 + 0.00360T$	273–543	2
KCl	c	$10.93 + 0.00376T$	273–1043	2
KClO ₃	c	25.7	289–371	?
KClO ₄	c	26.3	287–318	?
2KCl·CuCl ₂ ·2H ₂ O	c	63	292–323	?
2KCl·PtCl ₄	c	55	286–319	?
2KCl·SnCl ₄	c	54.5	292–323	?
2KCl·ZnCl ₂	c	43.4	279–319	?
2KCN·Zn(CN) ₂	c	57.4	277–319	?
K ₂ CO ₃	c	29.9	296–372	?
K ₂ CrO ₄	c	35.9	289–371	?
K ₂ Cr ₂ O ₇	c	$42.80 + 0.0410T$	273–671	5
	l	96.9	671–757	5
KF	c	$10.8 + 0.00284T$	273–1129	?
K ₄ Fe(CN) ₆	c	80.1	273–319	?
K ₄ Fe(CN) ₆ ·3H ₂ O	c	114.5	273–310	?
KH ₂ AsO ₄	c	32	289–319	?
KH ₂ PO ₄	c	28.3	290–320	?
KHSO ₄	c	30	292–324	?
KMnO ₄	c	28	287–318	?
KNO ₃	c	$6.42 + 0.0530T$	273–401	10
	c	28.8	401–611	5
	l	29.5	611–683	10
K ₂ O·Al ₂ O ₃ ·3SiO ₂	c, orthoclase	$69.26 + 0.00821T - 2331000/T^2$	273–1373	1½
	gls, orthoclase	$69.81 + 0.01053 - 2403000/T^2$	273–1373	1½
	c, microcline	$65.65 + 0.01102T - 1748000/T^2$	273–1373	1½
	gls, microcline	$64.83 + 0.01438T - 1641000/T^2$	273–1373	1½
K ₄ P ₂ O ₇	c	63.1	290–371	?
K ₂ SO ₄	c	33.1	287–371	?
K ₂ S ₂ O ₃	c	37	293–373	?
K ₂ SO ₄ ·Al ₂ (SO ₄) ₃ ·24H ₂ O	c	352	292–322	?
K ₂ SO ₄ ·Cr ₂ (SO ₄) ₃ ·24H ₂ O	c	324	292–324	?
K ₂ SO ₄ ·MgSO ₄ ·6H ₂ O	c	106	292–323	?
K ₂ SO ₄ ·NiSO ₄ ·6H ₂ O	c	107	289–319	?
K ₂ SO ₄ ·ZnSO ₄ ·6H ₂ O	c	120	293–317	?
Promethium				
Pr	c			
Radon				
Rn	g	4.97	All	0
Rhenium				
Re	c	$6.30 + 0.00053T$	273–2273	?
Rhodium				
Rh	c	$5.40 + 0.00219T$	273–1877	2
Rubidium				
Rb	c	$3.27 + 0.0131T$	273–312	2
	l	7.85	312–373	5
RbBr	c	$11.6 + 0.00255T$	273–954	?
RbCl	c	$11.5 + 0.00249T$	273–987	?
Rb ₂ CO ₃	c	28.4	291–320	?
RbF	c	$11.3 + 0.00256T$	273–1048	?
RbI	c	$11.6 + 0.00263T$	273–913	?
Scandium				
Sc ₂ O ₃	c	21.1	273–373	?
Sc ₂ (SO ₄) ₃	c	62.0	273–373	?
Selenium				
Se	c	$4.53 + 0.00550T$	273–490	2
	l	8.35	490–570	3
Silicon				
Si	c	$5.74 + 0.000617T - 101000/T^2$	273–1174	2
SiC	c	$8.89 + 0.00291T - 284000/T^2$	273–1629	2
SiCl ₄	l	32.4	293–373	?
SiO ₂	c, quartz, α	$10.87 + 0.008712T - 241200/T^2$	273–848	1
	c, quartz, β	$10.95 + 0.00550T$	848–1873	3½
	c, cristobalite, α	$3.65 + 0.0240T$	273–523	2½
	c, cristobalite, β	$17.09 + 0.000454T - 897200/T^2$	523–1973	2
	gls	$12.80 + 0.00447T - 302000/T^2$	273–1973	3½
Silver ⁴				
Ag	c	$5.60 + 0.00150T$	273–1234	1
	l	8.2	1234–1573	3

TABLE 2-194 Heat Capacities of the Elements and Inorganic Compounds (Continued)

Substance	State†	Heat capacity at constant pressure ($T = \text{K}$; $0^\circ\text{C} = 273.1 \text{ K}$), cal/deg mol	Range of temperature, K	Uncertainty, %
Silver—(Cont.)				
Ag ₃ Al	c	$22.56 + 0.00570T$	273–902	2
Ag ₂ Al	c	$16.85 + 0.00450T$	273–903	2
AgAl ₁₂	c	$58.62 + 0.0575T$	273–768	5
AgBr	c	$8.58 + 0.0141T$	273–703	6
	l	14.9	703–836	5
AgCl	c	$9.60 + 0.00929T$	273–728	2
	l	14.05	728–806	5
AgCNO	c	18.7	273–353	?
AgI	c, α	$8.58 + 0.0141T$	273–423	6
AgNO ₃	c, α	$18.83 + 0.0160T$	273–433	2
	c, β	25.7	433–482	5
	l	30.2	482–541	5
Ag ₃ PO ₄	c	37.5	293–325	?
Ag ₂ S	c, α	18.8	273–448	5
	c, β	21.8	448–597	5
Ag ₃ Sb	c	$19.53 + 0.0160T$	273–694	5
Ag ₂ Se	c, α	20.2	273–406	5
	c, β	20.4	406–460	5
Sodium ¹⁵				
Na	c	$5.01 + 0.00536T$	273–371	1½
	l	7.50	371–451	2
	g	4.97	All	0
NaBO ₃	c	$10.4 + 0.0199T$	273–1239	?
Na ₂ B ₄ O ₇	c	47.9	289–371	?
Na ₂ B ₄ O ₇ ·10H ₂ O	c	147	292–323	?
NaBr	c	$11.74 + 0.00233T$	273–543	2
NaCl	c	$10.79 + 0.00420T$	273–1074	2
	l	15.9	1073–1205	3
NaClO ₃	c	$9.48 + 0.0468T$	273–528	3
	l	31.8	528–572	5
NaCNO	c	13.1	273–353	?
Na ₂ CO ₃	c	28.9	288–371	?
NaF	c	$10.4 + 0.00289T$	273–1261	?
Na ₂ HPO ₄ ·7H ₂ O	c	86.6	275–307	?
Na ₂ HPO ₄ ·12H ₂ O	c	133.4	275–307	?
NaI	c	$12.5 + 0.00162T$	273–936	?
NaNO ₃	c	$4.56 + 0.0580T$	273–583	5
	l	37.2	583–703	10
Na ₂ O·Al ₂ O ₃ ·3SiO ₂	c, albite	$63.78 + 0.01171T - 1678000/T^2$	273–1373	1
	gls	$61.25 + 0.01768T - 1545000/T^2$	273–1173	1
NaPO ₃	c	22.1	290–319	?
Na ₄ P ₄ O ₇	c	60.7	290–371	?
Na ₂ SO ₄	c	32.8	289–371	?
Na ₂ S ₂ O ₃	c	34.9	273–307	?
Na ₂ S ₂ O ₃ ·5H ₂ O	c	86.2	273–307	?
Sodium-potassium alloys ¹⁵	l			
Strontium				
SrBr ₂	c	$18.1 + 0.00311T$	273–923	?
SrBr ₂ ·H ₂ O	c	28.9	277–370	?
SrBr ₂ ·6H ₂ O	c	82.1	276–327	?
SrCl ₂	c	$18.2 + 0.00244T$	273–1143	?
SrCl ₂ ·H ₂ O	c	28.7	276–365	?
SrCl ₂ ·2H ₂ O	c	38.3	277–366	?
SrCO ₃	c	21.8	281–371	?
SrI ₂	c	$18.6 + 0.00304T$	273–783	?
SrI ₂ ·H ₂ O	c	28.5	276–363	?
SrI ₂ ·2H ₂ O	c	39.1	275–336	?
SrI ₂ ·6H ₂ O	c	84.9	275–333	?
SrMoO ₄	c	37	273–297	?
Sr(NO ₃) ₂	c	38.3	290–320	?
SrSO ₄	c	26.2	293–369	?
Sulfur ¹⁶				
S	c, rhombic	$3.63 + 0.00640T$	273–368	3
	c, monoclinic	$4.38 + 0.00440T$	368–392	3
S ₂	g	$8.58 + 0.00030T$	300–2500	5
S ₂ Cl ₂	l	27.5	273–332	?
SO ₂	g	$7.70 + 0.00530T - 0.00000083T^2$	300–2500	2½
Tantalum				
Ta	c	$5.91 + 0.00099T$	273–1173	2
Tellurium				
Te	c	$5.19 + 0.00250T$	273–600	3
Thallium				
Tl	c, α	$5.32 + 0.00385T$	273–500	1
	c, β	8.12	500–576	1

TABLE 2-194 Heat Capacities of the Elements and Inorganic Compounds (Concluded)

Substance	State†	Heat capacity at constant pressure ($T = \text{K}$; $0^\circ\text{C} = 273.1 \text{ K}$), cal/deg mol	Range of temperature, K	Uncertainty, %
Thallium—(Cont.)				
Tl	<i>l</i>	7.12	576–773	3
TlBr	<i>c</i>	$12.53 + 0.00100T$	273–733	10
	<i>l</i>	16.0	733–800	10
TlCl	<i>c</i>	$12.56 + 0.00088T$	273–700	5
	<i>l</i>	14.2	700–803	10
Thorium				
Th	<i>c</i>	6.40	273–373	?
ThO ₂	<i>c</i>	$14.6 + 0.00507T$	273–1273	?
Th(SO ₄) ₂	<i>c</i>	41.2	273–373	?
Tin ⁴				
Sn	<i>c</i>	$5.05 + 0.00480T$	273–504	2
	<i>l</i>	6.6	504–1273	10
SnAu	<i>c</i>	$11.79 + 0.00233T$	273–581	1
SnCl ₂	<i>c</i>	$16.2 + 0.00926T$	273–520	?
SnCl ₄	<i>l</i>	38.4	286–371	?
SnO	<i>c</i>	$9.40 + 0.00362T$	273–1273	?
SnO ₂	<i>c</i>	$13.94 + 0.00565T - 252000/T^2$	273–1373	?
SnPt	<i>c</i>	$11.49 + 0.00190T$	273–1318	1
SnS	<i>c</i>	$12.1 + 0.00165T$	273–1153	?
SnS ₂	<i>c</i>	$20.5 + 0.00400T$	273–873	?
Titanium				
Ti	<i>c</i>	$8.91 + 0.00114T - 433000/T^2$	273–713	3
TiCl ₄	<i>l</i>	35.7	285–372	?
TiO ₂	<i>c</i>	$11.81 + 0.00754T - 41900/T^2$	273–713	3
Tungsten				
W	<i>c</i>	5.65 + 0.00866	273–2073	1
WO ₃	<i>c</i>	$16.0 + 0.00774T$	273–1550	?
Uranium				
U	<i>c</i>	6.64	273–372	?
U ₃ O ₈	<i>c</i>	59.8	276–314	?
Vanadium				
V	<i>c</i>	$5.57 + 0.00097T$	273–1993	?
Xenon				
Xe	<i>g</i>	4.97	All	0
Zinc ⁴				
Zn	<i>c</i>	$5.25 + 0.00270T$	273–692	1
	<i>l</i>	$7.59 + 0.00055T$	692–1122	3
ZnCl ₂	<i>c</i>	15.9 + 0.00080T	273–638	?
ZnO	<i>c</i>	$11.40 + 0.00145T - 182400/T^2$	273–1573	1
ZnS	<i>c</i>	$12.81 + 0.00095T - 194600/T^2$	273–1173	5
ZnSb	<i>c</i>	$11.5 + 0.00313T$	273–810	?
ZnSO ₄	<i>c</i>	28	293–373	?
ZnSO ₄ ·H ₂ O	<i>c</i>	34.7	282	?
ZnSO ₄ ·6H ₂ O	<i>c</i>	80.8	282	?
ZnSO ₄ ·7H ₂ O	<i>c</i>	100.2	273–307	?
Zirconium				
ZrO ₂	<i>c</i>	$11.62 + 0.01046T - 177700/T^2$	273–1673	5
ZrO ₂ ·SiO ₂	<i>c</i>	26.7	297–372	?

¹ See also Table 2-195. Data to 298 K are also given by Scott, *Cryogenic Engineering*, Van Nostrand, Princeton, N.J., 1959.² For liquid and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.³ Stalder, NACA Tech. Note 4141, 1957 (Fig. 5), gives data from 400 to 2600°R.⁴ See also Table 2-195.⁵ For data from 400 to 5500°R see Stalder, NACA Tech. Note 4141, 1975 (Fig. 4).⁶ For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.⁷ For data from 400 to 2350°R see Stalder, NACA Tech. Note 4141, 1957.⁸ For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.⁹ For liquid and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.¹⁰ For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-60-56, 1960.¹¹ See also Table 2-195; Douglas, Ball, et al., *Bur. Stand. J. Res.*, **46** (1951): 334; Busey and Giaque, *J. Am. Chem. Soc.*, **75** (1953): 806; Sheldon, ASME Pap. 49-A-30, 1949.¹² For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-56-60, 1960.¹³ For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-56-60, 1960.¹⁴ For solid, liquid, and gas data, see Johnson (ed.), WADD-TR-56-60, 1960. Ozone: For liquid see Brabets and Waterman, *J. Chem. Phys.*, **28** (1958): 1212.¹⁵ For data on liquid Na-K alloys to 1500°F and for liquid Na to 1460°F, see Lubarsky and Kaufman, NACA Rep. 1270, 1956.¹⁶ See also Evans and Wagman, *Bur. Stand. J. Res.*, **49** (1952): 141; Gratch, OTS PB 124957, 1950; Guthrie, Scott, et al., *J. Am. Chem. Soc.*, **76** (1954): 1488.

TABLE 2-195 Specific Heat [kJ/(kg·K)] of Selected Elements

Symbol	Temperature, K														
	4	6	8	10	20	40	60	80	100	200	250	300	400	600	800
Al	0.00026	0.00050	0.00088	0.00140	0.0089	0.0775	0.214	0.357	0.481	0.797	0.859	0.902	0.949	1.042	1.134
Be	0.00008			0.00028	0.0014				0.195	1.109	1.537	1.840	2.191	2.605	2.823
Bi	0.00054	0.00220	0.00541	0.01040	0.0340	0.0729	0.092	0.102	0.109	0.120	0.121	0.122	0.123	0.142	0.136
Cr	0.00016	0.00029	0.00050	0.00081	0.0021	0.0107	0.059	0.127	0.190	0.382	0.424	0.450	0.501	0.565	0.611
Co	0.00036	0.00059	0.00085	0.00121	0.0048	0.0404	0.110	0.184	0.234	0.376	0.406	0.426	0.451	0.509	0.543
Cu	0.00011	0.00024	0.00048	0.00086	0.0076	0.059	0.137	0.203	0.254	0.357	0.377	0.386	0.396	0.431	0.448
Ge			0.00037	0.00081	0.0129	0.0619	0.108	0.153	0.192	0.286	0.305	0.323	0.343	0.364	0.377
Au	0.00018	0.00047	0.00126	0.00255	0.0163	0.0569	0.084	0.100	0.109	0.124	0.127	0.129	0.131	0.136	0.141
Ir				0.00032	0.0021				0.090	0.122	0.128	0.131	0.133	0.140	0.146
Fe	0.00038	0.00061	0.00090	0.00127	0.0039	0.0276	0.086	0.154	0.216	0.384	0.422	0.450	0.491	0.555	0.692
Pb	0.00075	0.00242	0.00747	0.01350	0.0531	0.0944	0.108	0.114	0.118	0.125	0.127	1.129	0.132	0.142	
Mg	0.00034	0.00080	0.00155	0.00172	0.0148	0.138	0.336	0.513	0.648	0.929	0.985	1.005	1.082	1.177	1.263
Hg	0.00417	0.01420	0.01820	0.02250	0.0515	0.0895	0.107	0.116	0.121	0.136	0.141	0.139	0.136	0.135	0.104
Mo	0.00011	0.00019	0.00032	0.00050	0.0029	0.0236	0.061	0.105	0.140	0.223	0.241	0.248	0.261	0.280	0.292
Ni	0.00054	0.00086	0.00121	0.00178	0.0058	0.0380	0.103	0.173	0.232	0.383	0.416	0.444	0.490	0.590	0.530
Pt	0.00019	0.00028	0.00067	0.00112	0.0077	0.0382	0.069	0.088	0.101	0.127	0.132	0.134	0.136	0.140	0.146
Ag	0.00016	0.00035	0.00093	0.00186	0.0159	0.0778	0.133	0.166	0.187	0.225	0.232	0.236	0.240	0.251	0.264
Sn	0.00024	0.00127	0.00423	0.00776	0.0400	0.108	0.149	0.173	0.189	0.214	0.220	0.222	0.245	0.257	0.257
Zn	0.00011	0.00029	0.00096	0.00250	0.0269	0.123	0.205	0.258	0.295	0.366	0.380	0.389	0.404	0.435	0.479

TABLE 2-196 Heat Capacities of Inorganic and Organic Liquids

Cmpd. no.	Name	Formula	CAS no.	Mol wt	C1	C2	C3	C4	C5	T _{min} , K	C _p at T _{min} × 1E-05	T _{max} , K	C _p at T _{max} × 1E-05
1	Methane (eqn. 2)	CH ₄	74828	16.043	6.5708E+01	3.8883E+04	-2.5795E+02	6.1407E+02	0	90.69	0.5361	190	14.9780
2	Ethane (eqn. 2)	C ₂ H ₆	74840	30.070	4.4009E+01	8.9718E+04	9.1877E+02	-1.8860E+03	0	92	0.6855	290	1.2444
3	Propane (eqn. 2)	C ₃ H ₈	74986	44.097	6.2983E+01	1.1363E+05	6.3321E+02	-8.7346E+02	0	85.47	0.8488	360	2.6079
4	n-Butane (eqn. 2)	C ₄ H ₁₀	106978	58.123	6.4730E+01	1.6184E+05	9.8341E+02	-1.4315E+03	0	134.86	1.1380	420	5.0822
5	n-Pentane	C ₅ H ₁₂	109660	72.150	1.5908E+05	-2.7050E+02	9.9537E-01	0	0	143.42	1.4076	390	2.0498
6	n-Hexane	C ₆ H ₁₄	110543	86.177	1.7212E+05	-1.8378E+02	8.8734E-01	0	0	177.83	1.6750	460	2.7534
7	n-Heptane (eqn. 2)	C ₇ H ₁₆	142825	100.204	6.1260E+01	3.1441E+05	1.8246E+03	-2.5479E+03	0	182.57	1.9989	520	4.0657
8	n-Octane	C ₈ H ₁₈	111659	114.231	2.2483E+05	-1.8663E+02	9.5891E-01	0	0	216.38	2.2934	460	3.4189
9	n-Nonane	C ₉ H ₂₀	111842	128.258	3.8308E+05	-1.1398E+03	2.7101E+00	0	0	219.66	2.6348	325	2.9890
10	n-Decane	C ₁₀ H ₂₂	124185	142.285	2.7862E+05	-1.9791E+02	1.0737E+00	0	0	243.51	2.9409	460	4.1478
11	n-Undecane	C ₁₁ H ₂₄	1120214	156.312	2.9398E+05	-1.1498E+02	9.6936E-01	0	0	247.57	3.2493	433.42	4.2624
12	n-Dodecane	C ₁₂ H ₂₆	112403	170.338	5.0821E+05	-1.3687E+03	3.1015E+00	0	0	263.57	3.6292	330	3.9429
13	n-Tridecane	C ₁₃ H ₂₈	629505	184.365	3.5018E+05	-1.0470E+02	1.0022E+00	0	0	267.76	3.9400	508.62	5.5619
14	n-Tetradecane	C ₁₄ H ₃₀	629594	198.392	3.5314E+05	2.91130E+01	8.6116E-01	0	0	279.01	4.2831	526.73	6.0741
15	n-Pentadecane	C ₁₅ H ₃₂	629629	212.419	3.4691E+05	2.1954E+02	6.5632E-01	0	0	283.07	4.6165	543.84	6.6042
16	n-Hexadecane	C ₁₆ H ₃₄	544763	226.446	3.7035E+05	2.3147E+02	6.8632E-01	0	0	291.31	4.9602	560.01	7.1521
17	n-Heptadecane	C ₁₇ H ₃₆	629787	240.473	3.7697E+05	3.4782E+02	5.7895E-01	0	0	295.13	5.3005	575.3	7.6569
18	n-Octadecane	C ₁₈ H ₃₈	593453	254.500	3.9943E+05	3.7464E+02	5.8156E-01	0	0	301.31	5.6511	589.86	8.2276
19	n-Nonadecane	C ₁₉ H ₄₀	629925	268.527	3.4257E+05	7.6208E+02	2.0481E-01	0	0	305.04	5.9409	603.05	8.7663
20	n-Eicosane	C ₂₀ H ₄₂	112958	282.553	3.5272E+05	8.0732E+02	2.1220E-01	0	0	309.58	6.2299	616.93	9.3154
21	2-Methylpropane	C ₄ H ₁₀	75285	58.123	1.7237E+05	-1.7839E+03	1.4759E+01	-4.7909E-02	5.8050E-05	113.54	0.9961	380	2.0725
22	2-Methylbutane	C ₅ H ₁₂	78784	72.150	1.0830E+05	1.4600E+02	-2.9200E-01	1.5100E-03	0	113.25	1.2328	310	1.7048
23	2,3-Dimethylbutane	C ₆ H ₁₄	79298	86.177	1.2945E+05	1.8500E+01	6.0800E-01	0	0	145.19	1.4495	331.13	2.0224
24	2-Methylpentane	C ₆ H ₁₄	107835	86.177	1.4222E+05	-4.7830E+01	7.3900E-01	0	0	119.55	1.4706	333.41	2.0842
25	2,3-Dimethylpentane ¹	C ₇ H ₁₆	565593	100.204	1.4642E+05	5.9200E+01	6.0400E-01	0	0	90	1.5664	380	2.5613
26	2,3,3-Trimethylpentane	C ₈ H ₁₈	560214	114.231	3.8862E+05	-1.4395E+03	3.2187E+00	0	0	280	2.3791	320	2.5757
27	2,2,4-Trimethylpentane	C ₈ H ₁₈	540841	114.231	9.5275E+04	6.9670E+02	-1.3765E+00	2.1734E-03	0	165.78	1.8285	520	3.9095
28	Ethylene	C ₂ H ₄	74851	28.054	2.4739E+05	-4.4280E+03	4.0936E+01	-1.6970E-01	2.6816E-04	103.97	0.7013	252.7	0.9758
29	Propylene	C ₃ H ₆	115071	42.081	1.1720E+05	-3.8632E+02	1.2348E+00	0	0	87.89	0.9279	298.15	1.1178
30	1-Butene	C ₄ H ₈	106989	56.108	1.3589E+05	-4.7739E+02	2.1835E+00	-2.2230E-03	0	87.8	1.0930	300	1.2917
31	cis-2-Butene	C ₄ H ₈	590181	56.108	1.2668E+05	-6.5470E+01	-6.4000E-01	2.9120E-03	0	134.26	1.1340	350	1.5022
32	trans-2-Butene	C ₄ H ₈	624646	56.108	1.1276E+05	-1.0470E+02	5.2140E-01	0	0	167.62	1.0986	274.03	1.2322
33	1-Pentene	C ₅ H ₁₀	109671	70.134	1.5467E+05	-4.2600E+02	1.9640E+00	-1.8038E-03	0	107.93	1.2930	310	1.5761
34	1-Hexene	C ₆ H ₁₂	592416	84.161	1.9263E+05	-5.7116E+02	2.4004E+00	-1.9758E-03	0	133.39	1.5446	336.63	1.9700
35	1-Heptene	C ₇ H ₁₄	592767	98.188	1.8997E+05	-1.5670E+02	3.4300E-01	1.5222E-03	0	154.27	1.7955	330	2.3032
36	1-Octene	C ₈ H ₁₆	111660	112.215	3.7930E+05	-2.1175E+03	8.2362E+00	-9.0093E-03	0	171.45	2.1295	315	2.4793
37	1-Nonene	C ₉ H ₁₈	124118	126.242	2.5875E+05	-3.5450E+02	1.3126E+00	0	0	191.78	2.3904	420.02	3.4142
38	1-Decene	C ₁₀ H ₂₀	872059	140.269	3.1950E+05	-5.7621E+02	1.7087E+00	0	0	206.89	2.7343	443.75	4.0027
39	2-Methylpropene	C ₄ H ₆	115117	56.108	8.7680E+04	2.1710E+02	-9.1530E-01	2.2660E-03	0	132.81	1.0568	343.15	1.4596
40	2-Methyl-1-butene ²	C ₅ H ₁₀	563462	70.134	1.4951E+05	-2.4763E+02	9.1849E-01	0	0	135.58	1.3282	304.31	1.5921
41	2-Methyl-2-butene ²	C ₅ H ₁₀	513359	70.134	1.5160E+05	-2.6672E+02	9.0847E-01	0	0	139.39	1.3207	311.71	1.5673
42	1,2-Butadiene	C ₄ H ₆	590192	54.092	1.3515E+05	-3.1114E+02	9.7007E-01	-1.5230E-04	0	136.95	1.1034	290	1.2279
43	1,3-Butadiene	C ₄ H ₆	106990	54.092	1.2886E+05	-3.2310E+02	1.0150E+00	3.2000E-05	0	165	1.0333	350	1.4148
44	2-Methyl-1,3-butadiene	C ₅ H ₈	78795	68.119	1.4148E+05	-2.8870E+02	1.0910E+00	0	0	130.32	1.2239	307.2	1.5575
45	Acetylene	C ₂ H ₂	74862	26.038	2.0011E+05	-1.1988E+03	3.0027E+00	0	0	192.4	0.8061	250	0.8808
46	Methylacetylene	C ₃ H ₄	74997	40.065	7.9791E+04	8.9490E+01	0	0	0	200	0.9769	249.94	1.0216
47	Dimethylacetylene	C ₄ H ₆	503173	54.092	8.8153E+04	1.2416E+02	0	0	0	240.91	1.1806	300.13	1.2542
48	3-Methyl-1-butyne	C ₅ H ₈	598232	68.119	1.0520E+05	1.9110E+02	0	0	0	200	1.4342	299.49	1.6243
49	1-Pentyne	C ₅ H ₈	627190	68.119	8.6200E+04	2.5660E+02	0	0	0	200	1.3752	313.33	1.6660
50	2-Pentyne	C ₅ H ₈	627214	68.119	6.8671E+04	2.4666E+02	0	0	0	200	1.1800	329.27	1.4989

51	1-Hexyne	C ₆ H ₁₀	693027	82.145	9.3000E+04	3.2600E+02	0	0	0	200	1.5820	344.48	2.0530
52	2-Hexyne	C ₆ H ₁₀	764352	82.145	9.4860E+04	2.5415E+02	0	0	0	300	1.7110	357.67	1.8576
53	3-Hexyne	C ₆ H ₁₀	928494	82.145	8.2795E+04	2.8340E+02	0	0	0	300	1.6781	354.35	1.8322
54	1-Heptyne	C ₇ H ₁₂	628717	96.172	8.5122E+04	4.0247E+02	0	0	0	192.22	1.6248	372.93	2.3522
55	1-Octyne	C ₈ H ₁₄	629050	110.199	9.1748E+04	4.7140E+02	0	0	0	193.55	1.8299	399.35	2.8000
56	Vinylacetylene ³	C ₄ H ₄	689974	52.076	6.8720E+04	1.3500E+02	0	0	0	200	0.9572	278.25	1.0628
57	Cyclopentane	C ₅ H ₁₀	287923	70.134	1.2253E+05	-4.0380E+02	1.7344E+00	-1.0975E-03	0	179.28	0.9956	322.4	1.3584
58	Methylcyclopentane	C ₆ H ₁₂	96377	84.161	1.5592E+05	-4.9000E+02	2.1383E+00	-1.5585E-03	0	130.73	1.2492	366.48	1.8682
59	Ethylcyclopentane	C ₇ H ₁₄	1640897	98.188	1.7852E+05	-5.1835E+02	2.3255E+00	-1.6818E-03	0	134.71	1.4678	301.82	1.8767
60	Cyclohexane	C ₆ H ₁₂	110827	84.161	-2.2060E+05	3.1183E+03	-9.4216E+00	1.0687E-02	0	279.69	1.4836	400	2.0323
61	Methylcyclohexane	C ₇ H ₁₄	108872	98.188	1.3134E+05	-6.3100E+01	8.1250E-01	0	0	146.58	1.3955	320	1.9435
62	1,1-Dimethylcyclohexane	C ₈ H ₁₆	590669	112.215	1.3450E+05	8.7650E+00	8.1151E-01	0	0	239.66	1.8321	392.7	2.6309
63	Ethylcyclohexane	C ₈ H ₁₆	1678917	112.215	1.3236E+05	7.2740E+01	6.4738E-01	0	0	161.84	1.6109	404.95	2.6798
64	Cyclopentene	C ₅ H ₈	142290	68.119	1.2538E+05	-3.4970E+02	1.1430E+00	0	0	138.13	0.9888	317.38	1.2953
65	1-Methylcyclopentene	C ₆ H ₁₀	693890	82.145	5.3271E+04	3.2792E+02	0	0	0	200	1.1885	348.64	1.6760
66	Cyclohexene	C ₆ H ₁₀	110838	82.145	1.0585E+05	-6.0000E+01	6.8000E-01	0	0	169.67	1.1525	356.12	1.7072
67	Benzene	C ₆ H ₆	71432	78.114	1.2944E+05	-1.6950E+02	6.4781E-01	0	0	278.68	1.3251	353.24	1.5040
68	Toluene	C ₇ H ₈	108883	92.141	1.4014E+05	-1.5230E+02	6.9500E-01	0	0	178.18	1.3507	500	2.3774
69	<i>o</i> -Xylene	C ₈ H ₁₀	95476	106.167	3.6500E+04	1.0175E+03	-2.6300E+00	3.0200E-03	0	248	1.7315	415	2.2166
70	<i>m</i> -Xylene	C ₈ H ₁₀	108383	106.167	1.7555E+05	-2.9950E+02	1.0880E+00	0	0	225.3	1.6330	360	2.0873
71	<i>p</i> -Xylene	C ₈ H ₁₀	106423	106.167	-3.5500E+04	1.2872E+03	-2.5990E+00	2.4260E-03	0	286.41	1.7697	600	3.2520
72	Ethylbenzene	C ₈ H ₁₀	100414	106.167	1.3316E+05	4.4507E+01	3.9645E-01	0	0	178.15	1.5367	409.35	2.1781
73	Propylbenzene	C ₉ H ₁₂	103651	120.194	2.3477E+05	-8.0022E+02	3.4037	-3.1739E-03	0	173.59	1.8182	370	2.4389
74	1,2,4-Trimethylbenzene	C ₉ H ₁₂	95636	120.194	1.7880E+05	-1.2847E+02	8.3741E-01	0	0	229.33	1.9338	350	2.3642
75	Isopropylbenzene	C ₉ H ₁₂	98828	120.194	1.8290E+05	-1.7400E+02	9.1200E-01	0	0	177.14	1.8069	500	3.2390
76	1,3,5-Trimethylbenzene	C ₉ H ₁₂	108678	120.194	1.4805E+05	1.9700E+01	6.2260E-01	0	0	228.42	1.8503	350	2.3121
77	<i>p</i> -Isopropyltoluene	C ₁₀ H ₁₄	99876	134.221	1.4560E+05	2.4870E+02	1.8700E-01	0	0	205.25	2.0452	450.28	2.9550
78	Naphthalene	C ₁₀ H ₈	91203	128.174	2.9800E+04	5.2750E+02	0	0	0	353.43	2.1623	491.14	2.8888
79	Biphenyl	C ₁₂ H ₁₀	92524	154.211	1.2177E+05	4.2930E+02	0	0	0	342.2	2.6868	533.37	3.5075
80	Styrene	C ₈ H ₈	100425	104.152	1.1334E+05	2.9020E+02	-6.0510E-01	1.3567E-03	0	242.54	1.6749	418.31	2.2816
81	<i>m</i> -Terphenyl	C ₁₈ H ₁₄	92068	230.309	1.9567E+05	5.9407E+02	0	0	0	360	4.0954	650	5.8182
82	Methanol	CH ₄ O	67561	32.042	1.0580E+05	-3.6223E+02	9.3790E-01	0	0	175.47	0.7112	400	1.1097
83	Ethanol	C ₂ H ₆ O	64175	46.069	1.0264E+05	-1.3963E+02	-3.0341E-02	2.0386E-03	0	159.05	0.8787	390	1.6450
84	1-Propanol	C ₃ H ₈ O	71238	60.096	1.5876E+05	-6.3500E+02	1.9690E+00	0	0	146.95	1.0797	400	2.1980
85	1-Butanol	C ₄ H ₁₀ O	71363	74.123	1.9120E+05	-7.3040E+02	2.2998E+00	0	0	184.51	1.3473	390.81	2.5701
86	2-Butanol	C ₄ H ₁₀ O	78922	74.123	2.0670E+05	-1.0204E+03	3.2900E+00	0	0	158.45	1.2762	372.7	2.8340
87	2-Propanol	C ₃ H ₆ O	67630	60.096	7.2355E+05	-8.0950E+03	3.6662E+01	-6.6395E-02	4.4064E-05	185.28	1.1189	480	2.8122
88	2-Methyl-2-propanol	C ₄ H ₁₀ O	75650	74.123	-9.2546E+05	7.8949E+03	-1.7661E+01	1.3617E-02	0	298.96	2.2016	460	2.9455
89	1-Pentanol	C ₅ H ₁₂ O	71410	88.150	2.0120E+05	-6.5130E+02	2.2750E+00	0	0	200.14	1.6198	389.15	2.9227
90	2-Methyl-1-butanol	C ₅ H ₁₂ O	137326	88.150	8.2937E+04	4.5998E+02	0.0000E+00	0	0	250	1.9793	401.85	2.6778
91	3-Methyl-1-butanol	C ₅ H ₁₂ O	123513	88.150	-5.3777E+04	8.8342E+02	0	0	0	295.52	2.0729	350	2.5542
92	1-Hexanol	C ₆ H ₁₄ O	111273	102.177	4.8466E+05	-2.7613E+03	6.5555E+00	0	0	228.55	1.9599	320	2.7233
93	1-Heptanol	C ₇ H ₁₆ O	111706	116.203	4.3790E+05	-2.0947E+03	5.2090E+00	0	0	239.15	2.3487	370	3.7597
94	Cyclohexanol	C ₆ H ₁₂ O	108930	100.161	-4.0000E+04	8.5300E+02	0	0	0	296.6	2.1300	434	3.3020
95	Ethylene glycol	C ₂ H ₆ O ₂	107211	62.068	3.5540E+04	4.3678E+02	-1.8486E-01	0	0	260.15	1.3666	493.15	2.0598
96	1,2-Propylene glycol	C ₃ H ₆ O ₂	57556	76.095	5.8080E+04	4.4520E+02	0	0	0	213.15	1.5297	460.75	2.6321
97	Phenol	C ₆ H ₅ O	108952	94.113	1.0172E+05	3.1761E+02	0	0	0	314.06	2.0147	425	2.3670
98	<i>o</i> -Cresol	C ₇ H ₈ O	95487	108.140	-1.8515E+05	3.1480E+03	-8.0367E+00	7.2540E-03	0	304.2	2.3297	400	2.5243
99	<i>m</i> -Cresol	C ₇ H ₈ O	108394	108.140	-2.4670E+05	3.2568E+03	-7.4202E+00	6.0467E-03	0	285.39	2.1895	400	2.5578
100	<i>p</i> -Cresol	C ₇ H ₈ O	106445	108.140	2.5998E+05	-1.1123E+03	4.9427E+00	-5.4367E-03	0	307.93	2.2740	400	2.5794

TABLE 2-196 Heat Capacities of Inorganic and Organic Liquids (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol wt	C1	C2	C3	C4	C5	T _{min} , K	C _p at T _{min} × 1E-05	T _{max} , K	C _p at T _{max} × 1E-05
101	Dimethyl ether	C ₂ H ₆ O	115106	46.069	1.1010E+05	-1.5747E+02	5.1853E-01	0	0	131.65	0.9836	250	1.0314
102	Methyl ethyl ether	C ₃ H ₈ O	540670	60.096	1.2977E+05	-3.3196E+02	1.3869E+00	0	0	218.9	1.2356	328.35	1.7030
103	Methyl- <i>n</i> -propyl ether	C ₄ H ₁₀ O	557175	74.123	1.4411E+05	-1.0209E+02	5.8113E-01	0	0	133.97	1.4086	312.2	1.6888
104	Methyl isopropyl ether	C ₄ H ₁₀ O	598538	74.123	1.4344E+05	-1.5407E+02	7.2550E-01	0	0	127.93	1.3560	310	1.6540
105	Methyl- <i>n</i> -butyl ether	C ₅ H ₁₂ O	628284	88.150	1.7785E+05	-1.7157E+02	7.4379E-01	0	0	157.48	1.6928	343.35	2.0663
106	Methyl isobutyl ether	C ₅ H ₁₂ O	625445	88.150	5.1380E+04	4.5040E+02	0	0	0	300	1.8650	370	2.1803
107	Methyl tert-butyl ether	C ₅ H ₁₂ O	1634044	88.150	1.4012E+05	-9.0000E+00	5.6300E-01	0	0	164.55	1.5388	328.35	1.9786
108	Diethyl ether	C ₄ H ₁₀ O	60297	74.123	4.4400E+04	1.3010E+03	-5.5000E+00	8.7630E-03	0	156.92	1.4698	460	3.3202
109	Ethyl propyl ether	C ₅ H ₁₂ O	628320	88.150	1.0368E+05	7.2630E+02	-2.6047E+00	4.0957E-03	0	145.65	1.6686	320	2.0358
110	Ethyl isopropyl ether	C ₅ H ₁₂ O	625547	88.150	1.0625E+05	2.9215E+02	0	0	0	298.15	1.9335	326.15	2.0153
111	Methyl phenyl ether	C ₇ H ₈ O	100663	108.140	1.5094E+05	9.3455E+01	2.3602E-01	0	0	298.15	1.9978	484.2	2.5153
112	Diphenyl ether	C ₁₂ H ₁₀ O	101848	170.211	1.3416E+05	4.4767E+02	0	0	0	300.03	2.6847	570	3.8933
113	Formaldehyde ⁴	CH ₂ O	50000	30.026	6.1900E+04	2.8300E+01	0	0	0	204	0.6767	234	0.6852
114	Acetaldehyde	C ₂ H ₄ O	75070	44.053	1.1510E+05	-4.3300E+02	1.4250E+00	0	0	150.15	0.8221	294	1.1097
115	1-Propanal	C ₃ H ₆ O	123386	58.080	9.9306E+04	1.1573E+02	0	0	0	200	1.2245	328.75	1.3735
116	1-Butanal	C ₄ H ₈ O	123728	72.107	6.5682E+04	1.3291E+03	-7.1579E+00	1.2755E-02	0	176.75	1.4741	300	1.6459
117	1-Pentanal	C ₅ H ₁₀ O	110623	86.134	1.1205E+05	2.5778E+02	0	0	0	200	1.6361	376.15	2.0901
118	1-Hexanal	C ₆ H ₁₂ O	66251	100.161	1.1770E+05	3.2952E+02	0	0	0	217.15	1.8926	401.45	2.4999
119	1-Heptanal	C ₇ H ₁₄ O	111717	114.188	2.2236E+05	-1.0517E+02	6.5074E-01	0	0	229.8	2.3256	381.25	2.7685
120	1-Octanal	C ₈ H ₁₆ O	124130	128.214	3.0656E+05	4.6361E+02	0	0	0	246	2.4470	447.15	3.3795
121	1-Nonanal	C ₉ H ₁₈ O	124196	142.241	1.3682E+05	5.3129E+02	0	0	0	255.15	2.7238	468.15	3.8554
122	1-Decanal	C ₁₀ H ₂₀ O	112312	156.268	1.5046E+05	5.8663E+02	0	0	0	267.15	3.0718	488.15	4.3682
123	Acetone	C ₃ H ₆ O	67641	58.080	1.3560E+05	-1.7700E+02	2.8370E-01	6.8900E-04	0	178.45	1.1696	329.44	1.3271
124	Methyl ethyl ketone	C ₄ H ₈ O	78933	72.107	1.3230E+05	2.0087E+02	-9.5970E-01	1.9533E-03	0	186.48	1.4905	373.15	1.7511
125	2-Pentanone	C ₅ H ₁₀ O	107579	86.134	1.9459E+05	-2.6336E+02	7.6808E-01	0	0	196.29	1.7239	375.46	2.0380
126	Methyl isopropyl ketone	C ₅ H ₁₀ O	563804	86.134	1.8361E+05	-2.6885E+02	8.6808E-01	0	0	181.15	1.6316	367.55	2.0108
127	2-Hexanone	C ₆ H ₁₂ O	591786	100.161	2.7249E+05	-7.9070E+02	2.5834E+00	-2.0040E-03	0	220.87	2.0228	382.62	2.3590
128	Methyl isobutyl ketone	C ₆ H ₁₂ O	108101	100.161	1.2492E+05	3.0410E+02	0	0	0	298.15	2.1559	390	2.4352
129	3-Methyl-2-pentanone	C ₆ H ₁₂ O	565617	100.161	9.9815E+04	3.4672E+02	0	0	0	298.15	2.0319	390.55	2.3523
130	3-Pentanone	C ₅ H ₁₀ O	96220	86.134	1.9302E+05	-1.7643E+02	5.6690E-01	0	0	234.18	1.8279	375.14	2.0661
131	Ethyl isopropyl ketone	C ₆ H ₁₂ O	565695	100.161	8.3630E+04	3.9900E+02	0	0	0	298.15	2.0259	425	2.5320
132	Diisopropyl ketone	C ₇ H ₁₄ O	565800	114.188	1.7927E+05	2.8370E+01	5.3750E-01	0	0	204.81	2.0763	410	2.8126
133	Cyclohexanone	C ₆ H ₁₀ O	108941	98.145	1.0980E+05	2.6150E+02	0	0	0	290	1.8563	486.5	2.3702
134	Methyl phenyl ketone	C ₈ H ₈ O	98862	120.151	7.2692E+04	3.3783E+02	3.5572E-01	0	0	298.2	2.0506	532.12	3.5318
135	Formic acid	CH ₂ O ₂	64186	46.026	7.8060E+04	7.1540E+01	0	0	0	281.45	0.9820	380	1.0525
136	Acetic acid	C ₂ H ₄ O ₂	64197	60.053	1.3964E+05	-3.2080E+02	8.9850E-01	0	0	289.81	1.2213	391.05	1.5159
137	Propionic acid	C ₃ H ₆ O ₂	79094	74.079	2.1366E+05	-7.0270E+02	1.6605E+00	0	0	252.45	1.4209	414.32	2.0756
138	<i>n</i> -Butyric acid	C ₄ H ₈ O ₂	107926	88.106	2.3770E+05	-7.4640E+02	1.8290E+00	0	0	267.95	1.6902	436.42	2.6031
139	Isobutyric acid	C ₄ H ₈ O ₂	79312	88.106	1.2754E+05	-6.5350E+01	8.2867E-01	0	0	270	1.7031	427.65	2.5114
140	Benzoic acid	C ₇ H ₆ O ₂	65850	122.123	-5.4800E+03	6.4712E+02	0	0	0	395.45	2.5042	450	2.8572
141	Acetic anhydride	C ₄ H ₆ O ₃	108247	102.090	3.6600E+04	5.1100E+02	0	0	0	250	1.6435	350	2.1545
142	Methyl formate	C ₂ H ₄ O ₃	107313	60.053	1.3020E+05	-3.9600E+02	1.2100E+00	0	0	174.15	304.9	1.2195	
143	Methyl acetate	C ₃ H ₆ O ₂	79209	74.079	6.1260E+04	2.7090E+02	0	0	0	253.4	1.2991	373.4	1.6241
144	Methyl propionate	C ₄ H ₈ O ₃	554121	88.106	7.1140E+04	3.3550E+02	0	0	0	300	1.7179	390	2.0198
145	Methyl- <i>n</i> -butyrate	C ₅ H ₁₀ O ₂	623427	102.133	1.0293E+05	1.2910E+02	6.2516E-01	0	0	277.25	1.8678	415.87	2.6474
146	Ethyl formate	C ₃ H ₆ O ₂	109944	74.079	8.0000E+04	2.2360E+02	0	0	0	254.2	1.3684	374.2	1.6367
147	Ethyl acetate	C ₄ H ₈ O ₂	141786	88.106	2.2623E+05	-6.2480E+02	1.4720E+00	0	0	189.6	1.6068	350.21	1.8796
148	Ethyl propionate	C ₅ H ₁₀ O ₂	105373	102.133	7.6330E+04	4.0010E+02	0	0	0	298.15	1.9562	410	2.4037

149	Ethyl- <i>n</i> -butyrate	C ₆ H ₁₂ O ₂	105544	116.160	8.2434E+04	4.2245E+02	2.0992E-01	0	0	285.5	2.2015	428.25	3.0185
150	<i>n</i> -Propyl formate	C ₄ H ₈ O ₂	110747	88.106	7.5700E+04	3.2610E+02	0	0	298.15	1.7293	398.15	2.0554	
151	<i>n</i> -Propyl acetate	C ₅ H ₁₀ O ₂	109604	102.133	8.3400E+04	3.8410E+02	0	0	274.7	1.8891	404.7	2.3885	
152	<i>n</i> -Butyl acetate	C ₆ H ₁₂ O ₂	123864	116.160	1.1730E+05	3.5220E+02	0	0	289.58	2.1929	429.58	2.6860	
153	Methyl benzoate	C ₈ H ₈ O ₂	93583	136.150	1.1950E+05	2.9400E+02	0	0	260.75	1.9616	472.65	2.5846	
154	Ethyl benzoate	C ₉ H ₁₀ O ₂	93890	150.177	1.2450E+05	3.7060E+02	0	0	238.45	2.1287	486.55	3.0482	
155	Vinyl acetate	C ₄ H ₆ O ₂	108054	86.090	1.3630E+05	-1.0617E+02	7.5175E-01	0	0	259.56	1.5939	389.35	2.0892
156	Methylamine	CH ₅ N	74895	31.057	9.2520E+04	3.7450E+01	0	0	179.69	0.9925	266.82	1.0251	
157	Dimethylamine	C ₂ H ₇ N	124403	45.084	-2.1457E+05	3.7872E+03	-1.3781E+01	1.6924E-02	0	180.96	1.1947	298.15	1.3779
158	Trimethylamine	C ₃ H ₉ N	75503	59.111	1.3605E+05	-2.8800E+02	9.9130E-01	0	0	156.08	1.1525	276.02	1.3208
159	Ethylamine	C ₂ H ₇ N	75047	45.084	1.2170E+05	3.8993E+01	0	0	192.15	1.2919	289.73	1.3300	
160	Diethylamine	C ₄ H ₁₁ N	109897	73.138	1.0133E+05	2.4318E+02	0	0	223.35	1.5564	328.6	1.8124	
161	Triethylamine	C ₆ H ₁₅ N	121448	101.192	1.1148E+05	3.6813E+02	0	0	200	1.8511	361.92	2.4471	
162	<i>n</i> -Propylamine	C ₃ H ₉ N	107108	59.111	1.3953E+05	7.8000E+01	0	0	188.36	1.5422	340	1.6605	
163	di- <i>n</i> -Propylamine	C ₆ H ₁₅ N	142847	101.192	4.9120E+04	5.6224E+02	0	0	277.9	2.0537	407.9	2.7846	
164	Isopropylamine	C ₃ H ₉ N	75310	59.111	-3.2469E+04	1.9771E+03	-7.0145E+00	8.6913E-03	0	177.95	1.4621	320	1.6671
165	Diisopropylamine	C ₆ H ₁₅ N	108189	101.192	9.8434E+04	4.2904E+02	0	0	275	2.1642	357.05	2.5162	
166	Aniline	C ₆ H ₇ N	62533	93.128	1.4150E+05	1.7120E+02	0	0	267.13	1.8723	457.15	2.1976	
167	<i>N</i> -Methylaniline	C ₇ H ₉ N	100618	107.155	1.2850E+05	1.0020E+02	3.7400E-01	0	0	216.15	1.6763	469.02	2.5777
168	<i>N,N</i> -Dimethylaniline	C ₈ H ₁₁ N	121697	121.182	4.1860E+04	5.2750E+02	0	0	343.58	2.2310	513.58	3.1277	
169	Ethylene oxide	C ₂ H ₄ O	75218	44.053	1.4471E+05	-7.5887E+02	2.8261E+00	-3.0640E-03	0	160.65	0.8303	283.85	0.8693
170	Furan	C ₄ H ₄ O	110009	68.075	1.1437E+05	-2.1569E+02	7.2691E-01	0	0	187.55	0.9949	304.5	1.1609
171	Thiophene	C ₄ H ₆ S	110021	84.142	8.1350E+04	1.2980E+02	-3.9000E-03	0	0	234.94	1.1163	357.31	1.2723
172	Pyridine	C ₅ H ₅ N	110861	79.101	1.0785E+05	-3.4787E+01	3.9565E-01	0	0	231.51	1.2100	388.41	1.5403
173	Formamide ⁵	CH ₃ NO	75127	45.041	6.3400E+04	1.5060E+02	0	0	292	1.0738	493	1.3765	
174	<i>N,N</i> -Dimethylformamide	C ₃ H ₇ NO	68122	73.095	1.4790E+05	-1.0600E+02	3.8400E-01	0	0	273.82	1.4767	466.44	1.8200
175	Acetamide	C ₂ H ₅ NO	60355	59.068	1.0230E+05	1.2870E+02	0	0	354.15	1.4788	571	1.7579	
176	<i>N</i> -Methylacetamide	C ₃ H ₇ NO	79163	73.095	6.2600E+04	2.4340E+02	0	0	359	1.4998	538.5	1.9367	
177	Acetonitrile	C ₂ H ₃ N	75058	41.053	9.7582E+04	-1.2220E+02	3.4085E-01	0	0	229.32	0.8748	354.75	0.9713
178	Propionitrile	C ₃ H ₅ N	107120	55.079	1.1819E+05	-1.2098E+02	4.2075E-01	0	0	180.26	1.1005	370.5	1.3112
179	<i>n</i> -Butyronitrile	C ₄ H ₇ N	109740	69.106	1.0400E+05	1.7400E+02	0	0	161.25	1.3206	390.75	1.7199	
180	Benzonitrile	C ₇ H ₅ N	100470	103.123	7.6900E+04	3.1420E+02	0	0	260.4	1.5872	464.15	2.2274	
181	Methyl mercaptan	CH ₃ S	74931	48.109	1.1530E+05	-2.6323E+02	6.0412E-01	0	0	150.18	0.8939	298.15	0.9052
182	Ethyl mercaptan	C ₂ H ₅ S	75081	62.136	1.3467E+05	-2.3439E+02	5.9656E-01	0	0	125.26	1.1467	315.25	1.2007
183	<i>n</i> -Propyl mercaptan	C ₃ H ₈ S	107039	76.163	1.6733E+05	-3.1910E+02	8.1270E-01	0	0	159.95	1.3708	340.87	1.5299
184	<i>n</i> -Butyl mercaptan	C ₄ H ₁₀ S	109795	90.189	2.3219E+05	-8.0435E+02	2.7063E+00	-2.3017E-03	0	157.46	1.6365	390	1.9359
185	Isobutyl mercaptan	C ₄ H ₁₀ S	513440	90.189	1.7336E+05	-2.1732E+02	7.0933E-01	0	0	128.31	1.5715	361.64	1.8754
186	sec-Butyl mercaptan ²	C ₄ H ₁₀ S	513531	90.189	1.9789E+05	-4.9154E+02	1.7219E+00	-1.2499E-03	0	133.02	1.6003	370	1.8844
187	Dimethyl sulfide	C ₂ H ₆ S	75183	62.136	1.4695E+05	-3.8006E+02	1.2035E+00	-8.4787E-04	0	174.88	1.1276	310.48	1.1959
188	Methyl ethyl sulfide	C ₃ H ₈ S	624895	76.163	1.6124E+05	-2.8861E+02	7.8179E-01	0	0	167.23	1.3484	339.8	1.5344
189	Diethyl sulfide	C ₄ H ₁₀ S	352932	90.189	2.3852E+05	-1.0384E+03	4.0587E+00	-4.4691E-03	0	181.95	1.5703	322.08	1.7579
190	Fluoromethane ²	CH ₃ F	593533	34.033	7.4746E+04	-1.3232E+02	5.3772E-01	0	0	140	0.6676	220	0.7166
191	Chloromethane	CH ₃ Cl	74873	50.488	9.6910E+04	-2.0790E+02	3.7456E-01	4.8800E-04	0	175.43	0.7460	373.15	0.9684
192	Trichloromethane	CHCl ₃	67663	119.377	1.2485E+05	-1.6634E+02	4.3209E-01	0	0	233.15	1.0956	366.48	1.2192
193	Tetrachloromethane	CCl ₄	56235	153.822	-7.5270E+05	8.9661E+03	-3.0394E+01	3.4455E-02	0	250.33	1.2763	388.71	1.6374
194	Bromomethane	CH ₃ Br	74839	94.939	1.2973E+05	-5.9654E+02	2.1600E+00	-2.4234E-03	0	184.45	0.7798	276.71	0.7870
195	Fluoroethane	C ₂ H ₅ F	353366	48.060	8.3303E+04	6.5454E+01	0	0	200	0.9639	281.48	1.0173	
196	Chloroethane	C ₂ H ₅ Cl	75003	64.514	1.2790E+05	-3.4515E+02	9.1500E-01	0	0	134.8	0.9800	340	1.1632
197	Bromoethane	C ₂ H ₅ Br	74964	108.966	9.4364E+04	-1.0912E+02	4.4032E-01	0	0	160	0.8818	320	1.0453

TABLE 2-196 Heat Capacities of Inorganic and Organic Liquids (Concluded)

Cmpd. no.	Name	Formula	CAS no.	Mol wt	C1	C2	C3	C4	C5	T _{min} , K	C _p at T _{min} × 1E-05	T _{max} , K	C _p at T _{max} × 1E-05
198	1-Chloropropane	C ₃ H ₇ Cl	540545	78.541	9.6344E+04	1.1752E+02	0	0	0	230	1.2337	319.67	1.3391
199	2-Chloropropane	C ₃ H ₇ Cl	75296	78.541	6.9362E+04	2.1501E+02	0	0	0	200	1.1236	308.85	1.3577
200	1,1-Dichloropropane	C ₃ H ₆ Cl ₂	78999	112.986	7.0010E+04	2.6660E+02	0	0	0	280	1.4466	420	1.8198
201	1,2-Dichloropropane	C ₃ H ₆ Cl ₂	78875	112.986	1.1094E+05	8.3496E+00	4.7218E-01	0	0	286	1.5195	429	2.0142
202	Vinyl chloride	C ₂ H ₃ Cl	75014	62.499	-1.0320E+04	3.2280E+02	0	0	0	200	0.5424	400	1.1880
203	Fluorobenzene	C ₆ H ₅ F	462066	96.104	-9.9120E+05	1.1734E+04	-4.0669E+01	4.7333E-02	0	239.99	1.3675	319.99	1.5018
204	Chlorobenzene	C ₆ H ₅ Cl	108907	112.558	-1.3075E+06	1.5338E+04	-5.3974E+01	6.3483E-02	0	227.95	1.3617	360	1.8101
205	Bromobenzene	C ₆ H ₅ Br	108861	157.010	1.2160E+05	-9.4500E+00	3.5800E-01	0	0	293.15	1.4960	495.08	2.0467
206	Air		132259100	28.951	-2.1446E+05	9.1851E+03	-1.0612E+02	4.1616E-01	0	75	0.5307	115	0.7132
207	Hydrogen (eqn. 2)	H ₂	1333740	2.016	6.6653E+01	6.7659E+03	-1.2363E+02	4.7827E+02	0	13.95	0.1262	32	1.3122
208	Helium-4 ⁶	He	7440597	4.003	3.8722E+05	-4.6557E+05	2.1180E+05	-4.2494E+04	3.2129E+03	2.2	0.1087	4.6	0.2965
209	Neon	Ne	7440019	20.180	1.0341E+06	-1.3877E+05	7.1540E+03	-1.6255E+02	1.3841E+00	24.56	0.3666	40	0.6980
210	Argon	Ar	7440371	39.948	1.3439E+05	-1.9894E+03	1.1043E+01	0	0	83.78	0.4523	135	0.6708
211	Fluorine	F ₂	7782414	37.997	-9.4585E+04	7.5299E+03	-1.3960E+02	1.1301E+00	-3.3241E-03	58	0.5541	98	0.5966
212	Chlorine	Cl ₂	7782505	70.905	6.3936E+04	4.6350E+01	-1.6230E-01	0	0	172.12	0.6711	239.12	0.6574
213	Bromine	Br ₂	7726956	159.808	3.7570E+04	3.2850E+02	-6.7000E-01	0	0	265.9	0.7755	305.37	0.7541
214	Oxygen	O ₂	7782447	31.999	1.7543E+05	-6.1523E+03	1.1392E+02	-9.2382E-01	2.7963E-03	54.36	0.5365	142	0.9066
215	Nitrogen	N ₂	7727379	28.014	2.8197E+05	-1.2281E+04	2.4800E+02	-2.2182E+00	7.4902E-03	63.15	0.5593	112	0.7960
216	Ammonia (eqn. 2)	NH ₃	7664417	17.031	6.1289E+01	8.0925E+04	7.9940E+02	-2.6510E+03	0	203.15	0.7575	401.15	4.1847
217	Hydrazine	N ₂ H ₄	302012	32.045	7.9815E+04	5.0929E+01	4.3379E-02	0	0	274.69	0.9708	653.15	1.3158
218	Nitrous oxide	N ₂ O	10024972	44.013	6.7556E+04	5.4373E+01	0	0	0	182.3	0.7747	200	0.7843
219	Nitric oxide	NO	10102439	30.006	-2.9796E+06	7.6602E+04	-6.5259E+02	1.8879E+00	0	109.5	0.6229	150	1.9909
220	Cyanogen	C ₂ N ₂	460195	52.036	3.1322E+06	-2.4320E+04	4.8844E+01	0	0	245.25	1.0557	300	2.3216
221	Carbon monoxide (eqn. 2)	CO	630080	28.010	6.5429E+01	2.8723E+04	-8.4739E+02	1.9596E+03	0	68.15	0.5912	132	6.4799
222	Carbon dioxide	CO ₂	124389	44.010	-8.3043E+06	1.0437E+05	-4.3333E+02	6.0052E-01	0	220	0.7827	290	1.6603
223	Carbon disulfide	CS ₂	75150	76.143	8.5600E+04	-1.2200E+02	5.6050E-01	-1.4520E-03	2.0080E-06	161.11	0.7577	552	1.3125
224	Hydrogen fluoride	HF	7664393	20.006	6.2520E+04	-2.2302E+02	6.2970E-01	0	0	189.79	0.4288	292.67	0.5119
225	Hydrogen chloride	HCl	7647010	36.461	4.7300E+04	9.0000E+01	0	0	0	165	0.6215	185	0.6395
226	Hydrogen bromide	HBr	10035106	80.912	5.7720E+04	9.9000E+00	0	0	0	185.15	0.5955	206.45	0.5976
227	Hydrogen cyanide	HCN	74908	27.026	9.5398E+04	-1.9752E+02	3.8830E-01	0	0	259.83	0.7029	298.85	0.7105
228	Hydrogen sulfide (eqn. 2)	H ₂ S	7783064	34.082	6.4666E+01	4.9354E+04	2.2493E+01	-1.6230E+03	0	187.68	0.6733	370	4.9183
229	Sulfur dioxide	SO ₂	7446095	64.065	8.5743E+04	5.7443E+00	0	0	0	197.67	0.8688	350	0.8775
230	Sulfur trioxide	SO ₃	7446119	80.064	2.5809E+05	0.0000E+00	0	0	0	303.15	2.5809	303.15	2.5809
231	Water	H ₂ O	7732185	18.015	2.7637E+05	-2.0901E+03	8.1250E+00	-1.4116E-02	9.3701E-06	273.16	0.7615	533.15	0.8939

All substances are listed in alphabetical order in Table 2-6a.

Compiled from Daubert, T. E., R. P. Danner, H. M. Sibil, and C. C. Stebbins, DIPPR Data Compilation of Pure Compound Properties, Project 801 Sponsor Release, July, 1993, Design Institute for Physical Property Data, AIChE, New York, NY; and from Thermodynamics Research Center, "Selected Values of Properties of Hydrocarbons and Related Compounds," Thermodynamics Research Center Hydrocarbon Project, Texas A&M University, College Station, Texas (extant 1994).

Temperatures are expressed in kelvins; liquid heat capacities are in J/kmol·K.

J/(kmol·K) × 2.390E-04 = cal/(gmol·°C); J/(kmol·K) × 2.390059E-04 = BTu/(lbmol·°F).

Equation 1, heat capacity = C₁ + C₂ × T + C₃ × T² + C₄ × T³ + C₅ × T⁴, should be used except as otherwise specified.

Equation 2 is heat capacity = C₁²/t + C₂ - (2 × C₁ × C₃)t - (C₁ × C₄)t² - (C₃²)t³ - (C₃ × C₄/2)t⁴ - (C₄²)t⁵. t = (1 - T_r) and T_r is the reduced temperature, T/T_c.

¹ Coefficients are for the monomer and are hypothetical above 473 K.

² For the saturated heat capacity.

³ Coefficients are hypothetical; compound decomposes violently on heating.

⁴ Coefficients are hypothetical and are based on predicted data.

⁵ Coefficients are hypothetical.

⁶ Exhibits superfluid properties below 2.2 K.

TABLE 2-197 Specific Heats of Organic Solids
Recalculated from *International Critical Tables*, vol. 5, pp. 101–105

Compound	Formula	Temperature, °C	sp ht, cal/g °C
Acetic acid	C ₂ H ₄ O ₂	-200 to +25	0.330 + 0.00080t
Acetone	C ₃ H ₆ O	-210 to -80	0.540 + 0.0156t
Aminobenzoic acid (o-)	C ₇ H ₇ NO ₂	85 to mp	0.254 + 0.00136t
(m-)	C ₇ H ₇ NO ₂	120 to mp	0.253 + 0.00122t
(p-)	C ₇ H ₇ NO ₂	128 to mp	0.287 + 0.00088t
Aniline	C ₆ H ₅ N		0.741
Anthracene	C ₁₄ H ₁₀	50	0.308
		100	0.350
		150	0.382
Anthraquinone	C ₁₄ H ₈ O ₂	0 to 270	0.258 + 0.00069t
Apiole	C ₁₂ H ₁₄ O ₄	10	0.299
Azobenzene	C ₁₂ H ₁₀ N ₂	28	0.330
Benzene	C ₆ H ₆	-250	0.0399
		-225	0.0908
		-200	0.124
		-150	0.170
		-100	0.227
		-50	0.299
		0	0.375
Benzoic acid	C ₇ H ₆ O ₂	20 to mp	0.287 + 0.00050t
Benzophenone	C ₁₃ H ₁₀ O	-150	0.115
		-100	0.172
		-50	0.220
		0	0.275
		+20	0.303
Betol	C ₁₇ H ₁₂ O ₃	-150	0.129
		-100	0.167
		0	0.248
		+50	0.308
Bromoiodobenzene (o-)	C ₆ H ₄ BrI	-50 to 0	0.143 + 0.00025t
(m-)	C ₆ H ₄ BrI	-75 to -15	0.143
(p-)	C ₆ H ₄ BrI	-40 to 50	0.116 + 0.00032t
Bromonaphthalene (β-)	C ₁₀ H ₇ Br	41	0.260
Bromophenol	C ₆ H ₅ BrO	32	0.263
Camphene	C ₁₀ H ₁₆	35	0.380
Capric acid	C ₁₀ H ₂₀ O ₂	8	0.695
Caprylic acid	C ₈ H ₁₆ O ₂	-2	0.628
Carbon tetrachloride	CCl ₄	-240	0.013
		-200	0.081
		-160	0.131
		-120	0.162
		-80	0.182
		-40	0.201
Cerotic acid	C ₂₇ H ₅₄ O ₂	15	0.387
Chloral alcoholate	C ₄ H ₇ Cl ₃ O ₂	78	0.509
hydrate	C ₂ H ₃ Cl ₃ O ₂	32	0.213
Chloroacetic acid	C ₂ H ₃ ClO ₂	60	0.363
Chlorobenzoic acid (o-)	C ₇ H ₅ ClO ₂	80 to mp	0.228 + 0.00084t
(m-)	C ₇ H ₅ ClO ₂	94 to mp	0.232 + 0.00073t
(p-)	C ₇ H ₅ ClO ₂	180 to mp	0.242 + 0.00055t
Chlorobromobenzene (o-)	C ₆ H ₄ BrCl	-34	0.192
(m-)	C ₆ H ₄ BrCl	-52	0.150
(p-)	C ₆ H ₄ BrCl	-40	0.150
Crotonic acid	C ₄ H ₆ O ₂	38 to 70	0.520 + 0.00020t
Cyamelide	C ₃ H ₃ N ₃ O ₃	40	0.263
Cyanamide	CH ₂ N ₂	20	0.547
Cyanuric acid	C ₃ H ₃ N ₃ O ₃	40	0.318
Dextrin	(C ₆ H ₁₀ O ₅) _x	0 to 90	0.291 + 0.00096t
Dextrose	C ₆ H ₁₂ O ₆	-250	0.016
		-200	0.077
		-100	0.160
		0	0.277
		20	0.300
Dibenzyl	C ₁₄ H ₁₄	28	0.363
Dibromobenzene (o-)	C ₆ H ₄ Br ₂	-36	0.248
(m-)	C ₆ H ₄ Br ₂	-25	0.134
(p-)	C ₆ H ₄ Br ₂	-50 to +50	0.139 + 0.00038t
Dichloroacetic acid	C ₂ H ₂ Cl ₂ O ₂		0.406
Dichlorobenzene (o-)	C ₆ H ₄ Cl ₂	-48.5	0.185
(m-)	C ₆ H ₄ Cl ₂	-52	0.186
(p-)	C ₆ H ₄ Cl ₂	-50 to +53	0.219 + 0.0021t
Dicyandiamide	C ₂ H ₄ N ₄	0 to 204	0.456

TABLE 2-197 Specific Heats of Organic Solids (Continued)
Recalculated from *International Critical Tables*, vol. 5, pp. 101–105

Compound	Formula	Temperature, °C	sp ht, cal/g °C
Dihydroxybenzene (<i>o</i> -)	C ₆ H ₆ O ₂	-163 to mp	0.278 + 0.00098t
(<i>m</i> -)	C ₆ H ₆ O ₂	-160 to mp	0.269 + 0.00118t
(<i>p</i> -)	C ₆ H ₆ O ₂	-250 -240 -220 -200	0.025 0.038 0.061 0.081
Di-iodobenzene (<i>o</i> -)	C ₆ H ₄ I ₂	-150 to mp	0.268 + 0.00093t
(<i>m</i> -)	C ₆ H ₄ I ₂	-50 to +15	0.109 + 0.00026t
(<i>p</i> -)	C ₆ H ₄ I ₂	-52 to -42	0.100 + 0.00026t
Dimethyl oxalate	C ₄ H ₆ O ₄	-50 to +80	0.101 + 0.00026t
Dimethylpyrene	C ₇ H ₈ O ₂	10 to 50	0.212 + 0.0044t
Dinitrobenzene (<i>o</i> -)	C ₆ H ₄ N ₂ O ₄	-160 to mp	0.252 + 0.00083t
(<i>m</i> -)	C ₆ H ₄ N ₂ O ₄	-160 to mp	0.248 + 0.00077t
(<i>p</i> -)	C ₆ H ₄ N ₂ O ₄	119 to mp	0.259 + 0.00057t
Diphenyl	C ₁₂ H ₁₀	40	0.385
Diphenylamine	C ₁₂ H ₁₁ N	26	0.337
Dulcitol	C ₆ H ₁₄ O ₆	20	0.282
Erythritol	C ₄ H ₁₀ O ₄	60	0.351
Ethyl alcohol	C ₂ H ₆ O (crystalline)	-190 -180 -160 -140 -130 (vitreous) -190 -180 -175 -170	0.232 0.248 0.282 0.318 0.376 0.260 0.296 0.380 0.399
Ethylene glycol	C ₂ H ₆ O ₂	-190 to -40	0.366 + 0.00110t
Formic acid	CH ₂ O ₂	-22 0	0.387 0.430
Glutaric acid	C ₅ H ₈ O ₄	20	0.299
Glycerol	C ₃ H ₈ O ₃	-265 -260 -250 -220 -200 -100 0	0.009 0.022 0.047 0.085 0.115 0.217 0.330
Hexachloroethane	C ₂ Cl ₆	25	0.174
Hexadecane	C ₁₆ H ₃₄		0.495
Hydroxyacetanilide	C ₈ H ₉ NO ₂	41 to mp	0.249 + 0.00154t
Iodobenzene	C ₆ H ₅ I	40	0.191
Isopropyl alcohol	C ₃ H ₈ O	-200 to -160	0.051 + 0.00165t
Lactose	C ₁₂ H ₂₂ O ₁₁ C ₁₂ H ₂₂ O ₁₁ ·H ₂ O	20 20	0.287 0.299
Lauric acid	C ₁₂ H ₂₄ O ₂	-30 to +40	0.430 + 0.000027t
Levoglucosane	C ₆ H ₁₀ O ₅	40	0.607
Levulose	C ₆ H ₁₂ O ₆	20	0.275
Malonic acid	C ₃ H ₄ O ₄	20	0.275
Maltose	C ₁₂ H ₂₂ O ₁₁	20	0.320
Mannitol	C ₆ H ₁₄ O ₆	0 to 100	0.313 + 0.00025t
Melamine	C ₃ H ₆ N ₆	40	0.351
Myristic acid	C ₁₄ H ₂₈ O ₂	0 to 35	0.381 + 0.00545t
Naphthalene	C ₁₀ H ₈	-130 to mp	0.281 + 0.00111t
Naphthol (<i>α</i> -)	C ₁₀ H ₈ O	50 to mp	0.240 + 0.00147t
(<i>β</i> -)	C ₁₀ H ₈ O	61 to mp	0.252 + 0.00128t
Naphthylamine (<i>α</i> -)	C ₁₀ H ₉ N	0 to 50	0.270 + 0.0031t
Nitroaniline (<i>o</i> -)	C ₆ H ₅ N ₂ O ₂	-160 to mp	0.269 + 0.000920t
(<i>m</i> -)	C ₆ H ₆ N ₂ O ₂	-160 to mp	0.275 + 0.000946t
(<i>p</i> -)	C ₆ H ₆ N ₂ O ₂	-160 to mp	0.276 + 0.001000t
Nitrobenzoic acid (<i>o</i> -)	C ₇ H ₅ NO ₄	-163 to mp	0.256 + 0.00085t
(<i>m</i> -)	C ₇ H ₅ NO ₄	66 to mp	0.258 + 0.00091t
(<i>p</i> -)	C ₇ H ₅ NO ₄	-160 to mp	0.247 + 0.00077t
Nitronaphthalene	C ₁₀ H ₇ NO ₂	0 to 55	0.236 + 0.00215t

TABLE 2-197 Specific Heats of Organic Solids (Concluded)
Recalculated from *International Critical Tables*, vol. 5, pp. 101–105

Compound	Formula	Temperature, °C	sp ht, cal/g °C
Oxalic acid	C ₂ H ₂ O ₄	-200 to +50	0.259 + 0.00076t
	C ₂ H ₂ O ₄ ·2H ₂ O	-200	0.117
		-100	0.239
		0	0.338
		+50	0.385
		100	0.416
Palmitic acid	C ₁₆ H ₃₂ O ₂	-180	0.167
		-140	0.208
		-100	0.251
		-50	0.306
		0	0.382
		+20	0.430
Phenol	C ₆ H ₆ O	14 to 26	0.561
Phthalic acid	C ₈ H ₆ O ₄	20	0.232
Picric acid	C ₆ H ₃ N ₃ O ₇	-100	0.165
		0	0.240
		+50	0.263
		100	0.297
		120	0.332
		-33	0.726
Propionic acid	C ₃ H ₆ O ₂	-200	0.170
Propyl alcohol (<i>n</i> -)	C ₃ H ₈ O	-175	0.363
		-150	0.471
		-130	0.497
Pyrotartaric acid	C ₆ H ₈ O ₄	20	0.301
Quinhydrone	C ₁₂ H ₁₀ O ₄	-250	0.017
		-225	0.061
		-200	0.098
		-100	0.191
		0	0.256
		-250	0.031
Quinone	C ₆ H ₄ O ₂	-225	0.082
		-200	0.113
		-150 to mp	0.282 + 0.00083t
Salol	C ₁₃ H ₁₀ O ₃	32	0.289
Stearic acid	C ₁₈ H ₃₄ O ₂	15	0.399
Succinic acid	C ₄ H ₆ O ₄	0 to 160	0.248 + 0.00153t
Sucrose	C ₁₂ H ₂₂ O ₁₁	20	0.299
Sugar (cane)	C ₁₂ H ₂₂ O ₁₁	22 to 51	0.301
Tartaric acid	C ₄ H ₆ O ₆	36	0.287
	C ₄ H ₆ O ₆ ·H ₂ O	-150	0.112
		-100	0.170
		-50	0.231
		0	0.308
		+50	0.366
Tetrachloroethylene	C ₂ Cl ₄	-40 to 0	0.198 + 0.00018t
Tetryl	C ₇ H ₅ N ₅ O ₈	-100	0.182
		-50	0.199
		0	0.212
		+100	0.236
1 Tetryl + 1 picric acid	C ₁₃ H ₈ N ₃ O ₁₅	-100 to +100	0.253 + 0.00072t
1 Tetryl + 2 TNT	C ₂₁ H ₁₅ N ₁₁ O ₂₀	-100	0.172
		0	0.280
		+50	0.325
Thymol	C ₁₀ H ₁₄ O	0 to 49	0.315 + 0.0031t
	C ₈ H ₈ O ₂	54 to mp	0.277 + 0.00120t
	C ₈ H ₈ O ₂	54 to mp	0.239 + 0.00195t
	C ₈ H ₈ O ₂	130 to mp	0.271 + 0.00106t
	C ₇ H ₉ N	0	0.337
		20	0.387
Trichloroacetic acid	C ₂ HCl ₃ O ₂	40	0.440
	C ₄ H ₁₀ O	solid	0.459
	C ₇ H ₅ N ₃ O ₆	-4	0.559
		-100	0.170
		-50	0.253
		0	0.311
Trinitroxylene	C ₈ H ₇ N ₃ O ₆	+100	0.385
		-185 to +23	0.241
		20 to 50	0.423
Triphenylmethane	C ₁₉ H ₁₆	0 to 91	0.189 + 0.0027t
Urea	CH ₄ N ₂ O	20	0.320

TABLE 2-198 Heat Capacities of Inorganic and Organic Compounds in the Ideal Gas State

Cmpd. no.	Name	Formula	CAS no.	Mol wt.	C1 × 1E-05	C2 × 1E-05	C3 × 1E-03	C4 × 1E-05	C5	T _{min} , K	C _p at T _{min} × 1E-05	T _{max} , K	C _p at T _{max} × 1E-05
1	Methane	CH ₄	74828	16.043	0.3330	0.7993	2.0869	0.4160	991.96	50	0.3330	1500	0.8890
2	Ethane	C ₂ H ₆	74840	30.070	0.4033	1.3422	1.6555	0.7322	752.87	200	0.4256	1500	1.4562
3	Propane	C ₃ H ₈	74986	44.097	0.5192	1.9245	1.6265	1.1680	723.6	200	0.5632	1500	2.0556
4	n-Butane	C ₄ H ₁₀	106978	58.123	0.7134	2.4300	1.6300	1.5033	730.42	200	0.7673	1500	2.6602
5	n-Pentane	C ₅ H ₁₂	109660	72.150	0.8805	3.0110	1.6502	1.8920	747.6	200	0.9404	1500	3.2927
6	n-Hexane	C ₆ H ₁₄	110543	86.177	1.0440	3.5230	1.6946	2.3690	761.6	200	1.1117	1500	3.8620
7	n-Heptane	C ₇ H ₁₆	142825	100.204	1.2015	4.0010	1.6766	2.7400	756.4	200	1.2828	1500	4.4283
8	n-Octane	C ₈ H ₁₈	111659	114.231	1.3554	4.4310	1.6356	3.0540	746.4	200	1.4529	1500	4.9764
9	n-Nonane	C ₉ H ₂₀	111842	128.258	1.5175	4.9150	1.6448	3.4700	749.6	200	1.6257	1500	5.5407
10	n-Decane	C ₁₀ H ₂₂	124185	142.285	1.6720	5.3530	1.6141	3.7820	742	200	1.7967	1500	6.0932
11	n-Undecane	C ₁₁ H ₂₄	1120214	156.312	1.9529	6.0998	1.7087	4.1302	775.4	200	2.0594	1500	6.8342
12	n-Dodecane	C ₁₂ H ₂₆	112403	170.338	2.1295	6.6330	1.7155	4.5161	777.5	200	2.2442	1500	7.4325
13	n-Tridecane	C ₁₃ H ₂₈	629505	184.365	2.1496	7.3045	1.6695	4.9998	741.02	200	2.3156	1500	8.0251
14	n-Tetradecane	C ₁₄ H ₃₀	629594	198.392	2.3082	7.8678	1.6823	5.4486	743.1	200	2.4864	1500	8.6225
15	n-Pentadecane	C ₁₅ H ₃₂	629629	212.419	2.4679	8.4212	1.6865	5.8537	743.6	200	2.6586	1500	9.2209
16	n-Hexadecane	C ₁₆ H ₃₄	544763	226.446	2.6283	8.9733	1.6912	6.2640	744.41	200	2.8312	1500	9.8182
17	n-Heptadecane	C ₁₇ H ₃₆	629787	240.473	2.7878	9.5247	1.6935	6.6651	744.57	200	3.0034	1500	10.4160
18	n-Octadecane	C ₁₈ H ₃₈	593453	254.500	2.9502	10.0340	0.7711	-4.3012	916.73	200	3.1800	1500	11.0160
19	n-Nonadecane	C ₁₉ H ₄₀	629925	268.527	3.1062	10.5750	0.7679	-4.5661	-912.03	200	3.3533	1500	11.6130
20	n-Eicosane	C ₂₀ H ₄₂	112958	282.553	3.2481	11.0900	1.6360	7.4500	-726.27	200	3.5235	1500	12.2110
21	2-Methylpropane	C ₄ H ₁₀	75285	58.123	0.6549	2.4776	1.5870	1.5750	-706.99	200	0.7218	1500	2.6656
22	2-Methylbutane	C ₅ H ₁₂	78784	72.150	0.7460	3.2650	1.5450	1.9230	666.7	200	0.8546	1500	3.3792
23	2,3-Dimethylbutane	C ₆ H ₁₄	79298	86.177	0.7772	4.0320	1.5440	2.5080	-649.95	200	0.9363	1500	4.0353
24	2-Methylpentane	C ₆ H ₁₄	107835	86.177	0.9030	3.8010	1.6020	2.4530	-691.6	200	1.0192	1500	3.9617
25	2,3-Dimethylpentane	C ₇ H ₁₆	565593	100.204	0.8544	4.5772	1.5181	2.9740	641.01	200	1.0550	1500	4.5983
26	2,3,3-Trimethylpentane	C ₈ H ₁₈	560214	114.231	0.9820	5.4020	1.5310	3.4930	639.9	200	1.2194	1500	5.3754
27	2,2,4-Trimethylpentane	C ₈ H ₁₈	540841	114.231	1.1390	5.2860	1.5940	3.3510	677.94	200	1.3139	1500	5.3769
28	Ethylene	C ₂ H ₄	74851	28.054	0.3338	0.9479	1.5960	0.5510	740.8	60	0.3338	1500	1.0987
29	Propylene	C ₃ H ₆	115071	42.081	0.4339	1.5200	1.4250	0.7860	623.9	130	0.4388	1500	1.6836
30	1-Butene	C ₄ H ₈	106989	56.108	0.5998	2.0846	1.5884	1.2940	707.3	200	0.6547	1500	2.2853
31	cis-2-Butene	C ₄ H ₈	590181	56.108	0.5765	2.1150	1.6299	1.2872	739.1	200	0.6199	1500	2.2715
32	trans-2-Butene	C ₄ H ₈	624646	56.108	0.6592	2.0700	1.6733	1.2510	742.2	200	0.7004	1500	2.2904
33	1-Pentene	C ₅ H ₁₀	109671	70.134	0.7595	2.5525	1.5820	1.6660	713	200	0.8273	1500	2.8467
34	1-Hexene	C ₆ H ₁₂	592416	84.161	0.9180	3.0220	1.5742	2.0320	715	200	0.9995	1500	3.4088
35	1-Heptene	C ₇ H ₁₄	592767	98.188	1.0775	3.4900	1.5705	2.4030	717.4	200	1.1723	1500	3.9706
36	1-Octene	C ₈ H ₁₆	111660	112.215	1.2355	3.9570	1.5640	2.7669	718.17	200	1.3440	1500	4.5322
37	1-Nonene	C ₉ H ₁₈	124118	126.242	1.3950	4.4255	1.5624	3.1370	719.6	200	1.5168	1500	5.0938
38	1-Decene	C ₁₀ H ₂₀	872059	140.269	1.7573	5.1710	1.7664	3.6210	803.02	200	1.8333	1500	5.8682
39	2-Methylpropene	C ₄ H ₈	115117	56.108	0.6125	2.0660	1.5450	1.2057	676	200	0.6763	1500	2.2814
40	2-Methyl-1-butene	C ₅ H ₁₀	563462	70.134	0.8703	2.5556	1.7757	1.7636	807.82	200	0.9060	1500	2.8923
41	2-Methyl-2-butene	C ₅ H ₁₀	513359	70.134	0.8192	2.6038	1.7593	1.7195	800.93	200	0.8559	1500	2.8709
42	1,2-Butadiene	C ₄ H ₆	590192	54.092	0.5750	1.6476	1.5270	0.9900	677.3	200	0.6269	1500	1.9202
43	1,3-Butadiene	C ₄ H ₆	106990	54.092	0.5095	1.7050	1.5324	1.3370	685.6	200	0.5756	1500	1.9555
44	2-Methyl-1,3-butadiene	C ₅ H ₈	78795	68.119	0.6527	2.2993	1.4943	1.5164	-647.15	200	0.7508	1500	2.5571
45	Acetylene	C ₂ H ₂	74862	26.038	0.3199	0.5424	1.5940	0.4325	607.1	200	0.3566	1500	0.7575
46	Methylacetylene	C ₃ H ₄	74997	40.065	0.4478	1.0917	1.5508	0.6750	658.2	200	0.4882	1500	1.3293
47	Dimethylacetylene	C ₄ H ₆	503173	54.092	0.6534	1.6179	1.7837	1.0242	821.4	200	0.6721	1500	1.9148
48	3-Methyl-1-butyne	C ₅ H ₈	598232	68.119	0.8274	2.1377	1.7550	1.5149	782	200	0.8646	1500	2.5255
49	1-Pentyne	C ₅ H ₈	627190	68.119	0.7530	2.0905	1.5307	1.3780	672.8	200	0.8276	1500	2.4754
50	2-Pentyne	C ₅ H ₈	627214	68.119	0.7074	2.2229	1.5570	1.3125	690.78	200	0.7700	1500	2.5052
51	1-Hexyne	C ₆ H ₁₀	693027	82.145	0.9129	2.5577	1.5290	1.7370	683	200	1.0004	1500	3.0371
52	2-Hexyne	C ₆ H ₁₀	764352	82.145	1.0360	3.0090	2.1160	2.1060	902.4	300	1.2215	1500	3.1894
53	3-Hexyne	C ₆ H ₁₀	928494	82.145	0.9376	3.0150	1.9057	1.9860	817	300	1.1909	1500	3.1889
54	1-Heptyne	C ₇ H ₁₂	628717	96.172	1.0712	3.0258	1.5273	2.0975	689.62	200	1.1721	1500	3.5985

55	1-Octyne	C ₈ H ₁₄	629050	110.199	1.2307	3.4942	1.5280	2.4617	694.81	200	1.3448	1500	4.1604
56	Vinylacetylene	C ₄ H ₄	689974	52.076	0.5598	1.2141	1.6102	0.8908	-710.4	200	0.5967	1500	1.5590
57	Cyclopentane	C ₅ H ₁₀	287923	70.134	0.4160	3.0140	1.4617	1.8095	-668.8	100	0.4165	1500	2.9298
58	Methylcyclopentane	C ₆ H ₁₂	96377	84.161	0.6646	3.5070	1.5892	2.3526	727.13	200	0.7510	1500	3.5495
59	Ethylcyclopentane	C ₇ H ₁₄	1640897	98.188	0.8205	4.0342	1.5670	2.6697	715.52	200	0.9272	1500	4.1472
60	Cyclohexane	C ₆ H ₁₂	110827	84.161	0.4320	3.7350	1.1920	1.6350	-530.1	100	0.4366	1500	3.6516
61	Methylcyclohexane	C ₇ H ₁₄	108872	98.188	0.9227	4.1150	1.6504	2.9006	779.48	200	0.9953	1500	4.3180
62	1,1-Dimethylcyclohexane	C ₈ H ₁₆	590669	112.215	1.0776	4.6718	1.6540	3.3397	792.5	200	1.1535	1500	4.9543
63	Ethylcyclohexane	C ₈ H ₁₆	1678917	112.215	1.1059	4.6306	1.6628	3.2990	781.1	200	1.1875	1500	4.9184
64	Cyclopentene	C ₅ H ₈	142290	68.119	0.4807	2.5159	1.5803	1.7454	718.37	150	0.4918	1500	2.5619
65	1-Methylcyclopentene	C ₆ H ₁₀	693890	82.145	0.6941	3.0209	1.6903	2.1209	781.56	200	0.7464	1500	3.1496
66	Cyclohexene	C ₆ H ₁₀	110838	82.145	0.5817	3.1717	1.5435	2.1273	701.62	150	0.5978	1500	3.2132
67	Benzene	C ₆ H ₆	71432	78.114	0.4442	2.3205	1.4946	1.7213	-678.15	200	0.5340	1500	2.4169
68	Toluene	C ₇ H ₈	108883	92.141	0.5814	2.8630	1.4406	1.8980	-650.43	200	0.7016	1500	3.0029
69	<i>o</i> -Xylene	C ₈ H ₁₀	95476	106.167	0.8521	3.2954	1.4944	2.1150	-675.8	200	0.9643	1500	3.5965
70	<i>m</i> -Xylene	C ₈ H ₁₀	108383	106.167	0.7568	3.3924	1.4960	2.2470	-675.9	200	0.8759	1500	3.5920
71	<i>p</i> -Xylene	C ₈ H ₁₀	106423	106.167	0.7512	3.3970	1.4928	2.2470	-675.1	200	0.8710	1500	3.5923
72	Ethylbenzene	C ₈ H ₁₀	100414	106.167	0.7844	3.3990	1.5590	2.4260	-702	200	0.8912	1500	3.6147
73	Propylbenzene (eqn. 3)	C ₉ H ₁₂	103651	120.194	-21.4827	3.8070	54701	-0.001713	0	200	1.0802	1500	4.1537
74	1,2,4-Trimethylbenzene	C ₉ H ₁₂	95636	120.194	1.0106	3.8314	1.5010	2.3950	678.3	200	1.1354	1500	4.1854
75	Isopropylbenzene	C ₉ H ₁₂	98528	120.194	1.0810	3.7932	1.7505	3.0027	794.8	200	1.1480	1500	4.1808
76	1,3,5-Trimethylbenzene	C ₉ H ₁₂	108678	120.194	0.9154	3.9270	1.4980	2.5090	676.9	200	1.0474	1500	4.1807
77	<i>p</i> -Isopropyltoluene	C ₁₀ H ₁₄	99876	134.221	1.3186	4.3036	1.7734	3.2570	811.9	200	1.3825	1500	4.7952
78	Naphthalene	C ₁₀ H ₈	91203	128.174	0.6805	3.5494	1.4262	2.5984	650.1	200	0.8454	1500	3.7359
79	Biphenyl	C ₁₂ H ₁₀	92524	154.211	0.9060	4.2634	1.4553	3.1550	661.2	200	1.0913	1500	4.5581
80	Styrene	C ₈ H ₈	100425	104.152	0.8930	2.1503	0.7720	0.9990	2442	100	0.8931	1500	3.2416
81	<i>m</i> -Terphenyl	C ₁₅ H ₁₄	92068	230.309	1.6397	6.0125	1.6902	5.1314	757.5	298.15	2.4618	1500	6.6678
82	Methanol	CH ₃ O	67561	32.042	0.3925	0.8790	1.9165	0.5365	896.7	200	0.3980	1500	1.0533
83	Ethanol	C ₂ H ₅ O	64175	46.069	0.4920	1.4577	1.6628	0.9390	744.7	200	0.5224	1500	1.6576
84	1-Propanol	C ₃ H ₈ O	71238	60.096	0.6190	2.0213	1.6293	1.2956	727.4	200	0.6665	1500	2.2458
85	1-Butanol	C ₄ H ₁₀ O	71363	74.123	0.7454	2.5907	1.6073	1.7320	712.4	200	0.8162	1500	2.8509
86	2-Butanol	C ₄ H ₁₀ O	78922	74.123	0.8202	2.5220	1.6010	1.5864	-704.15	200	0.8890	1500	2.8513
87	2-Propanol	C ₃ H ₈ O	67630	60.096	0.5723	1.9100	1.4210	1.2155	626	150	0.5924	1500	2.1792
88	2-Methyl-2-propanol	C ₄ H ₁₀ O	75650	74.123	0.7704	2.5390	1.5502	1.6690	-679.3	200	0.8567	1500	2.8508
89	1-Pentanol	C ₅ H ₁₂ O	71410	88.150	0.9060	3.0620	1.6054	2.1150	-717.97	200	0.9890	1500	3.4133
90	2-Methyl-1-butanol	C ₅ H ₁₂ O	137326	88.150	1.0890	2.1850	0.8530	1.4000	2906	298.15	1.3247	1500.1	3.4718
91	3-Methyl-1-butanol	C ₅ H ₁₂ O	123513	88.150	1.1060	2.2100	0.8760	1.2200	2940	298.15	1.3213	1200.15	3.1770
92	1-Hexanol	C ₆ H ₁₄ O	111273	102.177	1.0625	3.5210	1.5835	2.4620	715.75	200	1.1607	1500	3.9726
93	1-Heptanol	C ₇ H ₁₆ O	111706	116.203	1.2215	3.9910	1.5800	2.8350	717.7	200	1.3330	1500	4.5346
94	Cyclohexanol	C ₆ H ₁₂ O	108930	100.161	0.9043	2.5771	0.7882	1.3068	1952.2	200	0.9648	1500	3.8251
95	Ethylene glycol	C ₂ H ₆ O ₂	107211	62.068	0.8200	1.2780	1.6980	0.9290	-754	200	0.8481	1500	1.8521
96	1,2-Propylene glycol	C ₃ H ₈ O ₂	57556	76.095	2.0114	0.8082	1.8656	-2.4404	279.98	298.15	1.0218	1000.15	2.1175
97	Phenol	C ₆ H ₆ O	108952	94.113	0.4340	2.4450	1.1520	1.5120	-507	100	0.4401	1500	2.6045
98	<i>o</i> -Cresol	C ₇ H ₈ O	95487	108.140	0.7988	2.8530	1.4765	2.0420	-664.7	200	0.9158	1500	3.2163
99	<i>m</i> -Cresol	C ₇ H ₈ O	108394	108.140	0.7515	2.0900	0.6666	1.2120	2214	200	0.8701	1500	3.2075
100	<i>p</i> -Cresol	C ₇ H ₈ O	106445	108.140	0.7384	2.9080	1.4559	2.0910	-650.42	200	0.8707	1500	3.2102
101	Dimethyl ether	C ₂ H ₆ O	115106	46.069	0.5148	1.4420	1.6034	0.7747	725.4	200	0.5436	1500	1.6581
102	Methyl ethyl ether	C ₃ H ₈ O	540670	60.096	0.6868	1.9959	1.5534	1.1168	692.04	200	0.7396	1500	2.2931
103	Methyl- <i>n</i> -propyl ether	C ₄ H ₁₀ O	557175	74.123	0.9215	2.3943	1.6936	1.4896	797.79	298	1.1251	1200	2.6391
104	Methyl isopropyl ether	C ₄ H ₁₀ O	598538	74.123	0.8923	2.4765	1.6960	1.5598	791.4	200	0.9250	1500	2.8696
105	Methyl- <i>n</i> -butyl ether	C ₅ H ₁₂ O	628284	88.150	0.8205	3.0869	1.3864	1.7886	613.87	300	1.3300	1200	3.1994
106	Methyl isobutyl ether	C ₅ H ₁₂ O	625445	88.150	0.7284	3.1713	1.3520	1.8948	585.14	300	1.3200	1200	3.1987

TABLE 2-198 Heat Capacities of Inorganic and Organic Compounds in the Ideal Gas State (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol wt.	C1 × 1E-05	C2 × 1E-05	C3 × 1E-03	C4 × 1E-05	C5	T _{min} , K	C _p at T _{min} × 1E-05	T _{max} , K	C _p at T _{max} × 1E-05
107	Methyl tert-butyl ether	C ₅ H ₁₂ O	1634044	88.150	0.9933	3.0667	1.7426	2.0764	795.59	200	1.0394	1500	3.4321
108	Diethyl ether	C ₄ H ₁₀ O	60297	74.123	0.8621	2.5510	1.5413	1.4370	-688.9	200	0.9316	1500	2.9244
109	Ethyl propyl ether	C ₅ H ₁₂ O	628320	88.150	1.1320	2.9400	1.8270	2.0550	-852	298.15	1.3538	1500	3.4535
110	Ethyl isopropyl ether	C ₅ H ₁₂ O	625547	88.150	1.0953	3.0032	1.7988	2.1311	817.35	298.15	1.3620	1200	3.2289
111	Methyl phenyl ether	C ₇ H ₈ O	100663	108.140	0.7637	2.9377	1.6051	2.1700	751.2	300	1.1302	1200	3.0226
112	Diphenyl ether	C ₁₂ H ₁₀ O	101848	170.211	1.0985	4.3412	1.6222	3.6455	743.62	300	1.7298	1200	4.5143
113	Formaldehyde	CH ₂ O	50000	30.026	0.3327	0.4954	1.8666	0.2808	934.9	50	0.3327	1500	0.7113
114	Acetaldehyde	C ₂ H ₄ O	75070	44.053	0.4451	1.0687	1.6141	0.6135	737.8	200	0.4660	1500	1.2994
115	1-Propanal	C ₃ H ₆ O	123386	58.080	0.7174	1.9140	2.0144	1.1708	930.6	200	0.7266	1500	2.1149
116	1-Butanal	C ₄ H ₈ O	123728	72.107	0.8966	2.3731	1.9754	1.5866	904.13	200	0.9119	1500	2.6775
117	1-Pentanal	C ₅ H ₁₀ O	110623	86.134	1.0743	2.8363	1.9549	2.0146	890.44	200	1.0960	1500	3.2404
118	1-Hexanal	C ₆ H ₁₂ O	66251	100.161	1.2320	2.2146	0.8400	1.2190	2205	200	1.2672	1500	3.7314
119	1-Heptanal	C ₇ H ₁₄ O	111717	114.188	1.4040	2.5907	0.8315	1.3120	2201	200	1.4479	1500	4.2863
120	1-Octanal	C ₈ H ₁₆ O	124130	128.214	1.6088	4.2180	1.9126	3.2780	869	200	1.6504	1500	4.9286
121	1-Nonanal	C ₉ H ₁₈ O	124196	142.241	1.7347	4.5115	1.7120	3.3256	810.96	200	1.8005	1500	5.4439
122	1-Decanal	C ₁₀ H ₂₀ O	112312	156.268	1.9641	5.1412	1.8989	4.1278	862.51	200	2.0192	1500	6.0539
123	Acetone	C ₃ H ₆ O	67641	58.080	0.5704	1.6320	1.6070	0.9680	731.5	200	0.6049	1500	1.8820
124	Methyl ethyl ketone	C ₄ H ₈ O	78933	72.107	0.7840	2.1032	1.5488	1.1855	693	200	0.8397	1500	2.4816
125	2-Pentanone	C ₅ H ₁₀ O	107879	86.134	0.9005	2.7085	1.6592	1.8012	743.96	200	0.9591	1500	3.0797
126	Methyl isopropyl ketone	C ₅ H ₁₀ O	563804	86.134	1.5914	1.7640	1.2076	-407.4000	10.503	300	1.1291	1500	2.9991
127	2-Hexanone	C ₆ H ₁₂ O	591786	100.161	1.0940	1.8070	0.6890	1.4740	1772	200	1.1815	1200	3.3207
128	Methyl isobutyl ketone	C ₆ H ₁₂ O	108101	100.161	1.2270	2.1950	0.8420	1.1910	2460	298.15	1.4755	1500.15	3.6532
129	3-Methyl-2-pentanone	C ₆ H ₁₂ O	565617	100.161	1.0028	3.3169	1.6900	2.3000	770.7	300	1.3604	1200	3.4275
130	3-Pentanone	C ₅ H ₁₀ O	96220	86.134	0.9690	2.4907	1.4177	1.3010	646.7	200	1.0536	1500	3.0358
131	Ethyl isopropyl ketone	C ₆ H ₁₂ O	565695	100.161	1.2400	3.2000	1.9670	2.3460	896	298.15	1.4479	1200	3.4234
132	Diisopropyl ketone	C ₇ H ₁₄ O	565800	114.188	1.0869	4.0540	1.7802	2.9786	791.6	300	1.5102	1500	4.3093
133	Cyclohexanone	C ₆ H ₁₀ O	108941	98.145	0.5776	3.3535	1.2202	1.5700	586.92	200	0.7321	1500	3.4570
134	Methyl phenyl ketone	C ₈ H ₈ O	98862	120.151	0.8540	2.3340	0.8310	0.7730	2227	298.15	1.1313	1500	3.2797
135	Formic acid ¹	CH ₂ O ₂	64186	46.026	0.3381	0.7593	1.1925	0.3180	550	50	0.3381	1500	0.9933
136	Acetic acid ²	C ₂ H ₄ O ₂	64197	60.053	0.4020	1.3675	1.2620	0.7003	569.7	50	0.4020	1500	1.5756
137	Propionic acid ²	C ₃ H ₆ O ₂	79094	74.079	0.6959	1.7778	1.7098	1.2654	-763.78	298.15	0.8938	1500	2.1248
138	n-Butyric acid ²	C ₄ H ₈ O ₂	107926	88.106	1.4880	1.3522	1.1460	-678.0000	6.98	298.15	1.1533	1200.1	2.4716
139	Isobutyric acid ²	C ₄ H ₈ O ₂	79312	88.106	0.7469	2.4356	1.7150	1.8484	757.75	298.15	1.0427	1200	2.5383
140	Benzoic acid	C ₇ H ₆ O ₂	65850	122.123	0.7759	2.6455	1.7925	2.2382	835.9	200	0.8126	1500	2.9712
141	Acetic anhydride	C ₄ H ₆ O ₃	108247	102.090	0.7130	2.2220	1.6203	1.6760	746.5	200	0.7665	1500	2.5675
142	Methyl formate	C ₂ H ₄ O ₂	107313	60.053	0.5060	1.2190	1.6370	0.8940	743	250	0.5888	1500	1.5109
143	Methyl acetate	C ₃ H ₆ O ₂	79209	74.079	0.5550	1.7820	1.2600	0.8530	562	298	0.8489	1500	2.0754
144	Methyl propionate	C ₄ H ₈ O ₃	554121	88.106	0.7765	2.4420	1.7140	1.8180	716	300	1.1242	1200	2.5276
145	Methyl n-butyrate	C ₅ H ₁₀ O ₃	623427	102.133	0.8940	2.9100	1.5700	2.0730	678.3	298	1.3461	1200	3.0766
146	Ethyl formate	C ₃ H ₆ O ₂	109944	74.079	0.5370	1.8860	1.2070	0.8640	496	100	0.5412	1500	2.1485
147	Ethyl acetate	C ₄ H ₈ O ₂	141786	88.106	0.9981	2.0931	2.0226	1.8030	928.05	200	1.0126	1500	2.6594
148	Ethyl propionate	C ₅ H ₁₀ O ₃	105373	102.133	0.9370	2.8290	1.6480	2.1550	724.7	300	1.3377	1200	3.0569
149	Ethyl n-butyrate	C ₆ H ₁₂ O ₃	105544	116.160	1.1150	3.3910	1.6705	2.5180	733.6	298	1.5583	1200	3.6213
150	n-Propyl formate	C ₄ H ₉ O ₂	110747	88.106	0.8710	2.4470	1.9254	1.8880	-821.3	298.15	1.1022	1500	2.7484
151	n-Propyl acetate	C ₅ H ₁₀ O ₃	109604	102.133	1.7994	1.7530	1.1960	-4.1200	108.2	298.15	1.3594	1500	3.2024
152	n-Butyl acetate	C ₆ H ₁₂ O ₂	123864	116.160	1.1684	3.7690	1.9560	2.8180	811.2	300	1.5358	1200	3.6724
153	Methyl benzoate	C ₈ H ₈ O ₂	93583	136.150	0.9396	2.5590	0.8250	1.3600	3000	300	1.2586	1200	3.3569
154	Ethyl benzoate	C ₉ H ₁₀ O ₂	93890	150.177	1.0944	4.1794	0.8838	-1.6090	-1183.1	300	1.4598	1500	4.2540
155	Vinyl acetate	C ₄ H ₆ O ₂	108054	86.090	0.5360	2.1190	1.1980	1.1470	510	100	0.5404	1500	2.3750
156	Methylamine	CH ₅ N	74895	31.057	0.4100	1.0578	1.7080	0.6836	735	150	0.4136	1500	1.2388
157	Dimethylamine	C ₂ H ₇ N	124403	45.084	0.5565	1.6384	1.7341	1.0899	793.04	200	0.5812	1500	1.8585
158	Trimethylamine	C ₃ H ₉ N	75503	59.111	0.7107	1.5051	0.7966	0.8454	2187.6	200	0.7439	1500	2.4322
159	Ethylamine	C ₂ H ₇ N	75047	45.084	0.5940	1.6180	1.8120	1.0780	820	200	0.6139	1500	1.8528

160	Diethylamine	C ₄ H ₁₁ N	109897	73.138	0.9102	2.6740	1.7190	1.7926	794.94	200	0.9502	1500	3.0519
161	Triethylamine	C ₆ H ₁₅ N	121448	101.192	1.2766	2.5559	0.8094	1.4829	2231.7	200	1.3278	1500	4.2046
162	<i>n</i> -Propylamine	C ₃ H ₉ N	107108	59.111	0.7608	2.1049	1.7256	1.3936	789.03	200	0.7933	1500	2.4353
163	di- <i>n</i> -Propylamine	C ₆ H ₁₅ N	142547	101.192	1.2114	2.6127	0.7896	1.6903	2394.4	300	1.5900	1500	4.2484
164	Isopropylamine	C ₃ H ₉ N	75310	59.111	0.6855	2.1876	1.5831	1.3855	691.76	200	0.7510	1500	2.4540
165	Diisopropylamine	C ₆ H ₁₅ N	108189	101.192	1.1384	2.5747	0.7384	1.6200	2143	300	1.5995	1500	4.1941
166	Aniline	C ₆ H ₅ N	62533	93.128	0.6533	2.5192	1.4608	1.8870	-653.1	200	0.7705	1500	2.8047
167	<i>N</i> -Methylaniline	C ₇ H ₉ N	100618	107.155	0.7796	3.0280	1.5203	2.3280	699.8	300	1.2602	1500	3.3641
168	<i>N,N</i> -Dimethylaniline	C ₈ H ₁₁ N	121697	121.182	0.8742	2.7204	0.7242	1.1300	1949	300	1.3903	1500	3.8844
169	Ethylene oxide	C ₂ H ₄ O	75218	44.053	0.3346	1.2116	1.6084	0.8241	737.3	50	0.3346	1500	1.3297
170	Furan	C ₄ H ₆ O	110009	68.075	0.3727	1.6606	1.5112	1.3145	686	200	0.4376	1500	1.7940
171	Thiophene	C ₄ H ₆ S	110021	84.142	0.4040	1.6270	1.4564	1.3212	649	200	0.4884	1500	1.8097
172	Pyridine	C ₅ H ₅ N	110861	79.101	0.4413	2.0830	1.4783	1.5330	676.8	200	0.5220	1500	2.2194
173	Formamide	CH ₃ NO	75127	45.041	0.3822	0.9300	1.8450	0.6900	850	150	0.3833	1500	1.1203
174	<i>N,N</i> -Dimethylformamide	C ₃ H ₇ NO	68122	73.095	0.7220	1.7830	1.5320	1.3100	762	200	0.7594	1500	2.2596
175	Acetamide	C ₂ H ₅ NO	60355	59.068	0.3420	1.2940	1.0750	0.6400	502	100	0.3448	1500	1.4997
176	<i>N</i> -Methylacetamide	C ₃ H ₇ NO	79163	73.095	0.6116	2.0290	1.7683	1.3302	835.5	300	0.7698	1500	2.2209
177	Acetonitrile	C ₂ H ₃ N	75058	41.053	0.4191	0.8876	1.5818	0.5032	699.8	100	0.4192	1500	1.1285
178	Propionitrile	C ₃ H ₅ N	107120	55.079	0.5357	1.4617	1.5530	0.9120	678.2	200	0.5832	1500	1.7235
179	<i>n</i> -Butyronitrile	C ₄ H ₇ N	109740	69.106	0.6906	1.9996	1.5494	1.3146	675	200	0.7607	1500	2.3273
180	Benzonitrile	C ₇ H ₅ N	100470	103.123	0.7186	2.2700	1.4669	1.6930	-680.77	200	0.8053	1500	2.6706
181	Methyl mercaptan	CH ₃ S	74931	48.109	0.4146	0.8307	1.5890	0.4612	716.7	200	0.4329	1500	1.0781
182	Ethyl mercaptan	C ₂ H ₅ S	75081	62.136	0.5576	1.3617	1.5221	0.8073	687.5	200	0.5970	1500	1.6729
183	<i>n</i> -Propyl mercaptan	C ₃ H ₈ S	107039	76.163	0.7474	1.9523	1.6310	1.2112	750.92	200	0.7848	1500	2.3216
184	<i>n</i> -Butyl mercaptan	C ₄ H ₁₀ S	109795	90.189	0.9248	2.7795	1.6837	1.5974	758.68	200	0.9714	1500	3.1008
185	Isobutyl mercaptan	C ₄ H ₁₀ S	513440	90.189	0.9142	2.4513	1.6265	1.6157	745.8	200	0.9660	1500	2.9095
186	sec-Butyl mercaptan	C ₄ H ₁₀ S	513531	90.189	0.9237	2.5166	1.6109	1.5641	739.2	200	0.9763	1500	2.9615
187	Dimethyl sulfide	C ₃ H ₆ S	75183	62.136	0.6037	1.3747	1.6410	0.7988	-743.5	200	0.6298	1500	1.6949
188	Methyl ethyl sulfide	C ₃ H ₈ S	624895	76.163	0.7508	1.9577	1.6424	1.1949	749.19	273.16	0.9004	1500	2.3178
189	Diethyl sulfide	C ₄ H ₁₀ S	352932	90.189	0.9429	2.6863	1.7624	1.6752	-798.3	200	0.9794	1500	3.0338
190	Fluoromethane	CH ₃ F	593533	34.033	0.3329	0.7399	1.8639	0.4608	891.16	50	0.3329	1500	0.9024
191	Chloromethane	CH ₃ Cl	74873	50.488	0.3409	0.7246	1.7230	0.4480	780.5	150	0.3424	1500	0.9097
192	Trichloromethane	CHCl ₃	67663	119.377	0.3942	0.6573	0.9250	0.4930	399.6	100	0.4048	1500	1.0063
193	Tetrachloromethane	CCl ₄	56235	153.822	0.3758	0.7054	0.5121	0.4850	236.1	100	0.4730	1500	1.0662
194	Bromomethane	CH ₃ Br	74839	94.939	0.3377	0.7150	1.5780	0.4175	691.4	100	0.3378	1500	0.9107
195	Fluoroethane	C ₂ H ₂ F	353366	48.060	0.4437	1.3119	1.6422	0.8544	738.77	200	0.4726	1500	1.5008
196	Chloroethane	C ₂ H ₅ Cl	75003	64.514	0.4568	1.2967	1.5992	0.8590	708.8	100	0.4569	1500	1.5112
197	Bromoethane	C ₂ H ₅ Br	74964	108.966	0.4719	1.2787	1.5957	0.8517	703.87	200	0.5089	1500	1.5121
198	1-Chloropropane	C ₃ H ₇ Cl	540545	78.541	0.6210	1.8430	1.6290	1.2337	724	200	0.6674	1500	2.1126
199	2-Chloropropane	C ₃ H ₆ Cl	75296	78.541	0.6181	1.8023	1.5438	1.1893	685.93	200	0.6768	1500	2.1023
200	1,1-Dichloropropane	C ₃ H ₆ Cl ₂	78999	112.986	0.7145	1.7344	1.5240	1.2230	674.2	150	0.7268	1500	2.1609
201	1,2-Dichloropropane	C ₃ H ₅ Cl ₂	78875	112.986	0.7866	1.7429	1.7157	1.2627	765.1	200	0.8217	1500	2.1894
202	Vinyl chloride	C ₂ H ₃ Cl	75014	62.499	0.4236	0.8735	1.6492	0.6556	739.07	200	0.4457	1500	1.1423
203	Fluorobenzene	C ₆ H ₅ F	462066	96.104	0.6265	2.1646	1.5640	1.7278	-724.29	200	0.6914	1500	2.4736
204	Chlorobenzene	C ₆ H ₅ Cl	108907	112.558	0.8011	2.3100	2.1570	2.0460	-897.6	200	0.8219	1500	2.5327
205	Bromobenzene	C ₆ H ₅ Br	108861	157.010	0.7210	2.0640	1.6504	1.6870	765.3	200	0.7679	1500	2.4628
206	Air		132259100	28.951	0.2896	0.0939	3.0120	0.0758	1484	50	0.2896	1500	0.3496
207	Hydrogen ³	H ₂	1333740	2.016	0.2762	0.0956	2.4660	0.0376	567.6	250	0.2843	1500	0.3225
208	Helium-4 (eqn 2)	He	7440597	4.003	0.2079	0	0	0	0	100	0.2079	1500	0.2079
209	Neon	Ne	7440019	20.180	0.2079	0	0	0	0	100	0.2079	1500	0.2079
210	Argon	Ar	7440371	39.948	0.2079	0	0	0	0	100	0.2079	1500	0.2079
211	Fluorine	F ₂	7782414	37.997	0.2912	0.1013	1.4530	0.0941	662.91	50	0.2912	1500	0.3812

TABLE 2-198 Heat Capacities of Inorganic and Organic Compounds in the Ideal Gas State (Concluded)

Cmpd. no.	Name	Formula	CAS no.	Mol wt.	C1 × 1E-05	C2 × 1E-05	C3 × 1E-03	C4 × 1E-05	C5	T _{min} , K	C _p at T _{min} × 1E-05	T _{max} , K	C _p at T _{max} × 1E-05
212	Chlorine	Cl ₂	7782505	70.905	0.2914	0.0918	0.9490	0.1003	425	50	0.2914	1500	0.3793
213	Bromine	Br ₂	7726956	159.808	0.3011	0.0801	0.7514	0.1078	314.6	100	0.3090	1500	0.3794
214	Oxygen	O ₂	7782447	31.999	0.2910	0.1004	2.5265	0.0936	1153.8	50	0.2910	1500	0.3653
215	Nitrogen	N ₂	7727379	28.014	0.2911	0.0861	1.7016	0.0010	909.79	50	0.2911	1500	0.3484
216	Ammonia	NH ₃	7664417	17.031	0.3343	0.4898	2.0360	0.2256	882	100	0.3343	1500	0.6647
217	Hydrazine	N ₂ H ₄	302012	32.045	0.3871	0.8576	1.7228	0.5664	733.53	200	0.4070	1500	1.0571
218	Nitrous oxide	N ₂ O	10024972	44.013	0.2934	0.3236	1.1238	0.2177	479.4	100	0.2948	1500	0.5828
219	Nitric oxide (eqn 2)	NO	10102439	30.006	0.3498	-3.5320E-04	7.7290E-05	-5.7357E-10	1.4526E-08	100	0.3217	1500	0.3586
220	Cyanogen	C ₂ N ₂	460195	52.036	0.3545	0.5015	1.0570	0.4520	-396	100	0.3648	1500	0.8100
221	Carbon monoxide	CO	630080	28.010	0.2911	0.0877	3.0851	0.0846	1538.2	60	0.2911	1500	0.3521
222	Carbon dioxide	CO ₂	124389	44.010	0.2937	0.3454	1.4280	0.2640	588	50	0.2937	5000	0.6335
223	Carbon disulfide	CS ₂	75150	76.143	0.3010	0.3338	0.8960	0.2893	374.7	100	0.3100	1500	0.6148
224	Hydrogen fluoride	HF	7664393	20.006	0.2913	0.0933	2.9050	0.0020	1326	50	0.2913	1500	0.3224
225	Hydrogen chloride	HCl	7647010	36.461	0.2916	0.0905	2.0938	-0.0011	120	50	0.2914	1500	0.3406
226	Hydrogen bromide	HBr	10035106	80.912	0.2912	0.0953	2.1420	0.0157	1400	50	0.2912	1500	0.3479
227	Hydrogen cyanide	HCN	74908	27.026	0.3013	0.3171	1.6102	0.2179	626	100	0.3014	1500	0.5522
228	Hydrogen sulfide	H ₂ S	7783064	34.082	0.3329	0.2609	0.9134	-0.1798	949.4	100	0.3329	1500	0.5143
229	Sulfur dioxide	SO ₂	7446095	64.065	0.3338	0.2586	0.9328	0.1088	423.7	100	0.3354	1500	0.5695
230	Sulfur trioxide	SO ₃	7446119	80.064	0.3341	0.4968	0.8732	0.2856	393.74	100	0.3408	1500	0.7967
231	Water	H ₂ O	7732185	18.015	0.3336	0.2679	2.6105	0.0890	1169	100	0.3336	2273.15	0.5276

All substances are listed in alphabetical order in Table 2-6a.

Compiled from Daubert, T. E., R. P. Danner, H. M. Sibul, and C. C. Stebbins, DIPPR Data Compilation of Pure Compound Properties, Project 801 Sponsor Release, July, 1993, Design Institute for Physical Property Data, AIChE, New York, NY; and from Thermodynamics Research Center, "Selected Values of Properties of Hydrocarbons and Related Compounds," Thermodynamics Research Center Hydrocarbon Project, Texas A&M University, College Station, Texas (extant 1994).

Temperatures are expressed in kelvins; heat capacities, in J/kmol·K.

J/(kmol·K) × 2.390E-04 = cal/(gmol·°C); J/(kmol·K) × 2.390059E-04 = Btu/(lbmol·°F).

Use heat capacity = $C_1 + C_2 \left[\frac{C_3}{T} \sinh \left(\frac{C_3}{T} \right) \right]^2 + C_4 \left[\frac{C_5}{T} \cosh \left(\frac{C_5}{T} \right) \right]^2$ unless otherwise specified.

Equation 2 is heat capacity = $C_1 + C_2 \times T + C_3 \times T^2 + C_4 \times T^3 + C_5 \times T^4$.Equation 3 is heat capacity = $C_1 + C_2 \times \ln T + C_3/T + C_4 \times T$.¹ For the monomer. Monomer and dimer are in equilibrium below 600 K.² For the monomer.³ For equilibrium mixture of *ortho* and *para* hydrogen.

TABLE 2-199 C_p/C_v : Ratios of Specific Heats of Gases at 1-atm Pressure*

Compound	Formula	Tempera-ture, °C	Ratio of specific heats, $(\gamma) = C_p/C_v$	Compound	Formula	Tempera-ture, °C	Ratio of specific heats, $(\gamma) = C_p/C_v$
Acetaldehyde	$\text{C}_3\text{H}_4\text{O}$	30	1.14	Hydrogen (Cont.)			
Acetic acid	$\text{C}_2\text{H}_4\text{O}_2$	136	1.15	iodide	HI	20–100	1.40
Acetylene	C_2H_2	15	1.26	sulfide	H_2S	15	1.32
Air		-71	1.31			-45	1.30
		925	1.36			-57	1.29
		17	1.403				
		-78	1.408	Iodine	I_2	185	1.30
		-118	1.415	Isobutane	C_4H_{10}	15	1.11
Ammonia	NH_3	15	1.310	Krypton	Kr	19	1.68
Argon	A	15	1.668	Mercury	Hg	360	1.67
		-180	1.76 (?)	Methane	CH_4	600	1.113
Benzene	C_6H_6	90	1.10			300	1.16
Bromine	Br_2	20–350	1.32			15	1.31
Carbon dioxide	CO_2	15	1.304			-80	1.34
disulfide	CS_2	-75	1.37	Methyl acetate	$\text{C}_3\text{H}_6\text{O}_2$	-115	1.41
monoxide	CO	100	1.21	alcohol	CH_3O	15	1.14
		15	1.404	ether	$\text{C}_2\text{H}_5\text{O}$	77	1.203
		-180	1.41	Methylal	$\text{C}_3\text{H}_8\text{O}_2$	6–30	1.11
Chlorine	Cl_2	15	1.355			13	1.06
Chloroform	CHCl_3	100	1.15	Neon	Ne	40	1.09
Cyanogen	$(\text{CN})_2$	15	1.256	Nitric oxide	NO	19	1.64
Cyclohexane	C_6H_{12}	80	1.08			15	1.400
Dichlorodifluormethane	CCl_2F_2	25	1.139			-45	1.39
Ethane	C_2H_6	100	1.19	Nitrogen	N_2	-80	1.38
		15	1.22			15	1.404
		-82	1.28	Nitrous oxide	N_2O	-181	1.47
Ethyl alcohol	$\text{C}_2\text{H}_5\text{O}$	90	1.13			100	1.28
ether	$\text{C}_4\text{H}_{10}\text{O}$	35	1.08			15	1.303
		80	1.086			-30	1.31
Ethylene	C_2H_4	100	1.18	Oxygen	O_2	-70	1.34
		15	1.255			15	1.401
		-91	1.35			-76	1.415
						-181	1.45
Helium	He	-180	1.660	Pentane (n-)	C_5H_{12}	86	1.086
Hexane (n-)	C_6H_{14}	80	1.08	Phosphorus	P	300	1.17
Hydrogen	H_2	15	1.410	Potassium	K	850	1.77
		-76	1.453				
bromide	HBr	-181	1.597	Sodium	Na	750–920	1.68
chloride	HCl	20	1.42	Sulfur dioxide	SO_2	15	1.29
		15	1.41				
cyanide	HCN	100	1.40	Xenon	Xe	19	1.66
		65	1.31				
		140	1.28				
		210	1.24				

*From International Critical Tables, vol. 5, pp. 80–82.

TABLE 2-200 Specific Heat Ratio, C_p/C_v , for Air

Temperature, K	Pressure, bar															
	1	10	20	40	60	80	100	150	200	250	300	400	500	600	800	1000
150	1.410	1.510	1.668	2.333	4.120	3.973	3.202	2.507	2.243	2.091	1.988	1.851	1.768	1.712	1.654	1.639
200	1.406	1.452	1.505	1.630	1.781	1.943	2.093	2.274	2.236	2.140	2.050	1.920	1.832	1.771	1.682	1.619
250	1.403	1.429	1.457	1.517	1.577	1.640	1.699	1.816	1.877	1.896	1.885	1.836	1.782	1.743	1.681	1.636
300	1.402	1.418	1.436	1.470	1.505	1.537	1.570	1.640	1.687	1.716	1.730	1.727	1.707	1.683	1.645	1.619
350	1.399	1.411	1.422	1.446	1.467	1.488	1.509	1.553	1.589	1.612	1.627	1.640	1.638	1.629	1.605	1.585
400	1.395	1.404	1.412	1.429	1.444	1.460	1.472	1.505	1.529	1.548	1.563	1.579	1.584	1.580	1.567	1.555
450	1.392	1.397	1.404	1.416	1.428	1.438	1.449	1.471	1.490	1.505	1.518	1.533	1.541	1.542	1.537	1.528
500	1.387	1.391	1.395	1.406	1.414	1.421	1.430	1.448	1.463	1.474	1.484	1.499	1.507	1.510	1.510	1.504
600	1.377	1.378	1.382	1.386	1.392	1.398	1.403	1.413	1.423	1.432	1.439	1.448	1.457	1.461	1.465	1.466
800	1.353	1.355	1.357	1.359	1.361	1.365	1.366	1.372	1.375	1.381	1.384	1.392	1.397	1.401	1.406	1.409
1000	1.336	1.337	1.338	1.339	1.342	1.343	1.343	1.345	1.348	1.350	1.354	1.358	1.361	1.365	1.368	1.372

Calculated from C_p , C_v values of Sychev, V. V., A. A. Vasserman, et al., "Thermodynamic Properties of Air," Standartov, Moscow, 1978 and Hemisphere, New York, 1988 (276 pp.).

SPECIFIC HEATS OF AQUEOUS SOLUTIONS

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

$$^{\circ}\text{F} = \% \ ^{\circ}\text{C} + 32.$$

To convert calories per gram-degree Celsius to British thermal units per pound-degree Fahrenheit, multiply by 1.0.

TABLE 2-201 Acetic Acid (at 38°C)

Mole % acetic acid Cal/g °C	0 1.0	6.98 0.911	30.9 0.73	54.5 0.631	100 0.535
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TABLE 2-202 Ammonia

Mole % NH ₃	Specific heat, cal/g °C			
	2.4°C	20.6°C	41°C	61°C
0	1.01	1.0	0.995	1.0
10.5	0.98	0.995	1.06	1.02
20.9	.96	.99	1.03	
31.2	.956	1.0		
41.4	.985			

TABLE 2-203 Aniline (at 20°C)

Mol % aniline Cal/g °C	100 0.497	95 0.52	90.5 0.53	82.3 0.56	75.2 0.581
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TABLE 2-204 Copper Sulfate

Composition	Temperature	Specific heat, cal/g °C
CuSO ₄ + 50H ₂ O	12° to 15°C	0.848
CuSO ₄ + 200H ₂ O	12° to 14°C	.951
CuSO ₄ + 400H ₂ O	13° to 17°C	.975

TABLE 2-205 Ethyl Alcohol

Mole % C ₂ H ₅ OH	Specific heat, cal/g °C		
	3°C	23°C	41°C
4.16	1.05	1.02	1.02
11.5	1.02	1.03	1.03
37.0	0.805	0.86	0.875
61.0	.67	.727	.748
100.0	.54	.577	.621

TABLE 2-206 Glycerol

Mole % C ₃ H ₅ (OH) ₃	Specific heat, cal/g °C	
	15°C	32°C
2.12	0.961	0.960
4.66	.929	.924
11.5	.851	.841
22.7	.765	.758
43.9	.67	.672
100.0	.555	.576

TABLE 2-207 Hydrochloric Acid

Mole % HCl	Specific heat, cal/g °C				
	0°C	10°C	20°C	40°C	60°C
0.0	1.00				
9.09	0.72	0.72	0.74	0.75	0.78
16.7	.61	.605	.631	.645	.67
20.0	.58	.575	.591	.615	.638
25.9	.55				.61

ADDITIONAL REFERENCES

For additional data, see *International Critical Tables*, vol. 5, pp. 115–116, 122–125.

TABLE 2-208 Methyl Alcohol

Mole % CH ₃ OH	Specific heat, cal/g °C		
	5°C	20°C	40°C
5.88	1.02	1.0	0.995
12.3	0.975	0.982	.98
27.3	.877	.917	.92
45.8	.776	.811	.83
69.6	.681	.708	.726
100	.576	.60	.617

TABLE 2-209 Nitric Acid

% HNO ₃ by Weight	Specific Heat at 20°C, cal/g °C
0	1.000
10	0.900
20	.810
30	.730
40	.675
50	.650
60	.640
70	.615
80	.575
90	.515

TABLE 2-210 Phosphoric Acid*

% H ₃ PO ₄	C _p at 21.3°C cal/g °C	% H ₃ PO ₄	C _p at 21.3°C cal/g °C
2.50	0.9903	50.00	0.6350
3.80	.9970	52.19	.6220
5.33	.9669	53.72	.6113
8.81	.9389	56.04	.5972
10.27	.9293	58.06	.5831
14.39	.8958	60.23	.5704
16.23	.8796	62.10	.5603
19.99	.8489	64.14	.5460
22.10	.8300	66.13	.5349
24.56	.8125	68.14	.5242
25.98	.8004	69.97	.5157
28.15	.7856	69.50	.5160
29.96	.7735	71.88	.5046
32.09	.7590	73.71	.4940
33.95	.7432	75.79	.4847
36.26	.7270	77.69	.4756
38.10	.7160	79.54	.4680
40.10	.7024	80.00	.4686
42.08	.6877	82.00	.4593
44.11	.6748	84.00	.4500
46.22	.6607	85.98	.4419
48.16	.6475	88.01	.4359
49.79	.6370	89.72	.4206

*Z. Physik. Chem., A167, 42 (1933).

TABLE 2-211 Potassium Chloride

Mole % KCl	Specific heat, cal/g °C			
	6°C	20°C	33°C	40°C
0.99	0.945	0.947	0.947	0.947
3.85	.828	.831	.835	.837
5.66	.77	.775	.778	.775
7.41	.727			

TABLE 2-212 Potassium Hydroxide (at 19°C)

Mole % KOH Cal/g °C	0 1.0	0.497 0.975	1.64 0.93	4.76 0.814	9.09 0.75
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TABLE 2-213 Normal Propyl Alcohol

Mole % C ₃ H ₇ OH	Specific heat, cal/g °C		
	5°C	20°C	40°C
1.55	1.03	1.02	1.01
5.03	1.07	1.06	1.03
11.4	1.035	1.032	0.99
23.1	0.877	0.90	.91
41.2	.75	.78	.815
73.0	612	645	.708
100.0	.534	.57	.621

TABLE 2-214 Sodium Carbonate*

% Na ₂ CO ₃ by weight	Temperature, °C			
	17.6	30.0	76.6	98.0
0.000	0.9992	0.9986	1.0098	1.0084
1.498	.9807			
2.000		.9786		
2.901	.9597			
4.000		.9594		
5.000	.9428		0.9761	
6.000		.9392		
8.000	.9183			
10.000	.9086		.9452	
13.790	.8924			
13.840		.8881		
20.000		.8631		
25.000			.8936	
			.8615	0.8911

*J. Chem. Soc. 3062-3079 (1931).

TABLE 2-215 Sodium Chloride

Mole % NaCl	Specific heat, cal/g °C			
	6°C	20°C	33°C	57°C
0.249			0.99	
.99		0.96	.97	0.97
2.44		.91	.915	.915
9.09		.805	.81	.82

TABLE 2-216 Sodium Hydroxide (at 20°C)

Mole % NaOH Cal/g °C	0 1.0	0.5 0.985	1.0 0.97	9.09 0.835	16.7 0.80	28.6 0.784	37.5 0.782
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TABLE 2-217 Sulfuric Acid*

% H ₂ SO ₄	C _p at 20°C, cal/g °C	% H ₂ SO ₄	C _p at 20°C, cal/g °C
0.34	0.9968		35.25
0.68	.9937		.7023
1.34	.9877		.6770
2.65	.9762		.6476
3.50	.9688		.6153
5.16	.9549		.5801
9.82	.9177		.5420
15.36	.8767		.5012
21.40	.8339		.4628
22.27	.8275		.4518
23.22	.8205		.4481
24.25	.8127		.4467
25.39	.8041		.4408
26.63	.7945		.4346
28.00	.7837		.4016
29.52	.7717		.3787
30.34	.7647		.3554
31.20	.7579		.3404
33.11	.7422	100.00	.3352

*Vinal and Craig, Bur. Standards J. Research, **24**, 475 (1940).

TABLE 2-218 Zinc Sulfate

Composition	Temperature	Specific heat, cal/g °C
ZnSO ₄ + 50H ₂ O	20° to 52°C	0.842
ZnSO ₄ + 200H ₂ O	20° to 52°C	.952

SPECIFIC HEATS OF MISCELLANEOUS MATERIALS

TABLE 2-219 Specific Heats of Miscellaneous Liquids and Solids

Material	Specific heat, cal/g °C
Alumina	0.2 (100°C); 0.274 (1500°C)
Alundum	0.186 (100°C)
Asbestos	0.25
Asphalt	0.22
Bakelite	0.3 to 0.4
Brickwork	About 0.2
Carbon	0.168 (26° to 76°C) 0.314 (40° to 892°C) 0.387 (56° to 1450°C)
(gas retort) (see under Graphite)	0.204
Cellulose	0.32
Cement, Portland Clinker	0.186
Charcoal (wood)	0.242
Chrome brick	0.17
Clay	0.224
Coal	0.26 to 0.37
tar oils	0.34 (15° to 90°C)
Coal tars	0.35 (40°C); 0.45 (200°C)
Coke	0.265 (21° to 400°C) 0.359 (21° to 800°C) 0.403 (21° to 1300°C)
Concrete	0.156 (70° to 312°F); 0.219 (72° to 1472°F)
Cryolite	0.253 (16° to 55°C)
Diamond	0.147
Fireclay brick	0.198 (100°C); 0.298 (1500°C)
Fluorspar	0.21 (30°C)
Gasoline	0.53
Glass (crown) (flint) (pyrex) (silicate)	0.16 to 0.20 0.117 0.20 0.188 to 0.204 (0 to 100°C) 0.24 to 0.26 (0 to 700°C) 0.157
wool	0.20 (20° to 100°C)
Granite	0.165 (26° to 76°C); 0.390 (56° to 1450°C)
Graphite	0.259 (16° to 46°C)
Gypsum	0.47
Kerosene	0.217
Limestone	0.055
Litharge	0.234 (100°C); 0.188 (1500°C)
Magnesia	0.222 (100°C); 0.195 (1500°C)
Magnesite brick	0.21 (18°C)
Marble	0.189 (60°C)
Porcelain, fired Berlin	0.185 (60°C)
Porcelain, green Berlin	0.186 (60°C)
Porcelain, fired earthenware	0.181 (60°C)

TABLE 2-219 Specific Heats of Miscellaneous Liquids and Solids (Concluded)

Material	Specific heat, cal/g °C
Pyrex glass	0.20
Pyrites (copper)	0.131 (30°C)
Pyrites (iron)	0.136 (30°C)
Pyroxylon plastics	0.34 to 0.38
Quartz	0.17 (0°C); 0.28 (350°C)
Rubber (vulcanized)	0.415
Sand	0.191
Silica	0.316
Silica brick	0.202 (100°C); 0.195 (1500°C)
Silicon carbide brick	0.202 (100°C)
Silk	0.33
Steel	0.12
Stone	about 0.2
Stoneware (common)	0.188 (60°C)
Turpentine	0.42 (18°C)
Wood (Oak)	0.570
Woods, miscellaneous	0.45 to 0.65
Wool	0.325
Zirconium oxide	0.11 (100°C); 0.179 (1500°C)

TABLE 2-219a Oils (Animal, Vegetable, Mineral Oils)

$C_p[\text{cal}/(\text{g} \cdot \text{°C})] = A/\sqrt{d_4^{15}} + B(t - 15)$
 where d = density, g/cm³.
 $^{\circ}\text{F} = \frac{9}{5} \text{ °C} + 32$; to convert calories per gram-degree Celsius to British thermal units per pound-degree Fahrenheit, multiply by 1.0; to convert grams per cubic centimeter to pounds per cubic foot, multiply by 62.43.

Oils	A	B
Castor	0.500	0.0007
Citron		(0.438 at 54°C)
Fatty drying	0.440	0.0007
non-drying	0.450	0.0007
semidrying	0.445	0.0007
oils (except castor)	0.450	0.0007
Naphthene base	0.405	0.0009
Olive		(0.47 at 7°C)
Paraffin base	0.425	0.0009
Petroleum oils	0.415	0.0009

HEATS AND FREE ENERGIES OF FORMATION

UNITS CONVERSIONS

$^{\circ}\text{F} = \frac{9}{5} \text{ °C} + 32$; to convert kilocalories per gram-mole to British thermal units per pound-mole, multiply by 1.799×10^{-3} .

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds

The values given in the following table for the heats and free energies of formation of inorganic compounds are derived from (a) Bichowsky and Rossini, "Thermochemistry of the Chemical Substances," Reinhold, New York, 1936; (b) Latimer, "Oxidation States of the Elements and Their Potentials in Aqueous Solution," Prentice-Hall, New York, 1938; (c) the tables of the American Petroleum Institute Research Project 44 at the National Bureau of Standards; and (d) the tables of Selected Values of Chemical Thermodynamic Properties of the National Bureau of Standards. The reader is referred to the preceding books and tables for additional details as to methods of calculation, standard states, and so on.

Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation ¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation ¶ ΔF (formation) at 25°C, kcal/mole
Aluminum							
Al	c	0.00	0.00	Barium (Cont.)			
AlBr ₃	c	-123.4		BaF ₂	c	-287.9	
	aq	-209.5	-189.2	BaH ₂	aq, 1600	-284.6	-265.3
Al ₄ C ₃	c	-30.8	-29.0	Ba(HCO ₃) ₂	c	-40.8	-31.5
AlCl ₃	c	-163.8		BaI ₂	aq	-459	-414.4
	aq, 600	-243.9	-209.5		c	-144.6	
AlF ₃	c	-329		Ba(IO ₃) ₂	aq, 400	-155.17	-158.52
	aq	-360.8	-312.6		c	-264.5	
AlI ₃	c	-72.8		BaMoO ₄	c	-237.50	-198.35
	aq	-163.4	-152.5	Ba ₃ N ₂	c	-370	
AlN	c	-57.7	-50.4	Ba(NO ₃) ₂	c	-90.7	
Al(NH ₄)(SO ₄) ₂	c	-561.19	-486.17		c	-184.5	
Al(NH ₄)(SO ₄) ₂ ·12H ₂ O	c	-1419.36	-1179.26	Ba(NO ₃) ₂	aq	-179.05	-150.75
Al(NO ₃) ₃ ·6H ₂ O	c	-680.89	-526.32		c	-236.99	-189.94
Al(NO ₃) ₃ ·9H ₂ O	c	-897.59		BaO	aq, 600	-227.74	
Al ₂ O ₃	c, corundum	-399.09	-376.87	Ba(OH) ₂	c	-133.0	
Al(OH) ₃	c	-304.8	-272.9		c	-225.9	
Al ₂ O ₃ ·SiO ₂	c, sillimanite	-648.7		Ba ₄ O·SiO ₂	c	-237.76	-209.02
Al ₂ O ₃ ·SiO ₂	c, disthene	-642.4		Ba ₃ (PO ₄) ₂	c	-363	
Al ₂ O ₃ ·SiO ₂	c, andalusite	-642.0		BaPtCl ₆	c	-992	
3Al ₂ O ₃ ·2SiO ₂	c, mullite	-1874		BaS	c	-284.9	
Al ₂ S ₃	c	-121.6		BaSO ₃	c	-111.2	
Al ₂ (SO ₄) ₃	c	-820.99	-739.53	BaSO ₄	c	-282.5	
	aq	-893.9	-759.3	BaWO ₄	c	-340.2	-313.4
Al ₂ (SO ₄) ₃ ·6H ₂ O	c	-1268.15	-1103.39	Beryllium	c	-402	
Al ₂ (SO ₄) ₃ ·18H ₂ O	c	-2120		Be	c	0.00	0.00
Antimony				BeBr ₂	c	-79.4	
Sb	c	0.00	0.00	BeCl ₂	aq	-142	-127.9
SbBr ₃	c	-59.9			c	-112.6	
SbCl ₃	c	-91.3	-77.8	BeI ₂	aq	-163.9	-141.4
SbCl ₅	l	-104.8			c	-39.4	
SbF ₃	c	-216.6		Be ₃ N ₂	aq	-112	-103.4
SbI ₃	c	-22.8		BeO	c	-134.5	-122.4
Sb ₂ O ₃	c, I, orthorhombic	-165.4	-146.0	Be(OH) ₂	c	-145.3	-138.3
	c, II, octahedral	-166.6		BeS	c	-215.6	
Sb ₂ O ₄	c	-213.0	-186.6	BeSO ₄	c	-56.1	
Sb ₂ O ₅	c	-230.0	-196.1		c	-281	
Sb ₂ S ₃	c, black	-38.2	-36.9	aq		-254.8	
Arsenic				Bismuth			
As	c	0.00	0.00	Bi	c	0.00	0.00
AsBr ₃	c	-45.9		BiCl ₃	c	-90.5	-76.4
AsCl ₃	l	-80.2	-70.5		c	-101.6	
AsF ₃	l	-223.76	-212.27	BiI ₃	c	-24	
AsH ₃	g	43.6	37.7		c	-27	
AsI ₃	c	-13.6		BiO	c	-49.5	-43.2
As ₂ O ₃	c	-154.1	-134.8	Bi ₂ O ₃	c	-137.1	-117.9
As ₂ O ₅	c	-217.9	-183.9	Bi(OH) ₃	c	-171.1	
As ₂ S ₃	c	-20	-20	Bi ₂ S ₃	c	-43.9	-39.1
	amorphous	-34.76		Bi ₂ (SO ₄) ₃	c	-607.1	
Barium				Boron			
Ba	c	0.00	0.00	B	c	0.00	0.00
BaBr ₂	c	-180.38		BBR ₃	l	-52.7	
	aq, 400	-185.67	-183.0		g	-44.6	-50.9
BaCl ₂	c	-205.25		BCl ₃	g	-94.5	-90.8
	aq, 300	-207.92	-196.5	BF ₃	g	-265.2	-261.0
Ba(ClO ₃) ₂	c	-176.6		B ₂ H ₆	g	7.5	19.9
	aq, 1600	-170.0	-134.4	BN	c	-32.1	-27.2
Ba(ClO ₄) ₂	c	-210.2		B ₂ O ₃	c	-302.0	-282.9
	aq, 800	-	-155.3		gls	-297.6	-280.3
Ba(CN) ₂	c	-48		B(OH) ₃	c	-260.0	-229.4
Ba(CNO) ₂	c	-212.1		B ₂ S ₃	c	-56.6	
	aq	-	-180.7	Bromine	l	0.00	0.00
BaCN ₂	c	-63.6		Br ₂	g	7.47	0.931
BaCO ₃	c, witherite	-284.2	-271.4	BrCl	g	3.06	-0.63

*For footnotes see end of table.

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds (Continued)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole
Cadmium				Cesium (Cont.)			
Cd	c	0.00	0.00	Cs_2CO_3	c	-271.88	
CdBr_2	c	-75.8	-70.7	CsF	c	-131.67	
	aq, 400	-76.6	-67.6		aq, 400	-140.48	-135.98
CdCl_2	c	-92.149	-81.889	CsH	c	-12	-7.30
	aq, 400	-96.44	-81.2	CsHCO_3	c	-230.6	
$\text{Cd}(\text{CN})_2$	c	36.2			aq, 2000	-226.6	-210.56
CdCO_3	c	-178.2	-163.2	CsI	c	-83.91	
CdI_2	c	-48.40			aq, 400	-75.74	-82.61
	aq, 400	-47.46	-43.22	CsNH_3	c	-28.2	
Cd_3N_2	c	39.8		CsNO_3	c	-121.14	
$\text{Cd}(\text{NO}_3)_2$	aq, 400	-115.67	-71.05		aq, 400	-111.54	-96.53
CdO	c	-62.35	-55.28	Cs_2O	c	-82.1	
$\text{Cd}(\text{OH})_2$	c	-135.0	-113.7	CsOH	c	-100.2	
CdS	c	-34.5	-33.6		aq, 200	-117.0	-107.87
CdSO_4	c	-222.23		Cs_2S	c	-87	
	aq, 400	-232.635	-194.65	Cs_2SO_4	c	-344.86	
					aq	-340.12	-316.66
Calcium				Chlorine			
Ca	c	0.00	0.00	Cl_2	g	0.00	0.00
CaBr_2	c	-162.20		ClF	g	-25.7	
	aq, 400	-187.19	-181.86	ClO	g	33	
CaC_2	c	-14.8	-16.0	ClO_2	g	24.7	29.5
CaCl_2	c	-190.6	-179.8	ClO_3	g	37	
	aq	-209.15	-195.36	Cl_2O	g	18.20	22.40
CaCN_2	c	-85		Cl_2O_7	g	63	
$\text{Ca}(\text{CN})_2$	c	-43.3		Chromium			
	aq	-54.0		Cr	c	0.00	0.00
CaCO_3	c, calcite	-289.5	-270.8	CrBr_3	aq	-122.7	
	c, aragonite	-289.54	-270.57	Cr_3C_2	c	-21.008	-21.20
$\text{CaCO}_3\text{-MgCO}_3$	c	-558.8		Cr_4C	c	-16.378	-16.74
CaC_2O_4	c	-332.2		CrCl_2	c	-103.1	-93.8
$\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2$	c	-356.3			aq	-102.1	
	aq	-364.1	-311.3	CrF_2	c	-152	
CaF_2	c	-290.2		CrF_3	c	-231	
	aq	-286.5	-264.1	CrI_2	c	-63.7	-64.1
CaH_2	c	-46	-35.7		aq		
CaI_2	c	-128.49		CrO_3	c	-139.3	
	aq, 400	-156.63	-157.37	Cr_2O_3	c	-268.8	-249.3
Ca_3N_2	c	-103.2	-88.2	$\text{Cr}_2(\text{SO}_4)_3$	aq	-626.3	
$\text{Ca}(\text{NO}_3)_2$	c	-224.05	-177.38	Cobalt			
	aq, 400	-228.29		Co	c	0.00	0.00
$\text{Ca}(\text{NO}_3)_2\cdot 2\text{H}_2\text{O}$	c	-367.95	-293.57	CoBr_2	c	-55.0	
$\text{Ca}(\text{NO}_3)_2\cdot 3\text{H}_2\text{O}$	c	-439.05	-351.58		aq	-73.61	-61.96
$\text{Ca}(\text{NO}_3)_2\cdot 4\text{H}_2\text{O}$	c	-509.43	-409.32	Co_3C	c	9.49	7.08
CaO	c	-151.7	-144.3	CoCl_2	c	-76.9	-66.6
$\text{Ca}(\text{OH})_2$	c	-235.58	-213.9		aq, 400	-95.58	-75.46
	aq, 800	-239.2	-207.9	CoCO_3	c	-172.39	-155.36
$\text{CaO}\text{-SiO}_2$	c, II, wollastonite	-377.9	-357.5	CoF_2	aq	-172.98	-144.2
	c, I, pseudo-wollastonite	-376.6	-356.6	CoI_2	c	-24.2	
CaS	c	-114.3	-113.1		aq	-43.15	-37.4
CaSO_4	c, insoluble form	-338.73	-311.9	$\text{Co}(\text{NO}_3)_2$	c	-102.8	
	c, soluble form α	-336.58	-309.8		aq	-114.9	-65.3
	c, soluble form β	-335.52	-308.8	CoO	c	-57.5	
$\text{CaSO}_4\cdot \frac{1}{2}\text{H}_2\text{O}$	c	-376.13		Co_3O_4	c	-196.5	
$\text{CaSO}_4\cdot 2\text{H}_2\text{O}$	c	-479.33	-425.47	$\text{Co}(\text{OH})_2$	c	-131.5	-108.9
CaWO_4	c	-387		$\text{Co}(\text{OH})_3$	c	-177.0	-142.0
Carbon				CoS	c	-22.3	-19.8
C	c, graphite	0.00	0.00	Co_2S_3	c	-40.0	
	c, diamond	0.453	0.685	CoSO_4	c	-216.6	
					aq, 400	-188.9	
CO	g	-26.416	-32.808	Columbium			
CO_2	g	-94.052	-94.260	Cb	c	0.00	0.00
				Cb_2O_5	c	-462.96	
Cerium				Copper			
Ce	c	0.00	0.00	Cu	c	0.00	0.00
CeN	c	-78.2	-70.8	CuBr	c	-26.7	-23.8
Cesium				CuBr_2	c	-34.0	
Cs	c	0.00	0.00		aq	-42.4	-33.25
CsBr	c	-97.64		CuCl	c	-31.4	-24.13
	aq, 500	-91.39	-94.86	CuCl_2	c	-48.83	
CsCl	c	-106.31			aq, 400	-64.7	
	aq, 400	-102.01	-101.61				

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds (Continued)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole
Copper (Cont.)				Hydrogen (Cont.)			
CuClO_4	aq	-28.3	1.34	H_2CO_3	aq	-167.19	-149.0
$\text{Cu}(\text{ClO}_3)_2$	aq, 400		15.4	HF	g	-64.2	-64.7
$\text{Cu}(\text{ClO}_4)_2$	aq		-5.5		aq, 200	-75.75	
CuI	c	-17.8	-16.66	HI	g	6.27	0.365
CuI_2	c		-4.8		aq, 400	-13.47	-12.35
	aq		-11.9	HIO	aq	-38	-23.33
Cu_3N	c		17.78	HIO_3	c	-56.77	
$\text{Cu}(\text{NO}_3)_2$	c		-73.1		aq	-54.8	-32.25
	aq, 200		-83.6	HN_3	g	70.3	78.50
CuO	c		-38.5	HNO_3	g	-31.99	-17.57
Cu_2O	c		-43.00		f	-41.35	-19.05
$\text{Cu}(\text{OH})_2$	c		-108.9	$\text{HNO}_3 \cdot \text{H}_2\text{O}$	aq, 400	-49.210	
CuS	c		-11.6	$\text{HNO}_3 \cdot 3\text{H}_2\text{O}$	I	-112.91	-78.36
Cu_2S	c		-18.97	H_2O	I	-252.15	-193.70
CuSO_4	c		-184.7		g	-57.7979	-54.6351
	aq, 800		-200.78		f	-68.3174	-56.6899
Cu_2SO_4	c		-160.19	H_2O_2	I	-45.16	-28.23
	aq		-179.6		aq, 200	-45.80	-31.47
			-152.0	H_3PO_2	c	-145.5	
Erbium				H_3PO_3	aq	-145.6	-120.0
Er	c	0.00	0.00		c	-232.2	
$\text{Er}(\text{OH})_3$	c	-326.8		H_3PO_4	aq	-232.2	-204.0
Fluorine					c	-306.2	
F_2	g	0.00	0.00	H_2S	aq, 400	-309.32	-270.0
F_2O	g	5.5	9.7		g	-4.77	-7.85
Gallium				H_2S_2	g	-9.38	
Ga	c	0.00	0.00	H_2SO_3	aq, 2000	-3.6	
GaBr_3	c	-92.4		H_2SO_4	I	-146.88	-128.54
GaCl_3	c	-125.4			aq, 200	-193.69	
GaN	c	-26.2		H_2Se	aq, 400	-212.03	
Ga_2O	c	-84.3			g	20.5	17.0
Ga_2O_3	c	-259.9		H_2SeO_3	aq	18.1	18.4
Germanium				H_2SeO_4	c	-126.5	
Ge	c	0.00	0.00		aq	-122.4	-101.36
Ge_3N_4	c	-15.7			c	-130.23	
GeO_2	c	-128.6		Au	aq, 400	-143.4	
Gold				H_2SiO_3	c	-267.8	-247.9
Au	c	0.00	0.00	H_4SiO_4	c	-340.6	
AuBr	c	-3.4		H_2Te	g	36.9	33.1
AuBr_3	c	-14.5		H_2TeO_3	c	-145.0	-115.7
	aq	-11.0	24.47	H_2TeO_4	aq	-145.0	
AuCl	c	-8.3		In	c	0.00	0.00
AuCl_3	c	-28.3		InBr_3	c	-97.2	
	aq	-32.96	4.21	InCl_3	aq	-112.9	-97.2
AuI	c	0.2	-0.76	InI_3	c	-128.5	
Au_2O_3	c	11.0	18.71		aq	-145.6	-117.5
$\text{Au}(\text{OH})_3$	c	-100.6		Iodine	c	-56.5	
Hafnium				I_2	c	-67.2	-60.5
Hf	c	0.00	0.00		g	0.00	0.00
HfO_2	c	-271.1	-258.2	InCl_3	c	14.88	4.63
Hydrogen				InI_3	g	10.05	1.24
H_3AsO_3	aq	-175.6	-153.04		g	4.20	-1.32
H_3AsO_4	c	-214.9		IBr	c	-21.8	-6.05
	aq	-214.8	-183.93	ICl	c	-42.5	
HBr	g	-8.66	-12.72	ICl_3	c	0.00	0.00
	aq, 400	-28.80	-24.58	I_2O_5	c	14.88	
HBrO	aq	-25.4	-19.90		c	10.05	
HBrO_3	aq	-11.51	5.00	Ir	c	4.20	
HCl	g	-22.063	-22.778	IrCl	c	-21.8	
	aq, 400	-39.85	-31.330	IrCl_3	c	-60.5	
HCN	g	31.1	27.94	IrF_6	l	-130	
	aq, 100	24.2	26.55	IrO_2	c	-40.14	
HClO	aq, 400	-28.18	-19.11	Iron	c, α	0.00	0.00
HClO_3	aq	-23.4	-0.25	Fe	c	-20.5	-16.9
HClO_4	aq, 660	-31.4	-10.70	FeBr_2	c	-40.6	-32.0
$\text{HC}_2\text{H}_3\text{O}_2$	l	-116.2	-93.56		c	-60.5	-46.5
	aq, 400	-116.74	-96.8		c	-57.15	
$\text{H}_2\text{C}_2\text{O}_4$	c	-196.7			c	-78.7	-69.47
HCOOH	aq, 300	-194.6	-165.64		aq, 540	0.00	
	l	-97.8	-82.7			-78.7	
	aq, 200	-98.0	-85.1				

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds (Continued)

Compound	State†	Heat of formation‡ § ΔH (formation) at 25°C, kcal/mole	Free energy of formation ¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡ § ΔH (formation) at 25°C, kcal/mole	Free energy of formation ¶ ΔF (formation) at 25°C, kcal/mole
Iron (Cont.)				Lithium (Cont.)			
FeBr ₃	aq	-95.5	-76.26	LiC ₂ H ₅ O ₂	aq	-183.9	-160.00
Fe ₃ C	c	5.69	4.24	Li ₂ CO ₃	c	-289.7	-269.8
Fe(CO) ₅	l	-187.6			aq, 1900	-293.1	-267.58
FeCO ₃	c, siderite	-172.4	-154.8	LiCl	c	-97.63	
FeCl ₂	c	-81.9	-72.6		aq, 278	-106.45	-102.03
FeCl ₃	aq	-100.0	-83.0	LiClO ₃	aq	-87.5	-70.95
	c	-96.4		LiClO ₄	aq	-106.3	-81.4
FeF ₂	aq, 2000	-128.5	-96.5	LiF	c	-145.57	
FeI ₂	aq, 1200	-177.2	-151.7		aq, 400	-144.85	-136.40
FeI ₃	c	-24.2		LiH	c	-22.9	
Fe ₂ I ₉	aq	-47.7	-45	LiHCO ₃	aq, 2000	-231.1	-210.98
Fe ₂ N	c	-49.7	-39.5	LiI	c	-65.07	
Fe(NO ₃) ₂	aq	-2.55	0.862		aq, 400	-80.09	-83.03
Fe(NO ₃) ₃	aq, 800	-118.9	-72.8	LiIO ₃	aq	-121.3	-102.95
FeO	c	-156.5	-81.3	Li ₃ N	c	-47.45	-37.33
Fe ₂ O ₃	c	-64.62	-59.38	LiNO ₃	c	-115.350	
Fe ₃ O ₄	c	-198.5	-179.1		aq, 400	-115.88	-96.95
Fe(OH) ₂	c	-266.9	-242.3	Li ₂ O	c	-142.3	
Fe(OH) ₃	c	-135.9	-115.7	Li ₂ O ₂	c	-151.9	-138.0
FeO·SiO ₂	c	-197.3	-166.3		aq	-159	
Fe ₂ P	c	-273.5		LiOH	c	-116.58	-106.44
FeSi	c	-13			aq, 400	-121.47	-108.29
FeS	c	-19.0		LiOH·H ₂ O	c	-188.92	
FeS ₂	c, pyrites	-22.64	-23.23	Li ₂ O·SiO ₂	gls	-374	
	c, marcasite	-38.62	-35.93	Li ₂ Se	c	-84.9	
FeSO ₄	c	-33.0			aq	-95.5	
	c	-221.3	-195.5	Li ₂ SO ₄	c	-340.23	-314.66
Fe ₂ (SO ₄) ₃	aq, 400	-236.2	-196.4		aq, 400	-347.02	
FeTiO ₃	c, ilmenite	-653.3	-533.4	Li ₂ SO ₄ ·H ₂ O	c	-411.57	-375.07
Lanthanum				Magnesium			
La	c	0.00	0.00	Mg	c	0.00	0.00
LaCl ₃	c	-253.1		Mg(AsO ₄) ₂	c	-731.3	
La ₂ H ₈	aq	-284.7		MgBr ₂	aq	-749	-630.14
LaN	c	-160			c	-123.9	
La ₂ O ₃	c	-72.0	-64.6	Mg(CN) ₂	aq, 400	-167.33	-156.94
LaS ₂	c	-539		MgCN ₂	aq	-39.7	-29.08
La ₂ S ₃	c	-148.3		Mg(C ₂ H ₃ O ₂) ₂	c	-61	
La ₂ (SO ₄) ₃	c	-351.4		MgCO ₃	aq	-344.6	-286.38
Lead	aq	-972		MgCl ₂	c	-261.7	-241.7
Pb	c	0.00	0.00		c	-153.220	-143.77
PbBr ₂	c	-66.24	-62.06		aq, 400	-189.76	
PbCO ₃	c, cerussite	-167.6	-150.0	MgCl ₂ ·H ₂ O	c	-230.970	-205.93
Pb(C ₂ H ₃ O ₂) ₂	c	-232.6		MgCl ₂ ·2H ₂ O	c	-305.810	-267.20
	c, 400	-234.2	-184.40	MgCl ₂ ·4H ₂ O	c	-453.820	-387.98
PbC ₂ O ₄	c	-205.3		MgCl ₂ ·6H ₂ O	c	-597.240	-505.45
PbCl ₂	c	-55.68	-75.04	MgF ₂	c	-263.8	
	c	-82.5	-68.47	MgI ₂	c	-86.8	
PbF ₂	c	-159.5	-148.1		aq, 400	-136.79	-132.45
PbI ₂	c	-41.77	-41.47	MgMoO ₄	c	-329.9	
Pb(NO ₃) ₂	c	-106.88		Mg ₃ N ₂	c	-115.2	-100.8
	c, 400	-99.46	-58.3	Mg(NO ₃) ₂	c	-188.770	-140.66
PbO	c, red	-51.72	-45.53	Mg(NO ₃) ₂ ·2H ₂ O	c, 400	-209.927	-160.28
	c, yellow	-50.86	-43.88	Mg(NO ₃) ₂ ·6H ₂ O	c	-336.625	
PbO ₂	c	-65.0	-52.0	MgO	c	-624.48	-496.03
Pb ₂ O ₇	c	-172.4	-142.2	MgO·SiO ₂	c	-143.84	-136.17
Pb(OH) ₂	c	-123.0	-102.2	Mg(OH) ₂	c, ppt.	-347.5	-326.7
PbS	c	-22.38	-21.98		c, brucite	-221.90	-200.17
PbSO ₄	c	-218.5	-192.9	MgS	c	-223.9	-193.3
Lithium					c	-84.2	
Li	c	0.00	0.00	MgSO ₄	c, aq	-108	
LiBr	c	-83.75			c, 400	-304.94	-277.7
	c, 400	-95.40	-95.28	MgTe	c	-325.4	-283.88
LiBrO ₃	c	-77.9	-65.70	MgWO ₄	c	-25	
Li ₂ C ₂	c	-13.0		Manganese	c	-345.2	
LiCN	c	-31.4	-31.35	Mn	c, α	0.00	0.00
LiCNO	c	-101.2	-94.12	MnBr ₂	c	-91	
	c			Mn ₃ C	c, aq	-106	-97.8
					c	1.1	1.26

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds (Continued)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole
Manganese (Cont.)				Nickel (Cont.)			
Mn(C ₂ H ₃ O ₂) ₂	c	-270.3		NiF ₂	aq, 400	-94.34	-74.19
	aq	-282.7	-227.2		c	-157.5	
MnCO ₃	c	-211	-192.5		aq	-171.6	-142.9
Mn ₂ O ₄	c	-240.9		NiI ₂	c	-22.4	
MnCl ₂	c	-112.0	-102.2		aq	-42.0	-36.2
	aq, 400	-128.9		Ni(NO ₃) ₂	c	-101.5	
MnF ₂	aq, 1200	-206.1	-180.0		aq, 200	-113.5	-64.0
MnI ₂	c	-49.8		NiO	c	-58.4	-51.7
	aq	-76.2	-73.3	Ni(OH) ₂	c	-129.8	-105.6
Mn ₅ N ₂	c	-57.77	-46.49	Ni(OH) ₃	c	-163.2	
Mn(NO ₃) ₂	c	-134.9		NiS	c	-20.4	
	aq, 400	-148.0	-101.1	NiSO ₄	c	-216	
Mn(NO ₃) ₂ .6H ₂ O	c	-557.07	-441.2		aq, 200	-231.3	-187.6
MnO	c	-92.04	-86.77	Nitrogen			
MnO ₂	c	-124.58	-111.49	N ₂	g	0.00	0.00
Mn ₂ O ₃	c	-229.5	-209.9	NF ₃	g	-27	
Mn ₃ O ₄	c	-331.65	-306.22	NH ₃	g	-10.96	-3.903
MnO ₂ SiO ₂	c	-301.3	-282.1		aq, 200	-19.27	
Mn(OH) ₂	c	-163.4	-143.1	NH ₄ Br	c	-64.57	
Mn(OH) ₃	c	-221	-190		aq	-60.27	-43.54
Mn ₃ (PO ₄) ₂	c	-736		NH ₄ C ₂ H ₃ O ₂	c	-148.1	
MnSe	c	-26.3	-27.5		aq, 400	-148.58	-108.26
MnS	c, green	-47.0	-48.0	NH ₄ CN	c	-0.7	
MnSO ₄	c	-254.18	-228.41		aq	3.6	20.4
	aq, 400	-265.2		NH ₄ CNS	c	-17.8	
Mn ₂ (SO ₄) ₃	c	-635			aq	-12.3	4.4
	aq	-657		(NH ₄) ₂ CO ₃	aq	-233.4	-164.1
Mercury				(NH ₄) ₂ C ₂ O ₄	c	-266.3	
Hg	l	0.00	0.00		aq	-260.6	-196.2
HgBr	g	23	18	NH ₄ Cl	c	-75.23	-48.59
HgBr ₂	c	-40.68	-38.8		aq, 400	-71.20	
	aq	-38.4	-9.74	NH ₄ ClO ₄	c	-69.4	
Hg(C ₂ H ₃ O ₂) ₂	c	-196.3			c	-63.2	-21.1
	aq	-192.5	-139.2	(NH ₄) ₂ CrO ₄	aq	-276.9	
HgCl ₂	c	-53.4	-42.2		c	-271.3	-209.3
	aq	-50.3	-23.25	NH ₄ F	c	-111.6	
HgCl	g	19	14		aq	-110.2	-84.7
Hg ₂ Cl ₂	c	-63.13		NH ₄ I	c	-48.43	
Hg(CN) ₂	c	62.8			aq	-44.97	-31.3
	aq, 1110	66.25		NH ₄ NO ₃	c	-87.40	
HgC ₂ O ₄	c	-159.3			aq, 500	-80.89	
HgH	g	57.1	52.25	NH ₄ OH	aq	-87.59	
HgI ₂	c, red	-25.3	-24.0	(NH ₄) ₂ S	aq, 400	-55.21	-14.50
HgI	g	33	23	(NH ₄) ₂ SO ₄	c	-281.74	-215.06
Hg ₂ I ₂	c	-28.88	-26.53		aq, 400	-279.33	-214.02
Hg(NO ₃) ₂	aq	-56.8	-13.09	N ₂ H ₄	l	12.06	
Hg ₂ (NO ₃) ₂	aq	-58.5	-15.65	N ₂ H ₄ ·H ₂ O	l	-57.96	
HgO	c, red	-21.6	-13.94	N ₂ H ₄ ·H ₂ SO ₄	c	-232.2	
	c, yellow ppt.	-20.8		N ₂ O	g	19.55	24.82
Hg ₂ O	c	-21.6	-12.80	NO	g	21.600	20.719
Hg ₂ S	c, black	-10.7	-8.80	NO ₂	g	7.96	12.26
HgSO ₄	c	-166.6		N ₂ O ₄	g	2.23	23.41
Hg ₂ SO ₄	c	-177.34	-149.12	N ₂ O ₅	c	-10.0	
Molybdenum				NOBr	l	11.6	19.26
Mo	c	0.00	0.00	NOCl	g	12.8	16.1
Mo ₂ C	c	4.36	2.91	Osmium			
Mo ₂ N	c	-8.3		Os	c	0.00	0.00
MoO ₃	c	-130	-118.0	OsO ₄	c	-93.6	-70.9
MoO ₂	c	-180.39	-162.01		g	-80.1	-68.1
MoS ₂	c	-56.27	-54.19	Oxygen			
MoS ₃	c	-61.48	-57.38	O ₂	g	0.00	0.00
Nickel				O ₃	g	33.88	38.86
Ni	c	0.00	0.00	Palladium			
NiBr ₂	c	-53.4		Pd	c	0.00	0.00
	aq	-72.6	-60.7	PdO	c	-20.40	
Ni ₃ C	c	9.2	8.88	Phosphorus			
Ni(C ₂ H ₃ O ₂) ₂	aq	-249.6	-190.1	P	c, white ("yellow")	0.00	0.00
Ni(CN) ₂	aq	230.9	66.3		c, red ("violet")	-4.22	-1.80
NiCl ₂	c	-75.0		P	g	150.35	141.88

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds (Continued)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole
Phosphorus (Cont.)				Potassium (Cont.)			
P ₂	g	33.82	24.60	KNH ₂	c	-28.25	
P ₄	g	13.2	5.89	KNO ₂	aq	-86.0	-75.9
PBr ₃	I	-45		KNO ₃	c	-118.08	-94.29
PBr ₅	c	-60.6		K ₂ O	aq, 400	-109.79	-93.68
PCl ₃	I	-70.0	-65.2	K ₂ O·Al ₂ O ₃ ·SiO ₂	c	-86.2	
PCl ₅	g	-76.8	-63.3	c, leucite	gls	-1379.6	
PH ₃	g	-91.0	-73.2	K ₂ O·Al ₂ O ₃ ·SiO ₂	c, adularia	-1368.2	
PI ₃	c	2.21	-1.45	c, microcline	gls	-1784.5	
P ₂ O ₅	c	-10.9		KOH	c	-1747	
POCl ₃	g	-360.0		c	-102.02		
Platinum			-127.2	aq, 400	c	-114.96	-105.0
Pt	c	0.00	0.00	K ₃ PO ₃	aq	-397.5	
PtBr ₄	c	-40.6		K ₃ PO ₄	aq	-478.7	-443.3
PtCl ₂	aq	-50.7		KH ₂ PO ₄	c	-362.7	-326.1
PtCl ₄	c	-34		K ₂ PtCl ₄	c	-254.7	
PtI ₄	c	-62.6		c	-242.6	-226.5	
Pt(OH) ₂	c	-82.3		K ₂ PtCl ₆	c	-299.5	-263.6
PtS	c	-18		c	-286.1		
PtS ₂	c	-87.5	-67.9	aq, 9400	c	-74.4	
Potassium				K ₂ Se	aq	-83.4	-99.10
K	c	-20.18		K ₂ SeO ₄	aq	-267.1	-240.0
K ₃ AsO ₃	aq	-26.64		K ₂ S	c	-121.5	
K ₃ AsO ₄	aq	-323.0		c	-110.75	-111.44	
KH ₂ AsO ₄	c	-390.3	-355.7	K ₂ SO ₃	c	-267.7	
KBr	c	-271.2	-236.7	c	-269.7	-251.3	
KBrO ₃	c	-94.06	-90.8	K ₂ SO ₄	c	-342.65	-314.62
KBrO ₃	c	-89.19	-92.0	c	-336.48	-310.96	
KC ₂ H ₅ O ₂	c	-81.58	-60.30	c	-1178.38	-1068.48	
KCl	c	-1667		K ₂ SO ₄ ·Al ₂ (SO ₄) ₃	c	-2895.44	-2455.68
KClO ₃	c	-71.68		24H ₂ O	c	-418.62	
KClO ₄	c	-173.80		K ₂ S ₂ O ₆	c		
KCN	c	-177.38	-156.73	Rhenium			
KCNO	c	-104.348	-97.76	Re	c	0.00	0.00
KCNS	c	-100.164	-98.76	ReF ₆	g	-274	
KClO ₄	c	-93.5	-69.30	Rhodium			
KClO ₄	c	-81.34		Rh	c	0.00	0.00
KCN	c	-103.8	-72.86	RhO	c	-21.7	
KCNO	c	-101.14		Rh ₂ O	c	-22.7	
KCNS	c	-28.1		Rh ₃ O ₃	c	-68.3	
K ₂ CO ₃	c	-25.3	-28.08	Rubidium			
K ₂ CO ₃	c	-99.6		Rb	c	0.00	0.00
K ₂ C ₂ O ₄	c	-94.5	-90.85	RbBr	c	-95.82	
K ₂ CrO ₄	c	-47.0		c	-45.0	-52.50	
K ₂ Cr ₂ O ₇	c	-41.07	-44.08	c	-90.54	-93.38	
K ₂ Cr ₂ O ₇	c	-274.01		RbCN	c	-25.9	
K ₂ Cr ₂ O ₇	c	-280.90	-264.04	Rb ₂ CO ₃	c	-273.22	
KF	c	-319.9		c	-282.61	-263.78	
K ₂ Cr ₂ O ₇	c	-315.5	-293.1	RbCl	c	-105.06	-98.48
K ₂ Cr ₂ O ₇	c	-333.4		c	-53.6	-57.9	
K ₂ Cr ₂ O ₇	c	-328.2	-306.3	c	-101.06	-100.13	
K ₂ Cr ₂ O ₇	c	-488.5		RbF	c	-133.23	
K ₂ Cr ₂ O ₇	c	-472.1	-440.9	c	-139.31	-134.5	
K ₂ Cr ₂ O ₇	c	-134.50		RbHCO ₃	c	-230.01	
K ₃ Fe(CN) ₆	c	-138.36	-133.13	c	-225.59	-209.07	
K ₃ Fe(CN) ₆	c	-48.4		RbI	c	-81.04	
K ₄ Fe(CN) ₆	c	-34.5		c	-31.2	-40.5	
KH	c	-131.8		c	-74.57	-81.13	
KHCO ₃	c	-119.9		RbNH ₂	c	-27.74	
KHCO ₃	c	-10	-5.3	RbNO ₃	c	-119.22	
KI	c	-299.8		c	-400	-110.52	-95.05
KI	c	-224.85	-207.71	Rb ₂ O	c	-82.9	
KI	c	-78.88	-77.37	Rb ₂ O ₂	c	-107	
KIO ₃	c	-73.95	-79.76	RbOH	c	-101.3	
KIO ₃	c	-121.69	-101.87	c	-200	-115.8	-106.39
KIO ₄	c	-115.18	-99.68	Ruthenium			
KMnO ₄	c	-98.1		Ru	c	0.00	0.00
K ₂ MoO ₄	c	-192.9	-169.1	RuS ₂	c	-46.99	-44.11
K ₂ MoO ₄	c	-182.5	-168.0	Selenium			
K ₂ MoO ₄	c	-364.2	-342.9	Se	c, I, hexagonal	0.00	0.00

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds (Continued)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole
Selenium (Cont.)				Sodium (Cont.)			
Se ₂ Cl ₂	c, II, red, monoclinic	0.2		Na ₂ CrO ₄	aq, 476	-97.66	-73.29
SeF ₆	l	-22.06	-13.73		c	-319.8	
SeO ₂	g	-246	-222	Na ₂ Cr ₂ O ₇	aq, 800	-323.0	-296.58
Silicon	c	-56.33		NaF	aq, 1200	-465.9	-431.18
Si	c	0.00	0.00		c	-135.94	-129.0
SiBr ₄	l	-93.0			aq, 400	-135.711	-128.29
SiC	c	-28	-27.4	NaH	c	-14	-9.30
SiCl ₄	l	-150.0	-133.9	NaHCO ₃	c	-226.0	-202.66
	g	-142.5	-133.0	NaI	aq	-222.1	-202.87
SiF ₄	g	-370	-360	NaIO ₃	aq, ∞	-71.10	-74.92
SiH ₄	g	-14.8	-9.4	Na ₂ MoO ₄	aq, 400	-112.300	-94.84
SiL ₄	c	-29.8			c	-364	
Si ₃ N ₄	c	-179.25	-154.74	NaNO ₂	aq	-358.7	-333.18
SiO ₂	c, cristobalite, 1600° form	-202.62		NaNO ₃	c	-86.6	
	c, cristobalite, 1100° form	-202.46			aq	-83.1	-71.04
	c, quartz	-203.35	-190.4	Na ₂ O	c	-111.71	-87.62
	c, tridymite	-203.23		Na ₂ O ₂	aq, 400	-106.880	-88.84
Silver				Na ₂ O·SiO ₂	c	-99.45	-90.06
Ag	c	0.00	0.00	Na ₂ O·Al ₂ O ₃ ·3SiO ₂	c	-119.2	-105.0
AgBr	c	-23.90	-23.02	Na ₂ O·Al ₂ O ₃ ·4SiO ₂	c	-383.91	-361.49
Ag ₂ C ₂	c	84.5		c, natrolite	c	-1180	
AgC ₂ H ₃ O ₂	c	-95.9			c	-1366	
	aq	-91.7	-70.86	NaOH	c	-101.96	-90.60
AgCN	c	33.8	38.70	Na ₃ PO ₃	aq, 400	-112.193	-100.18
Ag ₂ CO ₃	c	-119.5	-103.0	Na ₃ PO ₄	c	-389.1	
Ag ₂ C ₂ O ₄	c	-158.7		Na ₂ PtCl ₄	aq, 400	-457	
AgCl	c	-30.11	-25.98	Na ₂ PtCl ₆	c	-471.9	-428.74
AgF	c	-48.7		Na ₂ Se	c	-237.2	-216.78
	aq, 400	-53.1	-47.26		c	-272.1	
AgI	c	-15.14	-16.17	Na ₂ SeO ₄	aq, 400	-280.9	
AgIO ₃	c	-42.02	-24.08		c	-59.1	
AgNO ₂	c	-11.6	3.76	Na ₂ S	aq, 440	-78.1	-89.42
	aq	-2.9	9.99		c	-254	
AgNO ₃	c	-29.4	-7.66	Na ₂ SO ₃	aq, 800	-261.5	-230.30
	aq, 6500	-24.02	-7.81		c	-89.8	
Ag ₂ O	c	-6.95	-2.23	Na ₂ SO ₄	aq, 400	-105.17	-101.76
Ag ₂ S	c	-5.5	-7.6		c	-261.2	-240.14
Ag ₂ SO ₄	c	-170.1	-146.8	Na ₂ SO ₄ ·10H ₂ O	aq, 800	-264.1	-241.58
	aq	-165.8	-139.22	Na ₂ WO ₄	c	-330.50	-302.38
Sodium					c	-330.82	-301.28
Na	c	0.00	0.00		c	-1033.85	-870.52
Na ₃ AsO ₃	aq, 500	-314.61			c	-391	
Na ₃ AsO ₄	c	-366			c	-381.5	-345.18
	aq, 500	-381.97	-341.17	Strontium	c	0.00	0.00
NaBr	c	-86.72		Sr	c	-171.0	
	aq, 400	-86.33	-87.17	SrBr ₂	c	-187.24	-182.36
NaBrO	aq	-78.9		Sr(C ₂ H ₃ O ₂) ₂	c	-358.0	
NaBrO ₃	aq, 400	-68.89	-57.59		c	-364.4	-311.80
NaC ₂ H ₃ O ₂	c	-170.45		Sr(CN) ₂	aq	-59.5	-54.50
	aq, 400	-175.450	-152.31	SrCO ₃	c	-290.9	-271.9
NaCN	c	-22.47		SrCl ₂	c	-197.84	
	aq, 200	-22.29	-23.24	SrF ₂	c	-209.20	-195.86
NaCNO	c	-96.3		Sr(HCO ₃) ₂	c	-289.0	
	aq	-91.7	-86.00	SrI ₂	c	-459.1	-413.76
NaCNS	c	-39.94			c	-136.1	
	aq, 400	-38.23	-39.24	Sr ₃ N ₂	c	-156.70	-157.87
Na ₂ CO ₃	c	-269.46	-249.55	Sr ₃ (NO ₃) ₂	c	-91.4	-76.5
	aq, 1000	-275.13	-251.36	SrO	c	-233.2	
NaCO ₂ NH ₂	c	-142.17		SrO·SiO ₂	c	-228.73	-185.70
Na ₂ C ₂ O ₄	c	-313.8		SrO ₂	c	-140.8	-133.7
	aq, 600	-309.92	-283.42	Sr ₂ O	c	-364	
NaCl	c	-98.321	-91.894	Sr(OH) ₂	c	-153.3	-139.0
	aq, 400	-97.324	-93.92		c	-153.6	
NaClO ₃	c	-83.59		Sr ₃ (PO ₄) ₂	c	-228.7	
	aq, 400	-78.42	-62.84	SrS	c	-239.4	-208.27
NaClO ₄	c	-101.12			c	-980	
					c	-985	-881.54
					c	-985	
					c	-113.1	

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds (Continued)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole
Strontium (Cont.)				Tin			
SrSO ₄	aq	-120.4	-109.78	Sn	c, II, tetragonal	0.00	0.00
	c	-345.3			c, III, "gray," cubic	0.6	1.1
SrWO ₄	aq, 400	-345.0	-309.30	SnBr ₂	c	-61.4	
Sulfur S	c	-393		SnBr ₄	aq	-60.0	-55.43
S ₂	c, rhombic	0.00	0.00	SnCl ₂	c	-94.8	
S ₆	c, monoclinic	-0.071	0.023	SnCl ₄	aq	-110.6	-97.66
S ₈	l, λ	0.257	0.072	SnI ₂	c	-83.6	
S ₂ Br ₂	l, λμ equilibrium	0.071		SnO	aq	-81.7	-68.94
S ₂	g	53.25	43.57	SnO ₂	l	-127.3	-110.4
S ₆	g	31.02	19.36	Sn(OH) ₂	aq	-157.6	-124.67
S ₈	g	27.78	13.97	Sn(OH) ₄	c	-38.9	
S ₂ Cl ₂	—	27.090	12.770	SnS	c	-33.3	-30.95
S ₂ Cl ₄	—	-4		Titanium	c	-67.7	-60.75
SF ₆	g	-262	-237	Ti	c	-138.1	-123.6
SO	gg	19.02	12.75	TiC	c	-136.2	-115.95
SO ₂	gg	-70.94	-71.68	TiCl ₄	l	-268.9	-226.00
SO ₃	g	-94.39	-88.59	TiN	c	-181.4	-165.5
	l	-103.03	-88.28	TiO ₂	c	-80.0	-73.17
	c, α	-105.09	-88.22	Tungsten	c, III, rutile	-225.0	-211.9
	c, β	-105.92	-88.34	W	c, amorphous	-214.1	-201.4
	c, γ	-109.34	-88.98	WO ₂	c	0.00	0.00
SO ₂ Cl ₂	g	-82.04	-74.06	WO ₃	c	-130.5	-118.3
	l	-89.80	-75.06	WS ₂	c	-195.7	-177.3
Tantalum				Uranium	c	-84	
Ta	c	0.00	0.00	U	c	0.00	0.00
TaN	c	-51.2	-45.11	UC ₂	c	-29	
Ta ₂ O ₅	c	-486.0	-453.7	UCl ₃	c	-213	
Tellurium				UCl ₄	c	-251	
Te	c	0.00	0.00	U ₃ N ₄	c	-274	-249.6
TeBr ₄	c	-49.3		UO ₂	c	-256.6	-242.2
TeCl ₄	c	-77.4	-57.4	UO ₂ (NO ₃) ₂ ·6H ₂ O	c	-756.8	-617.8
TeF ₆	g	-315	-292	UO ₃	c	-291.6	
TeO ₂	c	-77.56	-64.66	U ₃ O ₈	c	-845.1	
Thallium				Vanadium	c	0.00	0.00
Tl	c	0.00	0.00	V	c	-147	
TlBr	c	-41.5	-39.43	VCl ₂	c	-187	
	aq	-28.0	-32.34	VCl ₃	l	-165	
TlCl	c	-49.37	-44.46	VCl ₄	l	-41.43	-35.08
	aq	-38.4	-39.09	VN	c	-195	
TlCl ₃	c	-82.4		V ₂ O ₂	c	-296	-277
	aq	-91.0	-44.25	V ₂ O ₃	c	-342	-316
TlF	aq	-77.6	-73.46	V ₂ O ₄	c	-373	-342
TlI	c	-31.1	-31.3	V ₂ O ₅	c	0.00	0.00
TlNO ₃	c	-12.7	-20.09	Zinc	c	-3.6	-3.88
	aq	-58.2	-36.32	Zn	c	-77.0	-72.9
	aq	-48.4	-34.01	ZnSb	c	-93.6	
Tl ₂ O	c	-43.18		ZnBr ₂	c	-192.9	
Tl ₂ O ₃	c	-120		aq, 400	c	-99.9	-88.8
TlOH	c	-57.44	-45.54	Zn(CN) ₂	c	-115.44	
	aq	-53.9	-45.35	ZnCO ₃	c	-192.9	-173.5
Tl ₂ S	c	-22		ZnCl ₂	c	-50.50	-49.93
Tl ₂ SO ₄	c	-222.8	-197.79	ZnF ₂	c	-61.6	
	aq, 800	-214.1	-191.62	ZnI ₂	c	-134.9	-87.7
Thorium				Zn(NO ₃) ₂	c, hexagonal	-83.36	-76.19
Th	c	0.00	0.00	ZnO	c, rhombic	-282.6	
ThBr ₄	c	-281.5		ZnO·SiO ₂	c, wurtzite	-153.66	
	aq	-352.0	-295.31	Zn(OH) ₂	c	-45.3	-44.2
ThC ₂	c	-45.1		ZnS	c	-233.4	
ThCl ₄	c	-335		ZnSO ₄	c	-252.12	-211.28
	aq	-392	-322.32	aq, 400	c	0.00	0.00
ThI ₄	aq	-292.0	-246.33				
Th ₃ N ₄	c	-309.0	-282.3				
ThO ₂	c	-291.6	-280.1				
Th(OH) ₄	c, "soluble"	-336.1					
Th(SO ₄) ₂	c	-632					
	aq	-668.1	-549.2				

TABLE 2-220 Heats and Free Energies of Formation of Inorganic Compounds (Concluded)

Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole	Compound	State†	Heat of formation‡§ ΔH (formation) at 25°C, kcal/mole	Free energy of formation¶ ΔF (formation) at 25°C, kcal/mole
Zirconium				Zirconium (Cont.)			
Zr	c	0.00	0.00	ZrO ₂	c, monoclinic	-258.5	-244.6
ZrC	c	-29.8	-34.6	Zr(OH) ₄	c	-411.0	
ZrCl ₄	c	-268.9		ZrO(OH) ₂	c	-337	-307.6
ZrN	c	-82.5	-75.9				

† The physical state is indicated as follows: *c*, crystal (solid); *l*, liquid; *g*, gas; *gls*, glass or solid supercooled liquid; *aq.*, in aqueous solution. A number following the symbol *aq* applies only to the values of the heats of formation (not to those of free energies of formation); and indicates the number of moles of water per mole of solute; when no number is given, the solution is understood to be dilute. For the free energy of formation of a substance in aqueous solution, the concentration is always that of the hypothetical solution of unit molality.

‡ The increment in heat content, ΔH , in the reaction of forming the given substance from its elements in their standard states. When ΔH is negative, heat is evolved in the process, and, when positive, heat is absorbed.

§ The heat of solution in water of a given solid, liquid, or gaseous compound is given by the difference in the value for the heat of formation of the given compound in the solid, liquid, or gaseous state and its heat of formation in aqueous solution. The following two examples serve as an illustration of the procedure: (1) For NaCl(*c*) and NaCl(*aq.* 400H₂O), the values of ΔH (formation) are, respectively, -98.321 and -97.324 kg-cal per mole. Subtraction of the first value from the second gives $\Delta H = 0.998$ kg-cal per mole for the reaction of dissolving crystalline sodium chloride in 400 moles of water. When this process occurs at a constant pressure of 1 atm, 0.998 kg-cal of energy are absorbed. (2) For HCl(*g*) and HCl(*aq.* 400H₂O), the values for ΔH (formation) are, respectively, -22.06 and -39.85 kg-cal per mole. Subtraction of the first from the second gives $\Delta H = -17.79$ kg-cal per mole for the reaction of dissolving gaseous hydrogen chloride in 400 moles of water. At a constant pressure of 1 atm, 17.79 kg-cal of energy are evolved in this process.

¶ The increment in the free energy, ΔF , in the reaction of forming the given substance in its standard state from its elements in their standard states. The standard states are: for gas, fugacity (approximately equal to the pressure) of 1 atm; for a pure liquid or solid, the substance at a pressure of 1 atm; for a substance in aqueous solution, the hypothetical solution of unit molality, which has all the properties of the infinitely dilute solution except the property of concentration.

|| The free energy of solution of a given substance from its normal standard state as a solid, liquid, or gas to the hypothetical one molal state in aqueous solution may be calculated in a manner similar to that described in footnote § for calculating the heat of solution.

HEATS OF COMBUSTION

TABLE 2-221 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds at 298.15 K

Cmpd. no.	Name	Formula	CAS no.	Mol wt	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
1	Methane	CH ₄	74828	16.043	-7.4520	-5.0490	1.8627	-0.8026
2	Ethane	C ₂ H ₆	74840	30.070	-8.3820	-3.1920	2.2912	-1.4286
3	Propane	C ₃ H ₈	74986	44.097	-10.4680	-2.4390	2.7020	-2.0431
4	<i>n</i> -Butane	C ₄ H ₁₀	106978	58.123	-12.5790	-1.6700	3.0991	-2.6573
5	<i>n</i> -Pentane	C ₅ H ₁₂	109660	72.150	-14.6760	-0.8813	3.4945	-3.2449
6	<i>n</i> -Hexane	C ₆ H ₁₄	110543	86.177	-16.6940	-0.0066	3.8874	-3.8551
7	<i>n</i> -Heptane	C ₇ H ₁₆	142825	100.204	-18.7650	0.8165	4.2798	-4.4647
8	<i>n</i> -Octane	C ₈ H ₁₈	111659	114.231	-20.8750	1.6000	4.6723	-5.0742
9	<i>n</i> -Nonane	C ₉ H ₂₀	111842	128.258	-22.8740	2.4980	5.0640	-5.6846
10	<i>n</i> -Decane	C ₁₀ H ₂₂	124185	142.285	-24.9460	3.3180	5.4570	-6.2942
11	<i>n</i> -Undecane	C ₁₁ H ₂₄	1120214	156.312	-27.0430	4.1160	5.8493	-6.9036
12	<i>n</i> -Dodecane	C ₁₂ H ₂₆	112403	170.338	-29.0720	4.9810	6.2415	-7.5137
13	<i>n</i> -Tridecane	C ₁₃ H ₂₈	629505	184.365	-31.1770	5.7710	6.6337	-8.1229
14	<i>n</i> -Tetradecane	C ₁₄ H ₃₀	629594	198.392	-33.2440	6.5990	7.0259	-8.7328
15	<i>n</i> -Pentadecane	C ₁₅ H ₃₂	629629	212.419	-35.3110	7.4260	7.4181	-9.3424
16	<i>n</i> -Hexadecane	C ₁₆ H ₃₄	544763	226.446	-37.4170	8.2160	7.8102	-9.9515
17	<i>n</i> -Heptadecane	C ₁₇ H ₃₆	629787	240.473	-39.4450	9.0830	8.2023	-10.5618
18	<i>n</i> -Octadecane	C ₁₈ H ₃₈	593453	254.500	-41.5120	9.9100	8.5945	-11.1715
19	<i>n</i> -Nonadecane	C ₁₉ H ₄₀	629925	268.527	-43.5790	10.7400	8.9866	-11.7812
20	<i>n</i> -Eicosane	C ₂₀ H ₄₂	112958	282.553	-45.6460	11.5700	9.3787	-12.3908
21	2-Methylpropane	C ₄ H ₁₀	75285	58.123	-13.4180	-2.0760	2.9539	-2.6490
22	2-Methylbutane	C ₅ H ₁₂	78784	72.150	-15.3700	-1.4050	3.4374	-3.2395
23	2,3-Dimethylbutane	C ₆ H ₁₄	79298	86.177	-17.6800	-0.3125	3.6592	-3.8476
24	2-Methylpentane	C ₆ H ₁₄	107835	86.177	-17.4550	-0.5338	3.8089	-3.8492
25	2,3-Dimethylpentane	C ₇ H ₁₆	565593	100.204	-19.4100	0.5717	4.1455	-4.4608
26	2,3,3-Trimethylpentane	C ₈ H ₁₈	560214	114.231	-21.8450	1.8280	4.2702	-5.0688
27	2,2,4-Trimethylpentane	C ₈ H ₁₈	540841	114.231	-22.4010	1.3940	4.2296	-5.0653
28	Ethylene	C ₂ H ₄	74851	28.054	5.2510	6.8440	2.1920	-1.3230
29	Propylene	C ₃ H ₆	115071	42.081	1.9710	6.2150	2.6660	-1.9257

TABLE 2-221 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol wt	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
30	1-Butene	C ₄ H ₈	106989	56.108	-0.0540	7.0270	3.0775	-2.5408
31	cis-2-Butene	C ₄ H ₈	590181	56.108	-0.7400	6.5360	3.0120	-2.5339
32	trans-2-Butene	C ₄ H ₈	624646	56.108	-1.1000	6.3160	2.9650	-2.5303
33	1-Pentene	C ₅ H ₁₀	109671	70.134	-2.1300	7.8450	3.4699	-3.1296
34	1-Hexene	C ₆ H ₁₂	592416	84.161	-4.2000	8.7390	3.8389	-3.7394
35	1-Heptene	C ₇ H ₁₄	592767	98.188	-6.2800	9.4830	4.2549	-4.3489
36	1-Octene	C ₈ H ₁₆	111660	112.215	-8.3600	10.3000	4.6469	-4.9606
37	1-Nonene	C ₉ H ₁₈	124118	126.242	-10.4000	11.1500	5.0399	-5.5684
38	1-Decene	C ₁₀ H ₂₀	872059	140.269	-12.4700	11.9800	5.4319	-6.1781
39	2-Methylpropene	C ₄ H ₈	115117	56.108	-1.7100	5.8080	2.9309	-2.5242
40	2-Methyl-1-butene	C ₅ H ₁₀	563462	70.134	-3.5300	6.6680	3.3950	-3.1159
41	2-Methyl-2-butene	C ₅ H ₁₀	513359	70.134	-4.1800	6.0450	3.3860	-3.1088
42	1,2-Butadiene	C ₄ H ₆	590192	54.092	16.2300	19.8600	2.9300	-2.4617
43	1,3-Butadiene	C ₄ H ₆	106990	54.092	10.9240	14.9720	2.7889	-2.4090
44	2-Methyl-1,3-butadiene	C ₅ H ₈	78795	68.119	7.5730	14.5896	3.1564	-2.9842
45	Acetylene	C ₂ H ₂	74862	26.038	22.8200	21.0680	2.0081	-1.2570
46	Methylacetylene	C ₃ H ₄	74997	40.065	18.4900	19.3840	2.4836	-1.8487
47	Dimethylacetylene	C ₄ H ₆	503173	54.092	14.5700	18.4900	2.8330	-2.4189
48	3-Methyl-1-butyne	C ₅ H ₈	598232	68.119	13.8000	20.7200	3.1890	-3.0460
49	1-Pentyne	C ₅ H ₈	627190	68.119	14.4400	21.0300	3.2980	-3.0510
50	2-Pentyne	C ₅ H ₈	627214	68.119	12.5100	19.0700	3.3084	-3.0291
51	1-Hexyne	C ₆ H ₁₀	693027	82.145	12.3700	21.8500	3.6940	-3.6610
52	2-Hexyne	C ₆ H ₁₀	764352	82.145	10.5000	19.9000	3.7200	-3.6400
53	3-Hexyne	C ₆ H ₁₀	928494	82.145	10.6000	19.9000	3.7600	-3.6400
54	1-Heptyne	C ₇ H ₁₂	628717	96.172	10.3000	22.7000	4.0850	-4.2717
55	1-Octyne	C ₈ H ₁₄	629050	110.199	8.2300	23.5000	4.4780	-4.8815
56	Vinylacetylene	C ₄ H ₄	689974	52.076	30.4600	30.6000	2.7940	-2.3620
57	Cyclopentane	C ₅ H ₁₀	287923	70.134	-7.7030	3.8850	2.9290	-3.0709
58	Methylcyclopentane	C ₆ H ₁₂	96377	84.161	-10.6200	3.6300	3.3990	-3.6741
59	Ethylcyclopentane	C ₇ H ₁₄	1640897	98.188	-12.6900	4.4800	3.7830	-4.2839
60	Cyclohexane	C ₆ H ₁₂	110827	84.161	-12.3300	3.1910	2.9728	-3.6560
61	Methylcyclohexane	C ₇ H ₁₄	108872	98.188	-15.4800	2.7330	3.4330	-4.2571
62	1,1-Dimethylcyclohexane	C ₈ H ₁₆	590669	112.215	-18.1000	3.5229	3.6501	-4.8639
63	Ethylcyclohexane	C ₈ H ₁₆	1678917	112.215	-17.1500	3.9550	3.8260	-4.8705
64	Cyclopentene	C ₅ H ₈	142290	68.119	3.3100	11.0500	2.9127	-2.9393
65	1-Methylcyclopentene	C ₆ H ₁₀	693890	82.145	-0.3800	10.3800	3.2640	-3.5340
66	Cyclohexene	C ₆ H ₁₀	110838	82.145	-0.4600	10.7700	3.1052	-3.5320
67	Benzene	C ₆ H ₆	71432	78.114	8.2880	12.9600	2.6930	-3.1360
68	Toluene	C ₇ H ₈	108883	92.141	5.0170	12.2200	3.2099	-3.7340
69	<i>o</i> -Xylene	C ₈ H ₁₀	95476	106.167	1.9080	12.2000	3.5383	-4.3330
70	<i>m</i> -Xylene	C ₈ H ₁₀	108383	106.167	1.7320	11.8760	3.5854	-4.3318
71	<i>p</i> -Xylene	C ₈ H ₁₀	106423	106.167	1.8030	12.1400	3.5223	-4.3330
72	Ethylbenzene	C ₈ H ₁₀	100414	106.167	2.9920	13.0730	3.6063	-4.3450
73	Propylbenzene	C ₉ H ₁₂	103651	120.194	0.7910	13.8090	3.9843	-4.9542
74	1,2,4-Trimethylbenzene	C ₉ H ₁₂	95636	120.194	-1.3800	11.7100	3.9610	-4.9307
75	Isopropylbenzene	C ₉ H ₁₂	98828	120.194	0.4000	13.7900	3.8600	-4.9510
76	1,3,5-Trimethylbenzene	C ₉ H ₁₂	108678	120.194	-1.5900	11.8100	3.8560	-4.9291
77	<i>p</i> -Isopropyltoluene	C ₁₀ H ₁₄	99876	134.221	-2.9000	13.3520	4.2630	-5.5498
78	Naphthalene	C ₁₀ H ₈	91203	128.174	15.0580	22.4080	3.3315	-4.9809
79	Biphenyl	C ₁₂ H ₁₀	92524	154.211	18.2420	28.0230	3.9367	-6.0317
80	Styrene	C ₈ H ₈	100425	104.152	14.7400	21.3900	3.4510	-4.2190
81	<i>m</i> -Terphenyl	C ₁₅ H ₁₄	92068	230.309	27.6600	42.3000	5.2630	-9.0530
82	Methanol	CH ₄ O	67561	32.042	-20.0940	-16.2320	2.3988	-0.6382
83	Ethanol	C ₂ H ₆ O	64175	46.069	-23.4950	-16.7850	2.8064	-1.2350
84	1-Propanol	C ₃ H ₈ O	71238	60.096	-25.5200	-15.9900	3.2247	-1.8438
85	1-Butanol	C ₄ H ₁₀ O	71363	74.123	-27.4600	-15.0300	3.6148	-2.4560
86	2-Butanol	C ₄ H ₁₀ O	78922	74.123	-29.2900	-16.9600	3.6469	-2.4408
87	2-Propanol	C ₃ H ₈ O	67630	60.096	-27.2700	-17.3470	3.0920	-1.8300
88	2-Methyl-2-propanol	C ₄ H ₁₀ O	75650	74.123	-31.2400	-17.7600	3.2630	-2.4239
89	1-Pentanol	C ₅ H ₁₂ O	71410	88.150	-29.8737	-14.6022	4.0250	-3.0605
90	2-Methyl-1-butanol	C ₅ H ₁₂ O	137326	88.150	-30.2085	-14.6709	3.9351	-3.0620
91	3-Methyl-1-butanol	C ₅ H ₁₂ O	123513	88.150	-30.2100	-14.5000	3.8770	-3.0623
92	1-Hexanol	C ₆ H ₁₄ O	111273	102.177	-31.6500	-13.4400	4.4010	-3.6766
93	1-Heptanol	C ₇ H ₁₆ O	111706	116.203	-33.6400	-12.5300	4.7919	-4.2860
94	Cyclohexanol	C ₆ H ₁₂ O	108930	100.161	-28.6200	-10.9500	3.2770	-3.4639
95	Ethylene glycol	C ₂ H ₆ O ₂	107211	62.068	-38.7500	-30.2600	3.2350	-1.0590
96	1,2-Propylene glycol	C ₃ H ₆ O ₂	57556	76.095	-42.1500	-30.4000	3.5200	-1.6476

TABLE 2-221 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol wt	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
97	Phenol	C ₆ H ₅ O	108952	94.113	-9.6399	-3.2637	3.1481	-2.9210
98	<i>o</i> -Cresol	C ₇ H ₈ O	95487	108.140	-12.8570	-3.5430	3.5259	-3.5280
99	<i>m</i> -Cresol	C ₇ H ₈ O	108394	108.140	-13.2300	-4.0190	3.5604	-3.5278
100	<i>p</i> -Cresol	C ₇ H ₈ O	106445	108.140	-12.5350	-3.1660	3.5075	-3.5226
101	Dimethyl ether	C ₂ H ₆ O	115106	46.069	-18.4100	-11.2800	2.6670	-1.3284
102	Methyl ethyl ether	C ₃ H ₈ O	540670	60.096	-21.6400	-11.7100	3.0881	-1.9314
103	Methyl <i>n</i> -propyl ether	C ₄ H ₁₀ O	557175	74.123	-23.8200	-11.1000	3.5200	-2.5174
104	Methyl isopropyl ether	C ₄ H ₁₀ O	598538	74.123	-25.2000	-12.1800	3.4160	-2.5311
105	Methyl <i>n</i> -butyl ether	C ₅ H ₁₂ O	628284	88.150	-25.8100	-10.1700	3.9010	-3.1282
106	Methyl isobutyl ether	C ₅ H ₁₂ O	625445	88.150	-26.6000	-10.7000	3.8100	-3.1220
107	Methyl tert-butyl ether	C ₅ H ₁₂ O	1634044	88.150	-28.3500	-11.7500	3.5780	-3.1049
108	Diethyl ether	C ₄ H ₁₀ O	60297	74.123	-25.2100	-12.2100	3.4230	-2.5035
109	Ethyl propyl ether	C ₅ H ₁₂ O	628320	88.150	-27.2200	-11.5200	3.8810	-3.1200
110	Ethyl isopropyl ether	C ₅ H ₁₂ O	625547	88.150	-28.5800	-12.6400	3.8000	-3.1030
111	Methyl phenyl ether	C ₇ H ₈ O	100663	108.140	-6.7900	2.2700	3.6100	-3.6072
112	Diphenyl ether	C ₁₂ H ₁₀ O	101848	170.211	5.2000	17.5000	4.1300	-5.8939
113	Formaldehyde	CH ₂ O	50000	30.026	-10.8600	-10.2600	2.1866	-0.5268
114	Acetaldehyde	C ₂ H ₄ O	75070	44.053	-16.6200	-13.3100	2.6420	-1.1045
115	1-Propanal	C ₃ H ₆ O	123386	58.080	-18.6300	-12.4600	3.0440	-1.6857
116	1-Butanal	C ₄ H ₈ O	123728	72.107	-20.7000	-11.6300	3.4365	-2.3035
117	1-Pentanal	C ₅ H ₁₀ O	110623	86.134	-22.7800	-10.7100	3.8289	-2.9100
118	1-Hexanal	C ₆ H ₁₂ O	66251	100.161	-24.8600	-10.0050	4.2214	-3.5200
119	1-Heptanal	C ₇ H ₁₄ O	111717	114.188	-26.9400	-9.1910	4.6138	-4.1360
120	1-Octanal	C ₈ H ₁₆ O	124130	128.214	-29.0200	-8.3770	5.0063	-4.7400
121	1-Nonanal	C ₉ H ₁₈ O	124196	142.241	-31.0900	-7.5530	5.3988	-5.3500
122	1-Decanal	C ₁₀ H ₂₀ O	112312	156.268	-33.1700	-6.7390	5.7912	-5.9590
123	Acetone	C ₃ H ₆ O	67641	58.080	-21.5700	-15.1300	2.9540	-1.6590
124	Methyl ethyl ketone	C ₄ H ₈ O	78933	72.107	-23.9000	-14.7000	3.3940	-2.2680
125	2-Pentanone	C ₅ H ₁₀ O	107879	86.134	-25.9200	-13.8300	3.7860	-2.8796
126	Methyl isopropyl ketone	C ₅ H ₁₀ O	563804	86.134	-26.2400	-13.9000	3.6990	-2.8770
127	2-Hexanone	C ₆ H ₁₂ O	591786	100.161	-27.9826	-13.0081	4.1786	-3.4900
128	Methyl isobutyl ketone	C ₆ H ₁₂ O	108101	100.161	-28.8000	-13.5000	4.0700	-3.4900
129	3-Methyl-2-pentanone	C ₆ H ₁₂ O	565617	100.161	-28.1000	-12.9000	4.1200	-3.4900
130	3-Pentanone	C ₅ H ₁₀ O	96220	86.134	-25.7900	-13.4400	3.7000	-2.8804
131	Ethyl isopropyl ketone	C ₆ H ₁₂ O	565695	100.161	-28.6100	-13.3000	4.0690	-3.4860
132	Diisopropyl ketone	C ₇ H ₁₄ O	565800	114.188	-31.1400	-13.2000	4.5700	-4.0950
133	Cyclohexanone	C ₆ H ₁₀ O	108941	98.145	-22.6100	-8.6620	3.2200	-3.2990
134	Methyl phenyl ketone	C ₈ H ₈ O	98862	120.151	-8.6700	-0.1364	3.8450	-3.9730
135	Formic acid	CH ₂ O ₂	64186	46.026	-37.8600	-35.1000	2.4870	-0.2115
136	Acetic acid	C ₂ H ₄ O ₂	64197	60.053	-43.2800	-37.4600	2.8250	-0.8146
137	Propionic acid	C ₃ H ₆ O ₂	79094	74.079	-45.3500	-36.6700	3.2300	-1.3950
138	<i>n</i> -Butyric acid	C ₄ H ₈ O ₂	107926	88.106	-47.5800	-36.0000	3.6200	-2.0077
139	Isobutyric acid	C ₄ H ₈ O ₂	79312	88.106	-48.4100	-36.2100	3.4120	-2.0004
140	Benzoic acid	C ₇ H ₆ O ₂	65850	122.123	-29.4100	-21.4200	3.6900	-3.0951
141	Acetic anhydride	C ₄ H ₆ O ₃	108247	102.090	-57.2500	-47.3400	3.8990	-1.6750
142	Methyl formate	C ₂ H ₄ O ₂	107313	60.053	-35.2400	-29.5000	2.8520	-0.8924
143	Methyl acetate	C ₃ H ₆ O ₂	79209	74.079	-41.1900	-32.4200	3.1980	-1.4610
144	Methyl propionate	C ₄ H ₈ O ₂	554121	88.106	-42.7500	-31.1000	3.5960	-2.0780
145	Methyl <i>n</i> -butyrate	C ₅ H ₁₀ O ₂	623427	102.133	-45.0700	-30.5300	3.9880	-2.6860
146	Ethyl formate	C ₃ H ₆ O ₂	109944	74.079	-38.8300	-30.3100	3.2820	-1.5070
147	Ethyl acetate	C ₄ H ₈ O ₂	141786	88.106	-44.4500	-32.8000	3.5970	-2.0610
148	Ethyl propionate	C ₅ H ₁₀ O ₂	105373	102.133	-46.3600	-31.9300	4.0250	-2.6740
149	Ethyl <i>n</i> -butyrate	C ₆ H ₁₂ O ₂	105544	116.160	-48.5500	-31.2200	4.4170	-3.2840
150	<i>n</i> -Propyl formate	C ₄ H ₈ O ₂	110747	88.106	-40.7600	-29.3600	3.6780	-2.0410
151	<i>n</i> -Propyl acetate	C ₅ H ₁₀ O ₂	109604	102.133	-46.4800	-32.0400	4.0230	-2.6720
152	<i>n</i> -Butyl acetate	C ₆ H ₁₂ O ₂	123864	116.160	-48.5600	-31.2600	4.4250	-3.2800
153	Methyl benzoate	C ₈ H ₈ O ₂	93583	136.150	-28.7900	-18.1000	4.1400	-3.7720
154	Ethyl benzoate	C ₉ H ₁₀ O ₂	93890	150.177	-32.6000	-19.0500	4.5500	-4.4100
155	Vinyl acetate	C ₄ H ₆ O ₂	108054	86.090	-31.4900	-22.7900	3.2800	-1.9500
156	Methylamine	CH ₃ N	74895	31.057	-2.2970	3.2070	2.4330	-0.9751
157	Dimethylamine	C ₂ H ₅ N	124403	45.084	-1.8450	6.8390	2.7296	-1.6146
158	Trimethylamine	C ₃ H ₉ N	75503	59.111	-2.4310	9.8990	2.8700	-2.2449
159	Ethylamine	C ₂ H ₇ N	75047	45.084	-4.7150	3.6160	2.8480	-1.5874
160	Diethylamine	C ₄ H ₁₁ N	109897	73.138	-7.1420	7.3080	3.5220	-2.8003
161	Triethylamine	C ₆ H ₁₅ N	121448	101.192	-9.5800	11.4100	4.0540	-4.0405
162	<i>n</i> -Propylamine	C ₃ H ₉ N	107108	59.111	-7.0500	4.1700	3.2420	-2.1650

TABLE 2-221 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds (Continued)

Cmpd. no.	Name	Formula	CAS no.	Mol wt	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
163	di- <i>n</i> -Propylamine	C ₆ H ₁₅ N	142847	101.192	-11.6000	8.6800	4.2900	-4.0189
164	Isopropylamine	C ₃ H ₉ N	75310	59.111	-8.3800	3.1920	3.1240	-2.1566
165	Diisopropylamine	C ₆ H ₁₅ N	108189	101.192	-15.0000	5.7900	4.1200	-3.9900
166	Aniline	C ₆ H ₅ N	62533	93.128	8.7100	16.6800	3.1980	-3.2390
167	N-Methylaniline	C ₇ H ₉ N	100618	107.155	8.8000	20.2000	3.4100	-3.9000
168	N,N-Dimethylaniline	C ₈ H ₁₁ N	121697	121.182	10.0500	24.7728	3.6600	-4.5250
169	Ethylene oxide	C ₂ H ₄ O	75218	44.053	-5.2630	-1.3230	2.4299	-1.2180
170	Furan	C ₄ H ₆ O	110009	68.075	-3.4800	0.0823	2.6714	-1.9959
171	Thiophene	C ₄ H ₆ S	110021	84.142	11.5440	12.6620	2.7865	-2.4352
172	Pyridine	C ₅ H ₅ N	110861	79.101	14.0370	19.0490	2.8278	-2.6721
173	Formamide	CH ₃ NO	75127	45.041	-19.2200	-14.7100	2.4857	-0.5021
174	N,N-Dimethylformamide	C ₃ H ₇ NO	68122	73.095	-19.1700	-8.8400	3.2600	-1.7887
175	Acetamide	C ₂ H ₅ NO	60355	59.068	-23.8300	-15.9600	2.7220	-1.0741
176	N-Methylacetamide	C ₃ H ₇ NO	79163	73.095	-24.0000	-13.5000	3.2000	-1.7100
177	Acetonitrile	C ₃ H ₅ N	75058	41.053	7.4040	9.1868	2.4329	-1.1904
178	Propionitrile	C ₃ H ₇ N	107120	55.079	5.1800	9.7495	2.8614	-1.8007
179	<i>n</i> -Butyronitrile	C ₄ H ₇ N	109740	69.106	3.4058	10.8658	3.2543	-2.4148
180	Benzonitrile	C ₇ H ₇ N	100470	103.123	21.8823	26.0872	3.2104	-3.5224
181	Methyl mercaptan	CH ₃ S	74931	48.109	-2.2900	-0.9800	2.5500	-1.1517
182	Ethyl mercaptan	C ₂ H ₅ S	75081	62.136	-4.6300	-0.4814	2.9610	-1.7366
183	<i>n</i> -Propyl mercaptan	C ₃ H ₈ S	107039	76.163	-6.7500	0.2583	3.3650	-2.3458
184	<i>n</i> -Butyl mercaptan	C ₄ H ₁₀ S	109795	90.189	-8.7800	1.1390	3.7520	-2.9554
185	Isobutyl mercaptan	C ₄ H ₁₀ S	513440	90.189	-9.6900	0.5982	3.6280	-2.9490
186	sec-Butyl mercaptan	C ₄ H ₁₀ S	513531	90.189	-9.6600	0.5120	3.6670	-2.9490
187	Dimethyl sulfide	C ₂ H ₆ S	75183	62.136	-3.7240	0.7302	2.8585	-1.7449
188	Methyl ethyl sulfide	C ₃ H ₈ S	624895	76.163	-5.9600	1.1470	3.3320	-2.3531
189	Diethyl sulfide	C ₄ H ₁₀ S	352932	90.189	-8.3470	1.7780	3.6800	-2.9607
190	Fluoromethane	CH ₃ F	593533	34.033	-23.4300	-21.0400	2.2273	-0.5219
191	Chloromethane	CH ₃ Cl	74573	50.488	-8.1960	-5.8440	2.3418	-0.6754
192	Trichloromethane	CHCl ₃	67663	119.377	-10.2900	-7.0100	2.9560	-0.3800
193	Tetrachloromethane	CCl ₄	56235	153.822	-9.5810	-5.3540	3.0991	-0.2653
194	Bromomethane	CH ₃ Br	74839	94.939	-3.7700	-2.8190	2.4580	-0.7054
195	Fluoroethane	C ₂ H ₃ F	353366	48.060	-26.4400	-21.2300	2.6440	-1.1270
196	Chloroethane	C ₂ H ₅ Cl	75003	64.514	-11.2260	-6.0499	2.7578	-1.2849
197	Bromoethane	C ₂ H ₅ Br	74964	108.966	-6.3600	-2.5820	2.8730	-1.2850
198	1-Chloropropane	C ₃ H ₇ Cl	540545	78.541	-13.3180	-5.2610	3.1547	-1.8670
199	2-Chloropropane	C ₃ H ₇ Cl	75296	78.541	-14.4770	-6.1360	3.0594	-1.8630
200	1,1-Dichloropropane	C ₂ H ₄ Cl ₂	78999	112.986	-15.0800	-6.5200	3.4480	-1.7200
201	1,2-Dichloropropane	C ₃ H ₆ Cl ₂	78875	112.986	-16.2800	-8.0180	3.5480	-1.7070
202	Vinyl chloride	C ₂ H ₄ Cl	75014	62.499	2.8450	4.1950	2.7354	-1.1780
203	Fluorobenzene	C ₆ H ₅ F	462066	96.104	-11.6566	-6.9036	3.0263	-2.8145
204	Chlorobenzene	C ₆ H ₅ Cl	108907	112.558	5.1090	9.8290	3.1403	-2.9760
205	Bromobenzene	C ₆ H ₅ Br	108861	157.010	10.5018	13.8532	3.2439	-3.0192
206	Air		132259100	28.951	0	0	1.9900	0
207	Hydrogen	H ₂	1333740	2.016	0	0	1.3057	-0.2418
208	Helium-4	He	7440597	4.003	0	0	1.2604	0
209	Neon	Ne	7440019	20.180	0	0	1.4622	0
210	Argon	Ar	7440371	39.948	0	0	1.5474	0
211	Fluorine	F ₂	7782414	37.997	0	0	2.0268	0
212	Chlorine	Cl ₂	7782505	70.905	0	0	2.2297	0
213	Bromine	Br ₂	7726956	159.808	3.0910	0.3140	2.4535	0
214	Oxygen	O ₂	7782447	31.999	0	0	2.0504	0
215	Nitrogen	N ₂	7727379	28.014	0	0	1.9150	0
216	Ammonia	NH ₃	7664417	17.031	-4.5898	-1.6400	1.9266	-0.3168
217	Hydrazine	N ₂ H ₄	302012	32.045	9.5353	15.9170	2.3861	-5.3420
218	Nitrous oxide	N ₂ O	10024972	44.013	8.2050	10.4160	2.1985	-0.0820
219	Nitric oxide	NO	10102439	30.006	9.0250	8.6570	2.1060	-0.0902
220	Cyanogen	C ₂ N ₂	460195	52.036	30.9072	29.7553	2.4146	-1.0961
221	Carbon monoxide	CO	630080	28.010	-11.0530	-13.7150	1.9756	-0.2830
222	Carbon dioxide	CO ₂	124389	44.010	-39.3510	-39.4370	2.1368	0
223	Carbon disulfide	CS ₂	75150	76.143	11.6900	6.6800	2.3790	-1.0769
224	Hydrogen fluoride	HF	7664393	20.006	-27.3300	-27.5400	1.7367	0.1524
225	Hydrogen chloride	HCl	7647010	36.461	-9.2310	-9.5300	1.8679	-0.0286
226	Hydrogen bromide	HBr	10035106	80.912	-3.6290	-5.3340	1.9859	-0.0690
227	Hydrogen cyanide	HCN	74908	27.026	13.5143	12.4725	2.0172	-0.6233

TABLE 2-221 Enthalpies and Gibbs Energies of Formation, Entropies, and Net Enthalpies of Combustion of Inorganic and Organic Compounds (Concluded)

Cmpd. no.	Name	Formula	CAS no.	Mol wt	Ideal gas enthalpy of formation, J/kmol × 1E-07	Ideal gas Gibbs energy of formation, J/kmol × 1E-07	Ideal gas entropy, J/(kmol·K) × 1E-05	Standard net enthalpy of combustion, J/kmol × 1E-09
228	Hydrogen sulfide	H ₂ S	7783064	34.082	-2,0630	-3,3440	2,0560	-0,5180
229	Sulfur dioxide	SO ₂	7446095	64.065	-29,6840	-30,0120	2,4810	0
230	Sulfur trioxide	SO ₃	7446119	80.064	-39,5720	-37,0950	2,5651	0,0989
231	Water	H ₂ O	7732185	18.015	-24,1814	-22,8590	1,8872	0

All substances are listed in alphabetical order in Table 2-6a.

Compiled from Daubert, T. E., R. P. Danner, H. M. Sibul, and C. C. Stebbins, DIPPR Data Compilation of Pure Compound Properties, Project 801 Sponsor Release, July, 1993, Design Institute for Physical Property Data, AIChE, New York, NY; and from Thermodynamics Research Center Hydrocarbon Project, Texas A&M University, College Station, Texas (extant 1994).

The compounds are considered to be formed from the elements in their standard states at 298.15 K and 101,325 Pa. These include C (graphite) and S (rhombic).

Enthalpy of combustion is the net value for the compound in its standard state at 298.15 K and 101,325 Pa.

Products of combustion are taken to be CO₂ (gas), H₂O (gas), F₂ (gas), Cl₂ (gas), Br₂ (gas), I₂ (gas), SO₂ (gas), N₂ (gas), H₃PO₄ (solid), and SiO₂ (cristobalite).

J/kmol × 2,390E-04 = cal/gmol; J/kmol × 4,302106E-04 = Btu/lbmol.

J/(kmol·K) × 2,390E-04 = cal/(gmol·°C); J/(kmol·K) × 2,390059E-04 = Btu/(lbmol·°F).

TABLE 2-222 Ideal Gas Sensible Enthalpies, $h_T - h_{298}$ (kJ/kgmol), of Combustion Products

Temperature, K	CO	CO ₂	H	OH	H ₂	N	NO	NO ₂	N ₂	N ₂ O	O	O ₂	SO ₂	H ₂ O
200	-2858	-3414	-2040	-2976	-2774	-2040	-2951	-3495	-2857	-3553	-2186	-2868	-3736	-3282
240	-1692	-2079	-1209	-1756	-1656	-1209	-1743	-2104	-1692	-2164	-1285	-1703	-2258	-1948
260	-1110	-1383	-793	-1150	-1091	-793	-1142	-1392	-1110	-1438	-840	-1118	-1496	-1279
280	-529	-665	-377	-546	-522	-378	-543	-672	-528	-692	-398	-533	-718	-609
298.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	54	69	38	55	53	38	55	68	54	72	41	54	74	62
320	638	823	454	654	630	454	652	816	636	854	478	643	881	735
340	1221	1594	870	1251	1209	870	1248	1571	1219	1654	913	1234	1702	1410
360	1805	2382	1285	1847	1791	1286	1845	2347	1802	2470	1346	1828	2538	2088
380	2389	3184	1701	2442	2373	1701	2442	3130	2386	3302	1777	2425	3387	2769
400	2975	4003	2117	3035	2959	2117	3040	3927	2971	4149	2207	3025	4250	3452
420	3563	4835	2532	3627	3544	2533	3638	4735	3557	5010	2635	3629	5126	4139
440	4153	5683	2948	4219	4131	2949	4240	5557	4143	5884	3063	4236	6015	4829
460	4643	6544	3364	4810	4715	3364	4844	6392	4731	6771	3490	4847	6917	5523
480	5335	7416	3779	5401	5298	3780	5450	7239	5320	7670	3918	5463	7831	6222
500	5931	8305	4196	5992	5882	4196	6059	8099	5911	8580	4343	6084	8758	6925
550	7428	10572	5235	7385	6760	5235	7592	10340	7395	10897	5402	7653	11123	8699
600	8942	12907	6274	8943	8811	6274	9144	12555	8894	13295	6462	9244	13544	10501
650	10477	15303	7314	10423	10278	7314	10716	14882	10407	15744	7515	10859	16022	12321
700	12023	17754	8353	11902	11749	8353	12307	17250	11937	18243	8570	12499	18548	14192
750	13592	20260	9392	13391	13223	9329	13919	19671	13481	20791	9620	14158	21117	16082
800	15177	22806	10431	14880	14702	10431	15548	22136	15046	23383	10671	15835	23721	18002
850	16781	25398	11471	16384	16186	11471	17195	24641	16624	26014	11718	17531	26369	19954
900	18401	28030	12510	17888	17676	12510	18585	27179	18223	28681	12767	19241	29023	21938
950	20031	30689	13550	19412	19175	13550	20537	29749	19834	31381	13812	20965	31714	23954
1000	21690	33397	14589	20935	20680	14589	22229	32344	21463	34110	14860	22703	34428	26000
1100	25035	38884	16667	24024	23719	16667	25653	37605	24760	39647	16950	26212	39914	30191
1200	28430	44473	18746	27160	26797	18746	29120	42946	28109	45274	19039	29761	45464	34506
1300	31868	50148	20824	30342	29918	20824	32626	48351	31503	50976	21126	33344	51069	38942
1400	35343	55896	22903	33569	33082	22903	36164	53808	34936	56740	23212	36957	56718	43493
1500	38850	61705	24982	36839	36290	24982	39729	59309	38405	62557	25296	40599	62404	48151
1600	42385	67569	27060	40151	39541	27060	43319	64846	41904	68420	27381	44266	68123	52908
1700	45945	73480	29139	43502	42835	29139	46929	70414	45429	74320	29464	47958	73870	57758
1800	49526	79431	31217	46889	46169	31218	50557	76007	48978	80254	31547	51673	79642	62693
1900	53126	85419	33296	50310	49541	33296	54201	81624	52548	86216	33630	55413	85436	67706
2000	56744	91439	35375	53762	52951	35375	57859	87259	56137	92203	35713	59175	91250	72790
2100	60376	97488	37453	57243	56397	37454	61530	92911	59742	98212	37796	62961	97081	77941
2200	64021	103562	39532	60752	59876	39534	65212	98577	63361	104240	39878	66769	102929	83153
2300	67683	109660	41610	64285	63387	41614	68904	104257	66995	110284	41962	70600	108792	88421
2400	71324	115779	43689	67841	66928	43695	72606	109497	70640	116344	44045	74453	114669	93741
2500	74985	121917	45768	71419	70498	45777	76316	115648	74296	122417	46130	78328	120559	99108
2600	78673	128073	47846	75017	74096	47860	80034	121357	77963	128501	48216	82224	126462	104520
2700	82369	134246	49925	78633	77720	49945	83759	127075	81639	134596	50303	86141	132376	109973
2800	86074	140433	52004	82267	81369	52033	87491	132799	85323	140701	52391	90079	138302	115464
2900	89786	146636	54082	85918	85043	54124	91229	138530	89015	146814	54481	94036	144238	120990
3000	93504	152852	56161	89584	88740	56218	94973	144267	92715	152935	56574	98013	150184	126549
3500	112185	184109	66554	108119	107555	66769	113768	173020	111306	183636	67079	118165	180057	154768
4000	130989	215622	75947	126939	126874	77532	132671	201859	130027	214453	77675	188705	210145	183552
4500	149895	247354	87340	145991	146660	88614	151662	230756	148850	245348	88386	159572	240427	212764
5000	168890	279283	97733	165246	166876	100111	170730	259692	167763	276299	99222	180749	270893	242313

Converted and usually rounded off from JANAF Thermochemical Tables, NSRDS-NBS-37, 1971 (1141 pp.)

2-200 PHYSICAL AND CHEMICAL DATA
TABLE 2-223 Ideal Gas Entropies, s° , kJ/kgmol·K, of Combustion Products

Temperature, K	CO	CO_2	H	OH	H_2	N	NO	NO_2	N_2	N_2O	O	O_2	SO_2	H_2O
200	186.0	200.0	106.4	171.6	119.4	145.0	198.7	225.9	180.0	205.6	152.2	193.5	233.0	175.5
240	191.3	206.0	110.1	177.1	124.5	148.7	204.1	232.9	185.2	211.9	156.2	198.7	239.9	181.4
260	193.7	208.8	111.8	179.5	126.8	150.4	206.6	235.0	187.6	214.8	158.0	201.1	242.8	184.1
280	195.3	211.5	113.3	181.8	129.2	151.9	208.8	237.7	189.8	217.5	159.7	203.3	245.8	186.6
298.15	197.7	213.8	114.7	183.7	130.7	153.3	210.8	240.0	191.6	220.0	161.1	205.1	248.2	188.8
300	197.8	214.0	114.8	183.9	130.9	153.4	210.9	240.3	191.8	220.2	161.2	205.3	248.5	189.0
320	199.7	216.5	116.2	185.9	132.8	154.8	212.9	242.7	193.7	222.7	162.6	207.2	251.1	191.2
340	201.5	218.8	117.4	187.7	134.5	156.0	214.7	245.0	195.5	225.2	163.9	209.0	253.6	193.3
360	203.2	221.0	118.6	189.4	136.2	157.2	216.4	247.2	197.2	227.5	165.2	210.7	256.0	195.2
380	204.7	223.2	119.7	191.0	137.7	158.3	218.0	249.3	198.7	229.7	166.3	212.5	258.2	197.1
400	206.2	225.3	120.8	192.5	139.2	159.4	219.5	251.3	200.2	231.9	167.4	213.8	260.4	198.8
420	207.7	227.3	121.8	194.0	140.6	160.4	221.0	253.2	201.5	234.0	168.4	215.3	262.5	200.5
440	209.0	229.3	122.8	195.3	141.9	161.4	222.3	255.1	202.9	236.0	169.4	216.7	264.6	202.0
460	210.4	231.2	123.7	196.6	143.2	162.3	223.7	257.0	204.2	238.0	170.4	218.0	266.6	203.6
480	211.6	233.1	124.6	197.9	144.5	163.1	225.0	258.8	205.5	239.9	171.3	219.4	268.5	205.1
500	212.8	234.9	125.5	199.1	145.7	164.0	226.3	260.6	206.7	241.8	172.2	220.7	270.5	206.5
550	215.7	239.2	127.5	201.8	148.6	166.0	229.1	264.7	209.4	246.2	174.2	223.7	274.9	210.5
600	218.3	243.3	129.3	204.4	151.1	167.8	231.9	268.8	212.2	250.4	176.1	226.5	279.2	213.1
650	220.8	247.1	131.0	206.8	153.4	169.4	234.4	272.6	214.6	254.3	177.7	229.1	283.1	215.9
700	223.1	250.8	132.5	209.0	155.6	171.0	236.8	276.0	216.9	258.0	179.3	231.5	286.9	218.7
750	225.2	255.4	133.9	211.1	157.6	172.5	239.0	279.3	219.0	261.5	180.7	233.7	290.4	221.3
800	227.3	257.5	135.2	213.0	159.5	173.8	241.1	282.5	221.0	264.8	182.1	235.9	293.8	223.8
850	229.2	260.6	136.4	214.8	161.4	175.1	243.0	285.5	223.0	268.0	183.4	237.9	297.0	226.2
900	231.1	263.6	137.7	216.5	163.1	176.3	245.0	288.4	224.8	271.1	184.6	239.9	300.1	228.5
950	232.8	266.5	138.8	218.1	164.7	177.4	246.8	291.3	226.5	274.0	185.7	241.8	303.0	230.6
1000	234.5	269.3	139.9	219.7	166.2	178.5	248.4	293.9	228.2	276.8	186.8	243.6	305.8	232.7
1100	237.7	274.5	141.9	222.7	169.1	180.4	251.8	298.9	231.3	282.1	188.8	246.9	311.0	236.7
1200	240.7	279.4	143.7	225.4	171.8	182.2	254.8	303.6	234.2	287.0	190.6	250.0	315.8	240.5
1300	243.4	283.9	145.3	228.0	174.3	183.9	257.6	307.9	236.9	291.5	192.3	252.9	320.3	244.0
1400	246.0	288.2	146.9	230.3	176.6	185.4	260.2	311.9	239.5	295.8	193.8	255.6	324.5	247.4
1500	248.4	292.2	148.3	232.6	178.8	186.9	262.7	315.7	241.9	299.8	195.3	258.1	328.4	250.6
1600	250.7	296.0	149.6	234.7	180.9	188.2	265.0	319.3	244.1	303.6	196.6	260.4	332.1	253.7
1700	252.9	299.6	150.9	236.8	182.9	189.5	267.2	322.7	246.3	307.2	197.9	262.7	335.6	256.6
1800	254.9	303.0	152.1	238.7	184.8	190.7	269.3	325.9	248.3	310.6	199.1	264.8	338.9	259.5
1900	256.8	306.2	153.2	240.6	186.7	191.8	271.3	328.9	250.2	313.8	200.2	266.8	342.0	262.2
2000	258.7	309.3	154.3	242.3	188.4	192.9	273.1	331.8	252.1	316.9	201.3	268.7	345.0	264.8
2100	260.5	312.2	155.3	244.0	190.1	193.9	274.9	334.5	253.8	319.8	202.3	270.6	347.9	267.3
2200	262.2	315.1	156.3	245.7	191.7	194.8	276.6	337.2	255.5	322.6	203.2	272.4	350.6	269.7
2300	263.8	317.8	157.2	247.2	193.3	195.8	278.3	339.7	257.1	325.3	204.2	274.1	353.2	272.0
2400	265.4	320.4	158.1	248.7	194.8	196.7	279.8	342.1	258.7	327.9	205.0	275.7	355.7	274.3
2500	266.9	322.9	158.9	250.2	196.2	197.5	281.4	344.5	260.2	330.4	205.9	277.3	358.1	276.5
2600	268.3	325.3	159.7	251.6	197.7	198.3	282.8	346.7	261.6	332.7	206.7	278.8	360.4	278.6
2700	269.7	327.6	160.5	253.0	199.0	199.1	284.2	348.9	263.0	335.0	207.5	280.3	362.6	280.7
2800	271.0	329.9	161.3	254.3	200.3	199.9	285.6	350.9	264.3	337.3	208.3	281.7	364.8	282.7
2900	272.3	332.1	162.0	255.6	201.6	200.6	286.9	352.9	265.6	339.4	209.0	283.1	366.9	284.6
3000	273.6	334.2	162.7	256.8	202.9	201.3	288.2	354.9	266.9	341.5	209.7	284.4	368.9	286.5
3500	279.4	343.8	165.9	262.5	208.7	204.6	294.0	363.8	272.6	350.9	212.9	290.7	378.1	295.2
4000	284.4	352.2	168.7	267.6	213.8	207.4	299.0	371.5	277.6	359.2	215.8	296.2	386.1	302.9
4500	288.8	359.7	171.1	272.1	218.5	210.1	303.5	378.3	282.1	366.5	218.3	301.1	393.3	309.8
5000	292.8	366.4	173.3	276.1	222.8	212.5	307.5	384.4	286.0	373.0	220.6	305.5	399.7	316.0

Usually rounded off from JANAF Thermochemical Tables, NSRDS-NBS-37, 1971 (1141 pp.). Equilibrium constants can be calculated by combining Δh_f° values from Table 2-221, $h_T - h_{298}$ from Table 2-222, and s° values from the above, using the formula $\ln k_p = -\Delta G/(RT)$, where $\Delta G = \Delta h_f^\circ + (h_T - h_{298}) - T_s^\circ$.

HEATS OF SOLUTION

TABLE 2-224 Heats of Solution of Inorganic Compounds in Water

Heat evolved, in kilogram-calories per gram formula weight, on solution in water at 18°C. Computed from data in Bichowsky and Rossini, *Thermochemistry of Chemical Substances*, Reinhold, New York, 1936.

Substance	Dilution°	Formula	Heat, kg-cal/ g-mole	Substance	Dilution°	Formula	Heat, kg-cal/ g-mole
Aluminum bromide chloride fluoride iodide sulfate	aq	AlBr ₃	+85.3	Calcium—(Cont.) bromide chloride formate iodide nitrate phosphate, mono- dibasic sulfate	∞	CaBr ₂	+24.86
	600	AlCl ₃	+77.9		∞	CaBr ₂ ·6H ₂ O	-0.9
	600	AlCl ₃ ·6H ₂ O	+13.2		∞	CaCl ₂	+4.9
	aq	AlF ₃	+31		∞	CaCl ₂ ·H ₂ O	+12.3
	aq	AlF ₃ ·½H ₂ O	+19.0		∞	CaCl ₂ ·2H ₂ O	+12.5
	aq	AlF ₃ ·¾H ₂ O	-1.7		∞	CaCl ₂ ·4H ₂ O	+2.4
	aq	AlI ₃	+89.0		∞	CaCl ₂ ·6H ₂ O	-4.11
	aq	Al ₂ (SO ₄) ₃	+126		400	Ca(CHO ₂) ₂	+0.7
	aq	Al ₂ (SO ₄) ₃ ·6H ₂ O	+56.2		∞	CaI ₂	+28.0
	aq	Al ₂ (SO ₄) ₃ ·18H ₂ O	+6.7		∞	CaI ₂ ·8H ₂ O	+1.8
Ammonium bromide chloride chromate dichromate iodide nitrate perborate sulfate sulfate, acid sulfite	aq	NH ₄ Br	-4.45	nitrate	∞	Ca(NO ₃) ₂	+4.1
	∞	NH ₄ Cl	-3.82		∞	Ca(NO ₃) ₂ ·H ₂ O	+0.7
	aq	(NH ₄) ₂ CrO ₄	-5.82		∞	Ca(NO ₃) ₂ ·2H ₂ O	-3.2
	600	(NH ₄) ₂ Cr ₂ O ₇	-12.9		∞	Ca(NO ₃) ₂ ·3H ₂ O	-4.2
	aq	NH ₄ I	-3.56		∞	Ca(NO ₃) ₂ ·4H ₂ O	-7.99
	∞	NH ₄ NO ₃	-6.47		aq	Ca(H ₂ PO ₄) ₂ ·H ₂ O	-0.6
	aq	NH ₄ BO ₃ ·H ₂ O	-9.0		aq	CaHPO ₄ ·2H ₂ O	-1
	∞	(NH ₄) ₂ SO ₄	-2.75		∞	CaSO ₄	+5.1
	800	NH ₄ HSO ₄	+0.56		∞	CaSO ₄ ·½H ₂ O	+3.6
	aq	(NH ₄) ₂ SO ₃	-1.2		∞	CaSO ₄ ·2H ₂ O	-0.18
Antimony fluoride iodide Arsenic acid	aq	(NH ₄) ₂ SO ₃ ·H ₂ O	-4.13	Chromous chloride	aq	CrCl ₂	+18.6
	aq	SbF ₃	-1.7		aq	CrCl ₂ ·3H ₂ O	+5.3
	aq	SbI ₃	-0.8		aq	CrCl ₂ ·4H ₂ O	+2.0
Barium bromate bromide chlorate chloride cyanide iodate iodide nitrate perchlorate sulfide	aq	H ₃ AsO ₄	-0.4	iodide Cobaltous bromide chloride iodide sulfate Cupric acetate formate nitrate sulfate Cuprous sulfate	aq	CrI ₂	+5.7
	∞	Ba(BrO ₃) ₂ ·H ₂ O	-15.9		aq	CoBr ₂	+18.4
	∞	BaBr ₂	+5.3		aq	CoBr ₂ ·6H ₂ O	-1.25
	∞	BaBr ₂ ·H ₂ O	-0.8		400	CoCl ₂	+18.5
	∞	BaBr ₂ ·2H ₂ O	-3.87		400	CoCl ₂ ·2H ₂ O	+9.8
	∞	Ba(ClO ₃) ₂	-6.7		400	CoCl ₂ ·6H ₂ O	-2.9
	∞	Ba(ClO ₃) ₂ ·H ₂ O	-10.6		400	CoI ₂	+18.8
	∞	BaCl ₂	+2.4		400	CoSO ₄	+15.0
	∞	BaCl ₂ ·H ₂ O	-2.17		400	CoSO ₄ ·6H ₂ O	-1.4
	∞	BaCl ₂ ·2H ₂ O	-4.5		400	CoSO ₄ ·7H ₂ O	-3.6
Beryllium bromide chloride iodide sulfate	aq	Ba(CN) ₂	+1.5	Cupric acetate formate nitrate sulfate Cuprous sulfate	aq	Cu(C ₂ H ₅ O ₂) ₂	+2.4
	aq	Ba(CN) ₂ ·H ₂ O	-2.4		aq	Cu(CHO ₂) ₂	+0.5
	aq	Ba(CN) ₂ ·2H ₂ O	-4.9		200	Cu(NO ₃) ₂	+10.3
	∞	Ba(IO ₃) ₂	-9.1		200	Cu(NO ₃) ₂ ·3H ₂ O	-2.6
	∞	Ba(IO ₃) ₂ ·H ₂ O	-11.3		200	Cu(NO ₃) ₂ ·6H ₂ O	-10.7
	∞	BaI ₂	+10.5		800	CuSO ₄	+15.9
	∞	BaI ₂ ·H ₂ O	+2.7		800	CuSO ₄ ·H ₂ O	+9.3
	∞	BaI ₂ ·2H ₂ O	+0.14		800	CuSO ₄ ·3H ₂ O	+3.65
	∞	BaI ₂ ·2½H ₂ O	-0.58		800	CuSO ₄ ·5H ₂ O	-2.85
	∞	BaI ₂ ·7H ₂ O	-6.61		aq	Cu ₂ SO ₄	+11.6
Bismuth iodide Boric acid	∞	Ba(NO ₃) ₂	-10.2	Ferric chloride Ferrous bromide chloride iodide sulfate	1000	FeCl ₃	+31.7
	∞	Ba(ClO ₄) ₂	-2.8		1000	FeCl ₃ ·2½H ₂ O	+21.0
	∞	Ba(ClO ₄) ₂ ·3H ₂ O	-10.5		1000	FeCl ₃ ·6H ₂ O	+5.6
	∞	BaS	+7.2		800	Fe(NO ₃) ₃ ·9H ₂ O	-9.1
	aq	BeBr ₂	+62.6		aq	FeBr ₂	+18.0
	aq	BeCl ₂	+51.1		400	FeCl ₂	+17.9
	aq	BeI ₂	+72.6		400	FeCl ₂ ·2H ₂ O	+8.7
	aq	BeSO ₄	+18.1		400	FeCl ₂ ·4H ₂ O	+2.7
	aq	BeSO ₄ ·H ₂ O	+13.5		400	FeI ₂	+23.3
	aq	BeSO ₄ ·2H ₂ O	+7.9		400	FeSO ₄	+14.7
Cadmium bromide chloride nitrate sulfate	aq	BeSO ₄ ·4H ₂ O	+1.1		400	FeSO ₄ ·H ₂ O	+7.35
	aq	BiI ₃	+3		400	FeSO ₄ ·4H ₂ O	+1.4
	aq	H ₃ BO ₃	-5.4		400	FeSO ₄ ·7H ₂ O	-4.4
	400	CdBr ₂	+0.4	Lead acetate bromide chloride formate nitrate Lithium bromide	400	Pb(C ₂ H ₅ O ₂) ₂	+1.4
	400	CdBr ₂ ·4H ₂ O	-7.3		400	Pb(C ₂ H ₅ O ₂) ₂ ·3H ₂ O	-5.9
	400	CdCl ₂	+3.1		aq	PbBr ₂	-10.1
	400	CdCl ₂ ·H ₂ O	+0.6		aq	PbCl ₂	-3.4
	400	CdCl ₂ ·2½H ₂ O	-3.00		aq	Pb(CHO ₂) ₂	-6.9
	400	Cd(NO ₃) ₂ ·H ₂ O	+4.17		400	Pb(NO ₃) ₂	-7.61
	400	Cd(NO ₃) ₂ ·4H ₂ O	-5.08		∞	LiBr	+11.54
	400	CdSO ₄	+10.69		∞	LiBr·H ₂ O	+5.30
	400	CdSO ₄ ·H ₂ O	+6.05		∞	LiBr·2H ₂ O	+2.05
	400	CdSO ₄ ·2½H ₂ O	+2.51		∞	LiBr·3H ₂ O	-1.59
Calcium acetate	∞	Ca(C ₂ H ₃ O ₂) ₂	+7.6		∞	LiCl	+8.66
	∞	Ca(C ₂ H ₃ O ₂) ₂ ·H ₂ O	+6.5		∞		

*The numbers represent moles of water used to dissolve 1 g formula weight of substance; ∞ means "infinite dilution"; and aq means "aqueous solution of unspecified dilution."

TABLE 2-224 Heats of Solution of Inorganic Compounds in Water (Continued)

Substance	Dilution°	Formula	Heat, kg-cal/g-mole	Substance	Dilution°	Formula	Heat, kg-cal/g-mole
Lithium—(Cont.)							
fluoride	∞	LiCl-H ₂ O	+4.45	Phosphoric acid, ortho-	400	H ₃ PO ₄	+2.79
hydroxide	∞	LiCl-2H ₂ O	+1.07	pyro-	400	H ₃ PO ₄ ·½H ₂ O	-0.1
	∞	LiCl-3H ₂ O	-1.98	aq	400	H ₄ P ₂ O ₇	+25.9
iodide	∞	LiF	-0.74	Potassium acetate	∞	H ₄ P ₂ O ₇ ·1½H ₂ O	+4.65
	∞	LiOH	+4.74	aluminum sulfate	600	KC ₂ H ₃ O ₂	+3.55
	∞	LiOH·½H ₂ O	+4.39		600	KAl(SO ₄) ₂	+48.5
	∞	LiOH-H ₂ O	+9.6			KAl(SO ₄) ₂ ·3H ₂ O	+26.6
nitrate	∞	LiI	+14.92	bicarbonate	2000	KAl(SO ₄) ₂ ·12H ₂ O	-10.1
	∞	LiI·½H ₂ O	+10.08	bromate	∞	KHCO ₃	-5.1
	∞	LiI-H ₂ O	+6.93	bromide	∞	KBrO ₃	-10.13
	∞	LiI·2H ₂ O	+3.43	carbonate	∞	KBr	-5.13
	∞	LiI-3H ₂ O	-0.17		∞	K ₂ CO ₃	+6.58
sulfate	∞	LiNO ₃	+0.466	chlorate	∞	K ₂ CO ₃ ·½H ₂ O	+4.25
	∞	LiNO ₃ ·3H ₂ O	-7.87	chloride	∞	K ₂ CO ₃ ·1½H ₂ O	-0.43
Magnesium bromide	∞	Li ₂ SO ₄	+6.71	chromate	2185	K ₂ CrO ₃	-10.31
	∞	Li ₂ SO ₄ ·H ₂ O	+3.77	chrome sulfate	600	K ₂ Cr(SO ₄) ₂	-4.404
chloride	∞	MgBr ₂	+43.7			KCr(SO ₄) ₂ ·½H ₂ O	-4.9
	∞	MgBr ₂ -H ₂ O	+35.9			KCr(SO ₄) ₂ ·2H ₂ O	+55
	∞	MgBr ₂ ·6H ₂ O	+19.8			KCr(SO ₄) ₂ ·6H ₂ O	+33
iodide	∞	MgCl ₂	+36.3	cyanide	200	KCr(SO ₄) ₂ ·12H ₂ O	+7
	∞	MgCl ₂ ·2H ₂ O	+20.8	dichromate	1600	KCN	-9.5
	∞	MgCl ₂ ·4H ₂ O	+10.5	fluoride	∞	K ₂ Cr ₂ O ₇	-3.0
nitrate	∞	MgCl ₂ ·6H ₂ O	+3.4	hydrosulfide	∞	KF	-17.8
phosphate	aq	Mg ₃ (PO ₄) ₂	+10.2		∞	KF·2H ₂ O	+3.96
sulfate	∞	MgSO ₄	+21.1	hydroxide	∞	KF·4H ₂ O	-1.85
	∞	MgSO ₄ ·H ₂ O	+14.0		∞	KHS	-6.05
	∞	MgSO ₄ ·2H ₂ O	+11.7		∞	KHS·½H ₂ O	+0.86
	∞	MgSO ₄ ·4H ₂ O	+4.9		∞	KOH	+12.91
	∞	MgSO ₄ ·6H ₂ O	+0.55		∞	KOH·¾H ₂ O	+1.21
	∞	MgSO ₄ ·7H ₂ O	-3.18	iodate	∞	KOH·H ₂ O	+4.27
sulfide	aq	MgS	+25.8	iodide	∞	KOH·7H ₂ O	+3.48
Manganic nitrate	400	Mn(NO ₃) ₂	+12.9	nitrate	∞	KIO ₃	+0.86
	400	Mn(NO ₃) ₂ ·3H ₂ O	-3.9	oxalate	400	KI	-6.93
	400	Mn(NO ₃) ₂ ·6H ₂ O	-6.2		∞	KNO ₃	-5.23
sulfate	aq	Mn ₂ (SO ₄) ₃	+22	perchlorate	∞	K ₂ C ₂ O ₄	-8.633
Manganous acetate	aq	Mn(C ₂ H ₃ O ₂) ₂	+12.2	permanganate	400	K ₂ C ₂ O ₄ ·H ₂ O	-4.6
	aq	Mn(C ₂ H ₃ O ₂) ₂ ·4H ₂ O	+1.6	phosphate, dihydrogen	aq	K ₂ S ₂ O ₅	-7.5
bromide	aq	MnBr ₂	+15	pyrosulfite	aq	K ₂ S ₂ O ₅ ·½H ₂ O	-12.94
	aq	MnBr ₂ ·H ₂ O	+14.4		∞	KClO ₄	-10.4
chloride	aq	MnBr ₂ ·4H ₂ O	+16.1	sulfate	∞	K ₂ SO ₄	-11.0
	400	MnCl ₂	+16.0	sulfate, acid	800	KHSO ₄	-6.32
	400	MnCl ₂ ·2H ₂ O	+8.2	sulfide	∞	K ₂ S	-3.10
formate	aq	MnCl ₂ ·4H ₂ O	+1.5	sulfite	aq	K ₂ SO ₃	-11.0
iodide	aq	Mn(CHO ₂) ₂	+4.3	thiocyanate	aq	K ₂ SO ₃ ·H ₂ O	+1.8
	aq	Mn(CHO ₂) ₂ ·2H ₂ O	-2.9		∞	KCNS	+1.37
	aq	MnI ₂	+26.2	thionate, di-	aq	K ₂ S ₂ O ₆	-6.08
	aq	MnI ₂ ·H ₂ O	+24.1	thiosulfate	∞	K ₂ S ₂ O ₃	-13.0
	aq	MnI ₂ ·2H ₂ O	+22.7		∞	K ₂ S ₂ O ₃ ·H ₂ O	-4.5
	aq	MnI ₂ ·4H ₂ O	+19.9	Silver acetate	aq	AgC ₂ H ₃ O ₂	-5.4
sulfate	aq	MnI ₂ ·6H ₂ O	+21.2	nitrate	200	AgNO ₃	-4.4
	400	MnSO ₄	+13.8	Sodium acetate	∞	NaC ₂ H ₃ O ₂	+0.085
	400	MnSO ₄ ·H ₂ O	+11.9		∞	NaC ₂ H ₃ O ₂ ·3H ₂ O	-4.665
	400	MnSO ₄ ·7H ₂ O	-1.7	arsenate	500	Na ₃ AsO ₄	+15.6
Mercuric acetate	aq	Hg(C ₂ H ₃ O ₂) ₂	-4.0	bicarbonate	500	Na ₃ AsO ₄ ·12H ₂ O	-12.61
bromide	aq	HgBr ₂	-2.4	borate, tetra-	900	NaHCO ₃	-4.1
chloride	aq	HgCl ₂	-3.3		900	Na ₂ B ₄ O ₇	+10.0
	aq	Hg(NO ₃) ₂ ·½H ₂ O	-0.7	bromide	900	Na ₂ B ₄ O ₇ ·10H ₂ O	-16.8
Mercurous nitrate	aq	Hg ₂ (NO ₃) ₂ ·2H ₂ O	-11.5		∞	NaBr	-0.58
Nickel bromide	aq	NiBr ₂	+19.0	carbonate	∞	NaBr·2H ₂ O	-4.57
	aq	NiBr ₂ ·3H ₂ O	+0.2		∞	Na ₂ CO ₃	+5.57
Nickel chloride	800	NiCl ₂	+19.23		∞	Na ₂ CO ₃ ·H ₂ O	+2.19
	800	NiCl ₂ ·2H ₂ O	+10.4		∞	Na ₂ CO ₃ ·7H ₂ O	-10.81
	800	NiCl ₂ ·4H ₂ O	+4.2	chlorate	∞	Na ₂ CO ₃ ·10H ₂ O	-16.22
iodide	aq	NiI ₃	+19.4	chloride	∞	NaClO ₃	-5.37
nitrate	200	Ni(NO ₃) ₂	+11.8	chromate	800	NaCl	-1.164
	200	Ni(NO ₃) ₂ ·6H ₂ O	-7.5		800	Na ₂ CrO ₄	+2.50
sulfate	200	NiSO ₄	+15.1	cyanide	200	Na ₂ CrO ₄ ·4H ₂ O	-7.52
	200	NiSO ₄ ·7H ₂ O	-4.2		800	Na ₂ CrO ₄ ·10H ₂ O	-16.0

TABLE 2-224 Heats of Solution of Inorganic Compounds in Water (Concluded)

Substance	Dilution°	Formula	Heat, kg-cal/ g-mole	Substance	Dilution°	Formula	Heat, kg-cal/ g-mole
Sodium—(Cont.)				Sodium—(Cont.)			
fluoride	200	NaCN·2H ₂ O	-4.41	thionate, di-	aq	Na ₂ S ₂ O ₆	-5.80
hydrosulfide	∞	NaF	-0.27		aq	Na ₂ S ₂ O ₆ ·2H ₂ O	-11.86
	∞	NaHS	+4.62	Sodium thiosulfate	aq	Na ₂ S ₂ O ₃	+2.0
	∞	NaHS·2H ₂ O	-1.49		aq	Na ₂ S ₂ O ₃ ·5H ₂ O	-11.30
Sodium hydroxide	∞	NaOH	+10.18	Stannic bromide	aq	SnBr ₄	+15.5
	∞	NaOH·½H ₂ O	+8.17	Stannous bromide	aq	SnBr ₂	-1.6
	∞	NaOH·¾H ₂ O	+7.08	iodide	aq	SnI ₂	-5.8
	∞	NaOH·¾H ₂ O	+6.48	Strontium acetate	∞	Sr(C ₂ H ₃ O ₂) ₂	+6.2
iodide	∞	NaOH·H ₂ O	+5.17	bromide	∞	Sr(C ₂ H ₃ O ₂) ₂ ·½H ₂ O	+5.9
	∞	NaI	+1.57		∞	SrBr ₃	+16.4
	∞	NaI·2H ₂ O	-3.89		∞	SrBr ₃ ·H ₂ O	+9.25
metaphosphate	600	NaPO ₃	+3.97		∞	SrBr ₃ ·2H ₂ O	+6.5
nitrate	∞	NaNO ₃	-5.05		∞	SrBr ₃ ·4H ₂ O	+0.4
nitrite	aq	NaNO ₂	-3.6		∞	SrBr ₃ ·6H ₂ O	-6.1
perchlorate	∞	NaClO ₄	-4.15	chloride	∞	SrCl ₂	+11.54
phosphate di	1600	Na ₂ HPO ₄	+5.21		∞	SrCl ₂ ·H ₂ O	+6.4
phosphate tri-	1600	Na ₃ PO ₄	+13		∞	SrCl ₂ ·2H ₂ O	+2.95
phosphate di-	1600	Na ₃ PO ₄ ·12H ₂ O	-15.3		∞	SrCl ₂ ·6H ₂ O	-7.1
	1600	Na ₂ HPO ₄ ·2H ₂ O	-0.82	iodide	∞	SrI ₂	+20.7
	1600	Na ₂ HPO ₄ ·7H ₂ O	-12.04		∞	SrI ₂ ·H ₂ O	+12.65
	1600	Na ₂ HPO ₄ ·12H ₂ O	-23.18		∞	SrI ₂ ·2H ₂ O	+10.4
phosphite, mono-	600	NaH ₂ PO ₃	+0.90		∞	SrI ₂ ·6H ₂ O	-4.5
di-	600	NaH ₂ PO ₃ ·2½H ₂ O	-5.29	nitrate	∞	Sr(NO ₃) ₂	-4.8
	800	Na ₂ HPO ₃	+9.30		∞	Sr(NO ₃) ₂ ·4H ₂ O	-12.4
pyrophosphate	1600	Na ₂ P ₂ O ₇	+4.54	sulfate	∞	SrSO ₄	+0.5
	1600	Na ₄ P ₂ O ₇ ·10H ₂ O	+11.9	Sulfuric acid, pyro-	∞	H ₂ S ₂ O ₇	-18.08
di-	1200	Na ₂ H ₂ P ₂ O ₇	-2.2	Zinc acetate	400	Zn(C ₂ H ₃ O ₂) ₂	+9.8
	1200	Na ₂ H ₂ P ₂ O ₇ ·6H ₂ O	-14.0		400	Zn(C ₂ H ₃ O ₂) ₂ ·H ₂ O	+7.0
sulfate	∞	Na ₂ SO ₄	+0.28		400	Zn(C ₂ H ₃ O ₂) ₂ ·2H ₂ O	+3.9
	∞	Na ₂ SO ₄ ·10H ₂ O	-18.74	bromide	400	ZnBr ₂	+15.0
sulfate, acid	800	NaHSO ₄	+1.74	chloride	400	ZnCl ₂	+15.72
	800	NaHSO ₄ ·H ₂ O	+0.15	iodide	aq	ZnI ₂	+11.6
sulfide	∞	Na ₂ S	+15.2	nitrate	400	Zn(NO ₃) ₂ ·3H ₂ O	-5
	∞	Na ₂ S·4½H ₂ O	+0.09		400	Zn(NO ₃) ₂ ·6H ₂ O	-6.0
	∞	Na ₂ S·5H ₂ O	-6.54	sulfate	400	ZnSO ₄	+18.5
	∞	Na ₂ S·9H ₂ O	-16.65		400	ZnSO ₄ ·H ₂ O	+10.0
sulfite	∞	Na ₂ SO ₃	+2.8		400	ZnSO ₄ ·6H ₂ O	-0.8
	∞	Na ₂ SO ₃ ·7H ₂ O	-11.1		400	ZnSO ₄ ·7H ₂ O	-4.3
thiocyanate	∞	NaCNS	-1.83				

NOTE: To convert kilocalories per gram-mole to British thermal units per pound-mole, multiply by 1.799×10^{-3} .

TABLE 2-225 Heats of Solution of Organic Compounds in Water (at Infinite Dilution and Approximately Room Temperature)Recalculated and rearranged from *International Critical Tables*, vol. 5, pp. 148–150. (g·cal)/(g·mol) = Btu/(lb·mol) × 1.799.

Solute	Heat of Solution, G-cal/g-mole Solute°	Solute	Heat of Solution, G-cal/g-mole Solute°
Acetic acid (solid), C ₂ H ₄ O ₂	-2,251	Oxalic acid, C ₂ H ₂ O ₄ (2H ₂ O)	-2,290
Acetylacetone, C ₅ H ₈ O ₂	-641	Phenol (solid), C ₆ H ₅ O	-8,485
Acetylurea, C ₃ H ₆ N ₂ O ₂	-6,812	Phthalic acid, C ₈ H ₆ O ₄	-2,605
Aconitic acid, C ₆ H ₆ O ₆	-4,206	Picric acid, C ₆ H ₃ N ₃ O ₇	-4,871
Ammonium benzoate, C ₇ H ₉ NO ₂	-2,700	Piperic acid, C ₁₂ H ₁₀ O ₄	-7,098
picrate	-8,700	Piperonylic acid, C ₈ H ₆ O ₄	-10,492
succinate (n-)	-3,489	Potassium benzoate	-9,106
Aniline, hydrochloride, C ₆ H ₅ ClN	-2,732	citrate	-1,506
Barium picrate	-4,708	tartrate (n-) (0.5 H ₂ O)	2,820
Benzoic acid, C ₇ H ₆ O ₂	-6,501	Pyrogallol, C ₆ H ₆ O ₃	-5,562
Camphoric acid, C ₁₀ H ₁₆ O ₄	-502	Pyrotartaric acid	-3,705
Citric acid, C ₆ H ₈ O ₇	-5,401	Quinone	-5,019
Dextrin, C ₁₂ H ₂₀ O ₁₀	268	Raffinose, C ₁₈ H ₃₂ O ₁₆ (5H ₂ O)	-3,991
Fumaric acid, C ₄ H ₄ O ₄	-5,903	Resorcinol, C ₆ H ₆ O ₂	-9,703
Hexamethylenetetramine, C ₆ H ₁₂ N ₄	4,780	Silver malonate (n-)	-3,960
Hydroxybenzamide (m-), C ₇ H ₇ NO ₂	-4,161	Sodium citrate (tri-)	-9,799
(m-), (HCl)	-7,003	picrate	5,270
(o-), C ₇ H ₇ NO ₂	-4,340	potassium tartrate	-6,441
(p-)	-5,392	(4H ₂ O)	-1,817
Hydroxybenzoic acid (o-), C ₇ H ₆ O ₃	-6,350	succinate (n-)	-12,342
(p-), C ₇ H ₆ O ₃	-5,781	(6H ₂ O)	2,390
Hydroxybenzyl alcohol (o-), C ₇ H ₈ O ₂	-3,203	tartrate (n-)	-10,994
Inulin, C ₃₆ H ₆₂ O ₃₁	-96	(2H ₂ O)	-1,121
Iosuccinic acid, C ₄ H ₆ O ₄	-3,420	Strontium picrate	-5,882
Itaconic acid, C ₅ H ₆ O ₄	-5,922	(6H ₂ O)	7,887
Lactose, C ₁₂ H ₂₂ O ₁₁ ·H ₂ O	-3,705	Succinic acid, C ₄ H ₆ O ₄	-14,412
Lead picrate	-7,098	Succinimide, C ₄ H ₆ NO ₂	-6,405
(2H ₂ O)	-13,193	Sucrose, C ₁₂ H ₂₂ O ₁₁	-4,302
Magnesium picrate	14,699	Tartaric acid (d-)	-1,319
(8H ₂ O)	-15,894	Thiourea, CH ₄ N ₂ S	-3,451
Maleic acid, C ₄ H ₄ O ₄	-4,441	Urea, CH ₄ N ₂ O	-5,330
Malic acid, C ₄ H ₆ O ₅	-3,150	acetate	-3,609
Malonic acid, C ₃ H ₄ O ₄	-4,493	formate	-8,795
Mandelic acid, C ₅ H ₂ O ₃	-3,090	nitrate	-7,194
Mannitol, C ₆ H ₁₂ O ₆	-5,260	oxalate	-10,803
Menthol, C ₁₀ H ₂₀ O	0	Vanillil acid	-17,806
Nicotine dihydrochloride, C ₁₀ H ₁₆ Cl ₂ N ₂	6,561	Vanillin	-5,160
Nitrobenzoic acid (m-), C ₇ H ₅ NO ₄	-5,593	Zinc picrate	-5,210
(o-), C ₇ H ₅ NO ₄	-5,306	(8H ₂ O)	-11,496
(p-), C ₇ H ₅ NO ₄	-8,891		-15,894
Nitrophenol (m-), C ₆ H ₅ NO ₃	-5,210		
(o-), C ₆ H ₅ NO ₃	-6,310		
(p-), C ₆ H ₅ NO ₃	-4,493		

°+ denotes heat evolved, and – denotes heat absorbed. All values are positive unless otherwise noted. The data in the *International Critical Tables* were calculated by E. Anderson.

THERMODYNAMIC PROPERTIES

EXPLANATION OF TABLES

The following subsection presents information on the thermodynamic properties of a number of fluids. In some cases transport properties are also included.

Notation

c_p	= specific heat
e	= specific internal energy
h	= enthalpy
k	= thermal conductivity
p	= pressure
s	= specific entropy
t	= temperature
T	= absolute temperature
u	= specific internal energy
μ	= viscosity
v	= specific volume
f	= subscript denoting saturated liquid
g	= subscript denoting saturated vapor

UNITS CONVERSIONS

For this subsection, the following units conversions are applicable:

c_p , specific heat: To convert kilojoules per kilogram-kelvin to British thermal units per pound-degree Fahrenheit, multiply by 0.23885.

e , internal energy: To convert kilojoules per kilogram to British thermal units per pound, multiply by 0.42992.

g , gravity acceleration: To convert meters per second squared to feet per second squared, multiply by 3.2808.

h , enthalpy: To convert kilojoules per kilogram to British thermal units per pound, multiply by 0.42992.

k , thermal conductivity: To convert watts per meter-kelvin to British thermal unit-feet per hour-square foot-degree Fahrenheit, multiply by 0.57779.

p , pressure: To convert bars to kilopascals, multiply by 1×10^5 ; to convert bars to pounds-force per square inch, multiply by 14.504; and to convert millimeters of mercury to pounds-force per square inch, multiply by 0.01934.

s , entropy: to convert kilojoules per kilogram-kelvin to British thermal units per pound-degree Rankine, multiply by 0.23885.

t , temperature: $^{\circ}\text{F} = \frac{9}{5} ^{\circ}\text{C} + 32$.

T , absolute temperature: $^{\circ}\text{R} = \frac{9}{5} \text{K}$.

u , internal energy: to convert kilojoules per kilogram to British thermal units per pound, multiply by 0.42992.

μ , viscosity: to convert pascal-seconds to pound-force-seconds per square foot, multiply by 0.020885; to convert pascal-seconds to c_p , multiply by 1000.

v , specific volume: to convert cubic meters per kilogram to cubic feet per pound, multiply by 16.018.

ρ , density: to convert kilograms per cubic meter to pounds per cubic foot, multiply by 0.062428.

ADDITIONAL REFERENCES

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2-206 PHYSICAL AND CHEMICAL DATA
TABLE 2-226 Thermophysical Properties of Saturated Acetone

Temperature, K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/kg·K	s_g , kJ/kg·K	c_{pf} , kJ/kg·K	μ_f , 10 ⁻⁶ Pa·s	k_f , W/m·K	Pr
300	0.318	0.001 261	1.415	-67	466	-0.213	1.561				
310	0.482	0.001 285	0.942	-46	476	-0.144	1.540				
320	0.710	0.001 309	0.645	-22	490	-0.068	1.531				
329.3 ^b	1.013	0.001 333	0.456	0	506	0	1.537	2.29	232	0.141	3.77
330	1.040	0.001 335	0.448	2	506	0.003	1.521	2.29	231	0.141	3.75
340	1.52	0.001 359	0.311	25	509	0.075	1.514	2.33	212	0.137	3.61
350	2.04	0.001 383	0.237	51	529	0.150	1.516	2.38	200	0.132	3.61
360	2.74	0.001 408	0.179	78	543			2.43	187	0.128	3.55
370	3.60	0.001 435	0.138	103	554			2.48	176	0.124	3.52
380	4.52	0.001 464	0.110	127	566			2.53	165	0.119	3.51
390	5.87	0.001 495	0.0854	151	577			2.59	153	0.115	3.45
400	7.31	0.001 528	0.0684	184	588			2.65	141	0.111	3.37
410	8.94	0.001 564	0.0556	207	598			2.73	130	0.107	3.32
420	10.82	0.001 604	0.0454	231	608			2.82	119	0.103	3.26
430	13.64	0.001 647	0.0356	256	618			2.92	109	0.099	3.21
440	16.37	0.001 695	0.0292	281	625			3.03	99	0.095	3.16
450	19.42	0.001 748	0.0240	308	632			3.15	90	0.092	3.08
460	22.79	0.001 81	0.0199	337	637			3.29	80	0.088	2.99
470	27.52	0.001 88	0.0159	365	641			3.45	71	0.083	2.95
480	32.52	0.001 98	0.0130	396	638			3.76	64	0.077	3.13
490	37.73	0.002 15	0.0091								
500	43.08	0.002 46	0.0063								
508.2 ^c	47.61	0.003 67	0.0037								

b = normal boiling point; *c* = critical point

P, *v*, *h*, and *s* interpolated and converted from *Heat Exchanger Design Handbook*, vol. 5, Hemisphere, Washington, DC, 1983 and reproduced in Beaton, C. F. and G. F. Hewitt, *Physical Property Data for the Design Engineer*, Hemisphere, New York, 1989 (394 pp.). Other values compiled by P. E. Liley

An enthalpy-pressure diagram to 1000 psia, 250–500 °F appears in *J. Chem. Eng. Data* 7, 1 (1962): 75–78.

TABLE 2-227 Saturated Acetylene*

Temperature, K	Pressure, bar	v_{cond} , m ³ /kg	v_g , m ³ /kg	h_{cond} , kJ/kg	h_g , kJ/kg	s_{cond} , kJ/(kg·K)	s_g , kJ/(kg·K)
162.0	0.101			5.081	158	983	2.967
169.3	0.203			2.644	173	994	3.039
173.9	0.304			1.805	182	999	3.095
180.0	0.507			1.116	194	1007	3.161
184.3	0.709			0.810	203	1011	3.216
189.1	1.013			0.5780	214	1015	3.272
192.4 ^t	1.283			0.4617	221	1018	3.312
192.4 ^t	1.283	0.00164	0.4617	378	1018	4.127	7.455
200.9	2.027	0.00165	0.3011	411	1027	4.296	7.362
209.4	3.040	0.00169	0.2074	445	1035	4.461	7.280
221.5	5.066	0.00174	0.1264	493	1046	4.684	7.180
230.4	7.093	0.00179	0.0907	528	1052	4.837	7.111
240.7	10.13	0.00186	0.0635	565	1058	4.990	7.037
253.2	15.20	0.00195	0.0420	602	1061	5.133	6.947
263.0	20.27	0.00204	0.0309	628	1061	5.231	6.878
271.6	25.33	0.00213	0.0240	654	1060	5.326	6.822
278.9	30.40	0.00223	0.0193	680	1057	5.414	6.767
284.9	35.46	0.00232	0.0159	704	1051	5.494	6.716
290.4	40.53	0.00242	0.0133	727	1041	5.576	6.658
300.0	50.66	0.00270	0.0093	778	1017	5.737	6.534
307.8	60.80	0.00335	0.0061	850	968	5.965	6.351
308.7 ^c	62.47	0.00434	0.0043	908	908	6.158	6.158

*Values recalculated into SI units from those of Din. *Thermodynamic Functions of Gases*, vol. 2, Butterworth, London, 1956. Above the solid line the condensed phase is solid; below the line it is liquid. *t* = triple point; *c* = critical point.

TABLE 2-228 Saturated Air*

<i>T</i> , K	<i>P_f</i> , bar	<i>P_g</i> , bar	<i>v_f</i> , m ³ /kg	<i>v_g</i> , m ³ /kg	<i>h_f</i> , kJ/kg	<i>h_g</i> , kJ/kg	<i>s_f</i> , kJ/(kg·K)	<i>s_g</i> , kJ/(kg·K)	<i>c_{pf}</i> , kJ/(kg·K)	$10^{-4} \mu_f$, Pa·s	<i>k_f</i> , W/(m·K)
60			1.040,-3	5.55	-159.2	59.7	2.528	6.255		3.25	0.180
62			1.050,-3	3.73	-155.2	61.7	2.585	6.164		2.98	0.176
64	0.123	0.071	1.060,-3	2.57	-151.4	63.6	2.641	6.080		2.75	0.173
66	0.174	0.104	1.070,-3	1.82	-147.8	65.5	2.696	6.002		2.54	0.169
68	0.239	0.147	1.080,-3	1.313	-144.2	67.4	2.747	5.929		2.36	0.166
70	0.323	0.205	1.089,-3	0.968	-140.6	69.2	2.797	5.862	1.817	2.21	0.163
72	0.429	0.280	1.101,-3	0.728	-137.1	71.0	2.847	5.799	1.827	2.07	0.160
74	0.560	0.376	1.113,-3	0.556	-133.5	72.8	2.895	5.740	1.838	1.95	0.156
76	0.721	0.495	1.125,-3	0.431	-129.9	74.5	2.941	5.685	1.849	1.84	0.152
78	0.915	0.644	1.136,-3	0.339	-126.3	76.2	2.988	5.634	1.861	1.74	0.148
80	1.146	0.825	1.146,-3	0.270	-122.6	77.8	3.034	5.585	1.873	1.65	0.145
82	1.420	1.043	1.160,-3	0.217	-118.8	79.4	3.079	5.540	1.885	1.58	0.142
84	1.741	1.305	1.173,-3	0.177	-115.0	80.9	3.123	5.496	1.898	1.51	0.139
86	2.114	1.614	1.187,-3	0.145	-111.2	82.3	3.167	5.454	1.912	1.44	0.135
88	2.544	1.976	1.201,-3	0.120	-107.4	83.6	3.209	5.414	1.927	1.38	0.132
90	3.036	2.397	1.216,-3	0.1002	-103.5	84.8	3.251	5.376	1.944	1.32	0.128
92	3.596	2.884	1.231,-3	0.0843	-99.5	85.9	3.293	5.340	1.962	1.27	0.125
94	4.229	3.441	1.247,-3	0.0713	-95.5	87.0	3.335	5.304	1.982	1.23	0.121
96	4.940	4.075	1.265,-3	0.0607	-91.5	87.9	3.376	5.270	2.003	1.18	0.117
98	5.736	4.792	1.283,-3	0.0520	-87.5	88.7	3.416	5.236	2.027	1.14	0.114
100	6.621	5.599	1.302,-3	0.0447	-83.3	89.3	3.456	5.204	2.053	1.10	0.110
105	9.265	8.056	1.355,-3	0.0312	-72.8	90.2	3.553	5.124	2.137	1.02	0.102
110	12.59	11.22	1.418,-3	0.0222	-61.9	90.1	3.649	5.045	2.264	0.95	0.093
115	16.68	15.21	1.495,-3	0.0159	-50.3	88.4	3.747	4.964	2.477	0.87	0.084
120	21.61	20.14	1.596,-3	0.0115	-37.5	84.8	3.850	4.877	2.916	0.75	0.076
125	27.43	26.14	1.757,-3	0.0081	-22.0	78.2	3.969	4.776	4.585	0.42	0.067
130	34.16	33.32	2.075,-3	0.0054	0.4	66.1	4.136	4.644			
132.55 ^c		37.69	3.196,-3	0.0032	37.4	37.4	4.410	4.410	∞		

*Liquid properties extracted or converted from Vasserman and Rabinovich, *Thermophysical Properties of Liquid Air and Its Components*, Moscow, 1968, and NBS-NSF transl. TT 69-55092, 1970. Copyrighted material. Reproduced by permission. Vapor properties extracted or converted from Vasserman, Kazavchinskii, and Rabinovich, *Thermophysical Properties of Air and Its Components*, Nauka, Moscow, 1966, and NBS-NSF transl. TT 70-50095, 1971. Copyrighted material. Reproduced by permission. Note that on pages 150–151 of the TT 69-55092 publication certain values of TT 70-50095 were adjusted. As a complete retabulation was not given, the tables here are based upon the two separate publications, as indicated. See also Table 2-235 for the argon-oxygen-nitrogen equilibrium data. c = critical point. The notation 1.040,-3 signifies 1.040×10^{-3} .

TABLE 2-229 Thermophysical Properties of Compressed Air*

Pressure, bar	Temperature, K												
	80	90	100	120	140	160	180	200	220	240	260	280	300
$1 v$ h s C_p μ k	0.251	0.281	0.340	0.399	0.457	0.515	0.537	0.631	0.688	0.746	0.803	0.861	
	87.9	98.3	118.8	139.1	159.3	179.5	199.7	219.8	239.9	260.0	280.2	300.3	
	Mix	5.650	5.759	5.946	6.103	6.238	6.357	6.463	6.559	6.647	6.727	6.802	6.871
	1.044	1.032	1.020	1.014	1.010	1.008	1.007	1.006	1.006	1.006	1.006	1.007	
	0.064	0.071	0.085	0.097	0.109	0.121	0.133	0.144	0.154	0.165	0.175	0.185	
	0.0084	0.0093	0.0112	0.0129	0.0147	0.0164	0.0181	0.0198	0.0214	0.0231	0.0247	0.0263	
$5 v$ h s C_p μ k	0.00115	0.00122	0.00509	0.00446	0.0773	0.0895	0.102	0.114	0.125	0.137	0.149	0.160	0.172
	-122.3	-103.3	90.6	113.6	135.3	156.4	177.1	197.7	218.1	238.5	258.8	279.1	299.4
	3.031	3.250	5.246	5.455	5.623	5.763	5.885	5.994	6.092	6.180	6.262	6.337	6.406
	1.868	1.941	1.212	1.107	1.065	1.045	1.033	1.025	1.020	1.017	1.015	1.013	1.013
	1.794	1.163	0.077	0.087	0.098	0.110	0.122	0.134	0.145	0.155	0.165	0.175	0.185
	0.146	0.128	0.0103	0.0119	0.0135	0.0151	0.0168	0.0185	0.0201	0.0217	0.0234	0.0250	0.0265
$10 v$ h s C_p μ k	0.00115	0.00121	0.00130	0.0298	0.0370	0.0436	0.0499	0.0561	0.0621	0.0681	0.0741	0.0800	0.0859
	-122.0	-103.1	-83.2	106.2	130.2	152.5	174.1	195.2	216.1	236.7	257.3	277.8	298.3
	3.028	3.246	3.452	5.214	5.398	5.548	5.675	5.786	5.885	5.975	6.058	6.134	6.204
	1.863	1.932	2.041	1.270	1.146	1.093	1.065	1.049	1.038	1.031	1.026	1.023	1.201
	1.816	1.177	0.838	0.089	0.101	0.112	0.124	0.135	0.146	0.156	0.166	0.176	0.186
	0.146	0.128	0.111	0.0126	0.0141	0.0157	0.0173	0.0189	0.0205	0.0221	0.0237	0.0253	0.0268
$20 v$ h s C_p μ k	0.00114	0.00121	0.00129	0.0116	0.0167	0.0206	0.0241	0.0274	0.0306	0.0337	0.0368	0.0398	0.0428
	-121.3	-102.5	-82.9	85.2	118.5	144.3	167.7	190.1	211.9	233.2	254.3	275.2	296.0
	3.022	3.239	3.442	4.882	5.140	5.312	5.450	5.568	5.672	5.765	5.849	5.927	5.998
	1.853	1.916	2.010	2.237	1.390	1.215	1.141	1.101	1.076	1.061	1.050	1.042	1.037
	1.859	1.205	0.857	0.098	0.106	0.116	0.127	0.137	0.148	0.158	0.168	0.178	0.187
	0.147	0.130	0.112	0.0152	0.0157	0.0169	0.0182	0.0197	0.0212	0.0228	0.0243	0.0258	0.0273
$40 v$ h s C_p μ k	0.00114	0.00120	0.00128	0.00153	0.00558	0.0090	0.0114	0.0131	0.0148	0.0165	0.0182	0.0198	0.0214
	-120.0	-101.4	-82.2	-39.8	83.6	125.3	154.3	179.7	203.5	226.3	248.5	270.2	291.7
	3.011	3.225	3.424	3.807	4.745	5.025	5.196	5.330	5.444	5.543	5.632	5.712	5.786
	1.834	1.886	1.958	2.432	3.193	1.610	1.335	1.221	1.159	1.122	1.097	1.081	1.068
	1.943	1.261	0.896	0.516	0.132	0.129	0.135	0.144	0.154	0.163	0.172	0.182	0.191
	0.149	0.132	0.115	0.0814	0.0460	0.0201	0.0206	0.0217	0.0229	0.0242	0.0256	0.0270	0.0284
$60 v$ h s C_p μ k	0.00113	0.00119	0.00126	0.00147	0.00222	0.00505	0.00687	0.00833	0.00963	0.0108	0.0120	0.0131	0.0142
	-118.6	-100.3	-81.4	-40.8	22.8	90.0	132.6	163.9	191.1	216.1	240.0	263.1	285.6
	3.000	3.211	3.407	3.773	4.260	4.798	5.020	5.174	5.298	5.404	5.497	5.581	5.657
	1.818	1.860	1.915	2.205	4.808	2.338	1.594	1.361	1.249	1.186	1.146	1.119	1.100
	2.028	1.318	0.936	0.559	0.277	0.153	0.149	0.154	0.161	0.169	0.178	0.186	0.195
	0.150	0.134	0.117	0.0861	0.0480	0.0238	0.0240	0.0248	0.0258	0.0270	0.0283	0.0296	
$80 v$ h s C_p μ k	0.00113	0.00119	0.00126	0.00145	0.00188	0.00327	0.00480	0.00601	0.00706	0.00803	0.00894	0.00981	0.0107
	-117.2	-99.1	-80.4	-41.3	9.0	78.4	125.3	158.7	187.1	212.9	237.3	260.8	283.7
	2.989	3.198	3.391	3.745	4.138	4.597	4.875	5.051	5.186	5.299	5.396	5.484	5.562
	1.802	1.838	1.881	2.078	2.992	3.029	1.887	1.510	1.342	1.250	1.194	1.156	1.130
	2.12	1.38	0.977	0.597	0.356	0.194	0.167	0.166	0.170	0.177	0.184	0.191	0.200
	0.152	0.134	0.120	0.0901	0.0599	0.0420	0.0278	0.0268	0.0269	0.0276	0.0286	0.0296	0.0308
$100 v$ h s C_p μ k	0.00112	0.00118	0.00125	0.00142	0.00174	0.00252	0.00366	0.00467	0.00556	0.00637	0.00713	0.00785	0.00855
	-115.8	-97.8	-79.4	-41.3	3.9	61.7	111.8	148.8	179.4	206.7	232.2	256.4	279.9
	2.978	3.186	3.376	3.721	4.076	4.457	4.753	4.949	5.095	5.214	5.315	5.406	5.486
	1.789	1.818	1.852	1.992	2.506	2.874	2.114	1.650	1.431	1.311	1.239	1.191	1.158
	2.21	1.44	1.02	0.631	0.405	0.249	0.193	0.181	0.181	0.185	0.191	0.198	0.205
	0.154	0.137	0.122	0.0936	0.0669	0.0500	0.0327	0.0299	0.0293	0.0295	0.0302	0.0311	0.0320
$150 v$ h s C_p μ k	0.00111	0.00116	0.00122	0.00137	0.00158	0.00194	0.00247	0.00309	0.00369	0.00425	0.00478	0.00529	0.00578
	-112.2	-94.5	-76.6	-40.1	0.5	45.2	89.5	129.2	163.2	193.4	221.0	247.0	271.8
	2.954	3.157	3.342	3.673	3.988	4.287	4.548	4.757	4.919	5.051	5.161	5.257	5.343
	1.789	1.818	1.852	1.992	2.506	2.874	2.114	1.650	1.431	1.311	1.239	1.267	1.220
	2.44	1.60	1.13	0.709	0.490	0.349	0.266	0.229	0.215	0.211	0.212	0.215	0.220
	0.157	1.142	0.127	0.101	0.0785	0.0588	0.0455	0.0389	0.0360	0.0348	0.0346	0.0349	0.0354
$200 v$ h s C_p μ k	0.00110	0.00115	0.00120	0.00133	0.00150	0.00174	0.00206	0.00245	0.00287	0.00328	0.00368	0.00407	0.00446
	-108.5	-91.2	-73.6	-38.0	0.2	40.2	79.8	117.6	152.2	183.6	212.5	239.6	265.5
	2.930	3.130	3.312	3.634	3.931	4.198	4.432	4.631	4.796	4.932	5.048	5.149	5.238
	1.733	1.747	1.761	1.809	1.905	1.988	1.953	1.814	1.643	1.501	1.396	1.321	1.266
	2.70	1.78	1.25	0.782	0.561	0.420	0.331	0.279	0.253	0.241	0.236	0.235	0.237
	0.161	0.146	0.132	0.107	0.0868	0.0691	0.0559	0.0476	0.0429	0.0405	0.0393	0.0389	0.0389
$250 v$ h s C_p μ k	0.00109	0.00114	0.00119	0.00130	0.00144	0.00162	0.00186	0.00214	0.00244	0.00276	0.00307	0.00338	0.00368
	-104.8	-87.6	-70.3	-35.4	1.3	38.9	75.8	111.7	145.6	177.1	206.6	234.3	260.8
	2.909	3.106	3.285	3.601	3.886	4.138	4.355	4.544	4.706	4.843	4.961	5.064	5.155
	1.712	1.722	1.733	1.767	1.824	1.854	1.831	1.748	1.635	1.522	1.427	1.353	1.297
	2.96	1.97	1.39	0.855	0.625	0.476	0.385	0.327	0.292	0.272	0.262	0.257	0.256
	0.165	0.150	0.137	0.113	0.0935	0.0769	0.0641	0.0552	0.0495	0.0460	0.0441	0.0430	0.0426

*For sources, units, and remarks, see Table 2-228. v = specific volume, m^3/kg ; h = specific enthalpy, kJ/kg ; s = specific entropy, $\text{kJ}/(\text{kg}\cdot\text{K})$; c_p = specific heat at constant pressure, $\text{kJ}/(\text{kg}\cdot\text{K})$; μ = viscosity, $10^{-4} \text{ Pa}\cdot\text{s}$; and k = thermal conductivity, $\text{W}/(\text{m}\cdot\text{K})$. For specific heat ratio, see Table 2-200; for Prandtl number, see Table 2-369.

Temperature, K												
350	400	450	500	600	800	1000	1200	1400	1600	1800	2000	2500
1.005	1.148	1.292	1.436	1.723	2.297	2.872	3.446	4.020	4.594	5.168	5.743	7.200
350.7	401.2	452.1	503.4	607.5	822.5	1046.8	1278	1515	1764	2017	2279	3011
7.026	7.161	7.282	7.389	7.579	7.888	8.138	8.349	8.531	8.695	8.844	8.983	9.308
1.009	1.014	1.021	1.030	1.051	1.099	1.141	1.175	1.207	1.248	1.286	1.337	1.665
0.208	0.230	0.251	0.270	0.306	0.370	0.424	0.473	0.527	0.584	0.637	0.689	0.818
0.0301	0.0336	0.0371	0.0404	0.0466	0.0577	0.0681	0.0783	0.0927	0.106	0.120	0.137	0.222
0.201	0.230	0.259	0.288	0.345	0.460	0.575	0.690	0.805	0.920	1.034	1.149	1.438
350.0	400.8	451.8	503.2	607.4	822.6	1046.9	1279	1516	1764	2017	2278	2981
6.563	6.698	6.818	6.927	7.116	7.426	7.676	7.887	8.069	8.233	8.382	8.520	8.832
1.014	1.017	1.024	1.032	1.053	1.100	1.142	1.175	1.208	1.248	1.285	1.326	1.516
0.208	0.230	0.251	0.270	0.306	0.370	0.425	0.473	0.527	0.584	0.637	0.689	0.818
0.0303	0.0338	0.0372	0.0405	0.0467	0.0578	0.0681	0.0783	0.0927	0.106	0.120	0.136	0.195
0.101	0.115	0.130	0.144	0.173	0.231	0.288	0.345	0.403	0.460	0.518	0.575	0.720
349.2	400.2	451.4	502.9	607.3	822.7	1047.2	1279	1516	1765	2018	2279	2974
6.361	6.497	6.618	6.727	6.917	7.226	7.477	7.688	7.870	8.034	8.183	8.321	8.630
1.019	1.021	1.027	1.034	1.055	1.100	1.142	1.175	1.208	1.248	1.284	1.324	1.481
0.209	0.231	0.252	0.271	0.306	0.370	0.425	0.473	0.527	0.584	0.637	0.689	0.817
0.0305	0.0340	0.0374	0.0407	0.0469	0.0579	0.0682	0.0784	0.0927	0.106	0.120	0.135	0.187
0.0503	0.0577	0.0650	0.0723	0.0868	0.116	0.145	0.173	0.202	0.231	0.260	0.288	0.360
347.7	399.1	450.7	502.4	607.2	823.0	1047.7	1280	1517	1766	2019	2279	2970
6.158	6.295	6.417	6.526	6.716	7.027	0.277	7.489	7.671	7.835	7.984	8.121	8.428
1.030	1.029	1.033	1.039	1.057	1.102	1.143	1.176	1.209	1.249	1.284	1.322	1.456
0.210	0.232	0.253	0.272	0.307	0.371	0.425	0.474	0.527	0.584	0.637	0.689	0.817
0.0309	0.0344	0.0377	0.0410	0.0471	0.0581	0.0685	0.0787	0.0928	0.106	0.120	0.135	0.181
0.0252	0.0290	0.0327	0.0364	0.0438	0.0583	0.0728	0.0872	0.102	0.116	0.130	0.145	0.181
344.6	397.0	449.2	501.5	606.9	823.7	1048.8	1281	1519	1768	2021	2281	2969
5.950	6.090	6.212	6.323	6.515	6.826	7.077	7.289	7.473	7.636	7.785	7.922	8.229
1.051	1.044	1.044	1.049	1.063	1.05	1.145	1.177	1.210	1.249	1.284	1.322	1.438
0.213	0.235	0.255	0.274	0.309	0.372	0.426	0.474	0.527	0.584	0.637	0.689	0.817
0.0318	0.0351	0.0384	0.0416	0.0476	0.0584	0.0687	0.0789	0.0928	0.106	0.120	0.135	0.177
0.0169	0.0194	0.0220	0.0245	0.0294	0.0392	0.0489	0.0585	0.0681	0.0776	0.0872	0.0968	0.1207
340.4	394.0	447.1	500.6	606.8	824.3	1050.0	1283	1521	1770	2023	2284	2969
5.824	5.967	6.091	6.202	6.396	6.708	6.960	7.172	7.355	7.520	7.669	7.806	8.112
1.072	1.059	1.055	1.057	1.069	1.108	1.147	1.178	1.210	1.249	1.286	1.322	1.430
0.217	0.237	0.257	0.275	0.310	0.373	0.427	0.475	0.527	0.584	0.637	0.689	0.817
0.0328	0.0359	0.0391	0.0422	0.0481	0.0588	0.0690	0.0790	0.0929	0.106	0.120	0.134	0.176
0.0127	0.0147	0.0166	0.0185	0.0223	0.0296	0.0369	0.0442	0.0513	0.0585	0.0657	0.0729	0.0908
339.0	393.1	446.5	499.8	606.7	825.1	1051.1	1284	1522	1772	2025	2285	2971
5.733	5.878	6.004	6.116	6.311	6.624	6.877	7.089	7.273	7.437	7.586	7.723	8.029
1.091	1.073	1.066	1.065	1.075	1.111	1.149	1.180	1.210	1.249	1.286	1.322	1.426
0.220	0.240	0.259	0.278	0.312	0.374	0.428	0.475	0.527	0.584	0.637	0.689	0.817
0.0337	0.0368	0.0398	0.0428	0.0486	0.0592	0.0693	0.0793	0.0929	0.106	0.120	0.134	0.175
0.0102	0.0118	0.0134	0.0149	0.0180	0.0239	0.0298	0.0356	0.0413	0.0470	0.0528	0.0584	0.0729
336.5	391.3	445.3	499.0	606.6	825.8	1052.4	1286	1524	1774	2027	2288	2972
5.661	5.807	5.935	6.048	6.244	6.559	6.812	7.024	7.208	7.373	7.522	7.659	7.964
1.110	1.087	1.076	1.073	1.080	1.114	1.151	1.181	1.211	1.250	1.288	1.323	1.423
0.224	0.243	0.262	0.280	0.314	0.375	0.429	0.477	0.527	0.584	0.637	0.689	0.817
0.0347	0.0376	0.0405	0.0434	0.0491	0.0595	0.0696	0.0795	0.0930	0.106	0.120	0.134	0.175
0.00695	0.00806	0.00914	0.0102	0.0123	0.0163	0.0202	0.0241	0.0279	0.0317	0.0356	0.0394	0.0490
330.9	387.5	442.9	497.5	606.6	827.8	1055.5	1290	1529	1779	2033	2294	2977
5.525	5.677	5.807	5.922	6.121	6.439	6.693	6.906	7.092	7.256	7.405	7.543	7.848
1.151	1.117	1.099	1.092	1.093	1.121	1.155	1.184	1.213	1.252	1.290	1.325	1.418
0.235	0.252	0.270	0.286	0.318	0.379	0.431	0.478	0.527	0.584	0.637	0.689	0.817
0.0374	0.0398	0.0424	0.0451	0.0504	0.0605	0.0703	0.0801	0.0932	0.106	0.120	0.133	
0.00534	0.00620	0.00702	0.00783	0.00940	0.0125	0.0154	0.0184	0.0212	0.0241	0.0269	0.0298	0.0370
326.5	384.5	440.9	496.6	607.0	829.9	1058.7	1294	1533	1783	2038	2299	2982
5.426	5.581	5.715	5.831	6.033	6.353	6.608	6.822	7.009	7.173	7.323	7.460	7.765
1.184	1.141	1.119	1.108	1.104	1.128	1.160	1.187	1.214	1.254	1.292	1.326	1.415
0.248	0.262	0.278	0.293	0.324	0.382	0.434	0.481	0.528	0.585	0.638		
0.0400	0.0420	0.0423	0.0467	0.0517	0.0614	0.0711	0.0808	0.0934	0.106	0.120		
0.00440	0.00509	0.00576	0.00642	0.00770	0.0102	0.0126	0.0149	0.0172	0.0195	0.0218	0.0241	0.0298
323.2	382.3	439.6	496.0	607.6	832.2	1062.0	1298	1538	1789	2043	2304	2988
5.348	5.506	5.641	5.760	5.963	6.286	6.542	6.757	6.944	7.108	7.258	7.396	7.701
1.208	1.161	1.135	1.121	1.115	1.135	1.164	1.190	1.216	1.256	1.294	1.328	1.414
0.262	0.273	0.286	0.301	0.329	0.386	0.437	0.483	0.528	0.585			
0.0429	0.0443	0.0462	0.0484	0.0531	0.0624	0.0718	0.0814	0.0937	0.106			

2-210 PHYSICAL AND CHEMICAL DATA

TABLE 2-229 Thermophysical Properties of Compressed Air (Concluded)

Temperature, K												
350	400	450	500	600	800	1000	1200	1400	1600	1800	2000	2500
0.00379	0.00437	0.00493	0.00548	0.00656	0.00864	0.0107	0.0126	0.0145	0.0164	0.0183	0.0202	0.0250
320.9	380.9	438.9	495.9	608.5	834.5	1065.3	1302	1542	1794	2049	2310	2993
5.283	5.443	5.580	5.700	5.906	6.230	6.488	6.703	6.891	7.056	7.206	7.344	7.648
1.226	1.176	1.148	1.133	1.124	1.140	1.168	1.193	1.217	1.257	1.298	1.330	1.413
0.276	0.284	0.296	0.308	0.335	0.390	0.440	0.485	0.529				
0.0457	0.0466	0.0481	0.0501	0.0544	0.0634	0.0726	0.0820	0.0940				
0.00304	0.00348	0.00390	0.00432	0.00514	0.00673	0.00826	0.00977	0.0111	0.0126	0.0140	0.0155	0.0190
319.1	380.0	439.0	496.8	611.0	839.4	1072.0	1310	1552	1804	2059	2321	3004
5.181	5.344	5.483	5.605	5.813	6.142	6.401	6.618	6.808	6.972	7.123	7.261	7.566
1.246	1.195	1.166	1.149	1.138	1.151	1.176	1.199	1.222	1.258	1.301	1.333	1.412
0.307	0.308	0.315	0.325	0.348	0.398	0.446	0.490					
0.0513	0.0512	0.0521	0.0535	0.0571	0.0653	0.0740	0.0832					
0.00262	0.00296	0.00330	0.00364	0.00430	0.00558	0.00683	0.00804	0.00911	0.0103	0.0114	0.0126	0.0154
319.9	381.3	440.8	499.1	614.3	844.6	1078.8	1318	1561	1814	2070	2332	3015
5.103	5.267	5.408	5.531	5.741	6.072	6.333	6.550	6.743	6.907	7.058	7.196	7.501
1.255	1.206	1.176	1.159	1.148	1.159	1.183	1.205	1.226	1.265	1.306	1.337	1.412
0.338	0.333	0.336	0.343	0.361	0.407	0.452	0.495					
0.0568	0.0557	0.0560	0.0569	0.0598	0.0672	0.0755	0.0844					
0.00234	0.00262	0.00290	0.00318	0.00374	0.00481	0.00586	0.00689	0.00776	0.00873	0.00970	0.0107	0.0130
322.6	384.2	444.0	502.6	618.5	850.1	1085.5	1326	1570	1824	2080	2343	3026
5.041	5.205	5.346	5.470	5.681	6.014	6.277	6.495	6.690	6.854	7.005	7.144	7.449
1.258	1.211	1.182	1.166	1.154	1.166	1.189	1.210	1.231	1.267	1.310	1.341	1.412
0.370	0.359	0.358	0.361	0.375	0.416	0.459	0.501					
0.0620	0.0602	0.0598	0.0603	0.0625	0.0691	0.0770	0.0857					
0.00200	0.00221	0.00242	0.00263	0.00304	0.00385	0.00465	0.00544	0.00608	0.00681	0.00754	0.00826	0.0101
331.6	393.8	453.4	512.3	625.8	862.0	1099.3	1341	1588	1844	2101	2365	3049
4.943	5.108	5.250	5.374	5.586	5.922	6.136	6.407	6.605	6.769	6.921	7.060	7.366
1.257	1.216	1.188	1.172	1.161	1.175	1.198	1.219	1.240	1.275	1.318	1.347	1.412
0.432	0.411	0.402	0.399	0.405	0.436	0.474	0.512					
0.0718	0.0688	0.0673	0.0669	0.0679	0.0730	0.0800	0.0881					
0.00180	0.00196	0.00213	0.00230	0.00262	0.00328	0.00392	0.00455	0.00507	0.00565	0.00624	0.00681	0.00825
343.4	405.1	465.3	524.4	641.2	875.1	1113.3	1356	1606	1863	2121	2386	3071
4.869	5.034	5.176	5.300	5.513	5.850	6.115	6.337	6.539	6.703	6.856	6.995	7.302
1.254	1.217	1.192	1.175	1.164	1.179	1.204	1.225	1.248	1.283	1.325	1.354	1.413
0.494	0.463	0.446	0.438	0.435	0.456	0.489	0.524					
0.0810	0.0768	0.0744	0.0733	0.0732	0.0768	0.0830	0.0906					

TABLE 2-230 Enthalpy and Psi Functions for Ideal-Gas Air*

T, K	<i>h</i> , kJ/kg	Ψ	T, K	<i>h</i> , kJ/kg	Ψ	T, K	<i>h</i> , kJ/kg	Ψ
200	200.0	-0.473	650	659.8	1.339	1200	1278	2.376
210	210.0	-0.400	660	670.5	1.364	1220	1301	2.406
220	220.0	-0.329	670	681.1	1.388	1240	1325	2.435
230	230.1	-0.262	680	691.8	1.412	1260	1349	2.463
240	240.1	-0.197	690	702.5	1.436	1280	1372	2.491
250	250.1	-0.135	700	713.3	1.459	1300	1396	2.519
260	260.1	-0.076	710	724.0	1.482	1320	1420	2.547
270	270.1	-0.018	720	734.8	1.505	1340	1444	2.574
280	280.1	0.037	730	745.6	1.528	1360	1467	2.601
290	290.2	0.090	740	756.4	1.550	1380	1491	2.627
300	300.2	0.142	750	767.3	1.572	1400	1515	2.653
310	310.3	0.191	760	778.2	1.594	1420	1539	2.679
320	320.3	0.240	770	789.1	1.615	1440	1563	2.705
330	330.4	0.286	780	800.0	1.637	1460	1587	2.730
340	340.4	0.332	790	811.0	1.658	1480	1612	2.755
350	350.5	0.376	800	821.9	1.679	1500	1636	2.779
360	360.6	0.419	810	832.9	1.699	1520	1660	2.803
370	370.7	0.461	820	844.0	1.720	1540	1684	2.827
380	380.8	0.502	830	855.0	1.740	1560	1709	2.851
390	390.9	0.541	840	866.1	1.760	1580	1738	2.875
400	401.0	0.580	850	877.2	1.780	1600	1758	2.898
410	411.2	0.618	860	888.3	1.800	1620	1782	2.921
420	421.3	0.655	870	899.4	1.819	1640	1806	2.944
430	431.5	0.691	880	910.6	1.838	1660	1831	2.966
440	441.7	0.727	890	921.8	1.857	1680	1855	2.988
450	451.8	0.761	900	933.0	1.876	1700	1880	3.010
460	462.1	0.795	910	944.2	1.895	1720	1905	3.032
470	472.3	0.829	920	955.4	1.914	1740	1929	3.054
480	482.5	0.861	930	966.7	1.932	1760	1954	3.075
490	492.8	0.893	940	978.0	1.950	1780	1979	3.096
500	503.1	0.925	950	989.3	1.969	1800	2003	3.117
510	513.4	0.956	960	1000.6	1.987	1820	2028	3.138
520	523.7	0.986	970	1011.9	2.004	1840	2053	3.158
530	534.0	1.016	980	1023.3	2.022	1860	2078	3.178
540	544.4	1.045	990	1034.7	2.039	1880	2102	3.198
550	554.8	1.074	1000	1046.1	2.057	1900	2127	3.218
560	565.2	1.102	1020	1068.9	2.091	1920	2152	3.238
570	575.6	1.130	1040	1091.9	2.125	1940	2177	3.258
580	586.1	1.158	1060	1114.9	2.158	1960	2202	3.277
590	596.5	1.185	1080	1138.0	2.190	1980	2227	3.296
600	607.0	1.211	1100	1161.1	2.223	2000	2252	3.215
610	617.5	1.238	1120	1184.3	2.254	2050	2315	3.362
620	628.1	1.264	1140	1207.6	2.285	2100	2377	3.408
630	638.6	1.289	1160	1230.9	2.316	2150	2440	3.453
640	649.2	1.314	1180	1254.3	2.346	2200	2504	3.496

*Values rounded off from Chappell and Cockshutt, Nat. Res. Coun. Can. Rep. NRC LR 759 (NRC No. 14300), 1974. This source tabulates values of seven thermodynamic functions at 1-K increments from 200 to 2200 K in SI units and at other increments for two other unit systems. An earlier report (NRC LR 381, 1963) gives a more detailed description of an earlier fitting from 200 to 1400 K. In the above table h = specific enthalpy, kJ/kg, and $\Psi_2 - \Psi_1 = \log_{10}(P_2/P_1)$, for an isentrope. In terms of the Keenan and Kaye function ϕ , $\Psi = (\log_{10} e/R) \cdot \phi$.

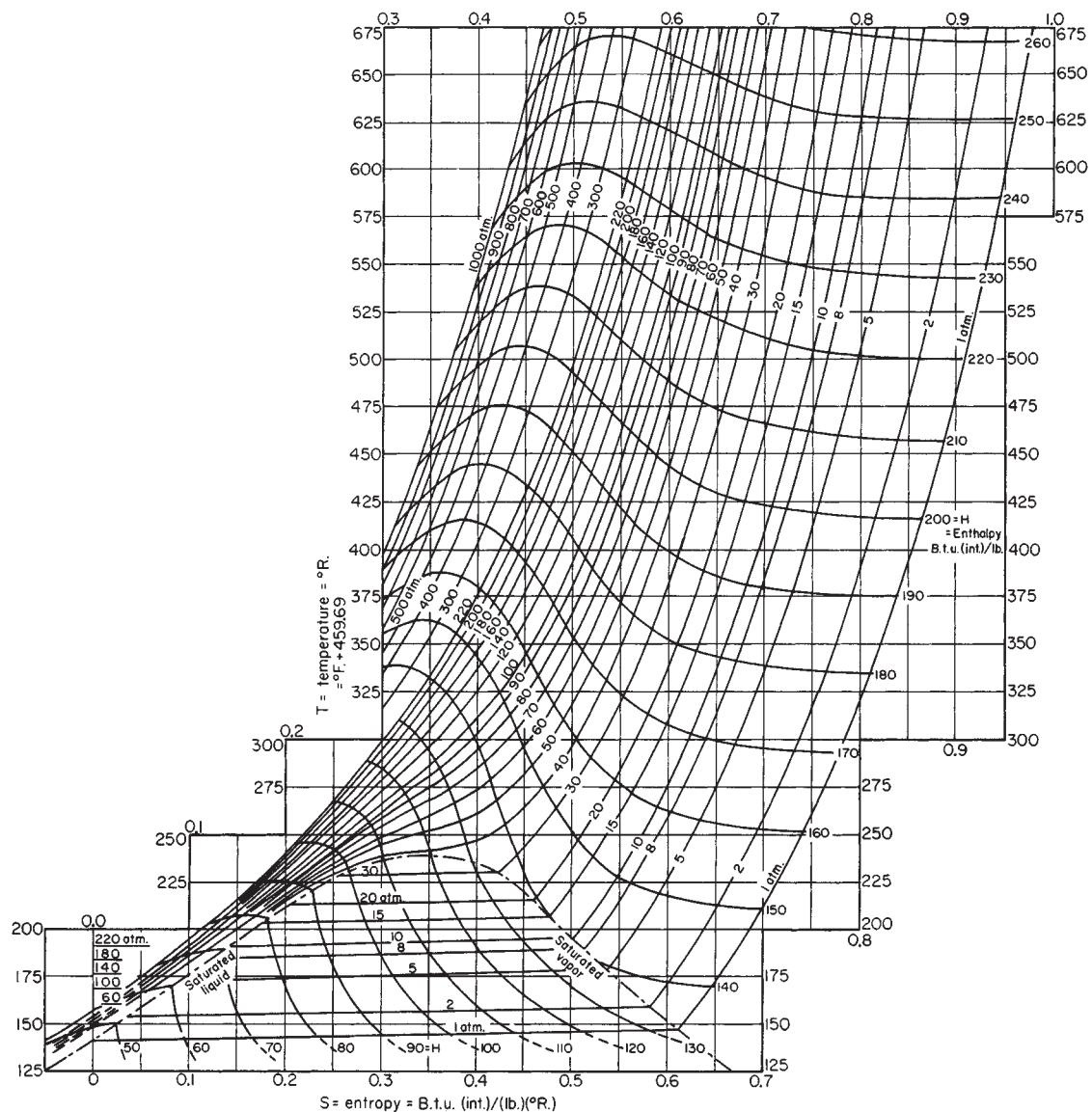


FIG. 2-5 Temperature-entropy diagram for air. [Landsbaum, Dadds, Stevens, et al., Am. Inst. Chem. Eng. J., **I**(3), 303 (1955). Reproduced by permission of the authors and of the editor, American Institute of Chemical Engineers.]

TABLE 2-231 Air

Other tables include Stewart, R. B., S. G. Penoncello, et al., University of Idaho CATS report, 85-5, 1985 (0.1–700 bar, 85–750 K), and a revision is in process of publication. Tables including reactions with hydrocarbons include Gordon, S., NASA Techn. Paper 1907, 4 vols., 1982. See also Gupta, R. N., K.-P. Lee, et al., NASA RP 1232, 1990 (89 pp.) and RP 1260, 1991 (75 pp.). Analytic expressions for high temperatures were given by Matsuzaki, R., *Jap. J. Appl. Phys.*, **21**, 7 (1982): 1009–1013 and Japanese National Aerospace Laboratory report NAL TR 671, 1981 (45 pp.). Functions from 1500 to 15000 K were tabulated by Hilsenrath, J. and M. Klein, AEDC-TR-65-58 = AD 612 301, 1965 (333 pp.). Tables from 10000 to 10,000,000 K were authored by Gilmore, F. R., Lockheed rept. 3-27-67-1, vol 1, 1967 (340 pp.), also published as *Radiative Properties of Air*, IFI/Plenum, New York, 1969 (648 pp.). Saturation and superheat tables and a chart to 7000 psia, 660°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

AIR, MOIST

An ASHRAE publication, *Thermodynamic Properties of Dry Air and Water and S. I. Psychrometric Charts*, 1983 (360 pp.), extensively reviews moist air properties. Candiduson, P., *Chem. Eng.*, Oct. 29, 1984 gives on page 118 a nomograph from 50 to 120°F, while equations in SI units were given by Nelson, B., *Chem. Eng. Progr.* **76**, 5 (May 1980): 83–85. Liley, P. E., *2000 Solved Problems in M.E. Thermodynamics*, McGraw-Hill, New York, 1989, gives four simple equations with which most calculations can be made. Devries, Y.O., *Appl. Energy* **48** (1994): 1–18 gives equations with which three known properties can be used to determine four others. KlapPERT, M. T. and G. F. Schilling, Rand RM-4244-PR = AD 604 856, 1984 (40 pp.) gives tables from 100 to 270 K, while programs from –60 to 2°F are given by Sando, F. A., *ASHRAE Trans.*, **96**, 2 (1990): 299–308.

Viscosity references include Kestin, J. and J. H. Whitelaw, *Int. J. Ht. Mass Transf.* **7**, 11 (1964): 1245–1255; Studnokov, E. L., *Inz.-Fiz. Zhur.* **19**, 2 (1970): 338–340; Hochramer, D. and F. Munczak, *Setzb. Ost. Acad. Wiss II* **175**, 10 (1966): 540–550. For thermal conductivity see, for instance, Mason, E. A. and L. Monchick, *Humidity and Moisture Control in Science and Industry*, Reinhold, New York, 1965 (257–272).

TABLE 2-232 Saturated Ammonia*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
195.5 ^t	0.0608	1.327–3	15.648	–1110.1	380.1	4.203	11.827	4.73	4.25	0.715
200	0.0865	1.372–3	11.237	–1088.8	388.5	4.311	11.698	4.61	4.07	0.709
210	0.1775	1.394–3	5.729	–1044.1	406.7	4.529	11.438	4.38	3.69	0.685
220	0.3381	1.417–3	3.135	–1000.6	424.1	4.731	11.207	4.35	3.34	0.661
230	0.6044	1.442–3	1.822	–957.0	440.7	4.925	11.002	4.38	3.02	0.638
240	1.0226	1.468–3	1.115	–912.9	456.2	5.113	10.817	4.43	2.73	0.615
250	1.6496	1.495–3	0.712	–868.2	470.6	5.294	10.650	4.48	2.45	0.592
260	2.5529	1.524–3	0.472	–823.1	483.8	5.471	10.498	4.54	2.20	0.569
270	3.8100	1.551–3	0.324	–777.3	495.6	5.643	10.358	4.60	1.97	0.546
280	5.5077	1.589–3	0.228	–730.9	506.0	5.811	10.228	4.66	1.76	0.523
290	7.741	1.626–3	0.165	–683.8	514.7	5.975	10.108	4.73	1.58	0.500
300	10.61	1.666–3	0.121	–636.0	521.5	6.135	9.994	4.82	1.41	0.477
310	14.24	1.710–3	0.091	–587.2	526.1	6.293	9.885	4.91	1.26	0.454
320	18.72	1.760–3	0.069	–537.5	528.2	6.448	9.779	5.02	1.13	0.431
330	24.20	1.815–3	0.053	–486.7	527.5	6.602	9.675	5.17	1.02	0.408
340	30.79	1.878–3	0.0410	–434.3	523.3	6.755	9.571	5.37	0.92	0.385
350	38.64	1.952–3	0.0319	–380.0	515.1	6.908	9.465	5.64	0.83	0.361
360	47.90	2.039–3	0.0249	–323.2	501.8	7.063	9.354	6.04	0.75	0.337
370	58.74	2.148–3	0.0194	–262.6	481.9	7.222	9.235	6.68	0.69	0.313
380	71.35	2.291–3	0.0149	–196.5	452.7	7.391	9.100	7.80	0.61	0.286
390	85.98	2.499–3	0.0113	–120.9	408.1	7.578	8.935	10.3	0.50	0.254
400	103.0	2.882–3	0.0077	–23.5	329.0	7.813	8.694	21.	0.39	0.21
405.4 ^c	113.0	4.255–3	0.0043	142.7	142.7	8.216	8.216	∞	0.25	∞

*P, v, h, and s values condensed from ASHRAE Handbook, 1981: *Fundamentals*. Copyright 1981 by the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., and reproduced by permission of the copyright owner. c_p , μ , and k values are interpolated and converted from *Thermophysical Properties of Refrigerants*, ASHRAE, New York, 1976. t = triple point; c = critical point. The notation 1.327–3 signifies 1.327×10^{-3} . At 195.5 K, the viscosity of the saturated liquid is 4.25×10^{-4} Pa·s.

Most recent tabulations of ammonia properties are based upon the extensive tabulation to 5000 bar, 750 K of Haar, L. and J. S. Gallagher, *J. Phys. Chem. Ref. Data*, **7**, 3 (1978): 635–792, which does, however, neglect dissociation. For tables to 70,000 psia, 920°F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). A chart in fps units corresponding with these tables appears on page 17.34 of the ASHRAE 1989 *Fundamentals Handbook*.

Simmons, A. L., C. E. Miller III, et al., *Tables and Charts of Equilibrium Thermodynamic Properties of Ammonia for Temperatures from 500 to 50000 K*, NASA SP 3099, 1976 (255 pp.), tabulates p , h , s , c_p , c_v , Z, and so on, from 0.01 to 400 bar and also 18 species of decomposition products.

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the ITS 90 scale for saturation temperatures from –77.66 to 132.22 °C. The same diagram reproduced here appears in that source.

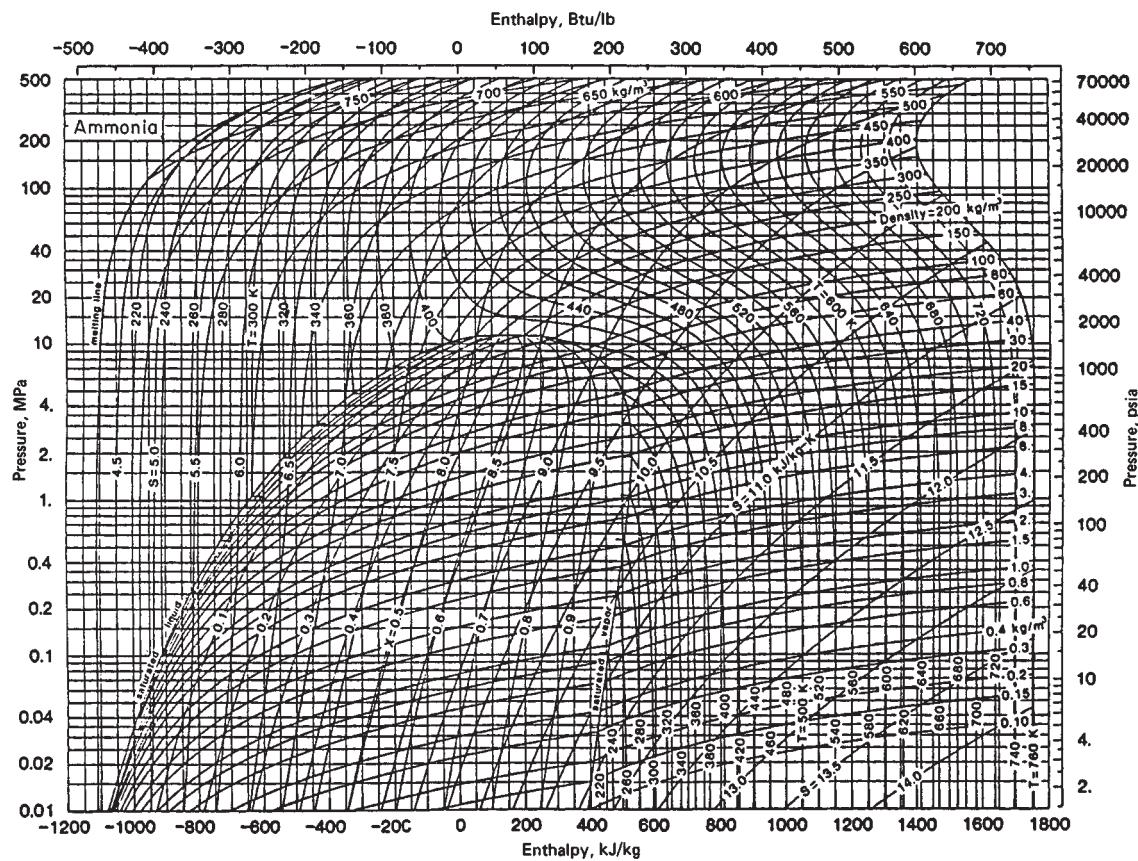


FIG. 2-6 Enthalpy-log-pressure diagram for ammonia. 1 MPa = 10 bar. (Copyright 1981 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers and reproduced by permission of the copyright owner.)

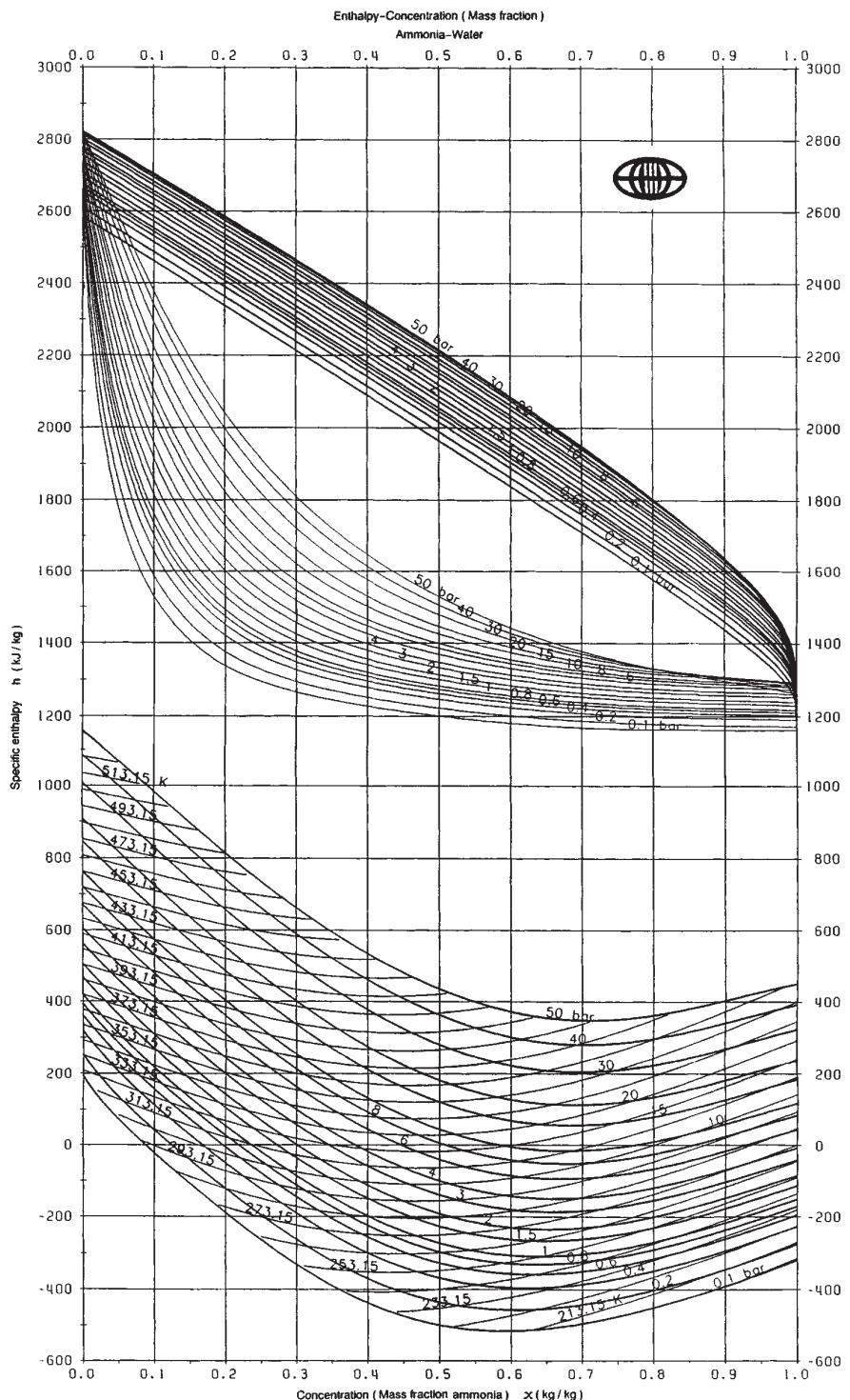


FIG. 2-7 Enthalpy-concentration diagram for aqueous ammonia. From *Thermodynamic and Physical Properties NH₃-H₂O*, Int. Inst. Refrigeration, Paris, France, 1994 (88 pp.). Reproduced by permission. In order to determine equilibrium compositions, draw a vertical from any liquid composition on any boiling line (the lowest plots) to intersect the appropriate auxiliary curve (the intermediate curves). A horizontal then drawn from this point to the appropriate dew line (the upper curves) will establish the vapor composition. The Int. Inst. Refrigeration publication also gives extensive P - v - x tables from -50 to 316°C. Other sources include Park, Y. M. and Sonntag, R. E., *ASHRAE Trans.*, **96**, 1 (1990): 150-159 (x , h , s , tables, 360 to 640 K); Ibrahim, O. M. and S. A. Klein, *ASHRAE Trans.*, **99**, 1 (1993): 1495-1502 (Eqs., 0.2 to 110 bar, 293 to 413 K); Smolen, T. M., D. B. Manley, et al., *J. Chem. Eng. Data*, **36** (1991): 202-208 (p - x correlation, 0.9 to 450 psia, 293-413 K); Ruiter, J. P., *Int. J. Refrig.*, **13** (1990): 223-236 gives ten subroutines for computer calculations.

TABLE 2-233 Saturated Argon (R740)*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
10		5.646,-4		0.20		0.0266		0.083		
20		5.666,-4		2.20		0.1559		0.306		
30		5.707,-4		6.12		0.3129		0.466		
40		5.763,-4		11.30		0.4610		0.560		
50		5.831,-4		17.26		0.5937		0.627		
60		5.912,-4		23.85		0.7138		0.687		
70	0.082	6.008,-4	2.1800	31.08	229.08	0.8250	3.415	0.752		
80	0.406	6.125,-4	0.3918	39.07	232.88	0.9316	3.364	0.836		
83.8 ^t	0.687	6.178,-4	0.2434	42.34	235.06	0.9720	3.280	0.877		
83.8 ^t	0.687	7.068,-4	0.2434	71.88	235.06	1.333	3.280	1.050	2.93	0.134
85	0.790	7.107,-4	0.2145	73.16	235.55	1.348	3.258	1.058	2.81	0.132
87.3	1.013	7.174,-4	0.1710	75.61	236.39	1.375	3.216	1.073	2.60	0.128
90	1.338	7.269,-4	0.1327	78.55	237.37	1.403	3.168	1.091	2.40	0.124
95	2.137	7.440,-4	0.0864	84.15	238.91	1.462	3.091	1.124	2.08	0.116
100	3.247	7.628,-4	0.0588	89.85	240.20	1.520	3.023	1.158	1.82	0.109
110	6.665	8.064,-4	0.0299	101.83	241.66	1.632	2.903	1.229	1.46	0.096
115	9.107	8.322,-4	0.0221	108.11	241.78	1.685	2.848	1.274	1.32	0.090
120	12.13	8.618,-4	0.0166	114.62	241.33	1.738	2.794	1.336	1.21	0.084
125	15.81	8.965,-4	0.0126	121.50	240.30	1.792	2.743	1.427	1.12	0.078
130	20.23	9.620,-4	0.0096	128.79	238.41	1.846	2.690	1.550	1.01	0.072
135	25.49	9.906,-4	0.0074	136.76	234.60	1.902	2.633	1.752	0.89	0.066
140	31.68	1.061,-3	0.0056	145.58	230.74	1.961	2.570		0.75	0.060
145	38.93	1.172,-3	0.0041	155.73	223.09	2.026	2.490		0.60	0.054
150	47.39	1.468,-3	0.0026	174.64	204.35	2.133	2.331		0.45	
150.9	48.98	1.867,-3	0.0019	189.94	189.94	2.201	2.201		0.28	∞

*Values extracted and in some cases rounded off from those cited in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. This source contains values for the compressed state for pressures up to 1000 bar, etc. t = triple point. Above the solid line the condensed phase is solid; below it, it is liquid. The notation 5.646,-4 signifies 5.646×10^{-4} . At 83.8 K, the viscosity of the saturated liquid is 2.93×10^{-4} Pa·s = 0.000293 Ns/m². This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

TABLE 2-234 Thermodynamic Properties of Compressed Argon*

T, K	Pressure, bar										
	1	100	200	300	400	500	600	700	800	900	1000
100 h	v	0.2035	7.420,-4	7.255,-4	7.120,-4	7.006,-4	6.907,-4	6.819,-4	6.050,-4	6.009,-4	5.976,-4
	h	243.4	93.6	97.9	102.5	107.2	112.0	116.8	91.1	96.1	101.0
	s	3.299	1.494	1.464	1.438	1.414	1.393	1.372	1.037	1.026	1.016
200 h	v	0.4151	2.96,-3	1.430,-5	1.159,-3	1.045,-3	9.778,-4	9.312,-4	8.962,-4	8.683,-4	8.454,-4
	h	296.4	250.2	217.1	209.1	207.9	209.2	211.9	215.1	218.9	223.0
	s	3.667	2.538	2.276	2.173	2.112	2.068	2.033	2.004	1.979	1.957
300 h	v	0.6241	5.96,-3	2.976,-3	2.071,-3	1.666,-3	1.443,-3	1.304,-3	1.207,-3	1.136,-3	1.081,-3
	h	348.6	330.9	316.3	306.6	301.4	299.3	299.2	300.5	302.7	305.6
	s	3.879	2.872	2.686	2.572	2.493	2.435	2.389	2.352	2.320	2.293
400 h	v	0.8326	8.37,-3	4.279,-3	2.957,-3	2.322,-3	1.955,-3	1.719,-3	1.557,-3	1.435,-3	1.344,-3
	h	400.7	391.3	383.6	378.4	375.2	373.8	373.8	374.8	376.6	379.2
	s	4.028	3.048	2.881	2.780	2.707	2.651	2.603	2.565	2.533	2.505
500 h	v	1.0409	1.062,-2	5.464,-3	3.772,-3	2.940,-3	2.448,-3	2.124,-3	1.899,-3	1.730,-3	1.607,-3
	h	452.8	447.7	444.3	442.0	440.9	440.6	441.4	422.9	444.7	447.1
	s	4.145	3.174	3.018	2.924	2.854	2.801	2.755	2.718	2.685	2.658
600 h	v	1.2489	1.280,-2	6.589,-3	4.539,-3	3.525,-3	2.922,-3	2.522,-3	2.238,-3	2.023,-3	1.866,-3
	h	504.9	502.4	501.6	501.4	501.8	503.0	504.6	506.6	508.7	511.2
	s	4.240	3.274	3.122	3.031	2.966	2.914	2.870	2.834	2.801	2.774
700 h	v	1.4569	1.495,-2	7.686,-3	5.281,-3	4.088,-3	3.377,-3	2.906,-3	2.570,-3	2.317,-3	2.123,-3
	h	556.9	556.5	556.9	558.0	559.8	561.8	564.2	566.9	569.6	572.5
	s	4.320	3.356	3.207	3.118	3.054	3.005	2.963	2.928	2.897	2.870
800 h	v	1.6659	1.708,-2	8.768,-3	6.011,-3	4.640,-3	3.822,-3	3.280,-3	2.893,-3	2.603,-3	2.376,-3
	h	609.9	609.8	611.0	612.9	615.2	618.1	621.2	624.5	627.8	631.3
	s	4.389	3.427	3.279	3.191	3.129	3.081	3.039	3.005	2.975	2.948
900 h	v	1.8739	1.920,-2	9.841,-3	6.732,-3	5.183,-3	4.259,-3	3.646,-3	3.209,-3	2.881,-3	2.626,-3
	h	661.0	662.7	664.6	667.2	670.1	673.3	676.8	680.7	684.4	688.3
	s	4.451	3.490	3.342	3.255	3.193	3.145	3.105	3.071	3.042	3.016
1000 h	v	2.0819	2.131,-2	1.091,-2	7.448,-3	5.723,-3	4.692,-3	4.008,-3	3.520,-3	3.156,-3	2.872,-3
	h	713.1	715.4	717.9	720.9	724.3	727.8	731.5	735.6	739.8	744.1
	s	4.506	3.545	3.398	3.312	3.250	3.203	3.163	3.129	3.100	3.074

*Values extracted and in some cases rounded off from those cited in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. v = specific volume, m³/kg; h = specific enthalpy, kJ/kg; s = specific entropy, kJ/(kg·K). This source contains an exhaustive tabulation of values. The notation 7.420,-4 signifies 7.420×10^{-4} . This book was published in English translation by Hemisphere, New York, 1988 (604 pp.). The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) has a thermodynamic chart for pressures from 1 to 2000 bar, temperatures from 90 to 700 K. Saturation and superheat tables and a chart to 50,000 psia, 1220 °R appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

Extensive tables for 10 properties from 0–100 bar, 86–400 K are given by Jacques, A., Fermi Accelerator Lab., Batavia, IL, rept TM 1517, 1988 (201 pp.). In Hilsenrath, J., C. G. Messina, et al., AEDC-TR-66-248 = AD 644 081, 1966 (121 pp.), thermodynamic properties and chemical composition from 2400 to 35,000 K are tabulated. See also Drelichshak, K. S. et al., AEDC-TDR-63-146, 1963; AEDC-TDR-64-12 = AD 427839, 1964.

TABLE 2-235 Liquid-Vapor Equilibrium Data for the Argon-Nitrogen-Oxygen System*

Liquid mole fraction		Vapor mole fraction			Temper- ature, °R	Relative volatility			Pressure activity coefficient			Enthalpy, Btu/(lb-mol)		Heat capacity, Btu/(lb-mol·°R)	
N ₂ /N ₂ + O ₂	Ar	N ₂	Ar	O ₂		N ₂ /Ar	N ₂ /O ₂	Ar/O ₂	N ₂	Ar	O ₂	Liquid	Vapor	Liquid	Vapor
Pressure, 1 atm															
0.	0.	0.	0.	1.0000	162.4	2.575	4.010	1.557	1.118	1.165	0.999	-1841.	1093.	13.2	7.406
0.	0.01	0.	0.0154	0.9845	162.3	2.581	4.007	1.553	1.117	1.161	1.000	-1844.	1087.	13.1	7.374
0.	0.02	0.	0.0306	0.9694	162.2	2.586	4.004	1.548	1.115	1.158	1.000	-1847.	1082.	13.1	7.342
0.	0.03	0.	0.0456	0.9544	162.1	2.592	4.001	1.544	1.113	1.155	1.000	-1850.	1076.	13.1	7.311
0.	0.04	0.	0.0603	0.9397	162.0	2.597	3.998	1.540	1.112	1.151	1.001	-1852.	1071.	13.0	7.281
0.	0.05	0.	0.0748	0.9253	161.9	2.602	3.995	1.535	1.110	1.148	1.001	-1855.	1066.	13.0	7.251
0.	0.07	0.	0.1031	0.8970	161.7	2.613	3.989	1.526	1.107	1.142	1.002	-1860.	1056.	12.9	7.192
0.	0.10	0.	0.1439	0.8561	161.5	2.629	3.979	1.513	1.103	1.132	1.003	-1868.	1041.	12.9	7.107
0.	0.20	0.	0.2687	0.7313	160.7	2.682	3.941	1.469	1.091	1.104	1.010	-1893.	997.	12.6	6.847
0.	0.40	0.	0.4796	0.5204	159.4	2.786	3.852	1.382	1.076	1.058	1.034	-1938.	924.	11.9	6.406
0.	0.60	0.	0.6605	0.3395	158.5	2.888	3.746	1.297	1.075	1.026	1.072	-1978.	862.	11.3	6.026
0.	0.80	0.	0.8293	0.1707	157.7	2.991	3.632	1.214	1.087	1.008	1.127	-2015.	807.	10.7	5.669
0.	0.90	0.	0.9136	0.0865	157.5	3.042	3.572	1.174	1.099	1.003	1.162	-2032.	779.	10.4	5.491
0.10	0.	0.3135	0.	0.6865	157.7	2.621	4.111	1.568	1.103	1.168	1.012	-1834.	1060.	13.2	7.410
0.10	0.01	0.3095	0.0119	0.6786	157.6	2.626	4.106	1.563	1.102	1.164	1.012	-1837.	1057.	13.1	7.386
0.10	0.02	0.3056	0.0237	0.6707	157.6	2.631	4.100	1.558	1.100	1.161	1.012	-1839.	1053.	13.1	7.361
0.10	0.03	0.3017	0.0354	0.6630	157.6	2.636	4.095	1.554	1.099	1.157	1.013	-1842.	1049.	13.1	7.337
0.10	0.04	0.2978	0.0470	0.6553	157.6	2.641	4.090	1.549	1.098	1.154	1.013	-1844.	1045.	13.1	7.313
0.10	0.05	0.2939	0.0585	0.6476	157.5	2.645	4.085	1.544	1.096	1.151	1.013	-1846.	1042.	13.0	7.289
0.10	0.07	0.2863	0.0812	0.6325	157.5	2.655	4.074	1.534	1.094	1.144	1.014	-1851.	1034.	13.0	7.242
0.10	0.10	0.2752	0.1145	0.6103	157.4	2.669	4.058	1.520	1.090	1.135	1.015	-1855.	1024.	12.9	7.173
0.10	0.20	0.2399	0.2207	0.5394	157.2	2.717	4.003	1.473	1.080	1.106	1.022	-1882.	990.	12.5	6.951
0.10	0.40	0.1759	0.4170	0.4072	157.0	2.812	3.887	1.382	1.070	1.061	1.045	-1926.	928.	11.9	6.540
0.10	0.60	0.1169	0.6036	0.2795	156.9	2.906	3.766	1.296	1.072	1.029	1.082	-1969.	871.	11.3	6.147
0.10	0.80	0.0595	0.7933	0.1471	156.9	3.001	3.640	1.213	1.086	1.009	1.134	-2009.	813.	10.7	5.746
0.10	0.90	0.0303	0.8937	0.0762	157.1	3.048	3.576	1.173	1.099	1.004	1.166	-2029.	783.	10.4	5.534
0.20	0.	0.5095	0.	0.4905	154.0	2.641	4.155	1.573	1.085	1.171	1.026	-1814.	1035.	13.2	7.422
0.20	0.01	0.5042	0.0096	0.4861	154.0	2.646	4.149	1.568	1.084	1.168	1.026	-1816.	1032.	13.2	7.402
0.20	0.02	0.4990	0.0192	0.4818	154.0	2.651	4.143	1.563	1.083	1.164	1.026	-1819.	1029.	13.1	7.382
0.20	0.03	0.4938	0.0288	0.4775	154.1	2.655	4.137	1.558	1.082	1.161	1.027	-1821.	1027.	13.1	7.362
0.20	0.04	0.4886	0.0383	0.4731	154.1	2.660	4.131	1.553	1.081	1.158	1.027	-1824.	1024.	13.1	7.342
0.20	0.05	0.4834	0.0477	0.4688	154.1	2.665	4.125	1.548	1.080	1.154	1.027	-1826.	1021.	13.0	7.322
0.20	0.07	0.4732	0.0666	0.4602	154.1	2.674	4.112	1.538	1.078	1.148	1.028	-1831.	1016.	13.0	7.283
0.20	0.10	0.4580	0.0946	0.4474	154.2	2.688	4.094	1.523	1.075	1.139	1.030	-1839.	1008.	12.9	7.224
0.20	0.20	0.4083	0.1866	0.4051	154.3	2.735	4.032	1.474	1.068	1.110	1.036	-1863.	981.	12.6	7.031
0.20	0.40	0.3123	0.3680	0.3197	154.8	2.829	3.907	1.381	1.062	1.064	1.058	-1911.	930.	11.9	6.648
0.20	0.60	0.2162	0.5550	0.2288	155.4	2.921	3.779	1.294	1.068	1.032	1.093	-1958.	877.	11.3	6.252
0.20	0.80	0.1144	0.7602	0.1254	156.2	3.009	3.647	1.212	1.086	1.011	1.140	-2004.	819.	10.7	5.817
0.20	0.90	0.0593	0.8744	0.0663	156.7	3.052	3.580	1.173	1.099	1.006	1.169	-2026.	787.	10.4	5.574
0.40	0.	0.7333	0.	0.2667	148.7	2.629	4.124	1.569	1.050	1.187	1.065	-1748.	997.	13.3	7.452
0.40	0.01	0.7279	0.0070	0.2651	148.8	2.634	4.119	1.564	1.049	1.183	1.065	-1751.	996.	13.3	7.437
0.40	0.02	0.7226	0.0140	0.2635	148.8	2.640	4.114	1.558	1.049	1.179	1.065	-1754.	994.	13.2	7.422
0.40	0.03	0.7172	0.0210	0.2619	148.9	2.645	4.108	1.553	1.048	1.176	1.066	-1757.	992.	13.2	7.407
0.40	0.04	0.7118	0.0280	0.2602	148.9	2.650	4.103	1.548	1.048	1.172	1.066	-1760.	991.	13.2	7.392
0.40	0.05	0.7064	0.0350	0.2586	149.0	2.656	4.098	1.543	1.047	1.169	1.066	-1763.	989.	13.1	7.377
0.40	0.07	0.6956	0.0491	0.2553	149.1	2.667	4.087	1.533	1.047	1.162	1.066	-1770.	986.	13.1	7.347
0.40	0.10	0.6794	0.0703	0.2503	149.3	2.683	4.072	1.517	1.046	1.152	1.067	-1779.	981.	13.0	7.301
0.40	0.20	0.6244	0.1426	0.2331	149.9	2.737	4.018	1.468	1.044	1.122	1.071	-1810.	964.	12.6	7.145
0.40	0.40	0.5075	0.2977	0.1948	151.2	2.841	3.907	1.375	1.048	1.074	1.088	-1871.	928.	11.9	6.811
0.40	0.60	0.3743	0.4776	0.1482	152.8	2.939	3.788	1.289	1.062	1.039	1.116	-1932.	885.	11.3	6.423
0.40	0.80	0.2121	0.7010	0.0870	154.8	3.025	3.657	1.209	1.084	1.016	1.154	-1991.	829.	10.7	5.944
0.40	0.90	0.1141	0.8382	0.0477	155.9	3.063	3.586	1.171	1.099	1.008	1.177	-2020.	794.	10.4	5.651
0.60	0.	0.8569	0.	0.1431	144.9	2.575	3.993	1.551	1.024	1.218	1.126	-1663.	970.	13.6	7.483
0.60	0.01	0.8521	0.0056	0.1424	145.0	2.582	3.991	1.546	1.024	1.214	1.125	-1667.	969.	13.5	7.471
0.60	0.02	0.8472	0.0111	0.1416	145.1	2.589	3.988	1.541	1.024	1.210	1.125	-1672.	968.	13.5	7.459
0.60	0.03	0.8424	0.0167	0.1409	145.1	2.595	3.985	1.536	1.024	1.206	1.124	-1676.	967.	13.4	7.446
0.60	0.04	0.8375	0.0224	0.1402	145.2	2.602	3.983	1.531	1.024	1.202	1.124	-1680.	966.	13.4	7.434
0.60	0.05	0.8326	0.0280	0.1395	145.3	2.609	3.980	1.526	1.023	1.198	1.123	-1684.	965.	13.4	7.421
0.60	0.07	0.8227	0.0394	0.1380	145.5	2.622	3.975	1.516	1.023	1.190	1.122	-1692.	963.	13.3	7.396
0.60	0.10	0.8076	0.0566	0.1357	145.7	2.642	3.966	1.501	1.023	1.179	1.121	-1704.	960.	13.2	7.357
0.60	0.20	0.7557	0.1163	0.1280	146.5	2.707	3.937	1.454	1.025	1.145	1.120	-1744.	948.	12.8	7.224
0.60	0.40	0.6391	0.2507	0.1102	148.4	2.833	3.867	1.365	1.036	1.090	1.126	-1824.	923.	12.0	6.926
0.60	0.60	0.4938	0.4191	0.0871	150.6	2.945	3.777	1.283	1.056	1.049	1.143	-1903.	888.	11.3	6.556
0.60	0.80	0.2961	0.6500	0.0539	153.5	3.037	3.662	1.206	1.083	1.021	1.169	-1978.	837.	10.7	6.055
0.60	0.90	0.1647	0.8047	0.0306	155.2	3.071</									

TABLE 2-235 Liquid-Vapor Equilibrium Data for the Argon-Nitrogen-Oxygen System (Continued)

Liquid mole fraction		Vapor mole fraction			Temper- ature, °R	Relative volatility			Pressure activity coefficient			Enthalpy, Btu/(lb-mol)		Heat capacity, Btu/(lb-mol·°R)	
N ₂ /N ₂ + O ₂	Ar	N ₂	Ar	O ₂		N ₂ /Ar	N ₂ /O ₂	Ar/O ₂	N ₂	Ar	O ₂	Liquid	Vapor	Liquid	Vapor
Pressure, 1 atm (Cont.)															
0.90	0.	0.9709	0.	0.0291	140.6	2.459	3.710	1.509	1.015	1.311	1.271	-1522.	939.	14.2	7.530
0.90	0.01	0.9667	0.0044	0.0289	140.7	2.468	3.712	1.504	1.014	1.305	1.268	-1527.	938.	14.2	7.519
0.90	0.02	0.9624	0.0088	0.0288	140.8	2.476	3.714	1.500	1.014	1.299	1.265	-1533.	938.	14.1	7.509
0.90	0.03	0.9581	0.0133	0.0286	140.9	2.485	3.716	1.496	1.013	1.293	1.263	-1538.	937.	14.1	7.498
0.90	0.04	0.9538	0.0177	0.0285	141.0	2.493	3.718	1.491	1.013	1.287	1.260	-1544.	937.	14.0	7.488
0.90	0.05	0.9494	0.0222	0.0284	141.1	2.502	3.720	1.487	1.013	1.281	1.257	-1550.	936.	14.0	7.477
0.90	0.07	0.9407	0.0312	0.0281	141.3	2.519	3.724	1.478	1.013	1.270	1.252	-1561.	935.	13.8	7.456
0.90	0.10	0.9274	0.0450	0.0276	141.6	2.545	3.729	1.465	1.012	1.254	1.245	-1578.	934.	13.7	7.423
0.90	0.20	0.8808	0.0931	0.0261	142.6	2.629	3.743	1.424	1.014	1.204	1.226	-1633.	928.	13.2	7.310
0.90	0.40	0.7723	0.2048	0.0229	144.9	2.793	3.755	1.344	1.026	1.126	1.200	-1745.	912.	12.3	7.050
0.90	0.60	0.6262	0.3552	0.0186	147.8	2.938	3.733	1.270	1.050	1.069	1.190	-1853.	889.	11.4	6.708
0.90	0.80	0.4018	0.5860	0.0122	151.7	3.048	3.660	1.201	1.081	1.029	1.192	-1956.	846.	10.7	6.197
0.90	0.90	0.2339	0.7589	0.0072	154.2	3.082	3.597	1.167	1.098	1.014	1.197	-2004.	809.	10.3	5.822
0.97	0.	0.9916	0.	0.0084	139.8	2.429	3.638	1.498	1.018	1.342	1.316	-1488.	933.	14.4	7.541
0.97	0.01	0.9874	0.0042	0.0084	139.9	2.438	3.641	1.494	1.018	1.335	1.313	-1494.	932.	14.4	7.531
0.97	0.02	0.9832	0.0085	0.0083	140.0	2.447	3.644	1.489	1.017	1.329	1.309	-1500.	932.	14.3	7.520
0.97	0.03	0.9790	0.0127	0.0083	140.1	2.456	3.647	1.485	1.017	1.322	1.306	-1505.	931.	14.2	7.510
0.97	0.04	0.9748	0.0170	0.0083	140.2	2.465	3.650	1.481	1.016	1.315	1.302	-1511.	931.	14.2	7.500
0.97	0.05	0.9705	0.0213	0.0082	140.3	2.474	3.653	1.477	1.016	1.309	1.299	-1517.	930.	14.1	7.489
0.97	0.07	0.9619	0.0300	0.0081	140.5	2.492	3.658	1.468	1.015	1.296	1.293	-1529.	929.	14.0	7.469
0.97	0.10	0.9488	0.0432	0.0080	140.8	2.519	3.667	1.456	1.014	1.278	1.284	-1547.	928.	13.9	7.437
0.97	0.20	0.9032	0.0893	0.0076	141.8	2.608	3.691	1.415	1.014	1.224	1.257	-1606.	923.	13.3	7.327
0.97	0.40	0.7965	0.1969	0.0066	144.2	2.780	3.722	1.339	1.025	1.137	1.220	-1725.	910.	12.3	7.073
0.97	0.60	0.6513	0.3433	0.0054	147.2	2.934	3.718	1.267	1.049	1.075	1.202	-1841.	889.	11.4	6.737
0.97	0.80	0.4236	0.5728	0.0036	151.3	3.050	3.658	1.199	1.081	1.031	1.198	-1951.	847.	10.7	6.226
0.97	0.90	0.2489	0.7489	0.0021	153.9	3.084	3.597	1.167	1.098	1.015	1.200	-2002.	810.	10.3	5.844
1.00	0.	1.0000	0.	0.	139.4	2.416	3.607	1.493	1.021	1.357	1.338	-1473.	930.	14.5	7.546
1.00	0.01	0.9959	0.0041	0.0000	139.5	2.425	3.611	1.489	1.020	1.350	1.334	-1479.	929.	14.4	7.535
1.00	0.02	0.9917	0.0083	0.0000	139.6	2.434	3.614	1.485	1.019	1.343	1.330	-1485.	929.	14.4	7.525
1.00	0.03	0.9875	0.0125	0.0000	139.7	2.443	3.617	1.480	1.019	1.336	1.326	-1491.	929.	14.3	7.515
1.00	0.04	0.9833	0.0167	0.0000	139.8	2.452	3.621	1.476	1.018	1.329	1.322	-1497.	928.	14.3	7.505
1.00	0.05	0.9791	0.0209	0.0000	139.9	2.462	3.624	1.472	1.018	1.322	1.318	-1503.	928.	14.2	7.495
1.00	0.07	0.9705	0.0295	0.0000	140.1	2.480	3.630	1.464	1.017	1.309	1.311	-1516.	927.	14.1	7.474
1.00	0.10	0.9576	0.0424	0.0000	140.4	2.507	3.640	1.452	1.016	1.290	1.301	-1534.	926.	13.9	7.443
1.00	0.20	0.9122	0.0578	0.0000	141.5	2.598	3.668	1.412	1.015	1.232	1.271	-1595.	921.	13.4	7.333
1.00	0.40	0.8063	0.1937	0.0000	143.9	2.774	3.708	1.337	1.025	1.142	1.230	-1716.	909.	12.4	7.082
1.00	0.60	0.6616	0.3384	0.	147.0	2.932	3.712	1.266	1.048	1.077	1.208	-1836.	888.	11.4	6.749
1.00	0.80	0.4327	0.5674	0.	151.1	3.050	3.657	1.199	1.080	1.032	1.201	-1949.	848.	10.7	6.838
1.00	0.90	0.2553	0.7447	0.	153.8	3.085	3.598	1.166	1.098	1.016	1.201	-2001.	811.	10.3	5.853
Pressure, 4 atm															
0.	0.	0.	0.	1.0000	190.6	2.020	2.776	1.375	0.987	1.111	1.000	-1466.	1224.	13.4	8.122
0.	0.01	0.	0.0137	0.9563	190.5	2.023	2.775	1.372	0.986	1.109	1.001	-1470.	1218.	13.4	8.094
0.	0.02	0.	0.0272	0.9728	190.4	2.026	2.773	1.369	0.985	1.106	1.001	-1473.	1212.	13.4	8.065
0.	0.03	0.	0.0405	0.9595	190.3	2.030	2.772	1.366	0.985	1.104	1.002	-1477.	1207.	13.4	8.037
0.	0.04	0.	0.0537	0.9463	190.2	2.033	2.770	1.362	0.984	1.102	1.002	-1480.	1201.	13.4	8.010
0.	0.05	0.	0.0668	0.9332	190.1	2.037	2.768	1.359	0.983	1.100	1.003	-1484.	1196.	13.3	7.982
0.	0.07	0.	0.0924	0.9076	189.9	2.043	2.765	1.353	0.982	1.096	1.004	-1490.	1185.	13.3	7.929
0.	0.10	0.	0.1299	0.8701	189.6	2.053	2.759	1.344	0.980	1.089	1.005	-1500.	1169.	13.3	7.850
0.	0.20	0.	0.2471	0.7529	188.8	2.086	2.738	1.313	0.974	1.070	1.013	-1533.	1121.	13.1	7.605
0.	0.40	0.	0.4548	0.5452	187.5	2.148	2.688	1.251	0.967	1.038	1.034	-1593.	1037.	12.7	7.166
0.	0.60	0.	0.6410	0.3590	186.5	2.207	2.627	1.190	0.967	1.016	1.066	-1647.	964.	12.3	6.771
0.	0.80	0.	0.8190	0.1811	185.8	2.264	2.560	1.131	0.976	1.003	1.110	-1698.	896.	11.9	6.389
0.	0.90	0.	0.9084	0.0916	185.5	2.292	2.524	1.101	0.983	1.000	1.137	-1723.	862.	11.8	6.196
0.10	0.	0.2393	0.	0.7607	186.2	2.063	2.831	1.372	0.994	1.120	1.020	-1452.	1193.	13.7	8.150
0.10	0.01	0.2363	0.0116	0.7521	186.1	2.066	2.828	1.369	0.994	1.117	1.021	-1455.	1188.	13.6	8.126
0.10	0.02	0.2334	0.0230	0.7436	186.1	2.069	2.825	1.365	0.993	1.115	1.021	-1459.	1184.	13.6	8.102
0.10	0.03	0.2305	0.0344	0.7351	186.0	2.072	2.822	1.362	0.992	1.113	1.021	-1462.	1180.	13.6	8.078
0.10	0.04	0.2277	0.0457	0.7267	186.0	2.075	2.820	1.359	0.991	1.110	1.022	-1465.	1175.	13.6	8.054
0.10	0.05	0.2248	0.0569	0.7183	186.0	2.078	2.817	1.356	0.990	1.108	1.022	-1469.	1171.	13.5	8.031
0.10	0.07	0.2192	0.0792	0.7017	185.9	2.083	2.811	1.349	0.988	1.104	1.023	-1475.	1163.	13.5	7.984
0.10	0.10	0.2109	0.1120	0.6772	185.8	2.092	2.802	1.340	0.986	1.097	1.024	-1485.	1150.	13.4	7.915
0.10	0.20	0.1843	0.2174	0.5983	185.5	2.119	2.772	1.308	0.979	1.077	1.030	-1517.	1110.	13.2	7.691
0.10	0.40	0.1353	0.4150	0.4497	185.2	2.173	2.707	1.246	0.971	1.044	1.049	-1578.	1037.	12.8	7.269
0.10	0.60	0.0896	0.6045	0.3058	185.0	2.224	2.638	1.186	0.971	1.020	1.078	-1637.	968.	12.4	6.860
0.10	0.80	0.0452	0.7961	0.1588	185.1	2.273	2.564	1.128	0						

TABLE 2-235 Liquid-Vapor Equilibrium Data for the Argon-Nitrogen-Oxygen System (Concluded)

Liquid mole fraction	Vapor mole fraction			Temper-ature, °R	Relative volatility			Pressure activity coefficient			Enthalpy, Btu/(lb-mol)		Heat capacity, Btu/(lb-mol·°R)		
	N ₂ /N ₂ + O ₂	Ar	N ₂		N ₂ /Ar	N ₂ /O ₂	Ar/O ₂	N ₂	Ar	O ₂	Liquid	Vapor	Liquid	Vapor	
Pressure, 4 atm (Cont.)															
0.40	0.	0.6560	0.	0.3441	176.3	2.124	2.859	1.346	0.992	1.146	1.090	-1372.	1121.	14.1	8.277
0.40	0.01	0.6506	0.0077	0.3417	176.4	2.127	2.856	1.343	0.991	1.143	1.090	-1376.	1119.	14.0	8.260
0.40	0.02	0.6453	0.0155	0.3393	176.4	2.129	2.853	1.340	0.991	1.140	1.090	-1380.	1117.	14.0	8.242
0.40	0.03	0.6400	0.0232	0.3369	176.5	2.132	2.850	1.337	0.990	1.138	1.090	-1384.	1115.	14.0	8.224
0.40	0.04	0.6347	0.0310	0.3345	176.6	2.135	2.846	1.333	0.990	1.135	1.090	-1387.	1112.	13.9	8.206
0.40	0.05	0.6293	0.0387	0.3320	176.6	2.137	2.843	1.330	0.989	1.133	1.090	-1391.	1110.	13.9	8.188
0.40	0.07	0.6186	0.0543	0.3271	176.8	2.143	2.837	1.324	0.988	1.128	1.090	-1399.	1106.	13.9	8.153
0.40	0.10	0.6025	0.0778	0.3197	177.0	2.151	2.827	1.315	0.986	1.120	1.090	-1410.	1099.	13.8	8.098
0.40	0.20	0.5482	0.1575	0.2943	177.7	2.176	2.794	1.284	0.982	1.098	1.091	-1449.	1077.	13.5	7.915
0.40	0.40	0.4348	0.3259	0.2393	179.2	2.223	2.725	1.226	0.978	1.061	1.100	-1525.	1029.	13.0	7.527
0.40	0.60	0.3104	0.5141	0.1756	180.9	2.264	2.652	1.171	0.979	1.033	1.116	-1600.	975.	12.5	7.095
0.40	0.80	0.1684	0.7334	0.0982	182.9	2.297	2.573	1.120	0.985	1.013	1.139	-1674.	910.	12.0	6.597
0.40	0.90	0.0882	0.8595	0.0523	184.1	2.309	2.531	1.096	0.989	1.006	1.153	-1710.	872.	11.8	6.312
0.60	0.	0.8076	0.	0.1924	171.7	2.120	2.798	1.320	0.986	1.173	1.154	-1296.	1086.	14.2	8.369
0.60	0.01	0.8023	0.0064	0.1913	171.8	2.123	2.796	1.317	0.986	1.170	1.153	-1301.	1084.	14.2	8.354
0.60	0.02	0.7971	0.0127	0.1902	171.9	2.127	2.794	1.314	0.985	1.167	1.152	-1305.	1083.	14.1	8.338
0.60	0.03	0.7918	0.0192	0.1891	172.0	2.130	2.792	1.311	0.985	1.164	1.152	-1310.	1082.	14.1	8.322
0.60	0.04	0.7865	0.0256	0.1879	172.1	2.133	2.790	1.308	0.985	1.161	1.151	-1315.	1080.	14.1	8.306
0.60	0.05	0.7812	0.0321	0.1868	172.2	2.137	2.788	1.305	0.984	1.159	1.150	-1319.	1079.	14.0	8.289
0.60	0.07	0.7704	0.0451	0.1845	172.4	2.143	2.784	1.299	0.984	1.153	1.149	-1329.	1076.	14.0	8.257
0.60	0.10	0.7542	0.0649	0.1810	172.6	2.153	2.778	1.290	0.983	1.144	1.148	-1343.	1072.	13.9	8.208
0.60	0.20	0.6980	0.1332	0.1688	173.7	2.184	2.757	1.262	0.981	1.119	1.143	-1389.	1056.	13.6	8.038
0.60	0.40	0.5739	0.2548	0.1413	175.9	2.239	2.708	1.209	0.980	1.076	1.141	-1482.	1021.	13.0	7.666
0.60	0.60	0.4261	0.4667	0.1073	178.5	2.283	2.648	1.160	0.984	1.043	1.145	-1573.	976.	12.5	7.228
0.60	0.80	0.2413	0.6963	0.0625	181.6	2.311	2.576	1.115	0.989	1.019	1.155	-1661.	916.	12.0	6.690
0.60	0.90	0.1293	0.8367	0.0340	183.4	2.317	2.533	1.093	0.992	1.009	1.161	-1704.	876.	11.8	6.367
0.80	0.	0.9152	0.	0.0848	168.0	2.095	2.699	1.288	0.986	1.216	1.239	-1209.	1057.	14.3	8.462
0.80	0.01	0.9102	0.0055	0.0843	168.1	2.099	2.699	1.286	0.986	1.212	1.237	-1215.	1056.	14.2	8.447
0.80	0.02	0.9052	0.0110	0.0839	168.2	2.103	2.699	1.283	0.986	1.209	1.235	-1220.	1055.	14.2	8.432
0.80	0.03	0.9001	0.0165	0.0834	168.3	2.107	2.698	1.280	0.985	1.205	1.234	-1226.	1054.	14.2	8.417
0.80	0.04	0.8950	0.0221	0.0829	168.4	2.112	2.698	1.278	0.985	1.201	1.232	-1232.	1053.	14.1	8.402
0.80	0.05	0.8899	0.0277	0.0825	168.5	2.116	2.698	1.275	0.984	1.198	1.230	-1237.	1052.	14.1	8.387
0.80	0.07	0.8795	0.0390	0.0815	168.7	2.124	2.698	1.270	0.984	1.190	1.227	-1249.	1050.	14.0	8.356
0.80	0.10	0.8638	0.0562	0.0801	169.1	2.136	2.697	1.263	0.983	1.180	1.222	-1266.	1047.	14.0	8.309
0.80	0.20	0.8087	0.1162	0.0751	170.3	2.175	2.693	1.238	0.981	1.148	1.208	-1322.	1037.	13.7	8.148
0.80	0.40	0.6826	0.2535	0.0638	173.1	2.244	2.674	1.192	0.983	1.095	1.188	-1434.	1012.	13.1	7.786
0.80	0.60	0.5231	0.4274	0.0496	176.4	2.295	2.636	1.149	0.988	1.055	1.176	-1543.	976.	12.5	7.347
0.80	0.80	0.3077	0.6624	0.0299	180.3	2.323	2.576	1.109	0.993	1.024	1.171	-1647.	920.	12.0	6.777
0.80	0.90	0.1684	0.8150	0.0166	182.7	2.325	2.535	1.090	0.994	1.012	1.169	-1698.	880.	11.8	6.420
0.90	0.	0.9596	0.	0.0404	166.3	2.077	2.641	1.271	0.990	1.245	1.292	-1163.	1044.	14.3	8.509
0.90	0.01	0.9547	0.0051	0.0402	166.4	2.081	2.641	1.269	0.990	1.241	1.289	-1169.	1043.	14.3	8.494
0.90	0.02	0.9497	0.0103	0.0399	166.5	2.086	2.642	1.267	0.989	1.236	1.287	-1175.	1042.	14.2	8.479
0.90	0.03	0.9448	0.0155	0.0397	166.7	2.091	2.643	1.264	0.989	1.232	1.284	-1181.	1042.	14.2	8.464
0.90	0.04	0.9397	0.0208	0.0395	166.8	2.095	2.644	1.262	0.988	1.228	1.281	-1188.	1041.	14.2	8.449
0.90	0.05	0.9347	0.0260	0.0393	166.9	2.100	2.645	1.260	0.988	1.224	1.279	-1194.	1040.	14.1	8.434
0.90	0.07	0.9245	0.0367	0.0388	167.2	2.109	2.646	1.255	0.987	1.215	1.274	-1206.	1039.	14.1	8.404
0.90	0.10	0.9090	0.0529	0.0381	167.5	2.122	2.649	1.248	0.986	1.203	1.267	-1225.	1036.	14.0	8.358
0.90	0.20	0.8546	0.1096	0.0358	168.8	2.166	2.653	1.225	0.984	1.167	1.246	-1287.	1028.	13.7	8.198
0.90	0.40	0.7287	0.2407	0.0305	171.8	2.242	2.651	1.182	0.985	1.107	1.215	-1409.	1007.	13.1	7.840
0.90	0.60	0.5659	0.4102	0.0239	175.3	2.299	2.627	1.143	0.990	1.062	1.193	-1527.	975.	12.5	7.400
0.90	0.80	0.3387	0.6467	0.0146	179.7	2.328	2.575	1.106	0.995	1.027	1.179	-1640.	922.	12.0	6.818
0.90	0.90	0.1873	0.8045	0.0082	182.4	2.329	2.536	1.089	0.995	1.013	1.173	-1694.	882.	11.8	6.446
0.97	0.	0.9882	0.	0.0118	165.2	2.062	2.598	1.260	0.995	1.269	1.334	-1130.	1035.	14.3	8.541
0.97	0.01	0.9834	0.0050	0.0117	165.3	2.067	2.599	1.257	0.994	1.264	1.330	-1136.	1035.	14.3	8.527
0.97	0.02	0.9784	0.0099	0.0116	165.5	2.072	2.601	1.255	0.994	1.259	1.327	-1143.	1034.	14.2	8.512
0.97	0.03	0.9735	0.0149	0.0116	165.6	2.077	2.602	1.253	0.993	1.254	1.324	-1149.	1033.	14.2	8.497
0.97	0.04	0.9685	0.0200	0.0115	165.7	2.082	2.604	1.251	0.992	1.250	1.321	-1156.	1033.	14.2	8.482
0.97	0.05	0.9635	0.0250	0.0114	165.8	2.087	2.605	1.248	0.992	1.245	1.317	-1163.	1032.	14.2	8.467
0.97	0.07	0.9534	0.0353	0.0113	166.1	2.097	2.608	1.244	0.991	1.236	1.311	-1176.	1031.	14.1	8.437
0.97	0.10	0.9380	0.0509	0.0111	166.5	2.111	2.612	1.237	0.989	1.220	1.302	-1195.	1029.	14.0	8.391
0.97	0.10	0.9380	0.0509	0.0111	166.5	2.111	2.612	1.237	0.989	1.222	1.302	-1195.	1029.	14.0	8.391
0.97	0.20	0.8840	0.1056	0.0104	167.9	2.158	2.624	1.216	0.987	1.182	1.276	-1261.	1022.	13.7	8.233
0.97	0.40	0.7584	0.2327	0.0089	170.9	2.240	2.633	1.176	0.986	1.116	1.235	-1390.	1003.	13.1	7.877
0.97	0.60	0.5940	0.3990	0.0070	174.6	2.302	2.620	1.138	0.991	1.067	1.2				

TABLE 2-236 Thermodynamic Properties of the International Standard Atmosphere*

Z, m	T, K	P, bar	ρ , kg/m ³	g, m/s ²	M	a, m/s	μ , Pa·s	k, W/(m·K)	λ , m	H, m
0	288.15	1.01325	1.2250	9.80665	28.964	340.29	1.79.-5	2.54.-5	6.63.-8	0
1,000	281.65	0.89876	1.1117	9.8036	28.964	336.43	1.76.-5	2.49.-5	7.31.-8	1,000
2,000	275.15	0.79501	1.0066	9.8005	28.964	332.53	1.73.-5	2.43.-5	8.07.-8	2,999
3,000	268.66	0.70121	0.90925	9.7974	28.964	328.58	1.69.-5	2.38.-5	8.94.-8	2,999
4,000	262.17	0.61660	0.81935	9.7943	28.964	324.59	1.66.-5	2.33.-5	9.92.-8	3,997
5,000	255.68	0.54048	0.73643	9.7912	28.964	320.55	1.63.-5	2.28.-5	1.10.-7	4,996
6,000	249.19	0.47217	0.66011	9.7882	28.964	316.45	1.59.-5	2.22.-5	1.23.-7	5,994
7,000	242.70	0.41105	0.59002	9.7851	28.964	312.31	1.56.-5	2.17.-5	1.38.-7	6,992
8,000	236.22	0.35651	0.52579	9.7820	28.964	308.11	1.53.-5	2.12.-5	1.55.-7	7,990
9,000	229.73	0.30800	0.46706	9.7789	28.964	303.85	1.49.-5	2.06.-5	1.74.-7	8,987
10,000	223.25	0.26499	0.41351	9.7759	28.964	299.53	1.46.-5	2.01.-5	1.97.-7	9,984
15,000	216.65	0.12111	0.19476	9.7605	28.964	295.07	1.42.-5	1.95.-5	4.17.-7	14,965
20,000	216.65	0.05529	0.08891	9.7452	28.964	295.07	1.42.-5	1.95.-5	9.14.-7	19,937
25,000	221.55	0.02549	0.04008	9.7300	28.964	298.39	1.45.-5	1.99.-5	2.03.-6	24,902
30,000	226.51	0.01197	0.01841	9.7147	28.964	301.71	1.48.-5	2.04.-5	4.42.-6	29,859
40,000	250.35	2.87.-3	4.00.-3	9.6844	28.964	317.19	1.60.-5	2.23.-5	2.03.-5	39,750
50,000	270.65	8.00.-4	1.03.-3	9.6542	28.964	329.80	1.70.-5	2.40.-5	7.91.-5	49,610
60,000	247.02	2.20.-4	3.10.-4	9.6241	28.964	315.07	1.58.-5	2.21.-5	2.62.-4	59,439
70,000	219.59	5.22.-5	8.28.-5	9.5942	28.964	297.06	1.44.-5	1.98.-5	9.81.-4	69,238
80,000	198.64	1.05.-5	1.85.-5	9.5644	28.964	282.54	1.32.-5	1.80.-5	4.40.-3	79,006
90,000	186.87	1.84.-6	3.43.-6	9.5348	28.95				2.37.-2	88,744
100,000	195.08	3.20.-7	5.60.-7	9.5052	28.40				0.142	98,451
150,000	634.39	4.54.-9	2.08.-9	9.3597	24.10				33	146,542
200,000	854.56	8.47.-10	2.54.-10	9.2175	21.30				240	193,899
250,000	941.33	2.48.-10	6.07.-11	9.0785	19.19				890	240,540
300,000	976.01	8.77.-11	1.92.-11	8.9427	17.73				2600	286,480
400,000	995.83	1.45.-11	2.80.-12	8.6799	15.98				1.6.+4	376,320
500,000	999.24	3.02.-12	5.22.-13	8.4286	14.33				7.7.+4	463,540
600,000	999.85	8.21.-13	1.14.-13	8.1880	11.51				2.8.+5	548,252
800,000	999.99	1.70.-13	1.14.-14	7.7368	5.54				1.4.+6	710,574
1,000,000	1000.00	7.51.-14	3.56.-15	7.3218	3.94				3.1.+6	864,071

*Extracted from U.S. Standard Atmosphere, 1976, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration and the U.S. Air Force, Washington, 1976. Z = geometric altitude, T = temperature, P = pressure, g = acceleration of gravity, M = molecular weight, a = velocity of sound, μ = viscosity, k = thermal conductivity, λ = mean free path, ρ = density, and H = geopotential altitude. The notation 1.79.-5 signifies 1.79×10^{-5} .

TABLE 2-237 Saturated Benzene*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
290	0.0860	1.133.-10 ⁻³	3.569.-10	371.1	810.3	2.172	3.686	1.719	6.75	0.147
300	0.1382	1.147.-10 ⁻³	2.292.-10	388.3	820.4	2.229	3.670	1.746	5.80	0.144
310	0.2139	1.162.-10 ⁻³	1.525.-10	405.9	830.8	2.286	3.657	1.774	5.14	0.141
320	0.3206	1.176.-10 ⁻³	1.046.-10	423.8	841.5	2.344	3.650	1.804	4.52	0.138
330	0.4665	1.192.-10 ⁻³	7.379.-10 ⁻¹	442.1	852.4	2.400	3.643	1.836	3.95	0.135
340	0.6615	1.207.-10 ⁻³	5.332.-10 ⁻¹	460.8	863.6	2.455	3.641	1.868	3.55	0.132
350	0.9162	1.224.-10 ⁻³	3.938.-10 ⁻¹	479.6	875.0	2.510	3.641	1.890	3.23	0.129
360	1.2419	1.241.-10 ⁻³	2.965.-10 ⁻¹	498.7	886.7	2.564	3.642	1.920	2.99	0.126
370	1.6517	1.259.-10 ⁻³	2.233.-10 ⁻¹	518.1	898.6	2.617	3.646	1.950	2.72	0.123
380	2.1588	1.277.-10 ⁻³	1.767.-10 ⁻¹	537.7	910.6	2.669	3.651	1.989	2.46	0.120
390	2.7774	1.297.-10 ⁻³	1.393.-10 ⁻¹	557.6	922.9	2.592	3.657	2.030	2.24	0.117
400	3.5228	1.318.-10 ⁻³	1.112.-10 ⁻¹	577.9	935.2	2.644	3.665	2.070	2.05	0.114
410	4.4091	1.340.-10 ⁻³	8.972.-10 ⁻²	598.6	947.8	2.823	3.674	2.110	1.88	0.111
420	5.4540	1.363.-10 ⁻³	7.309.-10 ⁻²	619.7	960.4	2.873	3.684	2.160	1.73	0.107
430	6.6739	1.388.-10 ⁻³	6.003.-10 ⁻²	641.3	973.0	2.924	3.695	2.210	1.60	0.104
440	8.0861	1.415.-10 ⁻³	4.965.-10 ⁻²	663.5	985.6	2.974	3.706	2.260	1.48	0.101
450	9.7088	1.444.-10 ⁻³	4.131.-10 ⁻²	686.3	998.2	3.025	3.718	2.320	1.37	0.098
460	11.451	1.475.-10 ⁻³	3.455.-10 ⁻²	709.7	1010.7	3.075	3.730	2.380	1.28	0.095
470	13.660	1.510.-10 ⁻³	2.901.-10 ⁻²	733.8	1022.9	3.126	3.742	2.450	1.10	0.092
480	16.028	1.548.-10 ⁻³	2.441.-10 ⁻²	758.6	1034.9	3.179	3.753	2.519	1.12	0.089
490	18.685	1.591.-10 ⁻³	2.059.-10 ⁻²	784.3	1046.4	3.230	3.765	2.590	1.05	0.086
500	21.651	1.640.-10 ⁻³	1.736.-10 ⁻²	810.9	1057.3	3.284	3.777	2.670	0.98	0.083
510	24.952	1.697.-10 ⁻³	1.462.-10 ⁻²	838.5	1067.5	3.336	3.785	2.750	0.91	
520	28.613	1.765.-10 ⁻³	1.226.-10 ⁻²	867.2	1076.6	3.391	3.794	2.839	0.84	
530	32.669	1.849.-10 ⁻³	1.020.-10 ⁻²	897.2	1084.3	3.446	3.800	2.941	0.77	
540	37.161	2.126.-10 ⁻³	8.349.-10 ⁻³	928.8	1089.5	3.504	3.802		0.70	
550	42.144	2.258.-10 ⁻³	6.616.-10 ⁻³	963.2	1090.4	3.565	3.797		0.65	
560	47.696	2.512.-10 ⁻³	4.696.-10 ⁻³	1007.3	1077.6	3.642	3.769		0.60	
562.2	48.979	3.290.-10 ⁻³	3.290.-10 ⁻³	1043.0	1043.0	3.706	3.706			

*Converted from a tabulation by Counsell, Lawrenson, and Lees, Nat. Phys. Lab. Teddington (U.K.) Rep. Chem. 52, 1976. Another tabulation by Kesselman et al., in Vargaftik (ed.), *Tables on the Thermophysical Properties of Liquids and Gases*, Hemisphere, Washington and London, 1975, shows some differences. The notation 1.133.-6 signifies 1.133×10^{-6} . Other tables are given by Goodwin, R. D., *J. Phys. Chem. Ref. Data*, 17, 4 (1988): 1541-1636.

2-222 PHYSICAL AND CHEMICAL DATA
TABLE 2-238 Saturated Bromine*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
260	0.042	3.106,-4	3.195	-147.2	51.8	0.903	1.669	0.486	13.4	0.131
280	0.124	3.168,-4	1.169	-138.9	56.2	0.933	1.629	0.479	11.5	0.127
300	0.310	3.232,-4	0.5002	-131.6	60.6	0.956	1.597	0.475	9.3	0.122
320	0.680	3.311,-4	0.2425	-124.2	64.8	0.978	1.570	0.473	7.8	0.118
340	1.330	3.385,-4	0.1309	-112.3	71.1	1.004	1.539	0.471	6.7	0.114
360	2.384	3.464,-4	0.0767	-108.6	73.1	1.026	1.531	0.470	5.7	0.109
380	4.010	3.550,-4	0.0477	-100.6	76.9	1.048	1.515	0.471	5.0	0.104
400	6.390	3.647,-4	0.0311	-93.4	80.6	1.063	1.501	0.475	4.5	0.099
420	9.730	3.752,-4	0.0211	-85.8	84.0	1.084	1.488	0.480	4.0	0.094
440	14.25	3.885,-4	0.0148	-77.7	87.1	1.103	1.477	0.489	3.7	0.089
460	20.17	4.023,-4	0.0107	-69.0	89.9	1.122	1.467	0.503	3.3	0.084
480	27.75	4.179,-4	0.00786	-59.7	92.2	1.142	1.457	0.527	3.1	0.079
500	37.21	4.378,-4	0.00589	-49.3	94.0	1.161	1.448	0.595	2.8	0.073
520	48.81	4.623,-4	0.00445	-37.7	95.0	1.183	1.438	0.710	2.6	0.066
540	62.80	4.938,-4	0.00337	-24.0	94.8	1.207	1.428	0.860	2.5	0.059
560	79.41	5.368,-4	0.00251	-7.1	92.5	1.237	1.414	1.063	2.3	0.050
580	98.90	6.250,-4	0.00167	18.8	82.5	1.280	1.390	2.31	2.2	0.035
584.2 ^c	103.4	8.475,-4	0.00085	64.8	64.8	1.356	1.356	∞	2.1	∞

*Reproduced or converted from a tabulation by Seshadri, Viswanath, and Kuloor, *Ind. J. Technol.*, 6 (1970): 191–198. c = critical point.

TABLE 2-239 Saturated Normal Butane (R600)*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
134.9 ^f	6.7,-6	1.360,-3	28630	0.00	494.21	2.3056	5.9702	1.946	15.8	0.181
140	1.7,-5	1.369,-3	11635	9.95	499.96	2.3778	5.8779	1.953	14.4	0.179
150	8.7,-5	1.387,-3	2470	29.44	511.39	2.5121	5.7251	1.970	12.0	0.175
160	3.5,-4	1.405,-3	654	49.10	523.13	2.6389	5.6016	1.985	9.94	0.171
170	1.17,-3	1.424,-3	207	68.94	535.16	2.7592	5.5017	2.001	8.26	0.167
180	3.37,-3	1.443,-3	76.4	88.97	547.48	2.8738	5.4211	2.018	6.87	0.163
190	8.53,-3	1.463,-3	31.8	109.22	560.07	2.9835	5.3564	2.035	5.71	0.160
200	1.94,-2	1.484,-3	14.7	129.71	572.93	3.0887	5.3048	2.055	4.83	0.156
210	4.05,-2	1.505,-3	7.39	150.45	586.06	3.1900	5.2643	2.077	4.15	0.152
220	7.81,-2	1.528,-3	4.00	171.49	599.42	3.2879	5.2331	2.101	3.61	0.148
230	0.1411	1.551,-3	2.31	192.83	613.02	3.3828	5.2097	2.128	3.18	0.144
240	0.2408	1.575,-3	1.40	214.50	626.83	3.4749	5.1929	2.158	2.83	0.140
250	0.3915	1.601,-3	0.893	236.52	640.82	3.5647	5.1818	2.192	2.55	0.136
260	0.6100	1.628,-3	0.592	258.92	654.97	3.6523	5.1755	2.231	2.31	0.132
270	0.9155	1.656,-3	0.406	281.72	669.24	3.7380	5.1732	2.274	2.10	0.128
280	1.3297	1.686,-3	0.286	309.94	683.60	3.8220	5.1744	2.323	1.93	0.124
290	1.8765	1.718,-3	0.207	328.62	697.99	3.9046	5.1783	2.377	1.77	0.120
300	2.5811	1.752,-3	0.1533	352.77	712.36	3.9860	5.1846	2.437	1.62	0.116
310	3.4706	1.790,-3	0.1156	377.46	726.67	4.0663	5.1928	2.503	1.47	0.113
320	4.5731	1.830,-3	0.0885	402.71	740.84	4.1458	5.2025	2.577	1.34	0.109
330	5.9179	1.874,-3	0.0687	428.61	754.80	4.2248	5.2132	2.657	1.21	0.105
340	7.5354	1.923,-3	0.0539	455.25	768.49	4.3035	5.2248	2.746	1.08	0.101
350	9.4573	1.978,-3	0.0427	482.74	781.79	4.3822	5.2367	2.842	0.97	0.097
360	11.72	2.041,-3	0.0340	511.22	794.60	4.4613	5.2485	2.947	0.87	0.093
370	14.35	2.114,-3	0.0272	540.88	806.72	4.5412	5.2597	3.062	0.78	0.089
380	17.40	2.200,-3	0.0218	571.94	817.86	4.6225	5.2696	3.20	0.69	0.085
390	20.90	2.307,-3	0.0174	604.76	827.56	4.7058	5.2771	3.34	0.62	0.081
400	24.92	2.447,-3	0.0138	639.85	834.95	4.7922	5.2800	3.50	0.55	0.077
410	29.54	2.652,-3	0.0106	678.30	838.10	4.8842	5.2740	3.69	0.49	0.074
420	34.86	3.048,-3	0.0075	723.89	830.34	4.9903	5.2437	3.84	0.44	0.072
425.2 ^c	37.96	4.405,-3	0.0044	783.50	783.50	5.1290	5.1290	∞	∞	∞

*Values rounded and reproduced or converted from Goodwin, NBSIR 79-1621, 1979. t = triple point; c = critical point. The notation 6.7,-6 signifies 6.7×10^{-6} .

TABLE 2-240 Superheated Normal Butane*

P, bar	Temperature, K									
	150	200	250	300	350	400	450	500	600	700
1.013 h s	v 0.00139	0.00148	0.00160	0.4106	0.4847	0.5575	0.6297	0.7013	0.8440	0.9861
	29.6	129.8	236.6	718.9	810.7	913.1	1026.0	1149.0	1423	1730
	s 2.512	3.088	3.564	5.334	5.616	5.889	6.155	6.414	6.913	7.386
5 h s	v 0.00139	0.00148	0.00160	0.00175	0.0909	0.1078	0.1238	0.1393	0.1693	0.1988
	30.0	130.2	237.0	352.9	798.5	904.3	1019.3	1143.7	1420	1728
	s 2.511	3.088	3.563	3.985	5.363	5.645	5.916	6.178	6.680	7.155
10 h s	v 0.00139	0.00148	0.00160	0.00175	0.00198	0.0502	0.0593	0.0677	0.0835	0.0987
	30.6	130.8	237.4	353.3	482.7	891.9	1010.3	1136.8	1415	1725
	s 2.510	3.087	3.562	3.983	4.382	5.524	5.803	6.069	6.575	7.052
20 h s	v 0.00138	0.00148	0.00160	0.00174	0.00196	0.0205	0.0268	0.0318	0.0406	0.0487
	31.7	131.8	238.4	354.0	482.6	860.0	990.1	1122.0	1406	1718
	s 2.509	3.085	3.560	3.980	4.376	5.364	5.670	5.948	6.464	6.945
30 h s	v 0.00138	0.00148	0.00159	0.00174	0.00195	0.00240	0.0156	0.0198	0.0263	0.0320
	32.8	132.9	239.3	354.7	482.6	637.3	965.5	1105.9	1396	1711
	s 2.507	3.082	3.557	3.976	4.370	4.783	5.570	5.866	6.394	6.880
40 h s	v 0.00138	0.00148	0.00159	0.00173	0.00194	0.00234	0.0097	0.0137	0.0192	0.0237
	33.9	134.0	240.3	355.4	482.7	633.6	932.2	1088.1	1387	1705
	s 2.505	3.080	3.555	3.973	4.365	4.768	5.468	5.797	6.341	6.832
50 h s	v 0.00138	0.00148	0.00159	0.00173	0.00193	0.00229	0.00549	0.0101	0.0149	0.0188
	35.0	135.0	241.3	356.2	428.8	631.0	877.0	1068.2	1377	1699
	s 2.503	3.078	3.552	3.970	4.360	4.755	5.329	5.734	6.297	6.792
60 h s	v 0.00138	0.00148	0.00159	0.00172	0.00192	0.00255	0.00352	0.00764	0.0121	0.0155
	36.2	136.1	242.3	356.9	483.1	629.1	825.1	1046.4	1367	1692
	s 2.501	3.076	3.550	3.967	4.355	4.745	5.204	5.673	6.258	6.759
80 h s	v 0.00138	0.00147	0.00158	0.00172	0.00190	0.00219	0.00286	0.00482	0.00868	0.0114
	38.4	138.3	244.2	358.5	483.7	626.5	798.1	1001.5	1347	1680
	s 2.498	3.072	3.545	3.960	4.346	4.727	5.130	5.559	6.191	6.704
100 h s	v 0.00138	0.00147	0.00158	0.00171	0.00188	0.00214	0.00264	0.00368	0.00669	0.00901
	40.6	140.4	246.2	360.1	484.5	624.9	787.9	971.3	1329	1668
	s 2.495	3.069	3.540	3.954	4.337	4.712	5.095	5.310	6.134	6.658
200 h s	v 0.00137	0.00146	0.00156	0.00167	0.00178	0.00200	0.00225	0.00258	0.00349	0.00460
	51.9	151.3	257.9	368.8	490.3	624.4	773.3	933.7	1270	1623
	s 2.478	3.049	3.518	3.927	4.301	4.660	5.010	5.348	5.960	6.849
300 h s	v 0.00136	0.00145	0.00154	0.00164	0.00176	0.00191	0.00209	0.00231	0.00284	0.00345
	63.2	162.2	266.7	378.3	498.0	629.2	773.4	928.4	1255	1603
	s 2.462	3.032	3.498	3.903	4.273	4.623	4.962	5.288	5.884	6.419
400 h s	v 0.00136	0.00144	0.00152	0.00162	0.00173	0.00185	0.00200	0.00217	0.00255	0.00298
	74.5	173.3	277.4	388.2	506.8	636.2	778.0	930.2	1253	1600
	s 2.447	3.015	3.479	3.882	4.248	4.593	4.927	5.247	5.836	6.366
500 h s	v 0.00136	0.00143	0.00151	0.00160	0.00170	0.00181	0.00193	0.00207	0.00240	0.00272
	85.8	184.4	288.1	398.4	516.3	644.5	784.8	935.3	1256	1599
	s 2.432	2.999	3.461	3.863	4.226	4.569	4.898	5.215	5.799	6.328

*Converted and rounded from tables of Goodwin, NBSIR 79-1621, 1979.

Saturation and superheat tables and a diagram to 100 bar, 580 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). For material to 10,000 psia, 640°F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

2-224 PHYSICAL AND CHEMICAL DATA
TABLE 2-241 Saturated Carbon Dioxide*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
216.6	5.180	8.484--4	0.0712	386.3	731.5	2.656	4.250	1.707		0.182
220	5.996	8.574--4	0.0624	392.6	733.1	2.684	4.232	1.761		0.178
225	7.357	8.710--4	0.0515	401.8	735.1	2.723	4.204			0.171
230	8.935	8.856--4	0.0428	411.1	736.7	2.763	4.178	1.879	1.64	0.164
235	10.75	9.011--4	0.0357	420.5	737.9	2.802	4.152			0.160
240	12.83	9.178--4	0.0300	430.2	738.9	2.842	4.128	1.933	1.45	0.156
245	15.19	9.358--4	0.0253	440.1	739.4	2.882	4.103			0.148
250	17.86	9.554--4	0.0214	450.3	739.6	2.923	4.079	1.992	1.28	0.140
255	20.85	9.768--4	0.0182	460.8	739.4	2.964	4.056			0.134
260	24.19	1.000--3	0.0155	471.6	738.7	3.005	4.032	2.125	1.14	0.128
270	32.03	1.056--3	0.0113	494.4	735.6	3.089	3.981	2.410	1.02	0.116
275	36.59	1.091--3	0.0097	506.5	732.8	3.132	3.954			0.109
280	41.60	1.130--3	0.0082	519.2	729.1	3.176	3.925	2.887	0.91	0.102
290	53.15	1.241--3	0.0058	547.6	716.9	3.271	3.854	3.724	0.79	0.088
300	67.10	1.470--3	0.0037	585.4	690.2	3.393	3.742		0.60	0.074
304.2 ^c	73.83	2.145--3	0.0021	636.6	636.6	3.558	3.558	∞	0.31	∞

* c = critical point. The notation 8.484--4 signifies 8.484×10^{-4} .

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the LPTS 68 scale for saturation temperatures from -56.57 to 30.98 degrees Celsius. The thermodynamic diagram from 4 to 1000 bar extends to 420°C.

Saturation and superheat tables and a chart to 15,000 psia, 840°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see ASHRAE *Thermophysical Properties of Refrigerants*, 1993.

Saturation and superheat tables and a diagram to 200 bar, 1000 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Holste, J. C., D. M. Bailey, et al., *Energy Progr.*, **6**, 2 (1986): 125-130, give properties mainly in the range 0-100 bar, 200-450 K for the superheated vapor. Compare these with Angus, S., B. Armstrong, et al., *International Tables of the Fluid State—Carbon Dioxide*, Pergamon, Oxford, 1976 (377 pp.). In Miller, C. E. III and S. E. Wilder, NASA SP 3097, 1976 (489 pp.), many properties and decomposition products are tabulated for pressures from 10^7 to 10^4 atm., 100-25,000 K. For the range to 50 kb, 400-2100 K, see Bottinga, Y. and P. Richet, *Amer. J. Sci.*, **281** (1981): 615-660.

TABLE 2-242 Superheated Carbon Dioxide*

P, bar	Temperature, K									
	300	350	400	450	500	600	700	800	900	1000
1 h	v 0.5639	0.6595	0.7543	0.8494	0.9439	1.1333	1.3324	1.5115	1.7005	1.8894
	s 809.3	853.1	899.1	947.1	997.0	1102	1212	1327	1445	1567
	s 4.860	4.996	5.118	5.231	5.337	5.527	5.697	5.850	5.990	6.120
5 h	v 0.1106	0.1304	0.1498	0.1691	0.1882	0.2264	0.2645	0.3024	0.3403	0.3782
	s 805.5	850.3	897.0	945.5	995.8	1101	1211	1326	1445	1567
	s 4.548	4.686	4.810	4.925	50.31	5.222	5.392	5.546	5.685	5.814
10 h	v 0.0539	0.0642	0.0742	0.0841	0.0938	0.1131	0.1322	0.1513	0.1703	0.1893
	s 800.7	846.9	894.4	943.5	994.1	1100	1211	1326	1445	1567
	s 4.405	4.548	4.674	4.790	4.897	5.089	5.260	5.414	5.555	5.683
20 h	v 0.0255	0.0311	0.0364	0.0416	0.0466	0.0564	0.0661	0.0757	0.0853	0.0948
	s 790.2	839.8	889.3	939.4	990.8	1098	1209	1325	1444	1567
	s 4.249	4.402	4.534	4.653	4.762	4.955	5.127	5.282	5.423	5.551
30 h	v 0.0159	0.0201	0.0238	0.0274	0.0309	0.0375	0.0441	0.0505	0.0570	0.0633
	s 778.5	832.4	883.8	935.2	987.3	1096	1208	1324	1444	1566
	s 4.144	4.341	4.447	4.569	4.679	4.876	5.049	5.204	5.346	5.474
40 h	v 0.0110	0.0146	0.0175	0.0203	0.0230	0.0281	0.0331	0.0379	0.0428	0.0476
	s 764.9	824.6	878.3	931.1	984.3	1094	1205	1323	1443	1566
	s 4.055	4.239	4.380	4.507	4.619	4.818	4.993	5.148	5.291	5.419
50 h	v 0.0080	0.0112	0.0138	0.0161	0.0183	0.0224	0.0265	0.0304	0.0343	0.0382
	s 748.2	816.3	872.6	926.9	981.1	1091	1205	1322	1443	1566
	s 3.968	4.179	4.330	4.457	4.572	4.773	4.948	5.104	5.247	5.377
60 h	v 0.0058	0.0090	0.0113	0.0133	0.0151	0.0187	0.0221	0.0254	0.0286	0.0318
	s 726.9	807.7	866.9	922.7	977.8	1089	1204	1321	1442	1565
	s 3.878	4.126	4.314	4.416	4.532	4.736	4.912	5.069	5.212	5.341
80 h	v 0.0062	0.0081	0.0097	0.0112	0.0140	0.0166	0.0191	0.0216	0.0240	
	s 788.4	855.1	914.2	971.3	1085	1201	1320	1441	1565	
	s 4.029	4.208	4.347	4.468	4.675	4.854	5.011	5.155	5.286	
100 h	v 0.0045	0.0062	0.0076	0.0089	0.0111	0.0133	0.0153	0.0173	0.0193	
	s 766.2	843.0	905.7	964.9	1081	1198	1318	1440	1564	
	s 3.936	4.144	4.290	4.417	4.627	4.808	4.967	5.111	5.241	
150 h	v 0.0023	0.0038	0.0049	0.0058	0.0074	0.0089	0.0103	0.0117	0.0130	
	s 704.5	811.9	884.8	949.4	1072	1192	1314	1437	1562	
	s 3.716	4.005	4.177	4.313	4.536	4.722	4.884	5.030	5.162	
200 h	v 0.0017	0.0027	0.0035	0.0043	0.0056	0.0067	0.0078	0.0088	0.0099	
	s 670.0	783.2	865.2	934.9	1063	1186	1310	1435	1561	
	s 3.591	3.894	4.088	4.234	4.468	4.668	4.824	4.970	5.104	
300 h	v 0.0017	0.0023	0.0023	0.0029	0.0038	0.0046	0.0053	0.0060	0.0067	
	s 745.3	834.0	910.6	1047	1176	1303	1431	1559		
	s 3.747	3.956	4.118	4.367	4.573	4.743	4.886	5.021		
400 h	v 0.0015	0.0018	0.0022	0.0029	0.0035	0.0041	0.0047	0.0052		
	s 728.1	814.6	893.3	1035	1168	1298	1428	1558		
	s 3.663	3.867	4.033	4.292	4.497	4.671	4.824	4.960		
500 h	v 0.0016	0.0018	0.0024	0.0024	0.0029	0.0034	0.0038	0.0043		
	s 803.5	881.9	1027	1162	1294	1426	1557			
	s 3.805	3.970	4.234	4.443	4.620	4.774	4.913			

*Interpolated and rounded from Vukalovich and Altunin, *Thermophysical Properties of Carbon Dioxide*, Atomizdat, Moscow, 1965; and Collett, England, 1968.

TABLE 2-243 Saturated Carbon Monoxide*

T, K	P, bar	v _f , m ³ /kg	v _g , m ³ /kg	h _f , kJ/kg	h _g , kJ/kg	s _f , kJ/(kg·K)	s _g , kJ/(kg·K)
81.62	1.01	1.268.-3	0.0666	150.25	365.30	3.005	5.640
83.36	1.52	1.295.-3	0.0631	158.56	368.07	3.104	5.559
88.25	2.03	1.317.-3	0.0606	165.00	370.00	3.178	5.501
96.16	4.05	1.385.-3	0.0547	182.76	374.21	3.368	5.359
101.51	6.08	1.440.-3	0.0513	195.0	375.98	3.489	5.271
105.69	8.12	1.489.-3	0.0318	204.8	376.6	3.580	5.206
109.17	10.13	1.535.-3	0.0253	213.2	376.6	3.656	5.152
116.08	15.20	1.651.-3	0.0163	231.0	374.5	3.807	5.043
121.48	20.27	1.778.-3	0.0116	246.3	370.2	3.918	4.948
125.97	25.33	1.936.-3	0.0085	261.2	363.6	4.041	4.854
129.84	30.40	2.168.-3	0.0063	277.6	313.15	4.161	4.747
132.91 ^c	34.96	3.337.-3	0.0033				

*Pressure and volume values converted, and enthalpy and entropy values reproduced, from Hust and Stewart, NBS Tech. Note 202, 1963. This source gives values at and above 72.373 K at closer pressure intervals. c = critical point. The notation 1.268.-3 signifies 1.268×10^{-3} .

Goodwin, R. D., *J. Phys. Chem. Ref. Data*, **14**, 4 (1985): 849-932, gives properties to 1000 bar, 68-1000 K.

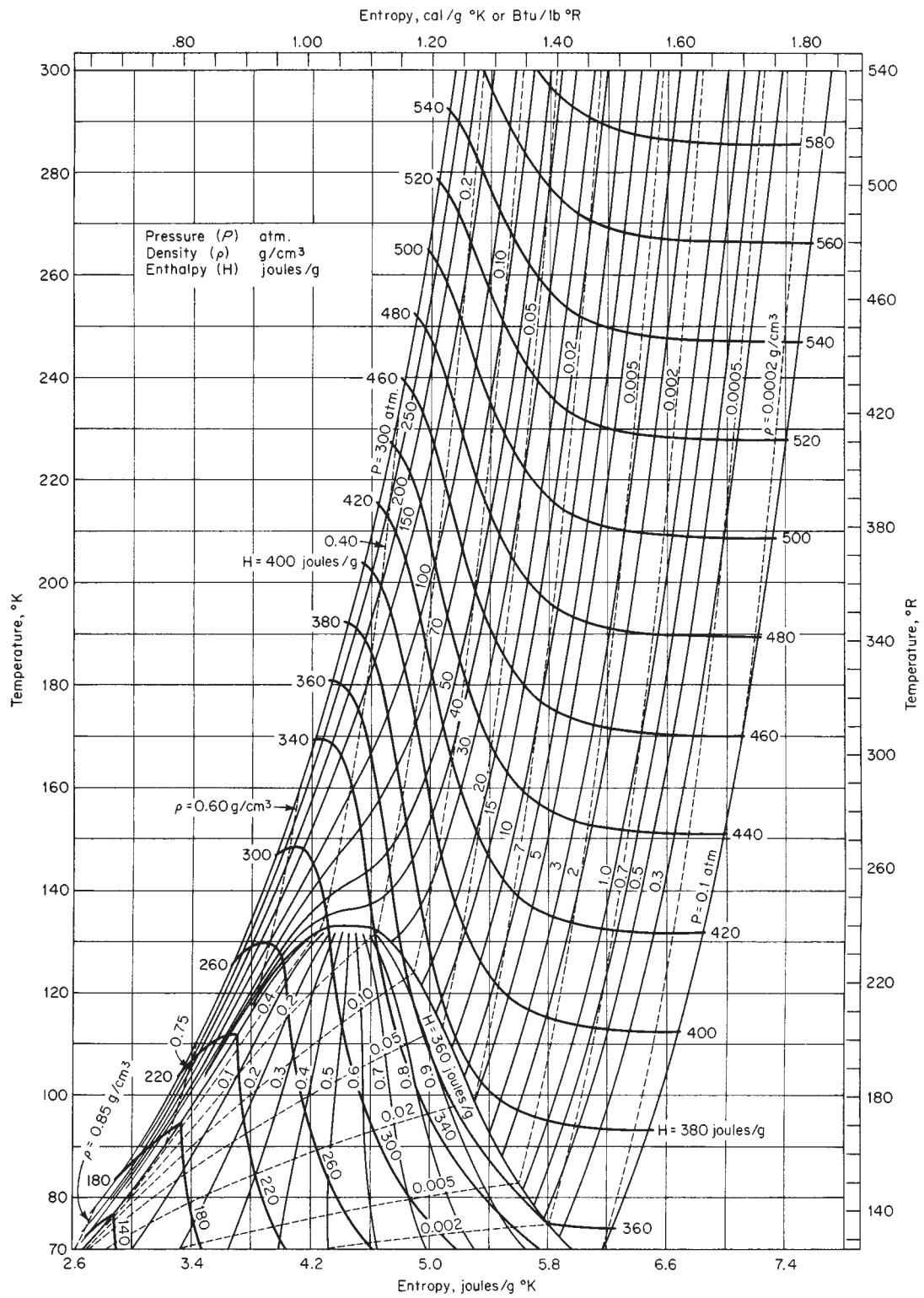


FIG. 2-8 Temperature-entropy diagram for carbon monoxide. Pressure P , in atmospheres; density ρ , in grams per cubic centimeter; enthalpy H , in joules per gram. (From Hust and Stewart, NBS Tech. Note 202, 1963.)

TABLE 2-244 Thermophysical Properties of Saturated Carbon Tetrachloride

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	Pr
280	0.064	0.000 619	2.414	205.5	420.7	1.018	1.787	0.835	1042	0.1043	8.34
290	0.105	0.000 625	1.495	212.9	425.7	1.042	1.775	0.844	892	0.1020	7.38
300	0.165	0.000 633	0.971	220.9	430.9	1.068	1.768	0.853	774	0.0998	6.62
310	0.251	0.000 641	0.669	228.8	436.1	1.095	1.764	0.863	679	0.0975	6.01
320	0.370	0.000 649	0.463	236.9	441.3	1.121	1.760	0.874	603	0.0952	5.54
330	0.531	0.000 657	0.3306	246.0	446.4	1.149	1.756	0.885	539	0.0930	5.13
340	0.743	0.000 666	0.2407	254.5	451.5	1.174	1.754	0.897	486	0.0907	4.81
350	1.017	0.000 674	0.1802	263.1	456.6	1.199	1.752	0.910	441	0.0884	4.54
360	1.361	0.000 684	0.1370	271.8	461.7	1.224	1.751	0.924	402	0.0861	4.31
370	1.795	0.000 694	0.1053	280.8	466.6	1.248	1.751	0.939	368	0.0839	4.12
380	2.327	0.000 704	0.0820	289.7	471.5	1.272	1.750	0.954	338	0.0816	3.95
390	2.970	0.000 715	0.0651	298.1	475.8	1.295	1.751	0.970	311	0.0794	3.80
400	3.735	0.000 727	0.0525	307.9	481.2	1.319	1.752	0.987	287	0.0771	3.67
410	4.642	0.000 739	0.0426	317.1	485.8	1.341	1.753	1.010	265	0.0749	3.57
420	5.700	0.000 753	0.0350	326.0	490.4	1.363	1.754	1.034	246	0.0726	3.50
430	6.927	0.000 766	0.02899	335.2	494.9	1.384	1.756	1.060	227	0.0704	3.42
440	8.342	0.000 780	0.02413	344.3	499.2	1.405	1.757	1.094	211	0.0682	3.38
450	9.958	0.000 796	0.02020	353.6	503.4	1.426	1.759	1.141	195	0.0660	3.37
460	11.792	0.000 801	0.01692	363.1	507.3	1.446	1.760	1.207	180	0.0638	3.36
470	13.869	0.000 834	0.01425	372.8	511.1	1.467	1.761	1.240	167	0.0666	3.36
480	16.21	0.000 856	0.01205	382.6	514.6	1.487	1.762	1.278	156	0.0594	3.36
490	18.83	0.000 880	0.01011	392.0	517.5	1.507	1.763	1.320	145	0.0511	3.35
500	21.77	0.000 858	0.00858	402.5	520.2	1.526	1.762	1.375	133	0.0549	3.35
510	25.02	0.000 945	0.00722	412.9	522.6	1.546	1.761	1.44			
520	28.68	0.000 987	0.00607	424.3	524.2	1.568	1.760	1.52			
530	32.71	0.001 041	0.00500	436.4	524.5	1.590	1.756				
540	37.18	0.001 121	0.00400	448.3	522.7	1.614	1.749				
550	44.12	0.001 248	0.00309	463.4	518.2	1.638	1.738				
556.4 ^c	45.60	0.001 792	0.00179	494.4	494.4	1.692	1.692				

^c = critical point. Base points: $h_f = 200$ at $273.15\text{ K} = 0^\circ\text{C} = h_A - 300 \text{ kJ/kg}$; $s_f = 1.000$ at $273.15\text{ K} = 0^\circ\text{C} = s_A - 4.000 \text{ kJ/(kg·K)}$. Values mostly rounded and converted from Altunin, V. V., V. Z. Geller, et al., *Thermophysical Properties of Freons*, vol. 9, Hemisphere, Washington, DC, 1987 (243 pp.). Some irregularities exist in these data.

TABLE 2-245 Saturated Carbon Tetrafluoride (R14)*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
100	0.0089	5.370.-4	10.77	495.8	648.4	5.487	7.003	0.887		0.136
110	0.0286	5.515.-4	3.648	502.7	652.9	5.556	6.919	0.887		0.128
120	0.0924	5.668.-4	1.228	510.4	657.1	5.624	6.847	0.890		0.119
130	0.2986	5.834.-4	0.4051	518.8	661.1	5.691	6.786	0.896		0.111
140	0.6901	6.018.-4	0.1855	527.7	664.8	5.757	6.736	0.904	3.56	0.104
150	1.4074	6.225.-4	0.0951	537.2	668.3	5.822	6.696	0.922	3.28	0.097
160	2.598	6.460.-4	0.0532	549.4	671.4	5.885	6.662	0.975	3.03	0.089
170	4.426	6.733.-4	0.0318	557.6	674.0	5.947	6.629	1.031	2.80	0.081
180	7.067	7.055.-4	0.0200	568.2	676.1	6.007	6.607	1.104	2.59	0.072
190	10.702	7.449.-4	0.0131	579.3	677.4	6.066	6.583	1.203	2.39	0.064
200	15.531	7.957.-4	0.0087	591.0	677.8	6.124	6.558	1.334	2.19	0.057
210	21.794	8.674.-4	0.0058	603.5	676.4	6.182	6.536	1.506	2.01	0.049
220	29.269	9.931.-4	0.0036	618.5	671.4	6.233	6.490	1.73	1.85	0.042
227.5 ^c	37.45	1.598.-3	0.0016	646.9	646.9	6.371	∞	∞	∞	∞

*P, v, h, and s values interpolated, extrapolated, and converted from Oguchi, *Reito*, **52** (1977): 869–889. c = critical point. The notation 5.370.-4 signifies 5.370×10^{-4} .

Equations and constants approximated to ASHRAE tables are given by Mecaryk, K. and M. Masaryk, *Heat Recovery Systems and CHP*, **11**, 2–3 (1991). The 1993 ASHRAE *Handbook—Fundamentals* (S.I. ed.) contains a saturation table from -140 to -45.65°C and an enthalpy-log-pressure diagram from 0.1 to 300 bar, -140 to 300°C. For properties to 1000 bar from 90 to 420 K, see Rublo, R. G., J. A. Zollweg, et al., *J. Chem. Eng. Data*, **36** (1991): 171–184. Saturation and superheat tables and a diagram to 80 bar, 600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Chari, Ph.D. thesis, University of Michigan, 1960, presents saturation-temperature tables in fps units for 1°F increments from -270 to -51°F. Thermodynamic and transport properties, equations, and computer code and tables at constant entropy from 89 to 845 K are given by Hunt, J. L. and Boney, L. R., NASA TN D-7181, 1973 (105 pp.), largely based upon the Chari data.

2-228 PHYSICAL AND CHEMICAL DATA

TABLE 2-246 Saturated Cesium*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)
301.6 ^m	2.66–9	5.444–4		7.01+7	74.6	637.6	0.696	2.563
400	3.83–6	5.615–4		6.54+4	98.5	651.9	0.765	2.148
500	3.11–4	5.800–4		1001	122.0	666.1	0.817	1.905
600	5.65–3	5.999–4		65.63	144.9	678.4	0.859	1.748
700	0.0440	6.215–4		9.671	167.0	688.9	0.893	1.638
800	0.2029	6.443–4		2.353	188.7	698.3	0.922	1.559
900	0.6620	6.689–4		0.796	210.6	707.3	0.975	1.500
1000	1.693	6.954–4		0.335	233.2	716.4	0.972	1.455
1200	6.790	7.628–4		0.097	281.1	736.1	1.015	1.394
1500	27.6	8.84–4		0.029	358.8	772.2	1.072	1.345

*Converted from tables in Vargaftik, *Tables of the Thermophysical Properties of Liquids and Gases*, Nauka, Moscow, 1972, and Hemisphere, Washington, 1975. m = melting point. The notation 2.66–9 signifies 2.66×10^9 .

Many of the Vargaftik values also appear in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals*, Blackwell Sci. Pubs., Oxford, 1985 (1020 pp.). This source contains superheat data.

Saturation and superheat tables and a diagram to 30 bar, 1550 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.).

For a Mollier diagram from 0.1 to 327 psia, 1300–2700°R, see Weatherford, W. D., J. C. Tyler, et al., WADD-TR-61-96, 1961.

An extensive review of properties of the solid and the saturated liquid was given by Alcock, C. B., M. W. Chase, et al., *J. Phys. Chem. Ref. Data*, **23**, 3 (1994): 385–497.

TABLE 2-247 Thermophysical Properties of Saturated Chlorine

T, °C	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	c_{pg} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	μ_g , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	k_g , W/(m·K)	Pr_f	Pr_g	
-50	0.475	0.000	623	0.5448	221.5	518.2	1.7650	3.0946	0.9454	0.476	565	10.3	0.1684	0.0061	3.17	0.809
-40	0.773	0.000	634	0.3481	231.0	522.2	1.8074	3.0562	0.9474	0.484	520	10.8	0.1650	0.0065	2.99	0.815
-30	1.203	0.000	645	0.2314	240.6	526.1	1.8480	3.0223	0.9496	0.497	483	11.4	0.1613	0.0069	2.85	0.820
-20	1.802	0.000	656	0.1593	250.3	529.9	1.8869	2.9921	0.9520	0.513	452	11.9	0.1573	0.0074	2.74	0.826
-10	2.608	0.000	668	0.1134	260.0	533.9	1.9243	2.9649	0.9547	0.532	422	12.4	0.1527	0.0078	2.64	0.841
0	3.664	0.000	681	0.0829	269.7	537.4	1.9604	2.9402	0.9579	0.554	393	13.0	0.1478	0.0083	2.55	0.864
10	5.014	0.000	695	0.0619	279.4	540.5	1.9953	2.9177	0.9618	0.579	368	13.5	0.1427	0.0088	2.48	0.888
20	6.702	0.000	710	0.0471	289.2	543.3	2.0291	2.8924	0.9667	0.607	348	14.1	0.1378	0.0093	2.45	0.918
30	8.774	0.000	726	0.0364	299.0	545.7	2.0622	2.8777	0.9728	0.638	333	14.7	0.1327	0.0099	2.44	0.950
40	11.27	0.000	744	0.0286	308.8	548.0	2.0946	2.8593	0.9816	0.674	318	15.2	0.1282	0.0104	2.43	0.985
50	14.25	0.000	763	0.02276	318.6	549.8	2.1264	2.8417	0.9968	0.720	304	15.8	0.1230	0.0110	2.46	1.034
60	17.76	0.000	784	0.01827	329.1	551.2	2.1578	2.8245	1.022	0.786	290	16.4	0.1171	0.0117	2.53	1.107
70	21.85	0.000	808	0.01481	340.0	552.1	2.1892	2.8074	1.054	0.885	278	17.1	0.1122	0.0126	2.61	1.201
80	26.65	0.000	834	0.01202	351.4	552.5	2.2207	2.7900	1.124	1.017	267	17.9	0.1050	0.0137	2.85	1.331
90	32.17	0.000	865	0.00972	364.1	552.4	2.2528	2.7714	1.253	1.205	256	18.7	0.0986	0.0149	3.26	1.510
100	38.44	0.000	901	0.00789	377.8	551.0	2.2860	2.7502	1.418	1.434	247	19.5	0.0916	0.0163	3.82	1.700
110	45.54	0.000	956	0.00639	391.3	548.8	2.3207	2.7317	1.632	1.696	238	20.6	0.0850	0.0178	4.57	1.96
120	53.57	0.001	1016	0.00508	407.1	543.7	2.3590	2.7064	1.891	1.960	230	22.2	0.0775	0.0195	5.61	2.23
130	62.68	0.001	121	0.00392	426.1	535.0	2.4032	2.6733								
140	72.84	0.001	135	0.00282	451.1	517.3	2.4595	2.6198								
144 ^c	77.10	0.001	77	0.00177	483.1	483.1	2.5365	2.5365								

^c = critical point.Values interpolated and converted from Martin, J. J., 1977 (private communication), and from *Heat Exchanger Design Handbook*, vol. 5, Hemisphere, Washington, DC, 1983. Values of Ziegler, *Chem.-Ing.-Tech.*, **22** (1950): 229, apparently were also used in Landolt-Bornstein, IVa, (1967): 238–239, and in Ullmanns *Enzyklopädie der technische Chemie*, 9, Verlag Chemie, Weinheim, 1975 (317–372).

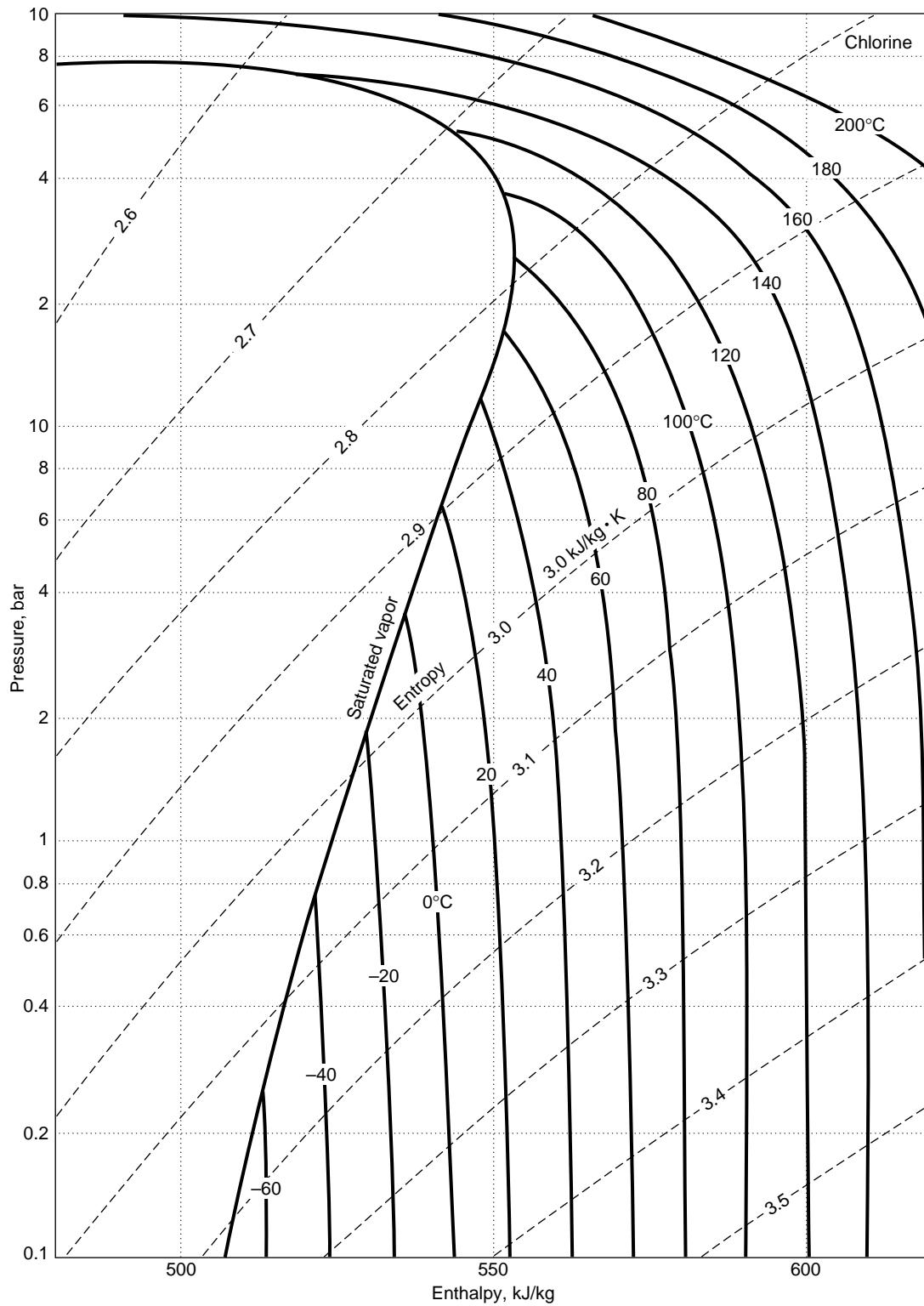


FIG. 2-9 Enthalpy–log-pressure diagram for chlorine.

TABLE 2-248 Saturated Chloroform (R20)

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	Pr_f
280	0.115	0.000 660	1.689	-46.0	219.5	-0.165	0.798		748	0.120	
300	0.293	0.000 675	0.714	-32.6	230.6	-0.105	0.773		587	0.114	
320	0.620	0.000 695	0.358	-13.4	241.1	-0.041	0.754		468	0.109	
340	1.224	0.000 715	0.190	5.2	252.1	0.015	0.741		381	0.103	
360	2.255	0.000 739	0.107	23.3	263.0	0.065	0.731	1.03	319	0.095	3.35
380	3.830	0.000 765	0.0653	41.7	273.7	0.114	0.725	1.07	273	0.0921	3.17
400	6.039	0.000 795	0.0425	61.4	284.2	0.165	0.722	1.11	237	0.0863	3.04
420	9.058	0.000 822	0.0288	82.8	294.2	0.217	0.721	1.15	206	0.0808	2.93
440	13.39	0.000 871	0.0195	106.1	303.6	0.270	0.719	1.21	177	0.0750	2.86
460	18.80	0.000 921	0.0137	131.6	311.2	0.325	0.716	1.32	155	0.0694	2.95
480	26.00	0.000 980	0.00962	157.4	316.5	0.380	0.711	1.43	129.6	0.0641	2.89
500	34.66	0.001 059	0.00673	186.2	320.8	0.436	0.706	1.59	105.5	0.0584	2.87
520	44.68	0.001 193	0.00467	219.6	321.3	0.499	0.694		81.2	0.0518	
530	50.44	0.001 328	0.00359	242.7	315.7	0.540	0.678		67.7	0.0461	
536.6 ^c	54.72	0.002 00	0.00200	284.1	284.1	0.602	0.602				

c = critical point. $h_f = s_f = 0$ at n.b.p., 334.5 K.

P, *v*, *h*, and *s* interpolated from Altunin, V. V., V. Z. Geller, et al., *Thermophysical Properties of Freons*, U.S.S.R. N.S.R.D.S. series, vol. 9., Hemisphere.

TABLE 2-249 Saturated Decane*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
243.5 ^m	0.00001	1.319.-3	20750	418.1	812.5	2.561	4.092	2.119	25.0	0.149
260	0.00006	1.334.-3	3300.	452.7	836.3	2.699	4.120	2.109	16.6	0.144
280	0.00042	1.356.-3	443.	495.3	866.9	2.856	4.158	2.155	11.3	0.139
300	0.00197	1.381.-3	88.74	539.0	899.2	3.007	4.200	2.217	8.2	0.134
320	0.00720	1.410.-3	22.73	584.0	933.2	3.153	4.246	2.286	6.5	0.129
340	0.02155	1.442.-3	8.883	631.1	968.9	3.303	4.296		5.2	0.124
360	0.05522	1.478.-3	3.763	680.1	1006.2	3.443	4.350		4.16	0.119
380	0.1248	1.515.-3	1.750	730.7	1045.0	3.581	4.408		3.52	0.116
400	0.2549	1.552.-3	0.892	782.0	1085.0	3.712	4.469		2.98	0.110
420	0.4789	1.591.-3	0.490	835.6	1126.2	3.842	4.534		2.54	
440	0.8387	1.632.-3	0.290	889.6	1168.4	3.968	4.602		2.23	
447.3	1.0133	1.650.-3	0.243	909.4	1184.0	4.014	4.627		2.09	
460	1.3852	1.682.-3	0.178	944.5	1211.4	4.089	4.670			
480	2.1745	1.735.-3	0.115	1002.6	1255.2	4.213	4.739			
500	3.2690	1.797.-3	0.0759	1062.7	1299.4	4.335	4.808			
520	4.733	1.868.-3	0.0525	1124.5	1344.4	4.456	4.879			
540	6.633	1.952.-3	0.0369	1190.1	1389.5	4.573	4.949			
560	9.062	2.067.-3	0.0248	1256.1	1432.2	4.698	5.011			
580	12.16	2.255.-3	0.0154	1318.5	1468.1	4.802	5.060			
600	16.12	2.588.-3	0.0093	1384.5	1495.6	4.913	5.098			
617.5 ^c	20.97	4.238.-3	0.0042	1483.2	1483.2	5.073	5.073			

*Values converted from Das and Kuloor, *Ind. J. Technol.*, **5** (1967): 75. *m* = melting point; *c* = critical point. The notation 1.319.-3 signifies 1.319×10^{-3} .

TABLE 2-250 Saturated Normal Deuterium*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
18.71	0.1709	0.005752	2.232	-161.1	158.6	4.54	21.62
19	0.1944	0.005771	1.988	-160.0	159.1	4.68	21.48
20	0.2944	0.005840	1.365	-152.8	163.9	4.97	20.81
21	0.4297	0.005914	0.968	-145.9	167.6	5.30	20.23
22	0.6072	0.005993	0.705	-138.7	170.6	5.63	19.69
23	0.8344	0.00608	0.5256	-131.4	173.0	5.95	19.18
24	1.1192	0.00617	0.3995	-123.8	174.6	6.26	18.70
25	1.4694	0.00627	0.3088	-116.1	175.5	6.57	18.23
26	1.8932	0.00638	0.2421	-108.2	175.7	6.87	17.79
27	2.3989	0.00650	0.1921	-100.2	175.1	7.16	17.36
28	2.995	0.00663	0.1540	-92.0	173.8	7.44	16.94
29	3.690	0.00678	0.1246	-83.6	171.7	7.72	16.52
30	4.493	0.00694	0.1015	-74.9	168.7	8.00	16.12
31	5.412	0.00713	0.0831	-65.9	165.0	8.27	15.72
32	6.457	0.00735	0.0683	-56.5	160.3	8.54	15.32
33	7.455	0.00761	0.0563	-46.4	154.7	8.83	14.92
34	8.962	0.00793	0.0465	-35.5	148.0	9.12	14.52
35	10.44	0.00834	0.0382	-23.2	140.0	9.45	14.11
36	12.09	0.00890	0.0311	-8.6	130.1	9.82	13.67
37	13.91	0.00976	0.0249	10.0	117.1	10.28	13.17
38	15.92	0.01158	0.0185	39.7	95.0	11.01	12.47
38.34 ^c	16.65	0.01433	0.0143	69.2	69.2	11.76	11.76

*Condensed and converted from tables of Prydz, NBS Rep. 9276, 1967. *c* = critical point.

For equations and *T-s* and *Z* charts from 0.1 to 100 atm, 20–300 K, see also Prydz, R. and K. D. Timmerhaus, *Advan. Cryog. Eng.*, **13** (1968): 384–396.

TABLE 2-251 Saturated Deuterium Oxide*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
277.0 ^t	0.00668	9.047–4	172.2	0.0	2320.9	0.000	8.380
278.2	0.00720	9.045–4	160.4	5.0	2322.5	0.0188	8.351
283.2	0.01030	9.042–4	114.1	25.9	2330.9	0.0920	8.233
288.2	0.01449	9.043–4	82.48	46.9	2339.3	0.166	8.122
293.2	0.02011	9.047–4	60.45	67.8	2347.6	0.239	8.016
298.2	0.02758	9.054–4	44.88	88.7	2356.0	0.311	7.915
303.2	0.03730	9.063–4	33.71	109.6	2364.0	0.382	7.818
308.2	0.04990	9.075–4	25.59	130.5	2372.3	0.450	7.725
313.2	0.06598	9.091–4	19.66	151.5	2380.7	0.518	7.637
318.2	0.08638	9.108–4	15.24	172.4	2388.6	0.585	7.550
323.2	0.1120	9.127–4	11.93	193.3	2396.6	0.650	7.468
333.2	0.1831	9.170–4	7.52	234.7	2413.3	0.776	7.315
353.2	0.4439	9.274–4	3.27	318.4	2445.1	1.020	7.042
373.2	0.9646	9.403–4	1.58	402.0	2474.8	1.253	6.807
398.2	2.2427	9.599–4	0.72	507.5	2509.6	1.527	6.555
423.2	4.653	9.835–4	0.362	612.5	2541.8	1.781	6.341
448.2	8.806	1.012–3	0.198	718.8	2569.4	2.020	6.149
473.2	15.46	1.044–3	0.115	826.8	2585.7	2.256	5.973
498.2	25.52	1.082–3	0.0704	938.5	2597.0	2.483	5.812
523.2	39.99	1.133–3	0.0447	1055.2	2598.7	2.707	5.658
548.2	60.04	1.200–3	0.0290	1177.4	2587.0	2.930	5.501
573.2	86.97	1.276–3	0.0191	1306.7	2555.6	3.153	5.332
598.2	122.4	1.392–3	0.0124	1445.6	2492.4	3.356	5.132
623.2	168.3	1.596–3	0.0075	1607.1	2366.5	3.631	4.850
644.7 ^c	218.4	2.950–3	0.0030				

*Extracted or converted from values in Kazachinskii, Kesselman, et al., *Thermophysical Properties of Heavy Water*, Moscow and Leningrad, 1963; NBS-NSF transl. 70-50094, 1971. *t* = triple point; *c* = critical point. The notation 9.047–4 signifies 9.047×10^{-4} .

Hill, P. G., MacMillan, R. D. and others give extensive tables for 0–1000 bar, 4–800°C in Atomic Energy of Canada, Chalk River rept. AECL-7531, 1981 (196 pp.). See also *J. Phys. Chem. Ref. Data*, **11**, 1 (1982); **19**, 5 (1990): 1233–1274.

TABLE 2-252 Deuterium Oxide Gas at 1-kg/cm³ Pressure

T, K	400	450	500	550	600	650	700	750
<i>v</i> , m ³ /kg	1.676	1.895	2.112	2.322	2.535	2.747	2.960	3.172
<i>h</i> , kJ/kg	2525	2619	2712	2807	2904	3002	3102	3205
<i>s</i> , kJ/(kg·K)	6.931	7.151	7.349	7.529	7.697	7.855	8.003	8.153

TABLE 2-253 Saturated Diphenyl*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
343	0.0010	1.010,-3	252.5	0.0	444.2	0.000	1.298	1.760	15.0	0.139
350	0.0016	1.014,-3	156.1	13.0	444.2	0.036	1.266	1.782	13.5	0.138
360	0.0029	1.021,-3	85.0	30.0	446.7	0.084	1.236	1.813	11.7	0.136
370	0.0049	1.030,-3	49.9	47.2	449.7	0.130	1.213	1.844	10.3	0.135
380	0.0064	1.037,-3	29.9	65.0	454.5	0.178	1.200	1.875	9.1	0.133
390	0.0129	1.046,-3	18.3	82.7	462.7	0.224	1.194	1.906	8.1	0.132
400	0.0200	1.054,-3	11.7	99.3	461.2	0.273	1.202	1.936	7.3	0.130
420	0.0432	1.072,-3	5.84	139.9	499.0	0.358	1.228	1.998	6.0	0.127
440	0.0879	1.092,-3	3.021	180.3	532.4	0.451	1.267	2.060	5.0	0.125
460	0.1694	1.112,-3	1.652	222.7	569.7	0.545	1.378	2.122	4.3	0.122
480	0.3112	1.132,-3	0.9594	267.6	611.6	0.652	1.367	2.184	3.7	0.119
500	0.5218	1.154,-3	0.4452	314.9	651.8	0.746	1.424	2.246	3.3	0.116
520	0.8375	1.177,-3	0.3652	361.5	687.8	0.824	1.477	2.308	2.7	0.113
540	1.290	1.204,-3	0.2261	404.5	723.8	0.915	1.529	2.370	2.4	0.110
560	1.941	1.230,-3	0.1447	457.2	762.7	1.032	1.582	2.432	2.2	0.107
580	2.818	1.258,-3	0.0977	522.3	801.7	1.125	1.635	2.494	1.90	0.105
600	3.926	1.291,-3	0.0685	563.7	842.4	1.223	1.688	2.556	1.71	0.102
620	5.408	1.326,-3	0.0504	630.4	886.4	1.316	1.740	2.618	1.54	0.099
640	7.328	1.366,-3	0.0381	689.1	930.9	1.375	1.748	2.680	1.39	0.096
660	9.572	1.412,-3	0.0301	745.9	977.1	1.457	1.791	2.741	1.24	0.093
680	12.05	1.465,-3	0.0236	802.8	1024.9	1.585	1.856	2.803	1.10	0.090
700	15.21	1.529,-3	0.0186	860.1	1073.1	1.663	1.951	2.865	0.97	0.087
720	19.14	1.56,-3	0.0147	917.5	1116.7	1.746	2.003	2.93		
740	23.93	1.70,-3	0.0113	975.2	1152.8	1.822	2.058	3.00		
760	28.71	1.95,-3	0.0085	1033.1	1182.5	1.901	2.099			
780	34.83	2.16,-3	0.0058	1091.2	1163.0	1.977	2.107			
800	42.46	3.18,-3	0.0032	1148.4	1148.4	2.047	2.047			

*Interpolated by P. E. Liley from the Landolt-Börnstein band IVa, p. 557, 1967 tables based on *Technical Data on Fuel*, British National Committee, World Energy Conference, London.

TABLE 2-254 Saturated Ethane (R170)*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
90.4 ^t	1.131,-5	1.534,-3	21945	176.8	769.4	2.560	9.113	2.260	14.19	0.215
100	1.110,-4	1.546	2484.5	198.7	782.4	2.790	8.627	2.274	9.37	0.208
110	7.467,-3	1.573	407.0	221.5	795.0	3.008	8.222	2.284	6.57	0.201
120	3.545,-3	1.615	93.61	244.4	807.2	3.207	7.897	2.292	4.89	0.194
130	1.291,-2	1.644	27.83	267.4	819.3	3.391	7.637	2.302	3.81	0.187
140	3.831,-2	1.675	10.08	290.5	831.4	3.562	7.426	2.316	3.07	0.180
150	9.672,-2	1.708	4.263	313.7	843.5	3.722	7.254	2.333	2.55	0.174
160	0.2146	1.743	2.039	337.2	855.6	3.873	7.113	2.355	2.17	0.167
170	0.4290	1.780	1.075	360.9	867.6	4.017	6.998	2.383	1.88	0.160
180	0.7874	1.819	0.6139	384.9	879.4	4.154	6.901	2.417	1.65	0.153
190	1.347	1.862	0.3738	409.3	890.8	4.285	6.819	2.458	1.47	0.147
200	2.174	1.908	0.2395	434.2	901.7	4.412	6.750	2.508	1.33	0.140
210	3.340	1.958	0.1602	459.7	911.9	4.535	6.689	2.568	1.21	0.133
220	4.922	2.014	0.1109	485.9	921.4	4.655	6.635	2.640	1.11	0.126
230	7.004	2.076	0.0789	512.8	929.6	4.773	6.585	2.730	1.03	0.119
240	9.670	2.148	0.0573	540.8	936.6	4.890	6.539	2.843	0.96	0.112
250	13.01	2.231	0.0423	569.9	941.9	5.006	6.493	2.991	0.82	0.106
260	17.12	2.330	0.0316	600.7	945.4	5.123	6.449	3.214	0.73	0.099
270	22.10	2.452	0.0237	633.6	946.4	5.233	6.392	3.511	0.64	0.092
280	28.06	2.613	0.0177	669.3	943.6	5.370	6.350	4.011	0.55	0.085
290	35.14	2.847	0.0129	709.8	934.7	5.502	6.278	5.089	0.44	0.078
300	43.54	3.295	0.0087	761.6	910.8	5.669	6.166	9.919	0.31	0.067
305.3 ^c	48.71	4.891	0.0048	841.2	841.2	5.919	5.919	∞		

*Values reproduced or converted from Goodwin, Roder, and Straty, NBS Tech. Note 684, 1976. t = triple point; c = critical point. The notation 1.131,-5 signifies 1.131×10^{-5} .

2-234 PHYSICAL AND CHEMICAL DATA
TABLE 2-255 Superheated Ethane*

P, bar	Temperature, K										
	100	150	200	250	300	350	400	450	500	600	700
1.013 h	v 0.00156	0.00171	0.5310	0.6725	0.8118	0.9500	1.0877	1.2250	1.3622	1.6360	1.9096
	198.9	313.8	909.3	984.7	1068.3	1161.5	1265.3	1379.8	1504.6	1783	2097
	s 2.790	3.722	6.993	7.330	7.634	7.921	8.198	8.467	8.730	9.237	9.720
5 h	v 0.00156	0.00171	0.00191	0.1288	0.1595	0.1890	0.2178	0.2464	0.2747	0.3308	0.3867
	199.4	314.3	434.5	973.3	1060.3	1155.6	1260.7	1376.1	1501.5	1781	2096
	s 2.789	3.720	4.411	6.858	7.175	7.468	7.748	8.020	8.284	8.793	9.227
10 h	v 0.00156	0.00171	0.00190	0.0590	0.0765	0.0923	0.1073	0.1220	0.1365	0.1650	0.1933
	200.0	314.9	435.0	956.5	1050.0	1148.2	1255.0	1371.5	1497.9	1777	2094
	s 2.788	3.719	4.408	6.618	6.959	7.262	7.547	7.821	8.087	8.598	9.083
20 h	v 0.00156	0.00170	0.00190	0.00222	0.0346	0.0438	0.0521	0.0599	0.0674	0.0822	0.0966
	201.3	316.1	435.9	569.8	1026.1	1132.3	1243.3	1362.4	1490.5	1774	2090
	s 2.785	3.715	4.404	4.999	6.710	7.038	7.334	7.614	7.884	8.399	8.886
40 h	v 0.00155	0.00170	0.00189	0.00219	0.0118	0.0193	0.0244	0.0288	0.0329	0.0407	0.0482
	203.9	318.5	437.9	569.9	947.9	1096.2	1218.6	1343.8	1475.9	1764	2083
	s 2.780	3.709	4.394	4.982	6.309	6.770	7.097	7.391	7.670	8.194	8.686
60 h	v 0.00155	0.00170	0.00188	0.00217	0.00290	0.0109	0.0132	0.0185	0.0215	0.0270	0.0321
	206.5	321.0	439.8	570.3	738.1	1050.9	1192.0	1324.8	1461.2	1754	2077
	s 2.775	3.702	4.385	4.966	5.574	6.557	6.934	7.247	7.535	8.068	8.564
80 h	v 0.00155	0.00169	0.00188	0.00215	0.00273	0.00667	0.0106	0.0134	0.0158	0.0201	0.0459
	209.1	323.4	441.9	570.9	728.1	993.8	1163.6	1305.5	1446.7	1745	2070
	s 2.769	3.696	4.377	4.951	5.522	6.345	6.800	7.135	7.432	7.975	8.476
100 h	v 0.00155	0.00169	0.00187	0.00213	0.00263	0.00465	0.00791	0.0104	0.0124	0.0160	0.0193
	211.7	325.8	443.9	571.8	722.7	924.4	1134.7	1286.3	1432.4	1736	2064
	s 2.764	3.690	4.368	4.938	5.486	6.166	6.682	7.040	7.348	7.900	8.406
150 h	v 0.00155	0.00168	0.00185	0.00209	0.00247	0.00328	0.00488	0.00655	0.00805	0.0107	0.0130
	218.1	332.0	449.2	574.6	716.4	887.4	1075.2	1242.3	1399.3	1715	2050
	s 2.752	3.674	4.348	4.907	5.423	5.955	6.457	6.851	7.182	7.758	8.274
200 h	v 0.00154	0.00167	0.00184	0.00205	0.00237	0.00291	0.00383	0.00495	0.00605	0.00806	0.00986
	224.6	338.2	454.7	578.2	714.8	870.5	1041.7	1210.2	1327.3	1697	2038
	s 2.738	3.660	4.329	4.880	5.377	5.863	6.320	6.717	7.059	7.651	8.176
300 h	v 0.00153	0.00166	0.00181	0.00200	0.00225	0.00259	0.00307	0.00367	0.00433	0.00563	0.00686
	237.6	350.6	465.9	586.8	715.9	860.9	1014.9	1175.5	1338.7	1671	2019
	s 2.715	3.632	4.294	4.833	5.309	5.757	6.168	6.547	6.891	7.496	8.032
400 h	v 0.00153	0.00165	0.00179	0.00195	0.00216	0.00244	0.00276	0.00316	0.00361	0.00454	0.00545
	250.6	363.2	477.6	596.6	723.7	861.6	1008.3	1262.7	1657	2008	
	s 2.692	3.605	4.262	4.793	5.257	5.688	6.080	6.443	6.780	7.388	7.930
500 h	v 0.00152	0.00163	0.00176	0.00192	0.00210	0.00232	0.00258	0.00288	0.00322	0.00392	0.00465
	263.5	375.8	489.3	607.1	732.0	866.5	1009.3	1159.3	1316.9	1650	2003
	s 2.670	3.580	4.234	4.758	5.213	5.634	6.015	6.369	6.00	7.306	7.851

*Converted and rounded off from the tables of Goodwin, Roder, and Straty, NBS Tech. Note 684, 1976. v = specific volume, m³/kg; h = specific enthalpy, kJ/kg; s = specific entropy, kJ/(kg·K).

Saturation and superheat tables and a diagram to 300 bar, 580 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Saturation and superheat tables and a chart to 10,000 psia, 640°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) contains a thermodynamic diagram from 0.1 to 700 bar for temperatures to 600 K.

TABLE 2-256 Saturated Ethanol

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	Pr_f
250	0.0027	0.001 184						2.113	295	0.177	35.2
260	0.0059	0.001 196						2.167	229	0.175	28.4
270	0.0128	0.001 208						2.227	193	0.173	24.8
280	0.025	0.001 220						2.294	156	0.171	20.9
290	0.048	0.001 233						2.369	127	0.170	17.7
300	0.088	0.001 246						2.45	104	0.168	15.2
310	0.151	0.001 260						2.54	86	0.165	13.2
320	0.253	0.001 274						2.64	72	0.162	11.7
330	0.406	0.001 288						2.75	61	0.159	10.6
340	0.632	0.001 304						2.86	52	0.157	9.5
350	0.956	0.001 318	0.7656	199.9	1161.9			2.99	45.0	0.155	8.7
360	1.409	0.001 337	0.5052	230.1	1178.4			3.12	39.0	0.153	8.0
370	2.023	0.001 357	0.3555	262.2	1193.9			3.27	34.2	0.151	7.4
380	2.837	0.001 379	0.2556	295.1	1208.4			3.42	30.0	0.149	6.9
390	3.897	0.001 403	0.1873	329.1	1221.5			3.58	26.1	0.147	6.3
400	5.251	0.001 430	0.1398	364.2	1233.6			3.74	22.7	0.145	5.9
410	6.954	0.001 461	0.1058	400.8	1244.2			3.99	20.0	0.144	5.5
420	9.063	0.001 495	0.0812	435.7	1254.2			4.26	17.6	0.142	5.3
430	11.64	0.001 532	0.0631	472.2	1262.3			4.55	15.3	0.140	5.0
440	14.72	0.001 574	0.0493	512.7	1269.2			4.88	13.9	0.139	4.9
450	18.33	0.001 623	0.0389	557.2	1274.2			5.23	12.5	0.137	4.8
460	22.61	0.001 682	0.0308	605.0	1275.5						
470	27.66	0.001 752	0.0243	653.7	1271.1						
480	33.55	0.001 832	0.0193	704.5	1262.3						
490	40.39	0.001 950	0.0148	757.7	1250.2						
500	48.28	0.002 091	0.0110	818.9	1232.7						
510	57.32										
516.3 ^c	63.90										

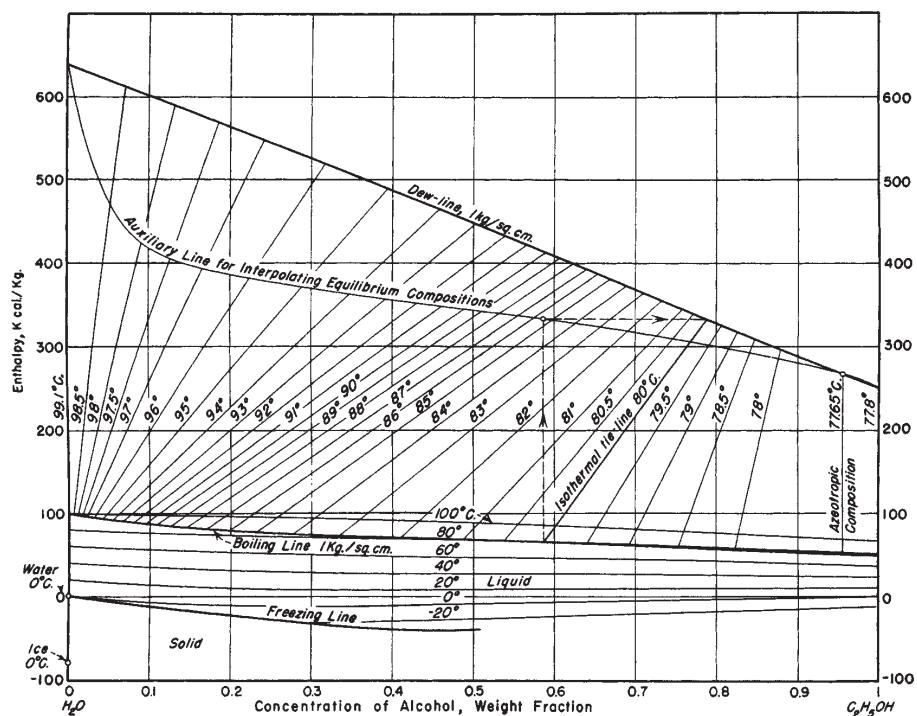
^c = critical point.Values interpolated and converted from *Heat Exchanger Design Handbook*, vol. 5, Hemisphere, Washington, DC, 1983, and from various literature sources.

FIG. 2-10 Enthalpy-concentration diagram for aqueous ethyl alcohol. Reference states: Enthalpies of liquid water and ethyl alcohol at 0°C are zero. NOTE: In order to interpolate equilibrium compositions, a vertical may be erected from any liquid composition on the boiling line and its intersection with the auxiliary line determined. A horizontal from this intersection will establish the equilibrium vapor composition on the dew line. (*Bosnjakovic, Technische Thermodynamik, T. Steinkopff, Leipzig, 1935.*)

2-236 PHYSICAL AND CHEMICAL DATA
TABLE 2-257 Saturated Ethylene (Ethene—R1150)

Temperature, K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pg} , kJ/kg·K
104.0 ^t	0.00123	0.001 527	251.36	-323.81	244.36	-1.9901	3.4730	2.497
110	0.00334	0.001 545	97.57	-309.54	251.47	-1.8571	3.2431	2.500
120	0.01380	0.001 576	25.75	-284.17	263.23	-1.6362	2.9255	2.539
130	0.04456	0.001 609	8.62	-259.13	274.87	-1.4358	2.6717	2.465
140	0.1191	0.001 644	3.46	-234.80	286.28	-1.2554	2.4663	2.405
150	0.2747	0.001 681	1.5977	-210.90	297.37	-1.0908	2.2977	2.377
160	0.5636	0.001 721	0.8232	-187.12	308.00	-0.9378	2.1566	2.377
170	1.0526	0.001 763	0.4625	-163.23	318.04	-0.7935	2.0375	2.395
180	1.8207	0.001 810	0.2784	-139.05	327.35	-0.6559	1.9352	2.427
190	2.9574	0.001 861	0.1770	-114.46	335.79	-0.5244	1.7812	2.472
200	4.560	0.001 918	0.1177	-89.33	343.21	-0.3967	1.7659	2.531
210	6.730	0.001 981	0.0810	-63.52	349.41	-0.2730	1.6932	2.608
220	9.575	0.002 054	0.0573	-36.84	354.18	-0.1515	1.6258	2.711
230	13.206	0.002 139	0.0413	-9.04	357.17	-0.0314	1.5609	2.852
240	17.742	0.002 241	0.0302	20.23	357.90	0.0088	1.4957	3.055
250	23.307	0.002 369	0.02222	51.55	355.37	0.2114	1.4276	3.372
260	30.046	0.002 541	0.01624	85.91	348.68	0.3397	1.3503	3.945
270	38.132	0.002 804	0.01152	125.79	333.71	0.4819	1.3054	5.40
280	47.834	0.003 442	0.00720	183.40	292.83	0.6803	1.0711	20.0
282.3 ^c	50.403	0.004 669	0.00467	234.55	234.55	0.8585	0.8585	

t = triple point; *c* = critical point. $h_f = s_f = 0$ at 233.15 K = -40°C.

Converted from Jacobson, R. T., M. Jahangiri, et al., *Ethylene—Intl. Thermodyn. Tables of the Fluid State—10*, Blackwell Sci. Publ., Oxford, U.K., 1988 (299 pp.). Saturation and superheat tables and a diagram to 100 bar, 460 K are given by Reynolds, W. C., *Thermodynamic properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Saturation and superheat tables and a chart to 6000 psia, 360°F appear in *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) has a thermodynamic chart for pressures from 0.1 to 400 bar and temperatures up to 460 K.

TABLE 2-258 Compressed Ethylene

Pressure, bar	Temperature, K							
	110	125	150	175	200	225	250	275
<i>v</i> (m ³ /kg)	0.001 545	0.001 592	0.001 681	0.5036	0.5814	0.6580	0.7337	0.8091
1 <i>h</i> (kJ/kg)	-309.4	-271.4	-210.8	324.8	357.0	389.9	424.0	459.7
<i>s</i> (kJ/kg·K)	-1.858	-1.534	-1.091	2.091	2.264	2.419	2.562	2.698
<i>v</i> (m ³ /kg)	0.001 544	0.001 591	0.001 680	0.001 785	0.001 917	0.1240	0.1407	0.1569
5 <i>h</i> (kJ/kg)	-308.9	-271.0	-210.4	-150.8	-89.3	378.4	415.0	452.3
<i>s</i> (kJ/kg·K)	-1.859	-1.535	-1.093	-0.726	-0.397	1.907	2.061	2.203
<i>v</i> (m ³ /kg)	0.001 543	0.001 591	0.001 679	0.001 783	0.001 914	0.05643	0.06672	0.07525
10 <i>h</i> (kJ/kg)	-308.3	-270.4	-209.8	-150.3	-89.0	361.2	402.4	442.3
<i>s</i> (kJ/kg·K)	-1.860	-1.537	-1.095	-0.728	-0.400	1.646	1.820	1.973
<i>v</i> (m ³ /kg)	0.001 542	0.001 589	0.001 676	0.001 780	0.001 908	0.002 084	0.02810	0.03405
20 <i>h</i> (kJ/kg)	-307.1	-269.2	-208.7	-149.4	-88.2	-23.0	370.3	419.7
<i>s</i> (kJ/kg·K)	-1.863	-1.540	-1.098	-0.733	-0.406	-0.099	1.520	1.708
<i>v</i> (m ³ /kg)	0.001 541	0.001 588	0.001 674	0.001 776	0.001 903	0.002 072	0.002 347	0.01978
30 <i>h</i> (kJ/kg)	-305.9	-268.0	-207.6	-148.4	-87.5	-22.8	50.5	390.7
<i>s</i> (kJ/kg·K)	-1.866	-1.543	-1.102	-0.737	-0.412	-0.107	0.201	1.508
<i>v</i> (m ³ /kg)	0.001 540	0.001 587	0.001 672	0.001 773	0.001 897	0.002 062	0.002 318	0.01163
40 <i>h</i> (kJ/kg)	-304.7	-266.8	-206.5	-147.4	-86.7	-22.5	49.1	344.7
<i>s</i> (kJ/kg·K)	-1.869	-1.546	-1.106	-0.741	-0.418	-0.115	0.186	1.284
<i>v</i> (m ³ /kg)	0.001 539	0.001 585	0.001 670	0.001 770	0.001 892	0.002 052	0.002 293	0.002 846
50 <i>h</i> (kJ/kg)	-303.5	-265.7	-205.4	-146.4	-85.9	-22.2	48.1	139.8
<i>s</i> (kJ/kg·K)	-1.872	-1.550	-1.110	-0.746	-0.423	-0.123	0.173	0.521
<i>v</i> (m ³ /kg)	0.001 538	0.001 584	0.001 668	0.001 767	0.001 887	0.002 043	0.002 270	0.002 723
60 <i>h</i> (kJ/kg)	-302.3	-264.5	-204.2	-145.4	-85.1	-21.8	47.4	132.3
<i>s</i> (kJ/kg·K)	-1.875	-1.553	-1.113	-0.750	-0.428	-0.130	0.161	0.484
<i>v</i> (m ³ /kg)	0.001 535	0.001 581	0.001 664	0.001 761	0.001 877	0.002 025	0.002 232	0.002 555
80 <i>h</i> (kJ/kg)	-299.8	-262.1	-202.0	-143.4	-83.5	-20.9	46.5	124.1
<i>s</i> (kJ/kg·K)	-1.881	-1.559	-1.120	-0.759	-0.439	-0.145	0.139	0.434
<i>v</i> (m ³ /kg)	0.001 533	0.001 579	0.001 660	0.001 754	0.001 867	0.002 009	0.002 199	0.002 495
100 <i>h</i> (kJ/kg)	-297.4	-259.7	-199.7	-141.2	-81.8	-19.9	46.1	119.6
<i>s</i> (kJ/kg·K)	-1.887	-1.565	-1.127	-0.767	-0.449	-0.158	0.120	0.400
<i>v</i> (m ³ /kg)	0.001 528	0.001 571	0.001 650	0.001 740	0.001 846	0.001 973	0.002 136	0.002 356
150 <i>h</i> (kJ/kg)	-291.3	-253.7	-194.0	-136.0	-77.3	-16.7	46.6	114.4
<i>s</i> (kJ/kg·K)	-1.901	-1.580	-1.145	-0.787	-0.473	-0.188	0.079	0.337
<i>v</i> (m ³ /kg)	0.001 522	0.001 565	0.001 641	0.001 727	0.001 826	0.001 943	0.002 086	0.002 268
200 <i>h</i> (kJ/kg)	-285.3	-247.7	-188.3	-130.7	-72.5	-13.0	48.6	113.2
<i>s</i> (kJ/kg·K)	-1.914	-1.595	-1.161	-0.806	-0.495	-0.215	0.045	0.291
<i>v</i> (m ³ /kg)	0.001 517	0.001 559	0.001 633	0.001 715	0.001 809	0.001 918	0.002 046	0.002 203
250 <i>h</i> (kJ/kg)	-279.2	-241.7	-182.5	-125.2	-67.6	-8.9	51.4	113.9
<i>s</i> (kJ/kg·K)	-1.928	-1.610	-1.177	-0.824	-0.516	-0.240	0.015	0.253
<i>v</i> (m ³ /kg)	0.001 512	0.001 552	0.001 625	0.001 704	0.001 793	0.001 895	0.002 012	0.002 151
300 <i>h</i> (kJ/kg)	-273.0	-235.7	-174.5	-119.6	-62.5	-4.4	54.9	115.9
<i>s</i> (kJ/kg·K)	-1.942	-1.623	-1.192	-0.841	-0.536	-0.262	-0.012	0.220
<i>v</i> (m ³ /kg)	0.001 503	0.001 542	0.001 609	0.001 683	0.001 765	0.001 855	0.001 957	0.002 072
400 <i>h</i> (kJ/kg)	-260.8	-223.6	-164.8	-108.3	-51.9	5.1	63.0	122.1
<i>s</i> (kJ/kg·K)	-1.968	-1.650	-1.221	-0.873	-0.572	-0.303	-0.059	0.166
<i>v</i> (m ³ /kg)	0.001 499	0.001 531	0.001 596	0.001 665	0.001 740	0.001 823	0.001 913	0.002 01
500 <i>h</i> (kJ/kg)	-246.9	-211.4	-152.9	-96.8	-40.9	15.3	72.3	130.1
<i>s</i> (kJ/kg·K)	-1.978	-1.676	-1.249	-0.906	-0.605	-0.339	-0.099	0.121

Converted from Jacobsen, R. T., M. Jahangiri, et al., *Ethylene—Intl. Thermodyn. Tables of the Fluid State—10*, Blackwell Sci. Publ., Oxford, 1988 (299 pp.). $s_f = h_f = 0$ at 233.15 K = -40°C.

TABLE 2-258 Compressed Ethylene (Concluded)

Pressure, bar	Temperature, K						
	300	325	350	375	400	425	450
<i>v</i> (m ³ /kg)	0.8842	0.9591	1.0339	1.1084	1.1830	1.2575	1.3319
1 <i>h</i> (kJ/kg)	497.3	536.9	578.8	622.8	668.9	717.2	767.9
<i>s</i> (kJ/kg·K)	2.829	2.956	3.079	3.201	3.320	3.437	3.553
<i>v</i> (m ³ /kg)	0.1728	0.1884	0.2039	0.2193	0.2346	0.2499	0.2650
5 <i>h</i> (kJ/kg)	491.0	531.5	574.1	618.6	665.2	713.9	764.9
<i>s</i> (kJ/kg·K)	2.338	2.467	2.593	2.716	2.836	2.954	3.071
<i>v</i> (m ³ /kg)	0.08380	0.09207	0.1002	0.1081	0.1160	0.1238	0.1316
10 <i>h</i> (kJ/kg)	482.8	542.5	568.0	613.3	660.5	709.7	761.1
<i>s</i> (kJ/kg·K)	2.113	2.247	2.375	2.500	2.622	2.742	2.859
<i>v</i> (m ³ /kg)	0.03914	0.04379	0.04823	0.05257	0.05675	0.06088	0.06491
20 <i>h</i> (kJ/kg)	465.0	509.8	555.5	602.4	650.9	701.2	753.5
<i>s</i> (kJ/kg·K)	1.866	2.009	2.144	2.274	2.399	2.521	2.640
<i>v</i> (m ³ /kg)	0.02404	0.02763	0.03090	0.03400	0.03700	0.03990	0.04270
30 <i>h</i> (kJ/kg)	444.7	493.8	542.3	591.2	641.2	692.6	745.9
<i>s</i> (kJ/kg·K)	1.696	1.853	1.996	2.131	2.261	2.387	2.508
<i>v</i> (m ³ /kg)	0.01630	0.01947	0.02220	0.02473	0.02710	0.02938	0.03160
40 <i>h</i> (kJ/kg)	420.6	476.3	528.3	579.5	631.2	688.9	738.2
<i>s</i> (kJ/kg·K)	1.550	1.728	1.882	2.023	2.157	2.286	2.409
<i>v</i> (m ³ /kg)	0.01140	0.01451	0.01697	0.01916	0.02119	0.02311	0.02495
50 <i>h</i> (kJ/kg)	390.4	456.9	513.4	567.5	621.1	675.1	730.5
<i>s</i> (kJ/kg·K)	1.404	1.617	1.784	1.933	2.072	2.207	2.330
<i>v</i> (m ³ /kg)	0.007757	0.01116	0.01347	0.01546	0.01725	0.01892	0.02052
60 <i>h</i> (kJ/kg)	347.8	435.1	497.7	555.2	610.9	666.3	722.9
<i>s</i> (kJ/kg·K)	1.230	1.510	1.696	1.854	1.999	2.135	2.263
<i>v</i> (m ³ /kg)	0.003672	0.006864	0.009136	0.01085	0.01237	0.01374	0.01502
80 <i>h</i> (kJ/kg)	238.7	382.8	463.5	529.4	590.1	648.5	707.6
<i>s</i> (kJ/kg·K)	0.832	1.295	1.534	1.717	1.874	2.016	2.151
<i>v</i> (m ³ /kg)	0.003094	0.004698	0.006596	0.008163	0.009492	0.01068	0.01177
100 <i>h</i> (kJ/kg)	210.2	330.2	427.5	503.1	569.3	630.9	692.7
<i>s</i> (kJ/kg·K)	0.715	1.098	1.387	1.596	1.768	1.918	2.059
<i>v</i> (m ³ /kg)	0.002684	0.003223	0.004040	0.004983	0.005914	0.006765	0.007578
150 <i>h</i> (kJ/kg)	188.8	272.7	361.4	445.5	521.6	592.1	658.1
<i>s</i> (kJ/kg·K)	0.596	0.864	1.126	1.359	1.556	1.722	1.878
<i>v</i> (m ³ /kg)	0.002508	0.002840	0.003292	0.003838	0.004445	0.005058	0.005664
200 <i>h</i> (kJ/kg)	181.7	255.0	332.4	410.6	487.0	560.1	629.5
<i>s</i> (kJ/kg·K)	0.529	0.763	0.992	1.208	1.406	1.580	1.742
<i>v</i> (m ³ /kg)	0.002397	0.002644	0.003024	0.003327	0.003743	0.004190	0.004648
250 <i>h</i> (kJ/kg)	179.2	247.7	319.1	392.1	465.5	538.2	608.5
<i>s</i> (kJ/kg·K)	0.480	0.698	0.910	1.111	1.301	1.476	1.639
<i>v</i> (m ³ /kg)	0.002317	0.002517	0.002578	0.003037	0.003351	0.003690	0.004042
300 <i>h</i> (kJ/kg)	179.1	244.6	312.6	382.2	452.9	524.1	593.9
<i>s</i> (kJ/kg·K)	0.440	0.670	0.850	1.043	1.226	1.398	1.558
<i>v</i> (m ³ /kg)	0.002203	0.002352	0.002522	0.002711	0.002919	0.003413	0.003382
400 <i>h</i> (kJ/kg)	182.7	244.9	308.8	374.3	441.3	509.8	578.3
<i>s</i> (kJ/kg·K)	0.377	0.576	0.764	0.946	1.119	1.285	1.442
<i>v</i> (m ³ /kg)	0.002122	0.002245	0.002379	0.002524	0.002678	0.002847	0.003022
500 <i>h</i> (kJ/kg)	189.1	250.7	312.8	376.1	440.4	505.8	572.0
<i>s</i> (kJ/kg·K)	0.326	0.523	0.707	0.882	1.048	1.206	1.358

TABLE 2-259 Saturated Fluorine*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
53.5'	0.0025	5.866–4	46.2	−158.6	40.9	1.602	5.314	1.446	8.8	0.186
55	0.0041	5.898–4	17.1	−153.5	42.0	1.642	5.235	1.442	8.0	0.184
60	0.0155	6.005–4	8.46	−149.1	45.8	1.768	5.004	1.437	6.0	0.177
65	0.0477	6.119–4	2.93	−141.8	49.6	1.885	4.816	1.442	4.7	0.170
70	0.1230	6.240–4	1.24	−134.4	53.2	1.995	4.666	1.450	3.8	0.162
75	0.276	6.369–4	0.583	−127.0	56.8	2.097	4.540	1.460	3.19	0.154
80	0.555	6.508–4	0.309	−119.5	60.1	2.194	4.433	1.474	2.71	0.146
85	1.019	6.657–4	0.176	−111.9	63.3	2.285	4.342	1.498	2.33	0.137
90	1.740	6.819–4	0.108	−104.3	66.1	2.372	4.262	1.535	2.00	0.129
95	2.802	6.997–4	0.069	−96.5	68.6	2.455	4.191	1.555	1.76	0.120
100	4.280	7.193–4	0.0466	−88.6	70.7	2.535	4.127	1.585	1.53	0.112
105	6.280	7.412–4	0.0323	−80.5	72.4	2.612	4.068	1.630	1.36	0.103
110	8.885	7.659–4	0.0231	−72.2	73.6	2.688	4.012	1.692	1.21	0.095
115	12.20	7.948–4	0.0168	−63.6	74.1	2.763	3.959	1.782	1.08	0.087
120	16.33	8.283–4	0.0125	−54.5	73.9	2.837	3.906	1.888	0.96	0.080
125	21.37	8.696–4	0.0093	−44.9	72.7	2.912	3.864	2.05	0.86	0.073
130	27.48	9.223–4	0.0069	−34.5	70.2	2.989	3.795	2.33	0.74	0.066
135	34.72	9.963–4	0.0051	−22.7	65.6	3.073	3.727	2.90	0.63	0.070
140	43.47	1.119–3	0.0036	−8.4	56.9	3.170	3.636	3.64	0.49	0.105
144.3°	52.15	1.743–3	0.0017	23.9	23.9	3.388	3.388	∞	∞	∞

*Values reproduced or converted from Prydz and Straty, NBS Tech. Note 392, rev., September 1973. *t* = triple point; *c* = critical point. The notation 5.866–4 signifies 5.866×10^{-4} .

TABLE 2-260 Fluorine Gas at Atmospheric Pressure*

T, K	84.95	90	100	120	140	160	180	200	220	240	260	280	300
<i>v</i> , m ³ /kg	0.1776	0.1892	0.2118	0.2562	0.3002	0.3439	0.3874	0.4309	0.4744	0.5176	0.5610	0.6043	0.6476
<i>h</i> , kJ/kg	63.22	67.30	75.27	90.96	106.53	122.06	137.62	153.2	169.0	184.9	201.0	217.2	233.7
<i>s</i> , kJ/(kg·K)	4.342	4.390	4.474	4.616	4.737	4.840	4.932	5.014	5.090	5.158	5.221	5.282	5.340

*Extracted from Prydz and Straty, NBS Tech. Note 392, 1970. This source is recommended for other pressures and temperatures. Other information is contained in *J. Chem. Phys.*, **53** (1970): 2359; and *J. Res. NBS*, **74A** (1970): 499, 661, 747.

TABLE 2-261 Flutec

Proprietary name for a series of fluorocarbons produced by the Imperial Smelting Corp., Avonmouth, Bristol, UK. Bulletins of thermodynamic properties include PP1 (C_6F_{14}), PP2 (C_7F_{14}), PP3 (C_8F_{16}), PP5 ($C_{10}F_{18}$), PP9 ($C_{11}F_{20}$), and PP50, usually for 0.1–100 kg/m³, 0–500°C. See also Green, S. W., *Chem. & Ind.* (1969): 63–67.

TABLE 2-262 Halon

A series of fire-extinguishing fluids. Halon 1211 is produced by ICI, and Halon 1301, by duPont, the latter issuing a bulletin with thermodynamic properties and a diagram for the range 0.6–600 psia, −160–460°F.

TABLE 2-263 Saturated Helium³*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
1.0	0.0122	0.01222	1.72	−5.69	6.75	2.28	14.72
1.1	0.0182	0.01224	1.33	−5.49	7.40	2.65	14.34
1.2	0.0274	0.01227	1.02	−5.26	8.03	2.95	14.02
1.3	0.0370	0.01231	0.805	−5.01	8.65	3.20	13.70
1.4	0.0517	0.01236	0.649	−4.75	9.27	3.40	13.41
1.5	0.0659	0.01241	0.526	−4.47	9.88	3.60	13.13
1.6	0.0871	0.01247	0.437	−4.17	10.46	3.80	12.88
1.7	0.107	0.01254	0.363	−3.84	11.04	3.91	12.53
1.8	0.137	0.01262	0.308	−3.47	11.60	4.01	12.38
1.9	0.163	0.01271	0.260	−3.07	12.15	4.13	12.14
2.0	0.202	0.01282	0.222	−2.64	12.68	4.26	11.91
2.1	0.237	0.01294	0.189	−2.17	13.19	4.40	11.69
2.2	0.284	0.01308	0.164	−1.55	13.67	4.55	11.47
2.3	0.326	0.01324	0.142	−0.99	14.13	4.71	11.25
2.4	0.385	0.01343	0.124	−0.34	14.57	4.87	11.04
2.5	0.438	0.01365	0.109	0.36	14.98	5.03	10.84
2.6	0.508	0.01390	0.096	1.16	15.37	5.20	10.64
2.7	0.576	0.01419	0.085	2.01	15.89	5.38	10.41
2.8	0.653	0.01456	0.074	2.96	16.40	5.57	10.17
2.9	0.732	0.01497	0.064	4.01	16.37	5.77	9.92
3.0	0.803	0.01549	0.055	5.28	16.32	6.00	9.66
3.1	0.907	0.01614	0.047	6.70	16.20	6.24	9.34
3.2	1.023	0.01720	0.039	8.44	15.98	6.54	8.90
3.3	1.128	0.01902	0.028	10.66	14.50	6.96	8.35
3.32°	1.165	0.02394	0.024	13.25	13.25	7.50	7.50

*Converted and smoothed from a tabulation of Gibbons and Nathan, USAF Rep. AFML-TR-67-175, 1967. *c* = critical point. Kelly, D. P. and W. K. Haubach, in AEC R&D rept. MLM 1161, 1963 (56 pp.), give a comprehensive graphical comparison of the properties of He^3 and He^4 .

TABLE 2-264 Saturated Helium⁴

Temperature, K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	c_{pg} , kJ/(kg·K)
0.8	1.475,-5	0.00689	1125.9	0.0019	19.42	0.0047	23.94	0.022	5.210
0.9	5.379,-5	0.00689	347.1	0.0054	19.94	0.0087	21.86	0.050	5.230
1.0	1.557,-4	0.00689	133.0	0.0127	20.44	0.0163	20.44	0.100	5.262
1.1	3.800,-4	0.00689	59.8	0.0268	20.95	0.0296	18.82	0.185	5.305
1.2	8.148,-4	0.00689	30.4	0.0518	21.44	0.0510	17.67	0.318	5.360
1.3	0.00158	0.00689	16.93	0.0932	21.92	0.0836	16.70	0.511	5.424
1.4	0.00282	0.00689	10.17	0.1579	22.40	0.1308	15.86	0.780	5.496
1.5	0.00472	0.00689	6.49	0.2543	22.87	0.1962	15.13	1.138	5.574
1.6	0.00746	0.00688	4.35	0.3923	23.32	0.2839	14.49	1.602	5.654
1.7	0.01128	0.00688	3.04	0.5836	23.77	0.3981	13.93	2.193	5.736
1.8	0.01638	0.00688	2.1993	0.8422	24.20	0.5437	13.43	2.938	5.818
1.9	0.02299	0.00687	1.6420	1.186	24.63	0.7270	12.98	3.893	5.898
2.0	0.03129	0.00686	1.2601	1.642	25.04	0.9578	12.58	5.187	5.975
2.1	0.04141	0.00685	0.9921	2.261	25.45	1.256	12.23	7.244	6.046
2.2	0.05335	0.00684	0.7994	3.090	25.85	1.638	11.92	4.222	6.111
2.3	0.06730	0.00685	0.6566	3.418	26.24	1.780	11.65	2.685	6.170
2.4	0.08354	0.00687	0.5470	3.678	26.63	1.886	11.40	2.375	6.228
2.5	0.01023	0.00690	0.4608	3.922	27.00	1.980	11.17	2.284	6.285
2.6	0.1237	0.00693	0.3923	4.161	27.37	2.068	10.96	2.320	6.344
2.7	0.1481	0.00695	0.3367	4.408	27.72	2.155	10.76	2.351	6.406
2.8	0.1755	0.00699	0.2913	4.662	28.06	2.240	10.57	2.403	6.470
2.9	0.2063	0.00703	0.2537	4.923	28.38	2.324	10.39	2.486	6.540
3.0	0.2405	0.00707	0.2223	5.195	28.69	2.408	10.22	2.597	6.616
3.1	0.2784	0.00713	0.1958	5.483	28.98	2.494	10.05	2.740	6.700
3.2	0.3201	0.00717	0.1728	5.787	29.26	2.581	9.90	2.896	6.792
3.3	0.3659	0.00723	0.1542	6.108	29.52	2.670	9.747	3.061	6.897
3.4	0.4159	0.00728	0.1376	6.448	29.76	2.780	9.600	3.273	7.015
3.5	0.4704	0.00735	0.1232	6.806	29.97	2.852	9.458	3.413	7.150
3.6	0.5296	0.00742	0.1107	7.184	30.17	2.946	9.318	3.601	7.305
3.7	0.5935	0.00749	0.0997	7.581	30.34	3.042	9.181	3.801	7.484
3.8	0.6625	0.00758	0.0900	7.998	30.48	3.140	9.046	4.017	7.694
3.9	0.7366	0.00766	0.0814	8.437	30.60	3.239	8.911	4.254	7.942
4.0	0.8162	0.00776	0.0738	8.899	30.68	3.341	8.776	4.519	8.238
4.1	0.9014	0.00786	0.0669	9.387	30.73	3.444	8.641	4.820	8.641
4.2	0.9923	0.00797	0.0606	9.901	30.74	3.551	8.504	5.170	9.033
4.3	1.089	0.00810	0.0550	10.45	30.71	3.661	8.363	5.587	9.58
4.4	1.193	0.00824	0.0499	11.02	30.62	3.775	8.218	6.097	10.29
4.5	1.303	0.00841	0.0452	11.64	30.47	3.893	8.067	6.742	11.22
4.6	1.419	0.00860	0.0408	12.31	30.24	4.018	7.906	7.590	12.50
4.7	1.543	0.00881	0.0367	13.04	29.91	4.151	7.732	8.763	14.37
4.8	1.674	0.00907	0.0329	13.85	29.45	4.296	7.539	10.51	17.32
4.9	1.813	0.00941	0.0291	14.76	28.80	4.458	7.327	13.38	22.64
5.0	1.960	0.00986	0.0252	15.85	27.83	4.649	7.041	19.02	34.93
5.1	2.116	0.01056	0.0207	17.26	26.08	4.898	6.624	34.60	95.84
5.195 ^c	2.275	0.01436	0.0145						

^c = critical pt.

From Arp, V. D. and R. D. McCarty, N.I.S.T. TN 1334, 1989 (142 pp.).

TABLE 2-265 Superheated Helium*

P, bars	Temp., °C								
	0	100	200	300	400	500	600	800	1000
1 v	5.677	7.754	9.831	11.908	13.985	16.063	18.140	22.294	26.448
	0.327	519.6	1039	1558	2078	2597	3116	4155	5193
	0.0116	1.620	2.853	3.849	4.684	5.403	6.035	7.106	7.993
5 v	1.138	1.553	1.968	2.384	2.799	3.215	3.630	4.461	5.291
	1.636	520.9	1040	1560	2079	2598	3117	4156	5194
	-3.343	-1.723	-0.490	0.506	1.341	2.060	2.692	3.763	4.650
10 v	0.5704	0.780	0.986	1.193	1.401	1.609	1.816	2.232	2.647
	3.272	522.5	1042	1561	2080	2600	3119	4157	5196
	-4.782	-3.162	-1.929	-0.934	-0.098	0.621	1.252	2.323	3.211
20 v	0.2867	0.3904	0.4942	0.5979	0.7017	0.9093	1.1169	1.3245	1.8435
	6.544	525.8	1045	1564	2083	2603	3122	4160	5199
	-6.221	-4.601	-3.368	-2.373	-1.537	-0.818	-0.187	0.884	1.771
50 v	0.1164	0.1579	0.1993	0.2408	0.2822	0.3257	0.3652	0.4481	0.5311
	16.360	535.5	1055	1574	2093	2612	3131	4169	5207
	-8.121	-6.501	-5.268	-4.273	-3.438	-2.719	-2.088	-1.017	-0.130
100 v	0.0597	0.0803	0.1010	0.1217	0.1424	0.1631	0.1838	0.2252	0.2666
	37.720	551.7	1071	1590	2108	2627	3146	4184	5222
	-9.555	-7.936	-6.703	-5.709	-4.874	-4.155	-3.524	-2.454	-1.567
150 v	0.0407	0.0545	0.0682	0.0820	0.0958	0.1095	0.1233	0.1509	0.1785
	49.080	567.9	1087	1605	2124	2643	3161	4199	5236
	-10.391	-8.773	-7.541	-6.546	-5.712	-4.994	-4.363	-3.293	-2.407
200 v	0.0312	0.0416	0.0518	0.0622	0.0725	0.0828	0.0931	0.1137	0.1344
	65.440	584.1	1103	1621	2140	2658	3176	4213	5250
	-10.983	-9.635	-8.134	-7.139	-6.306	-5.588	-4.957	-3.888	-3.002

*Extracted from Tsederberg, Popov, et al., *Thermodynamic and Thermophysical Properties of Helium*, Atomizdat, Moscow, 1969, and NBS-NF TT 50096, 1971. Copyright material. Reproduced by permission. This source contains entries for many more temperatures and pressures than can be reproduced here. v = volume, m³/kg; h = enthalpy, kJ/kg; s = entropy, kJ/(kg·K).

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) has a thermodynamic chart for pressures from 0.1 to 50 bar and temperatures from 2.5 to 15 K. Saturation and superheat tables to 9000 psia, 800°R; and a chart to 700 psia, 40°R appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. A useful compilation of properties is given by Betts, D. S., *Cryogenics*, **16**, 1 (1976): 3–16. A 32-term equation of state for the range up to 20,000 bar, 2–1500 K is given by McCarty, R. D. and V. D. Arp, *Advan. Cryog. Engng.*, **35** (1990): 1465–1475.

TABLE 2-266 Helium⁴ Gas at Atmospheric Pressure*

T, K	4.224	5	10	20	30	40	50	75	100	200	300	400	500	600	800	1000
v, m ³ /kg	0.0591	0.0834	0.1612	0.4094	0.6161	0.8218	1.0273	1.5403	2.053	4.102	6.154	8.191	10.24	12.31	16.40	20.50
h, kJ/kg	30.30	36.18	64.91	117.95	170.24	222.4	274.4	404.4	534.2	1054	1573	2092	2612	3131	4170	5208
s, kJ/(kg·K)	8.327	9.614	13.369	17.321	19.442	20.94	22.10	24.21	25.71	29.30	31.41	32.90	34.06	35.01	36.50	37.66

*From McCarty, NBS Rep. 9762, 1970. Reproduced by permission. The source contains values for further temperatures and for other functions, usually to additional significant figures.

2-242 PHYSICAL AND CHEMICAL DATA
TABLE 2-267 Saturated *n*-Heptane*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
182.6 ^t		1.292.-3		284.1		2.260		2.025	39.4	0.150
200	0.00002	1.316.-3		319.4	722.6	2.441	4.457	2.011	21.0	0.148
220	0.00019	1.344.-3		359.7	757.1	2.636	4.442	2.026	12.6	0.145
240	0.00133	1.374.-3		400.5	791.4	2.814	4.443	2.063	8.52	0.142
250	0.00303	1.389.-3		421.3	808.3	2.899	4.447	2.088	7.23	0.140
260	0.00635	1.405.-3		442.3	824.9	2.981	4.453	2.117	6.52	0.137
270	0.01316	1.422.-3		463.6	841.2	3.061	4.460	2.147	5.46	0.135
280	0.02347	1.440.-3		485.2	857.8	3.140	4.471	2.180	4.83	0.132
290	0.03997	1.457.-3		507.2	874.8	3.217	4.485	2.216	4.29	0.129
300	0.06674	1.475.-3	3.744	529.6	891.9	3.293	4.501	2.252	3.85	0.126
310	0.1070	1.494.-3	2.412	552.3	908.9	3.367	4.517	2.291	3.48	0.123
320	0.1656	1.514.-3	1.596	575.4	926.0	3.441	4.537	2.329	3.17	0.121
330	0.2461	1.534.-3	1.101	598.8	943.3	3.513	4.557	2.370	2.89	0.119
340	0.3614	1.555.-3	0.7650	622.8	961.2	3.584	4.579	2.412	2.66	0.116
350	0.5130	1.578.-3	0.5510	647.0	979.1	3.655	4.604	2.454	2.45	0.114
360	0.712	1.601.-3	0.4058	671.9	997.5	3.725	4.629	2.500	2.24	0.111
370	0.967	1.625.-3	0.3036	697.1	1016.1	3.794	4.656	2.548	2.04	0.109
371.6	1.013	1.629.-3	0.2904	701.9	1019.8	3.805	4.660	2.556	2.01	0.108
380	1.289	1.651.-3	0.2308	723.9	1035.4	3.864	4.684	2.60	1.86	0.107
390	1.689	1.678.-3	0.1781	750.4	1054.2	3.932	4.711	2.65	1.71	0.105
400	2.180	1.708.-3	0.1388	777.2	1073.2	4.000	4.740	2.70	1.58	0.103
420	3.471	1.775.-3	0.0734					2.81	1.35	0.099
440	5.268	1.853.-3	0.0576					2.93	1.15	0.095
460	7.691	1.954.-3	0.0389					3.05	0.97	0.091
480	10.92	2.065.-3	0.0265					3.19	0.82	0.087
500	15.10	2.235.-3	0.0178					3.38	0.67	0.080
520	20.43	2.52.-3						3.7		
540.1 ^c	27.35	4.3.-3	0.0043							

*Values of P and v interpolated and converted from tables in Vargaftik, *Handbook of Thermophysical Properties of Gases and Liquids*, Hemisphere, Washington, and McGraw-Hill, New York, 1975. Values of h and s calculated from API tables published by the Thermodynamics Research Center, Texas A&M University, College Station. t = triple point; c = critical point.

Saturation and superheat tables and a diagram to 200 bar, 680 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.).

TABLE 2-268 Hexane

Saturation and superheat tables and a diagram to 100 bar, 680 K, are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.).

TABLE 2-269 Saturated Hydrazine

Temperature, K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
386.6	1.013	0.001 053	0.9833	-105.9	65.4	0.5994	1.0426
390	1.135	0.001 060	0.8850	-104.8	66.0	0.6029	1.0409
400	1.560	0.001 081	0.6579	-101.4	68.2	0.6120	1.0360
410	2.102	0.001 104	0.4994	-97.6	70.6	0.6211	1.0314
420	2.786	0.001 127	0.3850	-93.9	73.0	0.6300	1.0275
440	4.732	0.001 178	0.2355	-86.1	77.6	0.6492	1.0212
460	7.610	0.001 235	0.1500	-76.9	82.1	0.6707	1.0163
480	11.76	0.001 299	0.1005	-67.1	86.6	0.6916	1.0118
500	17.42	0.001 374	0.0690	-57.3	90.8	0.7124	1.0086
520	29.59	0.001 460	0.0407	-47.8	94.6	0.7320	1.0058
540	34.75	0.001 563	0.0353	-36.0	97.7	0.7566	1.0042
560	47.09	0.001 681	0.0263	-25.2	101.2	0.7762	1.0020
580	62.44	0.001 835	0.0196	-12.4	103.6	0.8002	1.0002
600	81.17	0.002 045	0.0142	5.2	104.2	0.8335	0.9988
620	102.7	0.002 320	0.0106	23.2	103.6	0.8671	0.9967
640	128.1	0.002 86	0.0074	45.9	98.1	0.9035	0.9906
653 ^c	146.9	0.004 33	0.0043	83.7	83.7	0.9715	0.9715

Converted from E. F. Fricke, Republic Aviation Co. rept. F-5028-101. *c* = critical point.

TABLE 2-270 Saturated *n*-Hydrogen*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
13.95 ^t	0.072	0.01298	7.974	218.3	667.4	14.079	46.635	6.36	0.255	0.073
14	0.074	0.01301	7.205	219.6	669.3	14.173	46.301	6.47	0.248	0.075
15	0.127	0.01316	4.488	226.4	678.2	14.640	44.763	6.91	0.218	0.083
16	0.204	0.01332	2.954	233.8	686.7	15.104	43.418	7.36	0.194	0.089
17	0.314	0.01348	2.032	241.6	694.7	15.568	42.227	7.88	0.175	0.093
18	0.461	0.01366	1.449	249.9	702.1	16.032	41.158	8.42	0.159	0.095
19	0.654	0.01387	1.064	258.8	708.8	16.498	40.188	8.93	0.146	0.097
20	0.901	0.01407	0.8017	268.3	714.8	16.966	39.299	9.45	0.135	0.098
21	1.208	0.01430	0.6177	278.4	720.2	17.440	38.485	10.13	0.125	0.100
22	1.585	0.01455	0.4828	289.2	724.4	17.919	37.710	10.82	0.116	0.101
23	2.039	0.01483	0.3829	300.8	727.6	18.405	36.973	11.69	0.108	0.101
24	2.579	0.01515	0.3072	313.3	729.8	18.901	36.266	12.52	0.101	0.101
25	3.213	0.01551	0.2489	326.7	730.7	19.408	35.579	13.44	0.094	0.100
26	3.950	0.01592	0.2032	341.2	730.2	19.929	34.900	14.80	0.088	0.098
27	4.800	0.01639	0.1667	357.0	728.0	20.473	34.221	16.17	0.082	0.096
28	5.770	0.01696	0.1370	374.3	723.7	21.041	33.524	18.48	0.076	0.094
29	6.872	0.01765	0.1125	393.6	716.6	21.650	32.795	22.05	0.070	0.091
30	8.116	0.01854	0.0919	415.4	705.9	22.315	32.002	26.59	0.065	0.087
31	9.510	0.01977	0.0738	441.3	689.7	23.075	31.091	36.55	0.058	0.086
32	11.07	0.02174	0.0571	474.7	663.2	24.032	29.926	65.37	0.051	0.092
33.18 ^c	13.13	0.03182	0.0318	565.4	565.4	26.680	26.680	∞	∞	

*Values extracted and occasionally rounded off from McCarty, Hord, and Roder, NBS Monogr. 168, 1981. *t* = triple point; *c* = critical point.

2-244 PHYSICAL AND CHEMICAL DATA
TABLE 2-271 Compressed *n*-Hydrogen*

Pressure, bar	Temperature, K									
	15	20	30	40	50	60	80	100	150	200
0.1 <i>v</i> <i>h</i> <i>s</i>	6.076	8.176	12.333	16.473	20.606	24.736	32.991	41.244	61.870	82.495
	679.2	731.6	835.5	938.9	1042.3	1146	1356	1575	2172	2826
	46.02	49.04	53.25	56.23	58.53	60.43	63.45	65.89	70.68	74.46
1 <i>v</i> <i>h</i> <i>s</i>	0.0131	0.0141	1.196	1.625	2.046	2.463	3.295	4.123	6.190	8.254
	227.3	268.3	826.0	932.7	1037.9	1143	1354	1574	2172	2826
	14.62	16.96	43.56	46.63	48.98	50.89	53.93	56.38	61.17	64.96
5 <i>v</i> <i>h</i> <i>s</i>	0.0131	0.0140	0.2006	0.3039	0.3958	0.4839	0.6553	0.8238	1.241	1.655
	231.7	272.1	775.0	903.4	1017.6	1128	1345	1568	2170	2826
	14.57	16.88	35.80	39.52	42.07	44.07	47.20	49.68	54.66	58.31
10 <i>v</i> <i>h</i> <i>s</i>	0.0130	0.0138	0.0181	0.1376	0.1895	0.2366	0.3255	0.4116	0.6221	0.8303
	237.2	277.0	412.1	861.8	991.1	1109	1334	1560	2167	2826
	14.50	16.77	22.09	35.95	38.85	40.99	44.23	46.75	51.63	55.44
20 <i>v</i> <i>h</i> <i>s</i>	0.0129	0.0136	0.0167	0.0521	0.0866	0.1135	0.1611	0.2057	0.3129	0.4179
	248.2	286.9	406.5	752.0	934.7	1070	1312	1546	2163	2826
	14.37	16.58	21.33	31.07	35.19	37.67	41.15	43.76	48.71	52.55
40 <i>v</i> <i>h</i> <i>s</i>	0.0133	0.0155	0.0216	0.0376	0.0533	0.0796	0.1033	0.1586	0.2119	0.2826
	307.3	413.5	589.3	823.5	997	1271	1521	2155	2826	3286
	16.26	20.50	25.49	30.73	33.91	37.87	40.65	45.75	49.64	53.55
60 <i>v</i> <i>h</i> <i>s</i>	0.0130	0.0147	0.0182	0.0254	0.0351	0.0532	0.0697	0.1073	0.1433	0.2085
	328.0	427.2	570.1	757.0	940	1237	1499	2149	2826	3286
	15.98	19.95	24.03	28.19	31.54	35.82	38.76	43.99	47.92	51.73
80 <i>v</i> <i>h</i> <i>s</i>	0.0127	0.0142	0.0167	0.0211	0.0273	0.0406	0.0531	0.0818	0.1090	0.1433
	348.9	443.5	572.3	732.8	905	1210	1482	2146	2831	3286
	15.74	19.53	23.21	26.78	29.93	34.34	37.37	42.72	46.69	50.54
100 <i>v</i> <i>h</i> <i>s</i>	0.0125	0.0138	0.0158	0.0190	0.0233	0.0335	0.0434	0.0666	0.0885	0.1085
	369.8	461.1	581.5	727.4	888	1192	1469	2144	2835	3286
	15.53	19.19	22.63	25.88	28.80	33.19	36.28	41.73	45.73	49.54
200 <i>v</i> <i>h</i> <i>s</i>	0.0117	0.0125	0.0136	0.0150	0.0167	0.0207	0.0253	0.0368	0.0480	0.0600
	474.4	556.1	658.7	776.9	908	1182	1458	2156	2869	3286
	14.71	17.99	20.93	23.56	25.94	29.88	32.97	38.59	42.72	46.69
400 <i>v</i> <i>h</i> <i>s</i>	0.0113	0.0119	0.0126	0.0134	0.0151	0.0171	0.0225	0.0279	0.0325	0.0373
	751.0	841.9	945.4	1059	1303	1560	2249	2973	3286	3734
	16.59	19.20	21.50	23.58	27.07	29.94	35.48	39.67	43.86	47.75
600 <i>v</i> <i>h</i> <i>s</i>	0.0106	0.0110	0.0115	0.0120	0.0131	0.0144	0.0178	0.0214	0.0255	0.0286
	941.5	1027	1124	1231	1463	1709	2385	3107	3403	37.92
	15.68	18.14	20.29	22.24	25.57	28.31	33.74	37.92	41.73	45.54
800 <i>v</i> <i>h</i> <i>s</i>	0.0104	0.0107	0.0111	0.0120	0.0130	0.0155	0.0181	0.0214	0.0255	0.0286
	1209	1302	1405	1628	1870	2535	3255	39.67	43.86	47.75
	17.35	19.43	21.30	24.50	27.20	32.54	36.70	40.55	44.33	48.12
1000 <i>v</i> <i>h</i> <i>s</i>	0.0099	0.0102	0.0106	0.0112	0.0120	0.0140	0.0160	0.0181	0.0203	0.0224
	1387	1478	1578	1796	2032	2692	3403	39.67	43.86	47.75
	16.72	18.75	20.58	23.70	26.33	31.63	35.75	39.67	43.86	47.75

*Values extracted and sometimes rounded off from the tables of McCarty, Hord, and Roder, NBS Monogr. 168, 1981. This source contains an exhaustive tabulation of property values for both the normal and the para forms of hydrogen. *v* = specific volume, m³/kg; *h* = specific enthalpy, kJ/kg; *s* = specific entropy, kJ/(kg·K).

The 1993 ASHRAE Handbook—Fundamentals (SI ed.) has a thermodynamic diagram for 0.1 to 500 bar for temperatures up to 100 K. Tables and a Mollier chart from 10⁻⁴ to 1000 atm, 300–20,000 K are given by Kubin, R. F. and L. L. Presley, NASA SP 3002, 1964. Liebenberg, D. H., R. L. Mills, and others, in LA-6645-MS, 1977 (26 pp.), give properties from 75 to 307 K for pressures from 2 to 20 kbar. See also Baker, J. R. and H. F. Swift, *J. Appl. Phys.*, **43**, 3 (1972): 950–953. An extensive collection of data for H₂, D₂, T₂, and so on below 30 K is given by Souers, P. C., UCRL 52628, 1979 (91 pp.); and for temperatures below 40 K by Roder, H. M., G. E. Childs, et al., NBS TN 641, 1973 (114 pp.).

Saturation and superheat tables to 10,000 psia, 900°R and a chart to 180°R appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For viscosity, thermal conductivity, and specific heat, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

Temperature, K										
250	300	350	400	450	500	600	700	800	900	1000
103.12	123.23	144.35	164.97	185.60	206.22	247.46	288.70	329.94	371.18	412.43
3517	4227	4945	5668	6393	7118	8571	10028	11493	12969	14458
77.53	80.13	82.34	84.27	85.98	87.51	90.15	92.40	94.36	96.10	97.66
10.32	12.38	14.44	16.50	18.57	20.63	24.75	28.88	33.00	37.13	41.25
3517	4227	4946	5669	6393	7118	8571	10029	11494	12969	14459
68.03	70.63	72.85	74.78	76.48	78.01	80.66	82.91	84.86	86.60	88.17
2.069	2.482	2.895	3.307	3.720	4.132	4.957	5.782	6.607	7.432	8.257
3518	4229	4948	5671	6396	7121	8574	10032	11497	12973	14462
61.39	63.99	66.21	68.14	69.84	71.37	74.02	76.27	78.23	79.96	81.53
1.038	1.245	1.451	1.658	1.864	2.070	2.483	2.896	3.308	3.720	4.133
3519	4231	4951	5674	6399	7125	8578	10036	11501	12977	14467
58.52	61.12	63.34	65.28	66.98	68.51	71.16	73.41	75.37	77.10	78.67
0.522	0.6259	0.7294	0.8328	0.9361	1.040	1.246	1.452	1.658	1.865	2.071
3522	4235	4956	5680	6406	7132	8586	10044	11509	12985	14475
55.65	58.26	60.48	62.41	64.12	65.65	68.30	70.55	72.51	74.24	75.81
0.2644	0.3166	0.3685	0.4204	0.4721	0.5238	0.6271	0.7303	0.8335	0.9366	1.040
3527	4244	4967	5692	6419	7146	8601	10059	11525	13002	14492
52.76	55.38	57.61	59.55	61.26	62.79	65.44	67.69	69.65	71.39	72.95
0.1786	0.2136	0.2483	0.2829	0.3174	0.3519	0.4209	0.4897	0.5585	0.6273	0.6961
3533	4253	4978	5705	6432	7160	8616	10075	11542	13018	14508
51.05	53.69	55.92	57.86	59.58	61.11	63.76	66.02	67.97	70.51	71.28
0.1357	0.1621	0.1882	0.2142	0.2401	0.2660	0.3177	0.3694	0.4120	0.4726	0.5242
3540	4263	4989	5718	6446	7174	8631	10091	11558	13035	14525
49.84	52.49	54.73	56.67	58.39	59.92	62.57	64.83	66.79	68.52	70.09
0.1099	0.1312	0.1521	0.1730	0.1937	0.2145	0.2559	0.2972	0.3385	0.3798	0.4211
3547	4273	5001	5731	6460	7189	8647	10107	11574	13051	14542
48.89	51.55	53.79	55.74	57.46	59.00	61.65	63.90	65.87	67.60	69.17
0.0588	0.0695	0.0801	0.0905	0.1001	0.1114	0.1321	0.1528	0.1734	0.1941	0.2147
3594	4329	5064	5798	6531	7263	8724	10187	11656	13134	14625
45.94	48.62	50.89	52.85	54.58	56.12	58.78	61.04	63.00	64.74	66.31
0.0334	0.0388	0.0441	0.0493	0.0545	0.0597	0.0701	0.0804	0.0908	0.1011	0.1114
3716	4458	5202	5943	6681	7416	8883	10349	11820	13300	14792
42.98	45.68	47.97	49.95	51.69	53.24	55.91	58.17	60.14	61.88	63.45
0.0249	0.0285	0.0321	0.0355	0.0390	0.0425	0.0494	0.0562	0.0631	0.0700	0.0768
3854	4600	5349	6095	6836	7574	9045	10513	11985	13466	14958
41.24	43.95	46.26	48.26	50.00	51.56	54.24	56.50	58.47	60.21	61.78
0.0207	0.0234	0.0260	0.0286	0.0312	0.0338	0.0390	0.0441	0.0492	0.0543	0.0594
4003	4748	5501	6249	6993	7734	9207	10677	12150	13631	15124
40.03	42.73	45.05	47.05	48.81	50.37	53.05	55.32	57.29	59.03	60.60
0.0181	0.0202	0.0223	0.0244	0.0265	0.0286	0.0327	0.0367	0.0408	0.0449	0.0490
4156	4898	5654	6405	7151	7893	9370	10842	12316	13797	15289
39.10	41.79	44.12	46.12	47.88	49.45	52.14	54.41	56.38	58.12	59.69

2-246 PHYSICAL AND CHEMICAL DATA
TABLE 2-272 Saturated para-Hydrogen*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
13.8 ^t	0.070	0.0130	7.97	-308.9	140.3	4.97	37.52	6.37	0.255	0.073
14	0.079	0.0130	7.20	-307.6	142.1	5.06	37.19	6.47	0.248	0.075
15	0.134	0.0132	4.49	-300.9	151.1	5.53	36.65	6.91	0.218	0.082
16	0.216	0.0133	2.96	-293.4	159.6	5.99	34.31	7.36	0.194	0.089
17	0.329	0.0135	2.03	-285.6	167.6	6.45	33.11	7.88	0.175	0.092
18	0.482	0.0137	1.45	-277.3	175.0	6.92	32.05	8.42	0.159	0.095
19	0.682	0.0139	1.07	-268.4	181.7	7.38	31.08	8.93	0.146	0.097
20	0.935	0.0141	0.802	-258.9	187.7	7.85	30.19	9.45	0.135	0.098
21	1.250	0.0143	0.618	-248.8	193.0	8.32	29.37	10.13	0.125	0.100
22	1.634	0.0146	0.483	-237.9	197.3	8.80	28.60	10.82	0.116	0.101
23	2.096	0.0148	0.383	-226.3	200.5	9.29	27.86	11.69	0.108	0.101
24	2.645	0.0152	0.307	-213.9	202.7	9.78	27.15	12.52	0.101	0.100
25	3.288	0.0155	0.249	-200.4	203.6	10.29	26.46	13.44	0.094	0.099
26	4.035	0.0159	0.203	-185.9	203.1	10.81	25.79	14.81	0.088	0.098
27	4.892	0.0164	0.167	-170.2	200.9	11.36	25.11	16.18	0.082	0.096
28	5.88	0.0170	0.137	-152.9	196.5	11.93	24.41	18.5	0.076	0.094
29	6.98	0.0177	0.113	-133.6	189.5	12.54	23.68	22.1	0.070	0.091
30	8.23	0.0185	0.092	-111.7	178.8	13.20	22.89	26.6	0.065	0.087
31	9.63	0.0198	0.074	-85.8	162.6	13.96	21.98	36.6	0.058	0.088
32	11.20	0.0217	0.057	-52.4	136.1	14.92	20.81	65.4	0.051	0.092
33 ^c	12.93	0.0318	0.032	38.3	38.3	17.56	17.56	∞	∞	

*Values extracted and occasionally rounded off from McCarty, Hord, and Roder, NBS Monogr. 168, 1981. t = triple point; c = critical point.

Saturation and superheat tables to 12,000 psia, 900°R and a chart to 180°R appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) has a thermodynamic chart for pressures from 0.1 to 1000 bar for temperatures up to 100 K.

TABLE 2-273 Saturated Hydrogen Peroxide*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
273	0.0004	0.00068	1672	-5577	-4027	2.990	8.662	1.45	18.0	0.483
300	0.0031	0.00069	235	-5510	-3995	3.224	8.269	1.48	11.3	0.481
350	0.0564	0.00072	15.1	-5376	-3933	3.631	7.758	1.54	4.3	0.474
400	0.4521	0.00076	2.12	-5238	-3878	4.032	7.440	1.61	2.2	0.464
450	2.143	0.00081	0.487	-5091	-3820	4.346	7.172	1.68	1.3	0.453
500	7.126	0.00088	0.155	-4945	-3777	4.656	6.992	1.75	0.89	0.443
550	18.56	0.00095	0.0605	-4794	-3745	4.941	6.846	1.82	0.65	0.431
600	40.75	0.00107	0.0268	-4635	-3731	5.209	6.720	1.90	0.50	0.416
650	79.27	0.00125	0.0125	-4463	-3746	5.485	6.582			
700	141.7	0.00171	0.0048	-4195	-3860	5.682	6.339			
708.5 ^c	155.3	0.00284	0.0028	-4012	-4012	5.732	5.732			

*Values reproduced or converted from a tabulation by Tsykalov and Tabachnikov in V. A. Rabinovich (ed.), *Thermophysical Properties of Gases and Liquids*, Stadartov, Moscow, 1968; NBS-NSF transl. TT 69-55091, 1970. The reader may be reminded that very pure hydrogen peroxide is very difficult to obtain owing to its decomposition or instability. c = critical point. The FMC Corp., Philadelphia, PA tech. bull. 67, 1969 (100 pp.) contains an enthalpy-pressure diagram to 3000 psia, 1100 K.

TABLE 2-274 Hydrogen Sulfide

West, J. R., *Chem. Eng. Progr.*, 44, 4 (1948): 207–292 gives tables and a chart for the range 1–90 atm., -76 to 1300°F while properties from 10 to 330 bar, 300 to 500 K were tabulated by Lui, C.-H., D. M. Bailey, et al., *Hydroc. Proc.*, 65, 7 (July 1986): 41–43.

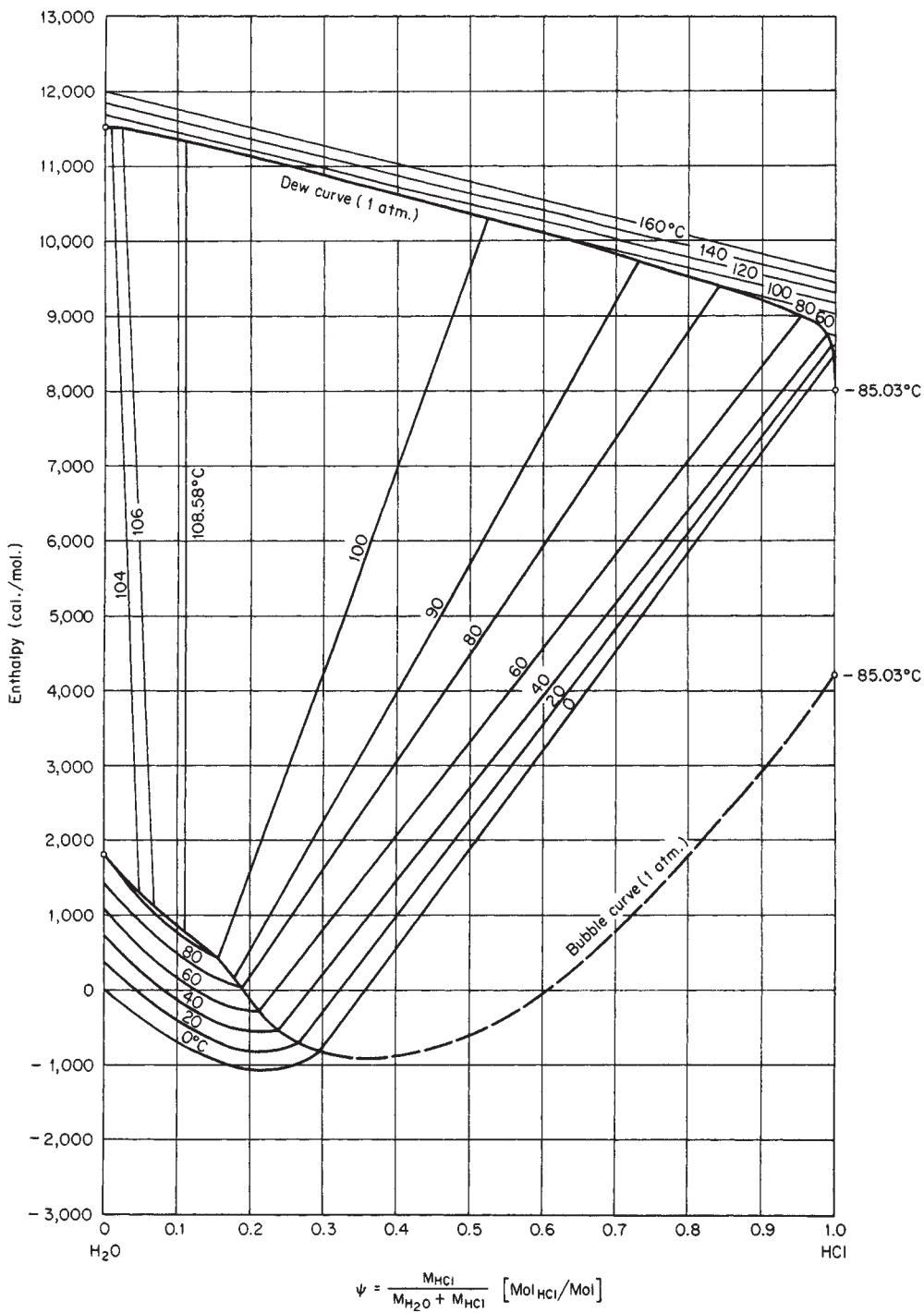


FIG. 2-11 Enthalpy-concentration diagram for aqueous hydrogen chloride at 1 atm. Reference states: enthalpy of liquid water at 0°C is zero; enthalpy of pure saturated HCl vapor at 1 atm (-85.03°C) is 8000 kcal/mol. NOTE: It should be observed that the weight basis includes the vapor, which is particularly important in the two-phase region. Saturation values may be read at the ends of the tie lines. [Van Nus, Trans. Am. Inst. Chem. Eng., 39, 663 (1943).]

TABLE 2-275 Saturated Isobutane (R600a)*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
113.6 ^t	1.9.-7	1.349.-3	8.60.+6	0.0	485.3	1.863	6.136			
120	9.3.-7	1.360.-3	1.84.+6	11.0	491.1	1.957	5.957	1.78		
140	4.8.-5	1.396.-3	4210	46.0	510.1	2.226	5.541	1.87		0.163
160	8.2.-4	1.435.-3	278.2	82.1	530.8	2.467	5.272	1.93		0.158
180	0.0070	1.476.-3	36.66	119.5	533.0	2.688	5.097	1.99	9.46	0.149
200	0.0369	1.520.-3	7.723	158.5	576.7	2.893	4.984	2.05	6.06	0.142
220	0.1374	1.568.-3	2.265	199.0	601.5	3.086	4.916	2.12	4.21	0.134
240	0.3989	1.621.-3	0.8432	241.4	627.4	3.270	4.878	2.19	3.11	0.127
260	0.9600	1.680.-3	0.3738	285.8	654.2	3.446	4.863	2.28	2.40	0.120
270	1.4081	1.712.-3	0.2617	308.8	667.7	3.532	4.861	2.33	2.14	0.117
280	2.0020	1.746.-3	0.1882	332.3	681.3	3.617	4.863	2.39	1.93	0.113
290	2.7686	1.784.-3	0.1385	356.4	694.9	3.700	4.867	2.46	1.75	0.110
300	3.7365	1.824.-3	0.1040	381.1	708.4	3.783	4.874	2.53	1.59	0.106
310	4.934	1.868.-3	0.0794	406.4	721.7	3.865	4.882	2.61	1.46	0.102
320	6.392	1.916.-3	0.0614	432.4	734.8	3.946	4.891	2.70	1.35	0.099
330	8.140	1.971.-3	0.0481	459.2	747.7	4.028	4.902	2.81	1.25	0.095
340	10.21	2.032.-3	0.0380	486.9	760.0	4.109	4.912	2.92	1.15	0.092
350	12.64	2.103.-3	0.0301	515.7	771.8	4.191	4.923	3.04	1.05	0.088
360	15.46	2.187.-3	0.0240	545.6	782.7	4.273	4.932	3.17	0.95	0.083
370	18.72	2.289.-3	0.0190	577.1	792.3	4.357	4.939	3.31	0.85	0.080
380	22.48	2.420.-3	0.0150	610.6	799.8	4.444	4.942	3.45	0.75	0.076
390	26.82	2.604.-3	0.0115	647.1	803.7	4.536	4.937	3.62	0.63	0.071
400	31.86	2.920.-3	0.0083	689.6	799.6	4.639	4.915	3.85	0.51	0.065
408.0 ^c	36.55	4.464.-3	0.0045	752.5	752.5	4.791	4.791	∞	∞	∞

*Values reproduced or converted from Goodwin, NBSIR 79-1612, 1979. t = triple point; c = critical point. The notation 1.9.-7 signifies 1.9×10^{-7} .

Slightly different values for the range 0.5 to 34.5 bar, 250–404 K appear in Waxman, M. and J. S. Gallagher, *J. Chem. Eng. Data*, **28**, (1983): 224–241. This source also contains superheat tables for 1–400 bar, 250–600 K.

Saturation and superheat tables and a diagram to 200 bar, 600 K are given by Reynolds, W. C., *Thermodynamic properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Saturation and superheat tables and a chart to 10,000 psia, 640°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. Equations and data for thermal conductivity and viscosity are given by Nieuwoldt, J. C., B. LeNeindre, et al., *J. Chem. Eng. Data*, **32**, (1987): 1–8.

TABLE 2-276 Saturated Krypton*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
10		3.235.-4		0.22		0.0256		0.070		
20		3.246.-4		1.59		0.1141		0.188		
30		3.265.-4		3.84		0.2034		0.247		
40		3.288.-4		6.49		0.2791		0.276		
50		3.313.-4		9.37		0.3431		0.295		
60		3.341.-4		12.40		0.3982		0.311		
70		3.372.-4		15.57		0.4471		0.327		
80		3.407.-4		18.97		0.4925		0.345		
90		3.446.-4		22.58		0.5353		0.366		
100		3.492.-4		26.42		0.5765		0.389		
110		3.544.-4		30.52		0.6165		0.414		
115.76	0.732	3.579.-4		33.18		0.6390		0.427		
115.76	1.013	4.090.-4	0.1529	52.78	161.8	0.8095	1.751	0.547		
120	1.032	4.143.-4	0.1136	54.99	162.6	0.8279	1.726	0.545		
130	2.112	4.284.-4	0.0578	60.55	164.1	0.8724	1.669	0.542	3.16	0.0828
140	3.878	4.440.-4	0.0330	66.02	165.3	0.9124	1.622	0.546	2.64	0.0756
150	6.552	4.619.-4	0.0201	71.58	166.1	0.9499	1.580	0.559	2.20	0.0688
160	10.37	4.831.-4	0.0130	77.34	166.4	0.9859	1.543	0.587	1.87	0.0625
170	15.57	5.091.-4	0.0086	83.48	166.0	1.022	1.507	0.641	1.54	0.0558
180	22.41	5.423.-4	0.0059	90.26	164.6	1.058	1.472	0.734	1.28	0.0494
190	31.20	5.882.-4	0.0040	98.19	161.8	1.098	1.433	0.905	1.05	0.0433
200	42.23	6.641.-4	0.0026	108.40	156.0	1.147	1.386	1.515	0.80	0.0348
209.39	54.96	1.098.-3	0.0011	133.90	133.9	1.262	1.262	∞	∞	

*Values extracted and in some cases rounded off from those cited in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. This source contains values for the compressed state for pressures up to 1000 bar, etc. The notation 3.235.-4 signifies 3.235×10^{-4} . This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

TABLE 2-277 Compressed Krypton*

Temperature, K	Pressure, bar											
	1	10	20	40	60	80	100	200	400	600	800	1000
100	<i>v</i> 26.42 <i>s</i> 0.5765	3.49–4 26.69 0.5760	3.49–4 26.99 0.5755	3.48–4 27.59 0.5745	3.48–4 28.18 0.5735	3.47–4 28.78 0.5724	3.47–4 29.38 0.5714	3.45–4 32.38 0.5667	3.42–4 38.42 0.5580	3.39–4 44.47 0.5503	3.36–4 50.52 0.5432	3.33–4 56.57 0.5366
	<i>v</i> 183.1 <i>s</i> 1.859	0.1971 179.3 1.618	0.0184 174.5 1.533	8.39–3 159.4 1.405	3.00–3 105.6 1.129	6.19–4 104.4 1.116	5.94–4 103.6 1.106	5.76–4 102.7 1.073	5.27–4 105.3 1.037	4.83–4 109.7 1.013	4.58–4 114.9 0.993	4.41–4 120.3 0.977
	<i>v</i> 208.1 <i>s</i> 1.961	0.2971 206.3 1.728	0.0292 204.2 1.654	0.0143 200.0 1.575	6.84–3 195.7 1.525	4.37–3 191.2 1.485	3.14–3 186.6 1.451	2.41–3 166.8 1.333	1.09–3 155.1 1.239	6.92–4 155.2 1.196	5.94–4 158.2 1.169	5.44–4 162.3 1.149
200	<i>v</i> 233.0 <i>s</i> 2.032	0.3966 231.9 1.802	0.0394 230.7 1.730	0.0196 228.3 1.657	9.67–3 225.9 1.612	6.37–3 223.6 1.579	4.73–3 221.3 1.552	3.75–3 211.4 1.463	1.85–3 199.7 1.368	1.01–3 196.8 1.317	7.79–4 197.9 1.284	6.76–4 200.8 1.259
	<i>v</i> 257.8 <i>s</i> 2.088	0.4960 257.1 1.858	0.0495 256.3 1.788	0.0247 254.9 1.716	8.20–3 253.3 1.673	6.15–3 251.9 1.642	4.91–3 250.5 1.617	2.49–3 244.5 1.537	1.33–3 236.9 1.451	9.81–4 234.2 1.400	8.22–4 237.4 1.365	7.29–4 237.4 1.340
	<i>v</i> 282.7 <i>s</i> 2.133	0.5953 282.2 1.904	0.0596 281.7 1.834	0.0298 280.7 1.763	9.96–3 279.7 1.721	7.49–3 278.8 1.691	6.01–3 277.9 1.667	3.07–3 274.2 1.591	1.64–3 269.6 1.511	1.18–3 268.1 1.462	9.67–4 269.1 1.428	8.44–4 271.7 1.403
300	<i>v</i> 307.5 <i>s</i> 2.171	0.6946 307.2 1.942	0.0696 306.9 1.873	0.0348 306.2 1.803	0.0175 305.6 1.761	0.0117 305.1 1.732	8.80–3 304.5 1.708	7.07–3 302.2 1.634	3.62–3 299.8 1.557	1.93–3 299.6 1.511	1.38–3 301.1 1.478	9.56–4 304.0 1.453
	<i>v</i> 332.3 <i>s</i> 2.204	0.7939 332.2 1.975	0.0795 331.9 1.906	0.0399 331.6 1.837	0.0200 331.2 1.795	0.0134 330.9 1.766	0.0101 330.5 1.743	8.11–3 329.3 1.671	4.16–3 328.6 1.596	2.21–3 329.4 1.551	1.57–3 331.5 1.518	1.25–3 334.6 1.494
	<i>v</i> 357.1 <i>s</i> 2.233	0.8931 357.0 2.005	0.0895 356.9 1.936	0.0448 356.8 1.866	0.0225 356.6 1.825	0.0151 356.4 1.796	0.0114 356.3 1.773	9.13–3 355.8 1.702	4.68–3 356.3 1.628	2.48–3 356.3 1.584	1.75–3 358.0 1.553	1.39–3 360.7 1.528
400	<i>v</i> 381.9 <i>s</i> 2.260	0.9924 381.9 2.031	0.0994 381.9 1.962	0.0498 381.8 1.893	0.0250 381.8 1.852	0.0168 381.8 1.823	0.0126 381.8 1.800	0.0102 381.8 1.729	5.20–3 381.9 1.657	2.74–3 383.4 1.614	1.93–3 385.9 1.583	1.53–3 389.0 1.559
	<i>v</i> 418.9 <i>s</i> 2.304	1.0925 418.8 2.074	0.1094 418.7 1.944	0.0500 418.6 1.874	0.0275 418.5 1.804	0.0175 418.4 1.734	0.0125 418.3 1.664	6.20–3 418.2 1.594	3.20–3 418.1 1.524	1.70–3 418.0 1.454	1.38–3 418.1 1.384	1.18–3 418.2 1.314
	<i>v</i> 453.7 ^m <i>s</i> 2.344	1.1922–3 453.6 2.274	0.1194 453.5 2.204	0.0596 453.4 2.134	0.0300 453.3 2.064	0.0180 453.2 1.994	0.0120 453.1 1.924	6.776 453.0 1.854	56.492 52.169 45.216	4.30 4.34 4.23		
500	<i>v</i> 489.1 <i>s</i> 2.384	1.2919–3 489.0 2.314	0.1294 488.9 2.244	0.0600 488.8 2.174	0.0305 488.7 2.104	0.0185 488.6 2.034	0.0125 488.5 1.964	6.776 488.4 1.894	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 525.7 <i>s</i> 2.424	1.3916–3 525.6 2.354	0.1394 525.5 2.284	0.0605 525.4 2.214	0.0310 525.3 2.144	0.0190 525.2 2.074	0.0130 525.1 2.004	6.776 525.0 1.934	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 562.3 <i>s</i> 2.464	1.4913–3 562.2 2.394	0.1494 562.1 2.324	0.0610 562.0 2.254	0.0315 561.9 2.184	0.0195 561.8 2.114	0.0135 561.7 2.044	6.776 561.6 1.974	56.492 52.169 45.216	4.30 4.34 4.23		
600	<i>v</i> 600.0 <i>s</i> 2.504	1.5910–3 600.0 2.434	0.1594 600.0 2.364	0.0615 600.0 2.294	0.0320 600.0 2.224	0.0200 600.0 2.154	0.0140 600.0 2.084	6.776 600.0 2.014	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 636.7 <i>s</i> 2.544	1.6907–3 636.7 2.474	0.1694 636.7 2.404	0.0620 636.7 2.334	0.0325 636.7 2.264	0.0205 636.7 2.194	0.0145 636.7 2.124	6.776 636.7 2.044	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 673.4 <i>s</i> 2.584	1.7904–3 673.4 2.514	0.1794 673.4 2.444	0.0625 673.4 2.374	0.0330 673.4 2.304	0.0210 673.4 2.234	0.0150 673.4 2.164	6.776 673.4 2.074	56.492 52.169 45.216	4.30 4.34 4.23		
700	<i>v</i> 710.1 <i>s</i> 2.624	1.8901–3 710.1 2.544	0.1894 710.1 2.474	0.0630 710.1 2.404	0.0335 710.1 2.334	0.0215 710.1 2.264	0.0155 710.1 2.194	6.776 710.1 2.104	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 746.8 <i>s</i> 2.664	1.9898–3 746.8 2.574	0.1994 746.8 2.504	0.0635 746.8 2.434	0.0340 746.8 2.364	0.0220 746.8 2.294	0.0160 746.8 2.224	6.776 746.8 2.134	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 783.5 <i>s</i> 2.704	2.0895–3 783.5 2.634	0.2094 783.5 2.564	0.0640 783.5 2.494	0.0345 783.5 2.424	0.0225 783.5 2.354	0.0165 783.5 2.284	6.776 783.5 2.144	56.492 52.169 45.216	4.30 4.34 4.23		
800	<i>v</i> 820.2 <i>s</i> 2.744	2.1892–3 820.2 2.674	0.2194 820.2 2.604	0.0645 820.2 2.534	0.0350 820.2 2.464	0.0230 820.2 2.394	0.0170 820.2 2.324	6.776 820.2 2.194	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 856.9 <i>s</i> 2.784	2.2890–3 856.9 2.714	0.2294 856.9 2.644	0.0650 856.9 2.574	0.0355 856.9 2.504	0.0235 856.9 2.434	0.0175 856.9 2.364	6.776 856.9 2.244	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 893.6 <i>s</i> 2.824	2.3887–3 893.6 2.744	0.2394 893.6 2.674	0.0655 893.6 2.604	0.0360 893.6 2.534	0.0240 893.6 2.464	0.0180 893.6 2.394	6.776 893.6 2.294	56.492 52.169 45.216	4.30 4.34 4.23		
900	<i>v</i> 930.3 <i>s</i> 2.864	2.4885–3 930.3 2.774	0.2494 930.3 2.704	0.0660 930.3 2.634	0.0365 930.3 2.564	0.0245 930.3 2.494	0.0185 930.3 2.424	6.776 930.3 2.344	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 967.0 <i>s</i> 2.904	2.5883–3 967.0 2.814	0.2594 967.0 2.744	0.0665 967.0 2.674	0.0370 967.0 2.604	0.0250 967.0 2.534	0.0190 967.0 2.464	6.776 967.0 2.394	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 1003.7 <i>s</i> 2.944	2.6881–3 1003.7 2.824	0.2694 1003.7 2.754	0.0670 1003.7 2.684	0.0375 1003.7 2.614	0.0255 1003.7 2.544	0.0195 1003.7 2.474	6.776 1003.7 2.424	56.492 52.169 45.216	4.30 4.34 4.23		
1000	<i>v</i> 1040.4 <i>s</i> 2.984	2.7879–3 1040.4 2.854	0.2794 1040.4 2.784	0.0675 1040.4 2.714	0.0380 1040.4 2.644	0.0260 1040.4 2.574	0.0200 1040.4 2.504	6.776 1040.4 2.474	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 1077.1 <i>s</i> 3.024	2.8877–3 1077.1 2.914	0.2894 1077.1 2.844	0.0680 1077.1 2.774	0.0385 1077.1 2.704	0.0265 1077.1 2.634	0.0205 1077.1 2.564	6.776 1077.1 2.534	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 1113.8 <i>s</i> 3.064	2.9875–3 1113.8 2.944	0.2994 1113.8 2.874	0.0685 1113.8 2.804	0.0390 1113.8 2.734	0.0270 1113.8 2.664	0.0210 1113.8 2.594	6.776 1113.8 2.564	56.492 52.169 45.216	4.30 4.34 4.23		
1100	<i>v</i> 1150.5 <i>s</i> 3.104	3.0873–3 1150.5 2.974	0.3094 1150.5 2.904	0.0690 1150.5 2.834	0.0395 1150.5 2.764	0.0275 1150.5 2.694	0.0215 1150.5 2.624	6.776 1150.5 2.594	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 1187.2 <i>s</i> 3.144	3.1871–3 1187.2 3.014	0.3194 1187.2 2.944	0.0695 1187.2 2.874	0.0400 1187.2 2.804	0.0280 1187.2 2.734	0.0220 1187.2 2.664	6.776 1187.2 2.634	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 1224.9 <i>s</i> 3.184	3.2869–3 1224.9 3.044	0.3294 1224.9 2.974	0.0700 1224.9 2.904	0.0405 1224.9 2.834	0.0285 1224.9 2.764	0.0225 1224.9 2.694	6.776 1224.9 2.664	56.492 52.169 45.216	4.30 4.34 4.23		
1200	<i>v</i> 1261.6 <i>s</i> 3.224	3.3867–3 1261.6 3.074	0.3394 1261.6 2.994	0.0705 1261.6 2.924	0.0410 1261.6 2.854	0.0290 1261.6 2.784	0.0230 1261.6 2.714	6.776 1261.6 2.684	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 1298.3 <i>s</i> 3.264	3.4865–3 1298.3 3.114	0.3494 1298.3 3.034	0.0710 1298.3 2.964	0.0415 1298.3 2.894	0.0295 1298.3 2.824	0.0235 1298.3 2.754	6.776 1298.3 2.724	56.492 52.169 45.216	4.30 4.34 4.23		
	<i>v</i> 1335.0 <i>s</i> 3.304	3.5863–3 1335.0 3.154	0.3594 1335.0 3.074	0.0715 1335.0 3.004	0.0420 1335.0 3.034	0.0295 1335.0 2.964	0.0240 1335.0 2.894	6.776 1335.0 2.864	56.492 52.169 45.216	4.30 4.34 4.23		
1300	<i>v</i> 1371.7 <i>s</i> 3.344	3.6861–3 1371.7 3.194	0.3694 1371.7 3.114	0.0720 1371.7 3.044								

2-250 PHYSICAL AND CHEMICAL DATA
TABLE 2-280 Saturated Mercury*

T, K	P, bar	$v_f \times 10^5$, m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	h_{fg} , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
203.15	$2.298 \cdot 10^{-11}$	7.26239	$3.665 \cdot 10^9$	33.131	342.637	309.506	0.32434	1.84787
213.15	$1.288 \cdot 10^{-10}$	7.27570	$6.862 \cdot 10^8$	34.567	343.674	309.107	0.33124	1.78142
223.15	$6.169 \cdot 10^{-10}$	7.28900	$1.499 \cdot 10^8$	35.997	344.710	308.713	0.33780	1.72123
233.15	$2.580 \cdot 10^{-9}$	7.30231	$3.746 \cdot 10^7$	37.422	345.746	308.324	0.34404	1.66647
243.15	$9.573 \cdot 10^{-9}$	7.31563	$1.053 \cdot 10^7$	38.842	346.782	307.940	0.35001	1.61647
253.15	$3.198 \cdot 10^{-8}$	7.32896	$3.281 \cdot 10^6$	40.258	347.819	307.561	0.35571	1.57065
263.15	$9.736 \cdot 10^{-8}$	7.34229	$1.120 \cdot 10^6$	41.668	348.855	307.187	0.36118	1.52852
273.15	$2.728 \cdot 10^{-7}$	7.35563	$4.150 \cdot 10^5$	43.074	349.891	306.817	0.36642	1.48967
283.15	$7.101 \cdot 10^{-7}$	7.36898	$1.653 \cdot 10^5$	44.476	350.927	306.451	0.37146	1.45375
293.15	$1.729 \cdot 10^{-6}$	7.38234	$7.026 \cdot 10^4$	45.874	351.964	306.090	0.37631	1.42045
303.15	$3.968 \cdot 10^{-6}$	7.39572	$3.167 \cdot 10^4$	47.268	353.000	305.732	0.38099	1.39951
313.15	$8.626 \cdot 10^{-6}$	7.40911	$1.505 \cdot 10^4$	48.659	354.036	305.377	0.38550	1.36068
323.15	$1.786 \cdot 10^{-5}$	7.42252	$7.501 \cdot 10^3$	50.046	355.072	305.026	0.38986	1.33378
333.15	$3.356 \cdot 10^{-5}$	7.43594	$3.905 \cdot 10^3$	51.430	356.108	304.678	0.39408	1.30862
343.15	$6.724 \cdot 10^{-5}$	7.44938	$2.115 \cdot 10^3$	52.810	357.145	304.335	0.39816	1.28505
353.15	$1.232 \cdot 10^{-4}$	7.46285	$1.188 \cdot 10^3$	54.188	358.181	303.993	0.40212	1.26292
363.15	$2.182 \cdot 10^{-4}$	7.47633	$6.899 \cdot 10^2$	55.563	359.217	303.654	0.40596	1.24213
373.15	$3.745 \cdot 10^{-4}$	7.48984	413.0	56.936	360.253	303.317	0.40969	1.22255
383.15	$6.247 \cdot 10^{-4}$	7.50337	254.2	58.306	361.289	302.983	0.41331	1.20408
393.15	$1.015 \cdot 10^{-3}$	7.51693	153.6	59.674	362.326	302.652	0.41684	1.18665
403.15	$1.608 \cdot 10^{-3}$	7.53052	103.9	61.039	363.362	302.323	0.42027	1.17017
413.15	$2.491 \cdot 10^{-3}$	7.55415	65.75	62.403	364.397	301.994	0.42361	1.15456
423.15	$3.778 \cdot 10^{-3}$	7.55780	46.43	63.765	365.433	301.668	0.42687	1.13978
433.15	$5.618 \cdot 10^{-3}$	7.57148	31.96	65.125	366.469	301.344	0.43004	1.12575
443.15	$8.204 \cdot 10^{-3}$	7.58520	22.39	66.484	367.504	301.020	0.43314	1.11242
453.15	$1.178 \cdot 10^{-2}$	7.59897	15.95	67.842	368.539	300.697	0.43617	1.09975
463.15	$1.664 \cdot 10^{-2}$	7.61277	11.54	69.198	369.574	300.376	0.43913	1.08768
473.15	$2.315 \cdot 10^{-2}$	7.62662	8.469	70.553	370.609	300.056	0.44203	1.07619
483.15	$3.177 \cdot 10^{-2}$	7.64051	6.301	71.908	371.642	299.734	0.44486	1.06524
493.15	$4.304 \cdot 10^{-2}$	7.65444	4.748	73.261	372.676	299.415	0.44763	1.05478
503.15	$5.758 \cdot 10^{-2}$	7.66843	3.621	74.614	373.708	299.094	0.45035	1.04479
513.15	$7.614 \cdot 10^{-2}$	7.68247	2.793	75.967	374.740	298.773	0.45301	1.03525
523.15	$9.959 \cdot 10^{-2}$	7.69656	2.176	77.319	375.771	298.452	0.45562	1.02611
533.15	0.12892	7.71071	1.7132	78.671	376.800	298.129	0.45818	1.01737
543.15	0.16527	7.72491	1.3613	80.023	377.829	297.806	0.46069	1.00899
553.15	0.20993	7.73918	1.0912	81.375	378.855	297.480	0.46316	1.00095
563.15	0.26435	7.75351	0.88213	82.728	379.880	297.152	0.46558	0.99324
573.15	0.33015	7.76769	0.71874	84.080	380.904	296.824	0.46796	0.98584
583.15	0.40910	7.7823	0.59002	85.434	381.925	296.491	0.47030	0.97893
593.15	0.50320	7.7969	0.48779	86.788	382.944	296.156	0.47260	0.97190
603.15	0.61460	7.8115	0.40600	88.143	383.960	295.817	0.47487	0.96532
613.15	0.74567	7.8262	0.34008	89.499	384.973	295.474	0.47709	0.95899
623.15	0.89896	7.8409	0.28660	90.856	385.984	295.128	0.47929	0.95289
633.15	1.0772	7.8558	0.24291	92.215	386.991	294.776	0.48145	0.94702
643.15	1.2834	7.8707	0.20702	93.575	387.994	294.419	0.48358	0.94135
653.15	1.5207	7.8858	0.17735	94.937	388.994	294.057	0.48568	0.93589
663.15	1.9725	7.9008	0.15269	96.300	389.989	293.689	0.48774	0.93061
673.15	2.1024	7.9160	0.13207	97.666	390.980	293.314	0.48978	0.92552
683.15	2.454	7.9313	0.11476	99.033	391.966	292.933	0.49180	0.92059
693.15	2.852	7.9467	0.10014	100.403	392.947	292.544	0.49378	0.91583
703.15	3.299	7.9622	0.08775	101.775	393.923	292.148	0.49574	0.91123
713.15	3.801	7.9778	0.07719	103.150	394.893	291.743	0.49768	0.90677
723.15	4.362	7.9935	0.06815	104.528	395.858	291.330	0.49959	0.90245
733.15	4.986	8.0094	0.06039	105.908	396.816	290.908	0.50148	0.89827
743.15	5.679	8.0252	0.05369	107.292	397.767	290.475	0.50335	0.89422
753.15	6.446	8.0413	0.04789	108.679	398.711	290.032	0.50519	0.89029
763.15	7.292	8.0574	0.04255	110.069	399.649	289.580	0.50702	0.88647
773.15	8.222	8.074	0.03846	111.463	400.579	289.116	0.50882	0.88277
783.15	9.242	8.090	0.03462	112.861	401.501	288.640	0.51061	0.87917
793.15	10.358	8.106	0.03124	114.262	402.415	288.153	0.51238	0.87568
803.15	11.576	8.123	0.02827	115.668	403.321	287.653	0.51412	0.87228
813.15	12.901	8.140	0.02565	117.078	404.218	287.140	0.51586	0.86898
823.15	14.340	8.157	0.02333	118.492	405.106	286.614	0.51757	0.86576
833.15	15.899	8.174	0.02126	119.911	405.985	286.074	0.51927	0.86263

*From Vukalovich, Ivanov, Fokin, and Yakovlev, *Thermophysical Properties of Mercury*, Standartov, Moscow, 1971. For the saturated liquid the specific volume at 203.15 K is 7.26239×10^{-5} m³/kg, etc. All the tabular values for 203.15 K, 213.15 K, 223.15 K, and 233.15 K represent a metastable equilibrium between the subcooled liquid and the saturated vapor.

Saturation and superheat tables and a diagram to 100 bar, 1600 K are given by Reynolds, W. C., *Thermodynamic properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). For a Mollier diagram from 1 to 8200 psia and 2700°R, see Weatherford, W. D., J. C. Tyler, et al., WADD-TR-61-96, 1961.

TABLE 2-280 Saturated Mercury* (Concluded)

T, K	P, bar	$v_f \times 10^5$, m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	h_{fg} , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
843.15	17.584	8.191	0.019426	121.335	406.855	285.520	0.52095	0.85959
853.15	19.403	8.209	0.017785	122.763	407.715	284.952	0.52262	0.85662
863.15	21.36	8.226	0.016317	124.197	408.565	284.368	0.52427	0.85372
873.15	23.46	8.244	0.015000	125.636	409.405	283.769	0.52591	0.85090
883.15	25.72	8.262	0.013815	127.080	410.235	283.155	0.52753	0.84815
893.15	28.14	8.280	0.012748	128.530	411.054	282.524	0.52914	0.84546
903.15	30.72	8.298	0.011784	129.986	411.861	281.875	0.53074	0.84284
913.15	33.47	8.316	0.010911	131.448	412.658	281.210	0.53232	0.84028
923.15	36.41	8.335	0.010120	132.915	413.444	280.529	0.53389	0.83777
933.15	39.53	8.353	0.009401	134.389	414.218	279.829	0.53545	0.83533
943.15	42.85	8.372	0.008746	135.869	414.980	279.111	0.53700	0.83294
953.15	46.36	8.391	0.008150	137.356	415.731	278.375	0.53854	0.83060
963.15	50.09	8.410	0.007604	138.850	416.469	277.619	0.54006	0.82831
973.15	54.03	8.430	0.007105	140.350	417.195	276.845	0.54158	0.82606
983.15	58.20	8.450	0.006648	141.858	417.909	276.051	0.54308	0.82387
993.15	62.59	8.468	0.006228	143.372	418.610	275.238	0.54458	0.82172
1003.15	67.22	8.488	0.005842	144.894	419.298	274.404	0.54607	0.81961
1013.15	72.10	8.508	0.005487	146.424	419.974	273.550	0.54754	0.81754
1023.15	77.22	8.529	0.005159	147.961	420.636	272.675	0.54901	0.81552
1033.15	82.60	8.550	0.004856	149.506	421.286	271.780	0.55047	0.81353
1043.15	88.25	8.570	0.004576	151.059	421.923	270.864	0.55192	0.81158
1053.15	94.17	8.590	0.004317	152.619	422.546	269.927	0.55336	0.80966
1063.15	100.37	8.612	0.004077	154.188	423.156	268.968	0.55479	0.80778
1073.15	106.85	8.632	0.003854	155.766	423.752	267.986	0.55621	0.80593

TABLE 2-281 Saturated Methane*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
90.7 ^t	0.117	2.215.-3	3.976	216.4	759.9	4.231	10.225	3.288	2.02	0.225
95	0.198	2.244.-3	2.463	232.5	769.0	4.406	10.034	3.318	1.71	0.215
100	0.345	2.278.-3	1.479	246.3	776.9	4.556	9.862	3.369	1.56	0.206
105	0.565	2.316.-3	0.940	263.2	785.7	4.719	9.710	3.425	1.33	0.197
110	0.884	2.353.-3	0.625	280.1	794.5	4.882	9.558	3.478	1.22	0.189
115	1.325	2.396.-3	0.430	297.7	802.5	5.035	9.436	3.525	1.09	0.181
120	1.919	2.438.-3	0.306	315.3	810.4	5.188	9.314	3.570	0.98	0.173
125	2.693	2.487.-3	0.223	333.5	817.3	5.332	9.062	3.620	0.89	0.165
130	3.681	2.536.-3	0.167	351.7	824.1	5.476	8.810	3.679	0.81	0.158
135	4.912	2.594.-3	0.127	370.6	829.5	5.614	8.871	3.755	0.73	0.150
140	6.422	2.652.-3	0.098	389.5	834.8	5.751	8.932	3.849	0.66	0.143
145	8.246	2.722.-3	0.077	409.5	844.4	5.885	8.891	3.965	0.61	0.136
150	10.41	2.792.-3	0.061	429.4	853.9	6.019	8.849	4.101	0.56	0.129
155	12.97	2.882.-3	0.049	450.8	848.5	6.151	8.725	4.27	0.51	0.122
160	15.94	2.971.-3	0.039	472.1	843.0	6.283	8.601	4.47	0.46	0.115
165	19.39	3.095.-3	0.032	495.4	840.0	6.417	8.513	4.75	0.42	0.108
170	23.81	3.218.-3	0.026	518.6	837.0	6.551	8.424	5.16	0.38	0.101
175	27.81	3.419.-3	0.020	545.8	827.6	6.697	8.315	5.89	0.34	0.094
180	32.86	3.619.-3	0.016	572.9	818.1	6.843	8.205	7.27	0.30	0.088
185	38.59	3.979.-3	0.012	605.4	797.7	7.017	8.049	11.1	0.25	0.085
190	45.20	4.900.-3	0.008	661.6	750.7	7.293	7.762	70.	0.19	0.090
190.6 ^c	45.99	6.233.-3	0.006	704.4	704.4	7.516	7.516	∞	0.17	∞

*Values reproduced or converted from Goodwin, NBS Tech. Note 653, 1974. t = triple point; c = critical point. The notation 2.215.-3 signifies 2.215×10^{-3} .

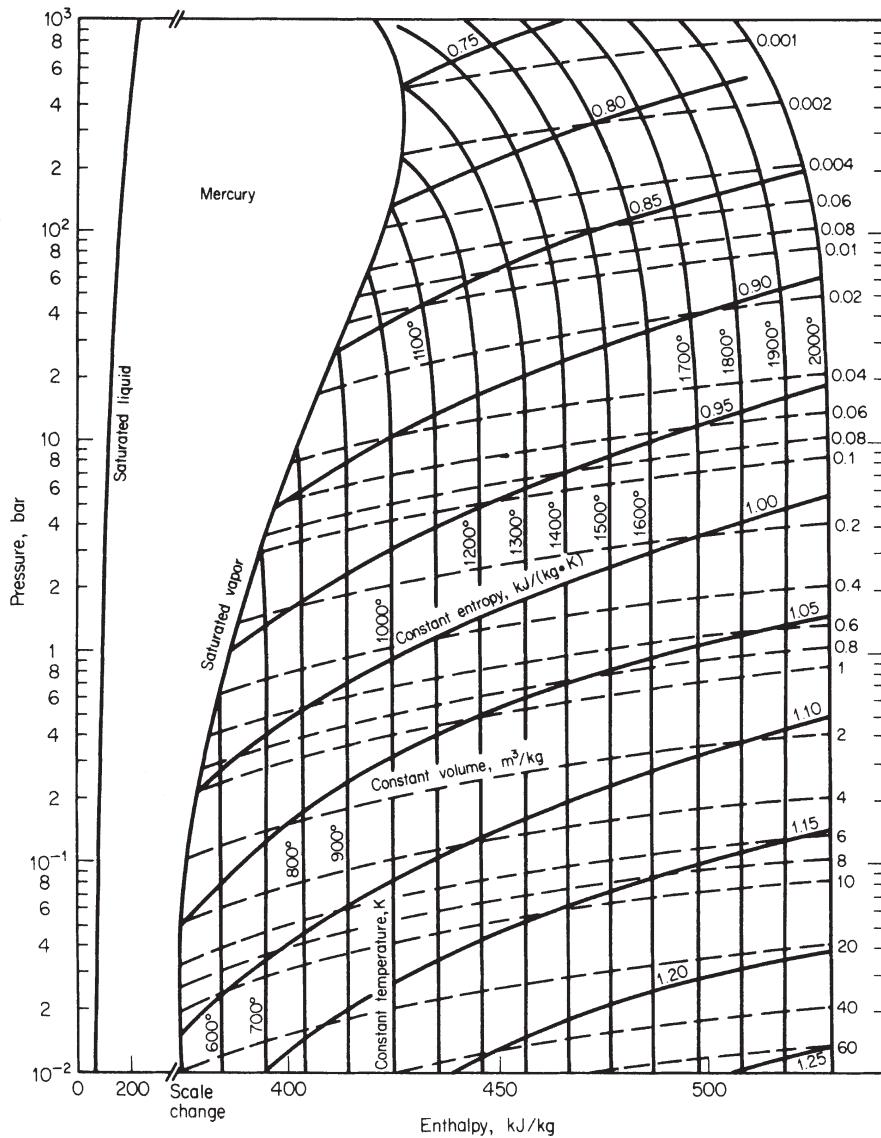


FIG. 2-12 Enthalpy-log-pressure diagram for mercury. (Drawn from tabular data in footnote reference to Table 2-280.)

TABLE 2-282 Superheated Methane*

<i>P</i> , bar	Temperature, K								
	100	150	200	250	300	350	400	450	500
1	<i>v</i> 246.4 <i>s</i> 4.555	0.00228 0.7661 10.152	0.7661 984.3 10.757	1.0299 1090.4 11.230	1.2915 1199.8 11.629	1.5521 1314.8 11.983	1.8122 1437.4 12.310	2.0719 1568.8 12.618	2.3669 1708.9 12.914
	<i>v</i> 247.0 <i>s</i> 4.553	0.00228 0.1434 9.256	0.1434 976.1 9.896	0.2006 1084.7 10.381	0.2549 1195.5 10.785	0.3083 1311.5 11.142	0.3611 1434.7 11.471	0.4136 1566.6 11.781	0.4657 1706.9 12.066
	<i>v</i> 247.8 <i>s</i> 4.549	0.00227 0.0643 8.797	0.0643 943.6 9.501	0.0968 965.5 10.002	0.1254 1077.9 10.414	0.1528 1190.6 10.775	0.1798 1307.9 11.106	0.2063 1432.0 11.417	0.2327 1564.1 11.715
20	<i>v</i> 249.4 <i>s</i> 4.542	0.00227 0.00277 6.003	0.00277 0.0446 9.059	0.0446 1063.6 9.603	0.0606 1180.7 10.030	0.0751 1300.6 10.400	0.0891 1426.5 10.736	0.1027 1560.3 11.050	0.1162 1702.1 11.349
	<i>v</i> 252.5 <i>s</i> 4.528	0.00226 0.00274 5.973	0.00274 0.0176 8.465	0.0176 1032.9 9.155	0.0281 1160.5 9.621	0.0363 1286.0 10.008	0.0438 1415.7 10.354	0.0510 1552.1 10.674	0.0579 1696.0 10.978
	<i>v</i> 255.7 <i>s</i> 4.515	0.00226 0.00271 5.946	0.00271 0.00615 7.623	0.00615 734.0 8.847	0.0173 999.8 9.359	0.0234 1140.0 9.765	0.0287 1271.7 10.121	0.0338 1405.1 10.440	0.0386 1544.2 10.756
80	<i>v</i> 258.9 <i>s</i> 4.502	0.00225 0.00268 5.920	0.00268 0.00411 7.209	0.00411 660.5 8.590	0.0119 964.4 9.158	0.0171 1119.7 9.584	0.0213 1257.7 9.951	0.0252 1394.9 10.283	0.0289 1536.6 10.595
	<i>v</i> 262.1 <i>s</i> 4.489	0.00224 0.00266 5.897	0.00266 0.00375 7.090	0.00375 644.5 8.364	0.00888 928.5 8.991	0.0133 1099.6 9.437	0.0169 1244.2 9.814	0.0201 1385.2 10.153	0.0231 1529.4 10.469
	<i>v</i> 270.2 <i>s</i> 4.458	0.00223 0.00261 5.843	0.00261 0.00337 6.930	0.00337 630.2 7.953	0.00555 860.0 8.664	0.00852 1054.1 9.155	0.0111 1213.1 9.555	0.0134 1362.8 9.907	0.0155 1513.0 10.233
200	<i>v</i> 278.3 <i>s</i> 4.429	0.00221 0.00256 5.796	0.00256 0.00318 6.829	0.00318 626.5 7.719	0.00447 825.0 8.426	0.00644 1019.8 8.944	0.00837 1187.2 9.362	0.0101 1343.8 9.727	0.0118 1498.9 10.060
	<i>v</i> 294.7 <i>s</i> 4.373	0.00218 0.00249 5.714	0.00249 0.00296 6.690	0.00296 629.2 7.471	0.00369 804.4 8.122	0.00474 982.9 8.649	0.00593 1153.6 9.085	0.00708 1316.8 9.465	0.00818 1478.5 9.811
	<i>v</i> 473.8 <i>s</i> 5.645	0.00244 0.00282 6.588	0.00282 0.00336 7.323	0.00336 802.4 7.935	0.00406 970.1 8.451	0.00486 1137.8 8.893	0.00569 1303.0 9.280	0.00560 1467.7 9.633	0.00729 1634.7 9.633
500	<i>v</i> 488.8 <i>s</i> 5.584	0.00239 0.00272 6.507	0.00272 0.00315 7.215	0.00315 807.7 7.802	0.00368 969.0 8.307	0.00428 1132.8 8.748	0.00492 1297.8 9.139	0.00555 1464.2 9.496	0.00616 1633.2 9.496

*Converted and rounded off from the tables of Goodwin, NBS Tech. Note 654, 1974. *v* = specific volume, m³/kg; *h* = specific enthalpy, kJ/kg; *s* = specific entropy, kJ/(kg·K).

For a thermodynamic diagram from 0.1 to 400 bar and 620°C, see the 1993 ASHRAE *Handbook—Fundamentals* (SI ed.).

Saturation and superheat tables and a chart to 6000 psia, 680°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. See also Friend, D. G., J. F. Ely, et al., *J. Phys. Chem. Ref. Data.* **18**, 2 (1989): 583–638.

2-254 PHYSICAL AND CHEMICAL DATA
TABLE 2-283 Thermophysical Properties of Saturated Methanol

Pressure, bar	Temp., K	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/kg·K	s_g , kJ/kg·K	c_{pf} , kJ/kg·K	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	P_f
$4 \times 10^{-6}^t$	175.6	0.001 057	1700000	0.0	1303.1	2.8114	10.2328				
0.1	288.4	0.001 257	7.309	261.0	1440.3	3.9383	8.0281	2.531	625	0.204	7.75
0.2	301.7	0.001 276	3.801	293.9	1455.4	4.0493	7.9032	2.554	525	0.196	6.84
0.5	320.7	0.001 307	1.599	345.0	1476.2	4.2117	7.7386	2.669	401	0.193	5.55
1.013	337.7	0.001 336	0.819	391.7	1492.1	4.3516	7.6104	2.777	329	0.189	4.83
1.5	348.0	0.001 356	0.5632	421.0	1500.3	4.4361	7.5379	2.845	288	0.186	4.41
2.0	356.0	0.001 371	0.4276	444.2	1505.8	4.5014	7.4836	2.894	268	0.184	4.22
2.5	362.5	0.001 385	0.3443	463.6	1509.8	4.5536	7.4398	2.946	242	0.182	3.92
3.0	368.0	0.001 396	0.2893	479.8	1512.4	4.5992	7.4051	2.984	227	0.181	3.74
4.0	377.1	0.001 417	0.2188	507.8	1515.9	4.6728	7.3474	3.050	204	0.179	3.48
5	384.5	0.001 434	0.17569	529.7	1517.4	4.7307	7.2992	3.117	187	0.178	3.27
6	390.8	0.001 450	0.14683	549.6	1518.4	4.7836	7.2624	3.176	174	0.177	3.12
8	401.3	0.001 479	0.11015	582.7	1518.0	4.8678	7.1988	3.265	156	0.175	2.91
10	409.8	0.001 504	0.08783	610.3	1516.1	4.9366	7.1471	3.349	141	0.173	2.73
15	426.3	0.001 560	0.05761	665.8	1507.9	5.0708	7.0461	3.540	117	0.171	2.42
20	438.9	0.001 611	0.04224	710.5	1553.8	5.1744	6.9677	3.72	102	0.169	2.25
25	449.3	0.001 666	0.03290	749.0	1486.4	5.2605	6.9017	3.91	92	0.167	2.15
30	458.2	0.001 710	0.02661	783.8	1474.7	5.3355	6.8435	4.12	84	0.165	2.10
40	472.9	0.001 814	0.01863	846.7	1450.1	5.4650	6.7409	4.67	72	0.160	2.10
50	484.9	0.001 934	0.01373	905.2	1423.2	5.5793	6.6475	5.55	63	0.154	2.27
60	495.1	0.002 086	0.01032	963.3	1391.8	5.6889	6.5543				
80	508.1	0.002 507	0.00642	1065.3	1318.7	5.8803	6.3791				
80.95 ^c	512.6	0.003 715	0.00372	1186.8	1186.8	6.0979	6.0979				

t = triple point; *c* = critical point. *v*, *h*, *s*, and *c_p* interpolated and converted from Goodwin, R. D., *J. Phys. Chem. Ref. Data*, **16**, 4 (1987): 799–891.

TABLE 2-284 Thermodynamic Properties of Compressed Methanol

Pressure, bar	Temperature, K									
	200	250	300	350	400	450	500	550	600	
<i>v</i> (m ³ /kg)	0.001137	0.001203	7.630	8.942	10.23	11.56	12.84			15.45
0.1 <i>h</i> (kJ/kg)	57.5	169.8	1456.7	1529.5	1607.5	1691.5	1781.7	1878.1		1980.2
<i>s</i> (kJ/kg-K)	3.096	3.597	8.081	8.305	8.514	8.711	8.901	9.085		9.263
<i>v</i> (m ³ /kg)	0.001137	0.001202	0.001274	1.764	2.033	2.296	2.558	2.818		3.078
0.5 <i>h</i> (kJ/kg)	57.5	169.9	290.5	1522.7	1603.0	1687.9	1778.9	1875.3		1977.4
<i>s</i> (kJ/kg-K)	3.096	3.597	4.038	7.877	8.091	8.291	8.482	8.666		8.844
<i>v</i> (m ³ /kg)	0.001137	0.001202	0.001274	0.8560	0.9958	1.1283	1.2843	1.3870		1.5157
1.013 <i>h</i> (kJ/kg)	57.6	169.9	290.5	1514.0	1598.7	1685.1	1795.4	1873.5		1975.8
<i>s</i> (kJ/kg-K)	3.096	3.597	4.038	7.675	7.902	8.105	8.117	8.482		8.660
<i>v</i> (m ³ /kg)	0.001136	0.001201	0.001272	0.001357	0.001474	0.1068	0.1236	0.1381		0.1519
10 <i>h</i> (kJ/kg)	58.4	170.7	291.2	427.4	578.8	1638.1	1751.5	1858.0		1965.2
<i>s</i> (kJ/kg-K)	3.095	3.596	4.036	4.451	4.857	7.427	7.667	7.870		8.056
<i>v</i> (m ³ /kg)	0.001136	0.001201	0.001272	0.001356	0.001472	0.0673	0.0806	0.0911		0.1007
15 <i>h</i> (kJ/kg)	58.8	171.1	291.6	427.7	578.9	1601.9	1735.6	1849.4		1960.2
<i>s</i> (kJ/kg-K)	3.094	3.595	4.035	4.450	4.856	7.253	7.536	7.752		7.946
<i>v</i> (m ³ /kg)	0.001135	0.001200	0.001271	0.001355	0.001469	0.0466	0.0589	0.0675		0.0751
20 <i>h</i> (kJ/kg)	59.2	171.6	292.0	428.1	579.0	1565.3	1717.7	1840.0		1954.8
<i>s</i> (kJ/kg-K)	3.094	3.595	4.035	4.449	4.854	7.087	7.431	7.664		7.864
<i>v</i> (m ³ /kg)	0.001134	0.001199	0.001269	0.001355	0.001465	0.001659	0.0367	0.0436		0.0492
30 <i>h</i> (kJ/kg)	60.1	172.4	292.9	428.8	579.4	751.3	1675.4	1818.7		1942.7
<i>s</i> (kJ/kg-K)	3.092	3.593	4.036	4.447	4.851	5.264	7.253	7.526		7.743
<i>v</i> (m ³ /kg)	0.001133	0.001198	0.001268	0.001350	0.001461	0.001649	0.0251	0.0314		0.0361
40 <i>h</i> (kJ/kg)	61.0	173.3	293.7	429.5	579.8	750.4	1623.0	1794.2		1928.8
<i>s</i> (kJ/kg-K)	3.091	3.592	4.032	4.445	4.849	5.258	7.088	7.414		7.650
<i>v</i> (m ³ /kg)	0.001133	0.001197	0.001266	0.001348	0.001457	0.001637	0.0176	0.0239		0.0282
50 <i>h</i> (kJ/kg)	61.9	174.2	294.5	430.2	580.2	749.7	1556.4	1766.7		1913.4
<i>s</i> (kJ/kg-K)	3.090	3.591	4.030	4.443	4.846	5.579	6.912	7.314		7.570
<i>v</i> (m ³ /kg)	0.001131	0.001196	0.001265	0.001346	0.001453	0.001628	0.0120	0.0188		0.0228
60 <i>h</i> (kJ/kg)	62.8	175.0	295.3	430.9	580.6	749.1	1461.8	1736.1		1896.6
<i>s</i> (kJ/kg-K)	3.089	3.589	4.029	4.442	4.843	5.248	6.692	7.220		7.500
<i>v</i> (m ³ /kg)	0.001130	0.001194	0.001263	0.001343	0.001448	0.001614	0.002084	0.01359		0.0174
75 <i>h</i> (kJ/kg)	64.1	176.3	296.6	431.9	581.2	748.3	982.1	1683.9		1869.1
<i>s</i> (kJ/kg-K)	3.087	3.587	4.027	4.439	4.839	5.241	5.718	7.081		7.405
<i>v</i> (m ³ /kg)	0.001128	0.001191	0.001259	0.001337	0.001439	0.001595	0.001952	0.		0.01188
100 <i>h</i> (kJ/kg)	66.3	178.5	298.6	433.8	582.4	747.5	964.8	1572.9		1818.8
<i>s</i> (kJ/kg-K)	3.084	3.584	4.023	4.435	4.833	5.230	5.673	6.829		7.261
<i>v</i> (m ³ /kg)	0.001125	0.001186	0.001252	0.001328	0.001423	0.001562	0.001825			0.006513
150 <i>h</i> (kJ/kg)	70.7	182.8	302.8	437.4	584.9	746.8	948.4	1248.8		1704.3
<i>s</i> (kJ/kg-K)	3.078	3.578	4.016	4.426	4.822	5.211	5.622	6.302		6.997
<i>v</i> (m ³ /kg)	0.001121	0.001182	0.001246	0.001317	0.001408	0.001535	0.001751	0.002314		0.004091
200 <i>h</i> (kJ/kg)	75.1	187.2	307.0	441.2	587.8	747.0	939.9	1223.5		1583.5
<i>s</i> (kJ/kg-K)	3.071	3.571	4.009	4.418	4.811	5.194	5.587	6.125		6.752
<i>v</i> (m ³ /kg)	0.001113	0.001172	0.001234	0.001302	0.001384	0.001492	0.001656	0.001957		0.002600
300 <i>h</i> (kJ/kg)	83.9	195.9	315.4	448.9	593.8	749.4	932.0	1173.4		1443.5
<i>s</i> (kJ/kg-K)	3.060	3.559	3.996	4.403	4.791	5.166	5.537	5.996		6.466
<i>v</i> (m ³ /kg)	0.001107	0.001164	0.001223	0.001288	0.001363	0.001459	0.001593	0.001808		0.002182
400 <i>h</i> (kJ/kg)	92.7	204.7	324.0	456.9	600.5	753.4	929.6	1154.4		1388.1
<i>s</i> (kJ/kg-K)	3.048	3.548	3.983	4.388	4.774	5.142	5.500	5.926		6.335
<i>v</i> (m ³ /kg)	0.001101	0.001156	0.001213	0.001274	0.001345	0.001431	0.001546	0.001716		0.001980
500 <i>h</i> (kJ/kg)	101.5	213.4	332.6	465.1	607.7	758.4	930.4	1145.6		1360.6
<i>s</i> (kJ/kg-K)	3.037	3.536	3.971	4.375	4.757	5.121	5.470	5.880		6.254

Converted and interpolated from Goodwin, R. D., *J. Phys. Chem. Ref. Data*, **16**, 4 (1987): 799–891. These extensive tables extend to 700 bar for temperatures from 175.6 to 800 K. Another extensive compilation is by deReuck, K. M. and R. J. B. Craven, *Methanol*, C.R.C. Press, 1993 (320 pp.).

Equations and diagrams to 30 bar, 200°C are given by Eichholz, H. D., S. Schulz, et al., *Kalte u Klim., no. 9*, (1981) 322–331. For pressures to 1040 bar, 298–489 K, see Machado, J. R. S. and W. B. Street, *J. Chem. Eng. Data*, **28** (1983): 218–223; to 2800 bar from 273 to 333 K, see Sun, T., S. N. Biswas, et al., *J. Chem. Eng. Data*, **33** (1988): 395–398. Dissociation was considered by Yerlett, T. K. and C. J. Wormald, *J. Chem. Thermo.*, **18** (1986): 719–726, and by Kazarnovskii, Ya. S. and E. V. Pavlova, *Russ. J. Phys. Chem.*, **56**, 6 (1982): 847–851.

TABLE 2-285 Saturated Methyl Chloride*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
175	0.0117	8.84,-4	27.90	274.5	764.3	3.529	6.328	1.469		
180	0.0165	8.91,-4	19.85	280.9	767.7	3.570	6.274	1.472		
185	0.0233	8.97,-4	14.12	287.5	771.0	3.603	6.222	1.475		
190	0.0327	9.04,-4	10.12	294.5	774.3	3.647	6.172	1.477		
195	0.0462	9.10,-4	7.208	301.7	777.5	3.684	6.124	1.480		
200	0.0653	9.17,-4	5.137	309.0	780.7	3.722	6.080	1.483	4.44	0.241
205	0.0919	9.25,-4	3.835	316.3	783.9	3.756	6.038	1.486	4.27	0.236
210	0.1315	9.33,-4	2.656	323.7	787.0	3.791	5.998	1.489	4.11	0.232
215	0.181	9.40,-4	1.975	331.0	790.1	3.825	5.961	1.492	3.96	0.228
220	0.243	9.48,-4	1.505	338.4	793.2	3.859	5.928	1.496	3.82	0.224
225	0.319	9.56,-4	1.168	345.7	796.3	3.892	5.896	1.500	3.69	0.219
230	0.417	9.65,-4	0.911	353.1	799.3	3.925	5.866	1.504	3.57	0.215
235	0.539	9.73,-4	0.718	360.5	802.3	3.957	5.845	1.508	3.46	0.211
240	0.688	9.81,-4	0.572	368.0	805.3	3.988	5.822	1.513	3.35	0.207
245	0.866	9.89,-4	0.462	375.6	808.2	4.019	5.786	1.518	3.25	0.202
250	1.076	9.98,-4	0.377	383.2	811.1	4.050	5.762	1.523	3.16	0.198
255	1.328	10.05,-4	0.311	390.7	814.0	4.080	5.740	1.528	3.08	0.194
260	1.627	10.18,-4	0.257	398.3	816.8	4.110	5.720	1.533	3.00	0.190
265	1.970	10.27,-4	0.215	406.0	819.4	4.139	5.699	1.539	2.92	0.186
270	2.364	10.36,-4	0.1807	413.7	822.0	4.168	5.680	1.546	2.85	0.182
275	2.830	10.46,-4	0.1524	421.5	824.4	4.197	5.662	1.554	2.78	0.177
280	3.347	10.57,-4	0.1301	429.4	826.8	4.225	5.644	1.565	2.72	0.173
285	3.936	10.68,-4	0.1115	437.3	829.0	4.253	5.628	1.574	2.66	0.169
290	4.612	10.79,-4	0.0960	445.2	831.2	4.280	5.612	1.583	2.61	0.165
295	5.361	10.91,-4	0.0830	453.2	833.2	4.308	5.597	1.594	2.56	0.160
300	6.189	11.03,-4	0.0723	461.2	835.2	4.334	5.581	1.605	2.51	0.156
305	7.110	11.15,-4	0.0632	469.3	837.0	4.361	5.567	1.617	2.46	0.152
310	8.111	11.27,-4	0.0556	477.4	838.8	4.388	5.553	1.631	2.42	0.148
315	9.243	11.40,-4	0.0489	485.6	840.5	4.414	5.540	1.644	2.37	0.143
320	10.47	11.55,-4	0.0433	493.8	841.9	4.440	5.527	1.658	2.33	0.139
325	11.78	11.70,-4	0.0386	502.1	843.3	4.465	5.516		2.30	0.135
330	13.27	11.86,-4	0.0343	510.4	844.5	4.491	5.504		2.27	0.131
340	16.52	12.17,-4	0.0282	518.8	846.4	4.542	5.481		2.12	0.124
350	20.53	12.54,-4	0.0228	538.3	847.5	4.592	5.457		1.99	0.117
360	25.29	12.97,-4	0.0186	562.9	847.6	4.643	5.434		1.87	0.110
370	30.74	13.47,-4	0.0151	581.6	845.9	4.694	5.398		1.77	0.103
380	36.99	14.11,-4	0.0117	602.8	842.6	4.747	5.382		1.67	0.095
390	44.05	14.67,-4	0.0096	622.9	837.4	4.805	5.358		1.59	0.086
400	52.29	15.66,-4	0.0075	643.6	826.4	4.870	5.323		1.51	0.075
405	56.6	16.48,-4	0.0063	663.2	819.1	4.904	5.289			
410	61.5	17.97,-4	0.0052	677.3	807.1	4.954	5.256			
415	67.4	21.10,-4	0.0038	714.1	778.6	5.025	5.200			
416 ^c	69.0	27.40,-4	0.0027	749.3	749.3	5.116	5.116			

*Interpolated by P. E. Liley from the Landolt-Börnstein band IVa, p. 677, 1967 tables by Steinle/Dienemann. *c* = critical point. The notation 8.84,-4 signifies 8.84×10^{-4} .

TABLE 2-286 Saturated Neon*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
10		6.654,-4		0.75		0.0992		0.278		
20		6.823,-4		6.78		0.4906		0.945		
24.6 ^m		6.696,-4		11.96		0.7257		1.345		
24.6 ^m	0.434	8.012,-4	0.2266	28.22	117.0	1.388	5.006	1.802	1.57	0.146
26	0.718	8.172,-4	0.1429	30.90	118.1	1.494	4.846	1.868	1.37	0.132
28	1.321	8.413,-4	0.0817	34.75	119.3	1.634	4.653	1.955	1.16	0.124
30	2.238	8.687,-4	0.0501	38.80	120.1	1.771	4.483	2.052	1.00	0.115
32	3.552	9.001,-4	0.0323	43.06	120.6	1.905	4.329	2.163	0.84	0.106
34	5.352	9.370,-4	0.0217	47.57	120.6	2.036	4.184	2.302	0.71	0.097
36	7.728	9.820,-4	0.0149	52.34	119.9	2.166	4.043	2.506	0.59	0.088
38	10.78	1.039,-3	0.0104	57.52	118.4	2.297	3.900	2.825	0.48	0.078
40	14.62	1.116,-3	0.0073	63.33	115.8	2.435	3.749	3.436	0.38	0.069
42	19.39	1.232,-3	0.0050	69.82	111.8	2.582	3.582	5.26	0.31	0.059
44	25.22	1.538,-3	0.0031	80.83	103.0	2.812	3.316	25.0	0.25	
44.4 ^c	26.53	2.070,-3	0.0021	92.50	92.5	3.062	3.062	∞		

*Values extracted and in some cases rounded off from those cited in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. *m* = melting point; *c* = critical point. The notation 6.654,-4 signifies 6.654×10^{-4} . This source contains values for the compressed state up to 1000 bar, etc. This book was published in English translation by Hemisphere, New York 1988 (604 pp.).

Saturation and superheat tables and a diagram to 200 bar, 320 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Saturation and superheat tables to 60,000 psia, 900°R and a chart to 4000 psia, 560°R appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

TABLE 2-287 Compressed Neon*

Temperature, K	Pressure, bar											
	1	10	20	40	60	80	100	200	400	600	800	1000
100	v 195.4	0.4117 0.0410	0.0204 194.0	0.0102 192.4	6.76.-3 189.4	5.08.-3 186.6	4.09.-3 184.0	2.22.-3 181.6	1.42.-3 174.1	1.18.-3 173.3	1.06.-3 180.0	9.74.-4 189.2
	h 6.129	5.168	4.869	4.556	4.363	4.221	4.106	3.739	3.386	3.197	3.066	199.2
	s 6.844	5.893	5.605	5.315	5.143	5.020	4.924	4.620	4.308	4.124	3.994	2.964
200	v 298.5	0.8243 0.0828	0.0416 298.4	0.0210 298.2	0.0142 298.2	0.0107 298.3	8.69.-3 298.3	4.61.-3 299.4	2.61.-3 304.6	1.95.-3 312.4	1.63.-3 321.8	1.43.-3 332.1
	h 401.6	505.0	505.4	402.8	403.5	404.1	404.9	408.8	417.8	427.8	438.5	449.7
	s 7.262	6.312	6.026	5.739	5.570	5.450	5.357	5.065	4.769	4.593	4.469	4.372
300	v 607.6	1.236 504.6	0.1241 505.4	0.0624 506.4	0.0315 507.4	0.0212 508.3	0.0129 509.3	6.77.-3 514.4	3.71.-3 525.3	2.69.-3 536.7	2.18.-3 548.4	1.87.-3 560.2
	h 7.558	6.609	6.323	6.037	5.896	5.750	5.657	5.369	5.078	4.907	4.785	4.690
	s 7.788	6.839	6.553	6.267	6.100	5.981	5.889	5.601	5.313	5.144	5.023	4.929
400	v 710.6	2.060 813.5	0.2066 814.1	0.1036 814.7	0.0521 816.0	0.0350 817.2	0.0264 818.5	0.0213 819.7	0.0110 826.0	5.82.-3 838.9	4.10.-3 851.9	3.24.-3 865.0
	h 7.975	7.027	6.741	6.455	6.288	6.169	6.077	5.791	5.504	5.335	5.215	5.122
	s 8.134	7.186	6.900	6.614	6.447	6.328	6.236	5.950	5.664	5.496	5.376	5.284
500	v 916.5	3.296 917.1	0.3302 917.7	0.1655 919.0	0.0831 920.3	0.0556 921.6	0.0419 922.9	0.0336 929.3	0.0172 942.4	8.92.-3 955.7	6.18.-3 969.0	4.81.-3 982.2
	h 8.272	7.323	7.038	6.752	6.585	6.466	6.374	6.088	5.802	5.634	5.515	5.423
	s 8.272	7.323	7.038	6.752	6.585	6.466	6.374	6.088	5.802	5.634	5.515	5.423
600	v 1020	3.708 1020	0.3714 1021	0.1861 1022	0.0934 1023	0.0625 1025	0.0470 1026	0.0378 1033	0.0192 1046	9.96.-3 1059	6.87.-3 1073	5.32.-3 1086
	h 8.393	7.444	7.159	6.873	6.706	6.588	6.496	6.210	5.924	5.756	5.637	5.545
	s 8.502	7.553	7.267	6.982	6.815	6.696	6.604	6.318	6.032	5.856	5.746	5.654

*Values extracted and in some cases rounded off from those cited in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. This source contains an exhaustive tabulation of values. v = specific volume, m³/kg; h = specific enthalpy, kJ/kg; s = specific entropy, kJ/(kg·K). The notation 6.76.-3 signifies 6.76 × 10⁻³. This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

TABLE 2-288 Saturated Nitrogen (R728)*

T, K	P, bar	v _f , 10 ⁻³ m ³ /kg	v _g , m ³ /kg	h _f , kJ/kg	h _g , kJ/kg	s _f , kJ/(kg·K)	s _g , kJ/(kg·K)	c _{pf} , kJ/(kg·K)	μ _f , 10 ⁻⁴ Pa·s	k _f , W/(m·K)
63.15°	0.1253	1.155	1477	-148.5	64.1	2.459	5.826	1.928		0.170
65	0.1743	1.165	1091	-144.9	65.8	2.516	5.757	1.930	2.74	0.160
70	0.3859	1.193	525.6	-135.2	70.5	2.657	5.595	1.937	2.17	0.151
75	0.7609	1.224	281.8	-125.4	74.9	2.789	5.460	1.948	1.77	0.141
77.35	1.0133	1.239	216.9	-120.8	76.8	2.849	5.404	1.955	1.60	0.136
80	1.369	1.258	164.0	-115.6	78.9	2.913	5.345	1.964	1.48	0.132
85	2.287	1.297	101.7	-105.7	82.3	3.032	5.244	1.989	1.27	0.123
90	3.600	1.340	66.28	-95.6	85.0	3.147	5.152	2.028	1.10	0.114
95	5.398	1.390	44.87	-85.2	86.8	3.256	5.067	2.086	0.97	0.105
100	7.775	1.447	31.26	-74.5	87.7	3.363	4.985	2.176	0.87	0.097
105	10.83	1.514	22.23	-63.8	87.4	3.469	4.904	2.319	0.79	0.088
110	14.67	1.597	15.98	-51.4	85.6	3.575	4.820	2.566	0.71	0.080
115	19.40	1.714	11.47	-38.1	81.8	3.687	4.729	3.063	0.60	0.071
120	25.15	1.892	8.031	-21.4	74.3	3.821	4.619		0.48	0.063
125	32.05	2.324	5.016	5.1	57.2	4.024	4.444		0.32	0.052
126.25°	33.96	3.289	3.289	34.8	34.8	4.252	4.252	∞		∞

*Reproduced and converted from Vasserman and Rabinovich, *Thermophysical Properties of Liquid Air and Its Components*, Standartov, Moscow, 1968; and Israel Program for Scientific Translations, TT 69-55092, 1970. t = triple point; c = critical point.

Other extensive tables are given by Angus, S., *International Thermodynamic Tables of the Fluid State—6. Nitrogen*, Pergamon, 1977 (244 pp.); Hanley, H. J. M., R. D. McCarty, et al., *J. Phys. Chem. Ref. Data*, 3 (1974): 979–1019.

Saturation and superheat tables to 30,000 psia and a chart to 10,000 psia, all to 860°F, appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

The 1993 ASHRAE Handbook—Fundamentals (SI ed.) has a thermodynamic chart for pressures from 0.1 to 800 bar and temperatures from 80 to 500 K.

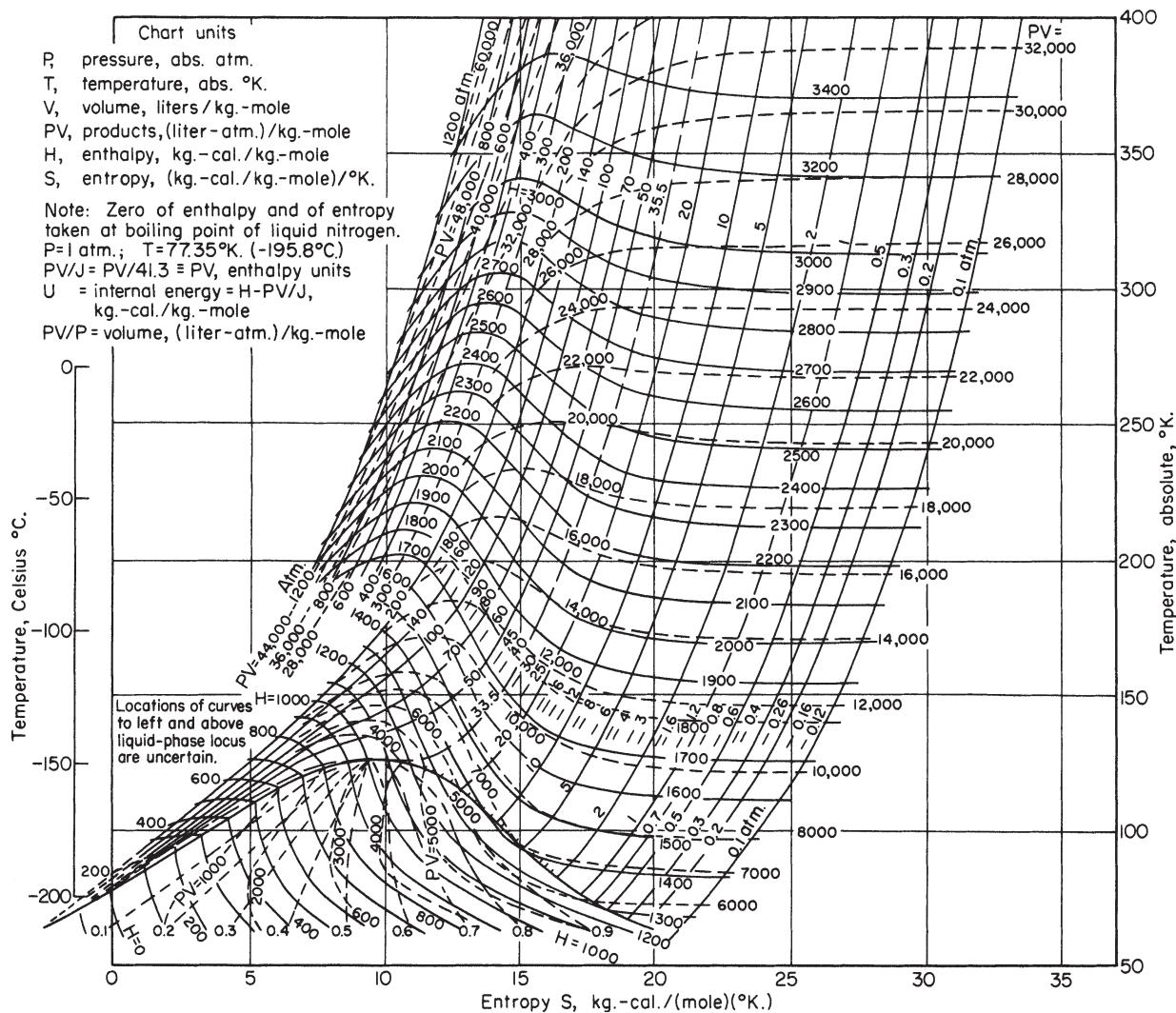


FIG. 2-13 Temperature-entropy diagram for nitrogen. Section of $T-S$ diagram for nitrogen by E. S. Burnett, 1950. (Reprinted from U.S. Bur. Mines Rep. Invest. 4729.)

TABLE 2-289 Thermophysical Properties of Nitrogen (R728) at Atmospheric Pressure

T (K)	77.4 ^b	80	100	120	140	160	180	200	220	240
v (m ³ /kg)	0.2164	0.2252	0.2871	0.3474	0.4071	0.4664	0.5255	0.5845	0.6434	0.7023
h (kJ/kg)	76.7	80.0	101.9	123.1	144.2	165.2	186.1	207.0	227.8	248.7
s (kJ/kg-K)	5.403	5.446	5.690	5.884	6.046	6.186	6.309	6.419	6.519	6.609
c _p (kJ/kg-K)	1.341	1.196	1.067	1.056	1.050	1.047	1.045	1.043	1.043	1.042
Z	0.9545	0.9610	0.9801	0.9883	0.9927	0.9952	0.9967	0.9977	0.9984	0.9990
\bar{v}_s (m/s)	172	177	202	222	240	257	273	288	302	316
η (10 ⁻⁶ Pa-s)	5.0	5.2	6.7	8.0	9.3	10.6	11.8	12.9	14.0	15.0
k (W/m-K)	0.0074	0.0077	0.0098	0.0117	0.0136	0.0154	0.0171	0.0187	0.0203	0.0218
N _{Pr}	0.913	0.811	0.728	0.727	0.723	0.721	0.720	0.719	0.718	0.717
T (K)	260	280	300	320	340	360	380	400	420	440
v (m ³ /kg)	0.7611	0.8199	0.8786	0.9371	0.9960	1.0546	1.1134	1.1719	1.2305	1.2892
h (kJ/kg)	269.5	290.3	311.2	332.0	352.8	373.7	394.5	411.5	436.3	457.3
s (kJ/kg-K)	6.693	6.770	6.842	6.909	6.972	7.032	7.088	7.142	7.193	7.242
c _p (kJ/kg-K)	1.042	1.041	1.041	1.042	1.042	1.043	1.044	1.045	1.047	1.048
Z	0.9994	0.9997	0.9998	0.9999	1.0000	1.0001	1.0002	1.0002	1.0002	1.0003
\bar{v}_s (m/s)	329	341	359	365	376	387	397	408	417	427
η (10 ⁻⁶ Pa-s)	16.0	17.0	17.9	18.8	19.7	20.5	21.4	22.2	23.0	23.8
k (W/m-K)	0.0232	0.0247	0.0260	0.0273	0.0286	0.0299	0.0311	0.0324	0.0336	0.0347
N _{Pr}	0.717	0.716	0.716	0.717	0.717	0.717	0.717	0.717	0.717	0.717
T (K)	460	480	500	600	700	800	900	1000	1500	2000
v (m ³ /kg)	1.3481	1.4065	1.4654	1.758	2.052	2.344	2.636	2.931	4.396	5.862
h (kJ/kg)	478.3	499.3	520.4	626.9	735.6	846.6	960.0	1075.7	1680.5	2313.5
s (kJ/kg-K)	7.288	7.333	7.376	7.570	7.738	7.886	8.019	8.141	8.630	8.995
c _p (kJ/kg-K)	1.051	1.053	1.056	1.075	1.098	1.122	1.146	1.167	1.244	1.284
Z	1.0003	1.0004	1.0004	1.000	1.000	1.000	1.000	1.001	1.001	1.001
\bar{v}_s (m/s)	437	446	455	496	534	568	601	631	765	879
η (10 ⁻⁶ Pa-s)	24.5	25.3	26.0	29.5	32.8	35.9	38.8	41.6		
k (W/m-K)	0.0359	0.0371	0.0383	0.0440	0.0496	0.0551	0.0606	0.0658		
N _{Pr}	0.718	0.718	0.718	0.722	0.726	0.730	0.734	0.737		

b = normal boiling point.

TABLE 2-290 Saturated Nitrogen Tetroxide

Pressure, bar	Temperature, K	v _f , m ³ /kg	v _g , m ³ /kg	M _f	M _g
1.0133	299.32	0.000 694	0.2996	91.857	79.157
2	309.57	0.000 711	0.1630	91.886	76.503
4	326.66	0.000 733	0.0876	91.766	73.538
6	337.43	0.000 749	0.0608	91.625	71.748
8	345.45	0.000 762	0.0469	91.488	70.480
10	351.88	0.000 774	0.0382	91.346	69.483
15	364.09	0.000 800	0.0262	90.979	67.742
20	373.17	0.000 822	0.0199	90.601	66.547
30	386.57	0.000 863	0.0133	89.823	64.997
40	396.52	0.000 903	0.0098	89.018	64.099
50	404.50	0.000 945	0.00761	88.191	63.532
60	411.20	0.000 993	0.00607	87.344	63.181
80	422.07	0.001 129	0.00394	85.602	62.959
100	430.76	0.001 577	0.00209	83.817	63.366

Condensed from McCarty, R. D., H-U. Steurer, et al., NBS IR 86 - 3054, 1986 (106 pp.). M = mol wt for the reaction N₂O₄ → 2NO₂. No derived thermodynamic functions were tabulated due to unduly large differences in literature values, but 92 references are given.

TABLE 2-291 Saturated Nitrous Oxide

Temp., °F	Pressure, psia	v _f , ft ³ /lb _m	v _g , ft ³ /lb _m	h _f , Btu/lb _m	h _g , Btu/lb _m	s _f , Btu/lb _m °R	s _g , Btu/lb _m °R
-127.2	14.70	0.01310	5.069	0.0	161.7	0.0000	0.4864
-100	33.68	0.01358	2.374	11.7	165.9	0.0304	0.4591
-80	56.79	0.01398	1.463	20.8	168.8	0.0534	0.4433
-60	90.29	0.01444	0.939	30.2	171.5	0.0782	0.4315
-40	136.68	0.01495	0.648	40.3	173.7	0.1044	0.4222
-20	198.62	0.01555	0.450	50.6	175.3	0.1296	0.4133
0	278.97	0.01625	0.316	60.5	176.2	0.1518	0.4036
20	380.88	0.01711	0.227	70.2	176.2	0.1718	0.3928
40	507.51	0.01819	0.164	80.3	175.0	0.1920	0.3815
60	662.69	0.01968	0.117	91.9	172.1	0.2145	0.3687
80	851.5	0.0222	0.0792	105.7	165.0	0.2382	0.3480
90	961.0	0.0247	0.0611	114.7	157.5	0.2523	0.3302
97.6 ^c	1052.2	0.0354	0.0354	136.4	136.4	0.2890	0.2890

Rounded and condensed from Couch, E. J. and K. A. Kobe, Univ. Texas Rep., Cont. DAI-23-072-ORD-685, June 1, 1956.
c = critical point.

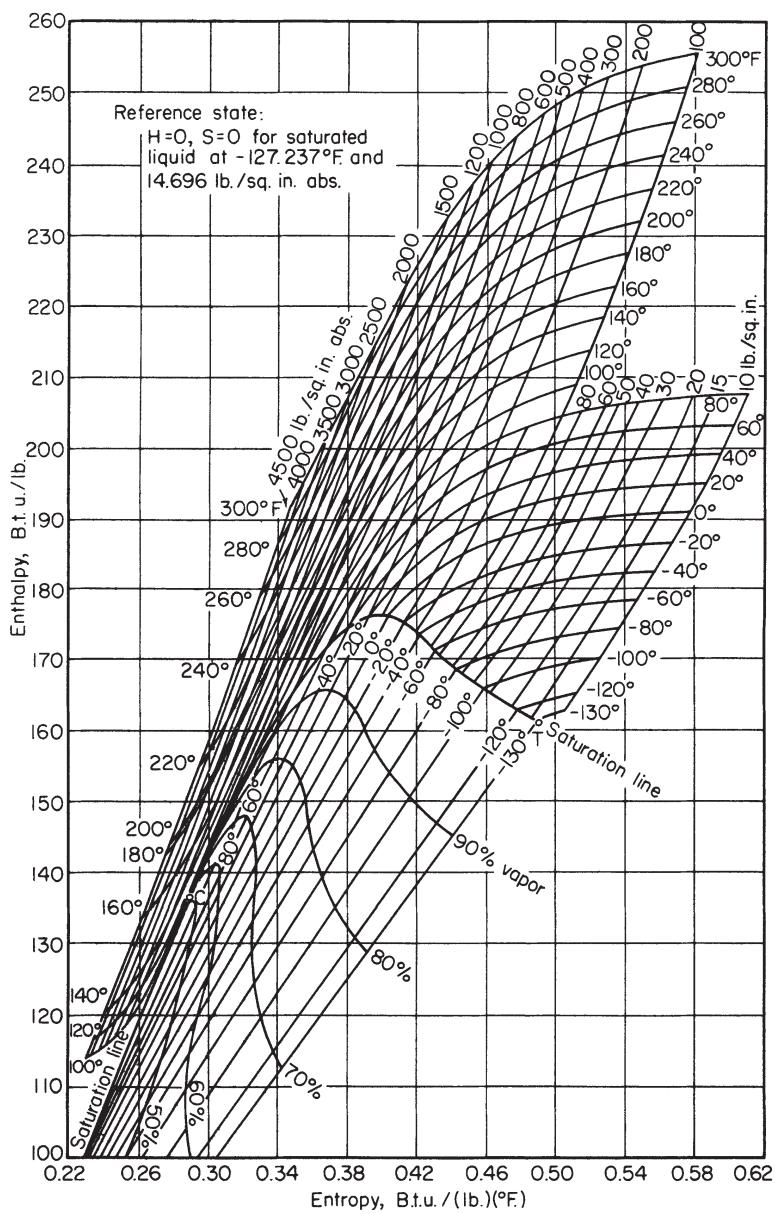


FIG. 2-14 Mollier diagram for nitrous oxide. (Fig. 9, Univ. Texas Rep., Cont. DAI-23-072-ORD-685, June 1, 1956, by Couch and Kobe. Reproduced by permission.) Some irregularity in the compressibility factors from 80 to 160 atm, 50 to 100°C exists (Couch, private communication, 1967). See Couch et al., *J. Chem. Eng. Data*, 6, (1961) for PVT data.

TABLE 2-292 Nonane*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
219.7 ^t	2.6–6			358.4		2.424		2.07	33.5	0.150
220	2.7–6			359.2		2.427		2.07	33.0	0.150
240	3.74–5			400.6		2.607		2.08	17.9	0.145
260	2.97–4			442.2	828.7	2.774	4.210	2.10	12.1	0.140
280	1.61–3			484.8	859.4	2.932	4.243	2.16	8.7	0.134
300	6.40–3	1.404–3	30.35	528.6	891.7	3.083	4.282	2.22	6.53	0.129
320	0.0203	1.436–3	10.19	573.8	925.6	3.229	4.324	2.30	5.13	0.123
340	0.0547	1.471–3	4.00	622.0	961.1	3.370	4.368		4.16	0.118
360	0.1279	1.508–3	1.80	671.3	998.2	3.511	4.419		3.44	0.112
380	0.2678	1.548–3	0.894	722.5	1036.5	3.650	4.476		2.91	0.107
400	0.513	1.591–3	0.485	776.7	1076.0	3.788	4.536		2.50	0.101
420	0.911	1.637–3	0.286	833.3	1116.6	3.927	4.601		2.18	0.096
440	1.521	1.690–3	0.161	890.2	1157.1	4.053	4.660			0.092
460	2.401	1.748–3	0.104	950.3	1199.2	4.186	4.727			0.089
480	3.639	1.815–3	0.069	1012.1	1241.3	4.316	4.794			0.085
500	5.309	1.895–3	0.045	1076.2	1282.9	4.444	4.857			0.082
520	7.437	2.00–3	0.030	1141.3	1324.5	4.569	4.921			
540	10.20	2.13–3	0.021	1207.7	1363.8	4.691	3.980			
560	13.76	2.35–3	0.013	1275.4	1338.7	4.811	5.029			
580	18.02	2.78–3	0.008	1342.9	1318.1	4.927	5.056			
594.6 ^c	22.90	4.23–3	0.004	1305.2	1305.2	5.032	5.032			

*Values of p and v interpolated and converted from tables in Vargaftik, *Handbook of Thermophysical Properties of Gases and Liquids*, Hemisphere, Washington, and McGraw-Hill, New York, 1975. Values of h and s calculated from API tables published by Texas A&M University, College Station. t = triple point; c = critical point.

TABLE 2-293 Octane*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻³ Pa·s	k_f , W/(m·K)
216.4 ^t	1.49–5			365.9		2.487		2.033	2.25	0.149
220	2.41–5			373.2		2.520		2.035	2.01	0.148
240	2.18–4	1.353–3	700	414.1	811.4	2.698	4.207	2.059	1.24	0.143
260	0.0014	1.368–3	125	455.8	842.1	2.865	4.259	2.105	0.87	0.138
280	0.0061	1.384–3	31.9	498.4	873.5	3.023	4.312	2.165	0.65	0.133
300	0.0207	1.420–3	10.7	542.4	906.2	3.175	4.366	2.231	0.504	0.128
320	0.0575	1.457–3	4.01	589.8	939.8	3.325	4.419		0.405	0.123
340	0.1384	1.495–3	1.752	637.9	974.6	3.471	4.461		0.334	0.118
360	0.3000	1.536–3	0.844	687.1	1010.4	3.611	4.509		0.282	0.112
380	0.5856	1.582–3	0.448	737.7	1047.3	3.747	4.562		0.244	0.107
400	1.0507	1.632–3	0.252	790.1	1084.8	3.881	4.617		0.200	0.102
420	1.758	1.685–3	0.155	843.1	1123.6	4.010	4.677		0.167	0.099
440	2.797	1.747–3	0.100	897.5	1162.5	4.137	4.740		0.143	0.095
460	4.246	1.818–3	0.066	954.8	1202.0	4.264	4.802		0.121	0.091
480	6.201	1.904–3	0.045	1013.5	1241.8	4.388	4.864		0.103	0.087
500	8.785	2.013–3	0.031	1072.8	1281.2	4.508	4.924		0.086	0.083
520	12.15	2.16–3	0.021	1136.0	1318.6	4.629	4.980		0.072	
540	16.46	2.37–3	0.014	1201.5	1352.4	4.749	5.028		0.058	
560	21.98	2.81–3	0.008	1276.7	1370.4	4.880	5.048		0.044	
568.8 ^c	24.97	4.26–3	0.004	1331.7	1331.7	4.977	4.977			

*Values of p and v interpolated and converted from tables in Vargaftik, *Handbook of Thermophysical Properties of Gases and Liquids*, Hemisphere, Washington, and McGraw-Hill, New York, 1975. Values of h and s calculated from API tables published by Texas A&M University, College Station. t = triple point; c = critical point. Saturation and superheat tables and a diagram to 100 bar, 680 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.).

TABLE 2-294 Saturated Oxygen (R732)*

T, K	P, bar	v_f , $10^{-3} \text{ m}^3/\text{kg}$	v_g , $10^{-3} \text{ m}^3/\text{kg}$	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , $10^{-4} \text{ Pa}\cdot\text{s}$	k_f , W/(m·K)
54.35 ^t	0.0015	0.776	93980	-189.8	48.9	2.156	6.548			
55	0.0018	0.778	77920	-188.9	49.5	2.172	6.507			
60	0.0073	0.790	21240	-181.1	53.8	2.308	6.223			
65	0.0233	0.802	7200	-173.3	58.1	2.432	5.992			
70	0.0624	0.816	2894	-165.5	62.4	2.545	5.801			
75	0.1448	0.827	1330	-159.2	66.6	2.631	5.642	1.570	3.04	0.170
80	0.3003	0.845	680.7	-149.7	70.8	2.754	5.510	1.589	2.54	0.164
85	0.5677	0.862	379.7	-141.7	74.9	2.849	5.397	1.607	2.16	0.157
90	0.9943	0.880	227.1	-133.7	78.8	2.940	5.301	1.625	1.88	0.151
90.18	1.0133	0.881	223.2	-133.4	78.9	2.943	5.297	1.626	1.87	0.151
95	1.634	0.899	143.9	-125.4	82.4	3.045	5.216	1.645	1.66	0.144
100	2.547	0.920	95.46	-117.1	85.7	3.113	5.141	1.672	1.51	0.138
105	3.794	0.944	65.81	-108.6	88.5	3.196	5.073	1.706	1.34	0.131
110	5.443	0.970	46.81	-99.9	90.8	3.276	5.009	1.752	1.20	0.125
115	7.559	0.998	34.15	-90.0	92.6	3.354	4.950	1.814	1.07	0.118
120	10.21	1.031	25.42	-81.6	93.6	3.432	4.892	1.896	0.97	0.111
125	13.48	1.070	19.21	-71.8	93.9	3.510	4.836	2.004	0.86	0.103
130	17.44	1.116	14.67	-61.5	93.3	3.588	4.779	2.148	0.78	0.096
135	22.19	1.170	11.25	-50.6	91.6	3.667	4.720	2.341	0.70	0.088
140	27.82	1.237	8.612	-38.9	88.4	3.748	4.657	2.629	0.60	0.080
145	34.45	1.332	6.499	-25.9	82.9	3.833	4.583	3.141	0.52	0.072
150	42.23	1.487	4.705	-10.8	73.1	3.928	4.487	3.935		
154.77 ^c	50.87	2.464	2.464	35.2	35.2	4.219	4.219	∞		

*Reproduced and converted from Vasserman and Rabinovich, *Thermophysical Properties of Liquid Air and Its Components*, Standartov, Moscow, 1968; and Israel Program for Scientific Translations, TT-69-55092, 1970. t = triple point; c = critical point.

Other tables are given by Sytchev, V. V., A. A. Vasserman, et al., *Thermodynamic Properties of Oxygen*, Hemisphere, New York, 1987 (307 pp.); Stewart, R. B., R. T. Jacobsen, et al., *J. Phys. Chem. Ref. Data*, **20**, 5 (1991): 917–1021; For fps units, see *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. See also Roder, H. M., *Transport Properties of Oxygen*, NASA Ref. Publ. 1102, 1983 (87 pp.); Laesecke, A., K. Krauss, et al., *J. Phys. Chem. Ref. Data*, **19**, 5 (1990): 1089–1122.

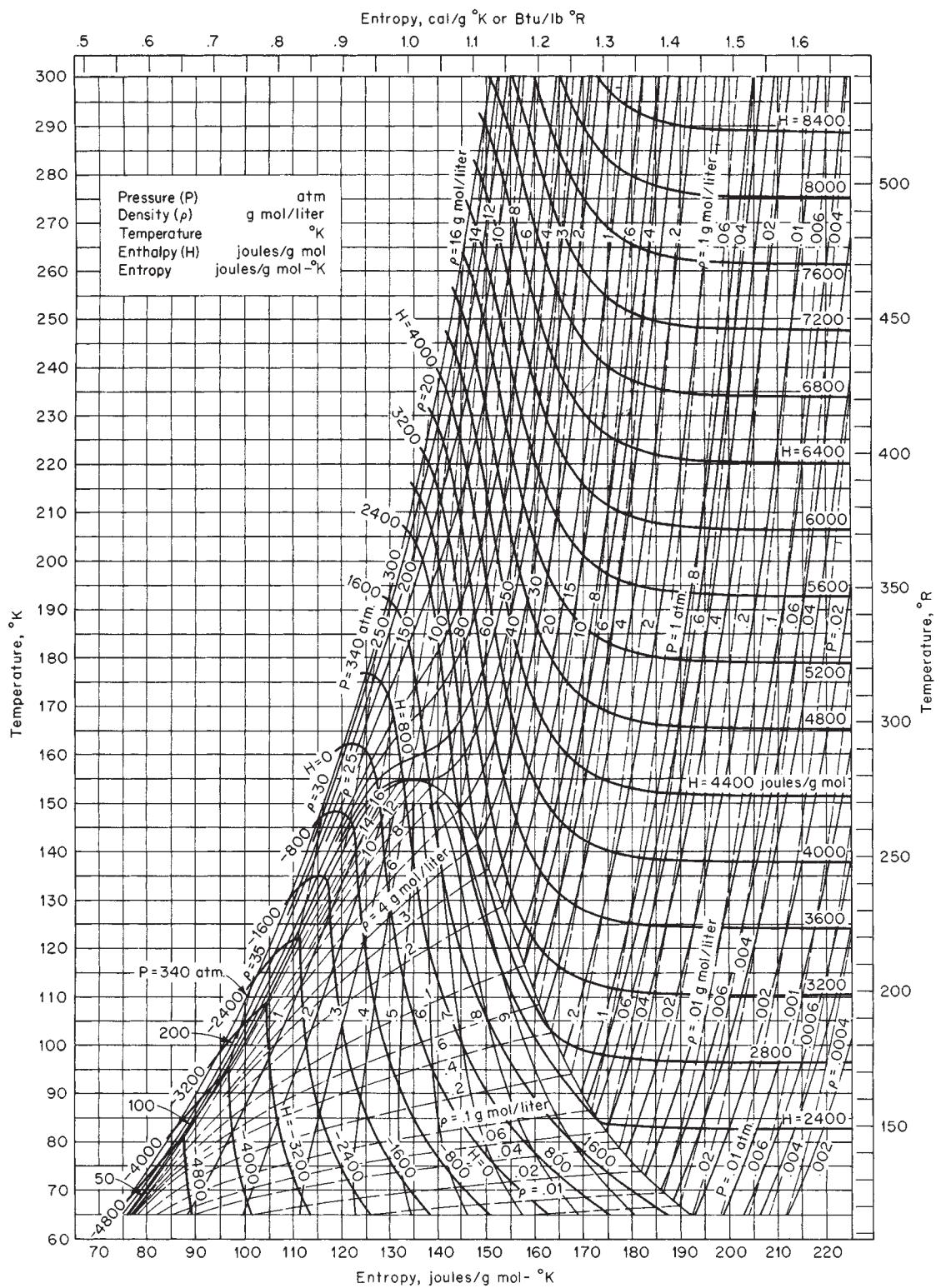


FIG. 2-15 Temperature-entropy chart for oxygen. Pressure P , atm; density ρ , (g·mol)/L; temperature, K; enthalpy H , J/(g·mol); entropy, J/(g·mol·K). (NBS Chart D-56. Reproduced by permission.)

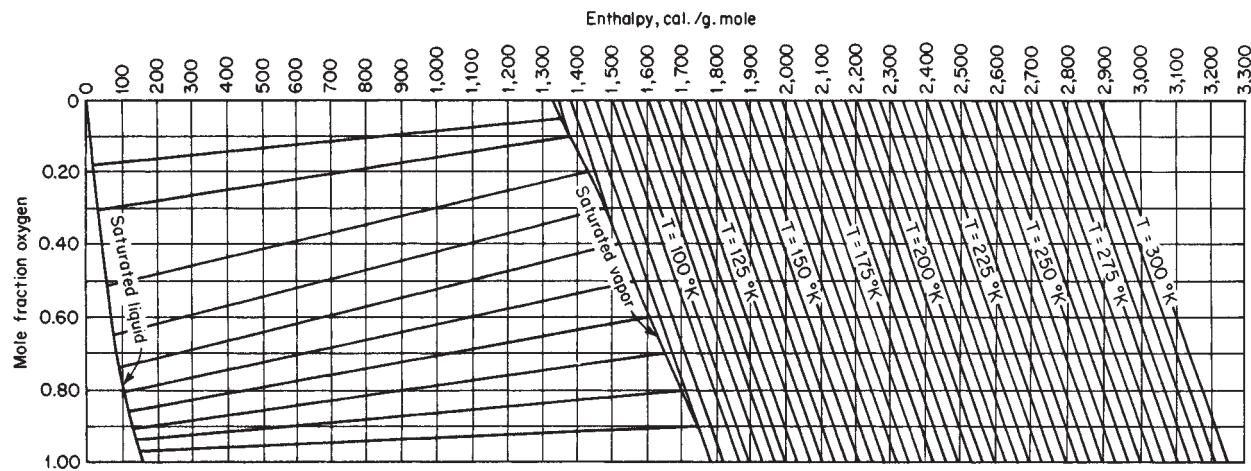


FIG. 2-16 Enthalpy-concentration diagram for oxygen-nitrogen mixture at 1 atm. Reference states: Enthalpies of liquid oxygen and liquid nitrogen at the normal boiling point of nitrogen are zero. (Dodge, Chemical Engineering Thermodynamics, McGraw-Hill, New York, 1944.) Wilson, Silverberg, and Zellner, AFAPL TDR 64-64 (AD 603151), 1964, p. 314, present extensive vapor-liquid equilibrium data for the three-component system argon-nitrogen-oxygen as well as for binary systems including oxygen-nitrogen.

TABLE 2-295 Pentane

Canjar and Manning (*Thermodynamic Properties and Reduced Correlations for Gases*, Gulf, Houston, 1967) give extensive tables and an enthalpy-log-pressure diagram, based upon Brydon, Walen, and Canjar [*Chem. Eng. Prog. Symp. Ser.*, **49**, 7, (1951): 151–157]. For isopentane, Arnold, Liou, and Eldridge [*J. Chem. Eng. Data*, **10**, 88 (1965)] used the Benedict-Webb-Rubin equation to generate information to 600°F and 60 atm. Das and Kuloor used the same equation in *Ind. J. Technol.*, **5**, 46 (1967) to calculate information up to 1500 K and 1000 atm. Saturation and superheat tables and a diagram to 200 bar, 600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). For equations, see Grigoryev, B. A., Yu. L. Rastorguyev, et al., *Int. J. Thermophys.*, **11**, 3 (1990): 487–502.

TABLE 2-296 Saturated Potassium*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)
336.4 ^m	1.37–9	0.001208		93.8	2327	1.928	8.567	0.822
400	1.84–7	0.001229	4.64+6	145.5	2342	2.068	7.559	0.805
500	3.13–5	0.001266	3.39+4	225.1	2390	2.246	6.576	0.785
600	9.26–4	0.001304	3164	302.7	2433	2.388	5.937	0.771
700	0.01022	0.001346	142.3	379.4	2468	2.506	5.490	0.762
800	0.06116	0.001389	26.75	455.5	2498	2.608	5.161	0.761
1000	0.7322	0.001488	2.691	609.7	2552	2.780	4.722	0.792
1200	3.913	0.001605	0.584	773.5	2610	2.929	4.459	0.846
1400	12.44	0.001742	0.207	948.0	2679	3.063	4.299	0.899
1500	20.0	0.001816	0.132	1040.0	2718	3.123	4.209	0.924

* Converted from tables in Vargaftik, *Tables of the Thermophysical Properties of Liquids and Gases*, Nauka, Moscow, 1972; and Hemisphere, Washington, 1975. ^m = melting point. The notation 1.37–9 signifies 1.37×10^{-9} .

Many of the Vargaftik values also appear in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals*, Blackwell Sci. Pubs., Oxford, 1985 (1020 pp.). This source contains saturation and superheat tables and a diagram to 30 bar, 1650 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). For a Mollier diagram from 0.1 to 250 psia, 1300 to 2700°R, see Weatherford, W. D., J. C. Tyler, et al., WADD-TR-61-96, 1961. An extensive review of properties of the solid and the saturated liquid is given by Alcock, C. B., M. W. Chase, et al., *J. Phys. Chem. Ref. Data*, **23**, 3 (1994): 385–497.

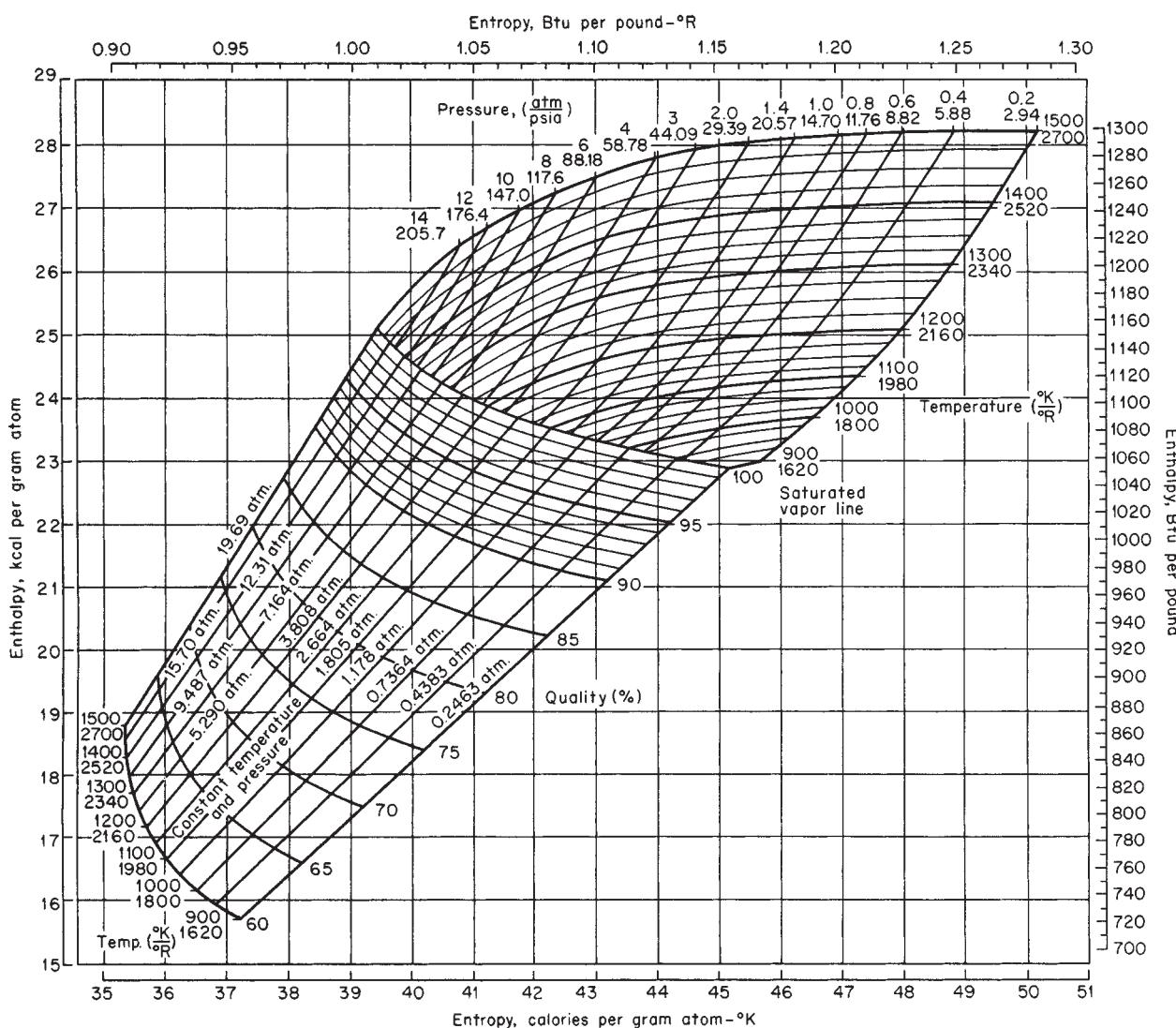


FIG. 2-17 Mollier diagram for potassium. Basis: enthalpy = 0.0 cal/g atom at 298 K; entropy = 15.8 cal/(g atom·K) at 298 K. (Aerojet-General Rep. AGN8194, vol. 2, 1967. Reproduced by permission.)

TABLE 2-297 Saturated Propane (R290)*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
85.5 ^t	3.0.-9	1.364.-3	5.37.+7	124.92	690.02	1.8738	8.3548	1.92		
90	1.5.-8	1.373.-3	1.12.+7	133.56	693.58	1.9723	8.0953	1.92		
100	3.2.-7	1.392.-3	5.85.+5	152.74	702.23	2.1743	7.6163	1.93		
110	3.9.-6	1.412.-3	53275	172.03	711.71	2.3581	7.2377	1.94		
120	3.1.-5	1.432.-3	7350	191.46	721.78	2.5271	6.9343	1.95		
130	1.8.-4	1.453.-3	1400	211.03	732.27	2.6838	6.6885	1.96		
140	7.7.-4	1.475.-3	344	230.77	743.07	2.8300	6.4881	1.98		
150	2.74.-3	1.497.-3	103	250.67	754.12	2.9674	6.3237	2.00	6.61	0.191
160	8.22.-3	1.521.-3	36.8	270.78	765.37	3.0971	6.1886	2.02	5.54	0.183
170	0.0214	1.545.-3	15.0	291.10	776.80	3.2202	6.0775	2.04	4.67	0.175
180	0.0495	1.570.-3	6.84	311.66	788.40	3.3377	5.9862	2.07	3.97	0.166
190	0.1035	1.597.-3	3.43	332.48	800.15	3.4503	5.9114	2.10	3.27	0.158
200	0.1993	1.625.-3	1.868	353.61	812.03	3.5586	5.8502	2.13	2.98	0.150
210	0.3574	1.654.-3	1.087	375.07	824.01	3.6631	5.8005	2.16	2.65	0.143
220	0.6031	1.686.-3	0.669	396.90	836.04	3.7645	5.7603	2.20	2.36	0.136
230	0.9661	1.719.-3	0.432	419.16	848.08	3.8631	5.7280	2.25	2.07	0.129
240	1.4800	1.754.-3	0.290	442.07	860.07	3.9605	5.7022	2.29	1.86	0.123
250	2.1819	1.792.-3	0.2020	465.58	871.94	4.0563	5.6817	2.34	1.69	0.117
260	3.1118	1.833.-3	0.1445	489.70	883.62	4.1505	5.6656	2.41	1.53	0.111
270	4.3120	1.878.-3	0.1059	514.45	895.02	4.2433	5.6528	2.48	1.40	0.106
280	5.8278	1.927.-3	0.0791	539.88	906.03	4.3349	5.6426	2.56	1.29	0.100
290	7.7063	1.982.-3	0.0600	566.06	916.54	4.4257	5.6343	2.65	1.19	0.096
300	9.9973	2.044.-3	0.0461	593.11	926.41	4.5160	5.6270	2.76	1.10	0.091
310	12.75	2.115.-3	0.0357	621.18	935.45	4.6062	5.6200	2.89	0.93	0.086
320	16.03	2.200.-3	0.0279	650.49	943.38	4.6971	5.6124	3.06	0.82	0.082
330	19.88	2.301.-3	0.0218	681.37	949.79	4.7896	5.6030	3.28	0.72	0.078
340	24.36	2.430.-3	0.0170	714.38	953.92	4.8850	5.5896	3.62	0.62	0.073
350	29.56	2.607.-3	0.0130	750.52	954.23	4.9861	5.5681	4.23	0.52	0.069
360	35.55	2.896.-3	0.0095	792.50	946.56	5.0997	5.5277	5.98	0.40	0.066
369.8 ^c	42.42	4.566.-3	0.0046	879.20	879.20	5.3300	∞	0.29	∞	

*Values converted and mostly rounded off from those of Goodwin, NBSIR 77-860, 1977. t = triple point; c = critical point. The notation 3.0.-9 signifies 3.0×10^{-9} . Later tables for the same temperature range for saturation and for the superheat state from 0.1 to 1000 bar, 85.5 to 600 K, were published by Younglove, B. A. and J. F. Ely, *J. Phys. Chem. Ref. Data*, **16**, 4 (1987): 685-721, but the lower temperature saturation tables contain some errors.

Saturation and superheat tables and a chart to 10,000 psia, 800°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.).

For thermodynamic properties for 0.1 to 1000 bar, 100 to 700 K, see Sychev, V. V., A. A. Vasserman, et al., *Thermodynamic Properties of Propane*, Hemisphere, New York, NY, 1991 (275 pp.).

Saturation and superheat tables and a diagram to 200 bar, 600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.).

For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

TABLE 2-298 Saturated Propylene (Propene, R1270)

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	Pr
87.9 ^f	9.54–9	0.001 301	1.82,+7	−290.1	279.2	−1.923	4.554				
90	2.05–8	0.001 305	8.66,+6	−285.1	281.1	−1.867	4.424				
100	4.81–7	0.001 325	411 165	−265.4	290.2	−1.659	3.897	1.695	2017	0.214	15.98
110	6.08–6	0.001 346	35 753	−247.7	299.6	−1.490	3.488	1.760	1526	0.209	12.85
120	4.88–5	0.001 367	4 856	−229.8	309.3	−1.335	3.158	1.820	1185	0.204	10.57
130	2.77–4	0.001 389	927.0	−211.4	319.3	−1.187	2.895	1.875	941	0.198	8.91
140	1.20–3	0.001 411	230.91	−192.4	329.4	−1.046	2.681	1.923	735	0.193	7.32
150	4.17–3	0.001 434	71.043	−172.9	339.8	−0.912	2.506	1.964	587	0.188	6.13
160	0.0122	0.001 458	25.903	−153.1	350.4	−0.784	2.363	1.996	478	0.183	5.21
170	0.0309	0.001 483	10.842	−133.1	361.2	−0.663	2.245	2.020	397	0.178	4.50
180	0.0697	0.001 508	5.080	−112.7	372.1	−0.547	2.147	2.044	334.5	0.173	3.95
190	0.1425	0.001 535	2.613	−92.2	383.1	−0.436	2.066	2.067	286.1	0.168	3.52
200	0.2686	0.001 563	1.452	−71.4	394.2	−0.329	1.999	2.094	244.9	0.162	3.17
210	0.4727	0.001 593	0.860	−50.3	405.3	−0.226	1.943	2.128	212.7	0.157	2.88
220	0.7849	0.001 624	0.538	−28.8	416.3	−0.127	1.896	2.162	187.0	0.152	2.66
225.5 ^b	1.0133	0.001 642	0.4241	−16.9	422.2	−0.073	1.874	2.182	175.0	0.149	2.56
230	1.2401	0.001 657	0.3515	−7.0	427.1	−0.030	1.857	2.199	166.2	0.147	2.49
240	1.8775	0.001 693	0.2388	15.3	437.8	0.064	1.825	2.243	149.2	0.142	2.36
250	2.7401	0.001 732	0.1674	38.0	448.2	0.157	1.797	2.298	135.0	0.137	2.26
260	3.8737	0.001 774	0.1206	61.3	458.2	0.247	1.774	2.369	123.0	0.131	2.22
270	5.3269	0.001 820	0.0888	85.2	467.8	0.336	1.753	2.418	112.9	0.126	2.17
280	7.1499	0.001 872	0.0666	109.9	476.9	0.425	1.735	2.494	106.6	0.121	2.20
290	9.3954	0.001 929	0.0507	135.3	485.3	0.512	1.719	2.584	100.0	0.116	2.23
300	12.12	0.001 995	0.0390	161.6	492.8	0.600	1.704	2.693	93.0	0.112	2.24
310	15.38	0.002 071	0.0303	189.0	499.3	0.688	1.688	2.842	85.6	0.109	2.23
320	19.23	0.002 162	0.0236	217.7	504.3	0.776	1.672	3.007	77.8	0.104	2.25
330	23.75	0.002 273	0.0184	248.2	507.4	0.867	1.652	3.335	69.6	0.097	2.39
340	29.01	0.002 418	0.0142	280.9	507.6	0.961	1.627	3.723	61.0	0.090	2.52
350	35.12	0.002 628	0.0107	317.6	502.8	1.062	1.592	4.669		0.082	
360	42.20	0.003 038	0.0075	364.1	486.0	1.188	1.527				
365.6 ^c	46.65	0.004 476	0.0045	433.3	433.3	1.374	1.374				

^t = triple point; ^b = normal boiling point; ^c = critical point. The notation 9.54–9 signifies 9.54×10^{-9} , $h_f = s_f = 0$ at 233.15 K = −40°C. Converted from Angus, S., B. Armstrong, et al., *Int'l. Thermodynamic Properties of the Fluid State—7. Propylene (Propene) R1270*, Pergamon Press, Oxford, 1980 (401 pp.).

TABLE 2-299 Compressed Propylene (Propene, R1270)

Pressure, bar	Temperature, K									
	225	250	275	300	325	350	375	400	425	450
<i>v</i> (m ³ /kg)	0.00164	0.4817	0.5334	0.5846	0.6354	0.6858	0.7361	0.7861	0.8361	0.8859
1 <i>h</i> (kJ/kg)	-17.9	455.5	491.2	529.1	569.1	611.4	656.0	702.8	751.9	803.2
<i>s</i> (kJ/kg·K)	-0.0779	2.0169	2.1530	2.2847	2.4128	2.5380	2.6610	2.7821	2.9010	3.0183
<i>v</i> (m ³ /kg)	0.00164	0.00173	0.00184	0.04986	0.05670	0.06295	0.06889	0.07460	0.08014	0.08557
10 <i>h</i> (kJ/kg)	-17.2	38.5	97.6	501.2	547.0	593.2	640.8	689.7	740.6	793.3
<i>s</i> (kJ/kg·K)	-0.0810	0.1535	0.3788	1.7631	1.9653	2.0466	2.1774	2.3042	2.4273	2.5480
<i>v</i> (m ³ /kg)	0.00163	0.00172	0.00184	0.00198	0.02324	0.02773	0.03149	0.03489	0.03803	0.04104
20 <i>h</i> (kJ/kg)	-16.3	39.3	98.1	161.5	512.7	568.2	621.5	673.5	726.5	781.5
<i>s</i> (kJ/kg·K)	-0.0841	0.1497	0.3736	0.5941	1.6920	1.8567	2.0024	2.1381	2.2674	2.3923
<i>v</i> (m ³ /kg)	0.00163	0.00172	0.00182	0.00196	0.00216	0.00256		0.01465	0.01682	0.01872
40 <i>h</i> (kJ/kg)	-14.4	40.8	99.0	161.3	230.0	313.3		633.6	695.4	755.6
<i>s</i> (kJ/kg·K)	-0.0908	0.1419	0.3638	0.5806	0.8001	1.0466		1.9256	2.0758	2.2131
<i>v</i> (m ³ /kg)	0.00162	0.00171	0.00181	0.00194	0.00211	0.00240		0.00743	0.00944	0.01126
60 <i>h</i> (kJ/kg)	-12.6	42.3	100.1	161.5	228.2	303.8		575.4	656.7	726.1
<i>s</i> (kJ/kg·K)	-0.0970	0.1345	0.3546	0.5684	0.7816	1.0055		1.7272	1.9250	2.0832
<i>v</i> (m ³ /kg)	0.00162	0.00170	0.00180	0.00192	0.00208	0.00231		0.00402	0.00605	0.00757
80 <i>h</i> (kJ/kg)	-10.7	44.0	101.3	162.0	227.2	299.0		499.7	607.7	693.3
<i>s</i> (kJ/kg·K)	-0.1031	0.1274	0.3458	0.5570	0.7657	0.9781		1.5107	1.7795	1.9693
<i>v</i> (m ³ /kg)	0.00161	0.00169	0.00179	0.00190	0.00204	0.00224	0.00256	0.00316	0.00426	0.00551
100 <i>h</i> (kJ/kg)	-8.8	45.6	102.6	162.7	226.7	296.1	373.5	464.9	567.8	660.1
<i>s</i> (kJ/kg·K)	-0.1091	0.1202	0.3374	0.5466	0.7514	0.9570	1.1704	1.4061	1.6456	1.8669
<i>v</i> (m ³ /kg)	0.00160	0.00167	0.00176	0.00186	0.00198	0.00214	0.00234	0.00262	0.00300	0.00354
150 <i>h</i> (kJ/kg)	-4.1	49.9	106.1	165.0	227.0	292.8	362.9	438.5	519.5	604.6
<i>s</i> (kJ/kg·K)	-0.1236	0.1038	0.3180	0.5228	0.7214	0.9163	1.1100	1.3049	1.5021	1.6958
<i>v</i> (m ³ /kg)	0.00159	0.00166	0.00174	0.00183	0.00194	0.00207	0.00222	0.00242	0.00266	0.00296
200 <i>h</i> (kJ/kg)	0.8	54.4	110.0	167.9	228.7	292.3	359.2	429.9	504.4	581.4
<i>s</i> (kJ/kg·K)	-0.1371	0.0884	0.3004	0.5021	0.6963	0.8852	1.0701	1.2521	1.4319	1.6086
<i>v</i> (m ³ /kg)	0.00157	0.00163	0.00170	0.00178	0.00187	0.00197	0.00208	0.00221	0.00236	0.00253
300 <i>h</i> (kJ/kg)	10.9	63.8	118.5	175.2	234.2	295.5	359.3	425.7	494.4	565.6
<i>s</i> (kJ/kg·K)	-0.1625	0.0601	0.2688	0.4660	0.6549	0.8367	1.0127	1.1839	1.3507	1.5133
<i>v</i> (m ³ /kg)	0.00155	0.00161	0.00167	0.00174	0.00182	0.00190	0.00199	0.00209	0.00220	0.00232
400 <i>h</i> (kJ/kg)	21.2	73.6	127.7	183.6	241.5	301.5	363.7	428.0	494.4	562.9
<i>s</i> (kJ/kg·K)	-0.1863	0.0347	0.2407	0.4351	0.6207	0.7985	0.9705	1.1362	1.2972	1.4536
<i>v</i> (m ³ /kg)	0.00153	0.00159	0.00165	0.00171	0.00178	0.00185	0.00193	0.00201	0.00210	0.00220
500 <i>h</i> (kJ/kg)	31.6	83.7	137.3	192.6	249.8	309.0	370.1	433.3	498.7	565.4
<i>s</i> (kJ/kg·K)	-0.2082	0.0112	0.2155	0.4080	0.5910	0.7664	0.9351	1.0981	1.2559	1.4092

Converted and interpolated from Angus, S., B. Armstrong, et al., *International Thermodynamic Tables of the Fluid State—7. Propylene*, Pergamon, Oxford, 1980 (401 pp.).

The 1993 ASHRAE Handbook—Fundamentals (SI ed.) has a thermodynamic chart for pressures from 0.1 to 1000 bar for temperatures up to 580 K. Saturation and superheat tables and a diagram to 30,000 psia, 580°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

TABLE 2-300 Saturated Refrigerant 11*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
200	0.0043	5.901,-4	28.06	-14.37	186.30	-0.0651	0.9431	0.815	1.674	0.115
220	0.0417	6.061,-4	6.272	-8.20	195.89	-0.0361	0.8925	0.828	1.142	0.110
240	0.0768	6.225,-4	1.882	4.97	205.85	0.0210	0.8581	0.842	0.831	0.104
260	0.2215	6.398,-4	0.703	21.01	216.06	0.0851	0.8353	0.856	0.635	0.098
270	0.3514	6.491,-4	0.458	29.53	221.23	0.1172	0.8272	0.863	0.563	0.095
280	0.5364	6.587,-4	0.309	38.25	226.40	0.1489	0.8209	0.870	0.504	0.093
290	0.7917	6.688,-4	0.216	47.10	231.58	0.1799	0.8160	0.878	0.454	0.090
300	1.1341	6.794,-4	0.154	56.06	236.73	0.2102	0.8124	0.887	0.413	0.087
310	1.5821	6.908,-4	0.113	65.10	241.83	0.2397	0.8099	0.897	0.377	0.084
320	2.1556	7.027,-4	0.0847	74.22	246.88	0.2686	0.8081	0.907	0.346	0.081
330	2.876	7.156,-4	0.0645	83.42	251.84	0.2967	0.8071	0.917	0.320	0.079
340	3.764	7.293,-4	0.0500	92.72	256.69	0.3243	0.8065	0.928	0.297	0.076
350	4.845	7.442,-4	0.0392	102.12	261.40	0.3513	0.8064	0.939	0.276	0.073
360	6.142	7.603,-4	0.0311	111.64	265.95	0.3778	0.8065	0.950	0.259	0.070
380	9.487	7.974,-4	0.0201	131.12	274.40	0.4298	0.8069	0.975	0.239	0.065
400	14.02	8.435,-4	0.0134	151.38	281.69	0.4808	0.8066	1.004	0.203	0.059
420	19.98	9.042,-4	0.0090	172.76	287.20	0.5317	0.8041	1.04	0.169	0.053
440	27.65	9.930,-4	0.0059	196.01	289.72	0.5840	0.7970	1.09	0.131	0.048
460	37.36	1.167,-3	0.0036	223.85	285.36	0.6435	0.7773	1.19	0.084	0.037
471.2 ^c	44.09	1.799,-3	0.0018	258.70	258.70	0.7162	∞	0.033	∞	

*Values reproduced or converted from Table 1, p. 17.75, *ASHRAE Handbook, 1981: Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 5.901,-4 signifies 5.901×10^{-4} . The 1993 *ASHRAE Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the ITS 90 scale. For experimental isochores for the compressed liquid from 12 to 301 bar, 254 to 453 K, see Blanke, W. and R. Weiss, *PTB Bericht W 30*, Braunschweig, Germany, 1992 (54 pp.). Equations and constants approximated to 1985 ASHRAE tables are given by Mecarik, K. and M. Masaryk, *Heat Recovery Systems and CHP*, 11, 2/3 (1991): 193-197. For tables and a chart to 3000 psia, 460°F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For similar material to 80 bar, 650 K, see Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). For specific heat at constant pressure, thermal conductivity, and viscosity in both SI and fps units, see Liley, P. E., *Thermophysical Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1993.

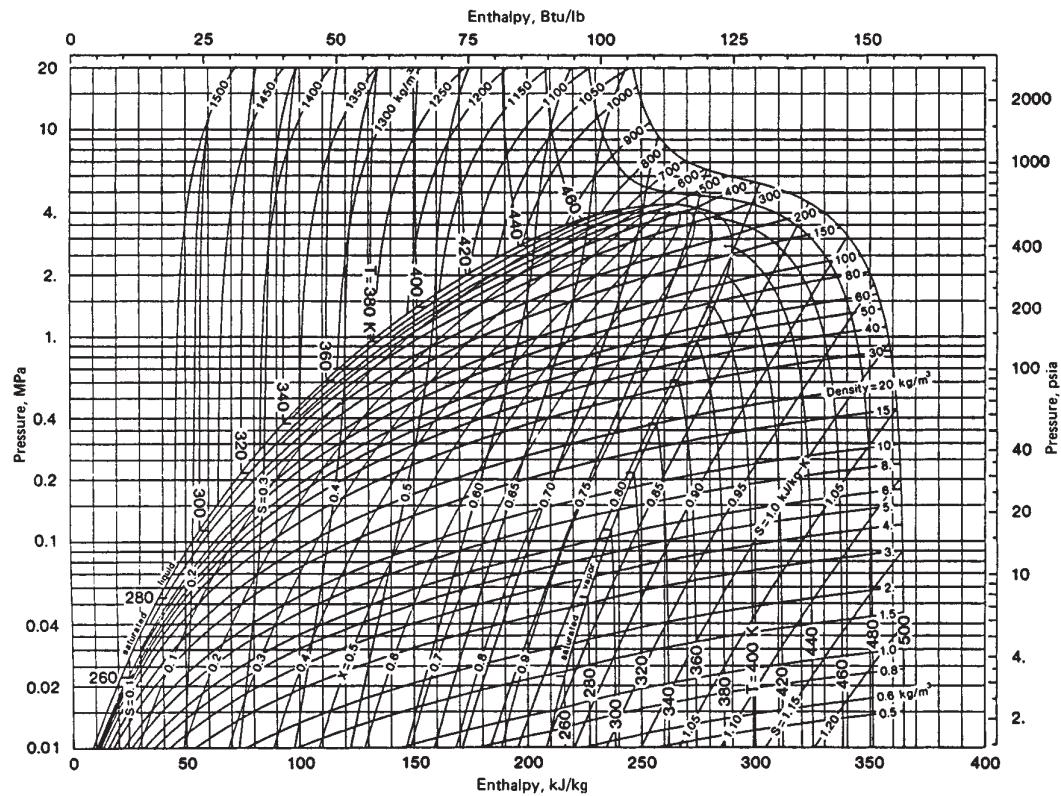


FIG. 2-18 Enthalpy-log-pressure diagram for Refrigerant 11. 1 MPa = 10 bar. (Copyright 1981 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers and reproduced by permission of the copyright owner.) This chart, redrawn with a different zero point and temperatures in Celsius, appears in *ASHRAE Handbook—Fundamentals* (SI ed.), Atlanta, GA, 1993.

2-270 PHYSICAL AND CHEMICAL DATA
TABLE 2-301 Saturated Refrigerant 12*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
150	0.00091	5.767.-4	179.12	294.6	496.0	3.492	4.835	0.808	18.9	0.123
160	0.00305	5.849.-4	36.05	302.3	500.2	3.543	4.780	0.817	15.1	0.119
170	0.00871	5.926.-4	13.40	310.3	504.5	3.591	4.734	0.827	12.1	0.116
180	0.02178	6.024.-4	5.666	318.3	508.9	3.637	4.696	0.836	9.69	0.113
190	0.04877	6.118.-4	2.665	326.5	513.5	3.681	4.665	0.845	7.94	0.109
200	0.0996	6.217.-4	1.370	334.8	518.1	3.724	4.640	0.855	6.64	0.105
210	0.1879	6.139.-4	0.7589	343.2	522.7	3.765	4.620	0.864	5.65	0.102
220	0.3317	6.431.-4	0.4476	351.8	527.4	3.805	4.603	0.873	4.88	0.098
230	0.5531	6.549.-4	0.2784	360.6	531.1	3.844	4.590	0.882	4.26	0.094
240	0.8781	6.675.-4	0.1811	369.5	536.8	3.881	4.579	0.891	3.77	0.090
250	1.3359	6.810.-4	0.1225	378.0	541.5	3.918	4.570	0.902	3.37	0.087
260	1.959	6.970.-4	0.08559	387.7	546.1	3.954	4.563	0.913	3.03	0.083
270	2.784	7.112.-4	0.06147	397.0	550.7	3.989	4.558	0.926	2.75	0.080
280	3.825	7.282.-4	0.04543	406.5	555.1	4.023	4.554	0.942	2.52	0.076
290	5.184	7.470.-4	0.03888	416.1	559.4	4.057	4.551	0.959	2.31	0.072
300	6.840	7.678.-4	0.02582	426.0	563.5	4.090	4.548	0.979	2.14	0.069
310	8.860	7.912.-4	0.01992	436.0	567.3	4.122	4.546	1.005	2.00	0.065
320	11.29	8.173.-4	0.01553	446.2	570.9	4.154	4.543	1.041	1.86	0.061
330	14.17	8.478.-4	0.01218	456.8	574.0	4.186	4.541	1.093	1.74	0.058
340	17.58	8.840.-4	0.00957	467.8	576.5	4.218	4.538	1.166	1.60	0.054
350	21.57	9.286.-4	0.00750	479.4	578.2	4.250	4.533	1.264	1.45	0.050
360	26.19	9.868.-4	0.00582	492.1	578.7	4.285	4.525	1.39	1.28	0.046
370	31.56	1.072.-3	0.00439	506.4	577.2	4.322	4.514	1.55	1.06	0.041
380	37.76	1.237.-3	0.00305	524.7	571.2	4.369	4.900		0.75	
385°	41.31	1.876.-3	0.00188	551.1	551.1	4.437	4.437	∞	0.31	∞

*P, v, h, and s data interpolated from Perelshteyn (ed.), *Tables and Diagrams of the Thermodynamic Properties of Refrigerants 12, 13, and 22*, Moscow, 1971. c_p , μ , and k data interpolated and converted from *Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. c = critical point. The notation 5.767.-4 signifies 5.767×10^{-4} .

TABLE 2-302 Saturated Refrigerant 13*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
91	3.817.-6	5.367.-4	19557	238.1	424.9	3.080	5.133			
100	3.418.-5	5.448.-4	2392	243.8	429.0	3.140	4.990			
110	2.563.-4	5.538.-4	347.0	251.1	433.1	3.205	4.860			
120	0.00137	5.635.-4	70.25	258.2	437.2	3.267	4.759			
130	0.00571	5.739.-4	18.15	265.8	441.3	3.327	4.677			
140	0.01895	5.850.-4	5.865	273.7	455.3	3.385	4.610			
150	0.05250	5.969.-4	2.2617	281.7	449.3	3.441	4.558	0.826	6.83	0.114
160	0.1258	6.095.-4	1.0019	290.0	453.5	3.494	4.516	0.845	5.60	0.109
170	0.2680	6.231.-4	0.4962	298.4	457.6	3.545	4.482	0.865	4.59	0.104
180	0.5186	6.380.-4	0.2689	307.1	461.8	3.594	4.454	0.884	3.83	0.099
190	0.9269	6.536.-4	0.1567	315.9	465.9	3.642	4.431	0.898	3.26	0.093
200	1.5507	6.709.-4	9.69.-2	325.0	469.9	3.688	4.413	0.910	2.82	0.088
210	2.456	6.899.-4	6.28.-2	334.3	473.8	3.732	4.397	0.924	2.48	0.083
220	3.712	7.110.-4	4.24.-2	343.8	477.5	3.777	4.385	0.943	2.20	0.078
230	5.396	7.346.-4	2.95.-2	353.6	481.0	3.820	4.374	0.972	1.97	0.072
240	7.589	7.615.-4	2.11.-2	363.5	484.1	3.862	4.364	1.014	1.79	0.067
250	10.37	7.928.-4	1.53.-2	373.9	486.1	3.903	4.355	1.072	1.63	0.062
260	13.85	8.302.-4	1.13.-2	384.7	489.1	3.944	4.346	1.151	1.50	0.057
270	18.13	8.769.-4	8.28.-3	396.2	490.5	3.986	4.336	1.255	1.34	0.051
280	23.32	9.320.-4	6.10.-3	408.8	490.6	4.029	4.323	1.386	1.14	0.045
290	29.57	1.035.-3	4.34.-3	423.6	488.3	4.080	4.303	1.549	0.87	0.038
300	37.05	1.284.-3	2.60.-3	445.3	477.5	4.151	4.257	1.75	0.52	
302.0	38.70	1.808.-3	1.81.-3	463.1	463.1	4.209	4.209	∞	0.29	∞

*P, v, h, and s data interpolated from Perelshteyn (ed.), *Tables and Diagrams of the Thermodynamic Properties of Refrigerants 12, 13 and 22*, Moscow, 1971. c_p , μ , and k data interpolated and converted from *Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. c = critical point. The notation 3.817.-6 signifies 3.817×10^{-6} . The 1993 ASHRAE Handbook—Fundamentals (SI ed.) contains a table at closer temperature increments and also an enthalpy-log-pressure diagram from 0.1 to 70 bar, -100 to 240°C. Equations and constants approximated to 1985 ASHRAE tables are given by Mecarik, K. and M. Masaryk, *Heat Recovery Systems and CHP*, 11, 2/3 (1991): 193–197. Saturation and superheat tables and a diagram to 60 bar, 600 K are given by Reynolds, W. C., *Thermodynamic Properties in SI*, Stanford Univ. publ., 1979 (173 pp.). For tables and a chart to 1000 psia, 520°F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

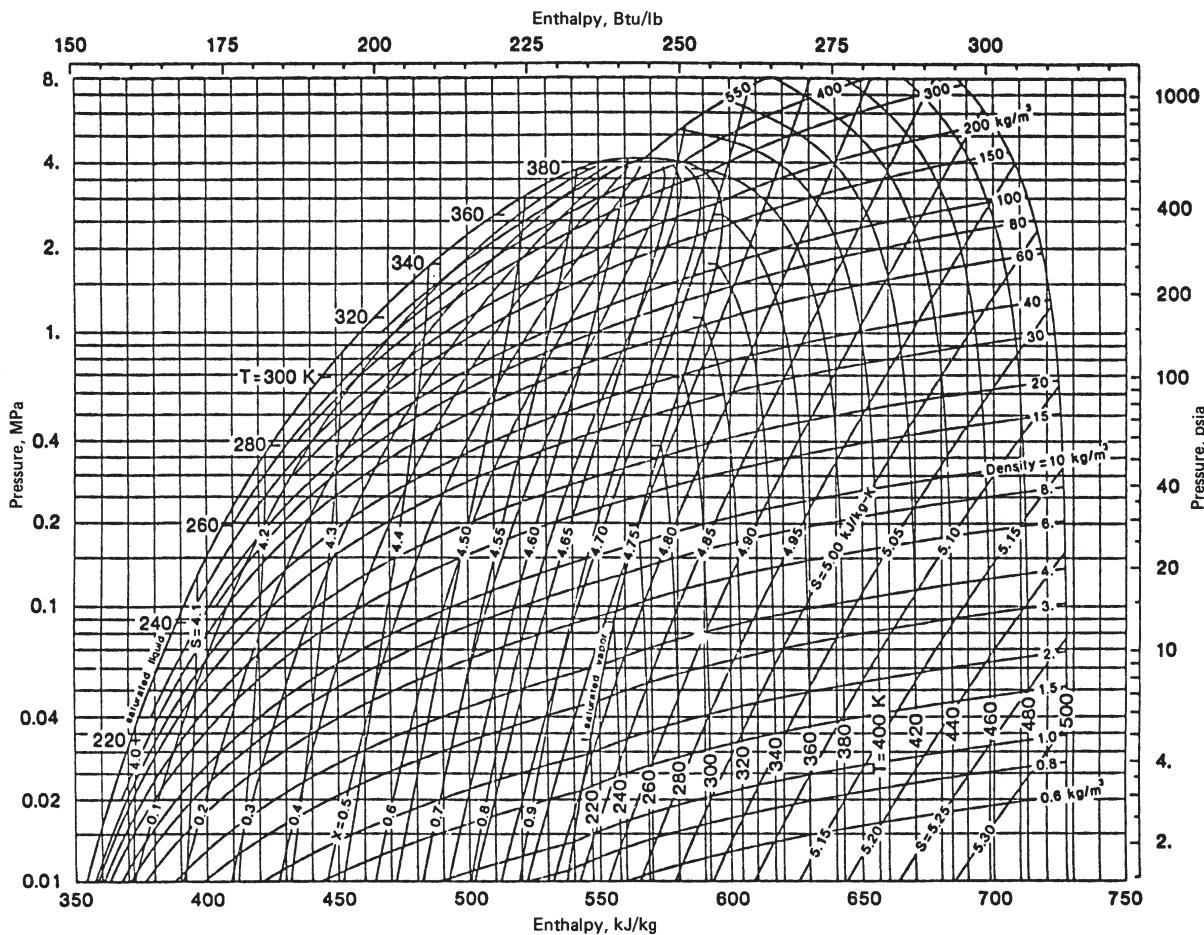


FIG. 2-19 Enthalpy–log-pressure diagram for Refrigerant 12. 1 MPa = 10 bar. (Copyright 1981 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers and reproduced by permission of the copyright owner.) This chart, redrawn for integral Celsius temperatures with a different zero point, appears on p. 17.4 of the 1993 ASHRAE Handbook—Fundamentals (SI ed.). This handbook gives material for integral degrees Celsius with temperatures on the ITS 90 scale. For experimental isochores for the compressed liquid from 10 to 302 bar, 122 to 462 K, see Blanke, W. and R. Weiss, *PTB Bericht W30*, Braunschweig, Germany, 1992 (54 pp.). Equations and constants approximated to 1985 ASHRAE tables are given by Mecarik, K. and M. Masaryk, *Heat Recovery Systems and CHP*, 11, 2/3 (1991): 193–197. Tables at 2°C increments to 240°C, 50 bar are given by Watson, J. T. R., *Thermophysical Properties of Refrigerant 12*, H.M.S.O., Edinburgh, Scotland, 1975 (183 pp.). Saturation and superheat tables and a diagram to 40 bar, 620 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ., 1979 (173 pp.). Tables and a chart to 1100 psia, 480°F are given by Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

2-272 PHYSICAL AND CHEMICAL DATA
TABLE 2-303 Saturated Refrigerant 13B1*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
170	0.059	4.594–4	1.6015	-40.90	90.95	-0.2033	0.5723	0.597	9.54	0.101
180	0.127	4.677–4	0.7840	-34.75	94.37	-0.1682	0.5491	0.618	7.60	0.096
190	0.250	4.765–4	0.4190	-28.51	97.83	-0.1345	0.5305	0.634	6.20	0.091
200	0.455	4.860–4	0.2407	-22.17	101.32	-0.1020	0.5154	0.648	5.13	0.086
210	0.777	4.961–4	0.1467	-15.68	104.82	-0.0704	0.5033	0.663	4.33	0.082
215.4	1.013	5.020–4	0.1147	-12.09	106.70	-0.0536	0.4978	0.670	3.97	0.079
220	1.254	5.071–4	0.0940	-9.02	108.28	-0.0396	0.4936	0.676	3.71	0.077
230	1.933	5.190–4	0.0628	-2.19	111.68	-0.0094	0.4857	0.690	3.22	0.073
240	2.863	5.321–4	0.0433	4.83	114.99	0.0202	0.4793	0.703	2.83	0.068
250	4.096	5.466–4	0.0308	12.03	118.16	0.0494	0.4739	0.721	2.51	0.063
260	5.690	5.627–4	0.0224	19.44	121.16	0.0781	0.4693	0.742	2.25	0.059
270	7.703	5.809–4	0.0166	27.06	123.93	0.1064	0.4652	0.767	2.04	0.054
280	10.20	6.018–4	0.0124	34.94	126.41	0.1345	0.4612	0.800	1.84	0.049
290	13.25	6.264–4	0.0094	43.11	128.51	0.1625	0.4570	0.842	1.69	0.045
300	16.91	6.562–4	0.0072	51.68	130.09	0.1908	0.4522	0.891	1.57	0.040
310	21.28	6.940–4	0.0055	60.81	130.97	0.2197	0.4460	0.951	1.45	0.035
320	26.44	7.458–4	0.0041	70.80	130.76	0.2503	0.4376	1.09	1.26	0.030
330	32.48	8.295–4	0.0030	82.42	128.59	0.2845	0.4245	1.29	0.99	0.026
340.2 ^c	39.64	1.344–3	0.0013	108.70	108.70	0.3605	0.3605	∞	0.35	∞

*Values reproduced or converted from Table 4, p. 17.83, *ASHRAE Handbook, 1981: Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 4.594–4 signifies 4.594×10^{-4} .

The 1993 *ASHRAE Handbook—Fundamentals* (SI ed.) contains a table at closer temperature increments and also an enthalpy-log-pressure diagram from 0.1 to 35 bar, -80 to 220°C. For tables and a chart to 500 psia, 480°F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

Refrigerant 14 (tetrafluoromethane) See Carbon Tetrafluoride (Table 2-245).

Refrigerant 20 See Chloroform (Table 2-248).

TABLE 2-304 Saturated Refrigerant 21

Temperature, K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
250	0.2415	0.000 677	0.8292	16.6	274.8	0.0687	1.1015
260	0.3953	0.000 687	0.5247	26.5	279.9	0.1076	1.0820
270	0.6200	0.000 698	0.3455	36.6	284.9	0.1454	1.0653
280	0.9364	0.000 709	0.2355	46.7	290.0	0.1824	1.0511
290	1.3682	0.000 722	0.1654	57.1	295.0	0.2186	1.0389
300	1.9417	0.000 735	0.1192	67.7	300.0	0.2543	1.0286
310	2.6849	0.000 748	0.0879	78.4	304.8	0.2894	1.0196
320	3.6279	0.000 763	0.0661	89.5	309.5	0.3242	1.0119
330	4.8022	0.000 778	0.0505	100.7	314.1	0.3586	1.0051
340	6.2409	0.000 794	0.0391	112.3	318.4	0.3927	0.9989
350	7.978	0.000 812	0.0307	124.1	322.4	0.4266	0.9932
360	10.049	0.000 830	0.0243	136.2	326.1	0.4602	0.9877
370	12.489	0.000 850	0.0194	148.6	329.3	0.4935	0.9820
380	15.337	0.000 870	0.0155	161.2	331.9	0.5264	0.9758
390	18.630	0.000 893	0.0125	173.9	333.8	0.5587	0.9688
400	22.41	0.000 918	0.01011	186.4	334.8	0.5896	0.9605
410	26.72	0.000 944	0.00820	198.3	334.7	0.6180	0.9506
420	31.60	0.000 972	0.00672	208.7	333.7	0.6418	0.9394
430	37.10	0.001 002	0.00564	216.4	332.4	0.6587	0.9286
440	43.26	0.001 034	0.00491	221.1	332.3	0.6682	0.9208

Reproduced and rounded from unpublished Center for Applied Thermodynamic Studies, Moscow ID report, 1981. For a thermodynamic diagram to 350 bar, 370°C, see Rombusch, U. K., *Allgem. Wärme.*, **11**, 3 (1962).

TABLE 2-305 Saturated Refrigerant 22*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
150	0.0017	6.209–4	83.40	268.2	547.3	3.355	5.215	1.059		0.161
160	0.0054	6.293–4	28.20	278.2	552.1	3.430	5.141	1.058		0.156
170	0.0150	6.381–4	10.85	288.3	557.0	3.494	5.075	1.057	0.770	0.151
180	0.0369	6.474–4	4.673	298.7	561.9	3.551	5.013	1.058	0.647	0.146
190	0.0821	6.573–4	2.225	308.6	566.8	3.605	4.963	1.060	0.554	0.141
200	0.1662	6.680–4	1.145	318.8	571.6	3.657	4.921	1.065	0.481	0.136
210	0.3116	6.794–4	0.6370	329.1	576.5	3.707	4.885	1.071	0.424	0.131
220	0.5470	6.917–4	0.3772	339.7	581.2	3.756	4.854	1.080	0.378	0.126
230	0.9076	7.050–4	0.2352	350.6	585.9	3.804	4.828	1.091	0.340	0.121
240	1.4346	7.195–4	0.1532	361.7	590.5	3.852	4.805	1.105	0.309	0.117
250	2.174	7.351–4	0.1037	373.0	594.9	3.898	4.785	1.122	0.282	0.112
260	3.177	7.523–4	0.07237	384.5	599.0	3.942	4.768	1.143	0.260	0.107
270	4.497	7.733–4	0.05187	396.3	603.0	3.986	4.752	1.169	0.241	0.102
280	6.192	7.923–4	0.03803	408.2	606.6	4.029	4.738	1.193	0.225	0.097
290	8.324	8.158–4	0.02838	420.4	610.0	4.071	4.725	1.220	0.211	0.092
300	10.956	8.426–4	0.02148	432.7	612.8	5.113	4.713	1.257	0.198	0.087
310	14.17	8.734–4	0.01643	445.5	615.1	4.153	4.701	1.305	0.186	0.082
320	18.02	9.096–4	0.01265	458.6	616.7	4.194	4.688	1.372	0.176	0.077
330	22.61	9.535–4	9.753–3	472.4	617.3	4.235	4.674	1.460	0.167	0.072
340	28.03	1.010–3	7.479–3	487.2	616.5	4.278	4.658	1.573	0.151	0.067
350	34.41	1.086–3	5.613–3	503.7	613.3	4.324	4.637	1.718	0.130	0.062
360	41.86	1.212–3	4.036–3	523.7	605.5	4.378	4.605	1.897	0.106	
369.3 ^c	49.89	2.015–3	2.015–3	570.0	570.0	4.501	4.501	∞		

*P, v, h, and s data interpolated from Perelshteyn (ed.), *Tables and Diagrams of the Thermodynamic Properties of Refrigerants 12, 13 and 22*, Moscow, 1971. c_p , μ , and k data interpolated and converted from *Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. c = critical point. The notation 6.209–4 signifies 6.209×10^{-4} . The 1993 ASHRAE Handbook—Fundamentals (SI ed.) gives a saturation table from –150 to 96.14°C and an enthalpy–log-pressure diagram from 0.1 to 150 bar, –60 to 200°C. For experimental isochores for the compressed liquid from 12 to 297 bar, 120 to 378 K, see Blanke, W. and R. Weiss, *PTB Bericht W 30*, Braunschweig, Germany, 1992 (54 pp.). Equations and constants approximated to 1985 ASHRAE tables are given by Mecarik, K. and M. Masaryk, *Heat Recovery Systems and CHP*, 11 2/3 (1991): 193–197. Saturation and superheat tables and a diagram to 100 bar, 620 K are given by Reynolds, W. C., *Thermodynamic Properties of Refrigerants in S.I.*, Stanford Univ. publ., 1979 (179 pp.). For tables and a chart to 2000 psia, 480°F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

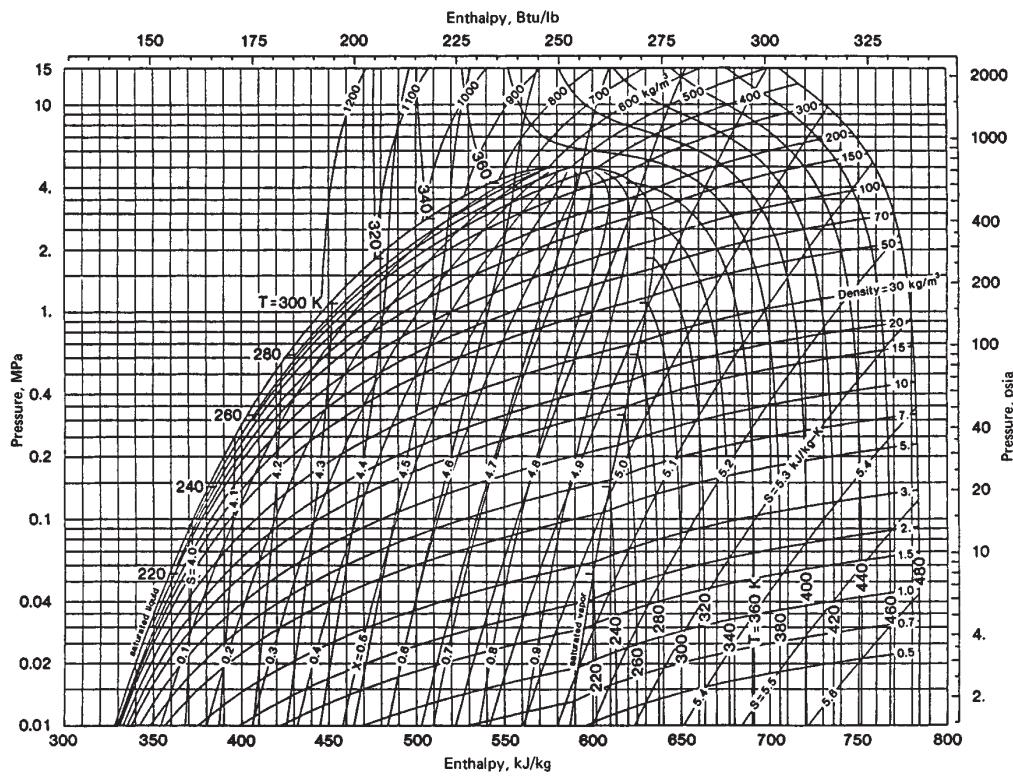


FIG. 2-20 Enthalpy–log-pressure diagram for Refrigerant 22. 1 MPa = 10 bar. (Copyright 1981 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers and reproduced by permission of the copyright owner.)

2-274 PHYSICAL AND CHEMICAL DATA
TABLE 2-306 Thermophysical Properties of Compressed R22

Pressure, bar	Property	Temperature, K							
		275	300	325	350	375	400	425	450
1	c_p (kJ/kg·K)	0.639	0.653	0.689	0.714	0.739	0.758	0.781	0.806
	μ (10^{-6} Pa·s)	11.8	12.8	13.9	14.9	15.8	16.7	17.7	18.7
	k (W/m·K)	0.0091	0.0106	0.0121	0.0136	0.0151	0.0166	0.0181	0.0196
	Pr	0.829	0.793	0.787	0.782	0.773	0.762	0.765	0.769
5	c_p (kJ/kg·K)	0.725	0.728	0.744	0.759	0.766	0.775	0.791	0.816
	μ (10^{-6} Pa·s)	11.8	12.8	13.8	15.0	16.2	17.0	18.0	18.8
	k (W/m·K)	0.0096	0.0107	0.0123	0.0138	0.0153	0.0170	0.0184	0.0199
	Pr	0.887	0.871	0.852	0.839	0.803	0.775	0.773	0.771
10	c_p (kJ/kg·K)	1.166	0.847	0.810	0.799	0.797	0.803	0.814	0.828
	μ (10^{-6} Pa·s)	211	13.7	14.4	15.1	16.1	17.1	18.1	19.0
	k (W/m·K)	0.0954	0.0121	0.0128	0.0144	0.0160	0.0175	0.0190	0.0205
	Pr	2.58	0.959	0.901	0.838	0.802	0.785	0.775	0.767
20	c_p (kJ/kg·K)	0.164	1.237		0.949	0.889	0.865	0.858	0.859
	μ (10^{-6} Pa·s)	211	159		16.5	17.3	18.0	18.8	19.6
	k (W/m·K)	0.0963	0.0849		0.0157	0.0172	0.0184	0.0199	0.0214
	Pr	2.55	2.32		0.997	0.894	0.846	0.811	0.787
40	c_p (kJ/kg·K)	1.152	1.217	1.359		1.373	1.089	0.996	0.956
	μ (10^{-6} Pa·s)	218	164	123		20.7	20.5	20.7	21.2
	k (W/m·K)	0.0980	0.0872	0.0767		0.0219	0.0210	0.0217	0.0233
	Pr	2.56	2.29	2.18		1.30	1.063	0.950	0.870
60	c_p (kJ/kg·K)	1.142	1.191	1.311	1.460		1.767	1.221	1.089
	μ (10^{-6} Pa·s)	221	170	128	94.6		24.7	24.2	23.9
	k (W/m·K)	0.0993	0.0889	0.0786		0.0305	0.0287	0.0268	
	Pr	2.54	2.28	2.14		1.431	1.030	0.971	
80	c_p (kJ/kg·K)	1.132	1.177	1.277	1.444	1.861		1.396	1.262
	μ (10^{-6} Pa·s)	226	175	133	101	73.6		29.9	27.7
	k (W/m·K)	0.1003	0.0904	0.0803	0.0690	0.0523		0.0374	0.0337
	Pr	2.55	2.28	2.12	2.12	2.62		1.12	1.04
100	c_p (kJ/kg·K)	1.122	1.154	1.247	1.361	1.564	2.073	1.923	1.471
	μ (10^{-6} Pa·s)	230	179	138	108	83.2	55.5	37.6	32.4
	k (W/m·K)	0.1013	0.0916	0.0817	0.0716	0.0607	0.0504	0.0421	0.0378
	Pr	2.55	2.26	2.11	2.04	2.14	2.28	1.72	1.26

Some values are approximate as significant differences exist in the literature.

TABLE 2-307 Saturated Refrigerant 23

Temp., K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10^{-6} Pa·s	k_f , W/(m·K)	Pr
180	0.510	0.000 678	0.4088	-66.0	181.1	-0.3179	1.0549				
190	0.950	0.000 693	0.2279	-54.4	185.3	-0.2554	1.0062				
191.1 ^b	1.013	0.000 695	0.2139	-53.1	185.7	-0.2485	1.0011				
200	1.652	0.000 710	0.1353	-42.6	189.1	-0.1948	0.9635				
210	2.709	0.000 729	0.0845	-30.3	192.4	-0.1353	0.9254				
220	4.298	0.000 751	0.0551	-17.5	195.4	-0.0764	0.8913				
230	6.312	0.000 777	0.0372	-4.3	197.8	-0.0182	0.8602	0.710	170.1	0.105	1.15
240	9.091	0.000 807	0.0259	9.4	199.6	0.0392	0.8314	1.043	150.4	0.098	1.56
250	12.69	0.000 844	0.0183	23.6	200.7	0.0957	0.8042	1.289	131.2	0.091	1.85
260	17.25	0.000 889	0.0132	38.1	200.9	0.1512	0.7773	1.497	113.0	0.084	2.00
270	22.94	0.000 948	0.0095	53.5	199.8	0.2071	0.7493				
280	29.98	0.001 031	0.0068	70.5	196.4	0.2665	0.7162				
290	38.68	0.001 169	0.0046	92.0	188.1	0.3387	0.6698				
299.1 ^c	48.36	0.001 905	0.0019	143.0	143.0	0.5062	0.5062				

^b = normal boiling point; ^c = critical point. $h_f = s_f = 0$ at 233.15 K = -40°C. Interpolated and converted from ASHRAE *Handbook—Fundamentals*, 1993. Experimental P–p–T data from 95 to 413 K reported in *J. Phys. Chem.*, **89** (1985): 4637–4646 were used by Rubio, R. G., J. A. Zollweg, et al., *J. Chem. Eng. Data*, **36**, (1991): 171–184, to calculate properties up to 1000 bar from 126 to 332° K.

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives a saturation table from -100 to 25.92°C and an enthalpy–log-pressure diagram from 0.1 to 80 bar, -100 to 280°C. Equations and constants approximated to the 1985 ASHRAE tables are given by Mecaryk, K. and M. Masaryk, *Heat Recovery Systems and CHP*, **11**, 2/3 (1991): 193–197.

For an enthalpy–log-pressure diagram from 0.005 to 200 bar, -140 to 180°C, see Morsy, T. E., *Kältetechnik—Klimat.*, **18**, 9 (1966): 347–349. Saturation and superheat tables and a diagram to 100 bar, 600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.).

For tables and a chart to 1000 psia, 560°F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (21 pp.).

For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

TABLE 2-308 Thermophysical Properties of Saturated Difluoromethane (R32)

Temp., K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	c_{pg} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	μ_g , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	k_g , W/(m·K)	Pr_f	Pr_g
200	0.2960	7.845,-4	1.0580	-52.340	351.160	-0.2418	1.7757								
210	0.5440	8.025,-4	0.5990	-37.750	356.880	-0.1652	1.7098								
220	0.9384	8.208,-4	0.3593	-20.690	361.970	-0.0909	1.6485	1.557	0.799	283.8	10.30				
230	1.5345	8.402,-4	0.2261	-4.984	366.773	-0.0215	1.5948	1.580	0.839	247.8	10.37				
240	2.3963	8.611,-4	0.1483	10.947	371.129	0.0459	1.5468	1.613	0.894	220.4	10.46				
250	3.5966	8.842,-4	0.1005	27.1778	374.971	0.1117	1.5030	1.642	0.963	198.1	10.66	0.1646	0.0097	1.98	1.06
260	5.2160	9.096,-4	0.07020	43.786	378.224	0.1763	1.4624	1.682	1.043	177.9	10.95	0.1562	0.0106	1.92	1.08
270	7.3423	9.376,-4	0.05009	60.849	380.786	0.2397	1.4247	1.730	1.138	159.1	11.31	0.1487	0.0115	1.85	1.12
280	10.070	9.696,-4	0.03643	78.456	382.525	0.3029	1.3886	1.786	1.244	141.8	11.70	0.1403	0.0125	1.81	1.16
290	13.502	1.006,-3	0.02687	96.713	383.262	0.3654	1.3534	1.863	1.375	126.1	12.21	0.1308	0.0136	1.80	1.23
300	17.749	1.049,-3	0.02001	115.754	382.737	0.4283	1.3182	1.955	1.560	112.0	12.82	0.1228	0.0149	1.78	1.34
310	22.931	1.100,-3	0.01497	135.801	380.576	0.4919	1.2815	2.084	1.810	98.8	13.71	0.1155	0.0165	1.78	1.50
320	29.186	1.166,-3	0.01117	157.212	376.163	0.5574	1.2415	2.282	2.16	86.1	14.4	0.1073	0.0184	1.83	1.69
330	36.675	1.243,-3	0.00822	180.724	368.357	0.6264	1.1950	2.620	2.62	75.1	15.3	0.0990	0.0205	1.99	1.96
340	45.603	1.394,-3	0.00581	208.262	354.460	0.7047	1.1347	3.560	4.21	65.4	17.3		0.0236		3.10
350	56.336		0.00317	274.640	337.933	0.8927	1.0735								
351.4 ^c	57.927		0.00237	286.675	286.675	0.9269	0.9269								

^c = critical point. The notation 7.845,-4 signifies 7.845×10^{-4} , P , v , T , h , s , and c_p converted and extrapolated from Defibaugh, D. R., G. Morrison, et al., *J. Chem. Eng. Data*, **39** (1994): 333–340. Saturated liquid and vapor viscosities from smooth curve fits of Oliveira, C. M. B. P. and W. A. Wakeham, *Int. J. Thermophys.*, **14**, 6 (1993): 1131–1143. Thermal conductivity values based upon papers by Geller, V. Z. and M. E. Perlaits, and by Gross, *Proc. 10th Symp. Thermophys. Props.*, Boulder, CO, 1994.

The 1993 ASHRAE Handbook—Fundamentals (SI ed.) gives a saturation table to 78.41°C and a diagram to 200 bar, 200°C.

2-276 PHYSICAL AND CHEMICAL DATA

TABLE 2-309 Specific Heat at Constant Pressure, Thermal Conductivity, Viscosity, and Prandtl Number of R32 Gas

Temp., K	Property	P, bar				Temp., K	P, bar						
		1	5	10	15		1	5	10	15	20	25	30
250	c_p (kJ/kg·K)	0.805				310	0.861	0.945	1.084	1.279	1.560		
	μ (10^{-6} Pa·s)	10.55					13.12	13.10	13.08	13.07	13.09		
	k (W/m·K)	0.0094					0.0135	0.0139	0.0144	0.0150	0.0159		
	Pr	0.908					0.878	0.891	0.985	1.114	1.284		
260	c_p (kJ/kg·K)	0.810	1.025			320	0.873	0.944	1.059	1.207	1.400	1.704	
	μ (10^{-6} Pa·s)	11.00	10.96				13.54	13.54	13.55	13.56	13.60	13.75	
	k (W/m·K)	0.0100	0.0104				0.0142	0.0146	0.0150	0.0156	0.0164	0.0173	
	Pr	0.890	1.080				0.836	0.875	0.957	1.049	1.161	1.354	
270	c_p (kJ/kg·K)	0.818	0.991			330	0.885	0.942	1.038	1.158	1.301	1.508	1.837
	μ (10^{-6} Pa·s)	11.42	11.37				13.96	13.96	13.98	14.01	14.15	14.28	14.52
	k (W/m·K)	0.0107	0.0111				0.0148	0.0152	0.0156	0.0162	0.0169	0.0177	0.0187
	Pr	0.873	1.015				0.834	0.865	0.930	1.001	1.089	1.217	1.426
280	c_p (kJ/kg·K)	0.825	0.969	1.238		340	0.897	0.937	1.020	1.135	1.242	1.388	1.612
	μ (10^{-6} Pa·s)	11.82	11.77	11.68			14.38	14.40	14.43	14.47	14.53	14.65	14.85
	k (W/m·K)	0.0116	0.0118	0.0125			0.0155	0.0159	0.0163	0.0168	0.0175	0.0182	0.0190
	Pr	0.860	0.967	1.157			0.832	0.849	0.903	0.978	1.031	1.117	1.260
290	c_p (kJ/kg·K)	0.837	0.959	1.161		350	0.910	0.934	1.004	1.118	1.200	1.308	1.440
	μ (10^{-6} Pa·s)	12.28	12.22	12.17			14.80	14.82	14.84	14.87	14.92	15.06	15.21
	k (W/m·K)	0.0121	0.0125	0.0131			0.0162	0.0165	0.0169	0.0174	0.0180	0.0186	0.0194
	Pr	0.849	0.938	1.079			0.831	0.839	0.882	0.955	0.995	1.060	1.130
300	c_p (kJ/kg·K)	0.849	0.951	1.118	1.370								
	μ (10^{-6} Pa·s)	12.70	12.69	12.66	12.62								
	k (W/m·K)	0.0128	0.0132	0.0138	0.0144								
	Pr	0.842	0.914	1.026	1.201								

Some values read from charts may be approximate. c_p values interpolated and converted from *Thermodynamic Properties of KLEA 32*, I.C.I., 1993 (47 pp.). Viscosity interpolated from Takahashi, M., C. Yokoyama, et al., *Proc. 14th Symp. Thermophys. Props.*, Japan, 1993 (pp. 427–430). Thermal conductivities are taken from Geller, V. Z. and M. E. Perlaitis, and from Gross, *Proc. 10th Symp. Thermophys. Props.*, Boulder, CO, 1994.

TABLE 2-310 Saturated SUVA MP 39

Temp., °C	P_f , bar	P_g , bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10^{-6} Pa·s	k_f , W/(m·K)	Pr_f
-40	0.733	0.533	0.000	712	0.3778	154.0	385.0	0.8188	1.8244	1.078	351	0.1209
-30	1.155	0.871	0.000	728	0.2391	164.9	390.6	0.8647	1.8059	1.109	323	0.1154
-20	1.748	1.361	0.000	744	0.1576	176.2	396.3	0.9099	1.7907	1.137	291	0.1107
-10	2.553	2.043	0.000	762	0.1075	188.6	401.8	0.9577	1.7781	1.165	266	0.1057
0	3.615	2.965	0.000	781	0.0755	200.0	407.3	1.0000	1.7675	1.197	241	0.1012
10	4.984	4.177	0.000	803	0.0544	212.7	412.6	1.0454	1.7587	1.233	221	0.0967
20	6.712	5.733	0.000	826	0.0399	225.3	417.6	1.0884	1.7510	1.277	202	0.0922
30	8.857	7.697	0.000	851	0.0298	238.3	422.2	1.1316	1.7439	1.329	186	0.0877
40	11.475	10.133	0.000	878	0.0225	252.0	426.5	1.1752	1.7372	1.392	170	0.0830
50	14.628	13.112	0.000	909	0.0172	266.4	430.1	1.2194	1.7304	1.468	157	0.0781
60	18.378	16.711	0.000	944	0.01313	281.6	433.0	1.2647	1.7228	1.564	143	0.0737
70	22.79	21.01	0.000	988	0.01005	297.9	434.9	1.3118	1.7138	1.652	131	0.0684
80	27.92	26.12	0.001	0.28	0.00764	315.9	435.4	1.3616	1.7022	1.802	122	0.0631
90	33.83	32.13	0.001	0.84	0.00570	336.2	433.5	1.4163	1.6858	1.958	115	0.0577
100	40.53	39.22	0.001	140	0.00403	361.4	426.9	1.4820	1.6584	2.16	110	0.0533
108.0 ^c	46.04	46.04	0.001	96	0.00196	397	397					

^c = critical point. SUVA MP 39 = R401A = CHClF₂ (R22) 53% wt + CH₃CHF₂ (R152a) 13% wt + CHClFCF₃ (R124) 34% wt, near-azeotropic blend. Some values read from charts are approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-311 SUVA MP 39 at Atmospheric Pressure

Temp., °C	-27.01	-20	0	20	40	60	80	100	120	140
v (m ³ /kg)	0.2102	0.2167	0.2351	0.2534	0.2715	0.2896	0.3076	0.3256	0.3435	0.3613
h (kJ/kg)	351.7	396.9	410.4	424.5	439.2	454.4	470.3	486.6	503.5	521.2
s (kJ/kg·K)	1.8009	1.8193	1.8706	1.9204	1.9689	2.0161	2.0623	2.1073	2.1513	2.1943
c_p (kJ/kg·K)	0.648	0.669	0.698	0.727	0.757	0.787	0.811	0.836	0.859	0.883
μ (10^{-6} Pa·s)	10.17	10.43	11.18	11.93	12.68	13.42	14.17	14.89	15.61	16.32
k (W/m·K)	0.00878	0.00921	0.01041	0.01161	0.01282	0.01404	0.01536	0.01668	0.01796	0.01929
Pr	0.750	0.758	0.750	0.749	0.749	0.748	0.748	0.748	0.747	0.747
Z	0.9829	0.9852	0.9906	0.9949	0.9979	1.0005	1.0025	1.0043	1.0056	1.0060

For composition see footnote to Table 2-310. Some values read from charts are approximate. Material used by permission of DuPont Fluoroproducts.

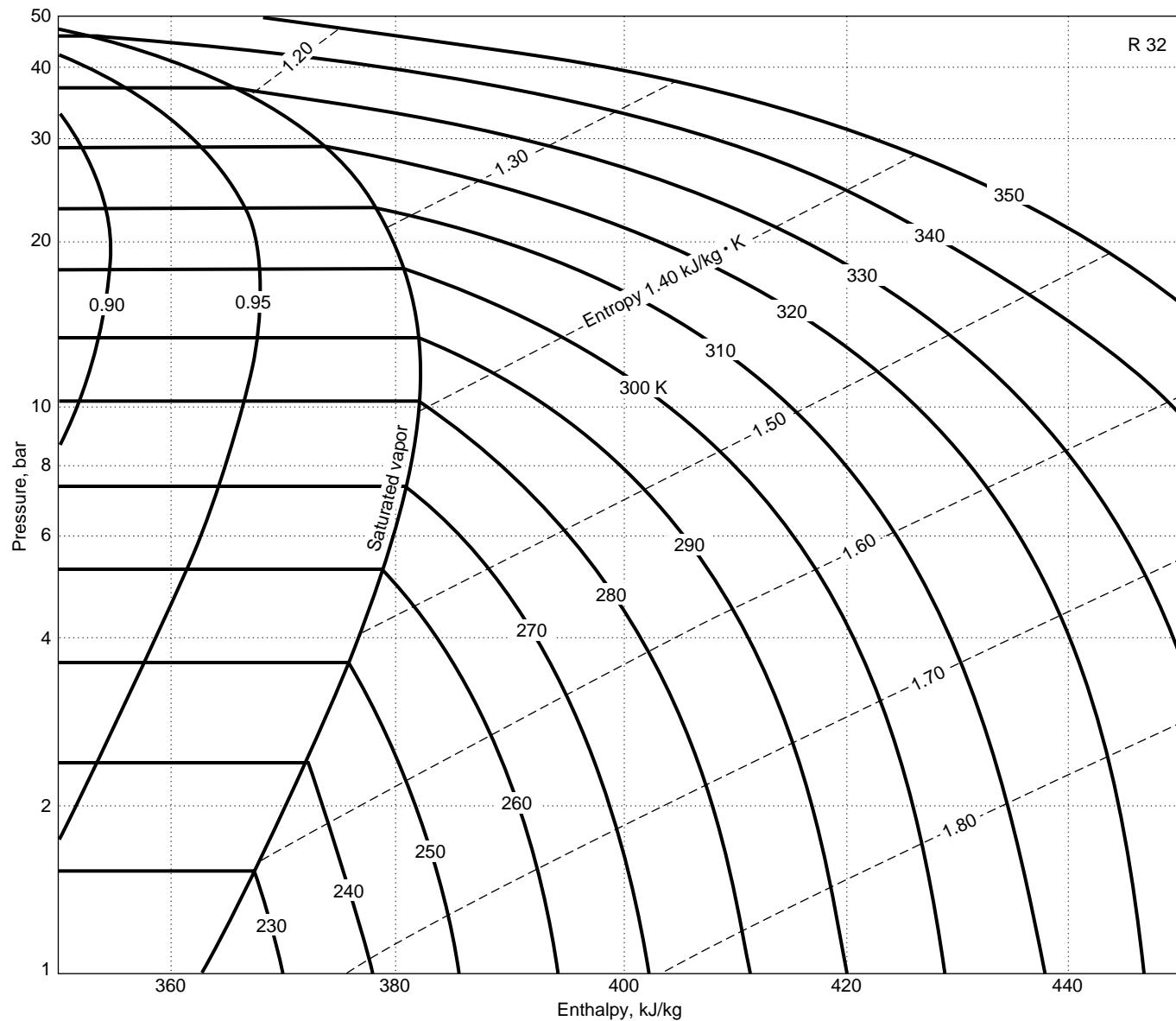


FIG. 2-21 Enthalpy-log-pressure diagram for Refrigerant 32.

TABLE 2-312 Thermodynamic Properties of Saturated KLEA 60

Pressure, bar	T_f , K	T_g , K	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
1	227.3	234.0	0.000 7118	0.2097	-7.80	229.64		0.9965
1.5	236.1	242.5	0.000 7263	0.1433	3.92	235.02		0.9833
2	242.8	249.1	0.000 7381	0.1093	12.89	239.07		0.9744
2.5	248.3	254.5	0.000 7483	0.0855	20.27	242.35		0.9679
3	253.0	259.1	0.000 7573	0.0744	26.57	245.08		0.9629
4	260.7	266.8	0.000 7735	0.0564	37.23	249.54		0.9552
5	267.3	273.1	0.000 7880	0.0442	46.12	253.07		0.9496
6	272.9	278.5	0.000 8012	0.0384	53.84	255.24		0.9450
8	282.1	287.5	0.000 8254	0.0286	67.02	260.70		0.9378
10	289.8	295.0	0.000 8480	0.0228	78.23	263.86		0.9318
12.5	297.9	302.8	0.000 8750	0.01802	90.50	266.95		0.9257
15	304.8	309.5	0.000 9017	0.01481	101.51	269.12		0.9190
17.5	311.0	315.4	0.000 9290	0.01247	111.64	270.58		0.9128
20	316.5	320.7	0.000 9613	0.01069	121.18	271.46		0.9065
22.5	321.4	325.5	0.000 9884	0.00928	130.31	271.79		0.8999
25	326.1	329.8	0.001 023	0.00828	139.17	271.63		0.8927
27.5	330.4	333.9	0.001 063	0.00717	147.89	270.97		0.8850
30	334.5	337.6	0.001 115	0.00635	156.58	269.81		0.8765

$h_f = s_f = 0$ at 233.15 K = -40°C. Converted and interpolated from *Thermodynamic Properties of Klea 60* (British units, 20 pp.), copyright ICI Chemicals and Polymers Limited, 1993. Reproduced by permission. T_f = bubble point temperature; T_g = dew point temperature.

TABLE 2-313 Thermodynamic Properties of Saturated KLEA 61

Pressure, bar	T_f , K	T_g , K	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
1	225.6	230.0	0.000 6852	0.1800	-9.45	191.64		0.8433
1.5	234.3	238.5	0.000 6994	0.1230	2.52	196.90		0.8341
2	241.8	245.0	0.000 7110	0.0937	9.72	200.88		0.8282
2.5	246.4	250.4	0.000 7211	0.0758	16.59	204.10		0.8245
3	251.1	254.9	0.000 7301	0.0637	22.47	206.80		0.8215
4	258.9	262.6	0.000 7463	0.04831	32.43	211.22		0.8172
5	265.4	269.0	0.000 7607	0.03888	40.76	214.74		0.8141
6	270.9	274.4	0.000 7740	0.03249	48.00	217.65		0.8123
8	280.2	283.4	0.000 7985	0.02435	59.82	222.21		0.8080
10	287.8	290.9	0.000 8214	0.01936	70.98	225.63		0.8048
12.5	295.8	298.7	0.000 8491	0.01528	82.59	228.80		0.8010
15	302.8	305.5	0.000 8768	0.01251	93.02	231.08		0.7971
17.5	308.8	311.4	0.000 9053	0.01049	102.67	232.64		0.7929
20	314.3	316.7	0.000 9353	0.00896	111.79	233.60		0.7882
22.5	319.3	321.5	0.000 9680	0.00774	120.55	233.99		0.7829
25	323.9	325.9	0.001 005	0.00674	129.11	233.85		0.7769
27.5	328.1	330.0	0.001 048	0.00590	137.62	233.16		0.7700
30	332.1	333.7	0.001 102	0.00518	146.21	231.84		0.7619

Converted and interpolated from *Thermodynamic Properties of Klea 61* (British units, 20 pp.), copyright ICI Chemicals and Polymers Limited, 1993. Reproduced by permission. T_f = bubble-point temperature; T_g = dew-point temperature. $h_f = s_f = 0$ at 233.15 K = -40 °C.

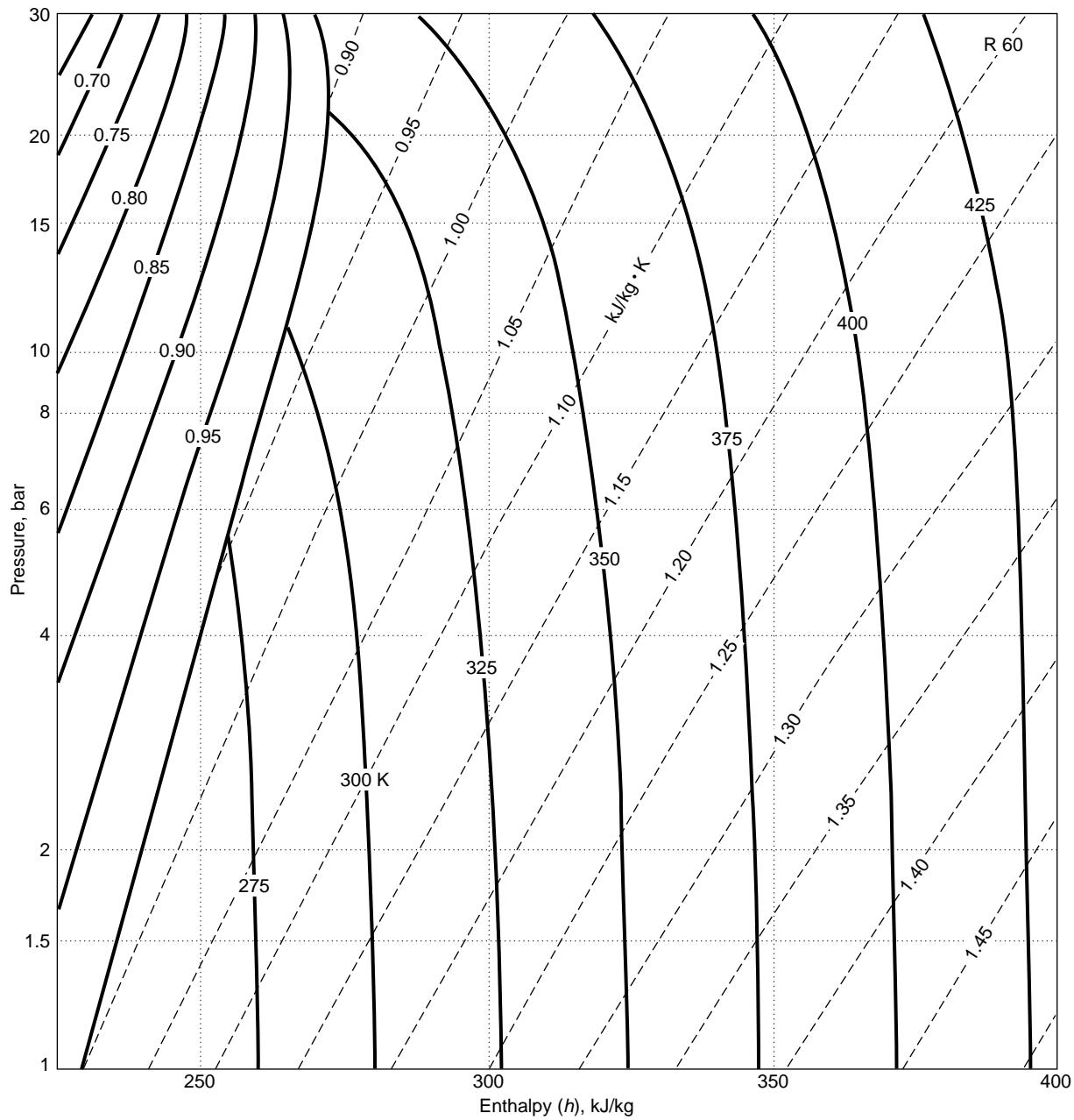


FIG. 2-22 Enthalpy–log-pressure diagram for KLEA 60.

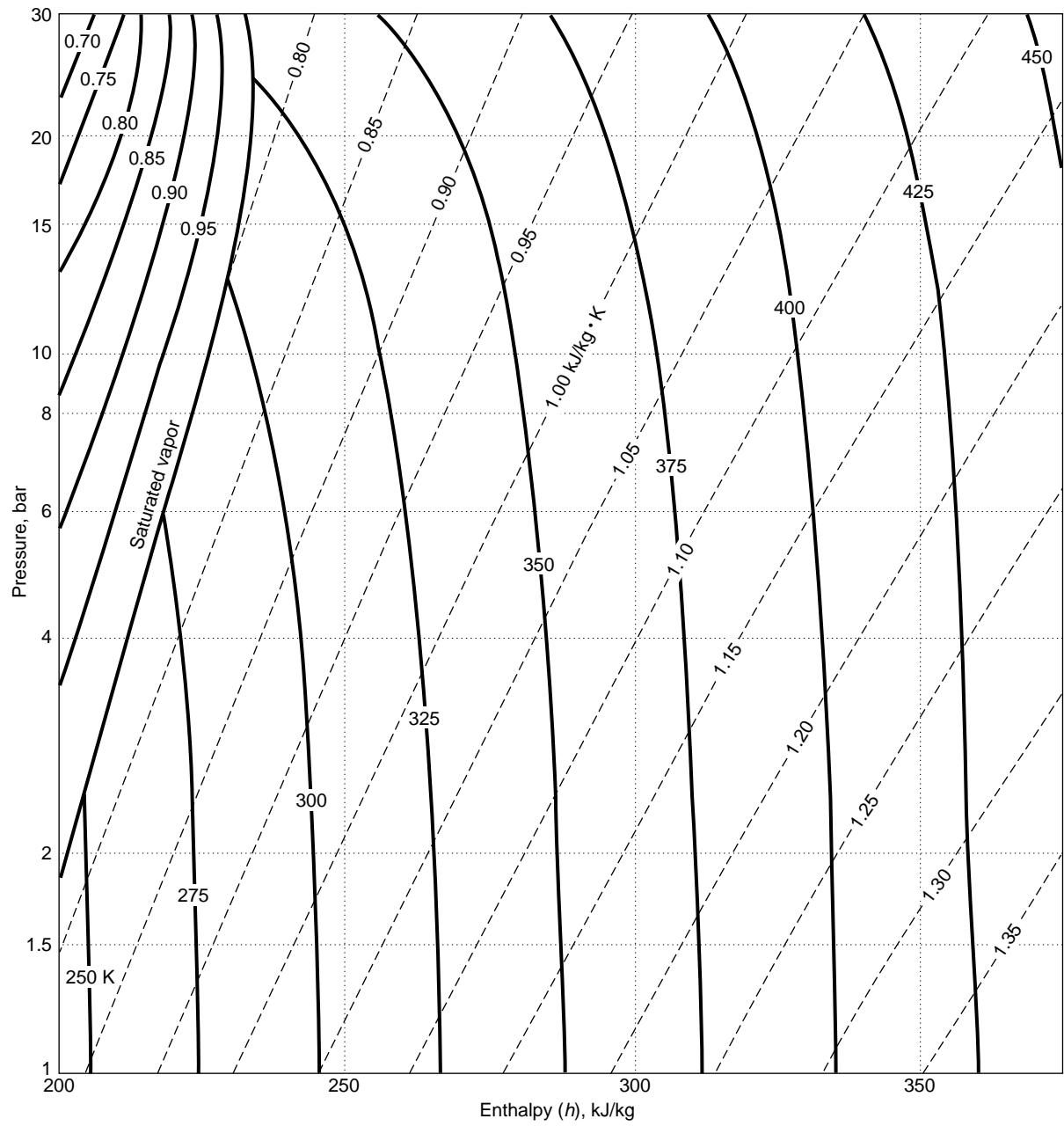


FIG. 2-23 Enthalpy–log-pressure diagram for KLEA 61.

TABLE 2-314 Saturated SUVA HP 62

Temp., °C	P_f , bar	P_g , bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	Pr_f
-50	0.852	0.821	0.000 761	0.2244	133.1	337.3	0.7318	1.6487		370	0.0970	
-40	1.367	1.325	0.000 779	0.1434	145.6	343.8	0.7862	1.6380		318		
-30	2.095	2.041	0.000 799	0.0953	159.9	350.3	0.8460	1.6301	1.220	276	0.0868	3.88
-20	3.087	3.018	0.000 820	0.0656	172.8	356.5	0.8975	1.6245	1.260	238	0.0834	3.60
-10	4.404	4.321	0.000 843	0.0463	186.1	362.6	0.9487	1.6202	1.302	207	0.0801	3.37
0	6.111	6.013	0.000 868	0.03338	200.0	368.3	1.0000	1.6188	1.351	181	0.0767	3.19
10	8.278	8.165	0.000 898	0.02444	214.5	373.6	1.0515	1.6138	1.412	158	0.0733	3.04
20	10.977	10.851	0.000 933	0.01809	229.9	378.3	1.1038	1.6106	1.489	138	0.0698	2.94
30	14.287	14.150	0.000 977	0.01348	246.2	382.2	1.1574	1.6065	1.592	122	0.0663	2.93
40	18.292	18.148	0.001 037	0.01003	263.8	385.0	1.2130	1.6005	1.753	106	0.0624	2.98
50	23.08	22.94	0.001 122	0.00739	283.2	386.1	1.2723	1.5910	2.09	91	0.0583	3.26
60	28.75	28.63	0.001 261	0.00527	305.8	384.2	1.3389	1.5742		76	0.0535	
70	35.58			0.00285	339.8	375.9				61		
72.1 ^c	37.32	37.32	0.002 06	0.00206	361	361						

^c = critical point. SUVA HP 62 = CHF₂CF₃ (R125) 44% wt + CH₃CF₃ (R143a) 52% wt + CH₂FCF₃ (R134a) 4% wt, near-azeotropic blend. Material used by permission of DuPont Fluoroproducts. Some values read from charts may be approximate.

TABLE 2-315 SUVA HP 62 at Atmospheric Pressure

Temp., °C	-45.63	-40	-20	0	20	40	60	80	100	120
v (m ³ /kg)	0.1866	0.1921	0.2100	0.2278	0.2455	0.2630	0.2805	0.2980	0.3153	0.3325
h (kJ/kg)	336.0	344.4	359.9	376.2	393.1	410.9	429.3	448.4	468.2	488.7
s (kJ/kg·K)	1.6599	1.6636	1.7274	1.7891	1.8491	1.9076	1.9646	2.0203	2.0747	2.1278
c_p (kJ/kg·K)	0.732	0.738	0.781	0.821	0.860	0.897	0.933	0.967	1.000	1.032
μ (10 ⁻⁶ Pa·s)	9.47	9.68	10.45	11.22	11.99	12.76	13.53	14.30	15.07	15.84
k (W/m·K)	0.00860	0.00932	0.01059	0.01186	0.01313	0.01440	0.01568	0.01695	0.01827	0.01949
Pr	0.806	0.767	0.771	0.777	0.785	0.795	0.805	0.816	0.827	0.839
Z	0.9755	0.9800	0.9867	0.9919	0.9961	0.9989	1.0014	1.0037	1.0050	1.0060

v, h , and s from DuPont bull. T—HP62—SI, June 1993 (17 pp.). c_p and k from DuPont bull. ART 18, June 1993 (37 pp.). Some values read from charts may be approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-316 Thermodynamic Properties of Saturated KLEA 66

Pressure, bar	T_f , K	T_g , K	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
0.69	221.46	228.77	0.000 7122	0.31325	-16.16	241.25		1.0729
1	228.89	236.05	0.000 7237	0.22131	-5.89	245.91		1.0580
1.5	237.69	244.69	0.000 7382	0.15140	6.22	251.38		1.0430
2	244.45	251.33	0.000 7501	0.11537	15.51	255.52		1.0330
2.5	249.99	256.76	0.000 7600	0.09104	23.12	258.95		1.0258
3	254.36	261.39	0.000 7695	0.07855	29.62	261.63		1.0201
4	262.60	269.14	0.000 7857	0.05964	40.60	266.16		1.0114
5	269.12	275.51	0.000 8001	0.04806	49.74	269.74		1.0055
6	274.70	280.98	0.000 8133	0.04021	57.69	272.68		0.9993
8	284.03	290.08	0.000 8375	0.03022	71.22	277.25		0.9913
10	291.74	297.56	0.000 8599	0.02410	82.73	280.64		0.9834
12.5	299.87	305.44	0.000 8867	0.01910	95.32	283.74		0.9770
15	306.87	312.18	0.000 9131	0.01571	106.59	285.93		0.9701
17.5	313.05	318.10	0.000 9400	0.01324	116.97	287.28		0.9633
20	318.60	323.40	0.000 9680	0.01137	126.73	288.26		0.9564
22.5	323.7	328.2	0.000 9981	0.00988	136.0	288.6		0.9493
25	328.3	332.5	0.001 032	0.00883	145.1	288.4		0.9418
27.5	332.7	336.6	0.001 072	0.00766	153.9	287.8		0.9338
30	336.7	340.4	0.001 125	0.00703	162.7	286.6		0.9251

Converted and interpolated from *Thermodynamic Properties of Klea 66* (British units, 22 pp.), copyright ICI Chemicals and Polymers Limited, 1993. Reproduced by permission. T_f = bubble-point temperature; T_g = dew-point temperature. $h_f = s_f = 0$ at 233.15 K = -40°C.

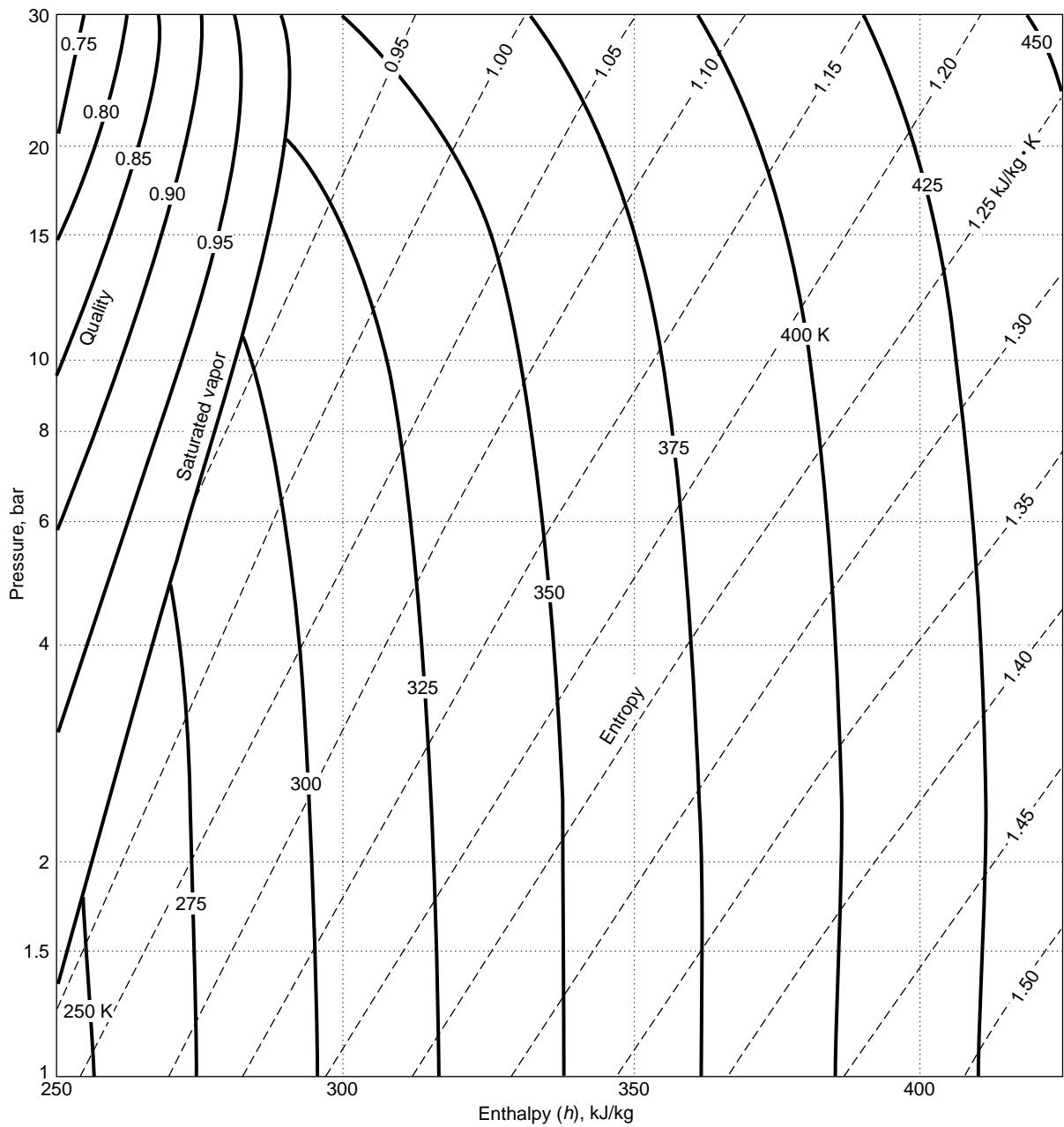


FIG. 2-24 Enthalpy–log-pressure diagram for KLEA 66.

TABLE 2-317 Saturated SUVA MP 66

Temp., °C	P_f , bar	P_g , bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	Pr_f
-40	0.788	0.585	0.000 710	0.3498	153.8	386.0	0.8184	1.8291	1.078	349	0.1209	3.11
-30	1.239	0.952	0.000 725	0.2224	164.8	391.6	0.8643	1.8100	1.109	313	0.1154	3.01
-20	1.872	1.479	0.000 740	0.1471	176.0	397.1	0.9095	1.7940	1.137	282	0.1106	2.90
-10	2.726	2.212	0.000 758	0.1008	188.6	402.6	0.9577	1.7807	1.165	257	0.1057	2.83
0	3.850	3.198	0.000 778	0.0710	200.0	407.8	1.0000	1.7694	1.197	236	0.1012	2.79
10	5.297	4.491	0.000 801	0.05124	212.6	412.9	1.0450	1.7598	1.233	217	0.0967	2.77
20	7.120	6.146	0.000 827	0.03771	225.1	417.7	1.0879	1.7512	1.277	198	0.0922	2.74
30	9.379	8.229	0.000 858	0.02818	238.2	422.1	1.1311	1.7433	1.329	181	0.0877	2.74
40	12.133	10.808	0.000 895	0.02131	251.9	426.1	1.1747	1.7357	1.392	168	0.0830	2.82
50	15.444	13.955	0.000 939	0.01625	266.3	429.4	1.2190	1.7278	1.468	151	0.0781	2.84
60	19.378	17.750	0.000 994	0.01244	281.6	431.9	1.2645	1.7191	1.564	139	0.0737	2.95
70	24.00	22.28	0.001 066	0.00951	298.1	433.4	1.3120	1.7088	1.652	127	0.0684	3.07
80	29.37	27.64	0.001 164	0.00721	316.3	433.2	1.3625	1.6956	1.802	116	0.0631	3.31
90	35.55	33.96	0.001 313	0.00534	337.2	430.4	1.4187	1.6768			0.0577	
100	42.30										0.0533	
106.1 ^c	46.82	46.82	0.001 95	0.00195	389	389						

^c = critical point. SUVA MP 66 = R401 = CHClF₂ (R22) 61% wt + CH₃CHF₂ (R152a) 11% wt + CHClFCF₃ (R124) 28% wt, near-azeotropic blend. Material used by permission of DuPont Fluoroproducts. Some values read from charts are approximate.

TABLE 2-318 SUVA MP 66 at Atmospheric Pressure

Temp., °C	-28.63 ^b	-20	0	20	40	60	80	100	120	140
v (m ³ /kg)	0.2086	0.2177	0.2362	0.2545	0.2727	0.2908	0.3089	0.3269	0.3449	0.3629
h (kJ/kg)	392.2	397.9	411.2	425.1	439.6	454.6	470.1	486.2	502.7	519.4
s (kJ/kg·K)	1.8081	1.8299	1.8804	1.9295	1.9772	2.0237	2.0690	2.1132	2.1564	2.1986
c_p (kJ/kg·K)	0.641	0.652	0.688	0.716	0.744	0.771	0.796	0.822	0.844	0.866
μ (10 ⁻⁶ Pa·s)	9.78	10.43	11.18	11.93	12.68	13.42	14.17	14.89	15.61	16.32
k (W/m·K)	0.00817	0.00921	0.01041	0.01161	0.01282	0.01404	0.01536	0.01668	0.01796	0.01929
Pr	0.767	0.738	0.737	0.736	0.735	0.735	0.734	0.734	0.733	0.733
Z	0.9652	0.9730	0.9783	0.9822	0.9852	0.9876	0.9896	0.9912	0.9925	0.9937

^v, ^h, and ^s from DuPont bull. T—MP 66—SI, Jan. 1993 (17 pp.). c_p , μ , and k from DuPont bull. ART 10, Jan. 1993 (27 pp.). Some values read from charts may be approximate. Material used by permission of DuPont Fluoroproducts. ^b = normal boiling point.

TABLE 2-319 Saturated SUVA HP 80

Temp., °C	P_f , bar	P_g , bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	Pr_f
-50	0.962	0.872	0.000 679	0.2033	139.6	334.1	0.7578	1.6327		377	0.0970	
-40	1.520	1.403	0.000 695	0.1303	150.8	339.9	0.8070	1.6206		317		
-30	2.305	2.156	0.000 713	0.0869	163.1	345.6	0.8584	1.6110	1.193	283	0.0880	3.84
-20	3.370	3.188	0.000 733	0.0598	174.9	351.1	0.9053	1.6034	1.217	247	0.0849	3.54
-10	4.776	4.560	0.000 757	0.0423	187.6	356.4	0.9541	1.5972	1.236	215	0.0813	3.27
0	6.588	6.336	0.000 785	0.03060	200.0	361.3	1.0000	1.5919	1.253	188	0.0778	3.03
10	8.877	8.592	0.000 819	0.02248	213.0	365.9	1.0461	1.5870	1.286	165	0.0743	2.86
20	11.720	11.404	0.000 860	0.01671	226.7	369.8	1.0927	1.5820	1.340	146	0.0708	2.76
30	15.195	14.855	0.000 911	0.01250	241.2	373.1	1.1403	1.5762	1.412	128	0.0672	2.69
40	19.388	19.034	0.000 977	0.00936	256.8	375.4	1.1897	1.5690	1.512	113	0.0634	2.70
50	24.39	24.04	0.001 070	0.00696	273.9	376.2	1.2420	1.5589	1.64	98	0.0593	2.71
60	30.30	29.97	0.001 212	0.00505	293.6	374.6	1.2998	1.5433	1.81	83	0.0551	2.79
70										68		
75.5 ^c	41.35	41.35	0.001 850	0.00185	340	340						

^c = critical point. SUVA HP 80 = R402 = CHF₂CF₃ (R125) 60% wt + CH₃CH₂CH₃ (R290) 2% wt + CHClF₂ (R22) 38% wt, near-azeotropic blend. Material used by permission of DuPont Fluoroproducts. Some values, read from charts, may be approximate.

2-284 PHYSICAL AND CHEMICAL DATA
TABLE 2-320 SUVA HP 80 at Atmospheric Pressure

Temp., °C	-46.95 ^b	-40	-20	0	20	40	60	80	100	120
<i>v</i> (m ³ /kg)	0.1768	0.1827	0.1996	0.2164	0.2331	0.2497	0.2663	0.2828	0.2992	0.3155
<i>h</i> (kJ/kg)	335.9	340.5	354.3	368.6	383.5	398.7	414.9	431.4	448.5	466.1
<i>s</i> (kJ/kg·K)	1.6286	1.6490	1.7055	1.7599	1.8124	1.8633	1.9128	1.9610	2.0081	2.0541
<i>c_p</i> (kJ/kg·K)	0.648	0.654	0.687	0.721	0.749	0.779	0.807	0.836	0.863	0.890
μ (10 ⁻⁶ Pa·s)	9.42	9.69	10.45	11.22	11.99	12.75	13.52	14.29	15.06	15.82
<i>k</i> (W/m·K)	0.00888	0.00932	0.01059	0.01186	0.01313	0.01440	0.01568	0.01695	0.01822	0.01949
<i>P_r</i>	0.687	0.680	0.678	0.681	0.685	0.690	0.696	0.703	0.713	0.722
<i>Z</i>	0.9673	0.9697	0.9758	0.9804	0.9840	0.9868	0.9892	0.9910	0.9923	0.9932

b = normal boiling pt. *v*, *h*, and *s* from DuPont bull. T—HP 80—SI, Jan. 1993 (17 pp.). *c_p*, μ , and *k* from DuPont bull. ART 18, June 1993 (37 pp.). Some values read from charts may be approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-321 Saturated SUVA HP 81

Temp., °C	<i>P_f</i> , bar	<i>P_g</i> , bar	<i>v_f</i> , m ³ /kg	<i>v_g</i> , m ³ /kg	<i>h_f</i> , kJ/kg	<i>h_g</i> , kJ/kg	<i>s_f</i> , kJ/(kg·K)	<i>s_g</i> , kJ/(kg·K)	<i>c_{pf}</i> , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	<i>k_f</i> , W/(m·K)	<i>P_{r_f}</i>
-50	0.883	0.787	0.000 687	0.2425	140.3	351.7	0.7606	1.7122		383	0.1031	
-40	1.403	1.273	0.000 702	0.1548	151.4	357.2	0.8092	1.6957		333	0.0983	
-30	2.135	1.967	0.000 719	0.1028	163.3	362.7	0.8589	1.6820	1.178	290	0.0941	3.63
-20	3.132	2.923	0.000 739	0.0707	174.9	368.0	0.9054	1.6706	1.191	253	0.0900	3.35
-10	4.451	4.198	0.000 761	0.0499	187.8	373.0	0.9550	1.6611	1.204	223	0.0863	3.11
0	6.153	5.852	0.000 787	0.03610	200.0	377.8	1.0000	1.6528	1.221	195	0.0818	2.91
10	8.307	7.959	0.000 817	0.02656	212.7	382.2	1.0450	1.6451	1.288	173	0.0790	2.82
20	10.984	10.591	0.000 854	0.01980	226.0	386.0	1.0905	1.6376	1.313	151	0.0753	2.63
30	14.261	13.827	0.000 899	0.01490	240.1	389.3	1.1367	1.6299	1.37	137	0.0715	2.49
40	18.216	17.750	0.000 955	0.01125	255.1	391.5	1.1842	1.6211	1.75	122	0.0676	3.16
50	22.93	22.45	0.001 030	0.00848	271.4	392.8	1.2339	1.6104	2.07	106	0.0633	3.47
60	28.50	28.03	0.001 136	0.00632	289.5	392.2	1.2873	1.5961		91	0.0586	
70	35.01	34.60	0.001 307	0.00456	299.6	390.9	1.3164	1.5866		75	0.0544	
80												
82.6°	44.45	44.45	0.001 88	0.00188	351	351						

c = critical point. SUVA HP 81 = R402 (38/2/60) = CH₂CF₃ (R125) 38% wt + CH₃CH₂CH₃ (R290) 2% wt + CHClF₂ (R22) 60% wt, near-azeotropic blend. Material used by permission of DuPont Fluoroproducts. Some values read from charts may be approximate.

TABLE 2-322 SUVA HP 81 at Atmospheric Pressure

Temp., °C	-44.87 ^b	-40	-20	0	20	40	60	80	100	120
<i>v</i> (m ³ /kg)	0.1903	0.1960	0.2142	0.2322	0.2500	0.2678	0.2856	0.3032	0.3209	0.3386
<i>h</i> (kJ/kg)	354.7	357.7	370.8	384.6	398.8	413.6	428.9	444.7	461.0	477.7
<i>s</i> (kJ/kg·K)	1.7032	1.7169	1.7711	1.8232	1.8735	1.9222	1.9696	2.0158	2.0607	2.1047
<i>c_p</i> (kJ/kg·K)	1.187	1.177	1.169	1.159	1.149	1.143	1.134	1.128	1.124	1.120
μ (10 ⁻⁶ Pa·s)	10.16	10.33	11.10	11.86	12.62	13.39	14.15	14.78	15.54	16.30
<i>k</i> (W/m·K)	0.00739	0.00768	0.00902	0.01036	0.01170	0.01304	0.01438	0.01572	0.01706	0.01840
<i>P_r</i>	1.632	1.583	1.439	1.327	1.239	1.174	1.124	1.061	1.024	0.992
<i>Z</i>	0.9622	0.9703	0.9766	0.9811	0.9843	0.9870	0.9894	0.9909	0.9926	0.9940

b = normal boiling point. *v*, *h*, and *s* from DuPont bull. T—HP 81—SI, Jan. 1993 (17 pp.). *c_p*, μ , and *k* from DuPont bull. ART 18, June 1993 (37 pp.). Some values, read from charts, may be approximate. Material used by permission of DuPont Fluoroproducts.

TABLE 2-323 Saturated Refrigerant 113*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
240	0.0233	5.908,-4	4.548	5.70	171.97	0.0241	0.7169	0.845	17.9	0.087
250	0.0435	5.956,-4	2.537	14.19	178.06	0.0587	0.7142	0.877	14.8	0.084
260	0.0767	6.066,-4	1.492	22.83	184.22	0.0926	0.7134	0.895	12.3	0.083
270	0.1290	6.150,-4	0.9189	31.65	190.46	0.1259	0.7141	0.916	10.4	0.081
280	0.2076	6.237,-4	0.5893	40.63	196.75	0.1585	0.7161	0.933	8.9	0.079
290	0.3217	6.328,-4	0.3917	49.77	203.08	0.1906	0.7192	0.946	7.6	0.077
300	0.4817	6.422,-4	0.2687	59.07	209.44	0.2221	0.7233	0.958	6.6	0.075
310	0.6999	6.522,-4	0.1895	68.51	215.80	0.2530	0.7281	0.971	5.9	0.073
320	0.9897	6.626,-4	0.1370	78.09	222.17	0.2833	0.7336	0.983	5.2	0.071
330	1.3657	6.737,-4	0.1012	87.80	228.53	0.3131	0.7396	0.992	4.7	0.069
340	1.8347	6.854,-4	0.0762	97.64	234.86	0.3424	0.7460	1.000	4.2	0.066
350	2.4406	6.979,-4	0.0584	107.58	241.16	0.3711	0.7528	1.013	3.8	0.065
360	3.174	7.112,-4	0.0454	117.65	247.41	0.3993	0.7598	1.029	3.4	0.062
370	4.062	7.255,-4	0.0357	127.82	253.59	0.4270	0.7669	1.042	3.2	0.060
380	5.123	7.411,-4	0.0284	138.11	259.70	0.4542	0.7742	1.059	2.9	0.058
390	6.379	7.580,-4	0.0229	148.52	265.71	0.4810	0.7815	1.084	2.7	0.056
400	7.849	7.767,-4	0.0185	159.07	271.59	0.5075	0.7888	1.109	2.46	0.054
410	9.556	7.975,-4	0.0151	169.78	277.31	0.5336	0.7958	1.14	2.28	0.052
420	11.52	8.211,-4	0.0124	180.69	282.83	0.5595	0.8027	1.18	2.10	0.050
430	13.78	8.483,-4	0.0102	191.85	288.09	0.5853	0.8091	1.22	1.93	0.047
440	16.35	8.806,-4	0.0083	203.35	292.98	0.6112	0.8149	1.27	1.75	0.045
450	19.26	9.201,-4	0.0068	215.31	297.38	0.6375	0.8198	1.32	1.58	0.042
460	22.56	9.713,-4	0.0055	227.97	301.03	0.6645	0.8234	1.38	1.33	0.039
470	26.29	1.044,-3	0.0044	241.79	303.41	0.6933	0.8244	1.45	1.07	0.035
480	30.52	1.174,-3	0.0032	258.16	303.00	0.7264	0.8198	1.54	0.77	0.031
487.5 ^c	34.11	1.754,-3	0.0018	288.10	288.10	0.7828	0.7828	∞	0.30	∞

*Values reproduced or converted from Table 8, p. 17.91, *ASHRAE Handbook, 1981: Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 5.908,-4 signifies 5.908×10^{-4} . The 1993 *ASHRAE Handbook—Fundamentals* (SI ed.) gives a saturation table from -30 to 214.4°C and an enthalpy-log-pressure diagram from 0.1 to 60 bar, 0 to 260°C. Equations and constants approximated to the 1985 ASHRAE tables were given by Mecaryk, K. and M. Masaryk, *Heat Recovery Systems and CHP*, 11, 2/3 (1991): 193-197. For experimental isochores for the compressed liquid from 21 to 304 bar, 266 to 453 K, see Blanke, W. and R. Weiss, PTB Bericht W 30, Braunschweig, Germany, 1992 (54 pp.).

For tables to 300 bar, 460 K, see Geller, V. Z. and V. A. Rabinovich (ed.), *Thermophysical Properties of Substances and Materials*, Standartov, Moscow, 7 (1973): 135-154. Mastroianni, M. J., R. F. Stahl, et al., *J. Chem. Eng. Data*, 23, 2 (1978): 113-118 give a diagram to 1000 psia, 600°F. Tables and a diagram to 800 psia, 520°F are given by Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

TABLE 2-324 Saturated Refrigerant 114*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
190	0.0058	6.326,-4	15.823	-42.58	125.78	-0.2091	0.6794	0.765	23.9	0.093
200	0.0137	6.344,-4	7.094	-31.87	131.01	-0.1542	0.6648	0.787	18.2	0.090
210	0.029	6.366,-4	3.465	-21.48	136.41	-0.1035	0.6541	0.810	14.3	0.088
220	0.059	6.391,-4	1.822	-11.37	141.95	-0.0565	0.6466	0.831	11.5	0.085
230	0.109	6.421,-4	1.021	-1.50	147.61	-0.0126	0.6419	0.854	9.4	0.082
240	0.190	6.457,-4	0.604	8.18	153.36	0.0286	0.6393	0.877	7.9	0.080
250	0.317	6.500,-4	0.375	17.74	159.18	0.0676	0.6387	0.900	6.61	0.077
260	0.505	6.554,-4	0.2431	27.22	165.05	0.1047	0.6396	0.923	5.66	0.075
270	0.773	6.619,-4	0.1633	36.71	170.95	0.1405	0.6418	0.946	4.96	0.072
280	1.143	6.700,-4	0.1132	46.27	176.85	0.1751	0.6452	0.967	4.30	0.069
290	1.636	6.799,-4	0.0807	55.95	182.75	0.2090	0.6494	0.991	3.80	0.067
300	2.279	6.918,-4	0.0590	65.79	188.61	0.2422	0.6543	1.015	3.35	0.064
310	3.096	7.060,-4	0.0440	75.79	194.44	0.2748	0.6598	1.038	3.02	0.061
320	4.116	7.224,-4	0.0334	85.92	200.19	0.3067	0.6657	1.062	2.69	0.059
330	5.366	7.412,-4	0.0257	96.16	205.84	0.3379	0.6719	1.087	2.48	0.056
340	6.877	7.624,-4	0.0201	106.49	211.37	0.3685	0.6781	1.111	2.27	0.054
350	8.683	7.863,-4	0.0158	116.96	216.71	0.3984	0.6843	1.136	2.07	0.051
360	10.82	8.135,-4	0.0125	127.63	221.82	0.4280	0.6903	1.160	1.91	0.048
370	13.32	8.453,-4	0.0099	138.60	226.57	0.4575	0.6957	1.185	1.76	0.045
380	16.24	8.836,-4	0.0079	149.99	230.84	0.4872	0.7002	1.210	1.59	0.042
390	19.62	9.324,-4	0.0062	162.01	234.36	0.5176	0.7032	1.236	1.39	0.038
400	23.52	1.001,-3	0.0048	175.03	236.61	0.5496	0.7036	1.261	1.17	0.034
410	28.00	1.118,-3	0.0035	190.13	236.20	0.5857	0.6980	1.5	0.87	0.030
419.0 ^c	32.61	1.795,-3	0.0018	219.90	219.90	0.6559	∞	0.34	∞	∞

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Saturation and superheat tables and a diagram to 60 bar, 540 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (179 pp.). Tables and a chart to 1500 psia, 480°F are given by Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

TABLE 2-325 Saturated Refrigerant 115*

Temp., °F	Pressure, lb/in ² abs.	Volume, ft ³ /lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)°F)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-100	2.327	0.00966	10.57	-13.07	45.83	-0.0335	0.1302
-80	4.573	0.00986	5.624	-8.78	48.39	-0.0219	0.1256
-60	8.306	0.01009	3.218	-4.43	50.96	-0.0108	0.1278
-40	14.13	0.01033	1.953	0.00	53.53	0.0000	0.1275
-20	22.74	0.01060	1.245	4.50	56.07	0.0104	0.1277
0	34.94	0.01090	0.8257	9.09	58.56	0.0206	0.1282
20	51.59	0.01123	0.5657	13.76	61.00	0.0305	0.1290
40	73.65	0.01161	0.3979	18.54	63.35	0.0401	0.1298
60	102.1	0.01204	0.2857	23.45	65.60	0.0496	0.1308
80	138.1	0.01255	0.2081	28.54	67.71	0.0591	0.1317
100	182.7	0.01316	0.1530	33.85	69.63	0.0686	0.1325
120	237.3	0.01393	0.1125	39.50	71.24	0.0782	0.1330
140	303.2	0.01496	0.0817	45.67	72.36	0.0884	0.1329
160	382.0	0.01664	0.0567	52.76	72.42	0.0996	0.1314
170	427.0	0.01838	0.0444	56.56	71.33	0.1055	0.1290
175.89 ^c	457.6	0.0261	0.0261	64.30	64.30	0.1175	0.1175

*Unpublished data of General Chemicals Division, Allied Chemical Company. Used by permission. *c* = critical temperature.

No material in SI units appears in the 1993 ASHRAE *Handbook—Fundamentals* (SI ed.). Tables and a chart to 50 ata, 200°C are given by Mathias, H. and H. J. Loffler, Techn. Univ. Berlin rept., 1966 (42 pp.). A chart to 1500 psia, 500°F was given by Mears, W. H., E. Rosenthal, et al., *J. Chem. Eng. Data*, 11, 3 (1966): 338-343.

TABLE 2-326 Thermodynamic Properties of Refrigerant 123

Pressure, bar	Temp., K	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	k_f , W/(m·K)	μ_f , 10 ⁻⁶ Pa·s	Pr_f
0.1	249.49	0.000 6315	1.3430	13.25	198.51	0.0548	0.7977	0.849	0.0908	798.7	7.46
0.5	282.87	0.000 6664	0.2993	41.72	218.53	0.1610	0.7563	0.923	0.0811	503.7	5.73
1.0	300.62	0.000 6862	0.1567	58.62	229.20	0.2195	0.7569	1.000	0.0759	409.8	5.40
1.013	300.99	0.000 6868	0.1546	58.99	229.43	0.2208	0.7870	1.001	0.0758	408.1	5.39
1.5	312.25	0.000 7008	0.1070	70.51	236.52	0.2582	0.7892	1.038	0.0726	361.5	5.17
2.0	321.18	0.000 7126	0.08139	79.90	241.76	0.2877	0.7917	1.063	0.0696	329.6	5.03
2.5	328.50	0.000 7230	0.06546	87.76	246.20	0.3118	0.7942	1.079	0.0678	306.1	4.87
3.0	334.79	0.000 7323	0.05525	94.59	249.96	0.3323	0.7965	1.091	0.0660	287.4	4.75
4.0	345.29	0.000 7490	0.03836	106.16	256.17	0.3661	0.8006	1.108	0.0630	259.7	4.57
5.0	353.95	0.000 7640	0.03358	115.83	261.17	0.3935	0.8042	1.120	0.0605	239.1	4.43
6	361.41	0.000 7779	0.02799	124.23	265.34	0.4168	0.8073	1.130			
8	373.92	0.000 8038	0.02090	138.48	272.04	0.4551	0.8124	1.148			
10	384.19	0.000 8280	0.01675	150.35	277.18	0.4860	0.8162	1.168			
15	404.54	0.000 8874	0.01062	174.49	286.01	0.5462	0.8218	1.234			
20	420.30	0.000 9512	0.00751	194.19	291.01	0.5928	0.8232	1.345			
25	433.33	0.001 030	0.00549	212.00	293.05	0.6334	0.8203	1.559			
30	444.10	0.001 136	0.00408	228.26	291.27	0.6692	0.8112	2.005			
36.68°	456.83	0.001 818	0.00182	264.54	264.54	0.7393	0.7393				

$h_f = s_f = 0$ at $-40^\circ\text{C} = 233.15 \text{ K}$. s_f , s_g , c_{pf} units: kJ/kg·K. Interpolated and converted from 1993 ASHRAE Handbook—Fundamentals (SI ed.) saturation table from -40 to 183.68°C . This source also contains an enthalpy–log-pressure diagram from 0.1 to 200 bar; -40 to 320°C .

TABLE 2-327 Saturated Refrigerant 124

Temp., °C	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
-40	0.2680	0.000 644	0.5173	159.1	334.9	0.8384	1.5927
-30	0.4499	0.000 655	0.3185	169.3	340.6	0.8813	1.5856
-20	0.7197	0.000 668	0.2049	179.5	346.2	0.9222	1.5808
-10	1.1044	0.000 681	0.1369	189.7	351.8	0.9616	1.5777
0	1.6348	0.000 696	0.0945	200.0	357.4	1.0000	1.5762
10	2.3447	0.000 711	0.06703	210.5	363.0	1.0376	1.5760
20	3.2710	0.000 728	0.04867	221.3	368.5	1.0747	1.5768
30	4.4529	0.000 747	0.03604	282.3	373.9	1.1115	1.5785
40	5.9320	0.000 768	0.02713	243.7	379.2	1.1480	1.5808
50	7.7521	0.000 791	0.02069	255.4	384.4	1.1843	1.5836
60	9.9599	0.000 818	0.01594	267.5	389.3	1.2207	1.5864
70	12.605	0.000 849	0.01236	280.1	393.9	1.2572	1.5890
80	15.742	0.000 887	0.00961	293.2	398.0	1.2942	1.5909
90	19.432	0.000 935	0.00744	307.0	401.3	1.3318	1.5915
100	23.749	0.000 999	0.00569	321.9	403.4	1.3710	1.5894
110	28.787	0.001 098	0.00420	338.4	403.0	1.4133	1.5820
120	34.702	0.001 338	0.00269	360.6	394.9	1.4685	1.5558
122.5°	36.340	0.001 810	0.00181	378.5	378.5		

c = critical point.

Bull. T-124-SI, Jan. 1993 (28 pp.). Used by permission of DuPont Fluoroproducts. The 1993 ASHRAE Handbook—Fundamentals (SI ed.) gives a saturation table to 122.47°C and a diagram to 200 bar, 320°C .

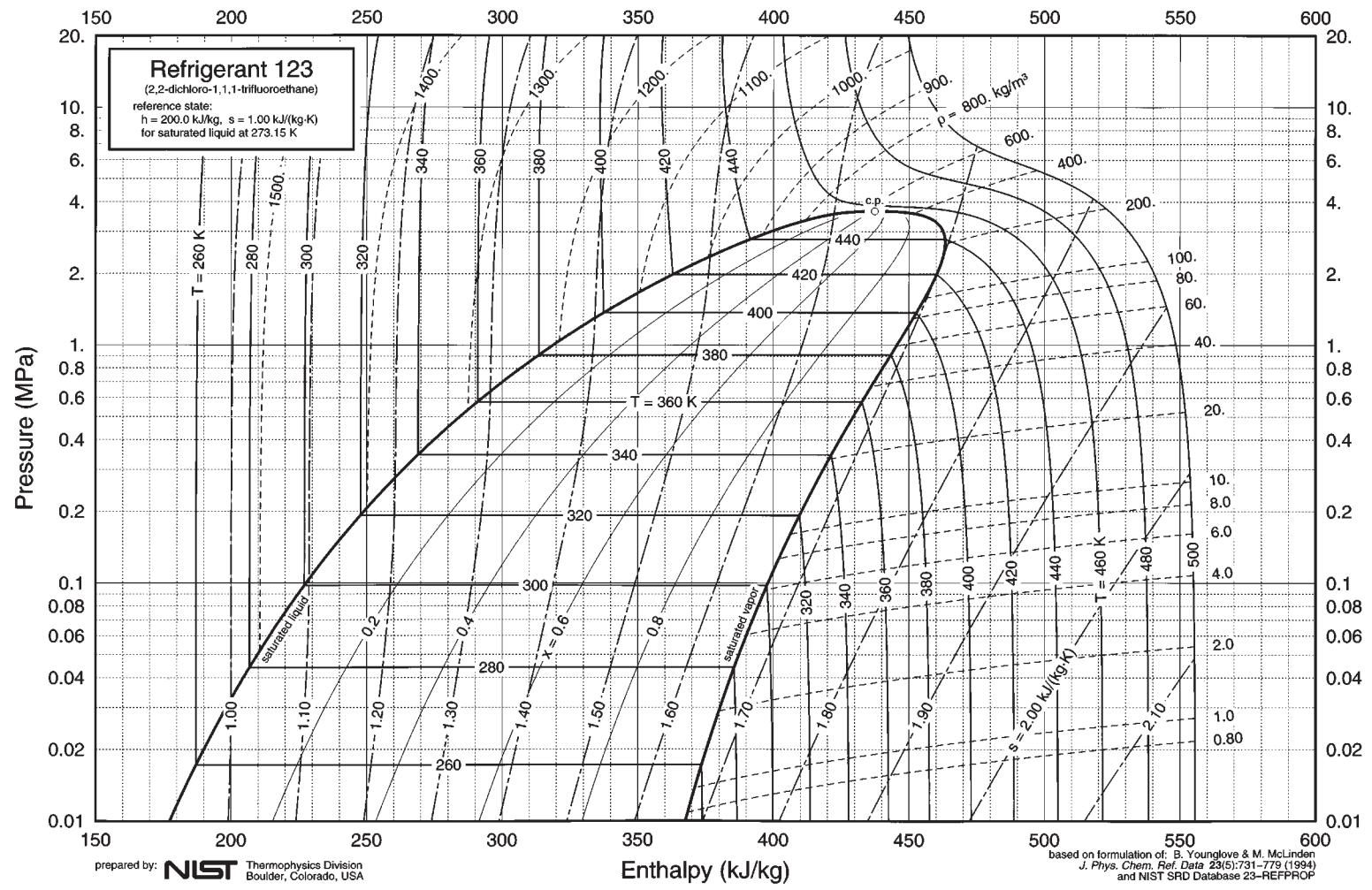


FIG. 2-25 Enthalpy-log-pressure diagram for Refrigerant 123.

TABLE 2-328 Thermophysical Properties of Saturated Refrigerant 125

Temp., K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s
172.5°	0.035	0.000591	3.48						
180	0.064	0.000599	1.958						
190	0.133	0.000611	0.986						
200	0.257	0.000624	0.5312	-30.5	140.8	-0.1386	0.7183		644
210	0.465	0.000638	0.3057	-23.3	146.7	-0.1024	0.7067		531
220	0.794	0.000653	0.1854	-13.9	152.6	-0.0604	0.6981		445.8
224.9†	1.013	0.000660	0.1475	-8.8	155.5	-0.0386	0.6948		411.2
230	1.290	0.000669	0.1175	-3.4	158.4	-0.0147	0.6919	1.077	379.6
240	2.005	0.000686	0.0775	7.7	164.2	0.0324	0.6875	1.139	326.6
250	3.000	0.000705	0.0527	19.3	170.0	0.0800	0.6847	1.184	282.8
260	4.336	0.000725	0.0369	31.3	175.3	0.1274	0.6831	1.221	245.8
270	6.078	0.000749	0.0264	43.7	180.5	0.1743	0.6822	1.257	213.6
280	8.298	0.000776	0.0193	56.5	185.4	0.2206	0.6819	1.299	185.3
290	11.068	0.000809	0.0143	69.7	189.9	0.2666	0.6815	1.356	159.7
300	14.476	0.000848	0.0106	83.5	194.2	0.3126	0.6805	1.437	136.3
310	18.62	0.000898	0.0079	98.1	196.9	0.3597	0.6774	1.57	115.0
320	23.63	0.000969	0.0059	113.9	198.5	0.4079	0.6726	1.82	95.4
330	29.65	0.001088	0.0041	132.2	197.4	0.4621	0.6639		
339.4‡	35.95	0.00175	0.0018	169.0	169.0	0.5699	0.5699		

* = triple point; † = normal boiling point; ‡ = critical point. Converted, extrapolated and interpolated from 1993 ASHRAE Handbook—Fundamentals (SI ed.) $h_f = s_f = 0$ at 233.15 K = -40°C. This source also contains an enthalpy–log-pressure diagram from 0.3 to 100 bar, -65 to 175°C. An apparently identical diagram but a different saturation table is contained in Duarte-Garza, H.A., Hwang, C.A. et al., ASHRAE Trans., 99, 2 (1993): 649–664. R124: The 1993 ASHRAE Handbook—Fundamentals (SI ed.) contains a saturation table from -60 to 122.47°C.

TABLE 2-329 Thermophysical Properties of Refrigerant 134a

Pressure, bar	Temp., K	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	Pr_f
0.0039t	169.85	0.0006285	35.263	-76.68	186.50	-0.3830	1.1665	1.147	2187		
0.5	232.69	0.0007062	0.3692	-0.57	225.27	-0.0025	0.9669	1.242	506	0.1121	5.61
0.6	236.22	0.0007113	0.3015	3.85	227.52	0.0161	0.9636	1.248	480	0.1105	5.42
0.8	242.04	0.0007199	0.2375	11.15	231.19	0.0467	0.9560	1.258	438	0.1078	5.12
1.0	246.80	0.0007272	0.1924	17.14	234.15	0.0713	0.9507	1.267	408	0.1056	4.90
1.013	247.03	0.0007276	0.1902	17.50	234.33	0.0728	0.9503	1.268	406	0.1054	4.89
1.5	256.03	0.0007421	0.1312	28.96	239.86	0.1181	0.9419	1.288	358.7	0.1013	4.56
2.0	263.09	0.0007543	0.0999	38.13	244.14	0.1533	0.9364	1.306	326.6	0.0980	4.35
2.5	268.88	0.0007648	0.0806	45.75	247.60	0.1819	0.9326	1.322	303.2	0.0954	4.20
3.0	273.82	0.0007743	0.0677	52.33	250.50	0.2059	0.9297	1.337	285.1	0.0931	4.09
4.0	282.08	0.0007912	0.0512	63.50	255.22	0.2458	0.9256	1.363	257.7	0.0893	3.93
5	288.89	0.0008063	0.04116	72.87	258.99	0.2784	0.9232	1.387	237.5	0.0861	3.83
6	294.72	0.0008203	0.03434	81.04	262.09	0.3062	0.9208	1.410	221.6	0.0835	3.74
8	304.47	0.0008460	0.02565	95.00	267.01	0.3522	0.9171	1.454	197.6	0.0790	3.64
10	312.53	0.0008703	0.02035	106.86	270.74	0.3901	0.9144	1.497	179.5	0.0753	3.57
12	319.47	0.0008938	0.01675	117.34	273.65	0.4227	0.9120	1.541	165.1	0.0721	3.53
14	325.57	0.0009170	0.01414	126.80	275.92	0.4515	0.9095	1.589	153.0	0.0693	3.51
16	330.11	0.0009362	0.01247	134.00	277.40	0.4729	0.9073	1.631	144.3	0.0672	3.50
18	336.04	0.0009555	0.01059	143.68	279.01	0.5013	0.9041	1.698	133.2	0.0645	3.51
20	340.63	0.0009894	0.00931	151.39	279.95	0.5236	0.9010	1.764	124.8	0.0623	3.53
25	350.73	0.0010585	0.00695	169.30	280.64	0.5738	0.8913	1.987	106.6	0.0577	3.67
30	359.37	0.001144	0.00528	185.05	278.32	0.6212	0.8807	2.418	90.4	0.0538	4.06
35	366.89	0.001270	0.00399	203.19	273.52	0.6657	0.8574				
40	373.50	0.001606	0.00255	229.24	257.12	0.7292	0.8038				
40.56 ^c	374.18	0.001948	0.00195	241.22	241.22	0.7620	0.7620				

t = triple point, c = critical point. $h_f = s_f = 0$ at -40°C = 233.15 K. T, v, h, and s interpolated and converted from Refrigerant 134a—Thermodynamic and Physical Properties, Int. Inst. Refrig., Paris, France, 1992 (28 pp.).

Other properties from this source and from Oliveira, C. M. B. P. and W. A. Wakeham, Int. J. Thermophys., 14, 1 (1993): 33–44; Krauss, R., J. Luettmer-Strathmann, et al., Int. J. Thermophys., 14, 4 (1993): 951–988; ASHRAE Handbook—Fundamentals, Atlanta, GA, 1993; ICI KLEA 134a bulletin, 1993 (43 pp.); and R134a—Thermodynamic and Physical Properties, Int. Inst. Refrig., Paris, France, 1992 (28 pp.).

Papers giving polynomial curve fits and similar simple equations include Cleland, A. C., Rev. Int. Froid = Int. J. Refrig., 17, 4 (1994): 245–249; Dobrokhov, A., A. Grebenkov, et al., Proc. 14th Japan Symp. Thermophys. Props., (1993): 271–274; Huber, M. L. and J. F. Ely, Rev. Int. Froid = Int. J. Refrig., 17, 1 (1994): 18–31 (includes extensive list of vapor pressure and liquid density sources for many refrigerants); Modic, J., Proc. 11th Int. Symp. Htg, Refrig and Air-Condg., Zagreb, (1991): 174–185; and Kabelac, S., Int. J. Refrig., 14, (1991): 217–222. The 1993 ASHRAE Handbook—Fundamentals (SI ed.) gives saturation data for integral degrees Celsius with temperatures on the ITS 90 scale from -103.03°C to 101.03°C. The thermodynamic diagram from 0.1 to 200 bar extends to 320°C.

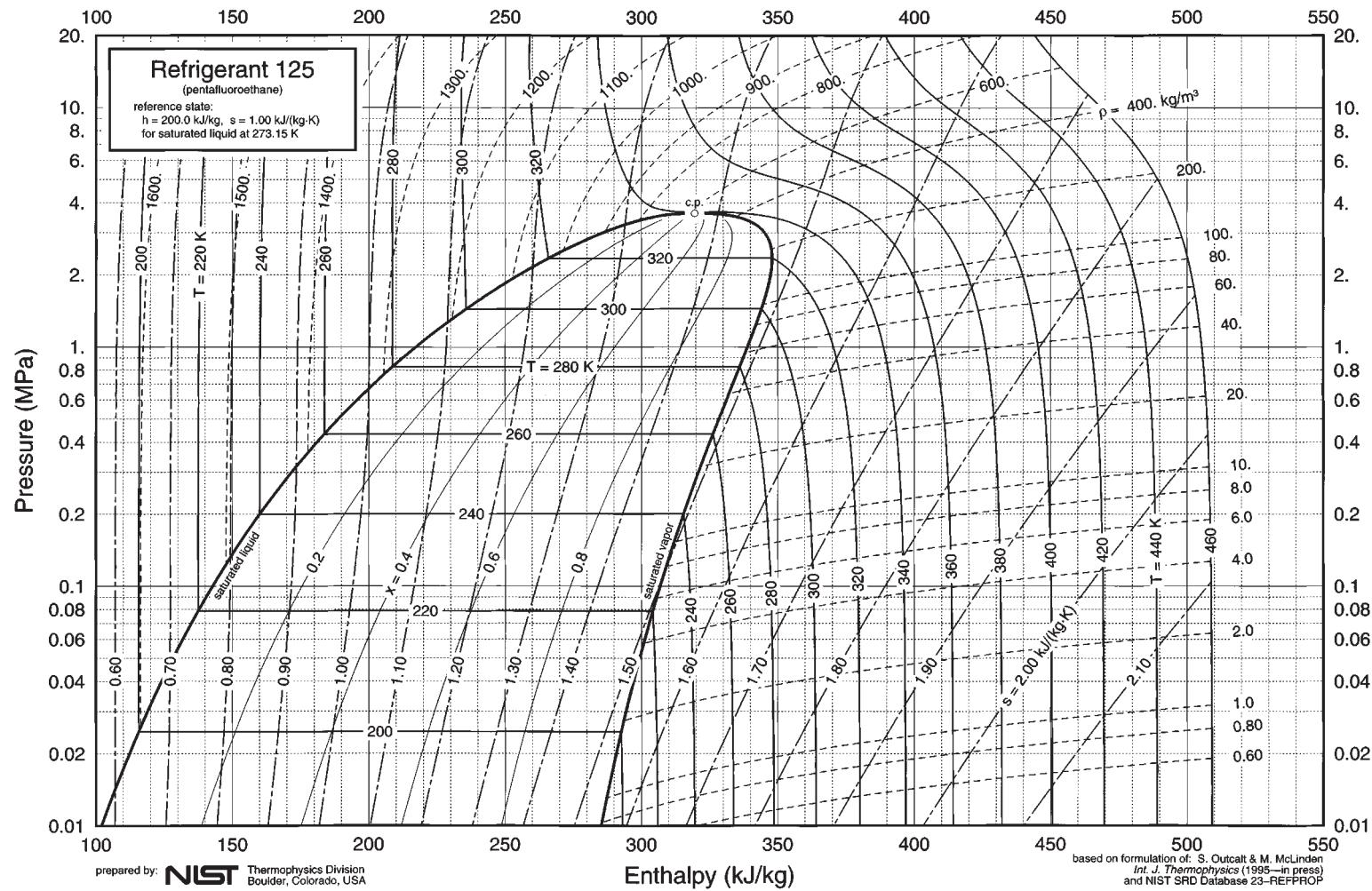


FIG. 2-26 Enthalpy-log-pressure diagram for Refrigerant 125.

TABLE 2-330 Thermophysical Properties of Compressed Gaseous Refrigerant 134a

Temp., K	Pressure, bar						
	0	1	2	3	4	5	6
230	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	— — — —	— — — —	— — — —	— — — —	— — — —	— — — —
240	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	— — — —	— — — —	— — — —	— — — —	— — — —	— — — —
250	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.7437 10.11 0.0096 0.783	0.7953 10.15 0.0097 0.797	— — — —	— — — —	— — — —	— — — —
260	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.7627 10.47 0.0105 0.761	0.8048 10.51 0.0107 0.790	— — — —	— — — —	— — — —	— — — —
270	c_p (kJ/kg) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.7813 10.84 0.0117 0.724	0.8158 10.88 0.0118 0.761	0.8557 10.94 0.0118 0.793	— — — —	— — — —	— — — —
280	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.7996 11.22 0.0122 0.735	0.8283 11.26 0.0123 0.757	0.8604 11.29 0.0123 0.790	— — — —	— — — —	— — — —
290	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.8176 11.62 0.0130 0.731	0.8412 11.65 0.0131 0.748	0.8673 11.68 0.0131 0.773	0.8938 11.71 0.0133 0.787	0.9335 11.74 — —	— — — —
300	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.8354 12.05 0.0139 0.730	0.8556 12.06 0.0139 0.742	0.8771 12.08 0.0140 0.757	0.8972 12.10 0.0141 0.770	0.9277 12.15 0.0142 0.792	0.9606 0.0143 0.816 —
310	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.8530 12.44 0.0145 0.730	0.8703 12.45 0.0146 0.742	0.8875 12.47 0.0147 0.753	0.9046 12.49 0.0148 0.763	0.9292 12.52 0.0149 0.781	0.9546 12.54 0.0150 0.798
320	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.8703 12.83 0.0153 0.730	0.8843 12.84 0.0153 0.740	0.8993 12.86 0.0154 0.751	0.9163 12.88 0.0155 0.761	0.9356 12.90 0.0156 0.774	0.9548 12.93 0.0157 0.786
330	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.8874 13.22 0.0160 0.729	0.8996 13.23 0.0161 0.739	0.9114 13.25 0.0161 0.750	0.9268 13.27 0.0162 0.759	0.9398 13.29 0.0163 0.766	0.9569 13.32 0.0164 0.777
340	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.9042 13.61 0.0169 0.728	0.9152 13.62 0.0169 0.738	0.9262 13.64 0.0169 0.748	0.9372 13.66 0.0170 0.755	0.9502 13.68 0.0170 0.765	0.9632 13.70 0.0171 0.772
350	c_p (kJ/kg·K) μ (10^{-6} Pa·s) k (W/m·K) Pr	0.9208 13.98 0.0175 0.730	0.9307 13.99 0.0176 0.740	0.9406 14.01 0.0176 0.749	0.9505 14.03 0.0177 0.754	0.9607 14.05 0.0177 0.763	0.9695 14.07 0.0178 0.767

Dashes indicate unavailable states; blanks indicate no data.

Note that "profound differences" presently exist in the transport properties of R134a according to *Chemistry International*, 16(6), 233, Nov. 1994, and 18(2) 44–47, 1996.

2-292 PHYSICAL AND CHEMICAL DATA
TABLE 2-330 Thermophysical Properties of Compressed Gaseous R134a (Concluded)

Temp., K	Pressure, bar						
	8	10	12.5	15	17.5	20	22.5
300	c_p (kJ/kg·K) —	—	—	—	—	—	—
	μ (10^{-6} Pa·s) —	—	—	—	—	—	—
	k (W/m·K) —	—	—	—	—	—	—
	Pr —	—	—	—	—	—	—
310	c_p (kJ/kg·K) 1.053	—	—	—	—	—	—
	μ (10^{-6} Pa·s) —	—	—	—	—	—	—
	k (W/m·K) 0.0155	—	—	—	—	—	—
	Pr —	—	—	—	—	—	—
320	c_p (kJ/kg·K) 1.028	1.097	—	—	—	—	—
	μ (10^{-6} Pa·s) 13.05	13.13	—	—	—	—	—
	k (W/m·K) 0.0161	—	—	—	—	—	—
	Pr 0.833	—	—	—	—	—	—
330	c_p (kJ/kg·K) 1.015	1.065	1.151	1.276	—	—	—
	μ (10^{-6} Pa·s) 13.41	13.49	13.64	13.86	—	—	—
	k (W/m·K) 0.0168	0.0171	0.0177	0.0184	—	—	—
	Pr 0.810	0.840	0.887	0.961	—	—	—
340	c_p (kJ/kg·K) 1.008	1.049	1.107	1.187	1.319	—	—
	μ (10^{-6} Pa·s) 13.79	13.86	13.98	14.17	—	—	—
	k (W/m·K) 0.0174	0.0177	0.181	0.0187	—	—	—
	Pr 0.799	0.821	0.855	0.899	—	—	—
350	c_p (kJ/kg·K) 1.008	1.040	1.086	1.148	1.225	1.340	1.525
	μ (10^{-6} Pa·s) 14.15	14.22	14.34	14.49	—	14.97	—
	k (W/m·K) 0.0181	0.0183	0.0186	0.0192	0.0198	0.0205	0.0215
	Pr 0.788	0.828	0.837	0.866	—	—	—

TABLE 2-331 Refrigerant 141b

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives saturation data to 150°C and a diagram to 20 bar, 150°C. For equation of state including decomposition, see Weber, L. A., paper 69, *Proc. 18th Int. Congr. Refrig.*, Montreal, 1991.

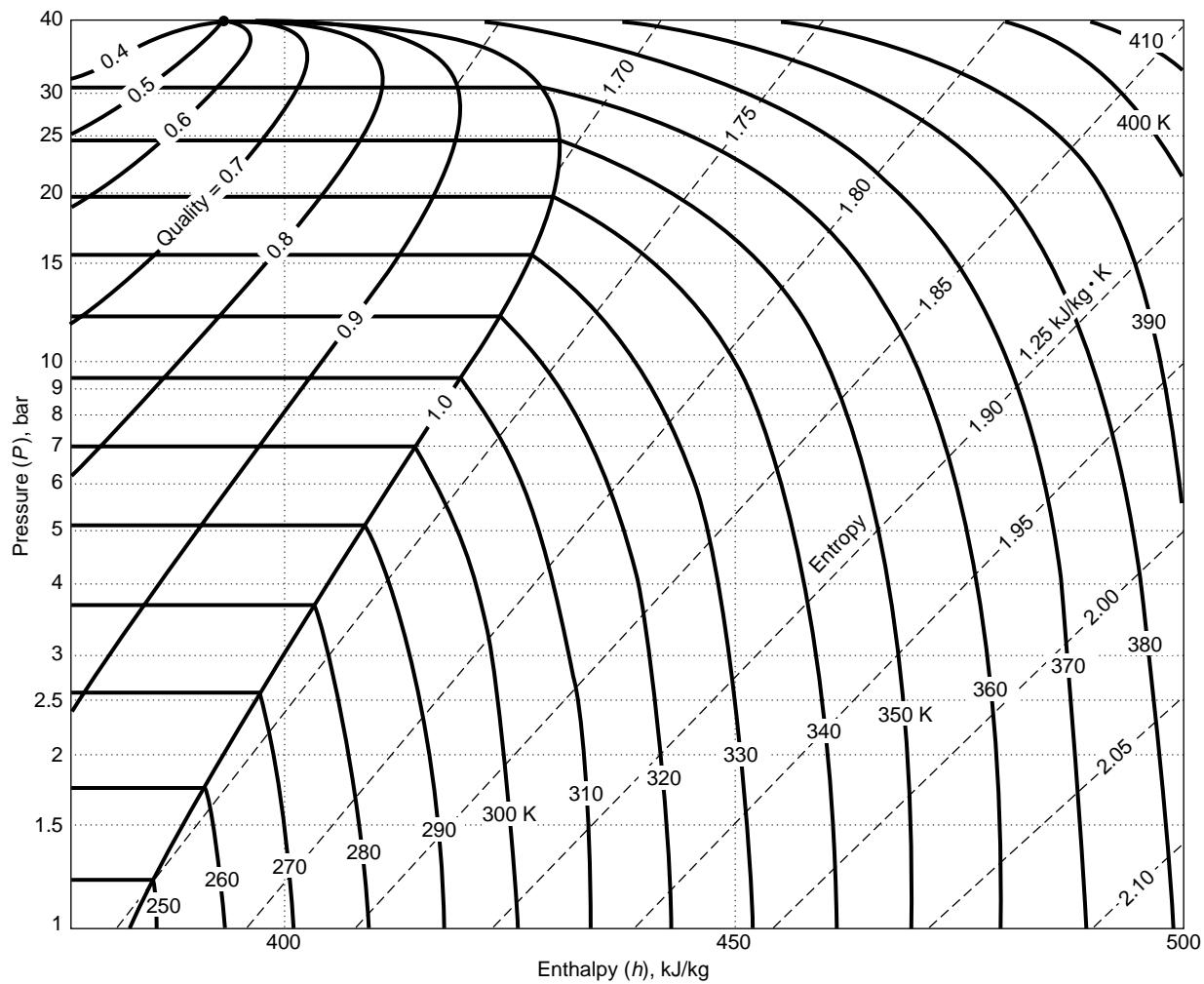


FIG. 2-27 Enthalpy-log-pressure diagram for Refrigerant 134a.

TABLE 2-332 Refrigerant 142b*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
200	0.0380	7.505,-4	4.337	-24.36	200.49	-0.1123	1.0119			0.123
210	0.0728	7.626,-4	2.374	-17.48	206.82	-0.0788	0.9893	1.15		0.118
220	0.1314	7.751,-4	1.373	-10.21	213.28	-0.0450	0.9708	1.17		0.114
230	0.2252	7.883,-4	0.833	-2.52	219.82	-0.0109	0.9558	1.18		0.111
240	0.3691	8.019,-4	0.527	9.92	229.74	0.0414	0.9387	1.19	0.517	0.109
250	0.5815	8.164,-4	0.346	14.32	233.05	0.0592	0.9341	1.21	0.466	0.103
260	0.8846	8.317,-4	0.234	23.54	239.66	0.0952	0.9264	1.22	0.422	0.099
270	1.3046	8.480,-4	0.162	33.32	246.18	0.1320	0.9204	1.24	0.385	0.095
280	1.8714	8.653,-4	0.115	43.68	252.57	0.1695	0.9155	1.26	0.355	0.091
290	2.6184	8.843,-4	0.0838	54.60	258.77	0.2076	0.9116	1.28	0.329	0.088
300	3.583	9.047,-4	0.0619	66.07	264.69	0.2462	0.9082	1.30	0.305	0.084
310	4.803	9.273,-4	0.0464	78.07	270.26	0.2851	0.9051	1.32	0.285	0.080
320	6.324	9.525,-4	0.0353	90.55	275.40	0.3243	0.9020	1.34	0.267	0.075
330	8.187	9.810,-4	0.0271	103.45	280.01	0.3634	0.8985		0.241	0.072
340	10.44	1.014,-3	0.0210	116.71	283.99	0.4024	0.8943		0.216	0.068
350	13.13	1.052,-3	0.0164	130.30	287.23	0.4409	0.8893		0.192	0.064
360	16.30	1.099,-3	0.0129	144.18	289.61	0.4791	0.8831			0.060
370	20.01	1.157,-3	0.0102	158.45	291.01	0.5170	0.8753			0.056
380	24.29	1.235,-3	0.0080	173.45	291.22	0.5557	0.8656			0.052
390	29.20	1.348,-3	0.0062	190.16	289.77	0.5974	0.8528			0.048
400	34.78	1.541,-3	0.0046	212.57	284.04	0.6521	0.8307			0.044
410 ^c	41.5	2.300,-3	0.0023	255.00	255.00					∞

*Values reproduced and converted from Table 10, p. 17.95, ASHRAE Handbook, 1981: Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 7.505,-4 signifies 7.505×10^{-4} .

The 1993 ASHRAE Handbook—Fundamentals (SI ed.) gives material for integral degrees Celsius with temperatures on the IPTS 68 scale from -50 to 125°C. The thermodynamic diagram from 0.1 to 35 bar extends to 180°C. For experimental isochores for the compressed liquid from 6 to 298 bar, 147 to 432 K, see Blanke, W. and R. Weiss, PTB Bericht W 30, Braunschweig, Germany, 1992 (54 pp.). Tables and a diagram to 500 psia, 400°F are given in Stewart, R. B., R. T. Jacobsen, et al., Thermodynamic Properties of Refrigerants, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat, thermal conductivity, and viscosity, see Thermophysical Properties of Refrigerants, ASHRAE, 1993.

TABLE 2-333 Saturated Refrigerant R143a*

Temp., K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
161.82 ^t	0.01124	0.000752	14.22	53.2	320.5	0.3181	1.970	1.188	6.011	0.1416
170	0.02497	0.000764	6.709	63.0	325.5	0.3774	1.922	1.215	5.366	0.1403
180	0.05914	0.000778	2.991	75.3	331.8	0.4474	1.872	1.235	4.692	0.1372
190	0.126	0.000793	1.474	87.7	338.1	0.5147	1.832	1.252	4.121	0.1331
200	0.2458	0.000809	0.7898	100.3	344.5	0.5792	1.800	1.268	3.636	0.1281
210	0.4455	0.000826	0.4532	113.1	350.8	0.6415	1.774	1.287	3.221	0.1226
220	0.7586	0.000845	0.2754	126.1	357.1	0.7018	1.752	1.308	2.864	0.1168
225.92	1.01325	0.000856	0.2098	133.9	360.8	0.7367	1.741	1.323	2.676	0.1133
230	1.225	0.000865	0.1755	139.3	363.3	0.7604	1.734	1.333	2.556	0.1108
240	1.89	0.000886	0.1164	152.8	369.4	0.8176	1.720	1.362	2.288	0.1047
250	2.806	0.000910	0.07975	166.6	375.3	0.8736	1.708	1.394	2.055	0.09862
260	4.027	0.000936	0.05617	180.8	380.9	0.9287	1.698	1.431	1.852	0.09272
270	5.613	0.000966	0.04045	195.3	386.2	0.983	1.690	1.475	1.673	0.08682
280	7.629	0.000999	0.02964	210.3	391.1	1.037	1.682	1.527	1.496	0.08098
290	10.14	0.001038	0.02200	225.9	395.4	1.091	1.675	1.593	1.334	0.07521
300	13.23	0.001084	0.01646	242.1	399.0	1.144	1.668	1.679	1.192	0.06951
310	16.98	0.001140	0.01234	259.2	401.6	1.199	1.659	1.804	1.067	0.06381
320	21.48	0.001214	0.009182	277.4	402.7	1.255	1.647	2.006	0.9569	0.05803
330	26.85	0.001321	0.006678	297.5	401.0	1.315	1.629	2.421	0.8321	0.05202
340	33.25	0.001514	0.004520	321.8	393.4	1.385	1.595	4.021	0.6560	0.04480
346.75 ^c	38.32	0.002311	0.002311	360.6	360.6	1.471	1.471	—	—	—

*Values calculated from NIST Thermodynamic Properties of Refrigerants and Refrigerant Mixtures Database (REFPROP, Version 5). Thermodynamic properties are from 32-term MBWR equation of state; transport properties are from extended corresponding states model. t = triple point; c = critical point.

TABLE 2-334 Saturated Refrigerant R152a*

Temp., K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
154.56t	0.000641	0.000839	303.6	14.0	419.8	0.1130	2.738	1.492	10.85	0.1932
160	0.001297	0.000846	155.2	22.2	423.5	0.1647	2.673	1.500	9.614	0.1894
170	0.004145	0.000859	51.59	37.2	430.6	0.2560	2.570	1.510	8.058	0.1822
180	0.01141	0.000873	19.82	52.4	437.9	0.3425	2.484	1.517	6.940	0.1753
190	0.02775	0.000887	8.588	67.6	445.3	0.4247	2.413	1.525	6.012	0.1685
200	0.06088	0.000902	4.110	82.9	452.8	0.5032	2.353	1.535	5.236	0.1618
210	0.1224	0.000918	2.138	98.3	460.4	0.5784	2.303	1.547	4.582	0.1552
220	0.2284	0.000935	1.193	113.8	468.0	0.6507	2.261	1.562	4.028	0.1487
230	0.4004	0.000952	0.7064	129.5	475.6	0.7205	2.225	1.580	3.556	0.1423
240	0.6647	0.000971	0.4397	145.5	483.1	0.7881	2.195	1.600	3.153	0.1361
249.12	1.01325	0.000989	0.2961	160.2	489.8	0.8481	2.171	1.622	2.834	0.1304
250	1.053	0.000991	0.2855	161.6	490.5	0.8538	2.169	1.624	2.805	0.1299
260	1.603	0.001012	0.1922	178.0	497.7	0.9178	2.147	1.651	2.500	0.1239
270	2.354	0.001035	0.1334	194.7	504.7	0.9805	2.129	1.681	2.231	0.1179
280	3.354	0.001060	0.09500	211.7	511.4	1.042	2.112	1.716	1.995	0.1121
290	4.650	0.001087	0.06916	229.1	517.8	1.103	2.098	1.756	1.789	0.1064
300	6.297	0.001118	0.05126	246.9	523.8	1.162	2.085	1.803	1.607	0.1008
310	8.351	0.001152	0.03857	265.2	529.3	1.222	2.073	1.859	1.447	0.09526
320	10.87	0.001190	0.02935	284.1	534.1	1.281	2.062	1.928	1.305	0.08986
330	13.92	0.001235	0.02251	303.7	538.2	1.340	2.051	2.015	1.180	0.08457
340	17.57	0.001289	0.01735	324.2	541.3	1.400	2.038	2.131	1.069	0.07939
350	21.90	0.001355	0.01335	345.7	542.9	1.460	2.024	2.299	1.005	0.07336
360	27.00	0.001440	0.01020	368.8	542.5	1.523	2.006	2.573	0.9225	0.06666
370	32.97	0.001563	0.007603	394.3	538.5	1.591	1.980	3.143	0.8191	0.06032
380	39.97	0.001785	0.005274	425.4	526.2	1.671	1.936	5.407	0.6638	0.05176
386.41c	45.17	0.002717	0.002717	477.3	477.3	1.778	1.778	—	—	—

*Values calculated from NIST Thermodynamic Properties of Refrigerants and Refrigerant Mixtures Database (REFPROP, Version 5). Thermodynamic properties are from 32-term MBWR equation of state; transport properties are from extended corresponding states model. t = triple point; c = critical point.

TABLE 2-335 Saturated Refrigerant 216*

Temp., °F	Pressure, lb/in ² abs.	Volume, ft ³ /lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)·(°F)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-40	0.339	0.00927	59.957	0.000	62.415	0.0000	0.1487
-20	0.713	0.00942	29.749	4.778	65.276	0.0111	0.1487
0	1.382	0.00958	15.986	9.541	68.208	0.0217	0.1493
20	2.497	0.00974	9.184	14.298	71.199	0.0318	0.1504
40	4.247	0.00992	5.582	19.056	74.239	0.0415	0.1520
60	6.862	0.01010	3.558	23.821	77.319	0.0509	0.1538
80	10.612	0.01030	2.361	28.598	80.429	0.0599	0.1559
100	15.797	0.01050	1.6215	33.391	83.559	0.0686	0.1582
120	22.753	0.01073	1.1462	38.205	86.701	0.0770	0.1607
140	31.845	0.01097	0.8304	43.049	89.845	0.0852	0.1632
160	43.468	0.01124	0.6142	47.930	92.981	0.0931	0.1658
180	58.046	0.01153	0.4623	52.861	96.099	0.1009	0.1685
200	76.033	0.01186	0.3529	57.857	99.186	0.1085	0.1712
220	97.913	0.01223	0.2725	62.939	102.225	0.1161	0.1739
240	124.21	0.01266	0.2121	68.132	105.196	0.1235	0.1765
260	155.50	0.01317	0.1660	73.474	108.066	0.1309	0.1790
280	192.40	0.01378	0.1300	79.015	110.789	0.1384	0.1813
300	235.63	0.01458	0.1013	84.835	113.282	0.1460	0.1834
320	286.03	0.01570	0.0776	91.089	115.373	0.1539	0.1851
340	344.81	0.01764	0.0565	98.234	116.538	0.1628	0.1856
355.98c	399.45	0.02771	0.0277	110.248	110.248	0.1773	0.1773

*From published data, Chemicals Division, Union Carbide Corporation. Used by permission. The paper describing these data is by Shank, *ASHRAE J.*, 7 (1965): 94–101. c = critical temperature.

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the ITS 90 scale from -118.59 to 113.26°C. The thermodynamic diagram from 0.1 to 30 bar extends to 180°C. For tables and a diagram to 400 psia, 360°F, see Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. Thermal conductivity data as a function of pressure and temperature are reported by Krauss, R. and K. Stephan, *Proc. 12th Symp. Thermophys. Props.*, Boulder, CO, 1994.

TABLE 2-336 Saturated Refrigerant 245*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
172	0.0034	6.46–4	31.49	-63.4	133.8	-0.3131	0.8327
180	0.0076	6.57–4	14.63	-55.9	138.7	-0.2707	0.8099
190	0.0190	6.70–4	6.20	-46.2	145.1	-0.2182	0.7885
200	0.0425	6.83–4	2.91	-36.0	151.7	-0.1666	0.7725
210	0.0870	6.97–4	1.48	-25.7	158.5	-0.1157	0.7612
220	0.1654	7.11–4	0.822	-14.8	165.4	-0.0654	0.7539
230	0.2946	7.25–4	0.475	-3.6	172.5	-0.0156	0.7500
240	0.4958	7.40–4	0.292	8.0	179.6	0.0337	0.7487
250	0.7946	7.55–4	0.192	19.9	186.8	0.0824	0.7497
260	1.2204	7.72–4	0.125	32.3	194.0	0.1305	0.7525
270	1.806	7.89–4	0.0862	44.9	201.1	0.1781	0.7567
280	2.584	8.08–4	0.0611	57.9	208.3	0.2249	0.7621
290	3.600	8.30–4	0.0443	71.1	215.3	0.2711	0.7683
300	4.888	8.53–4	0.0327	84.6	222.2	0.3161	0.7751
310	6.491	8.80–4	0.0246	98.4	228.9	0.3614	0.7822
320	8.456	9.11–4	0.0186	112.6	235.3	0.4057	0.7893
330	10.83	9.48–4	0.0143	127.1	241.4	0.4497	0.7960
340	13.67	9.93–4	0.0111	142.1	246.9	0.4937	0.8018
350	17.04	0.00105	0.0084	157.2	251.5	0.5382	0.8060
360	21.02	0.00113	0.0063	174.7	254.8	0.5844	0.8071
370	25.71	0.00125	0.0045	193.6	255.2	0.6349	0.8013
375	28.46	0.00137	0.0036	205.2	252.5	0.6649	0.7953
380.1 ^c	31.37	0.00204	0.0020	231.8	231.8	0.7341	0.7341

*Values converted from tables of Shank, *Thermodynamic Properties of UCON 245 Refrigerant*, Union Carbide Corporation, New York, 1966. See also Shank, *J. Chem. Eng. Data*, **12**, 474–480 (1967). *c* = critical point. The notation 6.46–4 signifies 6.46×10^{-4} .

TABLE 2-337 Refrigerant C 318*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
200	0.0216	5.507–4	3.810	353.5	498.0	3.909	4.560			
210	0.0449	5.593–4	1.931	361.0	500.1	3.947	4.564			
220	0.0875	5.683–4	1.038	369.2	502.2	3.984	4.569			
230	0.1608	5.778–4	0.588	377.6	504.4	4.022	4.574	0.98	11.7	0.088
240	0.2810	5.879–4	0.349	386.4	510.9	4.060	4.578	1.00	9.55	0.085
250	0.466	5.988–4	0.2166	395.6	517.4	4.097	4.584	1.02	7.90	0.082
260	0.741	6.106–4	0.1401	405.2	524.0	4.133	4.592	1.03	6.63	0.078
270	1.133	6.234–4	0.0938	415.1	530.7	4.172	4.599	1.05	5.64	0.075
280	1.672	6.375–4	0.0647	425.8	537.3	4.210	4.609	1.07	4.85	0.071
290	2.392	6.529–4	0.0458	436.2	543.9	4.247	4.618	1.09	4.22	0.068
300	3.325	6.694–4	0.0332	447.3	550.4	4.284	4.626	1.12	3.70	0.065
310	4.522	6.893–4	0.0245	458.7	556.9	4.322	4.638	1.15	3.20	0.061
320	6.007	7.115–4	0.0184	470.5	563.3	4.359	4.648	1.18	2.94	0.058
330	7.826	7.365–4	0.0139	482.7	569.4	4.396	4.659	1.23	2.66	0.054
340	10.018	7.666–4	0.0106	495.2	575.4	4.433	4.669	1.27	2.33	0.051
350	12.632	8.034–4	0.0082	508.1	581.0	4.469	4.678	1.32	2.00	0.048
360	15.71	8.508–4	0.0062	521.5	585.8	4.507	4.685	1.39		
370	19.33	9.172–4	0.0047	535.6	589.9	4.544	4.691			
380	23.59	1.031–3	0.0033	551.4	591.5	4.585	4.691			
388.5 ^c	27.83	1.613–3	0.0016	577.2	577.2	4.651	4.651			

*Values of P , v , h , and s interpolated, extrapolated, and converted from tables of Oguchi, *Reito*, **52** (1977): 869–889. Values of c_p , μ , and k interpolated and converted from tables in *Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. *c* = critical point.

Saturation and superheat tables and a diagram to 80 bar, 580 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). For equations, see Cipollone, R., *ASHRAE Trans.*, **97**, 2 (1991): 262–267.

TABLE 2-338 Saturated Refrigerant 500*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
200	0.1219	6.966,-4	1.360	-29.56	185.87	-0.1363	0.9408	1.044	6.11	0.113
210	0.2258	7.090,-4	0.766	-21.03	191.25	-0.0948	0.9161	1.018	5.15	0.109
220	0.3936	7.222,-4	0.457	-12.17	196.63	-0.0536	0.8955	0.997	4.42	0.106
230	0.6511	7.361,-4	0.286	-2.97	201.96	-0.0130	0.8782	0.987	3.85	0.102
240	1.0291	7.509,-4	0.187	6.58	207.23	0.0277	0.8638	0.987	3.42	0.098
250	1.5632	7.668,-4	0.1261	16.50	212.40	0.0680	0.8517	0.997	3.04	0.094
260	2.2932	7.839,-4	0.0879	26.78	217.45	0.1082	0.8415	1.017	2.74	0.090
270	3.2624	8.024,-4	0.0628	37.44	222.35	0.1481	0.8329	1.048	2.48	0.086
280	4.5172	8.226,-4	0.0459	48.48	227.06	0.1878	0.8257	1.089	2.26	0.082
290	6.1064	8.450,-4	0.0342	59.91	231.56	0.2275	0.8194	1.140	2.08	0.078
300	8.0809	8.699,-4	0.0259	71.76	235.79	0.2671	0.8139	1.201	1.92	0.074
310	10.49	8.951,-4	0.0198	84.05	239.69	0.3067	0.8088	1.273	1.77	0.070
320	13.40	9.306,-4	0.0154	96.83	243.19	0.3464	0.8038	1.355	1.63	0.066
330	16.86	9.690,-4	0.0119	110.17	246.14	0.3864	0.7985	1.447	1.48	0.062
340	20.93	1.016,-3	0.0093	124.20	248.36	0.4271	0.7922	1.550	1.34	0.058
350	25.70	1.077,-3	0.0072	139.18	249.47	0.4689	0.7841	1.663		
360	31.25	1.162,-3	0.0055	155.66	248.71	0.5135	0.7721	1.919		
370	37.72	1.307,-3	0.0040	175.59	244.26	0.5650	0.7509	2.07		
378.6 ^c	44.26	2.012,-3	0.0020	219.50	219.50	0.6729	0.6729	∞		

*Values reproduced and converted from Table 12, p. 17.99, *ASHRAE Handbook, 1981: Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 6.966,-4 signifies 6.966×10^{-4} .

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the IPTS 68 scale from -70 to 105.60°C. The thermodynamic diagram from 0.1 to 70 bar extends to 240°C. Equations and constants approximated to the 1985 ASHRAE tables were given by Mecaryk, K. and M. Masaryk, *Heat Recovery Systems and CHP*, 11, 2/3 (1991): 193–197. Saturation and superheat tables and a diagram to 80 bar, 560 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Tables and a chart to 1000 psia, 480°F are given by Stewart, R. B., R. T. Jacobsen, et al., *Thermophysical Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). Specific heat and viscosity appear in *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

TABLE 2-339 Saturated Refrigerant 502*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
200	0.2274	6.381,-4	0.646	-29.04	153.34	-0.1337	0.7782	1.018	5.72	0.103
210	0.4098	6.507,-4	0.374	-20.83	158.42	-0.0937	0.7599	1.036	4.88	0.099
220	0.6965	6.640,-4	0.228	-12.15	163.49	-0.0534	0.7449	1.055	4.23	0.095
230	1.1251	6.783,-4	0.146	-2.99	168.50	-0.0128	0.7328	1.075	3.71	0.091
240	1.7392	6.938,-4	0.0969	6.66	173.42	0.0280	0.7228	1.097	3.28	0.087
250	2.5867	7.105,-4	0.0665	16.78	178.20	0.0691	0.7148	1.120	2.94	0.083
260	3.7188	7.289,-4	0.0470	27.36	182.81	0.1102	0.7082	1.144	2.65	0.079
270	5.1893	7.492,-4	0.0340	38.36	187.21	0.1514	0.7027	1.170	2.41	0.075
280	7.0530	7.720,-4	0.0251	49.77	191.35	0.1923	0.6980	1.197	2.18	0.072
290	9.3660	7.979,-4	0.0188	61.55	195.16	0.2330	0.6937	1.225	1.99	0.068
300	12.19	8.280,-4	0.0143	73.68	198.56	0.2734	0.6896	1.254	1.79	0.064
310	15.57	8.637,-4	0.0109	86.17	201.43	0.3134	0.6852	1.285	1.59	0.060
320	19.60	9.081,-4	0.0084	99.06	203.57	0.3532	0.6798	1.317	1.40	0.056
330	24.35	9.666,-4	0.0064	112.53	204.62	0.3933	0.6723	1.351	1.23	0.052
340	29.95	1.053,-3	0.0048	127.13	203.71	0.4351	0.6604	1.386	1.07	0.048
350	36.62	1.220,-3	0.0033	145.44	197.82	0.4859	0.6355	1.422	0.93	0.044
355.3 ^c	40.75	1.786,-3	0.0018	174.00	174.00	0.5634	0.5634			

*Values reproduced and converted from Table 13, p. 17.101, *ASHRAE Handbook, 1981: Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c = critical point. The notation 6.381,-4 signifies 6.381×10^{-4} .

The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the IPTS 68 scale from -70 to 82.2°C. The thermodynamic diagram from 0.1 to 80 bar extends to 180°C. Equations and constants approximated to 1985 ASHRAE tables are given by Mecaryk, K., and M. Masaryk, *Heat Recovery Systems and CHP*, 11, 2/3 (1991): 193–197. Saturation and superheat tables and a diagram to 20 bar, 515 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Tables and a chart to 1000 psia, 400°F appear in Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat and viscosity, see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993.

TABLE 2-340 Saturated Refrigerant 503*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
150	0.0750	6.384,-4	1.894	-89.60	111.02	-0.4694	0.8681	0.482	6.12	0.128
160	0.1798	6.478,-4	0.837	-79.73	115.40	-0.4057	0.8139	0.554	5.05	0.123
170	0.3828	6.555,-4	0.414	-69.55	119.70	-0.3441	0.7691	0.620	4.16	0.116
180	0.7395	6.700,-4	0.224	-59.08	123.84	-0.2844	0.7318	0.682	3.43	0.111
190	1.3187	6.850,-4	0.130	-48.36	127.77	-0.2267	0.7003	0.747	2.94	0.105
200	2.1999	7.014,-4	0.0803	-37.45	131.45	-0.1710	0.6735	0.817	2.56	0.099
210	3.4713	7.204,-4	0.0520	-26.36	134.84	-0.1173	0.6503	0.896	2.25	0.094
220	5.2281	7.426,-4	0.0350	-15.10	137.87	-0.0656	0.6298	0.988	1.98	0.088
230	7.5713	7.687,-4	0.0242	-3.65	140.49	-0.0155	0.6112	1.017	1.73	0.082
240	10.61	8.001,-4	0.0172	8.07	142.58	0.0334	0.5939	1.227	1.52	0.076
250	14.46	8.386,-4	0.0124	20.22	143.98	0.0817	0.5767	1.382	1.33	0.070
260	19.25	8.874,-4	0.0090	33.10	144.38	0.1305	0.5585	1.57	1.17	0.065
270	25.13	9.526,-4	0.0064	47.22	143.23	0.1816	0.5373	1.79	1.03	0.059
280	32.27	1.050,-3	0.0045	63.64	139.25	0.2384	0.5085	2.03	0.91	0.054
290	40.87	1.264,-3	0.0028	86.41	127.51	0.3131	0.4548	2.35		
292.6 ^c	43.57	1.773,-3	0.0018	110.20	110.20	0.3864	0.3864	∞	∞	

* P , v , h , and s values reproduced and converted from Table 14, p. 17.103, *ASHRAE Handbook, 1981: Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 1981. Copyright material. Reproduced by permission of the copyright owner. c_p , μ , and k values interpolated and converted from *Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. c = critical point. The notation 6.384,-4 signifies 6.384 $\times 10^{-4}$.

Saturation and superheat tables and a diagram to 80 bar, 600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). Tables and a chart to 1000 psia, 460°F are given by Stewart, R. B., R. T. Jacobsen, et al., *Thermodynamic Properties of Refrigerants*, ASHRAE, Atlanta, GA, 1986 (521 pp.). For specific heat and viscosity see *Thermophysical Properties of Refrigerants*, ASHRAE, 1993. The 1993 ASHRAE *Handbook—Fundamentals* (SI ed.) gives material for integral degrees Celsius with temperatures on the IPTS 68 scale for saturation conditions from -125 to 19.50°C. The thermodynamic diagram from 0.1 to 80 bar extends to 220°C.

TABLE 2-341 Saturated Refrigerant 504*

Temp., °F	Pressure, lb/in ² abs.	Volume, ft ³ /lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)°F)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-120	2.964	0.01095	15.31	-21.48	86.69	-0.0565	0.2609
-100	6.042	0.01119	7.874	-16.39	89.31	-0.0420	0.2519
-80	11.34	0.01146	4.372	-11.12	91.84	-0.0277	0.2435
-60	19.85	0.01175	2.585	-5.65	94.25	-0.0137	0.2362
-40	32.76	0.01206	1.609	0.00	96.50	0.0000	0.2299
-20	51.44	0.01242	1.045	5.85	98.58	0.0135	0.2244
0	77.41	0.01282	0.7029	11.91	100.45	0.0269	0.2195
20	112.3	0.01323	0.4859	18.22	102.09	0.0401	0.2150
40	158.0	0.01379	0.3431	24.81	103.44	0.0533	0.2107
60	216.2	0.01443	0.2458	31.78	104.41	0.0667	0.2065
80	289.2	0.01522	0.1773	39.25	104.85	0.0804	0.2020
100	379.1	0.01629	0.1274	47.43	104.49	0.0948	0.1968
120	488.3	0.01783	0.0893	56.78	102.72	0.1107	0.1899
140	618.1	0.02083	0.0578	69.97	97.70	0.1322	0.1784
150	692.2	0.02597	0.0394	76.96	89.76	0.1432	0.1642

*Unpublished data of Allied Chemical Company, 1970. Used by permission.

TABLE 2-342 Thermodynamic Properties of Refrigerant 507*

Temp., K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)
230.5	1.013	0.000 574	0.1280	-3.1	143.3	-0.015	0.620
240	1.59	0.000 602	0.0826	10.3	150.2	0.042	0.623
250	2.42	0.000 627	0.0546	22.6	154.5	0.092	0.619
260	3.54	0.000 658	0.0377	37.6	159.0	0.149	0.617
270	4.95	0.000 695	0.0270	51.6	163.8	0.202	0.618
280	6.70	0.000 738	0.0198	64.7	169.0	0.250	0.620
290	8.85	0.000 787	0.0148	77.2	174.6	0.295	0.634
300	11.52	0.000 839	0.0112	89.4	180.3	0.336	0.640
310	14.74	0.000 903	0.0084	101.6	185.4	0.378	0.648
320	18.76	0.001 006	0.0062	115.7	188.6	0.422	0.649
330	23.65	0.001 221	0.0042	135.5	189.3	0.481	0.641
340	29.57	0.001 618	0.0025	161.7	179.9	0.557	0.611
341.5 ^c	32.67	0.001 97	0.0020	172.7	172.7	0.590	0.590

*Azeotropic mixture of R152a and R218. $h_f = s_f = 0$ at 233.15 K = -40°C. Interpolated, extrapolated and converted from Lavrenchenko, G. K., M. G. Khmel'nuk, et al., *Int. J. Refrig.*, **17**, 7 (1994): 461. Some values are tentative. This source also gives a ln P - h diagram from 0.6 to 30 bar, -50 to 70°C. Differences exist between the published diagram and tables. c = critical point.

TABLE 2-343 Saturated Rubidium*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)
312.7 ^m	2.46,-9	6.75,-4		118.7	1036	0.998	3.932	0.379
400	1.69,-6	6.98,-4	2.3,+5	151.6	1057	1.091	3.355	0.375
500	1.73,-4	7.22,-4	2790	188.8	1078	1.174	2.953	0.369
600	0.0037	7.46,-4		156.6	225.4	1.241	2.692	0.362
700	0.0317	7.73,-4		20.75	261.3	1.111	2.511	0.357
800	0.1584	8.10,-4		4.662	296.8	1.124	2.378	0.353
1000	1.467	8.65,-4		0.605	367.6	1.150	2.205	0.360
1200	6.466	9.40,-4		0.159	440.1	1.179	1.490	2.104
1400	18.6	1.03,-3						0.385
1500	28.5	1.08,-3						

*Converted from tables in Vargaftik, *Tables of the Thermophysical Properties of Liquids and Gases*, Nauka, Moscow, 1972, and Hemisphere, Washington, 1975. m = melting point. The notation 2.46,-9 signifies 2.46 \times 10⁻⁹.

Many of the Vargaftik values also appear in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals*, Blackwell Sci. Pubs., Oxford, 1985 (1020 pp.). This source contains superheat data.

Saturation and superheat tables and a diagram to 40 bar, 1600 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.).

For a Mollier diagram from 0.1 to 320 psia, 1200 to 2700°R, see Weatherford, W. D., J. C. Tyler, et al., WADD-TR-61-96, 1961. An extensive review of properties of the solid and the saturated liquid was given by Alcock, C. B., M. W. Chase, et al., *J. Phys. Chem. Ref. Data*, **23**, 3 (1994): 385-497.

TABLE 2-344 Thermophysical Properties of Saturated Seawater

Temp., °C	Pressure, bar	v , (m ³ /kg)10 ³	c_p , kJ/(kg·K)	μ , Ns/m ²	k , W/(m·K)	N_{Pr}	$10^5\kappa$, 1/bar
0	0.005993	1.000158	4.000	0.001884	0.560	13.46	5.06
1	0.006438	1.000099	4.000	0.001827	0.563	12.98	5.02
2	0.006916	1.000057	4.000	0.001772	0.565	12.55	4.98
3	0.007427	1.000033	4.000	0.001720	0.567	12.13	4.95
4	0.007970	1.000025	4.001	0.001669	0.569	11.74	4.92
5	0.008548	1.000033	4.001	0.001620	0.571	11.35	4.89
6	0.009163	1.000057	4.001	0.001574	0.574	10.97	4.86
7	0.009816	1.000096	4.002	0.001529	0.576	10.62	4.83
8	0.010511	1.000149	4.002	0.001486	0.578	10.29	4.80
9	0.011248	1.000261	4.002	0.001445	0.580	9.97	4.78
10	0.01203	1.000298	4.003	0.001405	0.582	9.70	4.76
11	0.01286	1.000392	4.003	0.001367	0.584	9.37	4.74
12	0.01374	1.000500	4.003	0.001330	0.586	9.09	4.72
13	0.01467	1.000620	4.004	0.001294	0.588	8.81	4.70
14	0.01566	1.000727	4.004	0.001259	0.590	8.54	4.68
15	0.01671	1.000899	4.005	0.001226	0.592	8.29	4.66
16	0.01781	1.001055	4.005	0.001195	0.594	8.06	4.65
17	0.01898	1.001224	4.006	0.001165	0.595	7.82	4.63
18	0.02022	1.001404	4.006	0.001136	0.597	7.62	4.62
19	0.02153	1.001595	4.007	0.001107	0.599	7.41	4.60
20	0.02291	1.001796	4.007	0.001080	0.600	7.21	4.59
21	0.02437	1.002009	4.007	0.001054	0.602	7.02	4.57
22	0.02591	1.002232	4.008	0.001029	0.604	6.82	4.56
23	0.02753	1.002465	4.008	0.001005	0.605	6.66	4.55
24	0.02924	1.002708	4.009	0.000981	0.607	6.48	4.54
25	0.03104	1.002961	4.009	0.000958	0.608	6.31	4.53
26	0.03294	1.003224	4.009	0.000936	0.609	6.16	4.52
27	0.03494	1.003496	4.010	0.000915	0.611	6.01	4.51
28	0.03705	1.003778	4.010	0.000895	0.612	5.86	4.50
29	0.03926	1.004069	4.011	0.000875	0.614	5.72	4.49
30	0.04159	1.004369	4.011	0.000855	0.615	5.58	4.48

$\kappa = (-1/V)(\partial v/\partial p)_T \cdot 10^5$. Thus, at 0°C, the compressibility is 5.06 \times 10⁻⁵/bar.

For further information see, for instance, Bromley, LeR. A., *J. Chem. Eng. Data*, **12**, 2 (1967): 202-206; **13**, 1 (1968): 60-62 and **13**, 3: 399-402; **15**, 2 (1970): 246-253; and *A.I.Ch.E.J.*, **20**, 2 (1974): 326-335.

Thermal conductivity data sources include Castelli, V. J., E. M. Stanley, et al., *Deep Sea Res.*, **211** (1974): 311-318; Levy, F. L., *Int. J. Refrig.*, **5**, 3 (1982): 155-159.

For velocity of sound, see, for instance, U.S. Naval Oceanographic Office SP 58, 1962 (50 pp.). More recent information is contained in UNESCO technical papers. See *Marine Science No. 38*, 1981 (6 pp.) and No. 44, 1983 (53 pp.).

For sea ice properties, see Fukusako, S., *Int. J. Thermophys.*, **11**, 2 (1990): 353-372.

TABLE 2-345 Saturated Sodium

Temp., K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	c_{pg} , kJ/(kg·K)	μ_f , 10 ⁻⁶ Pa·s	μ_g , 10 ⁻⁶ Pa·s	k_f , W/(m·K)	k_g , W/(m·K)	Pr_f	Pr_g
371	1.59–10	0.001 078	8.54+9	207	4739	2.259	14.475	1.383		688		89.4		0.0106	
400	1.80–9	0.001 088	8.08+8	247	4757	2.920	14.195	1.372	0.86	599		87.2		0.0094	
500	8.99–7	0.001 115	1.99+6	382	4817	3.222	12.092	1.334	1.25	415		80.1		0.0069	
600	5.57–5	0.001 144	38022	514	4872	3.462	10.745	1.301	1.80	321		73.7		0.0057	
700	0.00105	0.001 174	2320	642	4921	3.661	10.631	1.277	2.28	264		68.0		0.0050	
800	0.00941	0.001 208	291.5	769	4966	3.830	9.076	1.260	2.59	227	19.6	62.9	0.0343	0.0045	1.48
900	0.05147	0.001 242	58.8	895	5007	3.978	8.547	1.252	2.72	201	20.6	58.3	0.0406	0.0043	1.38
1000	0.1995	0.001 280	16.6	1020	5044	4.110	8.134	1.252	2.70	181	23.0	54.2	0.0455	0.0042	1.36
1100	0.6016	0.001 323	5.95	1146	5079	4.230	7.805	1.261	2.62	166	25.3	50.5	0.0492	0.0042	1.35
1154.7	1.013	0.001 347	3.89	1215	5097	4.290	7.652	1.271	2.56	159	26.5	48.7	0.0522	0.0041	1.30
1200	1.50	0.001 366	2.54	1273	5111	4.340	7.538	1.279	2.51	153	27.5	47.2	0.0547	0.0041	1.26
1300	3.26	0.001 416	1.24	1402	5140	4.444	7.319	1.305	2.43	143	29.9	44.0	0.0570	0.0042	1.27
1400	6.30	0.001 471	0.676	1534	5168	4.542	7.138	1.340	2.39	135	32.2	41.1	0.0592	0.0044	1.30
1500	11.13	0.001 531	0.400	1671	5193	4.636	6.984	1.384	2.36	128	34.6	38.2		0.0046	
1600	18.28	0.001 597	0.253	1812	5217	4.727	6.855	1.437	2.34	122	37.1	35.4		0.0050	
1700	28.28	0.001 675	0.168	1959	5238	4.816	6.745	1.500	2.41	117		32.6		0.0054	
1800	41.61	0.001 761	0.117	2113	5256	4.904	6.650	1.574	2.46	112		29.7		0.0059	
1900	58.70	0.001 862	0.084	2274	5268	4.992	6.568	1.661	2.53	108		26.6		0.0067	
2000	79.91	0.001 984	0.063	2444	5273	5.079	6.494	1.764	2.66	104		23.2		0.0079	
2100	105.5	0.002 174	0.0472	2625	5265			1.926	2.91						
2200	135.7	0.002 320	0.0361	2822	5241			2.190	3.40						
2300	170.6	0.002 584	0.0275	3047	5188			2.690	4.47						
2400	210.3	0.002 985	0.0203	3331	5078			4.012	8.03						
2500	254.7	0.004 19	0.0098	3965	4617			39.3	417.						
2503.7 ^c	256.4	0.004 57	0.0046	4294	4294										

^c = critical point.

s_f values converted from Cordfunke, E. H. P. and R. J. M. Konings, *Thermochemical Data for Reactor Materials and Fission Products*, North Holland Elsevier, NY, 1990. s_g determined as $s_f + (h_g - h_f)/T$. μ_g and k_g values estimated by P. E. Liley. All other values are from Fink, J. K. and L. Leibowitz, Argonne Nat. Lab Rept. ANL/RE-95-2, 1995. The Fink and Leibowitz work also appeared in *High Temp. Materials Sci.*, 35, 65–103, 1996. Saturation and superheat tables and a diagram to 14 bar, 1700 K are given by Reynolds, W. C., *Thermodynamic Properties in S.I.*, Stanford Univ. publ., 1979 (173 pp.). For a Mollier diagram for 0.1–150 psia, 1500–2700°R, see Weatherford, P. M., J. C. Tyler, et al., WADD-TR-61-96, 1961.

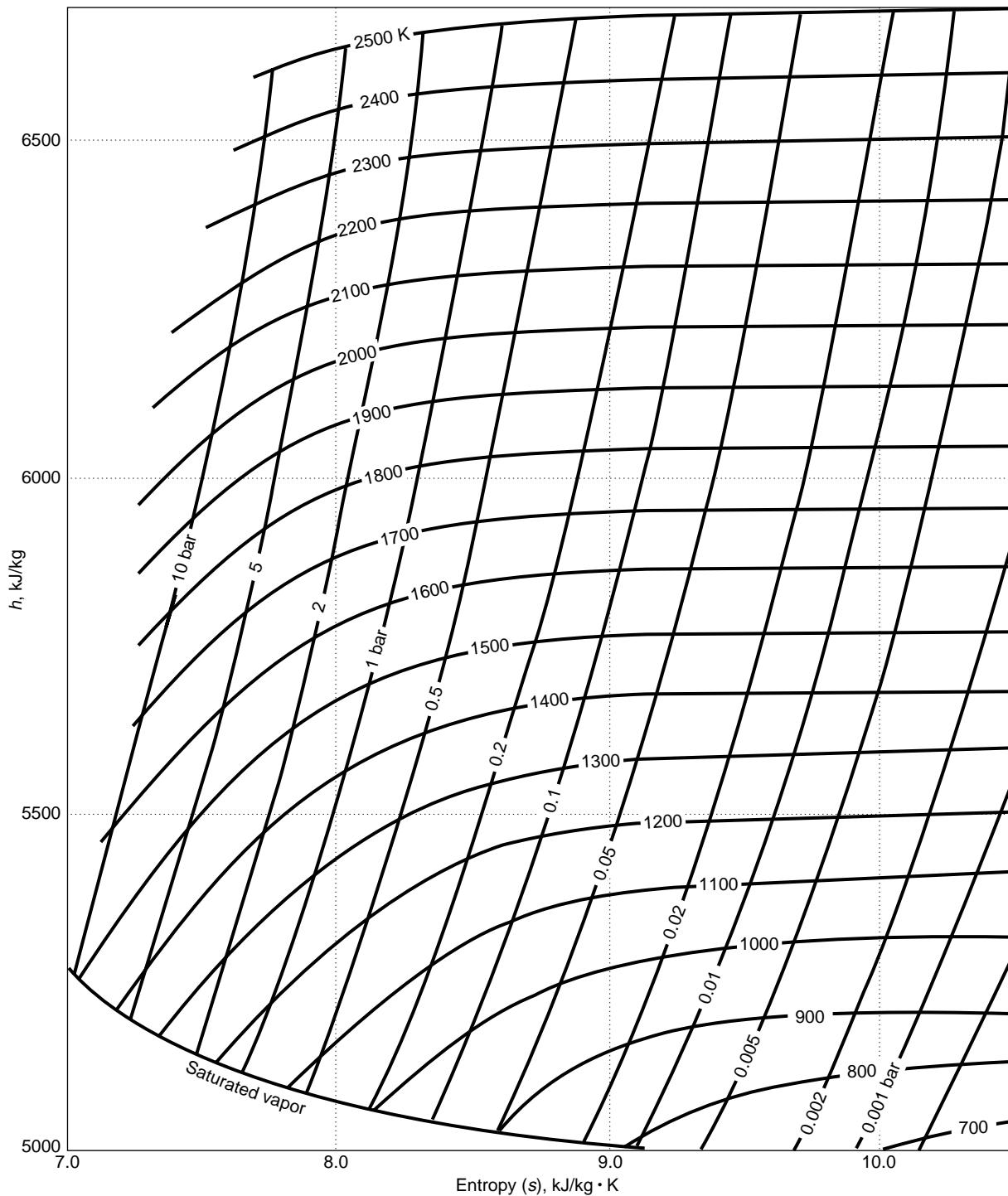


FIG. 2-28 Mollier Diagram for Sodium. Drawn from the Vargaftik et al. values in Ohse, R. W., *Handbook of Thermodynamic and Transport Properties of Alkali Metals*, Blackwell Sci. Pubs., Oxford, UK, 1985. These values are identical with those of Vargaftik, N. B., *Handbook of Thermophysical Properties of Gases and Liquids*, Moscow, 1972, and the Hemisphere translation, pp. 19. An apparent discontinuity exists between the superheat values and the saturation values, not reproduced here. For a Mollier diagram in f.p.s. units from 0.1 to 150 psia, 1500 to 2700°R, see Fig. 3-36, p. 3-232 of the 6th edition of this handbook. An extensive review of properties of the solid and the saturated liquid was given by Alcock, C. B., Chase, M. W. et al., *J. Phys. Chem. Ref. Data*, **23**(3), 385–497, 1994.

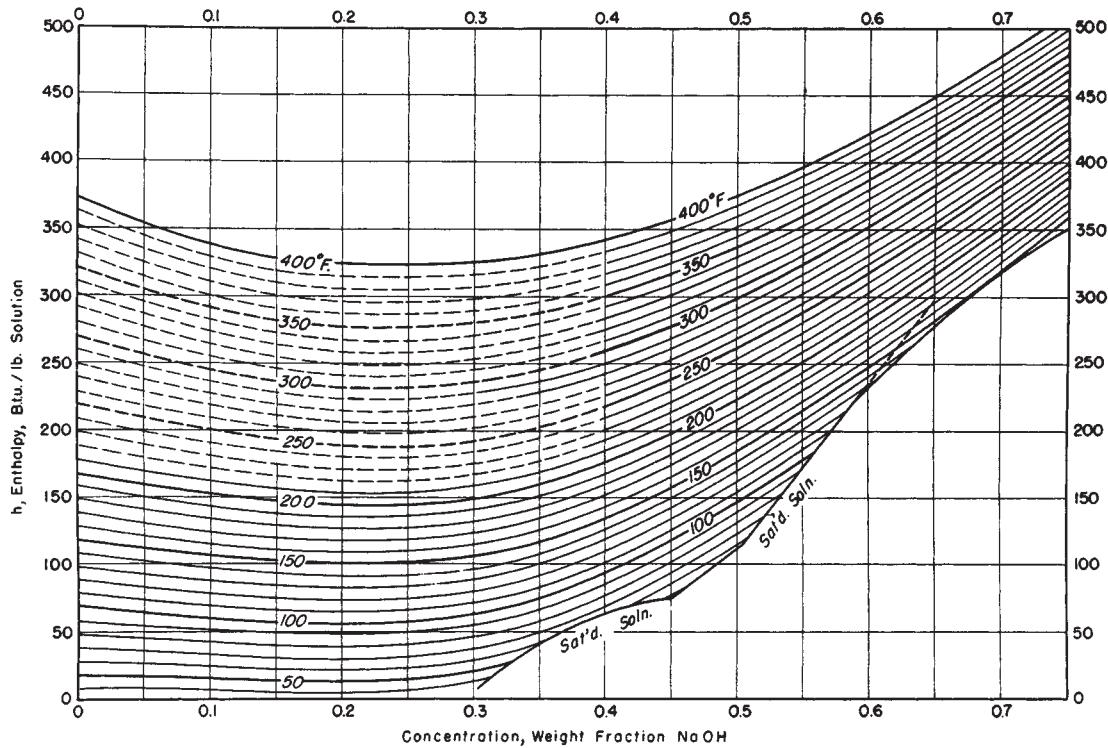


FIG. 2-29 Enthalpy-concentration diagram for aqueous sodium hydroxide at 1 atm. Reference states: enthalpy of liquid water at 32°F and vapor pressure is zero; partial molal enthalpy of infinitely dilute NaOH solution at 64°F and 1 atm is zero. [McCabe, Trans. Am. Inst. Chem. Eng., 31, 129 (1935).]

TABLE 2-346 Saturated Sulfur Dioxide*

T, K	P, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
200	0.02056	6.189.-4	12.602	7.4	433.3	0.033	2.212	1.280	12.3	
210	0.04569	6.284.-4	5.946	9.1	446.1	0.041	2.159	1.284	10.6	
220	0.09997	6.384.-4	2.876	28.6	453.8	0.123	2.075	1.288	8.37	
230	0.1844	6.488.-4	1.605	43.5	459.5	0.198	2.001	1.293	7.03	
240	0.3202	6.596.-4	0.9602	56.5	464.5	0.254	1.952	1.299	5.97	
250	0.5430	6.707.-4	0.5864	70.0	469.7	0.308	1.906	1.308	5.11	0.262
260	0.8778	6.819.-4	0.3745	85.1	474.5	0.363	1.865	1.317	4.39	0.243
270	1.3634	6.938.-4	0.2479	99.8	479.3	0.425	1.827	1.328	3.78	0.224
280	2.0402	7.057.-4	0.1699	114.8	484.3	0.473	1.793	1.343	3.30	0.206
290	2.9574	7.184.-4	0.1197	129.2	488.5	0.523	1.763	1.363	2.87	0.190
300	4.1675	7.312.-4	0.08647	143.1	492.5	0.568	1.732	1.389	2.51	0.174
310	5.7372	7.447.-4	0.06366	157.1	496.3	0.612	1.706	1.422	2.19	0.162
320	7.8226	7.590.-4	0.04707	170.1	498.9	0.649	1.678	1.459	1.91	0.151
330	10.301	7.847.-4	0.03572	183.0	501.2	0.690	1.654	1.499	1.67	0.139
340	13.229	8.066.-4	0.02792	196.0	502.5	0.731	1.633	1.546	1.46	0.128
350	16.759	8.303.-4	0.02209	211.2	502.9	0.781	1.614	1.603	1.27	0.117
360	21.01	8.571.-4	0.01755	223.7	503.1	0.817	1.593	1.68	1.11	0.108
370	26.01	8.877.-4	0.01399	239.9	502.9	0.862	1.573	1.75	0.96	0.098
380	31.92	9.236.-4	0.01110	257.9	502.7	0.910	1.555	1.84	0.84	0.089
390	38.76	9.671.-4	0.00877	277.7	500.7	0.962	1.534	1.97	0.73	0.081
400	46.67	1.023.-3	0.00685	300.2	496.7	1.020	1.511	2.12	0.63	0.072
410	55.80	1.098.-3	0.00559	326.2	489.5	1.083	1.481		0.53	0.064
420	66.19	1.235.-3	0.00387	355.6	474.1	1.155	1.436		0.44	0.055
425.1 ^c	78.81	1.906.-3	0.00191	423.6	423.6	1.304	1.304			

*Values interpolated and converted from tables of Kang, McKetta, et al., Bur. Eng. Res. Repr. 59, University of Texas, Austin, 1961. See also *J. Chem. Eng. Data*, 6 (1961): 220-227; and *Am. Inst. Chem. Eng. J.*, 7 (1961): 418. c = critical point. The notation 6.189.-4 signifies 6.189×10^{-4} . The AIChE publication contains a Mollier diagram to 4500 psia, 480°F, while the reprint contains saturation and superheat tables.

TABLE 2-347 Thermodynamic Properties of Saturated Sulfur Hexafluoride (SF_6)*

Temp., K	Pressure, bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	c_{pg} , kJ/(kg·K)
222.4	2.200	0.0005389	0.05428	-57.55	59.08	-0.2310	0.2935		0.579
225	2.470	0.0005429	0.04861	-54.41	60.49	-0.2171	0.2936		0.583
230	3.045	0.0005507	0.03978	-48.51	63.12	-0.1913	0.2940		0.592
235	3.710	0.0005588	0.03286	-42.67	65.68	-0.1663	0.2947		0.602
240	4.475	0.0005675	0.02737	-36.87	68.18	-0.1421	0.2956		0.613
245	5.346	0.0005768	0.02296	-31.13	70.61	-0.1186	0.2966		0.626
250	6.332	0.0005866	0.01939	-25.47	72.96	-0.0960	0.2977		0.640
255	7.442	0.0005971	0.01647	-19.87	75.22	-0.0741	0.2988		0.656
260	8.684	0.0006085	0.01406	-14.33	77.39	-0.0528	0.2999		0.674
265	10.07	0.0006207	0.01205	-8.85	79.44	-0.0323	0.3009		0.695
270	11.60	0.0006341	0.01035	-3.41	81.38	-0.0123	0.3017		0.720
275	13.30	0.0006488	0.00892	2.00	83.19	0.0071	0.3024		0.748
280	15.18	0.0006652	0.00769	7.42	84.84	0.0262	0.3027		0.783
285	17.25	0.0006836	0.00663	12.88	86.30	0.0451	0.3027		0.827
290	19.52	0.0007047	0.00571	18.45	87.52	0.0639	0.3021	0.409	0.882
295	22.01	0.0007295	0.00490	24.20	88.45	0.0829	0.3008	0.631	0.941
300	24.75	0.0007594	0.00418	30.22	89.00	0.1025	0.2984	0.870	1.070
305	27.76	0.000798	0.00352	36.75	88.97	0.1233	0.2945	1.17	1.26
310	31.05	0.000851	0.00291	44.05	88.06	0.1462	0.2881	1.63	1.63
315	34.67	0.000949	0.00228	53.98	85.22	0.1769	0.2761	2.48	2.40
318.7	37.79	0.001372	0.00137	71.74	71.74	0.2317	0.2317	∞	∞

*See also Oda, A., M. Uematsu, et al., *Bull. JSME*, **26**, 219 (1983): 1590–1596. Ulybin, S.A., *Thermodynamic Properties of Sulfur Hexafluoride*, Moscow, 1977 (53 pp.). For thermal conductivity to 500 bar, see Rastorguev, Yu L., B. A. Grigorev, et al., *Teploenergetika* **24**, 6 (1977): 78–81 and Bakulin, S. S. and S. A. Ulybin, *Teplofiz. Vysok. Temp.*, **16**, 1 (1978): 59–66. For viscosity to 400 bar, see Grigorev, B. A., A. S. Keramidi, et al., *Teploenergetika*, **24**, 9 (1977): 85–87; and Ulybin, S. A. and V. I. Makarushkin, *Teplofiz. Vysok. Temp.*, **15**, 6 (1977): 1195–1201.

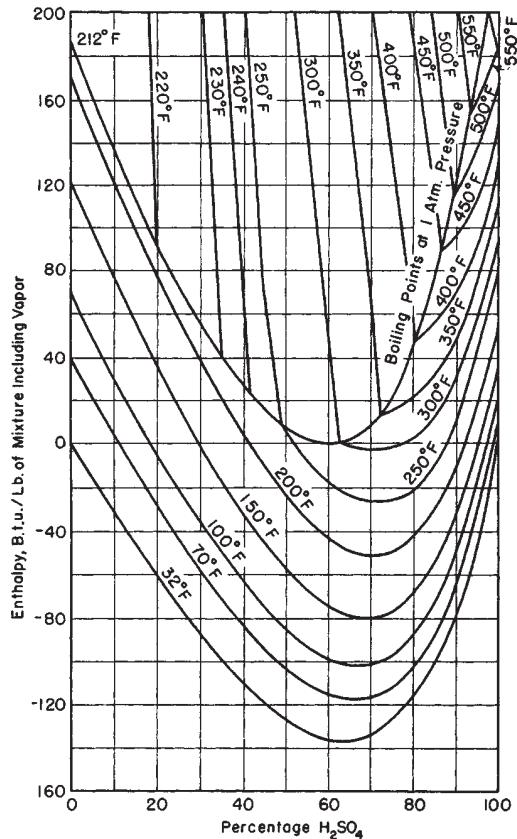


FIG. 2-30 Enthalpy-concentration diagram for aqueous sulfuric acid at 1 atm. Reference states: enthalpies of pure-liquid components at 32°F and vapor pressures are zero. NOTE: It should be observed that the weight basis includes the vapor, which is particularly important in the two-phase region. The upper ends of the tie lines in this region are assumed to be pure water. (Hougen and Watson, Chemical Process Principles, part I, Wiley, New York, 1943.)

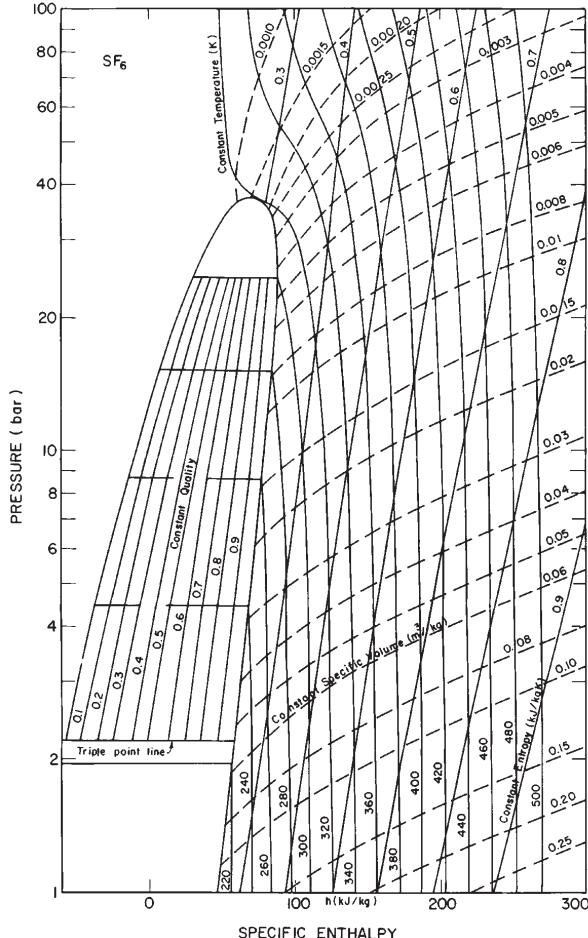


FIG. 2-31 Enthalpy-log-pressure diagram for sulfur hexafluoride.

TABLE 2-348 Saturated SUVA AC 9000

DuPont bulletin T-AC-9000-SI, 1994 (16 pp.) gives tables and a chart to 100 bar, 235°C. With a stated composition of 23% wt CH₂F₂ (R23), 25% wt CHF₂CF₃ (R125), and 52% wt CH₂FCH₃ (R134a) this is apparently identical to KLEA 66, to which the reader is referred.

TABLE 2-349 Saturated Toluene*

T, K	P, bar	<i>v_f</i> , m ³ /kg	<i>v_g</i> , m ³ /kg	<i>h_f</i> , kJ/kg	<i>h_g</i> , kJ/kg	<i>s_f</i> , kJ/(kg·K)	<i>s_g</i> , kJ/(kg·K)	<i>c_{pf}</i> , kJ/(kg·K)	$\mu_f \cdot 10^{-4}$ Pa·s	<i>k_f</i> , W/(m·K)
270	0.0076	1.127,-3	34.9	316.7	745.7	2.236	3.825	1.64	8.02	0.141
280	0.0139	1.138,-3	19.1	333.0	756.1	2.295	3.806	1.66	6.96	0.138
290	0.0246	1.150,-3	10.6	349.6	766.8	2.353	3.792	1.68	6.10	0.136
300	0.0418	1.162,-3	6.46	366.5	777.8	2.410	3.782	1.71	5.41	0.133
310	0.0682	1.175,-3	4.08	383.7	789.2	2.467	3.776	1.74	4.83	0.131
320	0.1072	1.188,-3	2.67	401.3	800.9	2.522	3.771	1.78	4.34	0.128
330	0.1633	1.201,-3	1.80	419.6	812.9	2.577	3.771	1.81	3.93	0.126
340	0.2416	1.215,-3	1.25	437.4	825.2	2.632	3.772	1.84	3.58	0.124
350	0.3480	1.230,-3	0.891	456.0	837.8	2.686	3.777	1.88	3.28	0.121
360	0.4894	1.245,-3	0.698	475.1	850.7	2.739	3.783	1.92	3.01	0.119
370	0.6736	1.261,-3	0.481	494.6	863.8	2.792	3.791	1.96	2.78	0.117
380	0.9090	1.277,-3	0.364	514.4	877.2	2.846	3.801	2.01	2.56	0.114
390	1.2049	1.294,-3	0.279	534.7	890.9	2.898	3.811	2.05	2.37	0.112
400	1.5713	1.312,-3	0.218	555.4	904.8	2.950	3.824	2.09	2.19	0.110
420	2.5589	1.350,-3	0.137	598.1	933.1	3.054	3.852	2.17	1.89	0.105
440	3.965	1.393,-3	9.00,-2	642.3	962.0	3.156	3.883	2.24	1.64	0.101
460	5.892	1.443,-3	6.11,-2	688.1	991.3	3.258	3.917	2.31		0.096
480	8.451	1.499,-3	4.26,-2	735.5	1021.1	3.358	3.953	2.38		0.091
500	11.76	1.567,-3	3.03,-2	784.4	1051.3	3.457	3.989	2.45		0.086
520	15.96	1.651,-3	2.19,-2	834.9	1081.4	3.554	4.027	2.53		0.082
540	21.99	1.761,-3	1.58,-2	887.3	1109.6	3.651	4.062	2.65		0.078
560	27.65	1.919,-3	1.13,-2	942.8	1132.1	3.750	4.088	2.82		0.074
580	35.56	2.213,-3	7.59,-3	1005.6	1142.3	3.857	4.093			
590	40.16	2.650,-3	5.28,-3	1050.2	1128.1	3.932	4.063			
591.8 ^c	41.04	3.432,-3	3.43,-3	1084.9	1084.9	3.989	3.989			

*Values converted and mostly rounded off from the tables of Counsell, Lawrenson, and Lees, Nat. Phys. Lab., Teddington (U.K.) Rep. Chem. 52, 1976. *c* = critical point. The notation 1.127,-6 signifies 1.127×10^{-6} . For other tables, see Goodwin, R. D., *J. Phys. Chem. Ref. Data*, **18**, 4 (1989): 1565–1636.

TABLE 2-350 Saturated Solid/Vapor Water*

Temp., °F	Pressure, lb/in ² abs.	Volume, ft ³ /lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)(°F)	
		Solid	Vapor	Solid	Vapor	Solid	Vapor
-160	4.949,-8	0.01722	3.607,+9	-222.05	990.38	-0.4907	3.5549
-150	1.620,-7	0.01723	1.139,+9	-218.82	994.80	-0.4801	3.4387
-140	4.928,-7	0.01724	3.864,+8	-215.49	999.21	-0.4695	3.3301
-130	1.403,-6	0.01725	1.400,+8	-212.08	1003.63	-0.4590	3.2284
-120	3.757,-6	0.01726	5.386,+7	-208.58	1008.05	-0.4485	3.1330
-110	9.517,-6	0.01728	2.189,+7	-204.98	1012.47	-0.4381	3.0434
-100	2.291,-5	0.01729	9.352,+6	-201.28	1016.89	-0.4277	2.9591
-90	5.260,-5	0.01730	4.186,+6	-197.49	1021.31	-0.4173	2.8796
-80	1.157,-4	0.01731	1.955,+6	-193.60	1025.73	-0.4069	2.8045
-70	2.443,-4	0.01732	9.501,+5	-189.61	1030.15	-0.3965	2.7336
-60	4.972,-4	0.01734	4.788,+5	-185.52	1034.58	-0.3862	2.6664
-50	9.776,-4	0.01735	2.496,+5	-181.34	1039.00	-0.3758	2.6028
-45	1.354,-3	0.01736	1.824,+5	-179.21	1041.21	-0.3707	2.5723
-40	1.861,-3	0.01737	1.343,+5	-177.06	1043.42	-0.3655	2.5425
-35	2.540,-3	0.01737	9.961,+4	-174.88	1045.63	-0.3604	2.5135
-30	3.440,-3	0.01738	7.441,+4	-172.68	1047.84	-0.3552	2.4853
-25	4.627,-3	0.01739	5.596,+4	-170.46	1050.05	-0.3501	2.4577
-20	6.181,-3	0.01739	4.237,+4	-168.21	1052.26	-0.3449	2.4308
-15	8.204,-3	0.01740	3.228,+4	-165.94	1054.47	-0.3398	2.4046
-10	1.082,-2	0.01741	2.475,+4	-163.65	1056.67	-0.3347	2.3791
-5	1.419,-2	0.01741	1.909,+4	-161.33	1058.88	-0.3295	2.3541
0	1.849,-2	0.01742	1.481,+4	-158.98	1061.09	-0.3244	2.3297
5	2.396,-2	0.01743	1.155,+4	-156.61	1063.29	-0.3193	2.3039
10	3.087,-2	0.01744	9.060,+3	-154.22	1065.50	-0.3142	2.2827
15	3.957,-2	0.01744	7.144,+3	-151.80	1067.70	-0.3090	2.2600
16	4.156,-2	0.01745	6.817,+3	-151.32	1068.14	-0.3080	2.2555
18	4.581,-2	0.01745	6.210,+3	-150.34	1069.02	-0.3060	2.2466
20	5.045,-2	0.01745	5.662,+3	-149.36	1069.90	-0.3039	2.2378
22	5.552,-2	0.01746	5.166,+3	-148.38	1070.38	-0.3019	2.2291
24	6.105,-2	0.01746	4.717,+3	-147.39	1071.66	-0.2998	2.2205
26	6.708,-2	0.01746	4.311,+3	-146.40	1072.53	-0.2978	2.2119
28	7.365,-2	0.01746	3.943,+3	-145.40	1073.41	-0.2957	2.2034
30	8.080,-2	0.01747	3.608,+3	-144.40	1074.29	-0.2937	2.1950
31	8.461,-2	0.01747	3.453,+3	-143.90	1074.73	-0.2927	2.1908
32	8.858,-2	0.01747	3.305,+3	-143.40	1075.16	-0.2916	2.1867

*Condensed from *Fundamentals*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1967 and 1972. Reproduced by permission. The validity of many standard reference tables has been critically reviewed by Jancso, Pupezin, and van Hook, *J. Phys. Chem.*, **74** (1970): 2984. This source is recommended for further study. The notation 4.949,-8, 3.607,+9, etc., means 4.949×10^{-8} , 3.607×10^9 , etc.

TABLE 2-351 Saturated Water Substance—Temperature (fps units)*

Temp., °F	Pressure, lb/in² abs.	Volume, ft³/lb		Enthalpy, Btu/lb		Entropy, Btu/(lb)°F	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
32.018	0.08865	0.016022	3302.4	0.000	1075.5	0.0000	2.1872
35	0.09991	0.016020	2948.1	3.002	1076.8	0.0061	2.1767
40	0.12163	0.016019	2445.8	8.027	1079.0	0.0162	2.1594
45	0.14744	0.016020	2037.8	13.044	1081.2	0.0262	2.1426
50	0.17796	0.016023	1704.8	18.054	1083.4	0.0361	2.1262
55	0.21392	0.016027	1432.0	23.059	1085.6	0.0458	2.1102
60	0.25611	0.016033	1207.6	28.060	1087.7	0.0555	2.0946
65	0.30545	0.016041	1022.1	33.057	1089.9	0.0651	2.0794
70	0.36292	0.016050	868.4	38.052	1092.1	0.0745	2.0645
75	0.42964	0.016060	740.3	43.045	1094.3	0.0839	2.0500
80	0.50683	0.016072	633.3	48.037	1096.4	0.0932	2.0359
85	0.59583	0.016085	543.6	53.027	1098.6	0.1024	2.0221
90	0.69813	0.016099	468.1	58.018	1100.8	0.1115	2.0086
95	0.81534	0.016114	404.4	63.008	1102.9	0.1206	1.9954
100	0.94294	0.016130	350.4	67.999	1105.1	0.1295	1.9825
110	1.2750	0.016165	265.39	77.98	1109.3	0.1472	1.9577
120	1.6927	0.016204	203.26	87.97	1113.6	0.1646	1.9339
130	2.2230	0.016247	157.33	97.96	1117.8	0.1817	1.9112
140	2.8892	0.016293	122.98	107.89	1122.0	0.1985	1.8895
150	3.7184	0.016343	97.07	117.95	1126.1	0.2150	1.8686
160	4.7414	0.016395	77.27	127.96	1130.2	0.2313	1.8487
170	5.9926	0.016451	62.06	137.97	1134.2	0.2473	1.8295
180	7.5110	0.016510	50.225	148.00	1138.2	0.2631	1.8111
190	9.340	0.016572	40.957	158.04	1142.1	0.2787	1.7934
200	11.526	0.016637	33.639	168.09	1146.0	0.2940	1.7764
210	14.123	0.016705	27.816	178.15	1149.7	0.3091	1.7600
212	14.696	0.016719	26.799	180.17	1150.5	0.3121	1.7568
220	17.186	0.016775	23.148	188.23	1153.4	0.3241	1.7442
230	20.779	0.016849	19.381	198.33	1157.1	0.3388	1.7290
240	24.968	0.016926	16.321	208.45	1160.6	0.3533	1.7142
250	29.825	0.017066	13.819	218.59	1164.0	0.3677	1.7000
260	35.427	0.017089	11.762	228.76	1167.4	0.3819	1.6862
270	41.856	0.017175	10.060	238.95	1170.6	0.3960	1.6729
280	49.200	0.017264	8.644	249.17	1173.8	0.4098	1.6599
290	57.550	0.01736	7.4603	259.4	1167.8	0.4236	1.6473
300	67.005	0.01745	6.4658	269.7	1179.7	0.4372	1.6351
320	89.643	0.01766	4.9138	290.4	1185.2	0.4640	1.6116
340	117.992	0.01787	3.7878	311.3	1190.1	0.4902	1.5892
360	153.01	0.01811	2.9573	332.3	1194.4	0.5161	1.5678
380	195.73	0.01836	2.3353	353.6	1198.0	0.5416	1.5473
400	247.26	0.01864	1.8630	375.1	1201.0	0.5667	1.5274
420	308.78	0.01894	1.4997	396.9	1203.1	0.5915	1.5080
440	381.54	0.01926	1.2169	419.0	1204.4	0.6161	1.4890
460	466.87	0.01961	0.99424	441.5	1204.8	0.6405	1.4704
480	566.15	0.02000	0.81717	464.5	1204.1	0.6648	1.4518
500	680.86	0.02043	0.67492	487.9	1202.2	0.6890	1.4333
520	812.53	0.02091	0.55956	512.0	1199.0	0.7133	1.4146
540	962.79	0.02146	0.46513	536.8	1194.3	0.7378	1.3954
560	1133.38	0.02207	0.38714	562.4	1187.7	0.7625	1.3757
580	1326.17	0.02279	0.32216	589.1	1179.0	0.7876	1.3550
600	1543.2	0.02364	0.26747	617.1	1167.7	0.8134	1.3330
620	1786.9	0.02466	0.22081	646.9	1153.2	0.8403	1.3092
640	2059.9	0.02595	0.18021	679.1	1133.7	0.8686	1.2821
660	2365.7	0.02768	0.14431	714.9	1107.0	0.8995	1.2498
680	2708.6	0.03037	0.11117	758.5	1068.5	0.9365	1.2086
700	3094.3	0.03662	0.07519	825.2	991.7	0.9924	1.1359
702	3135.5	0.03824	0.06997	835.0	979.7	1.0006	1.1210
704	3177.2	0.04108	0.06300	854.2	956.2	1.0169	1.1046
705.47	3208.2	0.05078	0.05078	906.0	906.0	1.0612	1.0612

*Extracted and condensed from 1967 ASME Steam Tables. Copyright reserved. Reproduced by permission.

TABLE 2-352 Saturated Water Substance—Temperature (SI units)

Temp., K	Pressure, bar°	Volume, m³/kg		Enthalpy, kJ/kg		Entropy, kJ/(kg·K)		Specific heat, C_p, kJ/(kg·K)		Viscosity, Ns/m²		Thermal conductivity, W/(m·K)		Prandtl no.		Surface tension, N/m	Temp., K
		Condensed†	Vapor	Condensed†	Vapor	Condensed†	Vapor	Condensed†	Vapor	Condensed†	Vapor	Condensed†	Vapor	Condensed†	Vapor		
150	6.30--11	1.073--3	9.55+9	-539.6	2273	-2.187	16.54	1.155					3.73				150
160	7.72--10	1.074--3	9.62+8	-525.7	2291	-2.106	15.49	1.233					3.52				160
170	7.29--9	1.076--3	1.08+8	-511.7	2310	-2.026	14.57	1.311					3.34				170
180	5.38--8	1.077--3	1.55+7	-497.8	2328	-1.947	13.76	1.389					3.18				180
190	3.23--7	1.078--3	2.72+6	-483.8	2347	-1.868	13.03	1.467					3.04				190
200	1.62--6	1.079--3	5.69+5	-467.5	2366	-1.789	12.38	1.545					2.91				200
210	7.01--6	1.081--3	1.39+5	-451.2	2384	-1.711	11.79	1.623					2.79				210
220	2.65--5	1.082--3	3.83+4	-435.0	2403	-1.633	11.20	1.701					2.69				220
230	8.91--5	1.084--3	1.18+4	-416.3	2421	-1.555	10.79	1.779					2.59				230
240	3.72--4	1.085--3	4.07+3	-400.1	2440	-1.478	10.35	1.857					2.50				240
250	7.59--4	1.087--3	1.52+3	-381.5	2459	-1.400	9.954	1.935					2.42				250
255	1.23--3	1.087--3	956.4	-369.8	2468	-1.361	9.768	1.974					2.38				255
260	1.96--3	1.088--3	612.2	-360.5	2477	-1.323	9.590	2.013					2.35				260
265	3.06--3	1.089--3	400.4	-351.2	2486	-1.281	9.461	2.052					2.31				265
270	4.69--3	1.090--3	265.4	-339.6	2496	-1.296	9.255	2.091					2.27				270
273.15	6.11--3	1.091--3	206.3	-333.5	2502	-1.221	9.158	2.116					2.26				273.15
273.15	0.00611	1.000--3	206.3	0.0	2502	0.000	9.158	4.217	1.854	1750--6	8.02--6	0.569	0.0182	12.99	0.815	0.0755	273.15
275	0.00697	1.000--3	181.7	7.8	2505	0.028	9.109	4.211	1.855	1652--6	8.09--6	0.574	0.0183	12.22	0.817	0.0753	275
280	0.00990	1.000--3	130.4	28.8	2514	0.104	8.980	4.198	1.858	1422--6	8.29--6	0.582	0.0186	10.26	0.825	0.0748	280
285	0.01387	1.000--3	99.4	49.8	2523	0.178	8.857	4.189	1.861	1225--6	8.49--6	0.590	0.0189	8.81	0.833	0.0743	285
290	0.01917	1.001--3	69.7	70.7	2532	0.251	8.740	4.184	1.864	1080--6	8.69--6	0.598	0.0193	7.56	0.841	0.0737	290
295	0.02617	1.002--3	51.94	91.6	2541	0.323	8.627	4.181	1.868	959--6	8.89--6	0.606	0.0195	6.62	0.849	0.0727	295
300	0.03531	1.003--3	39.13	112.5	2550	0.393	8.520	4.179	1.872	855--6	9.09--6	0.613	0.0196	5.83	0.857	0.0717	300
305	0.04712	1.005--3	27.90	133.4	2559	0.462	8.417	4.178	1.877	769--6	9.29--6	0.620	0.0201	5.20	0.865	0.0709	305
310	0.06221	1.007--3	22.93	154.3	2568	0.530	8.318	4.178	1.882	695--6	9.49--6	0.628	0.0204	4.62	0.873	0.0700	310
315	0.08132	1.009--3	17.82	175.2	2577	0.597	8.224	4.179	1.888	631--6	9.69--6	0.634	0.0207	4.16	0.883	0.0692	315
320	0.1053	1.011--3	13.98	196.1	2586	0.649	8.151	4.180	1.895	577--6	9.89--6	0.640	0.0210	3.77	0.894	0.0683	320
325	0.1351	1.013--3	11.06	217.0	2595	0.727	8.046	4.182	1.903	528--6	10.09--6	0.645	0.0213	3.42	0.901	0.0675	325
330	0.1719	1.016--3	8.82	237.9	2604	0.791	7.962	4.184	1.911	489--6	10.29--6	0.650	0.0217	3.15	0.908	0.0666	330
335	0.2167	1.018--3	7.09	258.8	2613	0.854	7.881	4.186	1.920	453--6	10.49--6	0.655	0.0220	2.88	0.916	0.0658	335
340	0.2713	1.021--3	5.74	279.8	2622	0.916	7.804	4.188	1.930	420--6	10.69--6	0.660	0.0223	2.66	0.925	0.0649	340
345	0.3372	1.024--3	4.683	300.7	2630	0.977	7.729	4.191	1.941	389--6	10.89--6	0.665	0.0226	2.45	0.933	0.0641	345
350	0.4163	1.027--3	3.846	321.7	2639	1.038	7.657	4.195	1.954	365--6	11.09--6	0.668	0.0230	2.29	0.942	0.0632	350
355	0.5100	1.030--3	3.180	342.7	2647	1.097	7.588	4.199	1.968	343--6	11.29--6	0.671	0.0233	2.14	0.951	0.0623	355
360	0.6209	1.034--3	2.645	363.7	2655	1.156	7.521	4.203	1.983	324--6	11.49--6	0.674	0.0237	2.02	0.960	0.0614	360
365	0.7514	1.038--3	2.212	384.7	2663	1.214	7.456	4.209	1.999	306--6	11.69--6	0.677	0.0241	1.91	0.969	0.0605	365
370	0.9040	1.041--3	1.861	405.8	2671	1.271	7.394	4.214	2.017	289--6	11.89--6	0.679	0.0245	1.80	0.978	0.0595	370
373.15	1.0133	1.044--3	1.679	419.1	2676	1.307	7.356	4.217	2.029	279--6	12.02--6	0.680	0.0248	1.76	0.984	0.0589	373.15
375	1.0815	1.045--3	1.574	426.8	2679	1.328	7.333	4.220	2.036	274--6	12.09--6	0.681	0.0249	1.70	0.987	0.0586	375
380	1.2569	1.049--3	1.337	448.0	2687	1.384	7.275	4.226	2.057	260--6	12.29--6	0.683	0.0254	1.61	0.995	0.0576	380
385	1.5233	1.053--3	1.142	469.2	2694	1.439	7.218	4.232	2.080	248--6	12.49--6	0.685	0.0258	1.53	1.004	0.0566	385
390	1.794	1.058--3	0.980	490.4	2702	1.494	7.163	4.239	2.104	237--6	12.69--6	0.686	0.0263	1.47	1.013	0.0556	390
400	2.455	1.067--3	0.731	532.9	2716	1.605	7.058	4.256	2.158	217--6	13.05--6	0.688	0.0272	1.34	1.033	0.0536	400
410	3.302	1.077--3	0.553	575.6	2729	1.708	6.959	4.278	2.221	200--6	13.42--6	0.688	0.0282	1.24	1.054	0.0515	410
420	4.370	1.088--3	0.425	618.6	2742	1.810	6.865	4.302	2.291	185--6	13.79--6	0.688	0.0293	1.16	1.075	0.0494	420
430	5.699	1.099--3	0.331	661.8	2753	1.911	6.775	4.331	2.369	173--6	14.14--6	0.685	0.0304	1.09	1.10	0.0472	430

440	7.333	1.110.-3	0.261	705.3	2764	2.011	6.689	4.36	2.46	162.-6	14.50.-6	0.682	0.0317	1.04	1.12	0.0451	440
450	9.319	1.123.-3	0.208	749.2	2773	2.109	6.607	4.40	2.56	152.-6	14.85.-6	0.678	0.0331	0.99	1.14	0.0429	450
460	11.71	1.137.-3	0.167	793.5	2782	2.205	6.528	4.44	2.68	143.-6	15.19.-6	0.673	0.0346	0.95	1.17	0.0407	460
470	14.55	1.152.-3	0.136	838.2	2789	2.301	6.451	4.48	2.79	136.-6	15.54.-6	0.667	0.0363	0.92	1.20	0.0385	470
480	17.90	1.167.-3	0.111	883.4	2795	2.395	6.377	4.53	2.94	129.-6	15.88.-6	0.660	0.0381	0.89	1.23	0.0362	480
490	21.83	1.184.-3	0.0922	929.1	2799	2.479	6.312	4.59	3.10	124.-6	16.23.-6	0.651	0.0401	0.87	1.25	0.0339	490
500	26.40	1.203.-3	0.0766	975.6	2801	2.581	6.233	4.66	3.27	118.-6	16.59.-6	0.642	0.0423	0.86	1.28	0.0316	500
510	31.66	1.222.-3	0.0631	1023	2802	2.673	6.163	4.74	3.47	113.-6	16.95.-6	0.631	0.0447	0.85	1.31	0.0293	510
520	37.70	1.244.-3	0.0525	1071	2801	2.765	6.093	4.84	3.70	108.-6	17.33.-6	0.621	0.0475	0.84	1.35	0.0269	520
530	44.58	1.268.-3	0.0445	1119	2798	2.856	6.023	4.95	3.96	104.-6	17.72.-6	0.608	0.0506	0.85	1.39	0.0245	530
540	52.38	1.294.-3	0.0375	1170	2792	2.948	5.953	5.08	4.27	101.-6	18.1.-6	0.594	0.0540	0.86	1.43	0.0221	540
550	61.19	1.323.-3	0.0317	1220	2784	3.039	5.882	5.24	4.64	97.-6	18.6.-6	0.580	0.0583	0.87	1.47	0.0197	550
560	71.08	1.355.-3	0.0269	1273	2772	3.132	5.808	5.43	5.09	94.-6	19.1.-6	0.563	0.0637	0.90	1.52	0.0173	560
570	82.16	1.392.-3	0.0228	1328	2757	3.225	5.733	5.68	5.67	91.-6	19.7.-6	0.548	0.0698	0.94	1.59	0.0150	570
580	94.51	1.433.-3	0.0193	1384	2737	3.321	5.654	6.00	6.40	88.-6	20.4.-6	0.528	0.0767	0.99	1.68	0.0128	580
590	108.3	1.482.-3	0.0163	1443	2717	3.419	5.569	6.41	7.35	84.-6	21.5.-6	0.513	0.0841	1.05	1.84	0.0105	590
600	123.5	1.541.-3	0.0137	1506	2682	3.520	5.480	7.00	8.75	81.-6	22.7.-6	0.497	0.0929	1.14	2.15	0.0084	600
610	137.3	1.612.-3	0.0115	1573	2641	3.627	5.318	7.85	11.1	77.-6	24.1.-6	0.467	0.103	1.30	2.60	0.0063	610
620	159.1	1.705.-3	0.0094	1647	2588	3.741	5.259	9.35	15.4	72.-6	25.9.-6	0.444	0.114	1.52	3.46	0.0045	620
625	169.1	1.778.-3	0.0085	1697	2555	3.805	5.191	10.6	18.3	70.-6	27.0.-6	0.430	0.121	1.65	4.20	0.0035	625
630	179.7	1.856.-3	0.0075	1734	2515	3.875	5.115	12.6	22.1	67.-6	28.0.-6	0.412	0.130	2.0	4.8	0.0026	630
635	190.9	1.935.-3	0.0066	1783	2466	3.950	5.025	16.4	27.6	64.-6	30.0.-6	0.392	0.141	2.7	6.0	0.0015	635
640	202.7	2.075.-3	0.0057	1841	2401	4.037	4.912	26	42	59.-6	32.0.-6	0.367	0.155	4.2	9.6	0.0008	640
645	215.2	2.351.-3	0.0045	1931	2292	4.223	4.732	90		54.-6	37.0.-6	0.331	0.178	12	26	0.0001	645
647.3†	221.2	3.170.-3	0.0032	2107	2107	4.443	4.443	∞	∞	45.-6	45.0.-6	0.238	∞	∞	∞	0.0000	647.3†

*1 bar = 10^5 N/m².

†Above the solid line, the condensed phase is solid; below it, liquid.

‡Critical temperature.

NOTE: The notations 6.30.-11, 1.073.-3, 9.55.+9, etc. signify 6.30×10^{-11} , 1.073×10^{-3} , 955×10^9 , etc.

Tables 2-351 and 2-352 are provided for general use. Tables to higher precision are available over certain ranges and for various properties. The most current internationally accepted tables are found in Haar, L., J. S. Gallagher, and G. S. Kell, *NBS/NRC Steam Tables*, Hemisphere, Washington, DC, 1984 (320 pp.). These do not tabulate certain properties at saturation states. A revised release on the IAPWS Skeleton Tables 1985 for the thermodynamic properties of ordinary water substance, Sept. 1993 (15 pp.), is apparently the latest international publication. In *J. Phys. Chem. Ref. Data* **17**, 4 (1988): 1439-1540, H. Sato, M. Uematsu, and others review existing steam tables and present the 1985 formulation of skeleton tables. Property codes and programs include Cheng, S. C. and C. Nguyen, *Modeling and Simulation on Microcomputers 1989* (R. W. Allen, ed.), S.C.S. Intl., San Diego, 1989 (pp. 138-141); Garland, W. J. and B. J. Hand, *Nucl. Engng. & Des.*, **113**, (1989): 21-34; Dickey, D. S., *Chem. Eng.* **98**, 9 (1991): 207-8 and **98**, 11: 235-6; Munneer, T. and S. M. Scott, *Proc. Inst. Mech. Eng.*, **205**, (1991): 25-29; and *Energy Convers. Mgmt.*, **31**, 4 (1991): 315-325. Useful pictorial representations of 20 properties as a function of both temperature (to 800°C) and pressure (to 1000 bar) are given by Grigull, U., J. Bach, et al., *Warme- u. Stoff.*, **1** (1968): 202-213. Property equations for the saturated liquid for the range 0-300°C are given by Charters, W. W. S. and H. A. Sadaf, *Rev. Int. Froid.*, **10**, (Mar. 1987): 105-6. Gordon, S., NASA Tech. Paper 1906, 1982 gives detailed tables for ice from 0 K. Ice and snow properties are reviewed by Fukusako, S., *Int. J. Thermophys.*, **11**, 2 (1990): 353-372. See also Wagner, W., A. Saul, et al., *J. Phys. Chem. Ref. Data*, **23**, 3 (1994): 515-525, and Table 2-358.

2-308 PHYSICAL AND CHEMICAL DATA
TABLE 2-353 Saturated Liquid Water—Miscellaneous Properties

Temperature, °C	$10^4 \beta$	$10^4 k_T/\text{bar}$	$10^4 k_s/\text{bar}$	$v_s, \text{m/s}$	$\mu_f, 10^{-6} \text{ Pa}\cdot\text{s}$	$c_p, \text{kJ/kg}\cdot\text{K}$	$k, \text{W/m}\cdot\text{K}$	Pr, bar	$\sigma, \text{N/m}$
0	-0.681	0.50885	0.50855	1402.4	1.793	4.2176	0.567	13.32	0.07565
1	-0.501	0.50509	0.50493	1407.4	1.732	4.2140	0.569	12.83	0.07551
2	-0.327	0.50151	0.50143	1412.2	1.675	4.2107	0.570	12.37	0.07537
3	-0.160	0.49808	0.49806	1417.0	1.621	4.2077	0.572	11.93	0.07522
4	0.003	0.49481	0.49481	1421.6	1.569	4.2048	0.573	11.51	0.07508
5	0.160	0.49169	0.49167	1426.2	1.520	4.2022	0.575	11.11	0.07494
6	0.312	0.48871	0.48865	1430.6	1.474	4.1999	0.577	10.73	0.07480
7	0.460	0.48587	0.48573	1434.9	1.429	4.1977	0.578	10.38	0.07465
8	0.604	0.48315	0.48291	1439.1	1.387	4.1956	0.580	10.04	0.07451
9	0.744	0.48056	0.48019	1443.3	1.346	4.1938	0.581	9.72	0.07436
10	0.880	0.47809	0.47757	1447.3	1.308	4.1921	0.5828	9.41	0.07422
11	1.012	0.47573	0.47504	1451.2	1.271	4.1906	0.5844	9.11	0.07407
12	1.141	0.47347	0.47260	1455.0	1.236	4.1892	0.5859	8.84	0.07393
13	1.267	0.47133	0.47024	1458.7	1.202	4.1879	0.5875	8.57	0.07378
14	1.389	0.46928	0.46797	1462.4	1.170	4.1867	0.5891	8.32	0.07364
15	1.509	0.46733	0.46578	1465.9	1.139	4.1856	0.5906	8.07	0.07349
16	1.626	0.46548	0.46366	1469.4	1.110	4.1847	0.5922	7.84	0.07334
17	1.740	0.46371	0.46162	1472.7	1.081	4.1838	0.5937	7.62	0.07319
18	1.852	0.46203	0.45966	1476.0	1.054	4.1830	0.5953	7.41	0.07304
19	1.961	0.46043	0.45776	1479.2	1.028	4.1823	0.5968	7.20	0.07289
20	2.068	0.45892	0.45593	1482.3	1.003	4.1817	0.5983	7.01	0.07274
21	2.173	0.45748	0.45417	1485.3	0.979	4.1812	0.5999	6.82	0.07259
22	2.275	0.45612	0.45248	1488.3	0.955	4.1807	0.6014	6.64	0.07244
23	2.376	0.45484	0.45084	1491.2	0.933	4.1802	0.6029	6.47	0.07228
24	2.475	0.45362	0.44927	1493.9	0.911	4.1798	0.6044	6.30	0.07213
25	2.572	0.45247	0.44776	1496.7	0.891	4.1795	0.6059	6.15	0.07198
26	2.667	0.45139	0.44630	1499.3	0.871	4.1792	0.6074	5.99	0.07182
27	2.761	0.45038	0.44490	1501.9	0.852	4.1790	0.6089	5.85	0.07167
28	2.852	0.44943	0.44355	1504.3	0.833	4.1788	0.6104	5.70	0.07151
30	3.032	0.44771	0.44102	1509.1	0.798	4.1785	0.6133	5.44	0.07120
32	3.206	0.44622	0.43869	1513.6	0.765	4.1783	0.6162	5.19	0.07089
34	3.375	0.44496	0.43655	1517.8	0.734	4.1782	0.6190	4.95	0.07058
36	3.539	0.44390	0.43459	1521.7	0.705	4.1783	0.6218	4.74	0.07025
38	3.698	0.44305	0.43280	1525.4	0.679	4.1784	0.6246	4.54	0.06992
40	3.853	0.44239	0.43118	1528.9	0.653	4.1786	0.6273	4.35	0.06960
42	4.004	0.44192	0.42972	1532.1	0.629	4.1789	0.6299	4.17	0.06927
44	4.152	0.44162	0.42842	1535.0	0.607	4.1792	0.6315	4.02	0.06894
46	4.296	0.44149	0.42726	1537.7	0.586	4.1797	0.6351	3.86	0.06861
48	4.438	0.44153	0.42624	1540.3	0.566	4.1801	0.6375	3.71	0.06828
50	4.576	0.44173	0.42535	1542.6	0.547	4.1807	0.6400	3.57	0.06795
55	4.910	0.44290	0.42370	1547.4	0.5043	4.1824	0.6457	3.267	0.06710
60	5.231	0.44496	0.42281	1551.0	0.4668	4.1844	0.6511	3.000	0.06624
65	5.539	0.44788	0.42262	1553.4	0.4338	4.1869	0.6561	2.768	0.06537
70	5.837	0.45162	0.42309	1554.8	0.4045	4.1897	0.6607	2.565	0.06449
75	6.128	0.45614	0.42418	1555.1	0.3784	4.1929	0.6649	2.386	0.06359
80	6.411	0.46143	0.42587	1554.4	0.3550	4.1965	0.6686	2.228	0.06268
85	6.689	0.46748	0.42812	1552.9	0.3340	4.2005	0.6721	2.088	0.06176
90	6.962	0.47429	0.43093	1550.5	0.3150	4.2050	0.6753	1.962	0.06083
95	7.233	0.48185	0.43429	1547.2	0.2979	4.2102	0.6779	1.850	0.05988
100	7.501	0.49019	0.43819	1543.1	0.2823	4.2164	0.6800	1.756	0.05892

Values mostly from Aleksandrov, A. A. and M. S. Trakhtenherz, *Thermophysical Properties of Water at Atmospheric Pressure*, Standartov, Moscow, 1977 (99 pp.).

TABLE 2-354 Thermodynamic Properties of Compressed Steam*

Temperature, K	Pressure, bar									
	0.1	0.5	1	5	10	20	40	60	80	100
350	<i>v</i> 2644 <i>s</i> 8.327	16.12 321.7 1.037	1,027.-3 231.8 1.037	1,027.-3 322.1 1.037	1,027.-3 322.5 1.037	1,026.-3 323.3 1.036	1,025.-3 324.9 1.035	1,024.-3 326.4 1.034	1,023.-3 328.1 1.032	1,023.-3 329.7 1.031
	<i>v</i> 2739 <i>s</i> 8.581	18.44 2735 7.831	3.67 1,827 7.502	1,067.-3 533.1 1,601	1,067.-3 533.4 1,600	1,066.-3 534.1 1,599	1,065.-3 535.4 1,597	1,064.-3 536.8 1,595	1,063.-3 538.2 1,593	1,061.-3 539.6 1,592
	<i>v</i> 2835 <i>s</i> 8.811	20.75 2833 8.061	4.14 2,063 7.736	0.410 1,124.-3 6.949	1,124.-3 749.0 2,110	1,123.-3 749.8 2,107	1,121.-3 750.8 2,105	1,119.-3 751.9 2,102	1,118.-3 753.0 2,099	1,116.-3 754.1 2,097
500	<i>v</i> 2932 <i>s</i> 9.012	23.07 2931 8.261	4.61 2,298 7.944	0.452 0.221 7.177	0.221 0.104 6.823	0.104 1,201.-3 6.422	1,201.-3 975.9 2,578	1,198.-3 976.3 2,575	1,196.-3 976.8 2,571	1,193.-3 977.3 2,567
	<i>v</i> 3131 <i>s</i> 9.374	27.7 3130 8.630	5.53 2,76 8.309	0.548 0.271 7.560	0.271 0.133 7.223	0.133 0,0630 6.875	0,0630 3036 6.590	0,0396 3036 6.224	0,0276 2976 5.997	0,0201 2906 5.775
	<i>v</i> 3335 <i>s</i> 9.692	32.3 3335 8.946	6.46 3,23 8.625	0.643 0.319 7.877	0.319 0.158 7.550	0.158 0,0769 7.215	0,0769 3278 6.864	0,0500 3247 6.644	0,0346 3214 6.431	0,0283 3179 6.334
800	<i>v</i> 3547 <i>s</i> 9.971	36.9 3546 9.228	7.38 3,69 8.908	0.736 0.367 8.161	0.367 0.182 7.837	0.182 0,0889 7.507	0,0889 3506 7.151	0,0589 3485 6.965	0,0436 3464 6.809	0,0343 3442 6.685
	<i>v</i> 3765 <i>s</i> 10.228	41.5 3765 9.485	8.31 4.15 9.165	0.829 0.414 8.420	0.414 0.206 8.097	0.206 0,102 7.770	0,102 3737 7.462	0,0674 3737 7.237	0,0501 3719 7.092	0,0398 3704 6.975
	<i>v</i> 3990 <i>s</i> 10.466	46.2 3990 9.723	9.23 4,615 9.402	0.921 0.460 8.659	0.460 0.229 8.336	0.229 0,114 8.011	0,114 3967 7.682	0,0758 3955 7.486	0,0564 3944 7.345	0,0449 3935 7.233
1500	<i>v</i> 5231 <i>s</i> 11.47	69.2 5228 10.77	13.9 5227 10.40	6.92 5225 9.66	1,385 5224 9.34	0.692 5221 9.015	0.341 5217 8.693	0.1730 5212 8.503	0.1153 5207 8.368	0.0865 5203 8.262
	<i>v</i> 6832 <i>s</i> 12.38	93.0 6734 11.58	18.6 6706 11.25	9.26 6662 10.48	1,850 6649 10.15	0.925 6639 9.828	0.462 6629 9.503	0.231 6623 9.313	0.1543 6619 9.178	0.1157 6616 9.073
	<i>v</i> 10417 <i>s</i> 13.95	123.7 9330 12.73	24.0 9046 12.28	11.90 8621 11.35	2.35 8504 10.80	1,171 8413 10.62	0.583 8342 10.26	0.291 8307 10.06	0.1942 8285 9.920	0.1457 8269 9.810

**v* = specific volume, m³/kg; *h* = specific enthalpy, kJ/kg; *s* = specific entropy, kJ/(kg·K). The notation 1,027.-3 signifies 1,027 × 10⁻³.

2-310 PHYSICAL AND CHEMICAL DATA

TABLE 2-354 Thermodynamic Properties of Compressed Steam (Concluded)

Temperature, K	Pressure, bar										
	150	200	250	300	400	500	600	700	800	900	1000
350	<i>v</i> <i>h</i> <i>s</i>	1.020.-3 333.7 1.028	1.018.-3 337.7 1.025	1.016.-3 341.7 1.022	1.014.-3 344.7 1.019	1.009.-3 353.8 1.013	1.005.-3 361.8 1.007	1.002.-3 369.7 1.001	9.977.-4 377.7 0.996	9.937.-4 385.7 0.991	9.900.-4 393.7 0.985
	<i>v</i> <i>h</i> <i>s</i>	1.059.-3 543.1 1.587	1.056.-3 546.5 1.583	1.053.-3 550.1 1.578	1.050.-3 553.5 1.574	1.045.-3 560.6 1.565	1.041.-3 567.8 1.557	1.035.-3 574.9 1.549	1.031.-3 582.1 1.541	1.027.-3 589.3 1.533	1.022.-3 596.5 1.526
	<i>v</i> <i>h</i> <i>s</i>	1.112.-3 756.8 2.088	1.108.-3 759.5 2.082	1.105.-3 762.3 2.076	1.101.-3 765.2 2.070	1.094.-3 771.0 2.060	1.088.-3 776.9 2.049	1.082.-3 783.0 2.039	1.076.-3 789.6 2.029	1.070.-3 795.3 2.019	1.065.-3 801.6 2.010
400	<i>v</i> <i>h</i> <i>s</i>	1.187.-3 978.8 2.558	1.181.-3 980.3 2.549	1.175.-3 981.9 2.541	1.170.-3 983.7 2.533	1.160.-3 987.4 2.517	1.151.-3 991.5 2.502	1.142.-3 995.9 2.488	1.134.-3 1000.5 2.474	1.126.-3 1005.3 2.461	1.119.-3 1010.3 2.449
	<i>v</i> <i>h</i> <i>s</i>	1.519.-3 1499 3.501	1.483.-3 1489 3.469	1.454.-3 1479 3.443	1.428.-3 1472 3.419	1.392.-3 1462 3.379	1.362.-3 1456 3.346	1.337.-3 1452 3.316	1.315.-3 1449 3.290	1.296.-3 1447 3.266	1.280.-3 1447 3.244
	<i>v</i> <i>h</i> <i>s</i>	1.724.-2 3082 6.037	1.157.-2 2965 5.770	7.986.-3 2821 5.494	5.416.-3 2635 5.179	2.630.-3 2233 4.554	2.038.-3 2084 4.308	1.831.-3 2021 4.192	1.716.-3 1986 4.116	1.639.-3 1962 4.058	1.589.-3 1946 4.012
500	<i>v</i> <i>h</i> <i>s</i>	2.195.-2 3386 6.444	1.575.-2 3325 6.252	1.201.-2 3261 6.086	9.512.-3 3193 5.934	6.391.-3 3047 5.654	4.576.-3 2895 5.397	3.496.-3 2734 5.175	2.866.-3 2648 4.998	2.484.-3 2567 4.864	2.239.-3 2508 4.761
	<i>v</i> <i>h</i> <i>s</i>	2.590.-2 3649 6.755	1.899.-2 3609 6.587	1.483.-2 3568 6.449	1.207.-2 3526 6.327	8.619.-3 3440 6.119	6.581.-3 3354 5.940	5.257.-3 3269 5.780	4.348.-3 3188 5.637	3.704.-3 3113 5.510	3.454.-3 3049 5.399
	<i>v</i> <i>h</i> <i>s</i>	2.954.-2 3904 7.023	2.186.-2 3874 6.867	1.726.-2 3845 6.741	1.420.-2 3816 6.633	1.038.-2 3756 6.453	8.102.-3 3697 6.302	6.605.-3 3640 6.172	5.557.-3 3584 6.055	4.792.-3 3532 5.951	4.212.-3 3482 5.856
600	<i>v</i> <i>h</i> <i>s</i>	0.0461 5202 8.074	0.0346 5198 7.936	0.0277 5186 7.827	0.0231 5171 7.738	0.0173 5157 7.597	0.0139 5144 7.484	0.0116 5133 7.391	0.00993 5120 7.310	0.00871 5108 7.239	0.00776 5095 7.176
	<i>v</i> <i>h</i> <i>s</i>	0.0619 6613 8.883	0.0465 6610 8.748	0.0372 6608 8.642	0.0311 6605 8.555	0.0234 6599 8.418	0.0188 6595 8.310	0.0157 6590 8.222	0.0135 6585 8.147	0.0119 6581 8.082	0.0106 6577 8.024
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.730
700	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
800	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
900	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
1000	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
1500	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
2000	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
2500	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777
	<i>v</i> <i>h</i> <i>s</i>	0.0778 8269 9.610	0.0584 8269 9.468	0.0468 8269 9.358	0.0391 8268 9.270	0.0294 8267 9.129	0.0236 8265 9.020	0.0197 8261 8.930	0.0170 8256 8.854	0.0149 8250 8.788	0.0133 8244 8.777

TABLE 2-355 Density, Specific Heats at Constant Pressure and at Constant Volume and Velocity of Sound for Compressed Water, 1–1000 bar, 0–150°C

0°C (ITS-90)					10°C (ITS-90)					20°C (ITS-90)					30°C (ITS-90)				
P, bar	density, kg/m ³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m ³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m ³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m ³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s			
1	999.702	4.1923	4.1877	1447.3	998.207	4.1812	4.1538	1482.3	995.650	4.1774	4.1148	1509.1	992.217	4.1775	4.0715	1528.9			
50	1002.03	4.174	4.168	1455	1000.44	4.166	4.137	1491	997.82	4.164	4.099	1517	994.36	4.166	4.058	1537			
100	1004.38	4.156	4.149	1464	1002.69	4.151	4.119	1499	1000.02	4.151	4.084	1526	996.52	4.154	4.044	1546			
150	1006.71	4.139	4.130	1472	1004.93	4.137	4.103	1507	1002.19	4.139	4.069	1534	998.66	4.142	4.031	1554			
200	1009.01	4.123	4.112	1480	1007.13	4.124	4.087	1516	1004.34	4.127	4.055	1543	1000.77	4.131	4.018	1563			
250	1011.28	4.108	4.095	1489	1009.32	4.110	4.071	1524	1006.47	4.115	4.041	1551	1002.87	4.121	4.005	1571			
300	1013.53	4.093	4.078	1497	1011.48	4.098	4.056	1532	1008.57	4.104	4.027	1559	1004.94	4.110	3.993	1579			
400	1017.97	4.065	4.046	1513	1015.74	4.074	4.027	1548	1012.72	4.083	4.001	1576	1009.03	4.091	3.969	1596			
500	1022.31	4.040	4.016	1529	1019.92	4.052	3.999	1565	1016.79	4.063	3.976	1592	1013.03	4.072	3.946	1612			
600	1026.57	4.018	3.988	1545	1024.02	4.032	3.974	1581	1020.79	4.044	3.952	1608	1016.97	4.055	3.924	1628			
800	1034.85	3.979	3.937	1577	1031.99	3.996	3.926	1613	1028.56	4.011	3.908	1640	1024.62	4.023	3.884	1660			
1000	1042.83	3.948	3.892	1609	1039.68	3.967	3.884	1644	1036.06	3.982	3.869	1671	1032.00	3.995	3.847	1692			

40°C (ITS-90)					50°C (ITS-90)					60°C (ITS-90)					70°C (ITS-90)				
P, bar	density, kg/m ³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m ³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m ³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m ³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s			
1	988.036	4.1799	4.0248	1542.6	983.197	4.1840	3.9755	1551.0	977.766	4.1896	3.9246	1554.8	971.791	4.1967	3.8727	1554.5			
50	990.16	4.169	4.012	1551	985.33	4.173	3.964	1560	979.92	4.179	3.915	1564	973.98	4.186	3.864	1564			
100	992.31	4.158	4.000	1560	987.48	4.163	3.953	1568	982.09	4.169	3.905	1573	976.18	4.176	3.855	1573			
150	994.44	4.147	3.988	1568	989.61	4.152	3.943	1577	984.23	4.158	3.895	1582	978.35	4.165	3.846	1582			
200	996.54	4.137	3.976	1577	991.71	4.142	3.932	1586	986.36	4.148	3.885	1590	980.51	4.155	3.838	1591			
250	998.62	4.126	3.965	1585	993.80	4.132	3.922	1594	988.46	4.139	3.876	1599	982.63	4.146	3.829	1600			
300	1000.68	4.117	3.954	1594	995.86	4.123	3.911	1603	990.53	4.129	3.867	1608	984.74	4.136	3.821	1609			
400	1004.74	4.098	3.932	1610	999.92	4.105	3.892	1620	994.62	4.111	3.849	1625	988.87	4.118	3.805	1627			
500	1008.72	4.080	3.911	1627	1003.90	4.087	3.873	1637	998.62	4.094	3.832	1642	992.92	4.101	3.789	1644			
600	1012.62	4.063	3.892	1643	1007.80	4.071	3.855	1653	1002.54	4.078	3.815	1659	996.88	4.085	3.774	1662			
800	1020.21	4.033	3.854	1676	1015.38	4.041	3.821	1686	1010.15	4.048	3.784	1693	1004.56	4.054	3.745	1696			
1000	1027.53	4.005	3.820	1707	1022.69	4.013	3.789	1718	1017.48	4.020	3.754	1726	1011.94	4.027	3.717	1730			

Prepared by H. Sato, Keio University, Japan, Oct. 1994. Based upon "An equation of state for the thermodynamic properties of water in the liquid phase including the metastable state," from Properties of Water and Steam, "Proc. 11th Int. Conf. Prop. Steam (M. Pichal and O. Sifner, eds.), Hemisphere, New York, 1990 (551 pp.).

TABLE 2-355 Density, Specific Heats at Constant Pressure and at Constant Volume and Velocity of Sound for Compressed Water, 1-1000 bar, 0-150°C (Concluded)

80°C (ITS-90)					90°C (ITS-90)				100°C (ITS-90)				110°C (ITS-90)			
P, bar	density, kg/m³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s	density, kg/m³	C _p , kJ/(kg·K)	C _v , kJ/(kg·K)	w, m/s
1	965.309	4.2056	3.8206	1550.5	958.348	4.2164	3.7689	1543.1	950.927	4.2296	3.7181	1532.5	943.059	4.2453	3.6684	1519.0
50	967.54	4.195	3.813	1560	960.64	4.205	3.762	1553	953.28	4.218	3.712	1543	945.50	4.233	3.663	1530
100	969.79	4.184	3.805	1569	962.94	4.194	3.755	1553	955.65	4.206	3.706	1553	947.95	4.221	3.657	1540
150	972.00	4.174	3.797	1579	965.21	4.184	3.748	1572	957.99	4.195	3.699	1563	950.36	4.209	3.652	1551
200	974.20	4.164	3.789	1588	967.45	4.173	3.741	1582	960.30	4.184	3.693	1573	952.74	4.198	3.646	1561
250	976.36	4.154	3.782	1597	969.67	4.163	3.734	1592	962.57	4.174	3.687	1583	955.09	4.187	3.641	1572
300	978.50	4.144	3.774	1607	971.85	4.153	3.727	1601	964.82	4.164	3.681	1593	957.40	4.176	3.635	1582
400	982.71	4.126	3.759	1625	976.15	4.135	3.714	1620	969.21	4.144	3.669	1613	961.92	4.155	3.624	1603
500	986.82	4.108	3.745	1643	980.34	4.117	3.701	1639	973.50	4.126	3.657	1632	966.32	4.136	3.613	1623
600	990.83	4.092	3.731	1661	984.43	4.100	3.688	1658	977.69	4.108	3.645	1652	970.61	4.118	3.602	1644
800	998.62	4.061	3.704	1696	992.34	4.068	3.663	1694	985.76	4.076	3.621	1690	978.87	4.084	3.579	1683
1000	1006.08	4.033	3.678	1731	999.92	4.039	3.639	1730	993.47	4.046	3.598	1727	986.73	4.053	3.556	1723

120°C (ITS-90)					130°C (ITS-90)				140°C (ITS-90)				150°C (ITS-90)			
P, bar	density, kg/m³	C _p , kJ/(kg K)	C _v , kJ/(kg K)	w, m/s	density, kg/m³	C _p , kJ/(kg K)	C _v , kJ/(kg K)	w, m/s	density, kg/m³	C _p , kJ/(kg K)	C _v , kJ/(kg K)	w, m/s	density, kg/m³	C _p , kJ/(kg K)	C _v , kJ/(kg K)	w, m/s
1	934.749	4.2639	3.6201	1502.8	925.997	4.2859	3.5733	1484.1	916.797	4.3114	3.5279	1463.0	907.143	4.3408	3.4848	1439.8
50	937.28	4.251	3.615	1514	928.64	4.271	3.569	1496	919.57	4.296	3.524	1475	910.06	4.324	3.481	1453
100	939.83	4.238	3.610	1525	931.29	4.257	3.564	1508	922.34	4.280	3.520	1488	912.97	4.307	3.477	1467
150	942.33	4.225	3.605	1536	933.90	4.244	3.560	1519	925.06	4.266	3.516	1501	915.82	4.291	3.473	1480
200	944.79	4.213	3.600	1547	936.46	4.231	3.555	1531	927.73	4.251	3.511	1513	918.61	4.276	3.469	1493
250	947.22	4.201	3.595	1558	938.97	4.218	3.550	1543	930.35	4.238	3.506	1525	921.34	4.261	3.464	1507
300	949.61	4.190	3.590	1569	941.45	4.206	3.545	1554	932.92	4.224	3.501	1538	924.03	4.246	3.459	1520
400	954.27	4.168	3.580	1591	946.28	4.183	3.535	1577	937.94	4.199	3.491	1562	929.24	4.219	3.448	1546
500	958.81	4.148	3.569	1612	950.96	4.161	3.525	1600	942.79	4.176	3.480	1586	934.27	4.194	3.436	1572
600	963.22	4.128	3.558	1634	955.51	4.140	3.514	1623	947.48	4.153	3.469	1610	939.13	4.169	3.423	1598
800	971.68	4.092	3.536	1676	964.20	4.101	3.491	1667	956.43	4.112	3.444	1658	948.36	4.124	3.395	1648
1000	979.72	4.059	3.512	1717	972.44	4.066	3.466	1710	964.88	4.073	3.417	1704	957.04	4.081	3.364	1698

TABLE 2-356 Specific Heat and Other Thermophysical Properties of Water Substance*

Pressure, bar	Temperature, K																
	300	350	400	450	500	600	700	800	900	1000	1200	1400	1600	1800	2000		
1 μ	8.57.-4	3.70.-4	1.32.-5	1.52.-5	1.73.-5	2.15.-5	2.57.-5	2.98.-5	3.39.-5	3.78.-5	4.48.-5	5.06.-5	5.65.-5	6.19.-5	6.70.-5		
	4.18	4.19	1.99	1.97	1.98	2.02	2.09	2.15	2.22	2.29	2.43	2.58	2.73	3.02	3.79		
	0.614	0.668	0.0268	0.0311	0.0358	0.0464	0.0581	0.0710	0.0843	0.0981	0.13	0.16	0.21	0.33	0.57		
5 μ	8.57.-4	3.70.-4	2.17.-4	1.49.-5	1.72.-5	2.15.-5	2.57.-5	2.98.-5	3.39.-5	3.78.-5	4.45.-5	5.06.-5	5.65.-5	6.19.-5	6.70.-5		
	4.18	4.19	4.26	2.21	2.10	2.07	2.11	2.16	2.23	2.29	2.43	2.58	2.73	2.98	3.40		
	0.614	0.668	0.689	0.0335	0.0369	0.0469	0.0585	0.0713	0.0846	0.0984	0.13	0.16	0.20	0.28	0.43		
10 μ	8.57.-4	3.70.-4	2.17.-4	1.51.-4	1.71.-5	2.15.-5	2.58.-5	2.99.-5	3.39.-5	3.78.-5	4.45.-5	5.06.-5	5.65.-5	6.19.-5	6.70.-5		
	4.18	4.19	4.25	4.39	2.29	2.13	2.13	2.18	2.24	2.30	2.44	2.58	2.73	2.95	3.29		
	0.615	0.668	0.689	0.677	0.0380	0.0474	0.0590	0.0717	0.0851	0.0988	0.13	0.16	0.20	0.26	0.39		
20 μ	8.56.-4	3.71.-4	2.18.-4	1.51.-4	1.68.-5	2.15.-5	2.59.-5	3.00.-5	3.40.-5	3.79.-5	4.46.-5	5.06.-5	5.65.-5	6.19.-5	6.70.-5		
	4.17	4.19	4.25	4.39	2.84	2.26	2.19	2.21	2.26	2.32	2.45	2.59	2.73	2.92	3.21		
	0.616	0.669	0.689	0.679	0.0402	0.0485	0.0599	0.0726	0.0859	0.0996	0.13	0.16	0.20	0.25	0.36		
40 μ	8.55.-4	3.71.-4	2.18.-4	1.52.-4	1.19.-4	2.15.-5	2.61.-5	3.02.-5	3.42.-5	3.80.-5	4.47.-5	5.07.-5	5.65.-5	6.19.-5	6.70.-5		
	4.17	4.19	4.25	4.38	4.65	2.60	2.32	2.28	2.30	2.34	2.46	2.59	2.73	2.90	3.14		
	0.617	0.671	0.690	0.680	0.644	0.516	0.0620	0.0744	0.0877	0.101	0.13	0.16	0.19	0.24	0.33		
60 μ	8.54.-4	3.72.-4	2.19.-4	1.53.-4	1.20.-4	2.14.-5	2.63.-5	3.04.-5	3.43.-5	3.82.-5	4.48.-5	5.07.-5	5.66.-5	6.19.-5	6.70.-5		
	4.16	4.18	4.24	4.37	4.63	3.11	2.47	2.35	2.34	2.37	2.48	2.60	2.73	2.89	3.11		
	0.619	0.672	0.692	0.682	0.646	0.0561	0.0645	0.0764	0.0895	0.103	0.13	0.16	0.19	0.24	0.32		
80 μ	8.53.-4	3.72.-4	2.19.-4	1.53.-4	1.20.-4	2.14.-5	2.66.-5	3.06.-5	3.45.-5	3.83.-5	4.48.-5	5.08.-5	5.66.-5	6.19.-5	6.70.-5		
	4.16	4.18	4.24	4.36	4.62	3.88	2.65	2.43	2.39	2.40	2.49	2.61	2.73	2.88	3.09		
	0.620	0.674	0.693	0.684	0.648	0.0628	0.0672	0.0785	0.0914	0.105	0.13	0.16	0.19	0.24	0.31		
100 μ	8.52.-4	3.73.-4	2.20.-4	1.53.-4	1.21.-4	2.14.-5	2.69.-5	3.08.-5	3.47.-5	3.85.-5	4.49.-5	5.08.-5	5.66.-5	6.19.-5	6.70.-5		
	4.15	4.17	4.23	4.35	4.60	5.22	2.85	2.52	2.44	2.44	2.50	2.62	2.73	2.88	3.08		
	0.622	0.675	0.694	0.685	0.651	0.0730	0.0704	0.0807	0.0934	0.107	0.13	0.16	0.19	0.24	0.31		
150 μ	8.51.-4	3.74.-4	2.22.-4	1.56.-4	1.22.-4	8.22.-5	2.72.-5	3.12.-5	3.51.-5	3.89.-5	4.52.-5	5.09.-5	5.67.-5	6.19.-5	6.70.-5		
	4.14	4.16	4.22	4.34	4.54	3.55	2.74	2.57	2.53	2.53	2.54	2.65	2.75	2.88	3.06		
	0.624	0.678	0.699	0.693	0.657	0.520	0.079	0.086	0.098	0.110	0.14	0.16	0.19	0.23	0.30		
200 μ	8.50.-4	3.75.-4	2.24.-4	1.57.-4	1.23.-4	8.32.-5	2.80.-5	3.17.-5	3.54.-5	3.93.-5	4.54.-5	5.11.-5	5.67.-5	6.19.-5	6.70.-5		
	4.12	4.15	4.21	4.32	4.51	4.67	3.04	2.71	2.62	2.57	2.67	2.76	2.88	3.05	3.05		
	0.626	0.681	0.702	0.697	0.661	0.525	0.095	0.095	0.104	0.113	0.14	0.16	0.19	0.24	0.30		
250 μ	8.49.-4	3.76.-4	2.26.-4	1.59.-4	1.23.-4	8.41.-5	2.89.-5	3.24.-5	3.59.-5	3.98.-5	4.56.-5	5.12.-5	5.68.-5	6.19.-5	6.70.-5		
	4.12	4.14	4.20	4.30	4.49	5.90	6.16	3.40	2.86	2.71	2.61	2.69	2.77	2.89	3.04		
	0.627	0.683	0.705	0.701	0.672	0.537	0.112	0.103	0.110	0.119	0.136	0.16	0.19	0.24	0.30		
300 μ	8.49.-4	3.77.-4	2.28.-4	1.60.-4	1.24.-4	8.50.-5	3.7.-5	3.4.-5	3.64.-5	4.02.-5	4.59.-5	5.14.-5	5.68.-5	6.19.-5	6.70.-5		
	4.10	4.13	4.19	4.29	4.44	5.60	10.20	3.82	3.03	2.81	2.65	2.72	2.78	2.90	3.04		
	0.629	0.685	0.708	0.704	0.675	0.548	0.173	0.113	0.113	0.123	0.14	0.16	0.19	0.24	0.30		
400 μ	8.49.-4	3.80.-4	2.30.-4	1.62.-4	1.26.-4	8.64.-5	5.3.-5	3.6.-5	3.8.-5	4.1.-5	4.6.-5	5.17.-5	5.78	2.81	2.91	3.04	
	4.08	4.12	4.16	4.26	4.42	5.31	13.20	4.86	3.39	3.01	2.70	2.77	2.81	2.91	3.04		
	0.631	0.689	0.714	0.710	0.676	0.567	0.327	0.145	0.129	0.134	0.15	0.17	0.19	0.24	0.30		
500 μ	8.50.-4	3.82.-4	2.31.-4	1.64.-4	1.28.-4	8.83.-5	5.8.-5	4.0.-5	4.0.-5	4.2.-5	4.7.-5	5.17.-5	5.77	2.81	2.84	2.92	3.04
	4.06	4.10	4.15	4.23	4.38	5.08	8.44	5.70	3.90	3.21	2.77	2.77	2.81	2.84	2.92	3.04	
	0.634	0.695	0.719	0.717	0.693	0.583	0.378	0.186	0.147	0.145	0.16	0.18	0.19	0.24	0.30		

TABLE 2-356 Specific Heat and Other Thermophysical Properties of Water Substance (Concluded)

Pressure, bar	μ	Temperature, K														
		300	350	400	450	500	600	700	800	900	1000	1200	1400	1600	1800	2000
600	c_p	8.51-4	3.85-4	2.32-4	1.66-4	1.30-4	9.17-5	6.5-5	4.4-5	4.2-5	4.4-5	2.87	2.86	2.86	2.92	3.04
	k	4.04	4.08	4.13	4.20	4.33	4.92	6.93	6.83	4.19	3.38					
	c_p/k	0.639	0.699	0.725	0.725	0.700	0.597	0.420	0.239	0.170	0.159					
	Pr	5.38	2.24	1.32	0.970	0.812	0.755	1.073	1.175	1.035	0.935					
700	c_p	8.52-4	3.87-4	2.33-4	1.69-4	1.33-4	9.50-5	6.9-5	4.9-5	4.5-5	4.6-5	2.94	2.91	2.88	2.93	3.05
	k	4.01	4.07	4.12	4.17	4.29	4.78	6.12	6.26	4.62	3.59					
	c_p/k	0.644	0.706	0.730	0.732	0.707	0.614	0.442	0.279	0.198	0.177					
	Pr	5.33	2.23	1.32	0.970	0.810	0.739	1.047	1.098	1.010	0.935					
800	c_p	8.53-4	3.90-4	2.34-4	1.72-4	1.36-4	9.82-5	7.3-5	5.4-5	4.8-5	4.8-5	3.01	2.96	2.91	2.95	3.05
	k	3.99	4.05	4.10	4.15	4.26	4.67	5.60	6.09	4.77	3.75					
	c_p/k	0.648	0.709	0.735	0.736	0.714	0.625	0.478	0.320	0.228	0.193					
	Pr	5.28	2.23	1.31	0.970	0.808	0.725	0.855	1.028	1.003	0.933					
900	c_p	8.54-4	3.93-4	2.35-4	1.74-4	1.38-4	1.00-4	7.6-5	5.8-5	5.1-5	5.0-5	3.08	3.00	2.94	2.97	3.06
	k	3.98	4.03	4.08	4.13	4.23	4.57	5.29	5.86	4.85	3.86					
	c_p/k	0.651	0.713	0.738	0.742	0.724	0.636	0.496	0.351	0.260	0.210					
	Pr	5.23	2.22	1.30	0.969	0.806	0.712	0.810	0.968	0.950	0.919					
1000	c_p	8.56-4	3.96-4	2.36-4	1.76-4	1.40-4	1.02-4	7.9-5	6.2-5	5.4-5	5.1-5	3.16	3.05	2.97	2.98	3.07
	k	3.97	4.02	4.06	4.11	4.20	4.47	5.08	5.51	4.88	3.96					
	c_p/k	0.653	0.717	0.743	0.747	0.731	0.650	0.516	0.372	0.288	0.228					
	Pr	5.19	2.22	1.30	0.968	0.804	0.701	0.778	0.918	0.900	0.886					

* μ = viscosity, Ns/m²; c_p = specific heat at constant pressure, kJ/(kg·K); k = thermal conductivity, W/(m·K); Pr = Prandtl number.

TABLE 2-357 Thermodynamic Properties of Water Substance along the Melting Line

P , bar	T , °C	$10^3 v_f$, m ³ /kg	h_f , kJ/kg	s_f , kJ/kg·K	c_{pf} , kJ/kg·K	c_{melt} , kJ/kg·K	$10^6 \alpha_f$, K ⁻¹	$10^6 K_{f,T}$ bar ⁻¹
6.117.-5 ^t	0.0100	1.00021	0	0	4.219	3.969	-67.42	50.90
1.01325	0.0026	1.00016	0.0719	-0.0001	4.218	3.970	-67.17	50.88
50	-0.3618	0.99770	3.5140	-0.0054	4.196	3.997	-54.92	50.30
100	-0.7410	0.99523	6.9794	-0.0110	4.174	4.023	-42.52	49.73
150	-1.1249	0.99278	10.3964	-0.0167	4.152	4.047	-30.24	49.17
200	-1.5166	0.99037	13.7648	-0.0225	4.132	4.070	-18.05	48.63
250	-1.9151	0.98798	17.0843	-0.0285	4.112	4.092	-5.93	48.11
300	-2.3206	0.98562	20.3547	-0.0347	4.092	4.113	6.12	47.59
400	-3.1532	0.98098	26.7472	-0.0474	4.056	4.150	30.09	46.61
500	-4.0156	0.97643	32.9403	-0.0607	4.022	4.184	53.97	45.68
600	-4.909	0.97196	38.932	-0.0747	3.992	4.215	77.87	44.80
800	-6.790	0.96326	50.300	-0.1046	3.937	4.270	126.18	43.19
1000	-8.803	0.95493	60.836	-0.1371	3.893	4.320	175.98	41.74

Condensed from U. Grigull, Private communication, January 18, 1995.

Materials prepared at Technical University München, Germany by U. Grigull and S. Marek. For a table as a function of temperature, see Grigull, U. and S. Marek, *Wärme u. Stoff*, **30** (1994): 1-8.

t = the triple point (at 6.117×10^{-5} bar, 0.01°C); $v_f = 0.0010021 \text{ m}^3/\text{kg}$; $\alpha_f = -67.42 \times 10^{-6}/\text{K}$.

Other equations for properties are given by Jones, F. E. and G. L. Harris, *J. Res. N.I.S.T.*, **97**, 3 (1992): 335-340, and by Wagner, W. and A. Pruss, *J. Phys. Chem. Ref. Data*, **22**, 3 (1993): 783-787. Steam tables include Walker, W. A., U.S. Naval Ordin. Lab. rept. NOLTR-66-217 = AD 651105 (0-1000 bar, 0-150°C), 1967 (72 pp.); Grigull, U., J. Straub, et al., *Steam Tables in S.I. Units* (0.01-1000 bar, 0-1000°C), Springer-Verlag, Berlin, 1990 (133 pp.); Tseng, C. M., T. A. Hamp, et al., Atomic Energy of Canada rept. (30 props, sat liq & vap., 1-220 bar), AECL-5910 1977 (90 pp.). For dissociation, see e.g., Kronicek, V., *Rozpr. Cesko Acad Ved, Ráda techn. ved* (0.01-100 bar, 1000-5000 K), **77**, 1 (1967). The proceedings of the 10th international conference on the properties of steam were edited by Sytchev, V. V. and A. A. Aleksandrov, Plenum, NY, 1984; and for the 11th conference by Pichal, M. and O. Sifner, Hemisphere, 1989 (550 pp.).

For electrical conductivity, see e.g., Marshall, W. L., *J. Chem. Eng. Data*, **32** (1987): 221-226.

TABLE 2-358 Saturated Xenon*

T , K	P , bar	v_f , m ³ /kg	v_g , m ³ /kg	h_f , kJ/kg	h_g , kJ/kg	s_f , kJ/(kg·K)	s_g , kJ/(kg·K)	c_{pf} , kJ/(kg·K)	μ_f , 10 ⁻⁴ Pa·s	k_f , W/(m·K)
10		2.642.-4		0.19		0.0236		0.058		
20		2.650.-4		1.21		0.0901		0.133		
30		2.661.-4		2.74		0.1510		0.164		
40		2.675.-4		4.47		0.2003		0.178		
50		2.689.-4		6.31		0.2410		0.186		
60		2.704.-4		8.21		0.2755		0.191		
80		2.737.-4		12.14		0.3319		0.202		
100		2.776.-4		16.30		0.3783		0.214		
120		2.820.-4		20.81		0.4197		0.231		
140		2.874.-4		25.67		0.4581		0.251		
160		2.941.-4		30.94		0.4946		0.270		
161.4 ^m	0.816	2.946.-4		31.30		0.4969		0.271		
161.4 ^m	1.336	3.372.-4	0.1219	48.98	145.5	0.6072	1.206	0.350		
170	2.218	3.439.-4	0.0776	52.01	146.5	0.6253	1.181	0.349	4.50	0.0707
		3.523.-4	0.0487	55.52	147.5	0.6452	1.156	0.349	3.99	0.0663
190	3.480	3.615.-4	0.0321	59.04	148.3	0.6641	1.134	0.352	3.51	0.0622
200	5.212	3.715.-4	0.0220	62.61	148.9	0.6820	1.113	0.357	3.09	0.0582
210	7.504	3.828.-4	0.0156	66.25	149.2	0.6994	1.095	0.365	2.71	0.0542
220	10.45	3.955.-4	0.0113	70.00	149.4	0.7163	1.077	0.379	2.39	0.0506
230	14.16	4.100.-4	0.0084	73.91	149.2	0.7330	1.060	0.400	2.09	0.0468
240	18.72	4.271.-4	0.0063	78.05	148.5	0.7498	1.044	0.432	1.83	0.0429
250	24.25	4.476.-4	0.0047	82.54	147.5	0.7671	1.027	0.482	1.60	0.0393
260	30.87	4.730.-4	0.0036	87.52	145.7	0.7855	1.009	0.560	1.38	0.0355
270	38.69	5.079.-4	0.0027	93.30	142.8	0.8058	0.989	0.685	1.18	0.0313
280	47.86	5.689.-4	0.0019	100.6	138.0	0.8308	0.964	0.995	0.95	0.0275
289.7 ^c	58.21	9.091.-4	0.0009	120.0	120.0	0.8962	0.896	∞	∞	

*Values extracted and in some cases rounded off from those cited in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, Standards Press, Moscow, 1976. This source contains values for the compressed state for pressures up to 1000 bar, etc. m = melting point; c = critical point. The notation 2.642.-4 signifies 2.642×10^{-4} . This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

2-316 PHYSICAL AND CHEMICAL DATA
TABLE 2-359 Compressed Xenon*

T, K	Pressure, bar										
	1	100	200	300	400	500	600	700	800	900	1000
100 <i>v</i> <i>h</i> <i>s</i>	2.776.-4	2.764.-4	2.752.-4	2.742.-4	2.731.-4	2.721.-4	2.711.-4	2.702.-4	2.693.-4	2.684.-4	2.675.-4
	16.30	18.84	21.40	23.95	26.50	29.05	31.59	34.13	36.67	39.21	41.74
	0.3783	0.3762	0.3742	0.3723	0.3704	0.3686	0.3669	0.3652	0.3636	0.3621	0.3802
200 <i>v</i> <i>h</i> <i>s</i>	0.1245	3.623.-4	3.547.-4	3.484.-4	3.430.-4	3.383.-4	3.342.-4	3.304.-4	3.270.-4	3.240.-4	3.211.-4
	151.8	64.22	66.14	68.19	70.34	72.56	74.83	77.13	79.46	81.81	84.18
	1.228	0.6727	0.6643	0.6570	0.6505	0.6446	0.6391	0.6340	0.6292	0.6247	0.6204
300 <i>v</i> <i>h</i> <i>s</i>	0.1890	5.729.-4	4.769.-4	4.431.-4	4.220.-4	4.068.-4	3.955.-4	3.862.-4	3.783.-4	3.716.-4	3.657.-4
	168.0	106.4	101.6	101.3	102.0	103.3	104.9	106.7	108.5	110.6	112.8
	1.294	0.8401	0.8073	0.7908	0.7789	0.7691	0.7608	0.7540	0.7477	0.7424	0.7370
400 <i>v</i> <i>h</i> <i>s</i>	0.2527	1.998.-3	8.759.-4	6.452.-4	5.604.-4	5.141.-4	4.839.-4	4.622.-4	4.457.-4	4.325.-4	4.217.-4
	183.9	164.2	145.4	137.4	134.7	134.1	134.5	135.5	136.8	138.3	140.0
	1.340	1.012	0.9330	0.8945	0.8730	0.8581	0.8467	0.8373	0.8292	0.8220	0.8162
500 <i>v</i> <i>h</i> <i>s</i>	0.3163	2.899.-3	1.389.-3	9.449.-4	7.577.-4	6.593.-4	5.986.-4	5.570.-4	5.268.-4	5.038.-4	4.859.-4
	199.8	187.8	177.1	169.4	165.1	163.0	162.3	162.4	163.1	164.3	165.7
	1.375	1.065	1.004	0.9664	0.9409	0.9228	0.9088	0.8975	0.8881	0.8801	0.8731
600 <i>v</i> <i>h</i> <i>s</i>	0.3798	3.673.-3	1.823.-3	1.240.-3	9.699.-4	8.206.-4	7.273.-4	6.636.-4	6.172.-4	5.820.-4	5.545.-4
	215.7	207.4	200.3	194.8	191.1	188.9	187.9	187.6	188.0	188.8	189.9
	1.404	1.101	1.047	1.013	0.9885	0.9700	0.9555	0.9435	0.9334	0.9247	0.9172
700 <i>v</i> <i>h</i> <i>s</i>	0.4432	4.397.-3	2.217.-3	1.513.-3	1.175.-3	9.815.-4	8.583.-4	7.734.-4	7.115.-4	6.642.-4	6.268.-4
	231.5	225.6	220.6	216.7	213.8	212.2	211.3	211.1	211.3	212.0	213.1
	1.428	1.129	1.078	1.047	1.023	1.006	0.9916	0.9797	0.9695	0.9606	0.9528
800 <i>v</i> <i>h</i> <i>s</i>	0.5066	5.093.-3	2.587.-3	1.769.-3	1.370.-3	1.137.-3	9.870.-4	8.824.-4	8.057.-4	7.469.-4	7.005.-4
	247.4	243.0	239.5	236.7	234.8	233.6	233.0	232.9	233.3	234.0	235.0
	1.450	1.152	1.103	1.073	1.052	1.035	1.021	1.009	0.9988	0.9901	0.9823
900 <i>v</i> <i>h</i> <i>s</i>	0.5700	5.773.-3	2.944.-3	2.014.-3	1.557.-3	1.288.-3	1.112.-3	9.893.-4	8.989.-4	8.289.-4	7.737.-4
	263.2	260.1	257.5	255.7	254.4	253.6	253.4	253.7	254.2	254.9	256.1
	1.468	1.172	1.125	1.096	1.075	1.058	1.045	1.033	1.023	1.015	1.007
1000 <i>v</i> <i>h</i> <i>s</i>	0.6333	6.441.-3	3.291.-3	2.252.-3	1.738.-3	1.435.-3	1.235.-3	1.094.-3	9.899.-4	9.097.-4	8.461.-4
	279.1	276.8	275.1	273.9	273.2	272.9	273.0	273.4	274.1	275.1	276.2
	1.485	1.190	1.143	1.115	1.095	1.079	1.065	1.054	1.044	1.036	1.028

*Values extracted and in some cases rounded off from those cited in Rabinovich (ed.), *Thermophysical Properties of Neon, Argon, Krypton and Xenon*. Standards Press, Moscow, 1976. This source contains an exhaustive tabulation of values. *v* = specific volume, m³/kg; *h* = specific enthalpy, kJ/kg; *s* = specific entropy, kJ/(kg·K). The notation 2.776.-4 signifies 2.776 × 10⁻⁴. This book was published in English translation by Hemisphere, New York, 1988 (604 pp.).

TABLE 2-360 Surface Tension (N/m) of Saturated Liquid Refrigerants*

R no.	Temperature, °C								
	-50	-25	0	25	50	75	100	125	150
11	0.0279	0.0244	0.0210	0.0178	0.0146	0.0116	0.0087	0.0060	0.0036
12	0.0188	0.0152	0.0118	0.0085	0.0055	0.0029	0.0007	—	—
13	0.0092	0.0056	0.0025	0.0002	—	—	—	—	—
22	0.0197	0.0156	0.0117	0.0081	0.0047	0.0018	—	—	—
23	0.0115	0.0065	0.0025	—	—	—	—	—	—
32	—	—	—	0.0069	0.0032	0.0002	—	—	—
113	—	0.0231	0.0201	0.0172	0.0144	0.0118	0.0092	0.0067	0.0045
114	—	—	0.0138	0.0109	0.0082	0.0056	0.0033	0.0012	—
115	—	—	0.0075	0.0047	0.0022	—	—	—	—
134a	0.0192	0.0154	0.0117	0.0082	0.0050	0.0021	0.0000	—	—
142b	0.0213	0.0178	0.0145	0.0113	0.0083	0.0055	0.0029	—	—
152a	0.0201	0.0166	0.0132	0.0100	0.0068	0.0038	0.0011	—	—
170	0.0100	0.0051	0.0032	0.0005	—	—	—	—	—
290	—	—	0.0101	0.0082	0.0041	0.0016	—	—	—
C318	—	0.0143	0.0113	0.0085	0.0048	0.0033	0.0011	—	—
502	0.0159	0.0121	0.0086	0.0054	0.0026	—	—	—	—
503	0.0094	0.0053	0.0018	—	—	—	—	—	—
600	—	0.0180	0.0150	0.0122	0.0094	0.0068	0.0043	0.0020	0.0001
600a	—	—	0.0132	0.0101	0.0073	0.0047	0.0024	0.0005	—
718	—	—	0.0755	0.0720	0.0680	0.0636	0.0590	0.0540	0.0488
744	—	0.0096	0.0044	0.0005	—	—	—	—	—
1150	0.0100	0.0055	0.0013	—	—	—	—	—	—
1270	0.0171	0.0136	0.0102	0.0070	0.0041	0.0014	—	—	—

*Dashes indicate inaccessible states; blanks indicate no available data.

Values and equations were given by Srinivasan, K., *Can. J. Chem. Eng.* (27 liquids), **68** (1990): 493; Lielmezs, J. and T. A. Herrick, *Chem. Eng. J.* (34 liquids), **32** (1986): 165–169; Somayajulu, G. R., *Int. J. Thermophys.* (64 liquids), **9**, 4 (1988): 559–566; Ibrahim, N. and S. Murad, *Chem. Eng. Commun.* (29 polar liquids), **79** (1979): 165–174; Yaws, C. L.; Morachevsky, A. G. and I. B. Sladkov, *Physico-Chemical Properties of Molecular Inorganic Compounds* (200 compounds), Khimiya, Leningrad, 1987; Jasper, J., *J. Phys. Chem. Ref. Data* (2200 compounds), **1**, (1972): 841–1009; and Vargaftik, N. B., B. N. Volkov, et al., *J. Phys. Chem. Ref. Data* (water), **12**, 3 (1983): 817–820. See also Escobedo, J. and Mansoori, G. R., *AICHE J.*, **42**(5), May 1996: 1425–1433.

TABLE 2-361 Velocity of Sound (m/s) in Gaseous Refrigerants at Atmospheric Pressure*

R. no.	Temperature, °C								
	-50	-25	0	25	50	75	100	125	150
11	—	—	—	141	147	153	158	163	168
12	—	136	143	150	156	162	168	173	179
13	142	150	157	164	170	176	182	188	193
14	158	166	173	180	187	194	200	206	212
22	—	166	174	182	189	196	202	208	215
23	179	188	197	205	212	220	227	234	240
32	—	—	—	—	121	126	131	135	140
113	—	—	—	120	126	131	136	141	146
114	—	—	146	154	162	169	175	180	186
134a	—	—	—	—	—	—	—	—	192
170	272	286	299	311	323	334	344	355	364
290	—	227	238	249	258	268	277	286	294
600	—	—	200	210	220	228	237	245	252
600a	—	—	201	211	221	229	237	246	253
718	—	—	—	—	—	—	473	490	505
744	—	248	258	269	279	288	297	307	316
1150	290	305	318	330	341	352	363	373	384
1270	—	235	246	257	267	277	286	295	303

*Dashes indicate inaccessible states; blanks indicate no available data.

TABLE 3-362 Velocity of Sound (m/s) in Saturated Liquid Refrigerants*

R. no.	Temperature, °C								
	-50	-25	0	25	50	75	100	125	150
11	933	843	772	705	639	569	493	408	323
12	829	695	564	434	—	—	—	—	—
13	602	444	302	—	—	—	—	—	—
14	182	—	—	—	—	—	—	—	—
22	899	790	682	571	446	319	—	—	—
23	—	538	348	191	—	—	—	—	—
32	—	—	—	—	—	—	—	—	—
113	—	871	786	700	633	—	—	—	—
114	853	726	623	540	453	371	284	183	—
115	—	—	454	346	255	—	—	—	—
134a	858	743	626	517	387	262	105	—	—
290	1210	982	884	719	551	367	—	—	—
600	1290	1163	1031	896	759	609	477	325	142
600a	1205	1078	947	812	661	528	378	208	—
718	—	—	1402	1495	1542	1554	1543	1514	1468
744	—	751	525	272	—	—	—	—	—
1150	874	644	372	—	—	—	—	—	—
1270	1184	1022	859	694	524	335	—	—	—

*Dashes indicate inaccessible states; blanks indicate no available data.

TRANSPORT PROPERTIES

INTRODUCTION

Extensive tables of the viscosity and thermal conductivity of air and of water or steam for various pressures and temperatures are given with the thermodynamic-property tables. The thermal conductivity and the viscosity for the saturated-liquid state are also tabulated for many fluids along with the thermodynamic-property tables earlier in this section.

UNITS CONVERSIONS

For this subsection the following units conversions are applicable:

Diffusivity: to convert square centimeters per second to square feet per hour, multiply by 3.8750; to convert square meters per second to square feet per hour, multiply by 38,750.

Pressure: to convert bars to pounds-force per square inch, multiply by 14.504.

Temperature: $^{\circ}\text{F} = \frac{9}{5}^{\circ}\text{C} + 32$; $^{\circ}\text{R} = \frac{9}{5}^{\circ}\text{K}$.

Thermal conductivity: to convert watts per meter-kelvin to British thermal unit-feet per hour-square foot-degree Fahrenheit, multiply by 0.57779; and to convert British thermal unit-feet per hour-square foot-degree Fahrenheit to watts per meter-kelvin, multiply by 1.7307.

Viscosity: to convert pascal-seconds to centipoises, multiply by 1000.

ADDITIONAL REFERENCES

An extensive coverage of the general pressure and temperature variation of thermal conductivity is given in the monograph by Vargaftik,

Filippov, Tarzimanov, and Totskiy, *Thermal Conductivity of Liquids and Gases* (in Russian), Standartov, Moscow, 1978, now published in English translation by CRC Press, Miami, FL.

For a similar work on viscosity, see Stephan and Lucas, *Viscosity of Dense Fluids*, Plenum, New York and London, 1979. Tables and polynomial fits for refrigerants in both the gaseous and the liquid state are contained in *ASHRAE Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating and Ventilating Engineers, Atlanta, GA, 1993. Other sources for viscosity include Fischer & Porter Co. catalog 10-A-94, "Fluid densities and viscosities," 1953 (200 industrial fluids in 48 pp.) and van Velzen, D., R. L. Cardozo et al., EURATOM Ispra, Italy rept. 4735 e, 1972 (160 pp.). Liquid viscosity, 314 cpds, is summarized in *I&EC Fundtts.*, 11 (1972): 20-26. Five hundred forty-nine binary and ternary systems are discussed in Skubla, P., *Coll. Czech. Chem. Commun.*, **46** (1981): 303-339.

See also Duhne, C. R., *Chem. Eng. (NY)*, **86**, 15 (July 16, 1979): 83-91 (equations and 326 liquids); and Rao, K. V. K., *Chem. Eng. (NY)*, **90**, 11 (May 30, 1983): 90-91 (nomograph, 87 liquids). For rheology, non-Newtonian behavior, and the like, see, for instance, Barnes, H., *The Chem. Engr. (UK)*, (June 24, 1993): 17-23; Hyman, W. A., *I&EC Fundtts.*, **16** (1976): 215-218; and Ferguson, J. and Z. Kemblowski, *Applied Fluid Rheology*, Elsevier, 1991 (325 pp.). Other sources for thermal conductivity include Ho, C. Y., R. W. Powell et al., *J. Phys. Chem. Ref. Data*, **1** (1972) and **3**, suppl. 1 (1974); Childs, Ericks et al., N.B.S. Monogr. 131, 1973; Jamieson, D. T., J. B. Irving et al., *Liquid Thermal Conductivity*, H.M.S.O., Edinburgh, Scotland, 1975 (220 pp.).

TABLE 2-363 Transport Properties of Selected Gases at Atmospheric Pressure*

Substance	Thermal conductivity, W/(m·K) Temperature, K					Viscosity, 10^{-4} Pa·s Temperature, K					Prandtl number, dimensionless Temperature, K				
	250	300	400	500	600	250	300	400	500	600	250	300	400	500	
Acetone	0.0080	0.0115	0.0201	0.0310		0.077	0.101	0.128	0.156						
Acetylene	0.0162	0.0213	0.0332	0.0452	0.0561	0.104	0.135	0.164							
Ammonia	0.0197	0.0246	0.0364	0.0506	0.0656	0.085	0.102	0.139	0.175	0.211	0.91	0.87	0.86		
Argon	0.0152	0.0177	0.0223	0.0264	0.0301	0.195	0.229	0.289	0.343	0.390	0.669	0.668	0.666	0.663	
Benzene	0.0077	0.0104	0.0195	0.0335	0.0524	0.076	0.101	0.127	0.154						
Bromine	0.0038	0.0048	0.0067			0.203	0.260	0.291							
Butane	0.0117	0.0160	0.0264	0.0377		0.076	0.101	0.125	0.151		0.805	0.820			
CO_2	0.0129	0.0166	0.0244	0.0323	0.0403	0.126	0.150	0.196	0.239	0.278	0.793	0.778	0.752	0.734	
CCl_4	0.0053	0.0067	0.0099	0.0126		0.101	0.131	0.162	0.191						
Chlorine	0.0071	0.0089	0.0124	0.0156	0.0190	0.136	0.178	0.218	0.259						
Deuterium	0.122	0.141	0.176			0.111	0.126	0.153	0.178	0.201					
Ethane	0.0156	0.0218	0.0360	0.0516	0.0685	0.079	0.094	0.123	0.148	0.171	0.817	0.773	0.746	0.746	
Ethylene	0.0152	0.0214	0.0342	0.0491	0.0653	0.087	0.103	0.135	0.162	0.187	0.812	0.796	0.769	0.750	
Helium	0.134	0.150	0.180	0.211	0.247	0.176	0.199	0.243	0.284	0.322	0.671	0.668	0.663	0.661	
Heptane	0.0082	0.0120	0.0214	0.0325	0.0447	0.080	0.099	0.116							
Hydrogen	0.156	0.182	0.221	0.256	0.291	0.080	0.090	0.109	0.126	0.143	0.71	0.71	0.71	0.71	
Methane	0.0277	0.0343	0.0484	0.0671	0.0948	0.095	0.112	0.142	0.170	0.195	0.742	0.739	0.737	0.736	
Nitrogen	0.0222	0.0260	0.0325	0.0386	0.0441	0.156	0.180	0.223	0.261	0.295	0.721	0.714	0.708	0.707	
Oxygen	0.0225	0.0267	0.0343	0.0412	0.0480	0.179	0.207	0.258	0.306	0.348					
Pentane	0.0107	0.0152	0.0250	0.0362											
Propane	0.0129	0.0183	0.0295	0.0417		0.069	0.082	0.108	0.131		0.810	0.774	0.788	0.826	
Propylene	0.0114	0.0168	0.0226	0.0430	0.0580	0.073	0.087	0.115	0.141		0.860	0.797	0.762		
R 11		0.0078	0.0119			0.094	0.110	0.144				0.814	0.761		
R 12	0.0072	0.0097	0.0151	0.0208		0.108	0.126	0.162			0.827	0.781	0.745	0.708	
R 13	0.0091	0.0121	0.0185	0.0248		0.123	0.145	0.190			0.796	0.766	0.759	0.757	
R 21		0.0088	0.0135	0.0181		0.100	0.115	0.154				0.779	0.773		
R 22	0.0080	0.0109	0.0170	0.0230	0.0290	0.109	0.129	0.168			0.820	0.771	0.760		
SO_2	0.0078	0.0096	0.0143	0.0200	0.0256	0.129	0.175	0.217	0.256						

*An approximate interpolation scheme is to plot the logarithm of the viscosity or the thermal conductivity versus the logarithm of the absolute temperature. At 250 K the viscosity of gaseous argon is to be read as 1.95×10^{-5} Pa·s = 0.0000195 Ns/m².

TABLE 2-364 Viscosities of Gases: Coordinates for Use with Fig. 2-32*

Gas	X	Y	$\mu \times 10^7 p$	Ref.	Gas	X	Y	$\mu \times 10^7 p$	Ref.
Acetic acid	7.0	14.6	825 (50°C)	1	Hydrogen-sulfur dioxide	8.7	18.1	1259 (17)	4
Acetone	8.4	13.2	735	1	10% H ₂ , 90% SO ₂	8.6	18.2	1277 (17)	
Acetylene	9.3	15.5	1017	1	20% H ₂ , 80% SO ₂	8.9	18.3	1332 (17)	
Air	10.4	20.4	1812	1	50% H ₂ , 50% SO ₂	9.7	17.7	1306 (17)	
Ammonia	8.4	16.0	1000	1	80% H ₂ , 20% SO ₂	8.4	21.6	1843	1
Amylene (β)	8.6	12.2	676	1	Hydrogen bromide	8.5	19.2	1425	1
Argon	9.7	22.6	2215	1	Hydrogen chloride	7.1	14.5	737	1
Arsine	8.6	20.0	1576	1	Hydrogen cyanide	8.5	21.5	1830	1
Benzene	8.7	13.2	746	1	Hydrogen iodide	8.4	18.0	1265	1
Bromine	8.8	19.4	1495	1	Hydrogen sulfide	8.7	18.7	1730 (100)	1
Butane (n)	8.6	13.2	735	1	Iodine	9.4	24.0	2480	1
Butane (iso)	8.6	13.2	744	1	Krypton	7.4	24.9	4500 (200)	1
Butyl acetate (iso)	5.7	16.3	778	1	Mercury	8.5	19.0	2253	1
Butylene (α)	8.4	13.5	761	1	Mercuric bromide	7.7	18.7	2200 (200)	1
Butylene (β)	8.7	13.1	746	1	Mercuric chloride	8.4	18.0	2045 (200)	1
Butylene (iso)	8.3	13.9	786	1	Mercuric iodide	9.5	10.2	660 (50)	1
Butyl formate (iso)	6.6	16.0	840	1	Mesitylene	9.5	15.8	1092	1
Cadmium	7.8	22.5	5690 (500)	1	Methane	9.5	17.6	1290	1
Carbon dioxide	8.9	19.1	1463	1	Methane (deuterated)	8.3	15.6	935	1
Carbon disulfide	8.5	15.8	990	1	Methanol	8.4	14.0	870 (50)	
Carbon monoxide	10.5	20.0	1749	1	Methyl acetate	8.9	14.3	867	1
Carbon oxsulfide	8.2	17.9	1220	1	Methyl acetylene	8.0	13.3	716	1
Carbon tetrachloride	8.0	15.3	966	1	3-Methyl-1-butene	6.6	15.8	824	1
Chlorine	8.8	18.3	1335	1	Methyl butyrate (iso)	8.1	18.7	1327	1
Chloroform	8.8	15.7	1000	1	Methyl bromide	8.5	16.5	1062	1
Cyanogen	8.2	16.2	1002	1	Methyl chloride	8.0	13.3	716	1
Cyclohexane	9.0	12.2	701	1	3-Methylene-1-butene	8.5	15.8	989	1
Cyclopropane	8.3	14.7	870	1	Methylene chloride	5.1	18.0	923	6
Deuterium	11.0	16.2	1240	1	Methyl formate	11.1	25.8	3113	1
Diethyl ether	8.8	12.7	730	1	Neon	10.4	20.8	1899	1
Dimethyl ether	9.0	15.0	925	1	Nitric oxide	10.6	20.0	1766	1
Diphenyl ether	8.6	10.4	610 (50)	1	Nitrogen	9.0	19.0	1460	1
Diphenyl methane	8.0	10.3	605 (50)	1	Nitrous oxide	9.2	8.9	554 (50)	1
Ethane	9.0	14.5	915	1	Nonane (n)	8.8	9.8	586 (50)	1
Ethanol	8.2	14.5	835	1	Oxygen	10.2	21.6	2026	1
Ethyl acetate	8.4	13.4	743	1	Pentane (n)	8.5	12.3	668	1
Ethyl chloride	8.5	15.6	978	1	Pentane (iso)	8.9	12.1	685	1
Ethylene	9.5	15.2	1010	1	Phosphene	8.8	17.0	1150	1
Ethyl propionate	12.0	12.4	890	1	Propane	8.9	13.5	800	1
Fluorine	7.3	23.8	2250	2	Propanol (n)	8.4	13.5	770	1
Freon-11	8.6	16.2	1298 (93)	3	Propanol (iso)	8.4	13.6	774	1
Freon-12	9.0	17.4	1496 (93)	3	Propyl acetate	8.0	14.3	797	1
Freon-14	9.5	20.4	1716	5	Propylene	8.5	14.4	840	1
Freon-21	9.0	16.7	1389 (93)	3	Pyridine	8.6	13.3	830 (50)	1
Freon-22	9.0	17.7	1554 (93)	3	Silane	9.0	16.8	1148	1
Freon-113	11.0	14.0	1166 (93)	3	Stannic chloride	9.1	16.0	1330 (100)	1
Freon-114	9.4	16.4	1364 (93)	3	Stannic bromide	9.0	16.7	142 (100)	1
Helium	11.3	20.8	1946	1	Sulfur dioxide	8.4	18.2	1250	1
Heptane (n)	8.6	10.6	618 (50)	1	Thiazole	10.0	14.4	958	1
Hexane (n)	8.4	12.0	644	1	Thiophene	8.3	14.2	901 (50)	1
Hydrogen	11.3	12.4	880	1	Toluene	8.6	12.5	686	1
Hydrogen-helium					2,2,3-Trimethylbutane	10.0	10.4	691 (50)	1
10% H ₂ , 90% He	11.0	20.5	1780 (0)		Trimethylmethane	8.0	13.0	686	1
25% H ₂ , 75% He	11.0	19.4	1603 (0)		Water	8.0	16.0	1250 (100)	1
40% H ₂ , 60% He	10.7	18.4	1431 (0)		Xenon	9.3	23.0	2255	
60% H ₂ , 40% He	10.8	16.7	1227 (0)		Zinc	8.0	22.0	5250 (500)	1

*Viscosity at 20°C unless otherwise indicated. From Beerman, *Meas. Control* (June 1982): 154–157.

References:

1. I. F. Golubev, *Viscosity of Gases and Gas Mixtures*, Moscow 1959; transl. U.S. Department of Commerce, Clearinghouse for Federal Scientific and Technical Information, Springfield, Va., TT 70-50022, ISPT Cat. No. 5680, Table 4, Jerusalem 1970.
 2. R. H. Perry and C. H. Chilton, *Chemical Engineers' Handbook*, 5th ed., McGraw-Hill, New York, 1973, pp. 3-210, 3-211.
 3. Ibid., Table 3-282, p. 3-210.
 4. By interpolation of data in Ref. 1.
 5. *Thermophysical Properties of Refrigerants*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York.
 6. N. A. Lange, *Handbook of Chemistry*, 4th ed., Handbook Publishers, Sandusky, Ohio, 1941.
- For another alignment chart for 165 hydrocarbons from -100 to 500°C, see Sastry, R. C. and A. Satyanarayan, *Chem. Industry Devs.* (July 1978): 11–14.

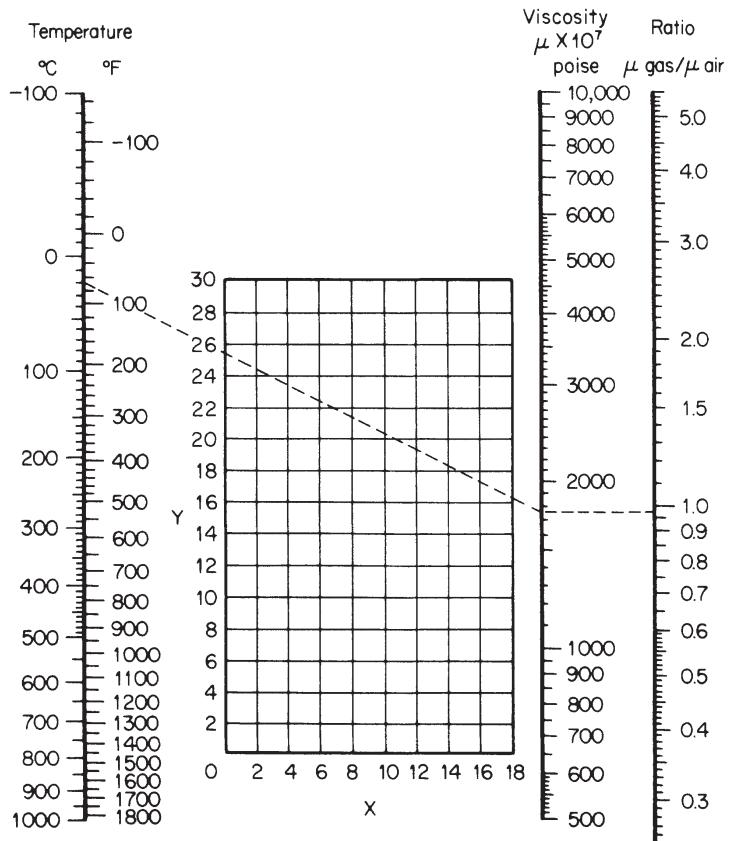


FIG. 2-32 Nomograph for determining (a) absolute viscosity of a gas as a function of temperature near ambient pressure and (b) relative viscosity of a gas compared with air. For coordinates see Table 2-364. To convert poises to pascal-seconds, multiply by 0.1. [From Beerman, Meas. Control, 154-157 (June 1982).]

TABLE 2-365 Viscosities of Liquids: Coordinates for Use with Fig. 2-33

Liquid	X	Y	Liquid	X	Y
Acetaldehyde	15.2	4.8	Freon-113	12.5	11.4
Acetic acid, 100%	12.1	14.2	Glycerol, 100%	2.0	30.0
Acetic acid, 70%	9.5	17.0	Glycerol, 50%	6.9	19.6
Acetic anhydride	12.7	12.8	Heptane	14.1	8.4
Acetone, 100%	14.5	7.2	Hexane	14.7	7.0
Acetone, 35%	7.9	15.0	Hydrochloric acid, 31.5%	13.0	16.6
Acetonitrile	14.4	7.4	Iodobenzene	12.8	15.9
Acrylic acid	12.3	13.9	Isobutyl alcohol	7.1	18.0
Allyl alcohol	10.2	14.3	Isobutyric acid	12.2	14.4
Allyl bromide	14.4	9.6	Isopropyl alcohol	8.2	16.0
Allyl iodide	14.0	11.7	Isopropyl bromide	14.1	9.2
Ammonia, 100%	12.6	2.0	Isopropyl chloride	13.9	7.1
Ammonia, 26%	10.1	13.9	Isopropyl iodide	13.7	11.2
Amyl acetate	11.8	12.5	Kerosene	10.2	16.9
Amyl alcohol	7.5	18.4	Linseed oil, raw	7.5	27.2
Aniline	8.1	18.7	Mercury	18.4	16.4
Anisole	12.3	13.5	Methanol, 100%	12.4	10.5
Arsenic trichloride	13.9	14.5	Methanol, 90%	12.3	11.8
Benzene	12.5	10.9	Methanol, 40%	7.8	15.5
Brine, CaCl ₂ , 25%	6.6	15.9	Methyl acetate	14.2	8.2
Brine, NaCl, 25%	10.2	16.6	Methyl acrylate	13.0	9.5
Bromine	14.2	13.2	Methyl <i>i</i> -butyrate	12.3	9.7
Bromotoluene	20.0	15.9	Methyl <i>n</i> -butyrate	13.2	10.3
Butyl acetate	12.3	11.0	Methyl chloride	15.0	3.8
Butyl acrylate	11.5	12.6	Methyl ethyl ketone	13.9	8.6
Butyl alcohol	8.6	17.2	Methyl formate	14.2	7.5
Butyric acid	12.1	15.3	Methyl iodide	14.3	9.3
Carbon dioxide	11.6	0.3	Methyl propionate	13.5	9.0
Carbon disulfide	16.1	7.5	Methyl propyl ketone	14.3	9.5
Carbon tetrachloride	12.7	13.1	Methyl sulfide	15.3	6.4
Chlorobenzene	12.3	12.4	Naphthalene	7.9	18.1
Chloroform	14.4	10.2	Nitric acid, 95%	12.8	13.8
Chlorosulfonic acid	11.2	18.1	Nitric acid, 60%	10.8	17.0
Chlorotoluene, ortho	13.0	13.3	Nitrobenzene	10.6	16.2
Chlorotoluene, meta	13.3	12.5	Nitrogen dioxide	12.9	8.6
Chlorotoluene, para	13.3	12.5	Nitrotoluene	11.0	17.0
Cresol, meta	2.5	20.8	Octane	13.7	10.0
Cyclohexanol	2.9	24.3	Octyl alcohol	6.6	21.1
Cyclohexane	9.8	12.9	Pentachloroethane	10.9	17.3
Dibromomethane	12.7	15.8	Pentane	14.9	5.2
Dichloroethane	13.2	12.2	Phenol	6.9	20.8
Dichloromethane	14.6	8.9	Phosphorus tribromide	13.8	16.7
Diethyl ketone	13.5	9.2	Phosphorus trichloride	16.2	10.9
Diethyl oxalate	11.0	16.4	Propionic acid	12.8	13.8
Diethylene glycol	5.0	24.7	Propyl acetate	13.1	10.3
Diphenyl	12.0	18.3	Propyl alcohol	9.1	16.5
Dipropyl ether	13.2	8.6	Propyl bromide	14.5	9.6
Dipropyl oxalate	10.3	17.7	Propyl chloride	14.4	7.5
Ethyl acetate	13.7	9.1	Propyl formate	13.1	9.7
Ethyl acrylate	12.7	10.4	Propyl iodide	14.1	11.6
Ethyl alcohol, 100%	10.5	13.8	Sodium	16.4	13.9
Ethyl alcohol, 95%	9.8	14.3	Sodium hydroxide, 50%	3.2	25.8
Ethyl alcohol, 40%	6.5	16.6	Stannic chloride	13.5	12.8
Ethyl benzene	13.2	11.5	Succinonitrile	10.1	20.8
Ethyl bromide	14.5	8.1	Sulfur dioxide	15.2	7.1
2-Ethyl butyl acrylate	11.2	14.0	Sulfuric acid, 110%	7.2	27.4
Ethyl chloride	14.8	6.0	Sulfuric acid, 100%	8.0	25.1
Ethyl ether	14.5	5.3	Sulfuric acid, 98%	7.0	24.8
Ethyl formate	14.2	8.4	Sulfuric acid, 60%	10.2	21.3
2-Ethyl hexyl acrylate	9.0	15.0	Sulfuryl chloride	15.2	12.4
Ethyl iodide	14.7	10.3	Tetrachloroethane	11.9	15.7
Ethyl propionate	13.2	9.9	Thiophene	13.2	11.0
Ethyl propyl ether	14.0	7.0	Titanium tetrachloride	14.4	12.3
Ethyl sulfide	13.8	8.9	Toluene	13.7	10.4
Ethylene bromide	11.9	15.7	Trichloroethylene	14.8	10.5
Ethylene chloride	12.7	12.2	Triethylene glycol	4.7	24.8
Ethylene glycol	6.0	23.6	Turpentine	11.5	14.9
Ethyldiene chloride	14.1	8.7	Vinyl acetate	14.0	8.8
Fluorobenzene	13.7	10.4	Vinyl toluene	13.4	12.0
Formic acid	10.7	15.8	Water	10.2	13.0
Freon-11	14.4	9.0	Xylene, ortho	13.5	12.1
Freon-12	16.8	5.6	Xylene, meta	13.9	10.6
Freon-21	15.7	7.5	Xylene, para	13.9	10.9
Freon-22	17.2	4.7			

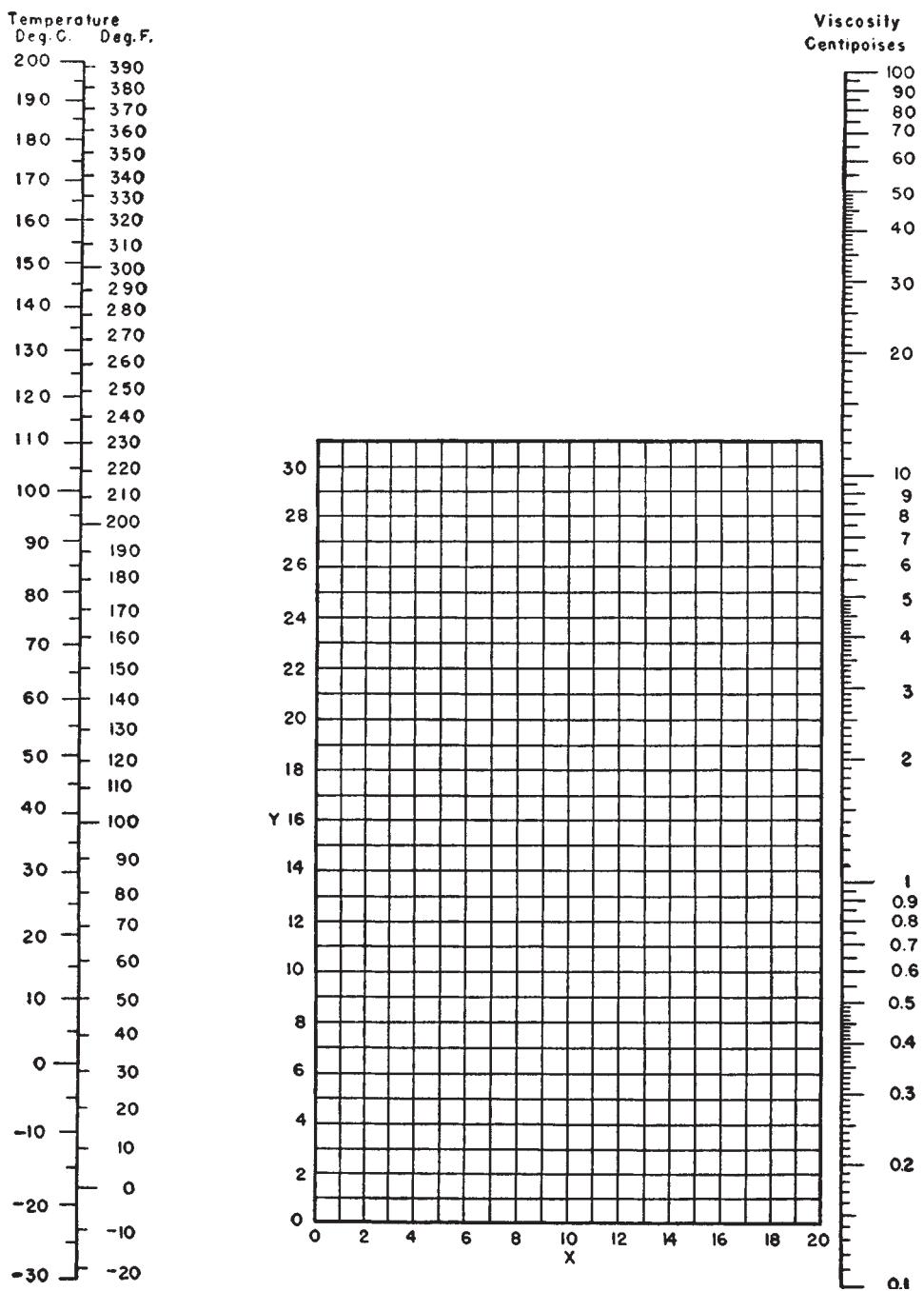


FIG. 2-33 Nomograph for viscosities of liquids at 1 atm. For coordinates see Table 2-365. To convert centipoises to pascal-seconds, multiply by 0.001.

TABLE 2-367

No.	Compound	Range, °C	Exp pt	% Avg abs devi
31	Acetaldehyde	0 - 30	2	0.4
40	Acetic acid	18 - 79	5	0.1
29	Acetone	0 - 40	3	0.4
20	Aniline	0 - 93	6	1.3
2	Benzaldehyde	16 - 68	4	0.7
13	Benzene	20 - 116	5	0.6
47	n-Butane	-21 - 0	2	0.2
16	n-Butanol	0 - 102	7	0.4
48	i-Butanol	0 - 20	2	0.6
49	s-Butanol	0 - 65	3	0.2
18	t-Butanol	20 - 77	3	2.5
28	Butyl acetate	0 - 38	4	1.1
23	Carbon tetrachloride	-20 - 25	4	1.1
25	Chlorobenzene	-40 - 80	6	0.5
42	Chloroform	0 - 40	3	1.3
19	m-Cresol	20 - 80	2	0.2
11	Cyclohexane	20 - 38	2	0.4
7	n-Decane	20 - 76	5	1.0
30	Diethyl ether	0 - 25	3	0.7
9	2,3-Dimethylbutane	32 - 49	2	0.3
38	n-Dodecane	0 - 63	6	1.1
15	Ethanol	17 - 77	7	0.5
27	Ethyl acetate	6 - 160	9	1.6
14	Ethylbenzene	0 - 80	3	0.7
24	Ethyl bromide	0 - 30	3	0.3
4	n-Heptane	0 - 60	3	0.3
3	n-Hexane	17 - 40	5	1.4
26	Iodobenzene	-20 - 80	4	0.7
41	Methanol	20 - 62	6	0.2
39	Methyl acetate	4 - 21	2	0.4
12	Methylcyclopentane	20 - 38	2	0.1
22	Methylene chloride	-20 - 20	3	0.9
8	2-Methylpentane	32 - 49	2	0.5
6	n-Nonane	16 - 77	5	2.0
5	n-Octane	0 - 77	3	0.3
10	i-Octane	20 - 77	4	1.6
17	n-Octanol	20 - 212	3	1.3
43	n-Pentanol	0 - 38	3	0.4
1	Propane	-60 - 50	4	1.6
32	n-Propanol	16 - 66	6	0.6
21	Propionic acid	12 - 30	3	1.7
44	i-Propyl acetate	0 - 38	2	0.1
33	i-Propylbenzene	0 - 38	4	0.2
45	Refrigerant-11, CFC ₃	0 - 20	4	0.5
46	Refrigerant-12, CF ₂ Cl ₂	-42 - 70	4	1.8
50	Refrigerant-13, CF ₃ Cl	-20 - 20	4	1.7
51	Refrigerant-22, CHF ₂ Cl	-65 - 60	7	2.5
52	Refrigerant-113, C ₂ F ₃ Cl ₃	0 - 20	4	0.7
53	Refrigerant-114, C ₂ F ₄ Cl ₂	-25 - 20	4	0.8
54	Refrigerant-142, C ₂ H ₃ F ₂ Cl	0 - 90	2	0.9
34	Toluene	-70 - 200	5	1.8
55	n-Tridecane	20 - 228	5	2.4
36	m-Xylene	0 - 208	5	1.0
35	o-Xylene	0 - 208	5	0.7
37	p-Xylene	0 - 251	5	1.4

TABLE 2-366 Viscosity of Sucrose Solutions*

Viscosity in centipoises

Temp., °C	Percentage sucrose by weight			Temp., °C	Percentage sucrose by weight		
	20	40	60		20	40	60
0	3.818	14.82		50	0.974	2.506	14.06
5	3.166	11.60		55	0.887	2.227	11.71
10	2.662	9.830	113.9	60	0.811	1.989	9.87
15	2.275	7.496	74.9	65	0.745	1.785	8.37
20	1.967	6.223	56.7	70	0.688	1.614	7.18
25	1.710	5.206	44.02	75	0.637	1.467	6.22
30	1.510	4.398	34.01	80	0.592	1.339	5.42
35	1.336	3.776	26.62	85	0.552	1.226	4.75
40	1.197	3.261	21.30	90		1.127	4.17
45	1.074	2.858	17.24	95		1.041	3.73

*International Critical Tables, vol. 5, p. 23. Bingham and Jackson, Bur. Standards Bull. 14 (1919): 59.

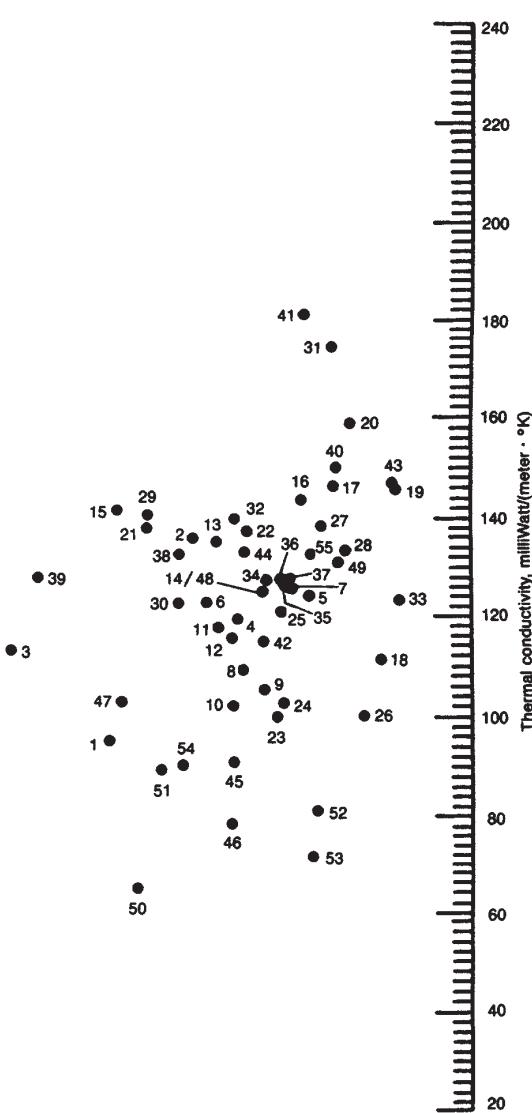


FIG. 2-34 and TABLE 2-367 Nomograph (right) for thermal conductivity of organic liquids.

TABLE 2-368 Prandtl Number of Air*

Temperature, K	Pressure, bar											
	1	5	10	20	30	40	50	60	70	80	90	100
80	mix	2.31	2.32	2.35	2.37	2.40	2.42	2.45	2.48	2.51	2.54	2.57
90	0.796	1.76	1.77	1.78	1.79	1.81	1.82	1.83	1.85	1.87	1.89	1.91
100	0.786	0.872	1.54	1.53	1.53	1.53	1.53	1.53	1.53	1.54	1.54	1.55
120	0.773	0.813	0.89	1.44	1.65	1.54	1.48	1.43	1.40	1.38	1.36	1.34
140	0.763	0.782	0.82	0.94	1.20	1.59	2.14	2.43	2.07	1.78	1.62	1.52
160	0.754	0.765	0.78	0.84	0.92	1.03	1.13	1.25	1.37	1.65	1.83	1.72
180	0.745	0.754	0.763	0.792	0.830	0.876	0.932	1.00	1.07	1.14	1.20	1.25
200	0.738	0.743	0.749	0.766	0.788	0.812	0.841	0.87	0.90	0.95	0.97	1.00
240	0.724	0.727	0.729	0.737	0.746	0.756	0.767	0.78	0.80	0.81	0.81	0.82
280	0.710	0.711	0.713	0.717	0.721	0.726	0.731	0.737	0.742	0.75	0.75	0.76
300	0.705	0.707	0.708	0.712	0.715	0.717	0.721	0.725	0.728	0.732	0.737	0.742
350	0.699	0.699	0.699	0.701	0.703	0.705	0.707	0.709	0.711	0.712	0.714	0.716
400	0.694	0.694	0.694	0.695	0.696	0.697	0.698	0.699	0.700	0.701	0.703	0.704
450	0.691	0.691	0.691	0.691	0.692	0.692	0.693	0.693	0.694	0.695	0.695	0.696
500	0.689	0.689	0.689	0.689	0.689	0.690	0.690	0.690	0.690	0.691	0.691	0.691
600	0.690	0.690	0.690	0.689	0.689	0.689	0.689	0.689	0.689	0.690	0.690	0.690
700	0.696	0.696	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695
800	0.705	0.704	0.704	0.704	0.703	0.703	0.703	0.703	0.703	0.702	0.702	0.702
900	0.709	0.709	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708	0.708
1000	0.711	0.711	0.711	0.711	0.711	0.710	0.710	0.710	0.710	0.709	0.709	0.709

*Compiled by P. E. Liley from tables of specific heat at constant pressure, thermal conductivity, and viscosity given in SI units for integral kelvin temperatures and pressures in bars by Vasserman. *Thermophysical Properties of Air and Its Components and Thermophysical Properties of Liquid Air and Its Components*. Nauka, Moscow, and in translated form by the National Bureau of Standards, Washington. The number of significant figures given above reflects the similar numbers appearing for the constituent properties in the source references. While reasonable agreement occurs for atmospheric pressure with some other works, the fragmentary data available for the saturated, etc., states show large deviations.

TABLE 2-369 Prandtl Number of Liquid Refrigerants*

Refrigerant	No.	Temperature, K										
		180	200	220	240	260	280	300	320	340	360	380
Trichlorofluoromethane	11		11.9	8.64	6.73	5.33	4.74	4.18				
Dichlorodifluoromethane	12	7.00	5.25	4.27	3.65	3.27	3.08	3.04	3.19	3.44	4.00	
Chlorotrifluoromethane	13		2.96	2.67	2.69	3.05	3.57	—	—	—	—	
Bromotrifluoromethane	13B1	4.80	3.75	3.27	2.94	2.83	3.03	3.61	4.52	—	—	
Dichlorofluoromethane	21			5.72	4.50	3.87	3.48	3.25	3.16	3.17		
Chlorodifluoromethane	22	4.68	3.76	3.23	2.93	2.79	2.77	2.87	3.18	3.54		
Methyl chloride	40			2.53	2.42	2.40	2.45	2.60	2.85			
Trichlorotrifluoroethane	113	—	—	—					7.04	6.23	5.61	5.18
Dichlorotetrafluoroethane	114	25.7	15.13	11.18	8.59	6.94	5.77	5.06	4.78	4.82	—	—
Chloropentafluoroethane	115	—	7.85	6.16	5.21	4.67	4.40	4.46	4.90	—	—	
Ethane	170	2.55	2.29	2.22	2.40	2.70		—	—	—	—	
Propane	290	5.28	4.46	3.88	3.44	3.16	3.02	3.16				
Octafluorocyclobutane	C318	—	—	—	11.2	8.74	7.35	6.37	5.87	5.96	—	
Dichlorodifluoromethane/difluoroethane	500		5.78	4.23	3.40	3.13	3.01	3.13	3.35	3.72	—	
Chlorodifluoromethane/chloropentafluoroethane	502			5.73	4.71	4.13	3.81			—	—	
Trifluoromethane/chlorotrifluoromethane	503	2.10	2.09	2.24	2.43	2.89		—	—	—	—	
Methylene fluoride/chloropentafluoroethane	504		4.90	3.60	3.04	2.79	2.69	2.85	3.30	—	—	
Butane	600	8.35	6.19	5.20	4.44	3.83	3.44	3.22	3.07	3.02		
Isobutane (2-methyl propane)	600a			8.26	6.36	5.18	4.49	3.93	3.66	3.53	3.53	3.77
Ammonia	717	—			1.97	1.76	1.54	1.40	1.29	1.24	1.25	1.34
Water	718	—	—	—	—	—	10.3	5.69	3.65	2.60	1.99	1.59
Ethylene	1150	1.85	1.74	1.78	2.07	2.70	4.4	—	—	—	—	
Propylene	1270	3.80	2.24	1.88	1.71	1.71	1.88	2.24	3.91	4.73	—	

*Dashes indicate inaccessible states. Average uncertainty is about 20 percent. Values derived from formulations for thermal conductivity, specific heat at constant pressure, and viscosity contained in *Thermophysical Properties of Refrigerants*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, New York, 1976. For further details see M. W. Johnson, M.S.M.E. thesis, Purdue University, West Lafayette, Ind., 1976.

TABLE 2-370 Thermophysical Properties of Miscellaneous Saturated Liquids

Substance	Property	Temperature, °C																	
		-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100		
Acetaldehyde	ρ (kg/m ³)	863	852	840	828	816	804	794	783										
	c_p (kJ/kg-K)	2.05	2.08	2.11	2.14	2.17	2.20	2.24	2.28										
	μ (10 ⁻⁶ Pa·s)	460	404	358	321	290	263	241	222										
	k (W/m-K)	0.211	0.206	0.200	0.195	0.189	0.184	0.182	0.180										
Acetic acid	Pr	4.47	4.08	3.78	3.52	3.33	3.14	2.97	2.81										
	ρ (kg/m ³)									1049	1039	1028	1018	1006	995	984	972	960	
	c_p (kJ/kg-K)									2.031									
	μ (10 ⁻⁶ Pa·s)									1210	1102	1010	795	600					
Aniline	k (W/m-K)									0.173	0.170	0.168	0.167	0.165	0.163	0.161			
	Pr									14.2									
	ρ (kg/m ³)	—	—	—	—	—	—	1039	1030	1022	1013	1005	996	987	978	969	960	951	
	c_p (kJ/kg-K)	—	—	—	—	—	—	2.024	2.047	2.071	2.093	2.113	2.132	2.17	2.20	2.23	2.27	2.32	
Butanol	μ (10 ⁻⁶ Pa·s)	—	—	—	—	—	—	10200	6500	4400	3160	2370	1850	1510	1270	1090	935	825	
	k (W/m-K)	—	—	—	—	—	—	0.186	0.184	0.182	0.180	0.177	0.174	0.171	0.169	0.168	0.167	0.167	
	Pr	—	—	—	—	—	—	111	72	50	36.7	28.3	22.7	19.2	16.5	14.5	12.7	11.5	
	ρ (kg/m ³)	845	841	837	833	829	825	817	810	803	797	791	784	776	768	760	753		
Carbon disulfide	c_p (kJ/kg-K)	1.947	1.996	2.046	2.100	2.153	2.202	2.262	2.345	2.437	2.524	2.621							
	μ (10 ⁻⁶ Pa·s)	34700	22400	14700	10300	7400	5190	3870	2950	2300	1780	1410	1140	930	760	630	535		
	k (W/m-K)	0.175	0.174	0.173	0.172	0.171	0.170	0.168	0.167	0.166	0.165	0.164	0.163	0.162	0.161	0.160	0.159		
	Pr	3860	2570	1740	1260	930	670	4120	33.8	27.2	22.5								
Cyclohexane	ρ (kg/m ³)	—	—	—	—	—	—	—	789	779	769	759	750	740	731	721			
	c_p (kJ/kg-K)	—	—	—	—	—	—	—	2.068	2.081	2.094	2.106	2.119						
	μ (10 ⁻⁶ Pa·s)	—	—	—	—	—	—	—	1175	980	820	710	605	540					
	k (W/m-K)	—	—	—	—	—	—	—	0.122	0.120	0.119	0.118	0.117	0.116	0.114	0.112			
Ethanol	Pr	—	—	—	—	—	—	—	19.9	17.0	14.4	12.7	11.0						
	ρ (kg/m ³)	—	—	—	—	—	—	—	806	798	789	781	776	763	754	745	735	725	716
	c_p (kJ/kg-K)	2.01	2.04	2.08	2.13	2.19	2.27	2.35	2.43	2.52	2.62	2.73	2.83	2.93	3.03	3.19	3.30		
	μ (10 ⁻⁶ Pa·s)	6400	4790	3650	2825	2220	1770	1470	1200	1000	835	700	590	500	435	370	314		
Ethyl acetate	k (W/m-K)	0.188	0.186	0.184	0.181	0.179	0.177	0.175	0.173	0.171	0.168	0.165	0.162	0.159	0.156	0.153	0.151		
	Pr	68.4	52.5	41.3	33.2	27.2	22.7	19.7	16.9	14.7	13.0	11.6	10.3	9.2	8.4	7.7	6.9		
	ρ (kg/m ³)	—	—	—	—	—	—	947	935	924	912	901	888	876	863	851	838	825	
	c_p (kJ/kg-K)	—	—	—	—	—	—	—	580	510	455	400	370	345	310	280	250	230	220
Ethylamine	μ (10 ⁻⁶ Pa·s)	1090							580	510	455	400	370	345	310	280	250	230	220
	k (W/m-K)	—	—	—	—	—	—	—	0.145	0.142	0.139	0.136	0.133	0.130	0.127	0.123	0.123	0.119	
	Pr	8.39	7.39	6.51	5.97	5.43	5.08												
	ρ (kg/m ³)	761	750	739	729	718	707	695	683	671	658	646	633	620	607				
Ethyl ether	c_p (kJ/kg-K)	2.95	2.97	2.98	3.00	3.01	3.03												
	μ (10 ⁻⁶ Pa·s)	580	500	435	390	350	320												
	k (W/m-K)	0.204	0.201	0.199	0.196	0.194	0.191												
	Pr	8.39	7.39	6.51	5.97	5.43	5.08												
Ethyl iodide	ρ (kg/m ³)	—	—	—	—	—	—	—	0.677	0.684	0.691	0.698	0.705	0.712	0.718	0.724			
	c_p (kJ/kg-K)	—	—	—	—	—	—	—	730	655	590	539	495	455	420	390			
	μ (10 ⁻⁶ Pa·s)	—	—	—	—	—	—	—	0.092	0.090	0.088	0.086	0.085	0.083	0.081	0.080			
	k (W/m-K)	—	—	—	—	—	—	—	5.37	4.98	4.63	4.30	4.11	3.90	3.72	3.53			
Ethylene glycol	Pr	—	—	—	—	—	—	—	1127	1120	1113	1106	1099	1092	1085	1077	1070	1063	1056
	ρ (kg/m ³)	—	—	—	—	—	—	—	2.272	2.327	2.381	2.431	2.484	2.536	2.586	2.636	2.685	2.734	2.779
	c_p (kJ/kg-K)	—	—	—	—	—	—	—	57000	33300	20200	13400	9100	7070	4000	3450	3000	2440	2000
	μ (10 ⁻⁶ Pa·s)	—	—	—	—	—	—	—	0.254	0.255	0.256	0.258	0.259	0.260					
Formic acid	k (W/m-K)	—	—	—	—	—	—	—	510	305	190	126	87.3	69.0					
	Pr	—	—	—	—	—	—	—	1241	1231	1220	1209	1196	1184	1170	1156	1140	1124	1108
	ρ (kg/m ³)	—	—	—	—	—	—	—	—	2260	1800	1470	1220	1030	890	780	680	615	550
	c_p (kJ/kg-K)	—	—	—	—	—	—	—	0.265	0.261	0.257	0.257	0.253	0.250	0.246	0.243	0.240	0.236	0.232

TABLE 2-370 Thermophysical Properties of Miscellaneous Saturated Liquids (Concluded)

Substance	Property	Temperature, °C																				
		-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100					
Gasoline	ρ (kg/m ³)	1710	1400	1170	990	784	775	767	759	751	743	735	721	717	708	699	690					
	c_p (kJ/kg·K)					1.88	1.92	1.97	2.02	2.06	2.11	2.15	2.20	2.25	2.30	2.35	2.41	2.46				
	μ (10 ⁻⁶ Pa·s)					0.125	0.123	0.121	0.120	0.118	0.116	0.114	0.112	0.110	0.108	0.106	0.104	0.102				
	k (W/m·K)					0.131	0.128	0.123	0.121	0.120	0.118	0.116	0.114	0.112	0.110	0.108	0.106	0.102				
Glycerol	ρ (kg/m ³)	—	—	—	—	—	—	1276	1270	1260	1254	1248	1242	1236	1230	1225	1220					
	c_p (kJ/kg·K)					—	—	—	—	2.393	2.406	2.457	2.504	2.548	2.588	2.625	2.657	2.680				
	μ (10 ⁻⁶ Pa·s)					—	—	—	—	4.0.+6	4.5.+6	4.8.+6	5.1.+6	5.4.+6	5.7.+6	6.0.+6	6.3.+6	6.6.+6				
	k (W/m·K)					—	—	—	—	0.284	0.285	0.287	0.288	0.289	0.291	0.293	0.294	0.295				
Kerosine	ρ (kg/m ³)	1150	725	500	360	275	781	774	767	760	754	748	742	736	730	725	720					
	c_p (kJ/kg·K)						1.91	1.96	2.02	2.07	2.13	2.18	2.23	2.28	2.32	2.35	2.38	2.40				
	μ (10 ⁻⁶ Pa·s)						215	173	149	126	108	95	83	73	66	60	55	50				
	k (W/m·K)						0.140	0.139	0.139	0.138	0.138	0.137	0.137	0.137	0.137	0.137	0.137	0.137				
Methanol	ρ (kg/m ³)	2.30	2.32	2.35	2.37	2.40	2.42	2.45	2.47	2.49	2.52	2.55	2.65	2.78	2.94	3.13	3.30					
	c_p (kJ/kg·K)						2305	1800	1410	1170	975	820	692	590	510	455	400	355	315			
	μ (10 ⁻⁶ Pa·s)						0.225	0.222	0.219	0.216	0.212	0.209	0.206	0.203	0.199	0.195	0.192	0.189	0.187			
	k (W/m·K)						Pr	23.6	18.8	15.1	12.9	11.0	9.53	8.23	7.18	6.38	5.88	5.31	4.98	4.68	4.34	4.13
Methyl formate	ρ (kg/m ³)	1069	1056	1043	1030	1017	1003	989	975	960	944	929	913	897	880	863	845					
	c_p (kJ/kg·K)						1.84	1.86	1.88	1.90	1.92	1.95	1.99	2.03	2.08	—	—	—	—	—		
	μ (10 ⁻⁶ Pa·s)						830	711	618	544	481	430	380	345	315	—	—	—	—	—		
	k (W/m·K)						0.217	0.213	0.209	0.205	0.200	0.195	0.191	0.186	0.180	—	—	—	—	—		
Oil, castor	ρ (kg/m ³)	—	—	—	—	—	—	—	2,420,000	986,000	451,000	231,000	125,000	74,000	43,000	21,000	10,000	5,000				
	c_p (kJ/kg·K)									0.182	0.181	0.180	0.179	0.178	0.177	0.176	0.175	0.174	0.173			
	μ (10 ⁻⁶ Pa·s)									—	—	—	—	—	—	—	—	—	—			
	k (W/m·K)									Pr	7.04	6.21	5.56	5.04	4.62	4.30	3.96	3.77	3.64	—	—	—
Oil, olive	ρ (kg/m ³)	—	—	—	—	—	—	—	138,000	84,000	52,000	36,300	24,500	17,000	12,400	8,000	4,000	2,000				
	c_p (kJ/kg·K)									0.170	0.169	0.168	0.167	0.166	0.165	0.164	0.163	0.162	0.161			
	μ (10 ⁻⁶ Pa·s)									Pr	—	—	—	—	—	—	—	—	—	—	—	—
	k (W/m·K)									Pr	—	—	—	—	—	—	—	—	—	—	—	—
Pentane	ρ (kg/m ³)	693	684	674	665	656	646	636	626	616	606	596	585	574	562	550	538					
	c_p (kJ/kg·K)						2,060	2,084	2,110	2,137	2,167	2,206	2,239	2,273	—	—	—	—	—	—	—	—
	μ (10 ⁻⁶ Pa·s)						489	428	379	339	307	279	254	234	209	190	175	161	148	137	124	113
	k (W/m·K)						0.142	0.139	0.136	0.132	0.128	0.125	0.122	0.119	0.115	0.112	0.108	0.105	0.101	0.098	0.095	0.090
Propanol	ρ (kg/m ³)	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849				
	c_p (kJ/kg·K)																					
	μ (10 ⁻⁶ Pa·s)																					
	k (W/m·K)																					
Sulfuric acid	ρ (kg/m ³)	—	—	—	—	—	—	—	48,400	35,200	25,400	15,700	11,500	8820	7220	6090	5190	4470	3550	3250	2950	
	c_p (kJ/kg·K)																					
	μ (10 ⁻⁶ Pa·s)																					
	k (W/m·K)																					
Toluene	ρ (kg/m ³)	932	923	913	904	895	886	876	867	858	848	839	829	820	810	800	790	780	770	760	750	
	c_p (kJ/kg·K)																					
	μ (10 ⁻⁶ Pa·s)																					
	k (W/m·K)																					
Turpentine	ρ (kg/m ³)	—	—	—	—	—	—	—	1.72	1.76	1.80	1.84	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93		
	c_p (kJ/kg·K)																					
	μ (10 ⁻⁶ Pa·s)																					
	k (W/m·K)																					
Turpentine	ρ (kg/m ³)	—	—	—	—	—	—	—	2250	1780	1490	1270	1070	925	820	730	675	675	675	675		
	c_p (kJ/kg·K)																					
	μ (10 ⁻⁶ Pa·s)																					
	k (W/m·K)																					
Turpentine	ρ (kg/m ³)	—	—	—	—	—	—	—	29.8	24.3	20.9	18.4	16.1	14.3								

2-328 PHYSICAL AND CHEMICAL DATA

TABLE 2-371 Diffusivities of Pairs of Gases and Vapors (1 atm)

D_e in cm^2/s

Substance	Temp., °C	Air	A	H_2	O_2	N_2	CO_2	N_2O	CH_4	C_2H_6	C_2H_4	$n\text{-C}_4\text{H}_{10}$	$i\text{-C}_4\text{H}_{10}$	Ref.
Acetic acid	0	0.1064		0.416			0.0716							8
Acetone	0	.109		.361										6, 16
<i>n</i> -Amyl alcohol	0	.0589		.235			.0422							8
<i>sec</i> -Amyl alcohol	30	.072												5
Amyl butyrate	0	.040												8
Amyl formate	0	.0543												8
<i>i</i> -Amyl formate	0	.058												8
Amyl isobutyrate	0	.0419		.171										8
Amyl propionate	0	.046		.1914			.0347							8
Aniline	0	.0610												8
	30	.075												5
Anthracene	0	.0421												8
Argon	20													18
Benzene	0	.077		.306	0.0797	0.194		.0528						8, 15
Benzidine	0	.0298												8
Benzyl chloride	0	.066												8
<i>n</i> -Butyl acetate	0	.058												8
<i>i</i> -Butyl acetate	0	.0612		.2364				.0425						8
<i>n</i> -Butyl alcohol	0	.0703		.2716				.0476						8
	30	.088												5
<i>i</i> -Butyl alcohol	0	.0727		.2771				.0483						8
Butyl amine	0	.0821												8
<i>i</i> -Butyl amine	0	.0853												8
<i>i</i> -Butyl butyrate	0	.0468		.185				.0327						8
<i>i</i> -Butyl formate	0	.0705												8
<i>i</i> -Butyl isobutyrate	0	.0457		.191				.0364						8
<i>i</i> -Butyl propionate	0	.0529		.203				.0366						8
<i>i</i> -Butyl valerate	0	.0424		.173				.0308						8
Butyric acid	0	.067		.264				.0476						8
<i>i</i> -Butyric acid	0	.0679		.271				.0471						8
Cadmium	0						.17							13
Caproic acid	0	.050												8
<i>i</i> -Caproic acid	0	.0513												8
Carbon dioxide	0	.138		.550	.139	.163		0.096	0.153					8
	20													19
	25													1, 9
	500†						.9							18
Carbon disulfide	0	.0892		.369			.063							8
Carbon monoxide	0			.651	.185	.137								8
	450‡						1.0							18
Carbon tetrachloride	0			.293	0.0636									16, 17
Chlorobenzene	30	.075												5
Chloroform	0	.091												6
Chloropicrin	25	.088												10
<i>m</i> -Chlorotoluene	0	.054												8
<i>o</i> -Chlorotoluene	0	.059												8
<i>p</i> -Chlorotoluene	0	.051												8
Cyanogen chloride	0	.111												10
Cyclohexane	15			.0719	.319	.0744	.0760							3
	45	.086												6
<i>n</i> -Decane	90				.306		.0841							3
Diethylamine	0	.0884												8
2,3-Dimethyl butane	15			.0657	.301	.0753	.0751							3
Diphenyl	0	.0610												8
<i>n</i> -Dodecane	126				.308		.0813							3
Ethane	0				.459									8
Ethanol	0				.377									20
Ether (diethyl)	0	.0778			.298			.0546						7, 8
Ethyl acetate	0	.0715			.273			.0487						8
	30	.089												5
Ethyl alcohol	0	.102			.375			.0685						8
Ethyl benzene	0	.0658												8
Ethyl <i>n</i> -butyrate	0	.0579			.224			.0407						8
Ethyl <i>i</i> -butyrate	0	.0591			.229			.0413						8
Ethylene	0				.486									8
Ethyl formate	0	.0840			.337			.0573						8
Ethyl propionate	0	.068			.236			.0450						4, 8
Ethyl valerate	0	.0512			.205			.0367						8
Eugenol	0	.0377												8
Formic acid	0	.1308			.510			.0874						8
Helium	20			.641			.705							19
<i>n</i> -Heptane	38													3
<i>n</i> -Hexane	15			.0663	.290	.0753	.0757							8
Hexyl alcohol	0	.0499			.200									2
Hydrogen	0	.611					.697	.674						2
	25													18
	500						4.2							

TABLE 2-371 Diffusivities of Pairs of Gases and Vapors (1 atm) (Concluded)
 D_v in cm^2/s

Substance	Temp., °C	Air	A	H ₂	O ₂	N ₂	CO ₂	N ₂ O	CH ₄	C ₂ H ₆	C ₂ H ₄	n-C ₄ H ₁₀	i-C ₄ H ₁₀	Ref.
Hydrogen cyanide	0	.173												10
Hydrogen peroxide	60	.188												11
Iodine	0	.07												8, 12, 14
Mercury	0	.112		.53		.070	.13							8, 12, 13
Mesitylene	0	.056												8
Methane	500					1.1								18
Methyl acetate	0	.084		.333			.0567							8
Methyl alcohol	0	.132		.506			.0879							8
Methyl butyrate	0	.0633		.242			.0446							8
Methyl i-butyrate	0	.0639		.257			.0451							8
Methyl cyclopentane	15		.0731	.318	.0742	.0758								3
Methyl formate	0	.0872												8
Methyl propionate	0	.0735		.295			.0528							8
Methyl valerate	0	0.0569												8
Naphthalene	0	.0513												8
Nitrogen	0					0.181								8
Nitrous oxide	25						0.165							2
n-Octane	0		.0505		.535		.096							8
Oxygen	30													8
Phosgene	0	.095												10
Propionic acid	0	.0829												8
Propyl acetate	0	.067												8
n-Propyl alcohol	0	.085												8
i-Propyl alcohol	0	.0818												8
n-Propyl benzene	30	.101												5
i-Propyl benzene	0	.0481												8
n-Propyl bromide	0	.0489												8
i-Propyl bromide	0	.085												8
Propyl bromide	0	.0902												8
Propyl butyrate	0	.0530			.206			.0364						8
Propyl formate	0	.0712			.281			.0490						8
n-Propyl iodide	0	.079												8
i-Propyl iodide	0	.0802												8
n-Propyl isobutyrate	0	.0549			.212			.0388						8
i-Propyl isobutyrate	0	.059												8
Propyl propionate	0	.057			.212			.0395						8
Propyl valerate	0	.0466			.189			.0341						8
Safrol	0	.0434												8
i-Safrol	0	.0455												8
Sulfur hexafluoride	25													2
Toluene	0	.076												4, 8
Trimethyl carbinol	30	.088												5
2,2,4-Trimethyl pentane	0	.087												8
2,2,3-Trimethyl heptane	30			.0618	.288	.0688	.0705							3
n-Valeric acid	90													3
i-Valeric acid	0	.050												8
Water	0	.0544												8
	450	.220												20
														18

* 320 mm Hg.

† 40 atm.

‡ Also at other temperatures.

§ Strong function of concentration.

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In this table are a representative selection of diffusion coefficients. The subsection "Prediction and Correlation of Physical Properties" should be consulted for estimation techniques. As general references, the works by Hirschfelder, Curtiss, and Bird, *Molecular Theory of Gases and Liquids*, Wiley, New York, 1964; Chapman and Cowling, *The Mathematical Theory of Non-Uniform Gases*, Cambridge, New York, 1970; Reid and Sherwood, *The Properties of Gases and Liquids*,

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TABLE 2-372 Diffusivities in Liquids (25°C)

Dilute solutions and 1 atm unless otherwise noted; use $D_L \mu/T = \text{constant}$ to estimate effect of temperature; * indicates that reference gives effect of concentration.

Solute	Solvent	$D_L \times 10^5$, sq cm/sec	Estimated possible, error, $\pm \%$	Ref.
Acetal*	Ethanol	1.25	5	11
Acetamide*	Ethanol	0.68	5	11
Acetamide*	Water	1.19	3	11
Acetic acid	Acetone	3.31	4	
Acetic acid	Benzene	2.11		1, 4
Acetic acid	Carbon tetrachloride	1.49	4	
Acetic acid	Ethylene glycol	0.13	4	
Acetic acid	Toluene	2.26	4	
Acetic acid*	Water	1.24	3	11
Acetonitrile	Water	1.66	5	11
Acetylene	Water	1.78, 2.11		1, 24
Allyl alcohol*	Ethanol	1.06	5	11
Allyl alcohol	Water	1.19	6	11
Ammonia*	Water	1.7, 2.0, 2.3		1, 11
i-Amyl alcohol*	Ethanol	0.87	5	11
i-Amyl alcohol	Water	1.0	8	11, 25
Benzene	Carbon tetrachloride	1.53	7	
Benzene (50 mole %)	n-Decane	1.72	26	
Benzene (50 mole %)	2,4-Dimethyl pentane	2.49	26	
Benzene (50 mole %)	n-Dodecane	1.40	26	
Benzene (50 mole %)	n-Heptane	2.47	26	
Benzene (50 mole %)	n-Hexadecane	0.96	26	
Benzene (50 mole %)	n-Octadecane	0.86	26	
Benzoic acid	Acetone	2.62	4	
Benzoic acid	Benzene	1.38	4	
Benzoic acid	Carbon tetrachloride	0.91	4	
Benzoic acid	Ethylene glycol	0.043	4	
Benzoic acid	Toluene	1.49	4	
Bromine	Benzene	2.7	11	
Bromine	Carbon disulfide	4.1	11	
Bromine	Water	1.3	11	
Bromobenzene	Benzene	2.30	25	
Bromoform*	Acetone	2.90	11	
Bromoform	i-Amyl alcohol	0.53	11	
Bromoform	Ethanol	1.08	5	11
Bromoform*	Ethyl ether	3.62	11	
Bromoform	Methanol	2.20	23	
Bromoform	n-Propanol	0.94	11	
n-Butanol	Water	0.96	5	1, 11, 18, 25
Caffeine	Water	0.63	6	11
Carbon dioxide	Ethanol	4.0	6	11
Carbon dioxide	Water	1.96	1	1, 3, 5, 20, 24, 28
Carbon disulfide (50 mole %, 200 atm.)	n-Butanol	3.57	14	
Carbon disulfide (50 mole %, 200 atm.)	i-Butanol	2.42	14	
Carbon disulfide (50 mole %, 218 atm.)	Chlorobenzene	3.00	14	
Carbon disulfide (50 mole %, 200 atm.)	2,4-Dimethyl pentane	3.63	14	
Carbon disulfide (50 mole %, 100 atm.)	n-Heptane	3.0	14	
Carbon disulfide (50 mole %, 50 atm.)	Methyl cyclohexane	3.5	14	
Carbon disulfide (50 mole %, 200 atm.)	n-Octane	3.10	14	
Carbon disulfide (50 mole %)	Toluene	2.06	14	
Carbon tetrachloride	Benzene	2.04	3	7, 9
Carbon tetrachloride*	Cyclohexane	1.49	2	9, 10*
Carbon tetrachloride	Decalin	0.776	2	9
Carbon tetrachloride	Dioxane	1.02	2	9
Carbon tetrachloride*	Ethanol	1.50	2	9, 10*
Carbon tetrachloride	n-Heptane	3.17	2	9
Carbon tetrachloride	Kerosene	0.961	2	9
Carbon tetrachloride	Methanol	2.30	2	9
Carbon tetrachloride	i-Octane	2.57	2	9
Carbon tetrachloride	Tetralin	0.735	2	9
Chloral*	Ethanol	0.68	5	11
Chloral hydrate	Water	0.77	7	11

TABLE 2-372 Diffusivities in Liquids (25°C) (Continued)

Dilute solutions and 1 atm unless otherwise noted; use $D_L \mu/T = \text{constant}$ to estimate effect of temperature; ° indicates that reference gives effect of concentration.

Solute	Solvent	$D_L \times 10^5$, sq cm/sec	Estimated possible, error, ± % ¹	Ref.
Chlorine	Water	1.44	4	1, 28
Chlorobenzene	Benzene	2.66	25	
Chloroform	Benzene	2.50	6	1, 25
Chloroform	Ethanol	1.38	3	11
Cinnamic acid	Acetone	2.41	4	
Cinnamic acid	Benzene	1.12	4	
Cinnamic acid	Carbon tetrachloride	0.76	4	
Cinnamic acid	Toluene	2.41	4	
1,1'-Dichloropropanol	Water	1.0	6	11
Dicyanodiamide°	Water	1.18	4	11
Diethyl ether	Benzene	2.73	25	
Diethyl ether	Water	0.85	2	
2,4-Dimethyl pentane (50 mole %)	<i>n</i> -Dodecane	1.44	26	
2,4-Dimethyl pentane (50 mole %)	<i>n</i> -Hexadecane	0.88	26	
Ethanol°	Water	1.28	4	1, 7, 9, ° 11, ° 22
Ethyl acetate	Ethyl benzoate	0.94	6	
Ethylene dichloride	Benzene	2.8	1, 25	
Formic acid	Acetone	3.77	4	
Formic acid	Benzene	2.28	4	
Formic acid	Carbon tetrachloride	1.89	4	
Formic acid	Ethylene glycol	0.094	4	
Formic acid	Toluene	2.65		
Formic acid	Water	1.37	10	11
Glucose	Water	0.69	6	11
Glycerol	<i>i</i> -Amyl alcohol	0.12	11	
Glycerol	Ethanol	0.56	11	
Glycerol°	Water	0.94	6	1, 11°
<i>n</i> -Heptane (50 mole %)	<i>n</i> -Dodecane	1.58	26	
<i>n</i> -Heptane (50 mole %)	<i>n</i> -Hexadecane	1.00	26	
<i>n</i> -Heptane (50 mole %)	<i>n</i> -Octadecane	0.92	26	
<i>n</i> -Heptane (50 mole %)	<i>n</i> -Tetradecane	1.29	26	
Hexamethylene tetramine	Water	0.67	11	
Hydrogen chloride°	Water	3.10	3	4, 11, ° 12°
Hydrogen	Water	5.85 (4.4)		1, 11, 24(?)
Hydrogen sulfide	Water	1.61	1	
Hydroquinone°	Ethanol	0.53	5	11
Hydroquinone°	Water	0.88, 1.12		2, 11°
Iodine	Acetic acid	1.13		11
Iodine	Anisole	1.25		11
Iodine	Benzene	1.98		9, 19, 23
Iodine	Bromobenzene	1.25	10	4, 11, 19
Iodine	Carbon disulfide	3.2		11, 19, 23
Iodine	Carbon tetrachloride	1.45	8	9, 11, 19
Iodine	Chloroform	2.30	3	11, 23
Iodine	Cyclohexane	1.80		4
Iodine	Dioxane	1.07		9
Iodine°	Ethanol	1.30		4, 11°
Iodine	Ethyl acetate	2.2		11, 19
Iodine	Ethyl ether	3.61		11
Iodine	Ethylene bromide	0.93		11
Iodine	<i>n</i> -Heptane	3.4, 2.5		9, 11, 19
Iodine	<i>n</i> -Hexane	4.15		4, 9
Iodine	Mesitylene	1.49		9
Iodine	Methanol	1.74		19
Iodine	Methyl cyclohexane	2.1		4
Iodine	<i>n</i> -Octane	2.76		4
Iodine	Tetrabromoethane	2.0		11
Iodine	<i>n</i> -Tetradecane	0.96		4
Iodine	Toluene	2.1		11
Iodine	<i>m</i> -Xylene	1.82		9, 11
Iodobenzene	Ethanol	1.09	3	11
Lactose°	Water	0.49	5	11
Maltose°	Water	0.48	5	11
Mannitol°	Water	0.65	5	11
Methanol	Water	1.6		1, 7, 11
Nicotine°	Water	0.60	8	11
Nitric acid°	Water	2.98	2	11
Nitrobenzene	Carbon tetrachloride	1.00		7
Nitrogen	Water	1.9		1, 24
Nitrous oxide	Water	1.8		1, 11
Oxalic acid°	Water	1.61	2	11

TABLE 2-372 Diffusivities in Liquids (25°C) (Concluded)

Dilute solutions and 1 atm unless otherwise noted; use $D_L \mu/T = \text{constant}$ to estimate effect of temperature; * indicates that reference gives effect of concentration.

Solute	Solvent	$D_L \times 10^5$, sq cm/sec	Estimated possible, error, $\pm \% 1$	Ref.
Oxygen	Glycerol*-water (106 poise)	0.24		13
Oxygen	Sucrose*-water (125 poise)	0.25		13
Oxygen	Water	2.5	20	1, 3, 15, 21, 24
Pentaerythritol*	Water	0.77	4	11
Phenol	<i>i</i> -Amyl alcohol	0.2		11
Phenol	Benzene	1.68		1
Phenol	Carbon disulfide	3.7		11
Phenol	Chloroform	2.0		11
Phenol	Ethanol	0.89		11
Phenol	Ethyl ether	3.9		11
<i>n</i> -Propanol	Water	1.1		1, 7, 11
Pyridine*	Ethanol	1.24	3	11
Pyridine	Water	0.76	7	11
Pyrogallol	Water	0.74	7	11
Raffinose*	Water	0.41	4	11
Resorcinol*	Ethanol	0.46	5	11
Resorcinol*	Water	0.87	4	11
Saccharose*	Water	0.49	4	11
Stearic acid*	Ethanol	0.65	5	11
Succinic acid*	Water	0.94		11
Sucrose	Water	0.56	6	2, 27
Sulfur dioxide	Water	1.7		15, 17
Sulfuric acid*	Water	1.97	3	11
Tartaric acid*	Water	0.80	10	11
1,1,2,2-Tetrabromoethane	1,1,2,2-Tetra-chloroethane	0.61	4	11
Toluene	<i>n</i> -Decane	2.09		4
Toluene	<i>n</i> -Dodecane	1.38		4
Toluene	<i>n</i> -Heptane	3.72		4
Toluene	<i>n</i> -Hexane	4.21		4
Toluene	<i>n</i> -Tetradecane	1.02		4
Urea	Ethanol	0.73		11
Urea	Water	1.37	2	8, 11
Urethane	Water	1.06		11, 25
Water	Glycerol	0.021		16

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TABLE 2-373 Thermal Conductivities of Some Building and Insulating Materials*

Material	Apparent density ρ , lb/ft ³ at room temperature	t , °C	k	Material	Apparent density ρ , lb/ft ³ at room temperature	t , °C	k
Aerogel, silica, opacified	8.5	120	0.013	Cotton wool	5	30	0.024
		290	.026	Cork board	10	30	.025
Asbestos-cement boards	120	20	.43	Cork (regranulated)	8.1	30	.026
Asbestos sheets	55.5	51	.096	(ground)	9.4	30	.025
Asbestos slate	112	0	.087	Diatomaceous earth powder, coarse	20.0	38	.036
	112	60	.114	(Note 2)	20.0	871	.082
Asbestos	29.3	-200	.043	fine (Note 2)	17.2	204	.040
	29.3	0	.090	molded pipe covering (Note 2)	17.2	871	.074
	36	0	.087	4 vol. calcined earth and 1 vol. cement, poured and fired (Note 2)	26.0	204	.051
	36	100	.111		26.0	871	.088
	36	200	.120				
	36	400	.129	Dolomite	61.8	204	.16
	43.5	-200	.090	Ebonite	61.8	871	.23
	43.5	0	.135	Enamel, silicate	167	50	1.0
Aluminum foil (7 air spaces per 2.5 in.)	0.2	38	.025	Felt, wool			.10
		177	.038	Fiber insulating board			0.5-0.75
Ashes, wood		0-100	.041	Fiber, red			0.03
Asphalt	132	20	.43	(with binder, baked)			.028
Boiler scale (Note 1)				Gas carbon			.20-0.97
Bricks:				Glass			0-100
Alumina (92-99% Al ₂ O ₃ by wt.) fused		427	1.8	Borosilicate type	139	30-75	2.0
Alumina (64-65% Al ₂ O ₃ by wt.)		1315	2.7	Window glass			0.2-0.73
(See also Bricks, fire clay)		115	800	Soda glass			0.3-0.61
Building brick work		115	1100	Granite			0.3-0.44
Carbon		20	.63	Graphite, longitudinal			1.0-2.3
Chrome brick (32% Cr ₂ O ₃ by wt.)	96.7		.4	powdered, through 100 mesh			
	200	200	3.0	Gypsum (molded and dry)	30	40	0.104
Diatomaceous earth, natural, across strata (Note 2)	200	650	.85	Hair felt (perpendicular to fibers)	78	20	.25
	200	1315	1.0	Ice	17	30	.021
	27.7	204	0.051	Infusorial earth, see diatomaceous earth	57.5	0	1.3
Diatomaceous, natural, parallel to strata (Note 2)	27.7	871	.077	Kapok			0.020
	27.7	204	.081	Lampblack	0.88	40	.038
Diatomaceous earth, molded and fired (Note 2)	27.7	871	.106	Lava	10	40	.49
	38	204	.14	Leather, sole	62.4		.092
Diatomaceous earth and clay, molded and fired (Note 2)	38	871	.18	Limestone (15.3 vol. % H ₂ O)	103	24	.54
	42.3	204	.14	Linen			.05
Diatomaceous earth, high burn, large pores (Note 3)	42.3	871	.19	Magnesia (powdered)	49.7	47	.35
	37	200	.13	Magnesia (light carbonate)	13	21	0.034
Fire clay (Missouri)	37	1000	.34	Magnesium oxide (compressed)	49.9	20	.32
		600	.58	Marble			1.2-1.7
		1000	.85	Mica (perpendicular to planes)	50	0.25	
Kaolin insulating brick (Note 3)		1000	.95	Mill shavings			0.033-0.05
		1400	1.02	Mineral wool	9.4	30	0.0225
Kaolin insulating firebrick (Note 4)	27	500	0.15	Paper	19.7	30	.024
	27	1150	.26	Paraffin wax			.075
Magnesite (86.8% MgO, 6.3% Fe ₂ O ₃ , 3% CaO, 2.6% SiO ₂ by wt.)	19	200	.050	Petroleum coke	0	.14	
	19	760	.113	Porcelain	100	34	
Silicon carbide brick, recrystallized (Note 3)	158	204	2.2	Portland cement, see concrete	500	2.9	
	158	650	1.6	Pumice stone	200	0.88	
	158	1200	1.1	Pyroxylin plastics	90	.17	
				Rubber (hard)	21-66	.14	
				(para)			.075
				(soft)			
Calcium carbonate, natural	129	600	10.7	Sand (dry)	94.6	21	0.075-0.092
White marble	129	800	9.2	Sandstone	20	0.19	
Chalk	129	1000	8.0	Sawdust	140	40	.106
Calcium sulfate (4H ₂ O), artificial plaster (artificial)	129	1200	7.0	Scale (Note 1)	12	21	.03
(building)	77.9	1400	6.3	Silk			
Cambric (varnished)		38	1.3	varnished	6.3		.026
Carbon, gas		0-100	1.7	Slag, blast furnace	38		.096
Carbon stock	94	-184	0.4	Slag wool	24-127		.064
		0	.55	Slate	12		.022
Cardboard, corrugated			3.6	Snow	30		.86
			0.037	Sulfur (monoclinic)	94		.27
				(rhombic)	34.7	0	
				Wall board, insulating type	100		0.09-0.097
				Wall board, stiff paste board	14.8	21	.028
				Wood shavings	43	30	.04

2-334 PHYSICAL AND CHEMICAL DATA

TABLE 2-373 Thermal Conductivities of Some Building and Insulating Materials* (Concluded)
 $k = \text{Btu}/(\text{h}\cdot\text{ft}^2)\text{(^{\circ}F}/\text{ft})$

Material	Apparent density ρ , lb/ft ³ at room temperature	t , °C	k	Material	Apparent density ρ , lb/ft ³ at room temperature	t , °C	k
Celluloid	87.3	30	.12	Wood (across grain):			
Charcoal flakes	11.9	80	.043	Balsa	7–8	30	0.025–0.03
	15	80	.051	Oak	51.5	15	0.12
Clinker (granular)		0–700	.27	Maple	44.7	50	.11
Coke, petroleum		100	3.4	Pine, white	34.0	15	.087
		500	2.9	Teak	40.0	15	.10
Coke, petroleum (20–100 mesh)	62	400	0.55	White fir	28.1	60	.062
Coke (powdered)		0–100	.11	Wood (parallel to grain):			
Concrete (cinder)			.20	Pine	34.4	21	.20
(stone)			.54	Wool, animal	6.9	30	.021
(1:4 dry)			.44				

*Marks, *Mechanical Engineers' Handbook*, 4th ed., McGraw-Hill, New York, 1941. *International Critical Tables*, McGraw-Hill, 1929, and other sources.

Note 1: B. Kamp [Z. techn. Physik, 12, 30 (1931)] shows the effect of increased porosity in decreasing thermal conductivity of boiler scale. Partridge [University of Michigan Eng. Research Bull., 15, 1930] has published a 170-page treatise on Formation and Properties of Boiler Scale.

Note 2: Townshend and Williams, *Chem. & Met.*, 39, 219 (1932).

Note 3: Norton, *Refractories*, 2d ed., McGraw-Hill, New York, 1942.

Note 4: Norton, private communication.

TABLE 2-374 Thermal-Conductivity-Temperature Table for Metals*

Thermal conductivities tabulated in watts per meter-kelvin

Substance	Temperature, K														
	10	20	40	60	80	100	200	300	400	500	600	800	1000	1200	1400
Alumina	7	32	121	174	160	125	55	36	26	20	16	10	8	7	6
Aluminum	38,000	13,500	2,300	850	380	300	237	273	240	237	232	220	93	99	105
Antimony	470	230	110	80	60	48	32	26	22	20					
Beryllium oxide	47	196	810	1,400	1,650	1,490	480	272	196	146	111	70	47	33	25
Bismuth	240	100	45	31	24	22	18	16	14	12					
Boron	165	305	400	327	230	170	45	25	15	12					
Cadmium	900	250	150	120	110	110	105	104	101	99					
Chromium	400	570	450	250	180	158	111	90	87	85	81	71	65	62	61
Cobalt	250	450	380	250	190	160	120	100	85	70					
Constantan	4	9	16	18	19	20	23	25	27	30					
Copper	19,000	10,700	2,100	850	570	483	413	398	392	388	383	371	357	342	
Gallium	2,200	640	250	200	170	140	100	85							
Gold	2,800	1,500	520	380	350	345	327	315	312	309	304	292	278	262	
Graphite†	27	108	135	81	54	39	15	10	7	5	4	3	3	2	2
Graphite‡	81	420	1,630	2,980	4,290	4,980	3,250	2,000	1,460	1,140	930	680	530	440	370
Hastelloy	1	3	4	5	6	7	9	10	11	13					
Inconel	2	4	8	10	11	11	14	15							
Iridium	1,300	1,900	750	360	230	172	147	145	143	140					
Iron	710	1,000	560	270	170	132	94	80	69	61	55	43	33	28	31
Lead	175	57	43	42	41	40	37	35	34	33	31	19	22	24	26
Magnesium	1,200	1,300	620	290	190	169	159	156	153	151	149	146	84	98	112
Magnesium oxide	1,100	3,100	2,200	950	460	260	75	48	36	27	21	13	10	8	7
Manganese	2	2	4	5	5	6	7	8	9	9					
Manganin	2	4	9	11	13	13	17	22	28	34	40				
Mercury	54	40	35	33	33	32	32	8	10	11	12	13	14		
Molybdenum	150	280	350	250	210	179	143	138	134	130	126	118	112	105	100
Nickel	2,600	1,700	570	290	200	158	106	91	80	72	66	67	72	76	80
Nylon	0.04	0.10	0.17	0.20	0.23	0.25	0.28	0.30							
Palladium	1,200	610	160	100	88	80	78	78	78	80					
Platinum	1,200	490	130	92	82	79	75	73	72	72	72	73	78	78	81
PTFE§	0.94	1.43	1.94	2.1	2.15	2.16	2.20	2.25	2.3	2.5					
Pyrex	0.12	0.20	0.33	0.42	0.51	0.57	0.88	1.1	1.6	2.1					
Quartz	1,200	480	82	40	30										
Rhodium	2,900	3,900	1,000	370	250	190	160	150	145	140					
Rubber				0.13	0.15	0.16	0.17	0.20	0.22	0.24	0.25				
Selenium (axis)	140	57	25	15	10	8	6	4	3	2					
Silica								1.34	1.52	1.70	1.87	2.22	2.60	358	
Silver	16,500	5,200	1,100	630	500	430	425	424	420	413	405	389	374	358	
Tantalum	108	146	88	68	62	59	58	57	58	58	59	59	60	61	62
Tellurium	300	93	29	17	13	11	6	4	3	3					
Tin		320	130	101	90	84	72	67	62	60					
Titanium	14	28	39	37	33	31	26	21	20	20	19				
Tungsten		880	330	310	280	190	180	170	150	140					
Uranium				20	22	23	26	28	30	32					
Zinc				150	135	130	123	120	116	110	110				
Zirconium	100	110	59	42	38	34	25	23	22	21	21				

* Especially at low temperatures, the thermal conductivity can often be markedly reduced by even small traces of impurities. This table, for the highest-purity specimens available, should thus be used with caution in applications with commercial materials. From Perry, *Engineering Manual*, 3d ed., McGraw-Hill, New York, 1976. A more detailed table appears as Section 5.5.6 in the *Heat Exchanger Design Handbook*, Hemisphere Pub. Corp., Washington, DC, 1983.

† Parallel to basal plane.

‡ Perpendicular to basal plane.

§ Also known as Teflon, etc.

TABLE 2-375 Thermal Conductivity of Chromium Alloys*
 $k = \text{Btu}/(\text{h}\cdot\text{ft}^2)(^\circ\text{F}/\text{ft})$

American Iron and Steel Institute Type No.	k at 212°F	k at 932°F
301, 302, 302B, 303, 304, 316†	9.4	12.4
308	8.8	12.5
309, 310	8.0	10.8
321, 347	9.3	12.8
403, 406, 410, 414, 416†	14.4	16.6
430, 430F†	15.1	15.2
442	12.5	14.2
501, 502†	21.2	19.5

* Table 3-322 is based on information from manufacturers.

† Shelton and Swanger (National Bureau of Standards), *Trans. Am. Soc. Steel Treat.*, **21**, 1061–1078 (1933).**TABLE 2-376 Thermal Conductivity of Some Alloys
at High Temperature***

°R	Thermal conductivity, Btu/(ft)(hr)(°R)					
	Kovar	Advance	Monel	Hastelloy A	Inconel	Nichrome V
500	7.8		9.0	5.6	6.0	5.5
600	8.3	11.4	10.2	6.2	6.5	6.1
700	8.6	12.6	11.2	6.8	7.0	6.7
800	8.7	13.9	12.3	7.3	7.6	7.3
900	8.7	15.1	13.4	7.8	8.1	7.8
1000	8.9	16.4	14.4	8.4	8.6	8.4
1100	9.2	17.6	15.4	9.0	9.1	9.0
1200	9.5	18.8	16.5	9.5	9.7	9.5
1300	9.8	20.0	17.6	10.1	10.2	10.1
1400	10.2	21.2	18.7	10.7	10.8	10.7
1500	10.5	22.5	19.8	11.3	11.3	11.3
1600	10.8	23.8	20.8	11.8	11.8	11.9
1700	11.1	25.0	21.9	12.3	12.4	12.4
1800	11.3	26.2	23.0	12.9	13.0	13.0
1900	11.5	27.4	24.0	13.4	13.6	13.5
2000	11.8	28.7	25.1	14.0	14.0	14.1
2100	12.1	30.0	26.1	14.6	14.5	14.7
2200	12.3		27.2	15.1	15.0	15.3

* Silverman, *J. Metals*, **5**, 631 (1953). Copyright American Institute of Mining, Metallurgical and Petroleum Engineers, Inc.**TABLE 2-377 Thermal Conductivities of Some Materials for Refrigeration and Building Insulation***
 $k = \text{Btu}/(\text{h}\cdot\text{ft}^2)(^\circ\text{F}/\text{ft})$ at approximately room temperature

Material	Apparent density, lb/cu ft room temp.	k
Soft flexible materials in sheet form:		
Chemically treated wood fiber	2.2	0.023
Eel grass between paper	3.4–4.6	0.021–0.022
Felted cattle hair	11–13	0.022
Flax fibers between paper	4.9	.023
Hair and asbestos fibers, felted	7.8	.023
Insulating hair, and jute	6.1–6.3	0.022–0.023
Jute and asbestos fibers, felted	10.0	0.031
Loose materials:		
Cork, regranulated, fine particles	8–9	.025
Charcoal, 6 mesh	15.2	.031
Diatomaceous earth, powdered	10.6	.026
Glass wool, curled	4–10	.024
Gypsum in powdered form	26–34	0.043–0.05
Mineral wool, fibrous	6	0.0217
	10	.0225
	14	.0233
	18	.0242
Sawdust	12	.034
Wood shavings, from planer	8.8	.034
Semiflexible materials in sheet form:		
Flax fiber	13.0	.026
Semirigid materials in board form:		
Corkboard	7.0	.0225
	10.6	.025
Mineral wool, block, with binder	16.7	.031
Stiff fibrous materials in sheet form:		
Wood pulp	16.2–16.9	.028
Sugar-cane fiber	13.2–14.8	.028
Cellular gypsum		
	8	.029
	12	.037
	18	.049
	24	.064
	30	.083

* Abstracted from *U.S. Bur. Standards Letter Circ.* **227**, Apr. 19, 1927.**TABLE 2-378 Thermal Conductivities of Insulating Materials at High Temperatures***
 $k = \text{Btu}/(\text{h}\cdot\text{ft}^2)(^\circ\text{F}/\text{ft})$

Material	For tem- peratures, °F up to	Mean temperatures, °F									
		100	200	300	400	500	600	800	1000	1500	2000
Laminated asbestos felt (approx. 40 laminations per in.)	700	0.033	0.037	0.040	0.044	0.048					
Laminated asbestos felt (approx. 20 laminations per in.)	500	.045	.050	.055	.060	.065					
Corrugated asbestos (4 plies per in.)	300	.050	.058	.069							
85% magnesia (density, 13 lb/ft ³)	600	.034	.036	.038	.040						
Diatomaceous earth, asbestos and bonding material	1600	.045	.047	.049	.050	.053	.055	.060	.065		
Diatomaceous earth brick	1600	.054	.056	.058	.060	.063	.065	.069	.073		
Diatomaceous earth brick	2000	.127	.130	.133	.137	.140	.143	.150	.158	0.176	
Diatomaceous earth brick	2500	.128	.131	.135	.139	.143	.148	.155	.163	.183	0.203
Diatomaceous earth powder (density, 18 lb/ft ³)		.039	.042	.044	.048	.051	.054	.061	.068		
Rock wool		.030	.034	.039	.044	.050	.057				

Asbestos cement, 1.2; 85% magnesia cement, 0.05; asbestos and rock wool cement, 0.075 approx.

* Marks, "Mechanical Engineers' Handbook," 4th ed., McGraw-Hill, New York, 1941.

2-336 PHYSICAL AND CHEMICAL DATA

TABLE 2-379 Thermal Conductivities of Insulating Materials at Moderate Temperatures (Nusselt)*

$k = \text{Btu}/(\text{h}\cdot\text{ft}^2)(^\circ\text{F}/\text{ft})$

Material	Weight, lb/cu ft	Temperatures, °F						
		32	100	200	300	400	600	800
Asbestos	36.0	0.087	0.097	0.110	0.117	0.121	0.125	0.130
Burned infusorial earth for pipe coverings	12.5	.043	.046	.052	.057	.062	.073	.085
Insulating composition (loose)	25.0	.040	.046	.050	.053	.055		
Cotton	5.0	.032	.035	.039				
Silk hair	9.1	.026	.030	.034				
Silk	6.3	.025	.028	.034				
Wool	8.5	.022	.027	.033				
Pulverized cork	10.0	.021	.026	.032				
Infusorial earth (loose)	22.0	.035	.039	.045	.047	.050	.053	

*Marks, *Mechanical Engineers' Handbook*, 4th ed., McGraw-Hill, New York, 1941.

TABLE 2-380 Thermal Conductivities of Insulating Materials at Low Temperatures (Gröber)*

$k = \text{Btu}/(\text{h}\cdot\text{ft}^2)(^\circ\text{F}/\text{ft})$

Material	Weight, lb/cu ft	Temperatures, °F				
		32	-50	-100	-200	-300
Asbestos	44.0	0.135	0.132	0.130	0.125	0.100
Asbestos	29.0	.0894	.0860	.0820	.0720	.0545
Cotton	5.0	.0325	.0302	.0276	.0235	.0198
Silk	6.3	.0290	.0256	.0235	.0196	.0155

*Marks, *Mechanical Engineers' Handbook*, 4th ed., McGraw-Hill, New York, 1941.

TABLE 2-381 Thermal Diffusivity (m^2/s) of Selected Elements*

Element	Temperature, K									
	20	40	60	80	100	200	400	600	800	1000
Aluminum	0.50	0.012	0.0014	4.4. - 4	2.3. - 4	1.1. - 4	9.4. - 5	8.4. - 5	7.4. - 5	6.6. - 5
Beryllium					0.0036	1.5. - 4	4.0. - 5	2.6. - 5	2.1. - 5	1.7. - 5
Chromium	0.038	0.0037	5.9. - 4	2.0. - 4	1.2. - 4	4.1. - 5	2.6. - 5	2.0. - 5	1.7. - 5	1.4. - 5
Copper	0.16	0.0040	6.9. - 4	3.1. - 4	2.2. - 4	1.3. - 4	1.1. - 4	1.0. - 4	9.0. - 5	9.0. - 5
Gold	0.005	4.5. - 4	2.3. - 4	1.8. - 4	1.5. - 4	1.3. - 4	1.2. - 4	1.2. - 4	1.1. - 4	9.8. - 5
Iridium	0.046				8.4. - 5	5.6. - 5	4.8. - 5	4.4. - 5	4.1. - 5	3.5. - 5
Iron	0.043	3.2. - 3	4.9. - 4	1.6. - 4	8.2. - 5	3.1. - 5	1.8. - 5	1.3. - 5	1.1. - 5	1.0. - 5
Lead	9.3. - 5	3.9. - 5	3.3. - 5	3.1. - 5	2.9. - 5	2.6. - 5	2.3. - 5	2.0. - 5	1.3. - 5	1.5. - 5
Molybdenum	0.0095	0.0014	4.0. - 4	2.0. - 4	1.3. - 4	6.3. - 5	5.1. - 5	4.5. - 5	4.2. - 5	3.8. - 5
Nickel	0.033	0.0017	3.1. - 4	1.3. - 4	8.0. - 5	3.1. - 5	1.9. - 5	1.3. - 5	1.4. - 5	1.5. - 5
Platinum	0.0029	1.6. - 4	6.3. - 5	4.3. - 5	3.6. - 5	2.7. - 5	2.5. - 5	2.5. - 5	2.5. - 5	2.5. - 5
Silver	0.031	0.0013	4.5. - 4	2.8. - 4	2.3. - 4	1.8. - 4	1.7. - 4	1.6. - 4	1.5. - 4	1.4. - 4
Zinc	0.0046	3.1. - 4	1.0. - 4	7.0. - 5	5.5. - 5	4.7. - 5	3.9. - 5	3.4. - 5	1.8. - 5	2.2. - 5

*Tables for up to 24 temperatures for 47 elements appear in the *Handbook of Heat Transfer*, 2d ed., McGraw-Hill, New York, 1984. The notation 3.2. - 4 signifies 2.3×10^{-4} .

TABLE 2-382 Thermophysical Properties of Selected Nonmetallic Solid Substances

Material	Density, kg/m ³	Emissivity	Specific heat, kJ/(kg K)	Thermal conductivity, W/(m·K)	Thermal diffusivity, m ² /s × 10 ⁶
Alumina	3975		0.765	36	11.9
Asphalt	2110		0.920	0.06	0.03
Bakelite	1300		1.465	1.4	0.74
Beryllia	3000	0.82	1.030	270	88
Brick	1925	0.93	0.835	0.72	0.45
Brick, fireclay	2640	0.93	0.960	1.0	0.39
Carbon, amorphous	1950	0.86	0.724	1.6	1.13
Clay	1460	0.91	0.880	1.3	1.01
Coal	1350	0.80	1.26	0.26	0.15
Cotton	80		1.30	0.06	0.58
Diamond	3500		0.509	2300	1290
Granite	2630		0.775	2.79	1.37
Hardboard	1000		1.38	0.15	0.11
Magnesite	3025	0.38	1.13	4.0	1.2
Magnesia	3635	0.72	0.943	48	14
Oak	770	0.90	2.38	0.18	0.10
Paper	930	0.83	1.34	0.011	0.01
Pine	525	0.84	2.75	0.12	0.54
Plaster board	800	0.91		0.17	
Plywood	540		1.22	0.12	0.18
Pyrex	2250	0.92	0.835	1.4	0.74
Rubber	1150	0.92	2.00	0.2	0.09
Rubber, foam	70	0.90		0.03	
Salt		0.34	0.854	7.1	
Sandstone	2150	0.59	0.745	2.9	1.8
Silica		0.79	0.743	1.3	
Sapphire	3975	0.48	0.765	46	15
Silicon carbide	3160	0.86	0.675	490	230
Soil	2050	0.38	1.84	0.52	0.14
Teflon	2200	0.92	0.35	0.26	0.34
Thorium	4160	0.28	0.71	14	4.7
Urethane foam	70		1.05	0.03	0.36
Vermiculite	120		0.84	0.06	0.60

NOTE: Difficulties of accurately characterizing many of the specimens mean that many of the values presented here must be regarded as being of order of magnitude only. For some materials, actual measurement may be the only way to obtain data of the required accuracy. To convert kilograms per cubic meter to pounds per cubic foot, multiply by 0.062428; to convert kilojoules per kilogram-kelvin to British thermal units per pound-degree Fahrenheit, multiply by 0.23885.

PREDICTION AND CORRELATION OF PHYSICAL PROPERTIES

INTRODUCTION

In the absence of reliable experimental data, the methods presented here provide physical property estimates that are sufficiently accurate for many engineering applications. These techniques have been selected on the basis of accuracy, generality, and, in most cases, simplicity; they are divided into 11 categories: (1) pure component constants: critical properties, normal freezing and boiling temperatures, acentric factor, radius of gyration, dipole moment, and van der Waals area and volume; (2) vapor pressure; (3) ideal gas thermal properties: heat capacity and enthalpy, Gibbs energy, and entropy of formation; (4) enthalpy of vaporization and fusion; (5) solid and liquid heat capacity; (6) vapor, liquid, and solid density; (7) vapor and liquid viscosity; (8) vapor and liquid thermal conductivity; (9) vapor and liquid diffusivity; (10) surface tension; and (11) flammability properties: flash point, flammability limits, and autoignition temperature. The definition of the property and limitations and accuracy of each method of correla-

tion or prediction are given for each property. Numerical examples are included for many of the methods. Equation symbols are listed under "Nomenclature," and literature citations, indicated by superscript numbers, follow the nomenclature under "References." Essentially all of the methods are derived from work on the *American Petroleum Institute Technical Data Book*²³ (hydrocarbon compounds and their mixtures), the AIChE Design Institute for Physical Property Data (DIPPR) *Data Prediction Manual*²² (nonhydrocarbon compounds and their mixtures), and the DIPPR Data Compilation Project²⁴.

UNITS

Applicable dimensional units are shown individually with each equation. The International Metric System (SI) is used when feasible; otherwise commonly used U.S. engineering units are employed. The reader is referred to Sec. 1 for unit conversion factors.

Nomenclature

Symbol	Definition	SI units	U.S. customary units
<i>B</i>	Second virial coefficient	m^3/kmol	$\text{ft}^3/\text{lbfmol}$
C_p	Heat capacity at constant pressure	$\text{J}/(\text{kmol}\cdot\text{K})$	$\text{Btu}/(\text{lbfm } ^\circ\text{F})$
C_v	Heat capacity at constant volume	kg/m^3	lbfm/ft^3
<i>d</i>	Mass density	m^3/s	ft^2/s
<i>D</i>	Diffusivity		
<i>F</i>	Conductivity factor in Eq. (2-136)		
<i>k</i>	Thermal conductivity		
<i>K</i>	Watson/UOP characterization factor = $(1.8T_b)^{1/3}/\text{rel den}$	$\text{W}/(\text{m}\cdot\text{K})$	$\text{Btu}/(\text{h}\cdot\text{ft } ^\circ\text{F})$
<i>ln</i>	Denotes natural logarithm		
<i>M</i>	Molecular weight		
<i>MeABP</i>	Mean average boiling point		
<i>N</i>	Carbon number		
<i>N_A</i>	Avogadro's number		
<i>P</i>	Pressure	Pa	lbf/in^2
P^{sat}	Vapor pressure	Pa	lbf/in^2
[<i>P</i>]	Parachor		
<i>rel den</i>	Relative density at 15°C and 0.1 MPa		
<i>R</i>	Universal gas constant; e.g., 8314 Pa·m ³ /kmol K		
\bar{R}	Radius of gyration		
<i>S</i>	Absolute entropy	J/kg	Btu/lbfm
<i>T</i>	Absolute temperature	K	R
<i>V</i>	Molar volume	m^3/kmol	$\text{ft}^3/\text{lbfmole}$
<i>x</i>	Mole fraction of component in liquid phase		
<i>y</i>	Mole fraction of component in vapor phase		
<i>Z</i>	Compressibility factor = PV/RT		

Greek symbols

ΔG_f	Gibbs energy of formation	J/kg	Btu/lbfm
ΔH_f	Enthalpy (heat) of formation	J/kg	Btu/lbfm
ΔH_{fus}	Enthalpy (heat) of fusion	J/kg	Btu/lbfm
ΔH_V	Enthalpy (heat) of vaporization	J/kg	Btu/lbfm
ΔS_f	Entropy of formation	$\text{J}/(\text{kg}\cdot\text{K})$	Btu/lbfm
ΔS_{fus}	Entropy of fusion	$\text{J}/(\text{kg}\cdot\text{K})$	Btu/lbfm
ΔZ_V	Difference of vapor and liquid compressibility factors defined in Eq. (2-55)		
Θ	T_b/T_c		
λ	Dipole moment		
μ	Absolute viscosity	$\text{Pa}\cdot\text{s}$	$\text{lbf}/(\text{ft}\cdot\text{s})$
ν	Kinematic viscosity	m^2/s	ft^2/s
ρ	Molar density	kmol/m^3	$\text{lb-mole}/\text{ft}^3$
σ	Surface tension	N/m	dyne/cm
ϕ	Volume fraction		
ω	Acentric factor		

Superscripts

<i>r</i>	At reference condition
(0)	Simple spherical molecule, corresponding states
(1)	Correction factor, corresponding states
$^\circ$	Of the ideal gas
,	At atmospheric pressure

Subscripts

<i>b</i>	At normal boiling temperature
<i>bp</i>	At bubble point
<i>c</i>	At critical point
<i>G</i>	Of the gas/vapor
<i>HI</i>	Upper limit
<i>i</i>	Component index, of the <i>i</i> th component
<i>j</i>	Component index, of the <i>j</i> th component
<i>L</i>	Of the liquid
<i>m</i>	Of the mixture
<i>mc</i>	Mixture correspondence
<i>mlt</i>	At melting temperature
<i>o</i>	Of organic component
<i>pc</i>	Pseudocritical quantity
<i>r</i>	Reduced quantity
<i>RA</i>	Rackett parameter
<i>sat</i>	Saturated
<i>S</i>	Of the solid
<i>V</i>	Of the vapor
<i>w</i>	Of water

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PURE COMPONENT CONSTANTS

Basic pure component constants required to characterize components or mixtures for calculation of other properties include the melting point, normal boiling point, critical temperature, critical pressure, critical volume, critical compressibility factor, acentric factor, and several other characterization properties. This section details for each property the method of calculation for an accurate technique of prediction for each category of compound, and it references other accurate techniques for which space is not available for inclusion.

Critical Temperature The critical temperature of a compound is the temperature above which a liquid phase cannot be formed, no matter what the pressure on the system. The critical temperature is important in determining the phase boundaries of any compound and is a required input parameter for most phase equilibrium thermal property or volumetric property calculations using analytic equations of state or the theorem of corresponding states. Critical temperatures are predicted by various empirical methods according to the type of compound or mixture being considered.

For **pure hydrocarbons**, the method of Ambrose² is the most accurate and will also be useful for predicting critical pressure and volume. Equation (2-1) requires only the normal boiling point, T_b , and the molecular structure of the compound.

$$T_c = T_b \left[1 + \frac{1}{1.242 + \sum \Delta_T - 0.023\Delta(\text{Platt no.})} \right] \quad (2-1)$$

T_c and T_b are the critical and normal boiling temperatures, respectively, expressed in kelvins. Values of Δ_T from Table 2-383 are summed for each part of the molecule to yield $\sum \Delta_T$ (e.g., for isobutane, $3 \times -\text{CH}_3 + 1 \times >\text{CH}-$). $\Delta(\text{Platt no.})$ is equal to the Platt number of any alkyl chains in the molecule minus the Platt number of the *n*-alkane with the same number of carbon atoms. The Platt number is defined as the number of pairs of carbon atoms that are separated by three carbon-carbon bonds and is an indicator of branching (e.g., for 2,2,3-trimethylpentane, the Platt number is 5). The Platt number of an *n*-alkane is the number of carbon atoms minus three (e.g., for *n*-octane, the Platt number is five). Errors in T_c average about 4 K for paraffins to C_{20} and other hydrocarbons to C_{14} .

Equation (2-2), another somewhat simpler method for estimating the critical temperature of pure hydrocarbons only, is the method of Nokay⁷⁶ and requires the normal boiling point, the relative density, and the compound family.

$$\log T_c = A + B \log_{10} (\text{rel den}) + C \log T_b \quad (2-2)$$

T_c and T_b are the critical and normal boiling temperatures, respectively, expressed in kelvins. The relative density (rel den) of the liquid at 15°C is 0.1 MPa. The regression constants A , B , and C are tabulated by family in Table 2-384. Errors average about 3 K.

For **pure nonhydrocarbon organics**, the most accurate method for prediction of critical temperature for all compound groups is also the Ambrose² method. Equation (2-1) applies to all nonhydrocarbon compounds except perfluorocarbons, where the constant 1.242 is replaced by 1.570. For compounds containing any of C, H, O, N, S, or halogens up to C_{13} and ranging in critical temperature from 228–790 K, the average error is about 6 K.

Alternate methods for nonhydrocarbon organics are the first order method of Lydersen⁶³ with an average error of 9 K although the method of Ambrose is considerably better for alcohols and ketones.

Equation (2-3) is the Lydersen equation for critical temperature and requires only the normal boiling point and the molecular structure for solution.

$$T_c = \frac{T_b}{[0.567 + \sum \Delta_T - (\sum \Delta_T)^2]} \quad (2-3)$$

Contributions to $\sum \Delta_T$ are given in Table 2-385.

For **pure inorganic compounds**, the method of Gambill³¹ was modified to yield Eq. (2-4) and only requires the normal boiling point as input.

$$T_c = 1.64T_b \quad (2-4)$$

Although this equation was tested with available experimental data (38 compounds), it can only be considered a rough approximation. **Inorganic-organic** and **inorganic-halide** compounds are predicted better by replacing the constant 1.64 in Eq. (2-4) by 1.55.

For both **hydrocarbons** and **nonhydrocarbon organic defined mixtures**, the method of Li⁶⁰ is used with a relatively simple volumetric average mixing rule as shown in Eq. (2-5) to calculate the true critical temperature.

$$T_{cm} = \sum_j \left(\frac{y_j V_{c_j}}{\sum_i y_i V_{c_i}} \right) T_{c_j} \quad (2-5)$$

T_{cm} is the mixture critical temperature in K. V_{c_i} is the critical volume of a component, m^3/kmole . The mole fraction of a component is y . The mixture contains i components.

For hydrocarbon systems, the average error is about 3 K, while for systems containing nonhydrocarbons, the average error is 15 K with the highest errors occurring where simple gases are present. The method of Chueh and Prausnitz¹⁸ yields average errors slightly lower than the method of Li, but it is computationally more complex.

Critical Pressure The critical pressure of a compound is the vapor pressure of the compound at the critical temperature. Below the critical temperature, any compound above its vapor pressure will be a liquid. The critical pressure is required for calculations discussed in the part of the section on critical temperature.

For **pure hydrocarbons**, the method of Ambrose² is the most accurate. Equation (2-6) requires only the molecular weight (M) and the molecular structure of the compound.

$$P_c = \frac{0.101325M}{[0.339 + \sum \Delta_p - 0.026\Delta(\text{Platt no.})]^2} \quad (2-6)$$

P_c is the critical pressure, MPa. Values of Δ_p from Table 2-383 are summed for each part of the molecule to yield $\sum \Delta_p$. Calculation of the Platt number is discussed under "Critical Temperature." Errors in P_c average 0.07 MPa and are less reliable for compounds with 12 or more carbon atoms.

TABLE 2-383 Group Increments for the Ambrose Method

Group description	Δ_T	Δ_P	Δ_V	Group description	Δ_T	Δ_P	Δ_V
—CH ₃	0.138	0.2260	55.1	Aromatic Compounds (Cont.)			
	0.138	0.2260	55.1		0.468	0.8840	222
	0.095	0.2200	47.1		0.468	0.8840	222
	0.018	0.1960	38.1		0.418	0.8040	222
=CH ₂	0.113	0.1935	45.1		0.368	0.7240	222
=CH—	0.113	0.1935	45.1		0.220	0.5150	148
=C\	0.070	0.1875	37.1				
=C=	0.088	0.1610	35.1	Nonring Increments	Use Eq. (a), below	Use Eq. (b), below	
≡CH	0.038	0.1410	35.1		0.138	0.160	
≡C—	0.038	0.1410	35.1		0.220	0.282	
Ring Increments					0.220	0.220	
	0.090	0.1820	44.5		0.578	0.450	
	0.090	0.1820	44.5		1.156	0.900	
	0.030	0.1820	44.5		0.330	0.470	
	0.090	0.1820	44.5		0.370	0.420	
=CH—	0.075	0.1495	37.0		0.208	0.095	
=C\	0.075	0.1495	37.0		0.208	0.135	
=C=	0.060	0.1170	29.5		0.088	0.170	
Aromatic Compounds					0.423	0.360	
	0.458	0.9240	222		0.105	0.270	
	0.448	0.8940	222		0.090	0.270	
	0.488	0.9440	222		0.138	0.461	
	0.488	0.9440	222		0.371	0.507	
	0.438	0.8640	222		0.195	—	
	0.478	0.9140	222		0.159	0.725	
	0.428	0.8340	222		0.131	0.663	

TABLE 2-383 Group Increments for the Ambrose Method (Concluded)

Group description	Δ_T	Δ_P	Δ_V	Group description	Δ_T	Δ_P	Δ_V
Double Bond	-0.050	-0.065		—Cl	0.080	0.318	
Triple Bond	-0.200	-0.170		—Br	0.080	0.600	
—F	0.180 (1st) 0.055	0.223		—I			0.850
—Cl	0.110 (1st) 0.055	0.318		The single or first substituent on an aromatic ring	0.010	0	
—Br	0.110 (1st) 0.055	0.500		The second or subsequent ring substituents	0.030	0.020	
Aromatic Compounds				Each pair of ring substituents in ortho positions with respect to each other	-0.040	-0.050	
Corrections				If one of the ortho pair is —OH	-0.080	0	
benzene	0.448	0.924					
pyridine	0.448	0.850					
—OH	0.198	-0.025					
C ₄ H ₄ (fused ring)	0.220	0.515					
—F	0.080	0.183					

^aGroup contributions for  and  in fused rings have been calculated from minimal data and may be less reliable than the other values.

Substituent increments do not apply to halogens.

$$\text{Eq. (a)}: \Delta_T^{\circ}(\text{---OH}) = 0.87 - 0.11n + 0.003n^2$$

$$\text{Eq. (b)}: \Delta_P^{\circ}(\text{---OH}) = 0.100 - 0.013n$$

n = carbon number of compound. For branched alcohols, an effective carbon number can be determined by interpolation between the normal alcohol of the same carbon number and the immediately lower normal alcohol using normal boiling points. (See Example 1.)

TABLE 2-384 Nokay Equation

Type compound	A	B	C
Paraffin	1.35940	0.43684	0.56224
Naphthene	0.65812	-0.07165	0.81196
Olefin	1.09534	0.27749	0.65563
Acetylene	0.74673	0.30381	0.79987
Diolenes	0.1384	-0.39618	0.99481
Aromatic	1.0615	0.22732	0.66929

Example 1 Estimate the critical temperature and critical pressure of 2-butanol using the Ambrose method, Eqs. (2-1) and (2-6). The experimental normal boiling point is 372.7 K.

$$T_c = T_b \left[1 + \frac{1}{1.242 + \sum \Delta_T - 0.023\Delta} \right]$$

$$P_c = \frac{0.101325M}{[0.339 + \sum \Delta_P - 0.026\Delta]^2}$$

Determine group contributions from Table 2-383 for a structure CH₃CHOHCH₂CH₃:

Group	Number of groups	Δ_T	Δ_P
—CH ₃	2	0.138	0.2260
	1	0.138	0.2260
	1	0.095	0.2200
—OH	1	(a)	(b)

$$\Delta_T^{\circ}(\text{---OH}) = 0.87 - 0.11(n) + 0.003n^2 = 0.558$$

$$\Delta_P^{\circ}(\text{---OH}) = 0.100 - 0.013(n) = 0.0597$$

To determine *n*, the normal boiling points of 1-propanol (370.3 K) and 1-butanol (390.9 K) are required:

$$n = 3 + \left(\frac{372.7 - 370.3}{390.9 - 370.3} \right)(4 - 3) = 3.1$$

The Platt number of the compound is determined by substituting a CH₃ group for the OH.



The Platt number of the *n*-alkane of the same carbon number is 5 - 3 = 2. Thus, Δ(Platt no.) = 2 - 2 = 0. Therefore:

$$\sum \Delta_T = 2(.138) + .138 + .095 + .558 = 1.067$$

$$T_c = 372.7 \left[1 + \frac{1}{1.242 + 1.067 - 0} \right]$$

$$T_c = 534.1 \text{ K}$$

An accurate experimental value is 536.05 K.

$$\sum \Delta_P = 2(.226) + .226 + .220 + .0597 = 0.9577$$

$$P_c = \frac{.101325(74.12)}{(.339 + .9577 - 0)^2}$$

$$P_c = 4.467 \text{ MPa}$$

An accurate experimental value is 4.179 MPa.

For pure nonhydrocarbon organics, the simplest accurate method for prediction of critical pressure is the method of Lydersen.⁶³ Equation (2-7) requires the molecular weight (*M*) and the molecular structure of the compound.

$$P_c = \frac{0.101325M}{(0.34 + \sum \Delta_P)^2} \quad (2-7)$$

P_c is the critical pressure, MPa. Values of Δ_P from Table 2-385 are summed to yield ∑Δ_P. The average error in *P_c* is about 0.2 MPa when tested on compounds ranging in carbon number from C₁ to C₁₀.

Example 2 Estimate the critical temperature and critical pressure of 2-butanol, which has an experimental normal boiling point of 372.7 K. Use the Lydersen method, Eqs. (2-3) and (2-7).

The structure of 2-butanol is CH₃CHOHCH₂CH₃. Determine group contributions from Table 2-385.

Group	Number of groups	Δ_T	Δ_P
—CH ₃	2	0.020	0.227
—CH ₂ —	1	0.020	0.227
—CH— 	1	0.012	0.210
—OH	1	<u>0.082</u>	<u>0.06</u>
		<u>Σ 0.154</u>	<u>0.951</u>

$$T_c = \frac{T_b}{0.567 + \sum \Delta_T - (\sum \Delta_T)^2} = \frac{372.7}{.567 + .154 - (.154)^2}$$

$$T_c = 534.5 \text{ K}$$

TABLE 2-385 Group Increments for the Lydersen Method

Group description	Incremental contributions			Group description	Incremental contributions		
	Δ_T	Δ_P	Δ_V		Δ_T	Δ_P	Δ_V
Nonring Elements							
—CH ₃ , —CH ₂ —	0.020	0.227	0.055	Oxygen Increments (Cont.)			
—CH— 	0.012	0.210	0.051	—COOH (acid)	0.085	(0.4)	0.080
 —C—	0.00	0.210	0.041	—COO—(ester)	0.047	0.47	0.080
 =CH ₂ , =CH	0.018	0.198	0.045	=O (except for combinations above)	(0.02)	(0.12)	(0.011)
 =C—, =C=	0.00	0.198	0.036	Halogen Increments			
≡CH, ≡C—	0.005	0.153	(0.036)	—F	0.018	0.224	0.018
Ring Increments							
—CH ₂ —	0.013	0.184	0.0445	—Cl	0.017	0.320	0.049
—CH— 	0.012	0.192	0.046	—Br	0.010	(0.50)	(0.070)
 —C—	(−0.007)	0.154	(0.031)	—I	0.012	(0.83)	(0.095)
 =C—, =C=	0.011	0.154	0.036	Nitrogen Increments			
—CH— 	0.011	0.154	0.037	—NH ₂	0.031	0.095	0.028
 	0.066	0.924		—NH (nonring)	0.031	0.135	(0.037)
Oxygen Increments				—NH (ring)	(0.024)	(0.09)	(0.027)
—OH (alcohols)	0.082	0.06	(0.018)	—N—(nonring)	0.014	0.17	(0.042)
—OH (phenols)	0.031	(−0.02)	(0.003)	—N—(ring)	(0.007)	(0.13)	(0.032)
—O—(nonring)	0.021	0.16	0.020	Sulfur Increments			
—O—(ring)	(0.014)	(0.12)	(0.008)	—SH	0.015	0.27	0.055
 —C=O (nonring)	0.040	0.29	0.060	—S—(nonring)	0.015	0.27	0.055
 —C=O (ring)	(0.033)	(0.2)	(0.050)	—S—(ring)	(0.008)	(0.24)	(0.045)
HC=O (aldehyde)	0.048	0.33	0.073	=S	(0.003)	(0.24)	(0.047)
Organometallic Increments							
				—Si— 	0.026	0.468	—
				—SiH 	0.040	0.513	—
				—SiH ₃ 	0.027	—	—
				—Si—O— 	0.025	0.730	—
				[—Si—O—] _{cyclic}	0.027	0.668	—

Values in parentheses are based on too few experimental points to be reliable.

The accurate experimental critical temperature is 536.05 K.

$$P_c = \frac{0.101325M}{(0.34 + \sum \Delta_p)^2} = \frac{(0.101325)(74.12)}{(0.34 + 0.951)^2}$$

$$P_c = 4.506 \text{ MPa}$$

The accurate experimental critical pressure is 4.179 MPa. No known method is available to predict the critical pressure of inorganic compounds.

For both **hydrocarbon** and **nonhydrocarbon organic defined mixtures**, the method of Kreglewski and Kay⁵² is recommended. The critical temperature, critical pressure, and acentric factor of each compound and the critical temperature of the mixture must be known or predicted from the methods of this section.

$$P_{cm} = P_{pc} + P_{pe} \left[5.808 + 4.93 \left(\sum_{i=1}^n x_i \omega_i \right) \right] \left[\frac{T_{cm} - T_{pc}}{T_{pc}} \right] \quad (2-8)$$

Use of Eq. (2-8) requires the pseudocritical properties defined by Eqs. (2-9) and (2-10)

$$T_{pc} = \sum_{i=1}^n x_i T_{ci} \quad (2-9)$$

$$P_{pe} = \sum_{i=1}^n x_i P_{ci} \quad (2-10)$$

Each component i of the mixture must have available its T_c , P_c , and ω . T_{cm} can be predicted from Eq. (2-5). For hydrocarbon systems, average errors in predicted critical pressures are about 0.2 MPa, except when organic gases are present and errors are unacceptably large. Errors for nonhydrocarbon organics not including inorganic gases average 0.5 MPa.

Critical Volume The critical volume of a compound is the volume occupied by a set mass of a compound at its critical temperature and pressure. While useful in itself, the critical volume is extensively used in equations for estimating volumetric fractions.

For **pure hydrocarbons**, two methods are quite accurate. The Ambrose² method used for T_c and P_c is also used for critical volume. Eq. (2-11) only requires the molecular structure of the compound.

$$V_c = 10^{-3}(40 + \sum \Delta_v) \quad (2-11)$$

V_c is the critical volume, m^3/kmole . Values of Δ_v are given in Table 2-383.

The average error for hydrocarbons of twelve or less carbon atoms is about 0.01 m^3/kmole .

The Riedel method⁹⁰ requires the critical temperature (T_c), critical pressure (P_c), and acentric factor (ω) of the compound as given by Eqs. (2-12) and (2-13). If the gas constant is in $\text{Pa}\cdot\text{m}^3/\text{kmole}\cdot\text{K}$, the critical volume will be in m^3/kmole .

$$V_c = \frac{RT_c}{P_c[3.72 + 0.26(\alpha - 7.00)]} \quad (2-12)$$

$$\alpha = 5.811 + 4.919\omega \quad (2-13)$$

The average error for paraffins up to C_{18} and other hydrocarbon families up to C_{11} is about 0.015 m^3/kmole . If estimated values of T_c and P_c are used, errors may be higher.

For **pure nonhydrocarbon organics**, the method of Fedors,²⁹ which requires only molecular structure, is the most accurate. Equation (2-14) shows the method to depend only on the molecular structure. The resulting V_c will be in m^3/kmole .

$$V_c = 0.0266 + \sum \Delta_v \quad (2-14)$$

Values for Δ_v are given in Table 2-386. The average error for compounds up to C_7 is about 0.007 m^3/kmole , although a maximum error of 0.03 m^3/kmole has been noted. No experimental data above C_7 are available for comparison.

Example 3 Estimate the critical volume of 2-butanol. Use the method of Fedors, Eq. (2-14).

$$V_c = 0.0266 + \sum \Delta_v$$

The molecular formula is $C_4H_{10}O$. Using the atomic contribution values from Table 2-386,

$$\sum \Delta_v = 4(0.034426) + 10(0.009172) + 1(0.018000)$$

$$\sum \Delta_v = 0.2474$$

$$V_c = 0.0266 + 0.2474 = 0.2740 \text{ m}^3/\text{kmole}$$

The accurate experimental critical volume is 0.2690 m^3/kmole .

TABLE 2-386 Atomic and Structural Contributions for the Fedors Method

Atomic increments		Structural increments	
Atom	Δ_v	Feature	Δ_v
C	0.034426	Cl	0.052801
H	0.009172	Br	0.071774
O	0.020291	I	0.096402
O (alcohols)	0.018000	S	0.050866
N	0.048855	3-membered ring	-0.105824
N (amines)	0.047422	4-membered ring	-0.017247
F	0.022242	5-membered ring	-0.039126
Si	0.086174	6-membered ring	-0.039508
Si _{siloxane}	0.126483	double bond	+0.005028
Si _{cyclic siloxane}	0.126483	triple bond	+0.000797
		ring attached directly to another ring	+0.035524

The method of Lydersen⁶³ may also be used for prediction of critical volume, but it is not so accurate as the method of Fedors. Equation (2-15) depends only on molecular structure and gives a critical volume in m^3/kmole .

$$V_c = 0.040 + \sum \Delta_v \quad (2-15)$$

Group contributions for Δ_v are given in Table 2-385. Errors average about 0.01 m^3/kmole .

There is no known method for predicting the critical volume of inorganic compounds.

For both **hydrocarbon** and **nonhydrocarbon organic defined mixtures**, the method of Chueh and Prausnitz¹⁰ is useful. For hydrocarbon systems, the mixing rule is shown by Eq. (2-16) for binaries and by Eq. (2-17) for multicomponents. Equations (2-18) through (2-20) give the input parameters. The mixture critical volume V_{cm} is a function of the pure component critical volumes. The constant C is zero for hydrocarbon systems and 0.1559 for systems containing a nonhydrocarbon gas.

$$V_{cm} = \phi_1 V_{c1} + \phi_2 V_{c2} + 2\phi_1\phi_2 v_{12} \quad (2-16)$$

$$V_{cm} = \sum_i^n \sum_j^n \phi_i \phi_j v_{ij} \quad (i \neq j) \quad (2-17)$$

$$\phi_j = \frac{x_j V_{cj}^{2/3}}{\sum_{i=1}^n x_i V_{ci}^{2/3}} \quad (2-18)$$

$$v_{ij} = \frac{V_{ji}(V_{ci} + V_{cj})}{2.0} \quad (2-19)$$

$$V_{ij} = -1.4684 \left(\left| \frac{V_{ci} - V_{cj}}{V_{ci} + V_{cj}} \right| \right) + C \quad (2-20)$$

Errors average about 10 percent for systems containing hydrocarbons.

Systems containing only organics or organics and gases may give very high errors. A specialized modification of the method (Chueh and Prausnitz¹⁸) is available for binary mixtures containing organics but may give errors over 20 percent.

Critical Compressibility Factor The critical compressibility factor of a compound is calculated from the experimental or predicted values of the critical properties by the definition, Eq. (2-21).

$$Z_c = \frac{P_c V_c}{R T_c} \quad (2-21)$$

Critical compressibility factors are used as characterization parameters in corresponding states methods (especially those of Lydersen) to predict volumetric and thermal properties. The factor varies from about 0.23 for water to 0.26–0.28 for most hydrocarbons to slightly above 0.30 for light gases.

Normal Freezing Temperature (Melting Point) The melting point is the temperature at which melting occurs at atmospheric pressure. In most cases, measurements are made in air, making values slightly lower than if the measurements were made in vacuum. Impurities can cause a substantial decrease in the measured melting point. The melting point is very slightly higher than the triple point temperature—the temperature at which equilibrium exists between solid, liquid, and vapor—for a pure compound. For practical purposes, the two temperatures are equal. Reliable methods for predicting melting points have not until recently been advanced. Constantinou and

Gani²⁰ derived a group contribution method that shows promise. Initial evaluations show average errors of 5 to 10 percent (10–30 K) on a wide variety of compounds, but larger errors can occur. It is recommended that several compounds of known melting point in the same or a similar family be predicted in order to estimate the probable error.

Normal Boiling Temperature The normal boiling temperature (point) is the temperature at which the vapor pressure equals exactly 101,325 Pa (1 atmosphere). Caution should be taken in using values from older references, where the temperature may be reported for the prevailing pressure (0.95–0.97 atm) rather than at 1 atmosphere. If at least two values of vapor pressure very close to 1 atmosphere are available, the normal boiling point can be interpolated or extrapolated on a plot of $\log P_r^{\text{sat}}$ vs. $1/T$. The section on vapor pressure discusses this in more detail.

Various methods are available for estimation of the normal boiling point of organic compounds. Lyman et al.⁶⁴ review and give calculational procedures for the methods of Meissner, Miller, and Lydersen/Forman-Thodos. A more recent method that has been determined to be more accurate is the method of Pailhes,⁵⁰ which requires one experimental vapor pressure point and Lydersen group contributions for critical temperature and critical pressure (Table 2-385).

$$T_b = T \frac{\log P_c + (1 - \Theta) \log (1/p)}{\log P_c} \quad (2-22)$$

where T and p = the one low pressure vapor pressure point, in K and atm, respectively

$\Theta = T_c/T_b$ calculated from Eq. (2-3) using Lydersen contributions

P_c = critical pressure calculated from Eq. (2-7) using Lydersen contributions

A recent study of the method on a wide variety of complex organics shows an overall average error of less than 2 percent (~10 K). If no vapor pressure point is available, the new group contribution method of Constantinou and Gani²⁰ discussed under the section on melting point gives an overall average error of about 4 percent (~20 K) and may be useful. The method of Miller (Lyman et al.⁶⁴), which requires only the molecular structure, has also been found to be relatively accurate for organics.

Example 4 Estimate the normal boiling point of 2-butanol. One vapor pressure point of 0.802 psia at 100°F is available.

Use the Pailhes method, Eq. (2-22).

$$T_b = T \frac{\log P_c + (1 - \Theta) \log (1/p)}{\log P_c}$$

From Example 2, $P_c = 4.506 \text{ MPa}$; $\Theta = T_c/T_b = 1.434$; $T = 100^\circ\text{F} = 310.9 \text{ K}$; and $p = 0.802 \text{ psia} = 5528 \text{ Pa}$.

$$T_b = (310.9) \frac{\log (4.506 \times 10^6) + (1 - 1.434) \log (1/5528)}{\log (4.506 \times 10^6)}$$

$$T_b = (310.9)(1.244) = 386.8 \text{ K}$$

An accepted experimental normal boiling point is 372.7 K.

Note the error here is 3.8 percent, a value above the average. If the vapor pressure point available would have been closer to one atmosphere, the error would have been much lower.

Acentric Factor The acentric factor of a compound (ω) is primarily a measure of the shape of a molecule, though it also measures a molecule's polarity. It is calculated from the reduced vapor pressure (P_r^{sat}) at a reduced temperature of 0.7 by the definition, Eq. (2-23).

$$\omega = -\log (P_r^{\text{sat}})_{T_r=0.7} - 1.000 \quad (2-23)$$

Critical temperature and pressure are required and can be estimated from the methods of this section. Vapor pressure is predicted by the methods of the next section. Experimental values should be used if available. The acentric factor is used as a third parameter with T_c and P_c in Pitzer-type corresponding states methods to predict volumetric properties and in cubic equations of state such as the Redlich-Kwong-Soave and Peng-Robinson equations. For simple spherical molecules, the acentric factor is essentially zero, rising as branching and molecu-

lar weight increases. For compounds of similar size and shape the acentric factor increases slightly with increasing polarity.

For mixtures, the acentric factor is usually taken as a simple molar average value of the n components of the mixture.

$$\omega = \sum_{i=1}^n x_i \omega_i \quad (2-24)$$

Miscellaneous Characterizing Constants The radius of gyration (\bar{R}) is a simultaneous size-shape factor varying with the manner in which mass is distributed about the center of gravity of the molecule. For planar molecules, the radius of gyration is

$$\bar{R} = \sqrt{\frac{(AB)^{1/2} N_A}{M}} \quad (2-25)$$

For three-dimensional molecules, it is

$$\bar{R} = \sqrt{\frac{(ABC)^{1/3} 2\pi N_A}{M}} \quad (2-26)$$

AB and ABC are the products of the principal moments of inertia. Moments of inertia are calculated from bond angles and bond lengths. Many values are given by Landolt-Bornstein.⁵³ N_A is Avogadro's number, and M is the molecular weight of the molecule. Stuper et al.¹⁰⁵ give a computerized method for prediction of the radius of gyration.

The dipole moment (λ) of a molecule is the first moment of the electric charge density of a molecule. Paraffins have dipole moments of zero, while dipole moments of almost all hydrocarbons are small. McClellan⁶⁸ lists many dipole moments. The computer method of Dixon and Jurs²⁷ is the most useful method for predicting dipole moments. Lyman et al.⁶⁴ give other methods of calculation.

The van der Waals volume and area are characterizing parameters relating molecular configurations. Bondi⁸ describes group contribution methods for their calculation.

VAPOR PRESSURE

Vapor pressure is the most important of the basic thermodynamic properties affecting liquids and vapors. The vapor pressure is the pressure exerted by a pure component at equilibrium at any temperature when both liquid and vapor phases exist and thus extends from a minimum at the triple point temperature to a maximum at the critical temperature, the critical pressure. This section briefly reviews methods for both correlating vapor pressure data and for predicting vapor pressure of pure compounds. Except at very high total pressures (above about 10 MPa), there is no effect of total pressure on vapor pressure. If such an effect is present, a correction, the Poynting correction, can be applied. The pressure exerted above a solid-vapor mixture may also be called vapor pressure but is normally only available as experimental data for common compounds that sublime.

Correlation Methods Vapor pressure is correlated as a function of temperature by numerous methods mainly derived from the Clapeyron equation discussed in the section on enthalpy of vaporization. The classic simple equation used for correlation of low to moderate vapor pressures is the Antoine⁴ equation (2-27).

$$\ln P^{\text{sat}} = A + \frac{B}{T + C} \quad (2-27)$$

A , B , and C are regression constants for the specific compound.

The Antoine equation does not fit data accurately much above the normal boiling point. Thus, as regression by computer is now standard, more accurate expressions applicable to the critical point have become usable. The entire DIPPR Compilation²⁴ is regressed with the modified Riedel⁸⁹ equation (2-28) with constants available for over 1500 compounds.

$$\ln P^{\text{sat}} = A + \frac{B}{T} + C \ln T + DT^E \quad (2-28)$$

A , B , C , and D are regression constants and E is an exponent equal to 1, 2, or 6 depending on which regression gives the most accurate fit of the data.

For purposes of the *API Technical Data Book* (Daubert and Danner²³), another modified Riedel equation (2-29) was chosen and found to fit hydrocarbon data well over the entire pressure range. Coefficients are given for several hundred hydrocarbons.

$$\ln P^{\text{sat}} = A + \frac{B}{T} + C \ln T + DT^2 + \frac{E}{T^2} \quad (2-29)$$

Both equations (2-28) and (2-29) are also extrapolatable above the critical temperature where necessary for thermodynamic calculations.

The other modern equation used for correlation is the modified and linearized Wagner¹²⁴ equation (2-30), which has the advantage that it will match critical data exactly, although it cannot be extrapolated above the critical point. The equation is also included with coefficients to several hundred compounds in the *Technical Data Book—Petroleum Refining*.

$$\ln P_r = aX_1 + bX_2 + cX_3 + dX_4 \quad (2-30)$$

$$\text{where } X_1 = \frac{1 - T_r}{T_r}, X_2 = \frac{(1 - T_r)^{1.5}}{T_r}, X_3 = \frac{(1 - T_r)^{2.6}}{T_r}, X_4 = \frac{(1 - T_r)^5}{T_r}$$

$$P_r = P^{\text{sat}}/P_c \quad T_r = T^{\text{sat}}/T_c$$

Both Riedel and Wagner regressions usually fit data within a few tenths of a percent over the entire range between the triple point and the critical point.

Prediction Methods Two methods have gained almost universal acceptance for prediction of the vapor pressure of **pure hydrocarbons**.

The method of Lee and Kesler⁵⁵ is the preferred method if the critical temperature and the critical pressure of the hydrocarbon is known or can be reasonably predicted by the methods of the first section. The corresponding states method is shown in equation (2-31) with the simple fluid and correction terms to be calculated from equations (2-32) and (2-33), respectively, for any T_r .

$$\ln P_r^{\text{sat}} = (\ln P_r^{\text{sat}})^{(0)} + \omega(\ln P_r^{\text{sat}})^{(1)} \quad (2-31)$$

$$(\ln P_r^{\text{sat}})^{(0)} = 5.92714 - 6.09648/T_r - 1.28862 \ln T_r + 0.169347T_r^6 \quad (2-32)$$

$$(\ln P_r^{\text{sat}})^{(1)} = 15.2518 - 15.6875/T_r - 13.4721 \ln T_r + 0.43577T_r^6 \quad (2-33)$$

The method is applicable at reduced temperatures above 0.30 or the freezing point, whichever is higher, and below the critical point. The method is most reliable when $0.5 < T_r < 0.95$, where errors in prediction average 3.5 percent when experimental critical properties are known. Errors are higher for predicted critials. The method is useful when solved iteratively with Eq. (2-23) to predict the acentric factor.

Example 5 Estimate the vapor pressure of 1-butene at 98°C. Use Eq. (2-31):

$$\ln P_r^{\text{sat}} = (\ln P_r^{\text{sat}})^{(0)} + \omega(\ln P_r^{\text{sat}})^{(1)}$$

Pure component properties of 1-butene are $T_c = 146.4^\circ\text{C}$, $P_c = 4.02 \text{ MPa}$, and $\omega = 0.1867$.

$$T_r = \frac{371.1}{419.5} = 0.885$$

From Eq. (2-32): $(\ln P_r^{\text{sat}})^{(0)} = -0.7227$

From Eq. (2-33): $(\ln P_r^{\text{sat}})^{(1)} = -0.6190$

$$\ln P_r^{\text{sat}} = -0.7227 + (.1867)(-0.6190)$$

$$\ln P_r^{\text{sat}} = -0.8383$$

$$P_r^{\text{sat}} = 0.4325$$

$$P^{\text{sat}} = P_r^{\text{sat}} P_c = (.4325)(4.02) = 1.74 \text{ MPa}$$

An experimental value is 1.72 MPa.

When critials cannot be estimated with reasonable accuracy, the method of Maxwell and Bonnell⁶⁷ is recommended. The normal boiling point and the specific gravity at 60°F (15.5°C) are required inputs. According to what vapor pressure range is expected, the vapor pressure is calculated from Eqs. (2-34), (2-35), or (2-36). If the wrong range is selected, the procedure will need to be repeated.

For $X > 0.0022$ ($P^{\text{sat}} < 2 \text{ mm Hg}$):

$$\log P^{\text{sat}} = \frac{3000.538X - 6.761560}{43X - 0.987672} \quad (2-34)$$

For $0.0013 \leq X \leq 0.0022$ ($2 \text{ mm Hg} \leq P^{\text{sat}} \leq 760 \text{ mm Hg}$):

$$\log P^{\text{sat}} = \frac{2663.129X - 5.994296}{95.76X - 0.972546} \quad (2-35)$$

For $X < 0.0013$ ($P^{\text{sat}} > 760 \text{ mm Hg}$):

$$\log P^{\text{sat}} = \frac{2770.085X - 6.412631}{36X - 0.989679} \quad (2-36)$$

X is calculated from Eq. (2-37) and T'_b is calculated from Eq. (2-38). Iterative calculation may be required.

$$X = \frac{\frac{T'_b}{T} - 0.0002867(T'_b)}{748.1 - 0.2145(T'_b)} \quad (2-37)$$

$$T_b - T'_b = 2.5f(K - 12) \log \frac{P^{\text{sat}}}{760} \quad (2-38)$$

where T_b = normal boiling point, °R

T'_b = normal boiling point corrected to $K = 12$, °R

T = absolute temperature, °R

f = correction factor. For all subatmospheric vapor pressures and for all substances having normal boiling points greater than 400°F, $f = 1$. For substances having normal boiling points less than 200°F, $f = 0$. For superatmospheric vapor pressures of substances having normal boiling points between 200°F and 400°F, f is given by $(T_b - 659.7)/200$

K = Watson characterization factor, $T_b^{1/3}/\text{sp gr}$

Evaluation of the method for pure hydrocarbons shows errors averaging 8 percent for vapor pressures above 1 mm Hg and 30 percent below 1 mm Hg. The method is also usable for narrow boiling (range up to 50°F) **undefined hydrocarbon mixtures** with the only change being that the mean average boiling point replaces the normal boiling point in all calculations.

Example 6 Estimate the vapor pressure of tetralin at 150°C (302°F). Its normal boiling point is 207.6°C (405.7°F) and its Watson characterization factor is 9.78.

Use the Maxwell-Bonnell method, Eq. (2-35).

$$\log P^{\text{sat}} = \frac{2663.129X - 5.994296}{95.76X - 0.972546}$$

At 150°C with a normal boiling point of 207.6°C, a vapor pressure between 2 and 760 mm Hg would be expected.

Assume $T'_b = T_b = 405.7^\circ\text{F}$ as a first trial. From Eq. (2-37):

$$X = \frac{(865.7/762) - 0.0002867(865.7)}{748.1 - 0.2145(865.7)}$$

$$X = 0.001579$$

$$\log P^{\text{sat}} = \frac{2663.129(0.001579) - 5.994296}{95.76(0.001579) - 0.972546} = 2.179$$

$$P^{\text{sat}} = 151.0 \text{ mm Hg}$$

Use Eq. (2-38) to calculate the correction.

$$T_b - T'_b = 2.5f(K - 12) \log \frac{P^{\text{sat}}}{760} = 2.5(1)(9.48 - 12) \log \frac{151}{760}$$

$$T_b - T'_b = 4.4^\circ$$

Thus, for the second trial, $T'_b = 405.7 - 4.4 = 401.3^\circ\text{F}$.

Using Eq. (2-37), recalculate X .

$$X = \frac{(861.3/762) - 0.0002867(861.3)}{748.1 - 0.2145(861.3)} = 0.001568$$

From Eq. (2-35), $\log P^{\text{sat}} = 2.214$; $P^{\text{sat}} = 163.7 \text{ mm Hg}$. Use Eq. (2-38) to recalculate the correction.

$$T_b - T'_b = 2.5(1)(9.48 - 12) \log \frac{163.7}{760} = 4.2^\circ$$

Thus, $T'_b = 401.5^\circ\text{F}$. If greater accuracy is desired, carry out a third trial. (An experimental vapor pressure is 161.8 mm Hg.)

For **nonhydrocarbon organics**, vapor pressures above 15 kPa for com-

pounds of known or estimable normal boiling point are predicted using the method of Riedel⁸⁹ given by Eq. (2-39).

$$\log P_r^o = \phi(T_r) - (\alpha - 7)\psi(T_r) \quad (2-39)$$

Correlation functions $\phi(T_r)$, $\psi(T_r)$, and $\zeta(T_r)$ are given by Eqs. (2-40), (2-41), and (2-42), respectively.

$$\phi(T_r) = 0.118\zeta(T_r) - 7 \log_{10} T_r \quad (2-40)$$

$$\psi(T_r) = 0.0364\zeta(T_r) - \log_{10} T_r \quad (2-41)$$

$$\zeta(T_r) = 36/T_r + 96.7 \log_{10} T_r - 35 - T_r^6 \quad (2-42)$$

The Riedel α is calculated from Eq. (2-43).

$$\alpha = \frac{0.136\zeta(T_r) + \log_{10} P_c - 5.01}{0.0364\zeta(T_r) - \log_{10} T_r} \quad (2-43)$$

Critical properties, if not available, can be estimated from the methods of the previous section. T_r is the reduced temperature at the temperature of interest, while T_{r_0} is the reduced temperature at the normal boiling point.

The method is accurate within 2 to 3 percent above 15 kPa, while errors increase to 10–30 percent at lower pressures. Care should be taken not to use the method below the freezing point temperature.

Example 7 Estimate the vapor pressure of thiophene at 500 K. Pure component properties are $T_c = 579.4$ K, $P_c = 5.694$ MPa, and $T_b = 357.5$ K. Use the Riedel method, Eq. (2-39).

$$\begin{aligned} \log P_r^{\text{sat}} &= -\phi(T_r) - (\alpha - 7)\psi(T_r) \\ T_{r_0} &= \frac{357.5}{579.4} = 0.6170 \quad T_r = \frac{500}{579.4} = 0.8629 \end{aligned}$$

From Eq. (2-42):

$$\zeta(T_{r_0}) = \frac{(36)}{(0.6170)} + 96.7 \log(0.6170) - 35 - (0.6170)^6 = 3.01$$

From Eq. (2-43):

$$\begin{aligned} \alpha &= \frac{0.136(3.01) + \log(5.694 \times 10^6) - 5.01}{(0.0364)(3.01) - \log(0.6170)} \\ \alpha &= 6.749 \end{aligned}$$

From Eq. (2-42), calculate $\zeta(T_r)$ and then calculate $\phi(T_r)$ and $\psi(T_r)$ from Eqs. (2-40) and (2-41).

$$\begin{aligned} \log P_r^{\text{sat}} &= -0.461 - (6.749 - 7)(0.068) \\ \log P_r^{\text{sat}} &= -0.444 \\ P_r^{\text{sat}} &= 0.3598 \\ P_r^{\text{sat}} &= P_r^{\text{sat}} P_c = (.3598)(5.694) = 2.049 \text{ MPa} \end{aligned}$$

An experimental value is 2.037 MPa.

For **nonhydrocarbon organics** for which normal boiling points are unknown or expected vapor pressures are below 15 kPa, the reference substance method of Othmer and Yu⁷⁸ as given by Eq. (2-44) is recommended.

$$\log P_r^{\text{sat}} = m \log P_w^{\text{sat}} + C \quad (2-44)$$

The vapor pressure of water P_w^{sat} may be calculated by Eq. (2-45).

$$\log P_w^{\text{sat}} = 31.51 - \frac{3.1298 \times 10^3}{T} - 7.1385 \log T + 1.757 \times 10^{-6} T^2 \quad (2-45)$$

with temperatures in K and vapor pressures in Pa.

Values of the compound specific constants m and c were originally derived by Othmer et al. and greatly expanded to over 600 common organics by Danner and Daubert.²² If constants are not available but any two vapor pressure data points are available, the constants m and C can be calculated using Eqs. (2-46) and (2-47).

$$m = \frac{\log P_1^{\text{sat}} - \log P_2^{\text{sat}}}{\log P_{w_1}^{\text{sat}} - \log P_{w_2}^{\text{sat}}} \quad (2-46)$$

$$C = \log P_1^{\text{sat}} - m \log P_{w_1}^{\text{sat}} \quad (2-47)$$

where the subscripts 1 and 2 refer to the two reference temperatures T_1 and T_2 .

Average errors at low pressures for compounds with tabulated m and C are within a few percent. When values of m and C are calculated from only two vapor pressure points, the method should be used only for interpolation and limited extrapolation. The method is usable from about 220 K (so long as it is above the freezing point of the compound) to the critical point of water (about 647 K).

Example 8 Estimate the vapor pressure of acetaldehyde at 0°C. Two vapor pressure points are 20.0 kPa at 256.55 K and 107.6 kPa at 294.85 K.

Use Eq. (2-44), determining parameters from Eqs. (2-45), (2-46), and (2-47).

$$\begin{aligned} \log P^{\text{sat}} &= m \log P_w^{\text{sat}} + C \\ \text{at } T_1 = 256.55 \text{ K, } P_1^{\text{sat}} &= 2.00 \times 10^4 \text{ Pa, } \log P_1^{\text{sat}} = 4.3010 \\ \text{at } T_2 = 294.95 \text{ K, } P_2^{\text{sat}} &= 1.067 \times 10^5 \text{ Pa, } \log P_2^{\text{sat}} = 5.0282 \end{aligned}$$

Use Eq. (2-45) to calculate the vapor pressure of water at T_1 and T_2 .

$$\begin{aligned} \log P_{w_1}^{\text{sat}} &= 2.2282, \quad P_{w_1}^{\text{sat}} = 169.12 \text{ Pa} \\ \log P_{w_2}^{\text{sat}} &= 3.4213, \quad P_{w_2}^{\text{sat}} = 2637.9 \text{ Pa} \end{aligned}$$

From Eq. (2-46):

$$m = \frac{\log P_1^{\text{sat}} - \log P_2^{\text{sat}}}{\log P_{w_1}^{\text{sat}} - \log P_{w_2}^{\text{sat}}} = \frac{4.3010 - 5.0282}{2.2282 - 3.4213} = 0.6093$$

From Eq. (2-47):

$$C = \log P_1^{\text{sat}} - m \log P_{w_1}^{\text{sat}} = 4.3010 - 0.6093(2.2282)$$

$$C = 2.9434$$

at $T = 273.15 \text{ K (0}^\circ\text{C)}$

$$\log P_w^{\text{sat}} = 31.51 - \frac{3129.8}{273.15} - 7.1385 \log 273.15 + 1.757 \times 10^{-6}(273.15)^2$$

$$\log P_w^{\text{sat}} = 2.7907$$

$$\log P^{\text{sat}} = (0.6093)(2.7907) + 2.9434$$

$$\log P^{\text{sat}} = 4.6438$$

$$P^{\text{sat}} = 44,030 \text{ Pa} = 44.0 \text{ kPa}$$

IDEAL GAS THERMAL PROPERTIES

A substance is in the ideal gas state when the volume of its molecules is a zero fraction of the total volume taken up by the substance and when the individual molecules are far enough apart from each other so that there is no interaction between them. Although this only occurs at infinite volume and zero pressure, in practice, ideal gas properties can be used for gases up to a pressure of two atmospheres with little loss of accuracy. Thermal properties of ideal gas mixtures may be obtained by mole-fraction averaging the pure component values.

Heat Capacity, C_p^o Heat capacity is defined as the amount of energy required to change the temperature of a unit mass or mole one degree; typical units are J/kg·K or J/mol·K. There are many sources of ideal gas heat capacities in the literature; e.g., Daubert et al.,²⁴ Daubert and Danner,²³ JANAF thermochemical tables,¹⁵ TRC thermodynamic tables,^{115,116} and Stull et al.¹⁰⁴ If C_p^o values are not in the preceding sources, there are several estimation techniques that require only the molecular structure. The methods of Thinh et al.¹¹³ and Benson et al.^{6,7} are the most accurate but are also somewhat complicated to use. The equation of Harrison and Seaton³⁶ for C_p between 300 and 1500 K is almost as accurate and easy to use:

$$\begin{aligned} C_p^o &= a_1 + a_2C + a_3H + a_4O + a_5N + a_6S + a_7F + a_8Cl \\ &\quad + a_9I + a_{10}Br + a_{11}Si + a_{12}Al + a_{13}B + a_{14}P + a_{15}E \quad (2-48) \end{aligned}$$

where C_p^o = ideal gas heat capacity, J/mol K
 a_1 – a_{15} = constant parameters obtained from Table 2-387 as a function of temperature

C = number of carbon atoms in the molecule

H = number of hydrogen atoms in the molecule

O = number of oxygen atoms in the molecule

N = number of nitrogen atoms in the molecule

S = number of sulfur atoms in the molecule

F = number of fluorine atoms in the molecule

Cl = number of chlorine atoms in the molecule

I = number of iodine atoms in the molecule

Br = number of bromine atoms in the molecule

Si = number of silicon atoms in the molecule

Al = number of aluminum atoms in the molecule

B = number of boron atoms in the molecule

P = number of phosphorus atoms in the molecule

E = number of atoms in the molecule excluding the 13 atom-types listed above

TABLE 2-387 Values of the Constant Parameters α_1 – α_{15} in Eq. (2-48) at Different Temperatures

Temp., K	Parameter a														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
300	4.86	9.04	5.69	11.4	11.9	15.3	12.7	16.8	18.7	17.8	14.6	15.8	11.5	18.0	19.5
400	0.864	12.6	7.37	13.9	14.0	17.0	16.2	18.9	20.5	19.9	17.5	18.3	14.7	20.9	20.8
500	-1.85	15.5	8.89	15.7	16.0	19.4	17.9	20.2	22.1	21.2	19.6	20.0	17.0	21.6	21.7
600	-4.61	17.5	10.5	17.5	17.3	20.3	20.1	21.4	23.3	22.4	20.9	21.1	18.3	22.8	22.1
800	-7.49	20.1	13.1	19.4	19.4	22.3	21.5	22.4	25.0	23.4	23.2	22.3	20.8	23.0	23.0
1000	-8.53	21.6	15.2	20.4	20.4	22.9	22.4	22.8	25.4	23.8	23.9	22.8	22.2	23.4	23.3
1500	-7.37	23.9	17.9	20.6	21.1	22.5	22.1	22.6	24.6	23.0	24.1	23.2	24.2	24.2	23.3

Results and parameters may be interpolated between temperatures. Average errors are between 2 and 6 percent, with the higher errors at the lower temperatures.

Example 9 Using Eq. 2-48 to estimate the ideal gas heat capacity of acetone (C_3H_6O) at 600 K:

$$C_p^\circ = -4.61 + (17.5)(3) + (10.5)(6) + (17.5)(1) = 128.39 \text{ J/mol K}$$

Daubert et al.²⁴ report a value of 121.8 J/mol K.

Enthalpy of Formation The ideal gas standard enthalpy (heat) of formation ($\Delta H_{f,298}^\circ$) of a chemical compound is the increment of enthalpy associated with the reaction of forming that compound in the ideal gas state from the constituent elements in their standard states, defined as the existing phase at a temperature of 298.15 K and one atmosphere (101.3 kPa). Sources for data are Refs. 15, 23, 24, 104, 115, and 116. The most accurate, but again complicated, estimation method is that of Benson et al.^{6,7} A compromise between complexity and accuracy is based on the additive atomic group-contribution scheme of Joback⁴⁴; his original units of kcal/mol have been converted to kJ/mol by the conversion 1 kcal/mol = 4.1868 kJ/mol:

$$\Delta H_{f,298}^\circ = 68.29 + \sum_{i=1}^n N_i \Delta_{Hi} \quad (2-49)$$

where $\Delta H_{f,298}^\circ$ = enthalpy of formation at 298.15 K, kJ/mol

n = number of different atomic groups contained in the molecule

N_i = number of atomic groups i contained in the molecule

Δ_{Hi} = numeric value of atomic group i obtained from Table 2-388.

Average expected errors are about 9 kJ/mol.

For other temperatures:

$$\Delta H_{f,T}^\circ = \Delta H_{f,298}^\circ + \int_{298}^T C_p^\circ dT \quad (2-50)$$

See above for discussion of the ideal gas heat capacity (C_p°).

Example 10 The $\Delta H_{f,298}^\circ$ of 2-butanol is estimated using Table 2-388. The molecular groups are 2CH₃, 1CH₂, 1CH (all nonring), and 1OH (alcohol). Therefore:

$$\Delta H_{f,298}^\circ = 68.29 + 2(-76.45) + (-20.64) + (29.89) + (-208.04) = -283.40 \text{ kJ/mol}$$

The value from Daubert et al.²⁴ is -292.9 kJ/mol.

Gibbs Energy of Formation The ideal gas standard Gibbs energy of formation ($\Delta G_{f,298}^\circ$) of a chemical compound is the increment of Gibbs energy associated with the reaction of forming that compound in the ideal gas state from the constituent elements in their standard state defined as the existing phase at a temperature of 298.15 K and one atmosphere (101.325 kPa). Refs. 15, 23, 24, 104, 115, and 116 are good sources of data. The additive atomic group-contribution scheme of Joback⁴⁴ may be used to estimate $\Delta G_{f,298}^\circ$; his original units of kcal/mol have been converted to kJ/mol by the conversion 1 kcal/mol = 4.1868 kJ/mol:

$$\Delta G_{f,298}^\circ = 53.88 + \sum_{i=1}^n N_i \Delta_{Gi} \quad (2-51)$$

where $\Delta G_{f,298}^\circ$ = Gibbs energy of formation at 298.15 K, kJ/mol

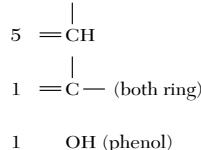
n = number of different atomic groups contained in the molecule

N_i = number of atomic groups i contained in the molecule

Δ_{Gi} = numeric value of atomic group i obtained from Table 2-388

Average errors of 8 to 9 kJ/mol may be expected.

Example 11 The $\Delta G_{f,298}^\circ$ of phenol is estimated using Table 2-388. The molecular groups are



Therefore,

$$\Delta G_{f,298}^\circ = 53.88 + 5(11.30) + (54.05) + (-197.37) = -32.94 \text{ kJ/mol}$$

The value from Daubert et al.²⁴ is -32.64 kJ/mol.

For other temperatures, the exact Eq. (2-52) may be used at temperature T (K):

$$\Delta G_{f,T}^\circ = \Delta H_{f,T}^\circ - T \Delta S_{f,T}^\circ \quad (2-52)$$

where $\Delta G_{f,T}^\circ$ = Gibbs energy of formation at T , kJ/mol

$\Delta H_{f,T}^\circ$ = enthalpy of formation at T , kJ/mol (see above)

$\Delta S_{f,T}^\circ$ = entropy of formation at T , kJ/mol K (see below)

Entropy of Formation The ideal gas standard entropy of formation ($\Delta S_{f,298}^\circ$) of a chemical compound is the increment of entropy associated with the reaction of forming that compound in the ideal gas state from the constituent elements in their standard state defined as the existing phase at a temperature of 298.15 K and one atmosphere (101.325 kPa). Thus:

$$\Delta S_{f,298}^\circ = S_{\text{compound}}^\circ - \sum_{i=1}^n N_i S_{\text{element } i}^\circ \quad (2-53)$$

where $\Delta S_{f,298}^\circ$ = entropy of formation at 298.15 K and 1 atm, J/mol K

$S_{\text{compound}}^\circ$ = ideal gas absolute entropy of the compound at 298.15 K and 1 atm, J/mol K

n = number of different elements contained in the compound

N_i = moles of element i contained in one mole of compound

$S_{\text{element } i}^\circ$ = absolute entropy of element i in its standard state at 298.15 K and 1 atm, J/mol K.

Ideal gas absolute entropies of many compounds may be found in Daubert et al.²⁴ Daubert and Danner²³ JANAF Thermochemical Tables,¹⁵ TRC Thermodynamic Tables,^{115,116} and Stull et al.¹⁰⁴ Otherwise, the estimation method of Benson et al.^{6,7} is reasonably accurate, with average errors of 1–2 J/mol K. Elemental standard-state absolute entropies may be found in Cox et al.²¹ Values from this source for some common elements are listed in Table 2-389. $\Delta S_{f,298}^\circ$ may also be calculated from Eq. (2-52) if values for $\Delta H_{f,298}^\circ$ and $\Delta G_{f,298}^\circ$ are known.

TABLE 2-388 Atomic Group Contributions to Estimate ΔH_f° ₂₉₈ and ΔG_f° ₂₉₈

	Δ_H	Δ_G		Δ_H	Δ_G
Nonring Increments			Oxygen Increments (Cont.)		
—CH ₃	-76.45	-43.96	—CHO (aldehyde)	-162.03	-143.48
—CH ₂ —	-20.64	8.42	—COOH (acid)	-426.72	-387.87
			—COO— (ester)	-337.92	-301.95
—CH	29.89	58.36	==O (except for above)	-247.61	-250.83
			Nitrogen Increments		
—C—	82.23	116.02	—NH ₂	-22.02	14.07
			—NH (nonring)	53.47	89.39
==CH ₂	-9.63	3.77	—NH (ring)	31.65	75.61
			—N— (nonring)	123.34	163.16
==CH	37.97	48.53	—N== (nonring)	23.61	—
			—N== (ring)	55.52	79.93
==C—	83.99	92.36	==NH	93.70	119.66
			—CN	88.43	89.22
==C==	142.14	136.70	—NO ₂	-66.57	-16.83
≡CH	79.30	77.71	Sulfur Increments		
≡C—	115.51	109.82	—SH	-17.33	-22.99
Ring Increments			—S— (nonring)	41.87	33.12
—CH ₂ —	-26.80	-3.68	—S— (ring)	39.10	27.76
			Halogen Increments		
—CH	8.67	40.99	—F	-251.92	-247.19
			—Cl	-71.55	-64.31
—C—	79.72	87.88	—Br	-29.48	-38.06
			—I	21.06	5.74
==CH (aromatic or cyclic olefin)	2.09	11.30			
==C— (aromatic or cyclic olefin)	46.43	54.05			
Oxygen Increments					
—OH (alcohol)	-208.04	-189.20			
—OH (phenol)	-221.65	-197.37			
—O— (nonring)	-132.22	-105.00			
—O— (ring)	-138.16	-98.22			
—C=O (nonring)	-133.22	-120.50			
—C=O (ring)	-164.50	-126.27			

ENTHALPY OF VAPORIZATION AND FUSION

Enthalpy of Vaporization The enthalpy (heat) of vaporization ΔH_V is defined as the difference of the enthalpies of a unit mole or mass of a saturated vapor and saturated liquid of a pure component; i.e., at a temperature (below the critical temperature) and corresponding vapor pressure. ΔH_V is related to vapor pressure by the thermodynamically exact Clausius-Clapeyron equation:

$$\Delta H_v = -R \Delta Z_V \frac{d \ln P_{\text{sat}}}{d(1/T)} \quad (2-54)$$

where R = gas constant in energy units

$$\Delta Z_V = Z_C - Z_L \quad (2-55)$$

Z_C = compressibility factor of the saturated vapor

Z_L = compressibility factor of the saturated liquid

P_{sat} = vapor pressure

T = absolute temperature

If accurate Z_C and Z_L data are available, excellent ΔH_V values can be obtained by differentiating a vapor pressure correlation and using Eq. (2-54). If not, ΔZ_V may be estimated by Haggenmacher's equation³⁴:

2-350 PHYSICAL AND CHEMICAL DATA

TABLE 2-389 Standard-State Entropy of Elements at 298.15 K and 1 Atmosphere

Element	State	Absolute entropy J/mol K
C	crystal (graphite)	5.74
H ₂	gas	130.571
O ₂	gas	205.043
N ₂	gas	191.500
S	crystal (rhombic)	32.054
F ₂	gas	202.682
Cl ₂	gas	222.972
Br ₂	liquid	152.21
I ₂	crystal	116.14

$$\Delta Z_v = \left(1 - \frac{P_r}{T_r^3}\right)^{1/2} \quad (2-56)$$

where P_r = reduced pressure = P/P_c
 T_r = reduced temperature = T/T_c

However, Eq. (2-56) should be used only near or below the normal boiling point; even then, the accuracy of the resulting ΔH_v is significantly reduced.

The corresponding states approach suggested by Pitzer et al.⁸² requires only the critical temperature and acentric factor of the compound. For a close approximation, an analytical representation of this method proposed by Reid et al.⁸⁶ for $0.6 < T_r < 1.0$ is:

$$\Delta H_v/RT_c = 7.08(1 - T_r)^{0.354} + 10.95\omega(1 - T_r)^{0.456} \quad (2-57)$$

where ΔH_v = enthalpy of vaporization, kJ/mol
 R = gas constant = 0.008314 kJ/mol K
 T_c = critical temperature, K
 T_r = reduced temperature, T/T_c
 T = temperature, K
 ω = acentric factor

Maximum errors are in the order of 8 percent.

Example 12 Estimate ΔH_v of Propionaldehyde at 350 K. The required properties from Daubert et al.²⁴ are $T_c = 504.4$ K and $\omega = 0.2559$. $T_r = 350.0/504.4 = 0.6939$. Substituting in Eq. (2-57):

$$\Delta H_v/RT_c = (7.08)(1 - 0.6939)^{0.354} + (10.95)(0.2559)(1 - 0.6939)^{0.456} = 6.289$$

$$\Delta H_v = (6.289)(0.008314)(504.4) = 26.37 \text{ kJ/mol}$$

The reported value is 26.85 kJ/mol.²⁴

The enthalpy of vaporization at the normal boiling temperature ΔH_{vb} (kJ/mol) can be estimated by an equation suggested by Riedel¹⁹⁰:

$$\Delta H_{vb} = 1.093 RT_c \left[T_{br} \frac{(\ln [P_c/101.325] - 1)}{0.930 - T_{br}} \right] \quad (2-58)$$

where R = gas constant = 0.008314 kJ/mol K
 T_c = critical temperature, K
 T_{br} = reduced normal boiling temperature = T_b/T_c
 T_b = normal boiling temperature, K
 P_c = critical pressure, kPa

Average errors are about 2 percent.

Example 13 Estimate ΔH_{vb} of Ethyl Acetate. The required properties for ethyl acetate are from Daubert et al.²⁴: $T_c = 523.3$ K, $T_b = 350.2$ K, and $P_c = 3880.0$ kPa. $T_{br} = 350.2/523.3 = 0.6692$. Substituting in Eq. (2-58):

$$\Delta H_{vb} = (1.093)(0.008314)(523.3) \left[(0.6692) \frac{(\ln [3880.0/101.325] - 1)}{0.930 - 0.6692} \right]$$

$$= 32.28 \text{ kJ/mol}$$

The value from Daubert et al.²⁴ is 32.23 kJ/mol.

The enthalpy of vaporization decreases with temperature and is zero at the critical point. If the value of an enthalpy of vaporization ΔH_{v1} is known at temperature T_1 , this temperature dependency can be represented by the Watson relation¹²⁷ to calculate another enthalpy of vaporization ΔH_{v2} at any other temperature T_2 :

$$\Delta H_{v2} = \Delta H_{v1} \left(\frac{1 - T_{r2}}{1 - T_{r1}} \right)^{0.38} \quad (2-59)$$

where $T_{r1,2}$ = reduced temperature = T_1/T_c or T_2/T_c
 $T_{r1,2}$ = temperature, K
 T_c = critical temperature, K

Equation (2-59) works best between the normal boiling and critical temperatures, producing values of engineering accuracy.

Example 14 Estimate ΔH_v of ethyl acetate at 450 K, using the normal boiling point values as a basis (see Example 13). $\Delta H_{v1} = 32.23$ kJ/mol, $T_{r1} = 0.6692$, and $T_{r2} = 450.0/523.3 = 0.8599$. Substituting in Eq. (2-59):

$$\Delta H_{v(450)} = 32.23 \left(\frac{1 - 0.8599}{1 - 0.6692} \right)^{0.38} = 23.25 \text{ kJ/mol}$$

A value of 23.16 kJ/mol is obtained from Daubert et al.²⁴

Enthalpy of Fusion The enthalpy (heat) of fusion ΔH_{fus} is defined as the difference of the enthalpies of a unit mole or mass of a solid and liquid at its melting temperature and one atmosphere pressure of a pure component. There are no generally applicable estimation techniques that are very accurate. However, if the melting temperature is known, the atomic group contribution method of Chickos et al.¹⁶ yields approximate results:

$$\Delta H_{fus} = T_{melt} \Delta S_{fus} \quad (2-60)$$

where ΔH_{fus} = enthalpy of fusion at the melting temperature, J/mol
 T_{melt} = melting temperature, K
 ΔS_{fus} = $a + b$ = entropy of fusion at the melting temperature, J/mol K.

It should be noted that the methodology for a and b results in a ΔS_{fus} associated with the phase change from a solid at 0 K to the liquid at T_{melt} . No entropy changes resulting from solid transitions are taken into account, and ΔS_{fus} for a substance that undergoes such a transition will be overestimated by this technique.

$$a = 35.19 N_R + 4.289 (N_{CH_2} - 3 N_R) \quad (2-61)$$

where N_R = number of nonaromatic rings
 N_{CH_2} = number of $-\text{CH}_2-$ atomic groups in nonaromatic ring(s) required to form a cyclic paraffin of the same ring size(s) as contained in the molecule of interest.

Example: For  , $N_{CH_2} = 5$; $a = 0$ if there are no nonaromatic rings

in the molecule of interest. If a nonaromatic ring in fact contains a $-\text{CH}_2-$ atomic group, then no consideration of that group in the b term in Eq. (2-62) is required.

$$b = \sum_{i=1}^{n_g} (N_g)_i (\Delta_i) + \sum_{j=1}^{n_s} (N_s)_j (C_s)_j (\Delta_j) + \sum_{k=1}^{n_f} (N_f)_k (C_t)_k (\Delta_k) \quad (2-62)$$

where n_g = number of different nonring or aromatic C-H atomic groups bonded to other carbon atoms in the molecule of interest

$(N_g)_i$ = number of C-H atomic groups i bonded to other carbon atoms in the molecule of interest

n_s = number of different nonring or aromatic C-H atomic groups bonded to at least one functional group or atom in the molecule of interest

$(N_s)_j$ = number of C-H atomic groups j bonded to at least one functional group or atom in the molecule of interest

n_f = number of different functional groups or atoms in the molecule of interest

$(N_f)_k$ = number of functional groups or atoms k in the molecule of interest

$(C_s)_j$ = coefficient for C-H atomic group j bonded to at least one functional group or atom in the molecule of interest; numeric values for C-H atomic groups are found in Table 2-390

C_i = coefficient for the functional group or atom k in the molecule of interest, where $t =$ the total number of functional groups or atoms in the molecule of interest. *Exception:* Molecules containing any number of fluorine atoms are treated as having only one functional fluorine atom. Numeric values of C_1-C_4 are in Table 2-391 for functional groups or atoms

$(\Delta_s)_{i,j,k}$ = contribution of the atomic group or atom i, j , or k to the entropy of fusion, J/mol K. Numeric values for C-H atomic groups are in Table 2-390; values for functional groups or atoms are in Table 2-391

TABLE 2-390 C_s and Δ_s Values for C-H Atomic Groups to Estimate ΔH_{fus}

	C_s	Δ_s
Nonring		
—CH ₃	1.0	18.33
—CH ₂ —	1.0	9.41
—CH	0.69	-16.19
—C—	0.67	-38.70
=CH ₂	1.0	14.56
=CH	3.23	4.85
=C—	1.0	-11.38
≡CH	1.0	10.88
≡C—	1.0	2.18
Aromatic		
≡CH	1.0	6.44
≡C— (bonded to paraffinic C)	1.0	-10.33
≡C— (bonded to olefinic C or non-C)	1.0	-4.27
≡C— (bonded to acetylenic C)	1.0	-2.51
Ring		
\ CH—	0.76	-15.98
\ C /	1.0	-32.97
\ CH	0.62	-4.35
\ C —	0.86	-11.72
\ C or =C=	1.0	-5.36

Chickos et al.¹⁶ report an average error of 2050 J/mol for monofunctional molecules and 3180 J/mol for multifunctional molecules when using their method to estimate ΔH_{fus} . Four **example** estimations are shown in Table 2-392.

SOLID AND LIQUID HEAT CAPACITY

The heat capacity is defined as the amount of energy required to change the temperature of a unit mass or mole one degree; typical units are J/kg·K or J/kmol·K.

Solid Heat Capacity Solid heat capacity increases with increasing temperature, with steep rises near the triple point for many compounds. When experimental data are available, a simple polynomial equation in temperature is often used to correlate the data. It should be noted that step changes in heat capacity occur if the compound undergoes crystalline state changes at different temperatures.

There are no reliable prediction methods for solid heat capacity as a function of temperature. However, the atomic element contribution method of Hurst and Harrison,⁴¹ which is a modification of Kopp's Rule,⁵⁰ provides estimations at 298.15 K and is easy to use:

$$C_{ps} = \sum_{i=1}^n N_i \Delta_{Ei} \quad (2-63)$$

where C_{ps} = solid heat capacity at 298.15 K, J/mol K
 n = number of different atomic elements in the compound
 N_i = number of atomic elements i in the compound
 Δ_{Ei} = numeric value of the contribution of atomic element i found in Table 2-393

Average errors are in the 9–10 percent range.

Example 15 Estimate solid heat capacity of dibenzothiophene, C₁₂H₈S. The required atomic element contributions from Table 2-393 are: C = 10.89, H = 7.56, and S = 12.36. Substituting in Eq. (2-63):

$$C_{ps} = (12)(10.89) + (8)(7.56) + (1)(12.36) = 203.52 \text{ J/mol K}$$

Daubert et al.²⁴ report a value of 198.5 J/mol K.

Liquid Heat Capacity The two commonly used liquid heat capacities are either at constant pressure or at saturated conditions. There is negligible difference between them for most compounds up to a reduced temperature (temperature/critical temperature) of 0.7. Liquid heat capacity increases with increasing temperature, although a minimum occurs near the triple point for many compounds.

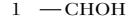
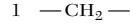
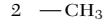
There are a number of reliable estimating techniques for obtaining **pure-component** liquid heat capacity as a function of temperature, including Ruzicka and Dolmalski,^{93,94} Tarakad and Danner,¹¹² and Lee and Kesler.⁵⁵ These methods are somewhat complicated. The relatively simple atomic group contribution approach of Chueh and Swanson¹⁷ for liquid heat capacity **at 293.15 K** is presented here:

$$C_{pl} = \sum_{i=1}^n N_i \Delta_{cip} + 18.83m \quad (2-64)$$

where C_{pl} = liquid heat capacity at 293.15 K, J/mol K.
 n = number of different atomic groups in the compound
 N_i = number of atomic groups i in the compound
 Δ_{cip} = numeric value of the contribution of atomic element i found in Table 2-394. The original units of cal/mol K have been converted to J/mol K by the conversion 1 cal/mol K = 4.184 J/mol K
 m = number of carbon groups requiring an additional contribution, which are those that are joined by a single bond to a carbon group, which in turn is connected to a third carbon group by a double or triple bond. If a carbon group meets this criterion in more than one way, m should be increased by one for each of the ways. *Exceptions:* —CH₃ groups or carbon groups in a ring never require an additional contribution; and the first additional contribution for a —CH₂— group is 10.46 J/mol K rather than 18.83 J/mol K. However, if the —CH₂— group meets the criterion in a second way, the *second* additional contribution reverts to the 18.83 J/mol K value (see Example 17, below).

Errors should be less than 6 percent for all compounds except for acids, amines, and halides.

Example 16 Estimate the liquid heat capacity at 293.15 K of 2-butanol. The atomic groups are:



Substituting in Eq. (2-64) the atomic group contributions from Table 2-394 with $m = 0$:

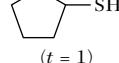
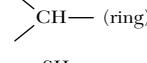
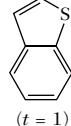
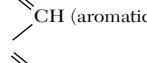
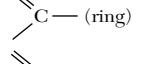
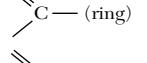
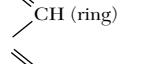
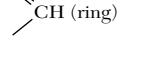
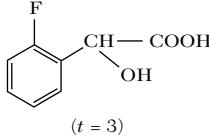
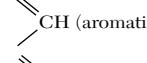
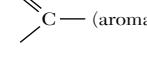
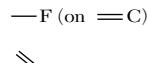
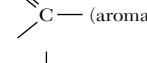
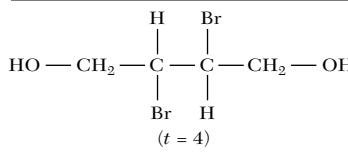
$$C_{pl} = (2)(36.82) + (1)(30.38) + (1)(76.15) = 180.17 \text{ J/mol K}$$

The value from Daubert et al.²⁴ is 190.3 J/mol K.

TABLE 2-391 C_i and Δ_s Values for Functional Groups and Atoms to Estimate ΔH_{fus}

	C_1	C_2	C_3	C_4	Δ_s
—OH (alcohol)	1.0	12.6	18.9	26.4	1.13
—OH (phenol)	1.0	1.0	1.0	1.0	16.57
—O— (ether, nonring)	1.0	1.0	1.0	1.0	1.09
—O— (ether, ring)	1.0	1.0	1.0	1.0	1.34
—C=O (ketone, nonring)	1.0	1.0			3.14
C=O (ketone, ring)	1.0	1.0			-1.88
—CHO (aldehyde)	1.0				19.66
—COOH (acid)	1.0	1.83	1.88	1.72	14.90
—COO— (ester)	1.0	1.0	1.0	1.0	3.68
—NH ₂ (aliphatic)	1.0	1.82			16.23
—NH ₂ (aromatic)	1.0	1.0			15.48
—NH (nonring)	1.0	1.0			-2.18
—NH (ring)	1.0				1.84
—N— (nonring)	1.0				-15.90
N— (ring)	1.0	1.0			-17.07
==N— (ring)	1.0	1.0			1.67
==N— (aromatic)	1.0	1.0	1.0		7.32
—CN (nitrile)	1.0	1.4			9.62
—NO ₂	1.0	1.0	1.0		17.36
NH ₂	1.0	1.0			26.19
NH—	1.0	1.0			-0.42
—SH	1.0	1.0			17.99
—S— (nonring)	1.0			0.36	7.20
—S— (ring)	1.0	1.0			2.18
—SO ₂ [−] (nonring)	1.0				3.26
—F (on —C)	1.0	1.0	1.0	1.0	14.73
—F (on ==C)	1.0	1.0	1.0	1.0	13.01
—F (on ring C)	1.0	1.0	1.0	1.0	15.90
—Cl	1.0	2.0	2.0	1.93	8.37
—Br	1.0	1.0	1.0	0.82	17.95
—I	1.0	1.0			16.95

TABLE 2-392 Examples of Estimations of ΔH_{fus} , J/mol

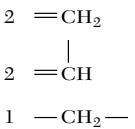
Molecule	Melting temp., K	Atomic group	Contribution
 (t = 1)	155.4	cyclopentane  —SH	(35.19)(1) + (4.289)[5 - (3)(1)] = 43.77 (1)(0.76)(-15.98) = -12.14 (1)(1.0)(17.99) = 17.99 ΔS_{fus} = 49.62 $\Delta H_{\text{fus}} = (49.62)(155.4)$ = 7710.9 $\Delta H_{\text{fus}} = (\text{experimental})^{16}$ = 7802
 (t = 1)	304.5	cyclopentane      —S—(ring)	(35.19)(1) + (4.289)[5 - (3)(1)] = 43.77 (4)(6.44) = 25.76 (1)(-11.72) = -11.72 (1)(0.86)(-11.72) = -10.08 (1)(-4.35) = -4.35 (1)(0.62)(-4.35) = -2.69 (1)(1.0)(2.18) = 2.18 ΔS_{fus} = 42.87 $\Delta H_{\text{fus}} = (42.87)(304.5)$ = 13054 $\Delta H_{\text{fus}} = (\text{experimental})^{16}$ = 11823
 (t = 3)	363.0	  —F (on =C)   —COOH —OH (alcohol)	(4)(6.44) = 25.76 (1)(1.0)(-4.27) = -4.27 (1)(1.0)(13.01) = 13.01 (1)(-10.33) = -10.33 (1)(0.69)(-16.19) = -11.17 (1)(1.88)(14.90) = 28.01 (1)(18.9)(1.13) = 21.36 ΔS_{fus} = 62.37 $\Delta H_{\text{fus}} = (62.37)(363.0)$ = 22640 $\Delta H_{\text{fus}} = (\text{experimental})^{16}$ = 20959
 (t = 4)	338.2	—CH ₂ —  —OH (alcohol) —Br	(2)(1.0) 9.41 = 18.82 (2)(0.69)(-16.19) = -22.34 (2)(26.4)(1.13) = 59.66 (2)(0.82)(17.95) = 29.44 ΔS_{fus} = 85.58 $\Delta H_{\text{fus}} = (85.58)(338.2)$ = 28943 $\Delta H_{\text{fus}} = (\text{experimental})^{16}$ = 29291

2-354 PHYSICAL AND CHEMICAL DATA

TABLE 2-393 Atomic Element Contributions to Estimate Solid Heat Capacity at 298.15 K

Atomic element	Δ_E	Atomic element	Δ_E	Atomic element	Δ_E
C	10.89	Ba	32.37	Mo	29.44
H	7.56	Be	12.47	Na	26.19
O	13.42	Ca	28.25	Ni	25.46
N	18.74	Co	25.71	Pb	31.60
S	12.36	Cu	26.92	Si	17.00
F	26.16	Fe	29.08	Sr	28.41
Cl	24.69	Hg	27.87	Ti	27.24
Br	25.36	K	28.78	V	29.36
I	25.29	Li	23.25	W	30.87
Al	18.07	Mg	22.69	Zr	26.82
B	10.10	Mn	28.06	All other	26.63

Example 17 Estimate liquid heat capacity at 293.15 K of 1,4-pentadiene, $\text{CH}_2=\text{CH}-\text{CH}_2-\text{CH}=\text{CH}_2$. The atomic groups are:



The $-\text{CH}_2-$ group is twice joined by a single bond to a carbon group, which in turn is connected to a third carbon group by a double bond, and $m=2$. However, by the second exception, the first additional contribution is 10.46 J/mol K rather than 18.83 J/mol K. Substituting in Eq. (2-64) the atomic group contributions from Table 2-394:

$$C_{pl} = (2)(21.76) + (2)(21.34) + (1)(30.38) + 10.46 + 18.83 = 145.87 \text{ J/mol K}$$

TABLE 2-394 Atomic Group Contributions to Estimate Liquid Heat Capacity at 293.15 K

	Δ_p		Δ_p
Nonring Increments		Oxygen Increments (Cont.)	
$-\text{CH}_3$	36.82	$-\text{CH}_2\text{OH}$	73.22
$-\text{CH}_2-$	30.38	$-\text{CHOH}$	76.15
$\begin{array}{c} \\ -\text{CH} \\ \end{array}$	20.92	$\begin{array}{c} \\ -\text{COH} \\ \end{array}$	111.29
$\begin{array}{c} \\ -\text{C} \\ \end{array}$	7.36	$-\text{OH}$ (except for above)	44.77
$=\text{CH}_2$	21.76	$-\text{ONO}_2$	119.24
$\begin{array}{c} \\ =\text{CH} \\ \end{array}$	21.34	Nitrogen Increments	
$\begin{array}{c} \\ =\text{C} \\ \end{array}$	15.90	$-\text{NH}_2$	58.58
$\equiv\text{CH}$	24.69	$-\text{NH}$	43.93
$\equiv\text{C}-$	24.69	$-\text{N}-$	31.38
Ring Increments		$-\text{N}=\text{(ring)}$	18.83
$-\text{CH}_2-$	25.94	$-\text{CN}$	58.16
$\begin{array}{c} \\ -\text{CH} \\ \end{array}$	18.41	Sulfur Increments	
$\begin{array}{c} \\ -\text{C} \text{ or } =\text{C} \\ \end{array}$	12.13	$-\text{SH}$	44.77
$\begin{array}{c} \\ =\text{CH} \\ \end{array}$	22.18	$-\text{S}-$	33.47
Oxygen Increments		Halogen Increments	
$-\text{O}-$	35.15	$-\text{F}$	16.74
$\begin{array}{c} \\ -\text{C}=\text{O} \end{array}$	52.97	$-\text{Cl}$ (first or second on a carbon)	35.98
$-\text{CHO}$ (aldehyde)	52.97	$-\text{Cl}$ (third or fourth on a carbon)	25.10
$-\text{COOH}$ (acid)	79.91	$-\text{Br}$	37.66
$-\text{COO}-$ (ester)	60.67	$-\text{I}$	35.98
		Hydrogen Increment	
		$-\text{H}$ (for formic acid, formates, hydrogen cyanide, etc.)	14.64

Daubert et al.²⁴ report a value of 145.6 J/mol K.

For **liquid mixtures**, the values of the pure components can be mole-fraction-averaged. This procedure neglects any heat of mixing effects.

DENSITY

Density is defined as the mass of a substance contained in a unit volume. In the SI system of units, the ratio of the density of a substance to the density of water at 15°C is known as its relative density, while the older term *specific gravity* is the ratio relative to water at 60°F. Various units of density, such as kg/m³, lb-mass/ft³, and g/cm³, are commonly used. In addition, molar densities, or the density divided by the molecular weight, is often specified. This section briefly discusses methods of correlation of density as a function of temperature and presents the most common accurate methods for prediction of vapor, liquid, and solid density.

Correlation Methods Vapor densities are not correlated as functions of temperature alone, as pressure and temperature are both important. At high temperatures and very low pressures, the ideal gas law can be applied; while at moderate temperature and low pressure, vapor density is usually correlated by the virial equation. Both methods will be discussed later.

Molar liquid density (ρ) is best correlated by an equation adopted from the Rackett predictor. The equation has the form of Eq. (2-65):

$$\rho = \frac{A}{B\left(1 - \frac{T}{C}\right)^D} \quad (2-65)$$

The regression constants A , B , and D are determined from the nonlinear regression of available data, while C is usually taken as the critical temperature. The liquid density decreases approximately linearly from the triple point to the normal boiling point and then nonlinearly to the critical density (the reciprocal of the critical volume). A few compounds such as water cannot be fit with this equation over the entire range of temperature. Liquid density data to be regressed should be at atmospheric pressure up to the normal boiling point, above which saturated liquid data should be used. Constants for 1500 compounds are given in the DIPPR compilation.²⁴

Solid density data are sparse and usually only available over a narrow temperature range, for which the general decrease in density with temperature is approximately linear.

Vapor Density Prediction A myriad of methods exist for prediction of vapor density as a function of temperature and pressure. This section will only present the most accurate and generally used methods.

For simple molecules at temperatures above the critical and at pressures no more than a few atmospheres, the ideal gas law, Eq. (2-66), may be used to estimate vapor density.

$$\rho = \frac{1}{V} = \frac{P}{RT} \quad (2-66)$$

At slightly higher pressures up to a reduced pressure of about 0.4, the truncated virial equation, Eq. (2-67), is commonly used for all types of organic fluids.

$$Z = \frac{PV}{RT} = 1 + \frac{B}{V} \quad (2-67a)$$

$$Z = \frac{P}{\rho RT} = 1 + B\rho \quad (2-67b)$$

Second virial coefficients, B , are a function of temperature and are available for about 1500 compounds in the DIPPR compilation.²⁴ The second virial coefficient can be regressed from experimental PVT data or can be reasonably and accurately predicted. Tsonopoulos¹¹⁷ proposed a prediction method for nonpolar compounds that requires the critical temperature, critical pressure, and acentric factor. Equations (2-68) through (2-70) describe the method.

$$\frac{BP_c}{RT_c} = B_0 + \omega B_1 \quad (2-68)$$

$$B_0 = 0.1445 - \left(\frac{0.330}{T_r}\right) - \left(\frac{0.1385}{T_r^2}\right) - \left(\frac{0.0121}{T_r^3}\right) - \left(\frac{0.000607}{T_r^5}\right) \quad (2-69)$$

$$B_1 = 0.0637 + \left(\frac{0.0331}{T_r^2}\right) - \left(\frac{0.423}{T_r^3}\right) - \left(\frac{0.008}{T_r^8}\right) \quad (2-70)$$

For non-hydrogen-bonding polar compounds such as carbonyls and ethers, Tsonopoulos¹¹⁷ recommends that Eq. (2-68) be expanded to a third term that is a function of the reduced dipole moment (μ_r) as described by Eqs. (2-71) through (2-73):

$$\frac{BP_c}{RT_c} = B_0 + \omega B_1 + B_2 \quad (2-71)$$

$$B_2 = -0.0002410\lambda_r - 4.308 \times 10^{-21}\lambda_r^8 \quad (2-72)$$

$$\lambda_r = \frac{10^5 \lambda_p^2 P_c}{T_c^2} \quad (2-73)$$

The dipole moment λ_p in Eq. (2-73) is in debyes, while P_c is in atm and T_c is in K. Units must be watched carefully. For hydrogen-bonding molecules, Eq. (2-71) can be used with a value of B_2 calculated by Eq. (2-74).

$$B_2 = \frac{a}{T_r^6} - \frac{b}{T_r^8} \quad (2-74)$$

Variables a and b are specific constants reported by Tsonopoulos¹¹⁷ for some alcohols and water (e.g., methanol: $a = 0.0878$, $b = 0.0560$; and water: $a = 0.0279$, $b = 0.0229$). Tsonopoulos also gives specific prediction methods for haloalkanes¹¹⁸ and water pollutants.¹¹⁹

Example 18 Estimate the molar volume of isobutane at 155°C and 1.0 MPa pressure. Properties of isobutane are $T_c = 135.0^\circ\text{C}$, $P_c = 3.647$ MPa, and $\omega = 0.1170$.

$$T_r = \frac{155 + 273.1}{135 + 273.1} = 1.05 \quad P_r = \frac{1.0}{3.647} = 0.274$$

Since reduced pressure is below 0.4, use virial equation (2-67a). Calculate B by the Tsonopoulos method, Eq. (2-68).

$$\frac{BP_c}{RT_c} = B_0 + \omega B_1$$

Using Eq. (2-69):

$$B_0 = 0.1445 - \left(\frac{0.330}{1.05}\right) - \left(\frac{0.1385}{1.05^2}\right) - \left(\frac{0.0121}{1.05^3}\right) - \left(\frac{0.000607}{1.05^5}\right)$$

$$B_0 = 0.1445 - 0.3143 - 0.1256 - 0.0105 - 0.0005 = -0.3064$$

Using Eq. (2-70):

$$B_1 = 0.0637 + \left(\frac{0.0331}{1.05^2}\right) - \left(\frac{0.423}{1.05^3}\right) - \left(\frac{0.008}{1.05^8}\right)$$

$$B_1 = 0.0637 + 0.0300 - 0.3654 - 0.0054 = -0.2771$$

$$B = \frac{[-0.3064 + (0.1770)(-0.2771)](8314)(408.1)}{(3.647 \times 10^6)} = -0.3307$$

$$\frac{PV}{RT} = 1 + \frac{B}{V}$$

$$\frac{10^6 V}{(8314)(428.1)} = 1 - \frac{0.3307}{V}$$

Trial and error or the quadratic formula can be used for the solution. If you opt for trial and error, start with the ideal gas value ($B = 0$) where $V = 3.559$ m³/kmole [Eq. (2-66)].

Solving, $V = 3.190$ m³/kmole.

For prediction of vapor density of **pure hydrocarbon and nonpolar gases**, the corresponding states method of Pitzer et al.⁸² is the most accurate method, with errors of less than 1 percent except in the critical region where errors of up to 30 percent can occur. The method correlates the compressibility factor by Eq. (2-75), after which the density can be calculated by Eq. (2-75):

$$Z = Z^{(0)} + \omega Z^{(1)} \quad (2-75)$$

$$\rho = \frac{P}{ZRT} = \frac{1}{V} \quad (2-76)$$

$Z^{(0)}$ is the compressibility factor for the simple fluid, while $Z^{(1)}$ is the correction term for molecular acentricity, both of which are functions of T_r and P_r . Both

plots and detailed tabulations of the functions are available in the *Technical Data Book*.²³ Critical temperature and pressure and the acentric factor from tabulations or as predicted are required. For hydrogen, T_c and P_c should be taken as 41.7 K and 2100 kPa, respectively. For approximate calculations, Figs. 2-35 and 2-36 should be used for calculating $Z^{(0)}$ and $Z^{(1)}$, respectively, for superheated vapors with $0.2 \leq P_r \leq 10$. $Z^{(0)}$ will approach 1, and $Z^{(1)}$ will approach 0 for $P_r < 0.2$. More accurately, Eq. (2-77) can be used for P_r between 0 and 0.2.

$$Z = 1 + \frac{P_r}{T_r} [(0.1445 + 0.073\omega) - (0.330 - 0.46\omega)T_r^{-1} - (0.1385 + 0.50\omega)T_r^{-2} - (0.0121 + 0.097\omega)T_r^{-3} - 0.0073\omega T_r^{-8}] \quad (2-77)$$

Extension of the pressure range to $P_r = 14$ is available in the *Technical Data Book*. For saturated vapor densities, the values of $Z^{(0)}$ and $Z^{(1)}$ are tabulated as a

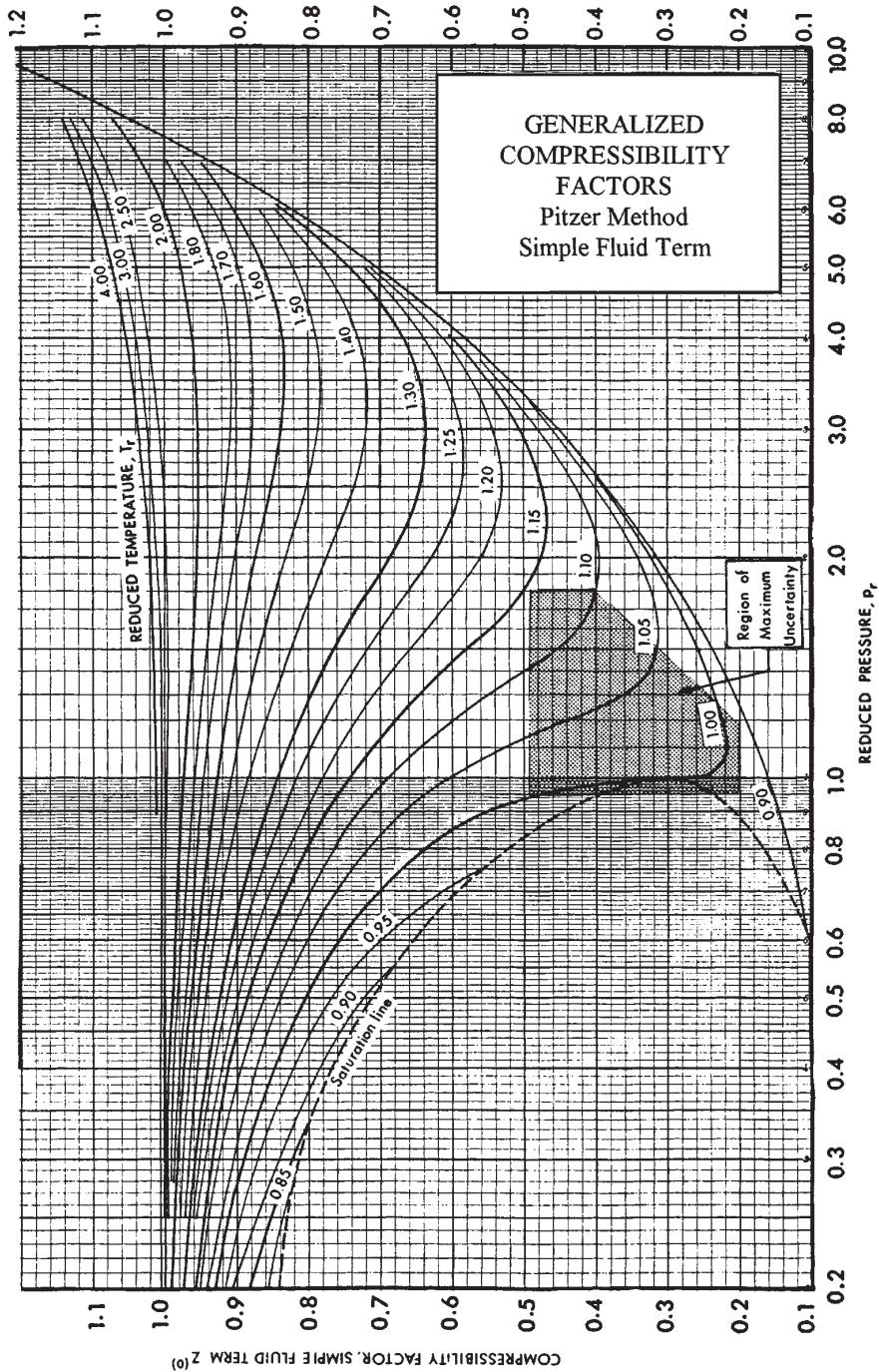


FIG. 2-35 Generalized compressibility factors—Pitzer Method, simple fluid term.

function of reduced pressure in Table 2-395. If the saturation temperature rather than the saturation pressure is known, the vapor pressure of the compound can be determined either from data or the vapor pressure prediction methods discussed earlier.

Example 19 Estimate the molar volume of isobutane at 155°C and 8.6 MPa pressure.

As high pressure, use Eq. (2-75) to calculate Z and then Eq. (2-76) to estimate the molar volume.

The properties of isobutane necessary are $T_c = 135.0^\circ\text{C}$, $P_c = 3.647 \text{ MPa}$, and $\omega = 0.1770$.

$$T_r = \frac{155 + 273.1}{135 + 273.1} = 1.05 \quad P_r = \frac{8.6}{3.647} = 2.36$$

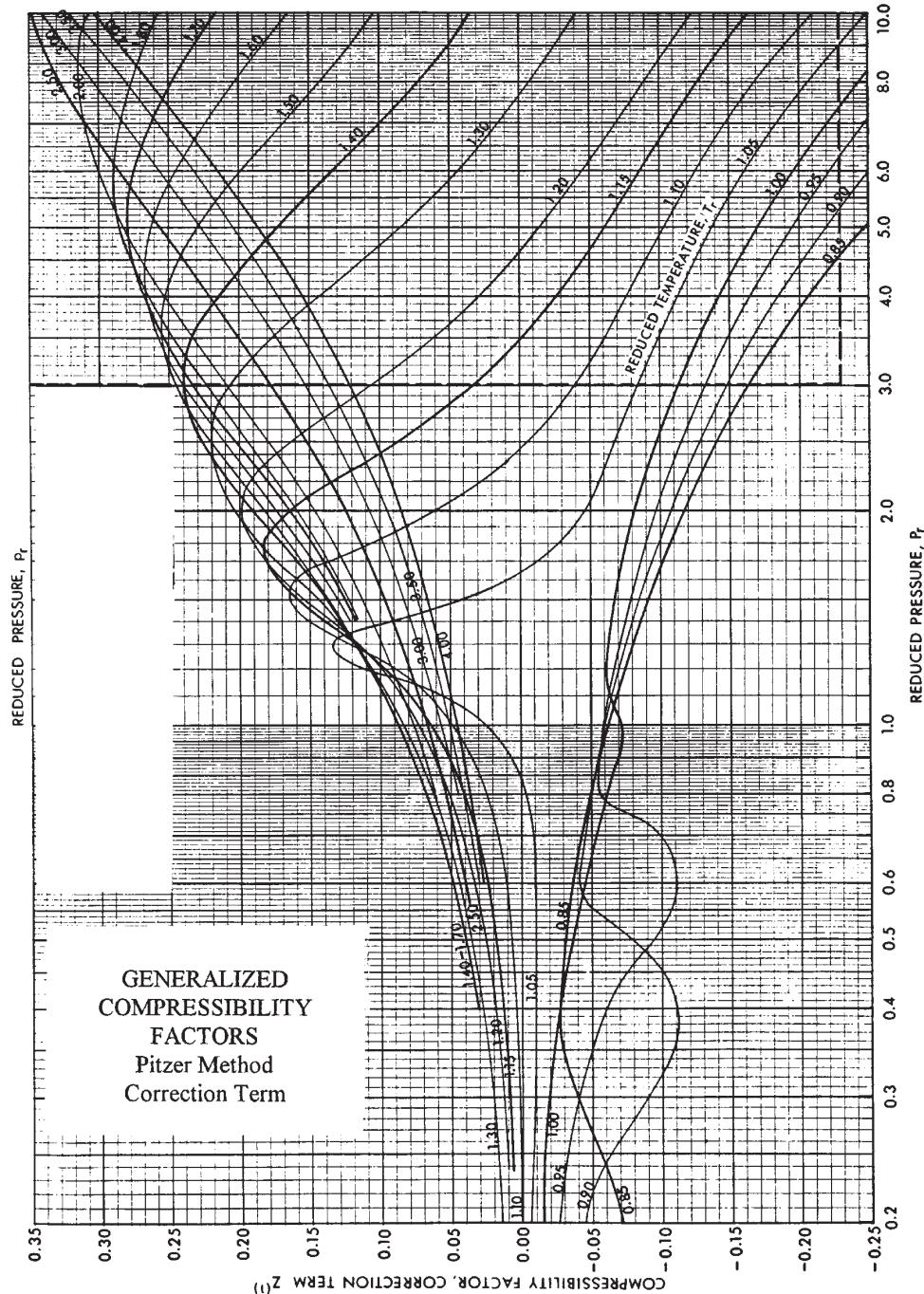


FIG. 2-36 Generalized compressibility factors—Pitzer Method, correction term.

TABLE 2-395 Saturated Vapor Density Parameters

P_r	$Z^{(0)}$	$Z^{(1)}$	P_r	$Z^{(0)}$	$Z^{(1)}$
1.00	0.291	-0.080	0.65	0.615	-0.069
0.99	0.35	-0.083	0.60	0.64	-0.063
0.98	0.38	-0.085	0.55	0.665	-0.056
0.97	0.40	-0.087	0.50	0.688	-0.049
0.96	0.41	-0.088	0.45	0.711	-0.041
0.95	0.42	-0.089	0.40	0.734	-0.033
0.94	0.43	-0.089	0.35	0.758	-0.025
0.92	0.45	-0.090	0.30	0.783	-0.018
0.90	0.47	-0.091	0.25	0.809	-0.012
0.85	0.50	-0.090	0.20	0.835	-0.008
0.80	0.53	-0.087	0.15	0.864	-0.005
0.75	0.56	-0.081	0.10	0.896	-0.002
0.70	0.59	-0.075	0.05	0.935	0.000

Using Fig. 2-35, $Z^{(0)} = 0.385$. Using Fig. 2-36, $Z^{(1)} = -0.063$.

$$\begin{aligned} Z &= Z^{(0)} + \omega Z^{(1)} \\ Z &= 0.385 + 0.1770(-0.063) = 0.374 \\ V &= \frac{ZRT}{P} = \frac{(0.374)(8314)(428.1)}{8.6 \times 10^6} \\ V &= 0.155 \text{ m}^3/\text{kmol} \end{aligned}$$

An experimental value for Z is 0.377.

Note that use of the Lee-Kesler fit [Eq. (2-78)] would give a slightly more accurate answer than the graphical method, and this fit is used for any computer applications.

Lee and Kesler⁵⁵ fit the entire Pitzer method to equations, rewriting the basic Eq. (2-75) with respect to a heavy reference fluid (*n*-octane) as shown by Eq. (2-78).

$$Z = Z^{(0)} + \frac{\omega}{\omega^{(h)}}(Z^{(h)} - Z^{(0)}) \quad (2-78)$$

where h specifies the heavy reference fluid with an acentric factor of 0.3978.

The parameters in the equation are calculated for the simple fluid and the heavy reference fluid with an acentric factor of 0.3978. The parameters in the equation are calculated for the simple fluid and the heavy reference fluid from Eq. (2-79)

$$\begin{aligned} Z^{(i)} &= \frac{P_r V_r}{T_r} = 1 + \frac{B}{V_r} + \frac{C}{V_r^2} + \frac{D}{V_r^5} + \frac{c_4}{T_r^3 V_r^2} \left[\beta + \frac{\gamma}{V_r^2} \right] \exp \left[\frac{-\gamma}{V_r^2} \right] \quad (2-79) \\ B &= b_1 - \left(\frac{b_2}{T_r} \right) - \left(\frac{b_3}{T_r^2} \right) - \left(\frac{b_4}{T_r^3} \right) \\ C &= c_1 - \left(\frac{c_2}{T_r} \right) - \left(\frac{c_3}{T_r^3} \right) \\ D &= d_1 + \left(\frac{d_2}{T_r} \right) \end{aligned}$$

where $Z^{(i)} = Z^{(0)}$ when the constants in the equation correspond to the simple fluid and $Z^{(h)}$ when the constants in the equation correspond to the heavy reference fluid

P = pressure, kPa

P_c = critical pressure of the compound whose density is sought, kPa
 V = molar volume of the simple fluid or the heavy reference fluid, as the case may be, in m^3/kmole .

R = gas constant = $8.3140 \text{ m}^3 \text{ kPa}/\text{k mole K}$

T_c = critical temperature of the compound whose density is sought, K
 T = temperature, K

Constant	Simple fluid	Heavy reference fluid
b_1	0.1181193	0.2026579
b_2	0.265728	0.331511
b_3	0.154790	0.027655
b_4	0.030323	0.203488
c_1	0.0236744	0.0313385
c_2	0.0186984	0.0503618
c_3	0.0	0.016901
c_4	0.042724	0.041577
$d_1 \times 10^4$	0.155488	0.48736
$d_2 \times 10^4$	0.623689	0.0740336
β	0.65392	1.226
γ	0.060167	0.03754

For **hydrocarbon and nonpolar gas mixtures**, the Pitzer pure component method can be used to predict vapor density by replacing the true critical properties with pseudocritical properties defined in Eqs. (2-80) and (2-81) by Kay.⁴⁷

$$T_{pc} = \sum_{i=1}^n x_i T_{ci} \quad (2-80)$$

$$P_{pc} = \sum_{i=1}^n x_i P_{ci} \quad (2-81)$$

The mixture acentric factor, Eq. (2-82), can also be used.

$$\omega = \sum_{i=1}^n x_i \omega_i \quad (2-82)$$

Errors in compressibility factors tabulated for over 6500 data points rarely exceed 2 percent except in the critical region, where 15 percent errors may be expected and 50 percent errors can occur. For mixtures near the critical point, special techniques are available as discussed in the sixth chapter of the *Technical Data Book*.

For **pure organic vapors**, the Lydersen et al.⁶³ corresponding states method is the most accurate technique for predicting compressibility factors and, hence, vapor densities. Critical temperature, critical pressure, and critical compressibility factor defined by Eq. (2-21) are used as input parameters. Figure 2-37 is used to predict the compressibility factor at $Z_c = 0.27$, and the result is corrected to the Z_c of the desired fluid using Eq. (2-83).

$$Z = Z_{@Z_c=0.27} + D_i(Z_c - 0.27) \quad (2-83)$$

D_i is equal to D_a read from Fig. 2-38 if $Z_c > 0.27$; and D_i is equal to D_b read from Fig. 2-39 if $Z_c < 0.27$. At reduced temperatures less than 0.9, D_i can be taken as 0. The density is then calculated from Eq. (2-76). All families of organic compounds except mercaptans and carboxylic acids are predicted within an average deviation of 5 percent.

No specific mixing rules have been tested for predicting compressibility factors for **defined organic mixtures**. However, the Lydersen method using pseudocritical properties as defined in Eqs. (2-80), (2-81), and (2-82) in place of true critical properties will give a reasonable estimate of the compressibility factor and hence the vapor density.

Vapor densities for pure compounds can also be predicted by cubic equations of state. For hydrocarbons, relatively accurate Redlich-Kwong-type equations such as the Soave⁹⁸ and Peng-Robinson⁸¹ equations are often used. Both require only T_c , P_c , and ω as inputs. For organic compounds, the Lee-Eyring-Emdister⁵⁴ equation (which requires the same input parameters) has been used with errors essentially equivalent to those determined for the Lydersen method. While analytical equations of state are not often used when only densities are required, values from equations of state are used as inputs to equation of state formulations for thermal and equilibrium properties.

Liquid Density Prediction Methods for the prediction of pure saturated hydrocarbons and nonhydrocarbon organics, compressed hydrocarbon liquids, and defined and undefined hydrocarbon mixtures were evaluated. Only the most accurate and convenient methods are included here.

The most convenient method for predicting the saturated liquid density of both **pure hydrocarbons and pure organic liquids**⁹⁹ is the method of Rackett⁸⁴ as modified by Spencer and Danner.⁹⁹ Equation (2-84) is used to calculate the saturated liquid molar density at any temperature using input parameters of T_c , P_c , and Z_{RA} . Z_{RA} is a parameter regressed from experimental data. Values for some common substances are given in Table 2-396. Extensive tabulations are given in the *Technical Data Book*²³ for hydrocarbons and nonhydrocarbons as well as organic and inorganic gases. Additional values are given in the *Data Prediction Manual*⁷² for nonhydrocarbons.

$$\frac{1}{\rho_{sat}} = V_{sat} = \left(\frac{RT_c}{P_c} \right) Z_{RA}^n \quad (2-84)$$

$$n = 1.0 + (1.0 - T_r)^{2/7}$$

Errors for hydrocarbons between the triple and critical points average about 0.7 percent, with organics averaging about 1.2 percent. The cor-

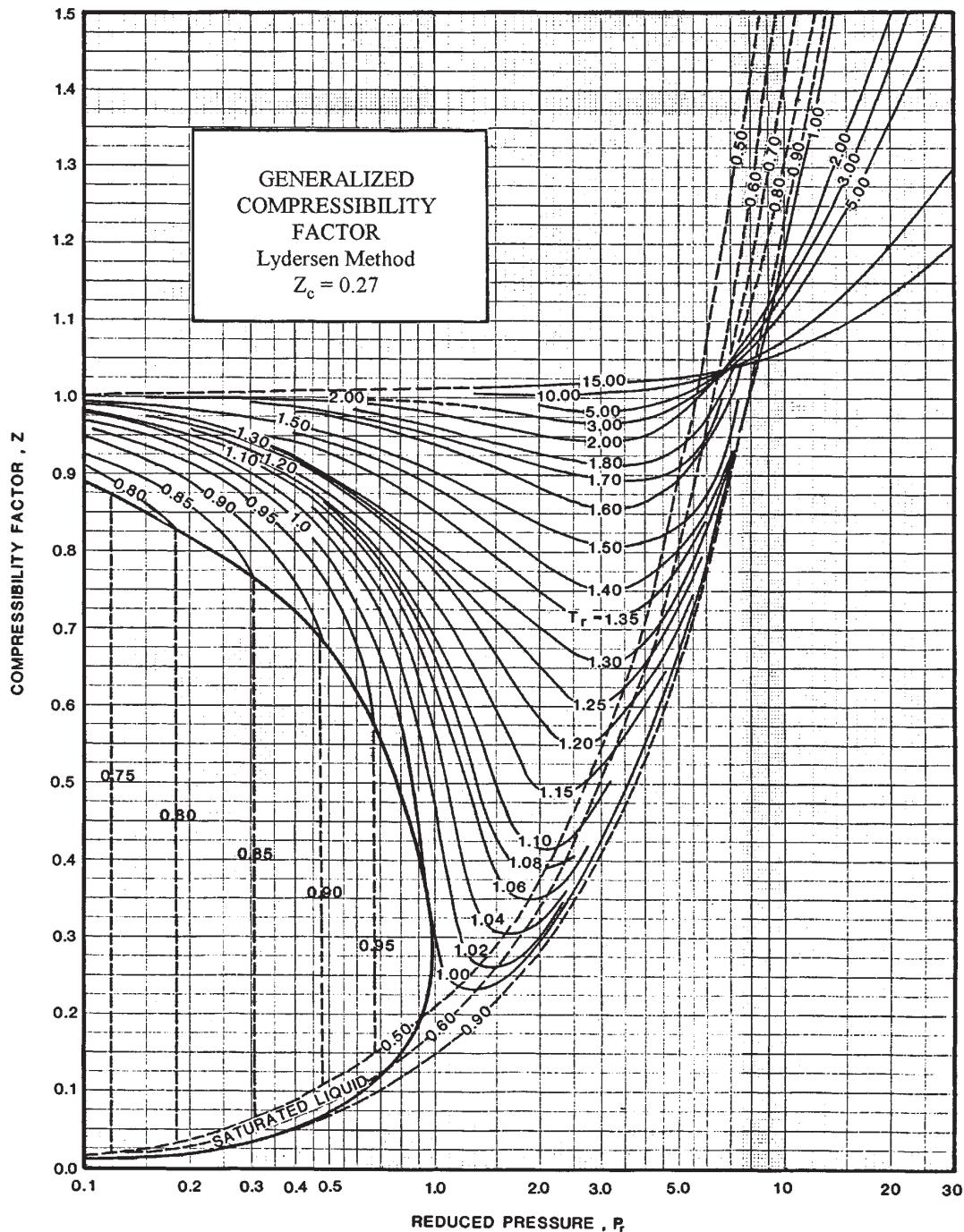


FIG. 2-37 Generalized compressibility factor—Lydersen Method, $Z_c = 0.27$.

relation is especially sensitive to the value of Z_{RA} near the critical point.

If no value of Z_{RA} is available or derivable, the critical compressibility factor can be used in Eq. (2-84) as originally proposed by Rackett. Use of Z_c increases the average error to about 3.0 percent.

Example 20 Estimate the density of saturated liquid propane at 0°C. Use Eq. (2-84).

$$\rho_{\text{sat}} = \left(\frac{P_c}{RT_c} \right) \left(\frac{1}{Z_{RA}^n} \right)$$

$$n = 1.0 + (1.0 - T_r)^{2/7}$$

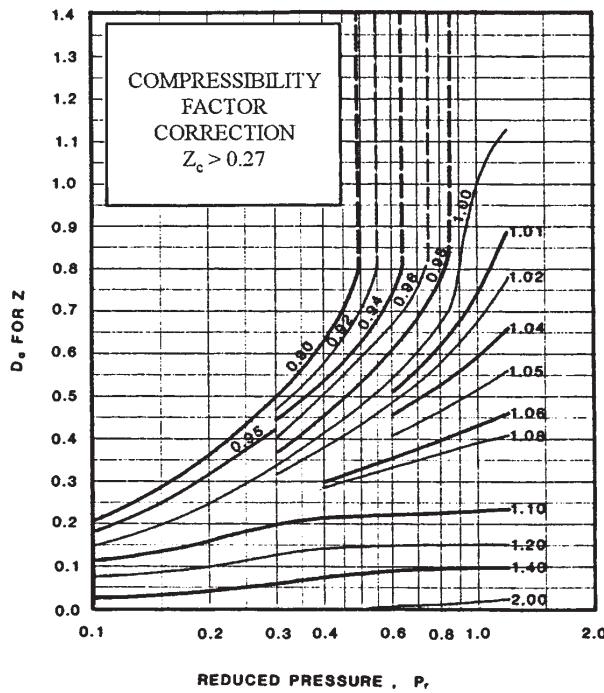


FIG. 2-38 Compressibility factor correction for Lydersen Method, $Z_c > 0.27$.

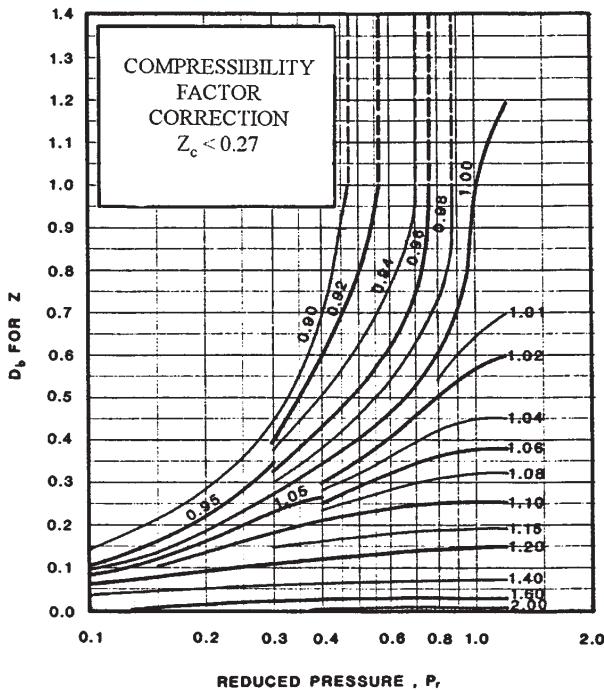


FIG. 2-39 Compressibility factor correction for Lydersen Method, $Z_c < 0.27$.

Pure component properties of propane are $M = 44.1$, $T_c = 96.7^\circ\text{C}$, and $P_c = 4.246 \text{ MPa}$. From Table 2-388, $Z_{RA} = 0.2763$.

$$T_r = \frac{273.1}{369.8} = 0.739, \quad n = 1.0 + (1.0 - 0.739)^{2/7} = 1.6813$$

$$n = 1.6813$$

$$\rho_{\text{sat}} = \frac{(4.246 \times 10^6)}{(8314)(369.8)} \left(\frac{1}{0.2763^{1.6813}} \right)$$

$$\rho_{\text{sat}} = 1.201 \text{ kmole/m}^3 = 529.6 \text{ kg/m}^3$$

An accepted experimental value is 531 kg/m^3 .

An alternate method with approximately the same accuracy as the Rackett method is the COSTALD method of Hankinson and Thomson.³⁵ The critical temperature, a characteristic volume near the critical volume, and an acentric factor optimized for vapor pressure prediction by the Soave⁹⁸ equation of state are required input parameters. The method is detailed in the *Technical Data Book*.²³

Prediction of the density of **compressed pure liquid hydrocarbons** and their defined mixtures are readily and accurately predicted by the method of Liu.⁶² One value of low pressure liquid density and the critical temperature and pressure are required to predict the density at higher pressures from Eq. (2-85).

$$\rho_2 = \left(\frac{C_2}{C_1} \right) \rho_1 \quad (2-85)$$

The constants C_1 and C_2 are both obtained from Fig. 2-40: C_1 , usually from the saturated liquid line; and C_2 , at the higher pressure. Errors should be less than 1 percent for pure hydrocarbons except at reduced temperatures above 0.95 where errors of up to 10 percent may occur. The method can be used for defined mixtures substituting pseudocritical properties for critical properties. For mixtures, the *Technical Data Book—Petroleum Refining* gives a more complex and accurate mixing rule than merely using the pseudocritical properties. The saturated low pressure value should be obtained from experiment or from prediction procedures discussed in this section for both pure and mixed liquids.

Example 21 Estimate the liquid density of *n*-nonane at 104.5°C and 6.893 MPa pressure.

A tabulated value of liquid density at 60°F (15.5°C) and 1 atm is 719.8 kg/m^3 . Pure component properties are $T_c = 321.5^\circ\text{C}$ and $P_c = 2.288 \text{ MPa}$.

Use Eq. (2-85) to correct a low pressure density.

$$\rho_2 = \left(\frac{C_2}{C_1} \right) \rho_1$$

where ρ_1 is a reference density. C_2 and C_1 are functions of T_r and P_r .

$$T_{r1} = \frac{288.6}{594.6} = 0.485 \quad T_{r2} = \frac{377.6}{594.6} = 0.635$$

$$P_{r1} = \frac{0.1013}{2.288} = 0.0443 \quad P_{r2} = \frac{6.893}{2.288} = 3.013$$

From Fig. 2-40, $C_1 = 1.08$ and $C_2 = 0.998$.

$$\rho_2 = \left(\frac{0.998}{1.08} \right) (719.8) = 665.1 \text{ kg/m}^3$$

An accepted experimental value at this temperature is 658.5 kg/m^3 , a 1 percent difference.

An analytical method for the prediction of compressed liquid densities was proposed by Thomson et al.¹¹⁴ The method requires the saturated liquid density at the temperature of interest, the critical temperature, the critical pressure, an acentric factor (preferably the one optimized for vapor pressure data), and the vapor pressure at the temperature of interest. All properties not known experimentally may be estimated. Errors range from about 1 percent for hydrocarbons to 2 percent for nonhydrocarbons.

For prediction of the densities of a **defined liquid mixture at its bubble point** (ρ_{bp}), the method of Spencer and Dammer¹⁰⁰ is the simplest. The density is calculated from Eq. (2-86) using inputs from Eqs. (2-87) and (2-88). For hydrocarbons, T_{mc} is calculated by Eqs. (2-89) through (2-92) if high accuracy is desired or by Eq. (2-93) for a less accurate answer.

$$\frac{1}{\rho_{bp}} = R \left(\sum_{i=1}^n x_i \frac{T_c}{P_{ci}} \right) Z_{RA_m}^{[1 + (1 - T_r)^{2/7}]} \quad (2-86)$$

$$Z_{RA_m} = \sum_{i=1}^n x_i Z_{RA_i} \quad (2-87)$$

$$T_r = \frac{T}{T_{mc}} \quad (2-88)$$

$$T_{mc} = \sum_{i=1}^n \sum_{j=i}^n \phi_i \phi_j T_{eq} \quad (2-89)$$

TABLE 2-396 The Modified Rackett Equation Input Parameters for Calculating Pure Saturated Liquid Densities

Liquid	Z_{RA}	Liquid	Z_{RA}
Hydrocarbons			
Methane	0.2880	Acetic acid	0.2242
Ethane	0.2819	Methanol	0.2340
Propane	0.2763	Ethanol	0.2523
<i>n</i> -Butane	0.2730	2-Propanol	0.2508
2-Methylpropane (isobutane)	0.2760	Acetaldehyde	0.2387
<i>n</i> -Pentane	0.2685	Acetone	0.2448
<i>n</i> -Hexane	0.2637	Methyl ethyl ketone	0.2524
<i>n</i> -Heptane	0.2610	Methyl isobutyl ketone	0.2589
<i>n</i> -Octane	0.2569	Ethylamine	0.2640
<i>n</i> -Nonane	0.2555	Aniline	0.2607
<i>n</i> -Decane	0.2527	Methyl formate	0.2581
<i>n</i> -Dodecane	0.2471	Methyl acetate	0.2553
<i>n</i> -Tetradecane	0.2270	Ethyl acetate	0.2538
<i>n</i> -Hexadecane	0.2386	Ethyl acrylate	0.2583
<i>n</i> -Octadecane	0.2292	Methyl- <i>n</i> -butyl ether	0.2655
<i>n</i> -Eicosane	0.2281	Diethyl ether	0.2643
Cyclopentane	0.2709	Diisopropyl ether	0.2699
Methylcyclopentane	0.2712		
Cyclohexane	0.2729		
Methylcyclohexane	0.2702		
Ethene (ethylene)	0.2813		
Propene (propylene)	0.2783		
1-Butene	0.2735		
cis-2-Butene	0.2705		
trans-2-Butene	0.2722		
2-Methylpropene (isobutylene)	0.2727		
1-Hexene	0.2654		
1,3-Butadiene	0.2713		
2-Methyl-1,3-butadiene	0.2680		
Ethyne (acetylene)	0.2707		
Propyne (methylacetylene)	0.2703		
Benzene	0.2696		
Methylbenzene (toluene)	0.2645		
Ethylbenzene	0.2619		
1,2-Dimethylbenzene (<i>o</i> -xylene)	0.2626		
1,3-Dimethylbenzene (<i>m</i> -xylene)	0.2594		
1,4-Dimethylbenzene (<i>p</i> -xylene)	0.2590		
Isopropylbenzene (cumene)	0.2616		
Biphenyl	0.2746		
Naphthalene	0.2611		
Organics			
Acetone			0.2448
Methanol			0.2340
Ethanol			0.2523
2-Propanol			0.2508
Acetaldehyde			0.2387
Acetone			0.2448
Methyl ethyl ketone			0.2524
Methyl isobutyl ketone			0.2589
Ethylamine			0.2640
Aniline			0.2607
Methyl formate			0.2581
Methyl acetate			0.2553
Ethyl acetate			0.2538
Ethyl acrylate			0.2583
Methyl- <i>n</i> -butyl ether			0.2655
Diethyl ether			0.2643
Diisopropyl ether			0.2699
Halogen Compounds			
Methyl chloride			0.2679
Dichloromethane			0.2619
Chloroform			0.2751
Tetrachloromethane			0.2721
Chlorobenzene			0.2650
Propionitrile			0.2156
Inorganics			
Ammonia			0.2466
Argon			0.2933
Carbon dioxide			0.2729
Carbon disulfide			0.2850
Carbon monoxide			0.2898
Chlorine			0.2781
Hydrogen			0.3218
Hydrogen chloride			0.2673
Hydrogen sulfide			0.2818
Nitrogen			0.2893
Oxygen			0.2890
Sulfur dioxide			0.2667
Sulfur trioxide			0.2513

$$\phi_i = \frac{x_i V_{ci}}{\sum_{j=1}^n x_j V_{cj}} \quad (2-90)$$

$$T_{cij} = \sqrt{T_{ci} T_{cj}} (1 - k_{ij}) \quad (2-91)$$

$$k_{ij} = 1.0 - \left[\frac{\sqrt{V_{ci}^{1/3} V_{cj}^{1/3}}}{(V_{ci}^{1/3} + V_{cj}^{1/3})/2} \right]^3 \quad (2-92)$$

$$T_{mc} = \sum_{i=1}^n x_i T_{ci} \quad (2-93)$$

Errors for binary hydrocarbon systems average about 2.5 percent except near the critical, where errors can approach 20 percent. If inorganic gases are included, errors average 4 percent except at high concentrations of carbon dioxide or hydrogen, where higher errors would be expected. If the simplified method for predicting T_{mc} is used, average errors of 5 to 7 percent should be expected for both binary hydrocarbon and nonhydrocarbon systems. No data are available to test the method for systems with more than two components.

A similarly accurate but slightly more complex method for prediction of densities of defined liquid hydrocarbon mixtures at their bubble points was published by Hankinson and Thomson³⁵ and was previously cited for prediction of pure liquid hydrocarbons.

For undefined hydrocarbon mixtures, the liquid density may be predicted at any temperature (T) from the mean average boiling point (MeABP) and the specific gravity (sp gr) by Eq. (2-94), adopted from Ritter et al.⁹²

$$P = 62.3636 \left[(\text{sp gr})^2 - \frac{(1.2655)(\text{sp gr}) - 0.5098 + 8.011 \times 10^{-5} \text{MeABP}(T - 519.67)}{\text{MeABP}} \right]^{1/2} \quad (2-94)$$

The density is calculated in lb_m/ft^3 if the temperatures are both in $^{\circ}\text{R}$. Errors

average about 0.3 percent at atmospheric pressure. At high pressures, the liquid density of undefined hydrocarbon mixtures can be predicted from the low pressure value by the method of Wright¹³¹ fully outlined in the *Technical Data Book*.²³

Solid Density Prediction The prediction of solid density is an inexact science and sometimes is taken as the liquid density at the triple point, although the solid density normally is higher than this value with a discontinuity at the triple point. Based on solid density data reviewed for the DIPPR compilation,²⁴ the solid density at the triple point can be estimated for organic compounds as 1.17 times the liquid density at the triple point. As liquid density at low temperatures varies little with temperature, the density of the liquid at the lowest estimable point above the triple point can be used with little degradation of the result. As solid density only decreases very slightly with increasing temperature and very little data on solid density as a function of temperature exist, no methods have been developed for predicting the solid density vs. temperature.

VISCOSITY

Viscosity is defined as the shear stress per unit area at any point in a confined fluid divided by the velocity gradient in the direction perpendicular to the direction of flow. If this ratio is constant with time at a given temperature and pressure for any species, the fluid is called a Newtonian fluid. This section is limited to Newtonian fluids, which include all gases and most nonpolymeric liquids and their mixtures. Most polymers, pastes, slurries, waxy oils, and some silicate esters are examples of non-Newtonian fluids.

The absolute viscosity (μ) is defined as the sheer stress at a point

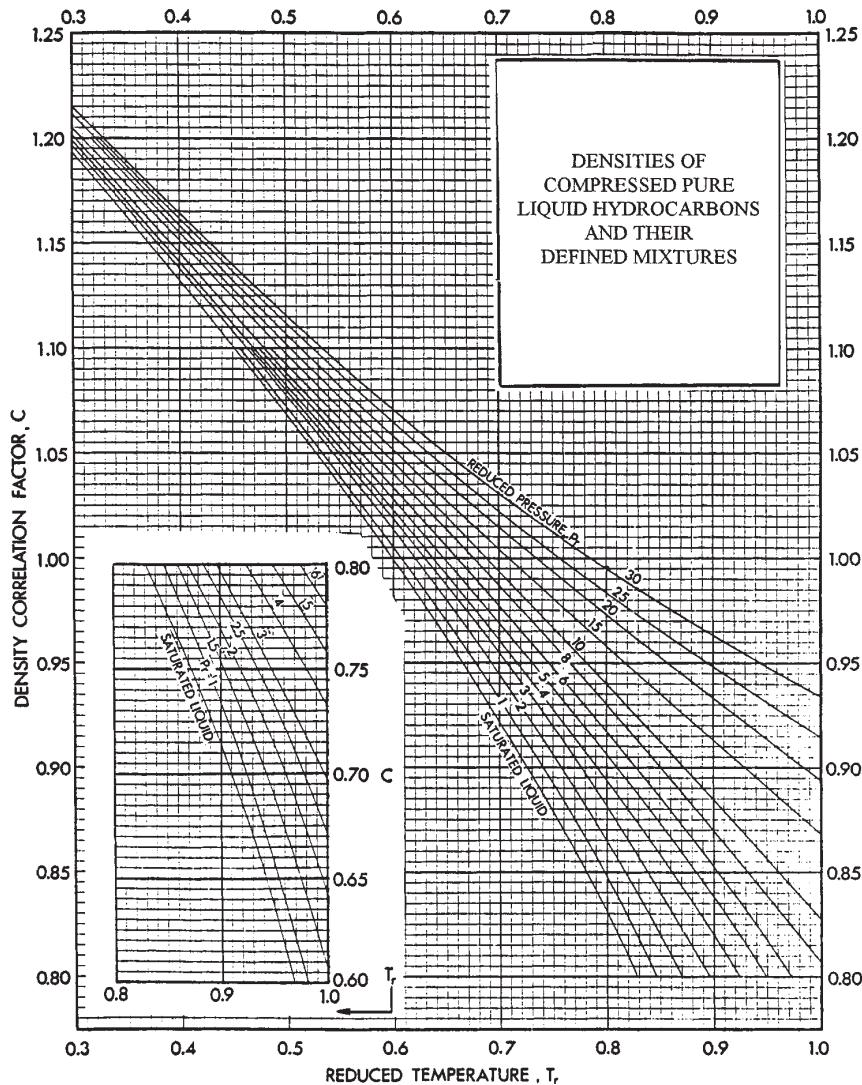


FIG. 2-40 Densities of compressed pure liquid hydrocarbons and their defined mixtures.

divided by the velocity gradient at that point. The most common unit is the poise (1 g/cm sec). The SI unit is the Pa·sec (1 kg/m sec). As many common fluids have viscosities in the hundredths of a poise the centipoise (cp) is often used. One centipoise is then equal to one mPa sec.

The kinematic viscosity (ν) is defined as the ratio of the absolute viscosity to density at the same temperature and pressure. The most common unit corresponding to the poise is the stoke (1 cm²/sec). The SI unit would be m²/sec.

Correlation Methods This section briefly discusses methods for correlating viscosities as a function of temperature and presents the most common accurate methods for prediction of vapor and liquid viscosity.

Vapor viscosity is accurately correlated as a function of temperature by Eq. (2-95).

$$\mu_v = \frac{AT^B}{1 + \frac{C}{T} + \frac{D}{T^2}} \quad (2-95)$$

If data are available over a wide range, all four regression constants (A , B , C , and D) are usually used. Over narrow temperature ranges, only constants A and B are necessary.

Liquid viscosity is accurately correlated as a function of temperature by the modified Riedel equation previously discussed for correlation of vapor pressure and shown by Eq. (2-96).

$$\mu_l = \exp \left(A + \frac{B}{T} + C \ln(T) + DT^E \right) \quad (2-96)$$

For most systems, only the first three terms are used. Only the first two terms are used for narrow ranges. If data are available in a wide range extending far above the normal boiling point, all four terms are used, with values of E varying in integers from -10 to 10 (excluding 0 and -1).

Constants for about 1500 compounds for both viscosities are available in the DIPPR compilation.²⁴

Vapor Viscosity Methods for prediction of vapor viscosity abound such that only the most accurate and generally used methods are included.

For prediction of the vapor viscosity of **pure hydrocarbons at low pressure** (below T_r of 0.6), the method of Stiel and Thodos¹⁰¹ is the most accurate. Only the molecular weight, the critical temperature, and the critical pressure are required. Equation (2-97) with values of N from Eqs. (2-98) and (2-99) is used.

$$\mu_v = 4.60 \times 10^{-4} \frac{NM^{1/2}P_c^{2/3}}{T_c^{1/6}} \quad (2-97)$$

$$N = 0.0003400T_r^{0.94} \text{ for } T_r \leq 1.5 \quad (2-98)$$

$$N = 0.0001778(4.58T_r - 1.67)^{0.625} \text{ for } T_r > 1.5 \quad (2-99)$$

The resultant viscosity is in centipoise (mPa·sec) if T_c and P_c are given in K and Pa, respectively. This method can also be used for light nonhydrocarbon gases except for hydrogen where, special N 's are required. For hydrocarbons below ten carbon atoms, average errors of about 3 percent can be expected, with errors increasing to 5–10 percent for heavier hydrocarbons.

Example 22 Estimate the vapor viscosity of propane at 101.3 kPa and 80°C.

Use Eq. (2-97).

$$\mu_v = 4.60 \times 10^{-4} N \frac{M^{1/2}P_c^{2/3}}{T_c^{1/6}}$$

$$T_c = 96.7^\circ\text{C}, P_c = 4.246 \text{ MPa, and } M = 44.1.$$

To determine whether Eq. (2-98) or (2-99) should be used to calculate N , calculate T_r .

$$T_r = \frac{80 + 273.1}{96.7 + 273.1} = 0.955$$

Use Eq. (2-98): $N = 0.0003400T_r^{0.94}$

Thus, $N = 3.255 \times 10^{-4}$.

$$\mu_v = \frac{(4.60 \times 10^{-4})(3.255 \times 10^{-4})(44.1)^{1/2}(4.246 \times 10^6)^{2/3}}{(369.8)^{1/6}}$$

$$\mu_v = 0.0097 \text{ cp}$$

An experimental value of 0.0095 cp compares favorably.

For prediction of the vapor viscosity of **gaseous mixtures of hydrocarbons and nonhydrocarbon gases at low pressures** below a T_r of 0.6, the method of Bromley and Wilke¹³ is recommended.

The mixing rule is given by Eq. (2-100) with the interaction parameter Q for each pair of components defined by Eq. (2-101).

$$\mu_m = \sum_{i=1}^n \frac{\mu_i}{1 + \sum_{j=1}^n \left(Q_{ij} \frac{x_j}{x_i} \right)} \quad (2-100)$$

$$Q_{ij} = \frac{1 + \left[\left(\frac{\mu_i}{\mu_j} \right)^{1/2} \left(\frac{M_j}{M_i} \right)^{1/4} \right]^2}{\sqrt{8} \left[1 + \frac{M_i}{M_j} \right]^{1/2}} \quad (2-101)$$

Errors, when tested against binary and multicomponent mixtures of both hydrocarbons and nonhydrocarbon gas mixtures, average about 3 percent.

For prediction of the vapor viscosity of **gaseous hydrocarbons and mixtures of hydrocarbons at high pressures** (not applicable to nonhydrocarbon gases) above a T_r of 0.6, low pressure values are calculated from Eq. (2-97) and/or (2-100) and then corrected for pressure by the method of Dean and Stiel²⁵ given by Eq. (2-102).

$$\mu - \mu_o = 5.0 \times 10^{-8} \frac{M^{1/2}P_c^{2/3}}{T_c^{1/6}} [\exp(1.439\rho_r) - \exp(-1.11\rho_r^{1.858})] \quad (2-102)$$

If critical pressure and critical temperature are given in Pa and K, respectively, viscosities in centipoise result. The variable μ_o is either the low pressure pure component or mixture viscosity according to whether a pure component or mixture is being considered. For mixtures, simple molar average pseudocritical temperature (Kays' rule), pressure, and density, and molar average molecular weight are used. The vapor density can be predicted by the methods previously discussed. Errors of above 5 percent are common for hydrocarbons and their mixtures. Experimental densities will reduce the errors slightly.

Example 23 Estimate the vapor viscosity of a mixture of propane and methane. Assume 60 mole percent methane and 40 mole percent propane at 125°C and 10.34 MPa total pressure. The low pressure viscosity is 0.0123 cp.

Use Eq. (2-102):

$$\mu - \mu_o = 5.0 \times 10^{-8} \frac{M^{1/2}P_c^{2/3}}{T_c^{1/6}} [\exp(1.439\rho_r) - \exp(-1.11\rho_r^{1.858})]$$

Properties of the pure components are:

Methane. $M = 16.04, T_c = -110.4^\circ\text{C}, P_c = 4.593 \text{ MPa}$

Propane. $M = 44.10, T_c = 96.7^\circ\text{C}, P_c = 4.246 \text{ MPa}$

For the mixture:

$$T_{pc} = (0.60)(-110.4 + 273.1) + (0.40)(96.7 + 273.1) = 245.5 \text{ K}$$

$$P_{pc} = (0.60)(4.593) + (0.40)(4.246) = 4.454 \text{ MPa}$$

$$M_m = (0.60)(16.04) + (0.40)(44.10) = 27.26$$

To calculate ρ_r , use Eq. (2-76) to calculate ρ using Pitzer corresponding states first to calculate Z . Then calculate $\rho_r = \rho/\rho_c = \rho V_{pc}$

Additional properties required are:

Methane $\omega = 0.0115, V_c = 0.0986 \text{ m}^3/\text{kmole}$

Propane $\omega = 0.1523, V_c = 0.2002 \text{ m}^3/\text{kmole}$

For the mixture:

$$\omega_m = (0.60)(0.0115) + (0.40)(0.1523) = 0.0678$$

$$V_{pc} = (0.60)(0.0986) + (0.40)(0.2002) = 0.1392 \text{ m}^3/\text{kmole}$$

Using Eq. (2-58):

$$Z = Z^{(0)} + \omega Z^{(1)}$$

$$T_r = \frac{398.1}{245.5} = 1.62 \quad P_r = \frac{10.34}{4.454} = 2.32$$

From Fig. 2-35: $Z^{(0)} = 0.87$

From Fig. 2-36: $Z^{(0)} \cong 0.20$

$$Z = 0.87 + (0.0678)(0.20) = 0.88$$

Hence: $\rho = \frac{P}{ZRT} = \frac{(10.34)}{(0.88)(8.314 \times 10^{-3})(398.1)}$

$$\rho = 3.55 \text{ kmole/m}^3$$

$$\rho_r = \rho V_{pc} = (3.55)(0.1392) = 0.494$$

$$\mu - \mu_o = \frac{(5.0 \times 10^{-8})(27.26)^{1/2}(4.454 \times 10^6)^{2/3}}{(245.5)^{1/6}} [e^{1.439(494)} - e^{-1.11(494)^{1.858}}]$$

$$\mu - \mu_o = \frac{(5.08 \times 10^{-8})(5.22)(27.085)}{(2.503)} [2.0358 - 0.7413]$$

$$\mu - \mu_o = 0.0037$$

$$\mu = 0.0037 + 0.0123 = 0.0160 \text{ cp}$$

An experimental value of 0.0167 cp compares favorably.

For **pure nonhydrocarbon polar gases at low pressures**, the viscosity can be estimated by the method of Reichenberg³⁵ given by Eq. (2-103).

$$\mu = \frac{AT_r}{[1 + 0.36T_r(T_r - 1)]^{1/6}} \quad (2-103)$$

For organic compounds:

$$A = \frac{M^{1/2}T_c}{\sum n_i C_i} \quad (2-104)$$

For inorganic gases:

$$A = 1.6104 \times 10^{-10} \left[\frac{M^{1/2}P_c^{2/3}}{T_c^{1/6}} \right] \quad (2-105)$$

Viscosities are calculated in Pa sec ($10^3 \text{ cp} = 1 \text{ Pa sec}$) with T_c in K and P_c in Pa. Group contributions based on atomic structure for organic compounds necessary for Eq. (2-104) are tabulated in Table 2-397. Errors average about 5 percent for most organics, with slightly higher errors for inorganic gases. For pure nonhydrocarbon nonpolar gases, an alternate method is the method of Yoon and Thodos,¹³² which requires the same input parameters as the Reichenberg method. The method, when evaluated for the *Technical Data Manual*, showed errors of about 3 percent for compounds with low dipole moments and requires special correlations for hydrogen and helium.

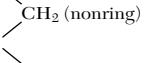
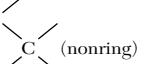
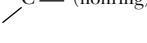
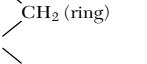
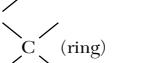
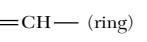
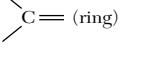
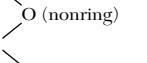
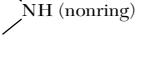
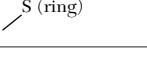
Example 24 Estimate the vapor viscosity of isopropyl alcohol at 251°C and atmospheric pressure.

Use Eq. (2-103) with A determined from Eq. (2-104).

$$\mu = \frac{AT_r}{[1 + 0.36T_r(T_r - 1)]^{1/6}}$$

$$A = \frac{M^{1/2}T_c}{\sum n_i C_i}$$

TABLE 2-397 Group Contribution Values for Eq. (2-104)

Group	Contribution $C_i \times 10^8 \text{ m}\cdot\text{s/K/kg}$
—CH ₃	0.904
 (nonring)	0.647
 (nonring)	0.267
 (nonring)	-0.153
=CH ₂	0.768
=CH— (nonring)	0.553
 (nonring)	0.178
≡CH	0.741
≡C— (nonring)	0.524
	0.691
	0.116
	0.023
=CH— (ring)	0.590
	0.359
—F	0.446
—Cl	1.006
—Br	1.283
—OH (alcohols)	0.796
	0.359
	1.202
—CHO (aldehydes)	1.402
—COOH (acids)	1.865
—COO— (esters) or HCOO— (formates)	1.341
—NH ₂	0.971
	0.368
=N— (ring)	0.497
—CN	1.813
	0.886

Pure component properties are $T_c = 508.3 \text{ K}$ and $M = 60.1$. Isopropyl alcohol group contributions for $\sum n_i C_i$ are calculated using Table 2-397.

$$2 \text{ —CH}_3 \text{ groups} = (2)(.904 \times 10^8) +$$

$$1 \text{ } \diagup \text{CH— group} = (1)(.267 \times 10^8) +$$

$$1 \text{ —OH group} = (1)(.796 \times 10^8) = 2.871 \times 10^8$$

$$T_r = \frac{524.1}{508.3} = 1.031$$

$$A = \frac{60.1^{1/2}(508.3)}{2.871} \times 10^8 = 1.373 \times 10^{-5} \text{ Pa sec}$$

$$\mu = \frac{(1.373 \times 10^{-5})(1.031)}{[1 + 0.36(1.031)(.031)]^{1/6}} = 1.413 \times 10^{-5} \text{ Pa sec}$$

(An experimental value of $1.380 \times 10^{-5} \text{ Pa sec}$ compares favorably.)

For pure **nonhydrocarbon polar and nonpolar gases at high pressure**, a method of prediction attributed to Stiel and Thodos¹⁰² depending on the reduced density as a corrector to the low pressure gas viscosity (μ^o) takes various forms for polar gases according to the reduced density (ρ_r) as shown in Eqs. (2-106) through (2-109).

$$\rho_r \leq 0.1 \quad (\mu - \mu^o)B = 1.656 \times 10^{-7} \rho_r^{1.111} \quad (2-106)$$

$$0.1 \leq \rho_r \leq 0.9 \quad (\mu - \mu^o)B = 6.07 \times 10^{-9}(9.045\rho_r + 0.63)^{1.739} \quad (2-107)$$

$$0.9 \leq \rho_r < 2.2 \quad \log [4 - \log_{10} [(\mu - \mu^o)10^7 B]] = 0.6439 - 0.1005\rho_r \quad (2-108)$$

$$2.2 \leq \rho_r < 2.6 \quad \log [4 - \log_{10} [(\mu - \mu^o)10^7 B]] = 0.6439 - 0.1005\rho_r$$

$$- 4.75 \times 10^{-4}(\rho_r^3 - 10.65)^2 \quad (2-109)$$

$$B = 2173.424 T_c^{1/6} M^{-1/2} P_c^{-2/3} \quad (2-110)$$

For nonpolar gases, Jossi et al.⁴⁵ extended the method as shown in Eq. (2-111) for $0.1 < \rho_r < 3.0$.

$$[(\mu - \mu^o)B10^7 + 1]^{1/4} = 1.0230 + 0.23364\rho_r + 0.58533\rho_r^2 - 0.40758\rho_r^3 + 0.093324\rho_r^4 \quad (2-111)$$

In all cases viscosities are in Pa sec with T_c in K and P_c in Pa. For nonpolars, errors are very small; while for polars, average errors reach 11 percent.

Example 25 Estimate the vapor viscosity of carbon dioxide at 350 K and a total pressure of 20 MPa. An experimental low pressure viscosity at 350 K is $1.7386 \times 10^{-5} \text{ Pa sec}$.

Use Eq. (2-111) with B calculated by Eq. (2-110).

The pure component properties necessary are $T_c = 304.19 \text{ K}$, $P_c = 7.3815 \text{ MPa}$, $V_c = 0.094 \text{ m}^3/\text{kmole}$, and $M = 44.01$.

Using the Lee-Kesler form of the Pitzer method [Eq. (2-78)], $Z = 0.4983$.

$$\rho_r = \frac{V_c}{V} = \frac{V_c P}{ZRT} = \frac{(0.094)(2 \times 10^7)}{(0.4983)(8314)(350)} = 1.2965$$

$$B = \frac{2173.424 T_c^{1/6}}{M^{1/2} P_c^{2/3}} = \frac{(2173.424)(304.19)^{1/6}}{(44.01)^{1/2}(7.3815 \times 10^6)^{2/3}}$$

$$B = 2.2411 \times 10^{-2}$$

$$[(\mu - \mu^o)B10^7 + 1]^{1/4} = 1.0230 + 0.23364(1.2965) + 0.58533(1.2965)^2 - 0.40758(1.2965)^3 + 0.093324(1.2965)^4$$

$$= 1.6852$$

$$(\mu - 1.7386 \times 10^{-5})(2.2411 \times 10^{-2})(10^7) + 1 = 8.0659$$

$$\mu - 1.7386 \times 10^{-5} = 3.1529 \times 10^{-5}$$

$$\mu = 4.89 \times 10^{-5} \text{ Pa sec}$$

An experimental value of $4.73 \times 10^{-5} \text{ Pa sec}$ compares favorably.

For both polar and nonpolar **nonhydrocarbon gaseous mixtures at low pressures**, the most accurate viscosity prediction method is the method of Brokaw.^{10,11} The method is quite accurate but requires the dipole moment and the Stockmayer energy parameter (ϵ/k) for polar components as well as pure component viscosities, molecular weights, the normal boiling point, and the liquid molar volume at the normal boiling point. The *Technical Data Manual* should be consulted for the full method.

For nonpolar, nonhydrocarbon vapor mixtures at high pressures, the method of Dean and Stiel¹²³ [Eq. (2-102)] discussed earlier can be used. The accuracy of the method is excellent and dependent on the pure component viscosity values used as input parameters.

Liquid Viscosity The viscosity of both **pure hydrocarbon and pure nonhydrocarbon liquids** are most accurately predicted by the method of van Velzen et al.¹²² The basic equation (2-112) depends on group contributions which are dependent on structure for the calculation of compound-specific constants B and T_o .

$$\log \mu = B\left(\frac{1}{T} - \frac{1}{T_o}\right) - 3.0 \quad (2-112)$$

Resultant viscosities are in Pa sec. If the -3.0 on the right is deleted,

answers are in cp. T_o is calculated by Eq. (2-114) or (2-115) according to the value of an adjusted carbon number N^* calculated by Eq. (2-113) using the actual carbon number N and group contributions from Table 2-398.

$$N^* = N + \sum_i \Delta N_i \quad (2-113)$$

$$N^* \leq 20 \quad T_o = 28.86 + 37.439N^* - 1.3547N^{*2} + 0.02076N^{*3} \quad (2-114)$$

$$N^* > 20 \quad T_o = 8.164N^* + 238.59 \quad (2-115)$$

TABLE 2-398 Group Contribution Values for Liquid Viscosity Prediction

Structures or functional group	ΔN_i	ΔB_i	Remarks
<i>n</i> -Alkanes	0	0	
Isoalkanes	1.389 - 0.238 <i>N</i>	15.51	
Saturated hydrocarbons with two methyl groups in isoposition	2.319 - 0.238 <i>N</i>	15.51	
<i>n</i> -Alkanes	-0.152 - 0.042 <i>N</i>	-44.94 + 5.410 <i>N</i> ^o	
<i>n</i> -Alkadienes	-0.304 - 0.084 <i>N</i>	-44.94 + 5.410 <i>N</i> ^o	
Isoalkanes	1.237 - 0.280 <i>N</i>	-36.01 + 5.410 <i>N</i> ^o	
Isoalkadienes	1.085 - 0.322 <i>N</i>	-36.01 + 5.410 <i>N</i> ^o	
Hydrocarbon with one double bond and two methyl groups in isoposition	2.626 - 0.518 <i>N</i>	-36.01 + 5.410 <i>N</i> ^o	For any additional CH ₃ groups in isoposition, increase ΔN by 1.389 - 0.238 <i>N</i>
Hydrocarbon with two double bonds and two methyl groups in isoposition	2.474 - 0.560 <i>N</i>	-36.01 + 5.410 <i>N</i> ^o	For any additional CH ₃ groups in isoposition, increase ΔN by 1.389 - 0.238 <i>N</i>
Cyclopentanes	0.205 + 0.069 <i>N</i> 3.971 - 0.172 <i>N</i>	-45.96 + 2.224 <i>N</i> ^o -339.67 + 23.135 <i>N</i> ^o	$N \leq 16$; not recommended for $N = 5, 6$ $N \geq 16$
Cyclohexanes	1.48 6.517 - 0.311 <i>N</i>	-272.85 + 25.041 <i>N</i> ^o -272.85 + 25.041 <i>N</i> ^o	$N < 17$; not recommended for $N = 6, 7$ $N \geq 17$
Alkyl benzenes	0.60 3.055 - 0.161 <i>N</i>	-140.04 + 13.869 <i>N</i> ^o -140.04 + 13.869 <i>N</i> ^o	$N < 16$; not recommended for $N = 6, 7$ ^{a,e,f} $N \geq 16$ ^{a,e,f}
Polyphenols	-5.340 + 0.815 <i>N</i>	-188.40 + 9.558 <i>N</i> ^o	^a
Alcohols			
Primary	10.606 - 0.276 <i>N</i>	-589.44 + 70.519 <i>N</i> ^o	^b
Secondary	11.200 - 0.605 <i>N</i>	497.58	^b
Tertiary	11.200 - 0.605 <i>N</i>	928.83	^b
Diols (correction)	See remarks	557.77	For ΔN , use alcohol contributions and add $N - 2.50$
Phenols (correction)	16.17 - <i>N</i>	213.68	^{a,c,d}
—OH on side chain to aromatic ring (correction)	-0.16	213.68	
Acids	6.795 + 0.365 <i>N</i> 10.71	-249.12 + 22.449 <i>N</i> ^o -249.12 + 22.449 <i>N</i> ^o	$N < 11$, not recommended for $N = 1, 2$ $N \geq 11$
Isoacids	See remarks	-249.12 + 22.449 <i>N</i> ^o	Calculate ΔB as for straight-chain acid; calculate ΔN for straight-chain acid but reduce ΔN by 0.24 for each methyl group in isoposition
Acids with aromatic nucleus in structure (correction)	4.81	-188.40 + 9.558 <i>N</i> ^o	
Esters	4.337 - 0.230 <i>N</i> -1.174 + 0.376 <i>N</i>	-149.13 + 18.695 <i>N</i> ^o -140.04 + 13.869 <i>N</i> ^o	If hydrocarbon groups have isoconfiguration, see ^c Add to values of ΔN , ΔB calculated for ester
Esters with aromatic nucleus in structure (correction)			
Ketones	3.265 - 0.122 <i>N</i>	-117.21 + 15.781 <i>N</i> ^o	If hydrocarbon groups have isoconfiguration, see ^c Add to values of ΔN , ΔB calculated for ketone
Ketones with aromatic nucleus in structure (correction)	2.70	-760.65 + 50.478 <i>N</i> ^o	
Ethers	0.298 + 0.209 <i>N</i>	-9.39 + 2.848 <i>N</i> ^o	If hydrocarbon groups have isoconfiguration, see ^c The ΔN value is not a correction to regular ether value, but the ΔB value is a correction to regular ether ^e
Aromatic ethers	11.5 - <i>N</i>	-140.04 + 13.869 <i>N</i> ^o	
Amines			
Primary	3.581 + 0.325 <i>N</i>	25.39 + 8.744 <i>N</i> ^o	If hydrocarbon groups have isoconfiguration, see ^c Corrections to be added to amine calculation ^e
Primary amine in side chain of aromatic compound (correction)	-0.16	0	
Secondary	1.390 - 0.461 <i>N</i>	25.39 + 8.744 <i>N</i> ^o	If hydrocarbon groups have isoconfiguration, see ^c
Tertiary	3.27	25.39 + 8.744 <i>N</i> ^o	If hydrocarbon groups have isoconfiguration, see ^c
Primary amines with NH ₂ group on aromatic nucleus	15.04 - <i>N</i>	0	The ΔN value is not a correction to regular amine value; to find ΔB , use primary amine value ^{a,c}
Secondary or tertiary amine with at least one aromatic group attached to amino nitrogen	f	f	
Nitro compounds			
1-Nitro	7.812 - 0.236 <i>N</i>	-213.14 + 18.330 <i>N</i> ^o	Note alkene contribution is necessary
2-Nitro	5.84	-213.4 + 18.330 <i>N</i> ^o	
3-Nitro	5.56	-338.01 + 25.086 <i>N</i> ^o	
4-Nitro; 5-Nitro	5.36	-338.01 + 25.086 <i>N</i> ^o	
Aromatic nitrocompounds	7.182 - 0.236 <i>N</i>	-213.14 + 18.330 <i>N</i> ^o	
Nitrile	4.039 - 0.0103 <i>N</i>	-241.66 + 27.937 <i>N</i> ^o	For aromatic correction, see ^f

TABLE 2-398 Group Contribution Values for Liquid Viscosity Prediction (Concluded)

Structures or functional group	ΔN_i	ΔB_i	Remarks
Amines (Cont.)			
Isomethyl on nitrile	$-0.7228 + 0.1755N$	$286.26 - 31.009N^*$	
Aromatic nitrile	$2.321 - 0.2357N$	$-26.063 - 11.516N^*$	
Dinitrile	$10.452 - 1.1276N$	$3599.9 - 199.96N^*$	
Halogenated compounds			
Fluoride	1.43	5.75	
Chloride	3.21	-17.03	e,f
Bromide	4.39	$-101.97 + 5.954N^*$	e,f
Iodide	5.76	-85.32	e,f
Special configurations (corrections)			
$C(Cl)_x$	$1.91 - 1.459x$	-26.38	
—CCl—CCl—	0.96	0	
—C(Br) _x —	0.50	$81.34 - 86.850x$	
—CBr—CBr—	1.60	-57.73	
CF_3			
In alcohols	-3.93	341.68	
In other compounds	-3.93	25.55	
Aldehydes	3.38	$146.45 - 25.11N^*$	
Aldehydes with an aromatic nucleus in structure (correction)	2.70	$-760.65 + 50.478N^*$	
Anhydrides	$7.97 - 0.50N$	-33.50	
Anhydrides with an aromatic nucleus in structure (correction)	2.70	$-760.65 + 50.478N^*$	
Amides	$13.12 + 1.49N$	$524.63 - 20.72N^*$	
Amides with an aromatic nucleus in structure (correction)	2.70	$-760.65 + 50.478N^*$	
Sulfide	$3.9965 - 0.1861N$	$-76.676 + 8.1403N^*$	
Isomethyl on sulfide	0.1601	-25.026	

^a For substitutions on an aromatic nucleus in more than one position, additional corrections are required:

Ortho	$\Delta N = 0.51$	$\Delta B = \begin{cases} -571.94 & (\text{with } —OH) \\ 54.84 & (\text{without } —OH) \end{cases}$
Meta	$\Delta N = 0.11$	$\Delta B = 27.25$
Para	$\Delta N = -0.04$	$\Delta B = 17.57$

^b For alcohols, if there is a methyl group in the isoposition, increase ΔN by 0.24 and ΔB by 94.23.

^c If the compound has an aromatic —OH or —NH₂, or if there is an aromatic ether, use ΔN contribution in table but neglect other substituents on the ring such as halogen, CH₃, NO₂, and the like. For the calculation of ΔB , however, such substituents must be taken into account.

^d For aromatic alcohols and compounds with an —OH on a side chain, the alcohol contribution (primary, etc.) must be included. For example, *o*-chlorophenol:

$$\Delta B = \Delta B(\text{primary alcohol}) + \Delta B(\text{chlorine}) + \Delta B(\text{phenol}) + \Delta B(\text{ortho correction—see footnote } a)$$

With $N^* = 16.17$ (see footnote *c*):

$$\Delta B = (-589.44 + 70.519 \times 16.17) + (-17.03) + (213.68) + (-571.94) = 175.56$$

$$B_a = 745.94 \quad B = B_a + \Delta B = 921.50$$

2-Phenylethanol:

$$N = 8; \Delta N = \Delta N(\text{primary alcohol}) + \Delta N(\text{correction}) = [10.606 - (0.276)(8)] + (-0.16) = 8.24$$

$$N^* = N + \Delta N = 8 + 8.24 = 16.24$$

$$\Delta B = \Delta B(\text{primary alcohol}) + \Delta B(\text{correction}) = [-589.44 + (70.519)(16.24)] + 213.68 = 769.47$$

$$B_a = 747.43 \quad B = B_a + \Delta B = 1516.9$$

^e For esters, alkylbenzenes, halogenated hydrocarbons, and ketones: If the hydrocarbon chain has a methyl group in an isoposition, decrease ΔN by 0.24 and increase ΔB by 8.93 for each such grouping. For ethers and amines, decrease ΔN by 0.50 and increase ΔB by 8.93 for each isogroup.

^f For alkylbenzenes, nitrobenzenes, halogenated benzenes and for secondary or tertiary amines where at least one aromatic group is connected to an amino nitrogen, add the following corrections for each aromatic nucleus. If $N < 16$, increase ΔN by 0.60; if $N \geq 16$, increase ΔN by 3.055 - 0.161N for each aromatic group. For any N , increase ΔB by (-140.04 + 13.869N°).

From van Velzen et al. (122).

B is calculated by Eq. (2-116) using values of B_a calculated from Eq. (2-117) or (2-118) according to the value of N^* and group contributions from Table 2-398.

$$B = B_a + \sum_i \Delta B_i \quad (2-116)$$

$$N^* \leq 20 \quad B_a = 24.79 + 66.885N^* - 1.3173N^{*2} - 0.00377N^{*3} \quad (2-117)$$

$$N^* > 20 \quad B_a = 530.59 + 13.740N^* \quad (2-118)$$

The method should not be used for the first member of a homologous series or for temperatures much above the normal boiling point ($T_r \approx 0.75$). Errors for both hydrocarbons and nonhydrocarbons average 15 percent for a wide variety of compounds. Higher errors are noted for amines, diols, ethers, and fluorides. Table 2-398 gives ΔN and ΔB contributions for most common groups. Space prohibits examples for

each type of compound or inclusion of specialized cases that are more fully discussed in the *Technical Data Manual*.

Example 26 Estimate the liquid viscosity of *cis*-1,4-dimethylcyclohexane at 0°C.

Use Eq. (2-112) with N^* calculated from Eq. (2-113) and B calculated from Eq. (2-116).

Determine group contributions from Table 2-398.

	ΔN_i	ΔB_i
Cyclohexanes	(1)	1.48
<i>n</i> -Alkanes	(2)	0

$$N^* = N + \sum_i n_i \Delta N_i$$

$$N^* = 8 + (1)(1.48) + (2)(0) = 9.48$$

Use Eq. (2-114) to calculate T_o :

$$T_o = 28.86 + 37.439(9.48) - 1.3547(9.48)^2 + (.02076)(9.48)^3 \\ T_o = 279.72$$

$$B = B_a + \sum_i n_i \Delta B_i$$

Use Eq. (2-117) to calculate B_a :

$$B_a = 24.79 + 66.885(9.48) - 1.3173(9.48)^2 - 0.00377(9.48)^3$$

$$B_a = 537.26$$

$$B = 537.26 + (1)[-272.85 + 25.041 (9.48)]$$

$$B = 501.80$$

$$\log \mu = B \left(\frac{1}{T} - \frac{1}{T_o} \right) - 3.0$$

$$\log \mu = 501.80 \left(\frac{1}{273.15} - \frac{1}{279.72} \right) - 3.0$$

$$\log \mu = -2.9569$$

$$\mu = 0.001104 \text{ Pa sec} = 1.104 \text{ cp}$$

An experimental value at 0°C is 1.224 cp.

A mixing rule developed by Kendall and Monroe⁴⁸ is useful for determining the **liquid viscosity of defined hydrocarbon mixtures**. Equation (2-119) depends only on the pure component viscosities at the given temperature and pressure and the mixture composition.

$$\mu_m = \left(\sum_{i=1}^n x_i \mu_i^{1/3} \right)^3 \quad (2-119)$$

For mixtures of the same chemical family, errors average less than 3 percent, while errors overall average 5–6 percent, with errors of mixed families averaging from 10–15 percent.

For estimating the liquid viscosity of **defined nonhydrocarbon mixtures**, a mixing rule shown by Eq. (2-120) was recommended by the *Technical Data Manual*.

$$\ln \mu_m = \sum_i x_i \ln \mu_i \quad (2-120)$$

Errors average near 15 percent.

For interpolating viscosities of hydrocarbon mixtures within a limited range knowing viscosities at two temperatures, ASTM Procedure D341-89, including both charts and equations, is recommended. Several recommended methods for predicting the viscosity of undefined hydrocarbon mixtures, such as petroleum fractions and coal liquids, are presented and evaluated in the *Technical Data Book—Petroleum Refining*. In addition, several methods for determining the liquid viscosity of blends of hydrocarbon mixtures and a method for liquid viscosity of pure hydrocarbons blended with undefined mixtures are given.

The most accurate method for predicting the liquid viscosity of **hydrocarbons containing fewer than 20 carbon atoms at high pressure** is a corresponding states method developed by Grabski and included in the *Technical Data Book—Petroleum Refining*. Critical temperature, critical pressure, the acentric factor, and knowing or being able to calculate at least one viscosity at a reference temperature and pressure are required. Errors average about 5 percent. For high molecular weight hydrocarbons at high pressure, low pressure viscosities can be converted instead of using the method of Kouzel,⁵¹ which requires a low pressure liquid viscosity as input. Compounds of more than 20 carbon atoms and their mixtures are treated in this way.

For predicting the **liquid viscosity of pure hydrocarbon mixtures at high temperatures**, the method of Letsou and Stiel⁵² is available. Error analyses with only a small amount of data shows errors averaging 34 percent in the reduced temperature range of 0.76 to 0.98. Equation (2-121) defines the method with inputs of Eqs. (2-122) and (2-123).

$$\mu \left(2173.424 \frac{T_c^{1/6}}{M^{1/2} P_c^{2/3}} \right) = \mu^{(0)} + \alpha \mu^{(1)} \quad (2-121)$$

$$\mu^{(0)} = 1.5174 \times 10^{-5} - 2.135 \times 10^{-5} T_r + 7.5 \times 10^{-6} T_r^2 \quad (2-122)$$

$$\mu^{(1)} = 4.2552 \times 10^{-5} - 7.674 \times 10^{-5} T_r + 3.4 \times 10^{-5} T_r^2 \quad (2-123)$$

Results are in Pa sec with inputs of T_c in K and P_c in Pa.

VAPOR AND LIQUID THERMAL CONDUCTIVITY

Thermal conductivity describes the ease with which conductive heat can flow through a vapor, liquid, or solid layer of a substance. It is defined as the proportionality constant in Fourier's law of heat conduction in units of energy · length/time · area · temperature; e.g., W/m K.

Gases For **pure component, low pressure (<350 kPa) hydrocarbon** gases, Misic and Thodos^{70,71} recommend the following equations. For **methane** and **cyclic compounds** below reduced temperatures of 1.0:

$$k_G = 4.45 \times 10^{-7} T_r \frac{C_p}{\lambda} \quad (2-124)$$

For these hydrocarbons above reduced temperatures of 1.0 and for other hydrocarbons at any temperature:

$$k_G = 10^{-7} (14.52 T_r - 5.14)^{2/3} \left(\frac{C_p}{\lambda} \right) \quad (2-125)$$

In these equations,

$$\lambda = T_c^{1/6} M^{1/2} \left(\frac{101.325}{P_c} \right)^{2/3} \quad (2-126)$$

where k_G = vapor thermal conductivity, W/m K

T_r = reduced temperature, T/T_c

T = temperature, K

T_c = critical temperature, K

C_p = heat capacity at constant pressure, J/kmol K

M = molecular weight

P_c = critical pressure, kPa

C_p may be assumed to be the ideal gas heat capacity, C_p^o . Average errors can be expected to be less than 5 percent.

Example 27 Estimate thermal conductivity for *n*-hexane. For *n*-hexane at 373.15 K and low pressure, the required properties from Daubert et al.²⁴ are: $T_c = 507.6$ K, $M = 86.18$, $P_c = 3025.0$ kPa, and $C_p^o = 1.721 \times 10^5$. $T_r = 373.15/507.6 = 0.7351$. Using Eq. (2-126):

$$\lambda = (507.6)^{1/6} (86.18)^{1/2} \left(\frac{101.325}{3025.0} \right)^{2/3}$$

$$\lambda = 2.724$$

Substituting into Eq. (2-125):

$$k_G = 10^{-7} [(14.52)(0.7351) - 5.14]^{2/3} \left(\frac{1.721 \times 10^5}{2.724} \right)$$

$$k_G = 0.01977 \text{ W/m K}$$

The reported value is 0.02025 W/m K.²⁴

For **pure nonhydrocarbon** gases at low pressures (up through 1 atm), the following equations may be used at temperature T (K):

$$\text{Monatomic gases}^{12}: \quad k_G = 2.5 \frac{\eta_G C_v}{M} \quad (2-127)$$

$$\text{Linear molecules}^{12}: \quad k_G = \frac{\eta_G}{M} \left(1.30 C_v + 14644.0 - \frac{2928.8}{T_r} \right) \quad (2-128)$$

$$\text{Nonlinear molecules}^{102}: \quad k_G = \frac{\eta_G}{M} (1.15 C_v + 16903.36) \quad (2-129)$$

where k_G = vapor thermal conductivity, W/m K

η_G = vapor viscosity, Pa·s

C_v = heat capacity at constant volume, J/kmol K

M = molecular weight

T_r = reduced temperature, T/T_c

T_c = critical temperature, K

C_v may be calculated as $C_p^o - R$, where C_p^o is the ideal gas heat capacity in J/kmol K and R is the gas constant, 8314 J/kmol K. Average errors are in the 8–10 percent range but may be higher for polar compounds. This method should not be used for molecules that associate; e.g., organic acids.

Example 28 Estimate thermal conductivity of carbon dioxide at 370 K and low pressure. For carbon dioxide (a linear molecule) at 370.0 K and low pressure, the required properties from Daubert et al.²⁴ are: $T_c = 304.2$ K, $\eta_G = 1.828 \times 10^{-5}$ Pa·s, $M = 44.01$, and $C_p^o = 40520$ J/kmol K. $T_r = 370.0/304.2 = 1.2163$, and $C_v = 40520 - 8314 = 32206$ J/kmol K. Substituting in Eq. (2-128):

$$k_G = \frac{1.828 \times 10^{-5}}{44.01} \left[(1.30)(32206) + 14644.0 - \frac{2928.8}{1.2163} \right]$$

$$k_G = 0.02247 \text{ W/m K}$$

A value of 0.0220 W/m K is obtained from Vargaftik et al.¹²⁴

For pure gases **above atmospheric pressure**, the method of Stiel and Thodos⁶² may be used:

$$k_G = k'_G + \frac{A \times 10^{-4} (e^{B\rho_r} + C)}{\left(\frac{T_c^{1/6} M^{1/2}}{P_c^{2/3}} \right) Z_c^5} \quad (2-130)$$

$\rho_r < 0.5$	$A = 2.702$	$B = 0.535$	$C = -1.000$
$0.5 < \rho_r > 2.0$	$A = 2.528$	$B = 0.670$	$C = -1.069$
$2.0 < \rho_r > 2.8$	$A = 0.574$	$B = 1.155$	$C = 2.016$

where k_G = vapor thermal conductivity at the temperature T (K) and pressure P of interest, W/m K

k'_G = vapor thermal conductivity at T and atmospheric pressure, W/m K

ρ_r = reduced density = V_c/V

V_c = critical molar volume, m³/kmol

V = molar volume at T and P , m³/kmol

T_c = critical temperature, K

M = molecular weight

P_c = critical pressure, MPa

Z_c = critical compressibility factor = $P_c V_c / RT_c$

R = gas constant = 0.008314 MPa m³/kmol K

Errors in the range of 5–6 percent are typical with this method but may be higher for branched compounds.

Example 29 Estimate the thermal conductivity of carbon dioxide at 370 K and 10 MPa pressure. The required properties from Daubert et al.²⁴ are: $T_c = 304.2$ K, $M = 44.01$, $P_c = 7.383$ MPa, and $V_c = 0.0940$ m³/kmol; $Z_c = (7.383) \times (0.0940)/(0.008314)(304.2) = 0.274$. $k'_G = 0.0220$ W/m K¹²³, and $V = 0.22809$ m³/kmol³; $\rho_r = 0.0940/0.22809 = 0.4121$. Substituting in Eq. (2-130) using the equation constants A , B , and C for $\rho_r < 0.5$:

$$k_G = 0.0220 + \frac{(2.702 \times 10^{-4})(e^{(0.535)(0.4121)} - 1.000)}{\left(\frac{(304.2)^{1/6}(44.01)^{1/2}}{(7.383)^{2/3}} \right)(0.274)^5} = 0.0315 \text{ W/m K}$$

Vargaftik et al.¹²⁴ report a value of 0.0308 W/m K.

The thermal conductivity of **low pressure** (1 atm or less) **gas mixtures** can be determined from the relation of Wassiljewa¹²⁶:

$$k_m = \sum_{i=1}^n \frac{y_i k_i}{\sum_{j=1}^n y_j A_{ij}} \quad (2-131)$$

where k_m = mixture thermal conductivity, W/m K

n = number of components

$y_{i,j}$ = mole fraction of component i or j in the vapor mixture

k_i = thermal conductivity of pure component i at the temperature of interest

The binary interaction parameter A_{ij} is obtained by the method of Lindsay and Bromley⁶¹:

$$A_{ij} = \frac{1}{4} \left[1 + \left[\frac{\mu_i}{\mu_j} \left(\frac{M_j}{M_i} \right)^{3/4} \left(\frac{T + S_i}{T + S_j} \right) \right]^{1/2} \right]^2 \left(\frac{T + S_j}{T + S_i} \right) \quad (2-132)$$

where $\mu_{i,j}$ = vapor viscosity of pure component i or j at the temperature T of interest and low pressure, Pa·s

$M_{i,j}$ = molecular weight of pure component i or j

T = temperature, K

$S_{ij} = S_{ji}$; see Eq. (2-133)

$C = 1.0$ except when either or both components i and j are very polar; then $C = 0.73$

$S_{i,j} = 79$ K for helium, hydrogen, and neon; for all others, see Eq. (2-134)

$T_{bi,j}$ = normal boiling temperature of pure component i or j , K

$$S_{ji} = C(S_i S_j)^{1/2} \quad (2-133)$$

$$S_{i,j} = 1.5 T_{bi,j} \quad (2-134)$$

Expected errors for this method are 4–5 percent. At **higher pressures**, a pressure correction using Eq. (2-130) may be used. The mixture is treated as a hypothetical pure component with mixture critical properties obtained via Eqs. (2-5), (2-8), and (2-17) and with the molecular weight being mole-averaged.

Example 30 Estimate thermal conductivity of a mixture of 0.23 mole fraction dimethylether (1) and 0.77 mole fraction methyl chloride (2) at

373.15 K and low pressure. The required pure component properties from Daubert et al.²⁴ are: $k_1 = 0.02504$ W/m K, $k_2 = 0.01587$ W/m K, $\mu_1 = 1.161 \times 10^{-5}$ Pa·s, $\mu_2 = 1.361 \times 10^{-5}$ Pa·s, $M_1 = 46.07$, $M_2 = 50.49$, $T_{b1} = 248.3$ K, and $T_{b2} = 248.9$ K. By Eq. (2-134), $S_1 = (1.5)(248.3) = 372.45$, and $S_2 = (1.5)(248.9) = 373.35$. By Eq. (2-133), $S_{12} = S_{21} = (1.0)[(372.45)(373.35)]^{1/2} = 372.90$. Substituting in Eq. (2-132):

$$\begin{aligned} A_{11} &= A_{22} = 1.0 \\ A_{12} &= \frac{1}{4} \left\{ 1 + \left[\left(\frac{1.161 \times 10^{-5}}{1.361 \times 10^{-5}} \right) \left(\frac{50.49}{46.07} \right)^{3/4} \left(\frac{373.15 + 372.45}{373.15 + 373.35} \right) \right]^{1/2} \right\}^2 \\ &\quad \times \left(\frac{373.15 + 372.90}{373.15 + 372.45} \right) = 0.956 \\ A_{21} &= \frac{1}{4} \left\{ 1 + \left[\left(\frac{1.361 \times 10^{-5}}{1.161 \times 10^{-5}} \right) \left(\frac{46.07}{50.49} \right)^{3/4} \left(\frac{373.15 + 373.35}{373.15 + 372.45} \right) \right]^{1/2} \right\}^2 \\ &\quad \times \left(\frac{373.15 + 372.90}{373.15 + 373.35} \right) = 1.047 \end{aligned}$$

Using Eq. (2-131):

$$k_m = \frac{(0.23)(0.02504)}{(0.23)(1.0) + (0.77)(0.956)} + \frac{(0.77)(0.01587)}{(0.23)(1.047) + (0.77)(1.0)} = 0.01805 \text{ W/m K}$$

The experimental value is 0.01778 W/m K.⁶⁶

Liquids For **pure component hydrocarbon** liquids at reduced temperatures between 0.25 and 0.8 and at pressures below 3.4 MPa, an equation based on the methods of Pachaiyappan et al.⁷⁹ and Riedel⁸⁸ may be used:

$$k_L = C \rho M^n \left[\frac{3 + 20(1 - T_r)^{2/3}}{3 + 20 \left(1 - \frac{293.15}{T_c} \right)^{2/3}} \right] \quad (2-135)$$

where k_L = liquid thermal conductivity, W/m K

M = molecular weight

ρ = molar density at 293.15 K, kmol/m³

T_r = reduced temperature, T/T_c

T = temperature, K

T_c = critical temperature, K

For unbranched, straight chain hydrocarbons, $n = 1.001$ and $C = 1.811 \times 10^{-4}$.

For branched and cyclic hydrocarbons, $n = 0.7717$ and $C = 4.407 \times 10^{-4}$.

Average errors are 5 percent when this equation is used. For pressures greater than 3.4 MPa, the thermal conductivity from Eq. (2-135) may be corrected by the technique suggested by Lenoir.⁵⁷ The correction factor is the ratio of conductivity factors F/F' , where F is at the desired temperature and higher pressure, and F' is at the same temperature and lower pressure (usually atmospheric). The conductivity factors are calculated from:

$$F = 17.77 + 0.065P_r - 7.764T_r - \frac{2.054T_r^2}{e^{0.2P_r}} \quad (2-136)$$

where T_r = reduced temperature as in Eq. (2-135)

P_r = reduced pressure, P/P_c

P = pressure, MPa

P_c = critical pressure, MPa

The average error in the pressure correction alone is typically 3 percent.

Example 31 Estimate thermal conductivity of *n*-octane at 373.15 K and pressures of 0.1 MPa and 20.0 MPa. The required properties from Daubert et al.²⁴ are: ρ at 293.15 K = 6.155 kmol/m³, $M = 114.2$, $T_c = 568.7$ K, and $P_c = 2.490$ MPa. $T_r = 373.15/568.7 = 0.6561$, $n = 1.001$, and $C = 1.811 \times 10^{-4}$. Substituting in Eq. (2-135) for the thermal conductivity at 0.1 MPa:

$$\begin{aligned} k_L &= (1.811 \times 10^{-4})(6.155)(114.2)^{1.001} \left[\frac{3 + (20)(1 - 0.6561)^{2/3}}{3 + (20) \left(1 - \frac{293.15}{568.7} \right)^{2/3}} \right] \\ &= 0.107 \text{ W/m K} \end{aligned}$$

The reported value is 0.111 W/m K.¹²³ To correct to 20 MPa, $P_r = 20.0/2.490 = 8.032$, and $P'_r = 0.1/2.490 = 0.04016$. Substituting in Eq. (2-136) to calculate F and F' :

$$F = 17.77 + (0.065)(8.032) - (7.764)(0.6561) - \frac{(2.054)(0.6561)^2}{e^{(0.2)(8.032)}}$$

$$F = 13.02$$

$$F' = 17.77 + (0.065)(0.04016) - (7.764)(0.6561) - \frac{(2.054)(0.6561)^2}{e^{(0.2)(0.04016)}}$$

$$F' = 11.80$$

Thus, the thermal conductivity of *n*-octane at 373.15 K and 20.0 MPa is estimated to be $(0.111)(13.02/11.80) = 0.122$ W/m K as compared with an experimental value of 0.121 W/m K.¹²³

For pure component hydrocarbon liquids **above the normal boiling point and all pressures**, the method of Kanitkar and Thodos⁴⁶ is recommended:

$$k_L = \frac{\alpha e^{\beta_p}}{\lambda} \quad P < 10,000 \text{ kPa} \quad (2-137)$$

$$k_L = \frac{2.596 \times 10^{-4} P_r^{1.6} + \alpha e^{\beta_p}}{\lambda} \quad P > 10,000 \text{ kPa} \quad (2-138)$$

where k_L = liquid thermal conductivity at the temperature T (K) and pressure P (kPa) of interest, W/m K

$$\alpha = 0.0112 \beta^{-3.322} \quad (2-139)$$

$$\beta = 0.40 + 0.986e^{-(0.64)} \quad (2-140)$$

$$\lambda = T_c^{1/6} M^{1/2} \left(\frac{101.325}{P_c} \right)^{2/3} \quad (2-141)$$

$$\rho_r = \text{reduced density} = V_r/V$$

$$V_c = \text{critical molar volume, m}^3/\text{kmol}$$

$$V = \text{molar volume at } T \text{ and } P, \text{ m}^3/\text{kmol}$$

$$T_c = \text{critical temperature, K}$$

$$M = \text{molecular weight}$$

$$P_c = \text{critical pressure, kPa}$$

$$P_r = \text{reduced pressure, } P/P_c$$

Average errors can be expected to be in the order of 10 percent.

Example 32 Estimate thermal conductivity of *n*-octane at 473.15 K and 15,000 kPa. The required properties from Daubert et al.²⁴ are: $T_c = 568.7$ K, $M = 114.2$, $P_c = 2490.0$ kPa, and $V_c = 0.4860 \text{ m}^3/\text{kmol}$. The specific volume at 473.15 K and 15,000 kPa is $0.001717 \text{ m}^3/\text{kg}$ ¹²³; $V = (0.001717)/(114.2) = 0.0161 \text{ m}^3/\text{kmol}$. Thus, $P_r = 15000/2490 = 6.024$, and $\rho_r = 0.4860/0.0161 = 2.478$. Substituting in Eqs. (2-141), (2-140), and (2-139):

$$\lambda = (568.7)^{1/6} (114.2)^{1/2} \left(\frac{101.325}{2490} \right)^{2/3} = 3.639$$

$$\beta = 0.40 + 0.986e^{-(0.64)(3.639)} = 0.496$$

$$\alpha = (0.0112)(0.496)^{-3.322} = 0.115$$

Using Eq. (2-138):

$$k_L = \frac{(2.596 \times 10^{-4})(6.024)^{1.6} + 0.115e^{(0.496)(2.478)}}{3.639} = 0.109 \text{ W/m K}$$

The reported value is 0.106 W/m K.¹²³

The thermal conductivity of **pure component nonhydrocarbon** liquids may be estimated by the method of Baroncini et al.,⁵ with a modification by Myers¹⁵ for silicon compounds, at reduced temperatures between 0.3 and 0.8 and at pressures below 3.5 MPa:

$$k_L = \left(\frac{abc}{m} \right) \left(\frac{(1 - T_r)^{0.38}}{T_r^{1/6}} \right) \quad (2-142)$$

where k_L = liquid thermal conductivity, W/m K

$$T_r = \text{reduced temperature, } T/T_c$$

$$T = \text{temperature, K}$$

$$T_c = \text{critical temperature, K}$$

$$a = \text{constant parameter}$$

$$b = \text{constant parameter} = \text{function of normal boiling temperature}$$

$$T_b, \text{ K}$$

$$c = \text{constant parameter} = \text{function of critical temperature } T_c, \text{ K}$$

$$m = \text{constant parameter} = \text{function of molecular weight } M$$

Values of a , b , c , and m for various compound classes are found in Table 2-399. Average errors are about 8 percent.

Example 33 Estimate thermal conductivity of *n*-butanol. The properties required to estimate the liquid thermal conductivity of *n*-butanol at 360.0 K and 0.1 MPa from Daubert et al.²⁴ are: $T_c = 563.0$ K, $M = 74.12$, and $T_b =$

TABLE 2-399 Values of Constant Parameters in Eq. (2-142) for Various Compound Classes

Compound class	a	b	c	m
Acids*	0.00319	$T_b^{6/5}$	$T_c^{-1/6}$	$M^{1/2}$
Alcohols, phenols	0.00339	$T_b^{6/5}$	$T_c^{-1/6}$	$M^{1/2}$
Esters†	0.0415	$T_b^{6/5}$	$T_c^{-1/6}$	M
Ethers	0.0385	$T_b^{6/5}$	$T_c^{-1/6}$	M
Halides‡	0.494	1.0	$T_c^{1/6}$	$M^{1/2}$
Refrigerants R20–R23	0.562	1.0	$T_c^{1/6}$	$M^{1/2}$
Ketones	0.00383	$T_b^{6/5}$	$T_c^{-1/6}$	$M^{1/2}$
Alkoxy silanes	0.00482	$T_b^{6/5}$	$T_c^{-1/6}$	$M^{1/2}$
Alkyl-(aryl)-chlorosilanes	0.6510	1.0	$T_c^{1/6}$	$M^{1/2}$

* Do not use for formic, myristic, or oleic acids.

† Do not use for butyl stearate.

‡ Do not use for refrigerants R20–R23 (CHCl_3 , CHFCl_2 , CHClF_2 , or CHF_3).

390.8 K, $T_r = 360.0/563.0 = 0.6394$. From Table 2-399, $a = 0.00339$, $b = (T_b)^{6/5} = (390.8)^{6/5} = 1289.3$, $c = (T_c)^{-1/6} = (563.0)^{-1/6} = 0.3480$, and $m = M^{1/2} = (74.12)^{1/2} = 8.609$. Substituting in Eq. (2-142):

$$k_L = \left[\frac{(0.00339)(1289.3)(0.3480)}{8.609} \right] \left[\frac{(1 - 0.6394)^{0.38}}{(0.6394)^{1/6}} \right] = 0.1292 \text{ W/m K}$$

The reported value is 0.1429 W/m K.¹²³

For pure component nonhydrocarbon liquids **for which Eq. (2-142) is not applicable**, the method of Missenard^{72,73} may be used at temperature T (K) and below pressures of 3.5 MPa:

$$k_L = k_L^r \left[\frac{3 + 20 (1 - T_r)^{2/3}}{3 + 20 \left(1 - \frac{273.15}{T_c} \right)^{2/3}} \right] \quad (2-143)$$

$$k_L^r = 2.656 \times 10^{-7} \frac{(T_b \rho^r)^{1/2} C_p^r}{M^{1/2} N^{1/4}} \quad (2-144)$$

where k_L = liquid thermal conductivity, W/m K

$$k_L^r = \text{liquid thermal conductivity at } 273.15 \text{ K, W/m K}$$

$$T_r = \text{reduced temperature, } T/T_c$$

$$T_c = \text{critical temperature, K}$$

$$T_b = \text{normal boiling temperature, K}$$

$$\rho^r = \text{molar density at } 273.15 \text{ K, kmol/m}^3$$

$$C_p^r = \text{molar heat capacity at } 273.15 \text{ K, J/kmol K}$$

$$M = \text{molecular weight}$$

$$N = \text{number of atoms in the molecule}$$

Errors in the order of 8 percent can be expected.

Example 34 Estimate the thermal conductivity of *n*-propionaldehyde ($\text{CH}_3\text{CH}_2\text{CHO}$) at 318.15 K and low pressure (0.1 MPa); the necessary properties from Daubert et al.²⁴ are: $T_c = 504.4$ K, $T_b = 321.1$ K, $\rho^r = 14.11 \text{ kmol/m}^3$, $C_p^r = 1.309 \times 10^5 \text{ J/kmol K}$, and $M = 58.08$. $N = 10$, and $T_r = 318.15/504.4 = 0.6307$. Substituting in Eq. (2-144):

$$k_L^r = (2.656 \times 10^{-7}) \frac{[(321.1)(14.11)]^{1/2} (1.309 \times 10^5)}{(58.08)^{1/2} (10)^{1/4}} = 0.1727 \text{ W/m K}$$

Using Eq. (2-143):

$$k_L = 0.1727 \left[\frac{3 + 20 (1 - 0.6307)^{2/3}}{3 + 20 (1 - 273.15/504.4)^{2/3}} \right] = 0.1542 \text{ W/m K}$$

A value from the literature is 0.1541 W/m K.²⁴

For **pressures greater than 3.5 MPa**, the correction factor suggested by Missenard⁷⁴ may be used to obtain the thermal conductivity of pure component nonhydrocarbon liquids. Thus:

$$k_L = k_L' \left[0.98 + 0.0079 P_r T_r^{1.4} + 0.63 T_r^{1.2} \left(\frac{P_r}{30 + P_r} \right) \right] \quad (2-145)$$

where k_L = liquid thermal conductivity at the desired temperature T (K) and pressure P (MPa), W/m K

$$k_L' = \text{liquid thermal conductivity at } T \text{ and pressure of } 0.1 \text{ MPa, W/m K}$$

$$P_r = \text{reduced pressure, } P/P_c$$

$$P_c = \text{critical pressure, MPa}$$

$$T_r = \text{reduced temperature, } T/T_c$$

$$T_c = \text{critical temperature, K}$$

Average errors are in the range of 5–20 percent.

Example 35 Estimate thermal conductivity of *n*-butanol. The required properties at 360 K and 15 MPa from Daubert et al.²⁴ are: $T_c = 563.0$ K and

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$P_c = 4.423 \text{ MPa}$, $T_r = 360.0/563.0 = 0.6394$ and $P_r = 15.0/4.423 = 3.391$. $k'_L = 0.1429 \text{ W/m K}$.¹²³ Substituting in Eq. (2-145):

$$k_L = 0.1429 \left[0.98 + (0.0079) (3.391) (0.6394)^{1.4} + (0.63) (0.6394)^{1.2} \left(\frac{3.391}{30 + 3.391} \right) \right] \\ = 0.1474 \text{ W/m K}$$

Vargafitk¹²³ reports a value of 0.1494 W/m K.

For both aqueous and nonaqueous **liquid mixtures**, the method of Li⁵⁹ is suggested for pressures below 3.5 MPa:

$$k_m = \sum_{i=1}^n \sum_{j=1}^n \phi_i \phi_j k_{ij} \quad (2-146)$$

$$\phi_i = \frac{x_i V_i}{\sum_{j=1}^n x_j V_j} \quad (2-147)$$

$$k_{ij} = \frac{2}{(1/k_i) + (1/k_j)} \quad (2-148)$$

where k_m = mixture liquid thermal conductivity at temperature T (K), W/m K

n = number of components

$x_{i,j}$ = mole fraction of component i or j in the liquid mixture

$V_{i,j}$ = liquid molar volume of pure component i or j at temperature T , m³/kmol

$k_{i,j}$ = liquid thermal conductivity of pure component i or j at temperature T , W/m K

Expected errors are in the 4–6 percent range. At **pressures greater than 3.5 MPa**, a pressure correction using Eq. (2-145) may be used. The mixture is treated as a hypothetical pure component with mixture critical properties obtained via Eqs. (2-5) and (2-8).

Example 36 Estimate thermal conductivity of a mixture of 0.302 mole fraction diethyl ether (1) and 0.698 mole fraction methanol (2) at 273.15 K and 0.1 MPa. The required properties from Daubert et al.²⁴ are: $V_1 = 0.1007 \text{ m}^3/\text{kmol}$, $V_2 = 0.03942 \text{ m}^3/\text{kmol}$, $k_1 = 0.1383 \text{ W/m K}$, and $k_2 = 0.2069 \text{ W/m K}$. Substituting in Eq. (2-148):

$$k_{12} = \frac{2}{1/0.1383 + 1/0.2069} = 0.1658$$

Then, using Eq. (2-147) to obtain ϕ_1 and ϕ_2 :

$$\phi_1 = \frac{(0.302)(0.1007)}{(0.302)(0.1007) + (0.698)(0.03942)} = \frac{0.03041}{0.05793} = 0.525$$

$$\phi_2 = \frac{(0.698)(0.03942)}{0.05793} = 0.475$$

Substituting in Eq. (2-146):

$$k_m = (0.525)^2(0.1383) + 2(0.525)(0.475)(0.1658) + (0.475)^2(0.2069) = 0.167 \text{ W/m K}$$

Jamieson and Hastings⁴² report a value of 0.173 W/m K for this mixture.

DIFFUSIVITY

Diffusion is the molecular transport of mass without flow. The diffusivity (D) or diffusion coefficient is the proportionality constant between the diffusion and the concentration gradient causing diffusion. It is usually defined by Fick's first law for one-dimensional, binary component diffusion for molecular transport without turbulence shown by Eq. (2-149)

$$\frac{N_1}{A} = -D_{12} \frac{dC_1}{dL} \quad (2-149)$$

The molar flow of species 1(N_1) per unit area (A) is directly proportional to the change in concentration of species 1 (C_1) per distance diffused (L). The usual units of diffusivity are m²/sec.

In chemical engineering, the primary application of the diffusivity is to calculate the Schmidt number (μ/pD) used to correlate mass transfer properties. This number is also used in reaction rate calculations involving transport to and away from catalyst surfaces.

Experimental diffusion coefficients are scarce and not highly accurate, especially in the liquid phase, leading to prediction methods with marginal accuracy. However, use of the values predicted are generally suitable for engineering calculations. At concentrations above about 10 mole percent, predicted values should be used with caution. Diffusivities in liquids are 10^4 – 10^5 times lower than those in gases.

Gas Diffusivity For prediction of the gas diffusivity of **binary hydrocarbon-hydrocarbon gas systems at low pressures** (below about 500 psia [3.5 MPa]) the method of Gilliland³² given by Eq. (2-150) is recommended.

$$D_{12} = \frac{0.1014 T^{1.5} \left(\frac{1}{M_1} + \frac{1}{M_2} \right)^{0.5}}{P(V_1^{1/3} + V_2^{1/3})^2} \quad (2-150)$$

Component 1 is the solute, while component 2 is the solvent. Units of T , P , and V are °R, psia, and cm³/gmole, respectively. Diffusivity is then in ft²/hr. The molar volumes V_1 and V_2 at the normal boiling point are estimated by Tyn and Calus,¹²⁰ Eq. (2-151).

$$V_i = 0.285 V_i^{0.048} \quad (2-151)$$

The method gives average errors of less than 4 percent.

For prediction of the gas diffusivity of **binary air-hydrocarbon or nonhydrocarbon gas mixtures at low pressures**, the method of Fuller et al.³⁰ given by Eq. (2-152) is recommended.

$$D_{12} = \frac{0.1013 T^{1.75} \left(\frac{1}{M_1} + \frac{1}{M_2} \right)^{0.5}}{P[(\sum v_1)^{1/3} + (\sum v_2)^{1/3}]^2} \quad (2-152)$$

Units of T and P are K and Pa, respectively, with the resulting diffusivity in m²/sec. All v_i are group contribution values for the subscript component summed over atoms, groups, and structural features given in Table 2-400.

For air-hydrocarbon systems, average deviations do not exceed 9 percent. For general nonhydrocarbon gas systems, the average deviation is about 6 percent.

Example 37 Estimate the diffusivity of benzene vapor diffusing into air at 30°C and 96.5 kPa total pressure.

Use Eq. (2-152).

$$D_{12} = \frac{0.1013 T^{1.75} \left(\frac{1}{M_1} + \frac{1}{M_2} \right)^{0.5}}{P[(\sum v_1)^{1/3} + (\sum v_2)^{1/3}]^2}$$

$$T = 303.1 \text{ K}, M_1 = 78.1, M_2 = 28.86, \text{ and } P = 96,500 \text{ Pa}.$$

Now consult Table 2-400. For benzene (C₆H₆):

$$\sum v_1 = 6(16.5) + 6(1.98) - 20.2$$

$$\sum v_1 = 90.68$$

For air, $\sum v_2 = 20.1$:

$$D_{12} = \frac{(.01013)303.1^{1.75} \left(\frac{1}{78.1} + \frac{1}{28.86} \right)^{0.5}}{(96,500)(90.68)^{1/3} + 20.1^{1/3})^2} \\ D_{12} = 9.68 \times 10^{-6} \text{ m}^2/\text{sec}$$

This value is within 1 percent of an available experimental value.

TABLE 2-400 Atomic Diffusion Volumes for Use in Eq. (2-153)

Atomic and structural diffusion-volume increments v			
C	16.5	Cl	(19.5)
H	1.98	S	(17.0)
O	5.481	Aromatic ring	-20.2
N	(5.69)	Heterocyclic ring	-20.2
Diffusion volumes for simple molecules			
H ₂	7.07	CO	18.9
D ₂	6.70	CO ₂	26.9
He	2.88	N ₂ O	35.9
N ₂	17.9	NH ₃	14.9
O ₂	16.6	H ₂ O	12.7
Air	20.1	CCl ₂ F ₂	(114.8)
Ar	16.1	SF ₆	(69.7)
Kr	22.8	Cl ₂	(37.7)
Xe	(37.9)	Br ₂	(67.2)
		SO ₂	(41.1)

Parentheses indicate that the value listed is based only on a few data points.

TABLE 2-401 Parameters for Eq. (2-153)

P_r	$(D_{12}P)_R$	A	B	C	E
0.1	1.01	0.38042	1.52267	0.0	
0.2	1.01	0.067433	2.16794	0.0	
0.3	1.01	0.098371	2.42910	0.0	
0.4	1.01	0.137610	2.77605	0.0	
0.5	1.01	0.175081	2.98256	0.0	
0.6	1.01	0.216376	3.11384	0.0	
0.8	1.01	0.314051	0.50264	0.0	
1.0	1.02	0.385736	3.07773	0.141211	13.45454
1.2	1.02	0.514553	3.54744	0.278407	14.00000
1.4	1.02	0.599184	3.61216	0.372683	10.00000
1.6	1.02	0.557725	3.41882	0.504894	8.57519
1.8	1.03	0.593007	3.18415	0.678469	10.37483
2.0	1.03	0.696001	3.3760	0.0665702	11.21674
2.5	1.04	0.790770	3.27984	0.0	
3.0	1.05	0.502100	2.39031	0.602907	6.19043
4.0	1.06	0.837452	3.23513	0.0	
5.0	1.07	0.890390	3.13001	0.0	

An alternate method for gas diffusivity of binary gas mixtures at low pressures is the method of Hirschfelder et al.⁴⁰ The method requires several molecular parameters and, when evaluated, gives an average absolute error of about 10 percent. The method is discussed in detail in the *Data Prediction Manual*.

For predicting the diffusivity of *binary gas mixtures at high pressures*, the method of Takahashi,¹⁰⁹ Eq. (2-153), applies.

$$D_{12} = 1.013 \times 10^5 \frac{D'_{12}}{P} (D_{12}P)_R (1 - AT_r^{-B}) (1 - CT_r^{-E}) \quad (2-153)$$

D'_{12} is the low pressure diffusivity at the temperature of interest. $(D_{12}P)_R$ is a reduced diffusivity pressure product at infinite reduced temperature; and A, B, C, and E are constants. All are a function of P_r , tabulated in Table 2-401. Component 1 is the diffusing species, while component 2 is the concentrated species. Critical properties are for the solvent. The pressure is given in Pa. The diffusivity is in m^2/sec . Errors from evaluation average near 15 percent.

Example 38 Estimate the diffusivity of hydrogen (1) in nitrogen (2) at 60°C and 17.23 MPa. A value of the low pressure diffusivity obtained using Eq. (2-152) is $D'_{12} = 9.2 \times 10^{-5} \text{ m}^2/\text{sec}$. Use Eq. (2-153):

$$D_{12} = 1.013 \times 10^5 \frac{D'_{12}}{P} (D_{12}P)_R (1 - AT_r^{-B}) (1 - CT_r^{-E})$$

For nitrogen, $T_c = 126.2 \text{ K}$ and $P_c = 3.394 \text{ MPa}$.

$$T_r = \frac{333.2}{126.2} = 2.640 \quad P_r = \frac{17.23}{3.394} = 5.077$$

From Table 2-401:

$$(D_{12}P)_R = 1.07, \quad A = 0.89039, \quad B = 3.1300, \quad C = 0$$

$$D_{12} = 1.013 \times 10^5 \left(\frac{9.2 \times 10^{-5}}{1.723 \times 10^7} \right) (1.07) [1 - .89039(2.64)^{-3.13}]$$

$$D_{12} = 5.54 \times 10^{-7} \text{ m}^2/\text{sec}$$

An available experimental value is $4.89 \times 10^{-7} \text{ m}^2/\text{sec}$.

For prediction of gas phase diffusion coefficients in **multicomponent hydrocarbon/nonhydrocarbon gas systems**, the method of Wilke¹³⁵ shown in Eq. (2-154) is used.

$$D_{im} = \frac{1 - y_i}{\sum_j y_j / D_{ij}} \quad (2-154)$$

This mixing rule is used to determine the diffusivity of any component in a $j+1$ component mixture and requires binary diffusivities of component i with all other components. It has been estimated that errors are about 5 percent greater than the greatest error in the binary diffusivities. Fairbanks and Wilke,³⁸ using the same Eq. (2-154), made the same recommendation with essentially the same errors.

For prediction of the diffusivity of a **dilute dissolved gas (hydrocarbon or nonhydrocarbon) in a liquid**, the standard method is that of Wilke and Chang¹²⁹ shown by Eq. (2-155).

$$D_{12} = 1.1728 \times 10^{-16} \frac{T(\chi_2 M_2)^{1/2}}{\mu_2 V_1^{0.6}} \quad (2-155)$$

Component 1 is the diffusing gas, while component 2 is the solvent. The solvent viscosity μ_2 in Pa sec, the solute molar volume at the normal boiling point V_1 in m^3/kmole , and the solvent association parameter χ_2 multiplied by the solvent

molecular weight are required input parameters. For the common solvents, χ decreases to 1 as polarity decreases, with values of 2.6 for water, 1.9 for methanol, 1.5 for ethanol, and 1.0 for less polar solvents. When tested with both hydrocarbon and nonhydrocarbon systems, average errors are about 25 percent—not excessive, considering the magnitude of the diffusivity.

Example 39 Estimate the infinite dilution diffusivity of propane (1) in chlorobenzene (2) at 25°C. Use Eq. (2-113):

$$D_{12} = 1.1728 \times 10^{-16} \frac{T(\chi_2 M_2)^{1/2}}{\mu_2 V_1^{0.6}}$$

For chlorobenzene, $M_2 = 112.56$, $\chi_2 = 1.0$, $\mu_2 @ 25^\circ\text{C} = 7.548 \times 10^{-4} \text{ Pa sec}$, and $V_1 = 0.0745 \text{ m}^3/\text{kmole}$.

$$D_{12} = \frac{(1.1728 \times 10^{-16})(298.15)(1.0 \times 112.56)^{1/2}}{(7.548 \times 10^{-4})(0.0745)^{0.6}}$$

$$D_{12} = 2.33 \times 10^{-9} \text{ m}^2/\text{sec}$$

An experimental value of $2.77 \times 10^{-9} \text{ m}^2/\text{sec}$ is available.

Liquid Diffusivity Liquid diffusivities are in general not as accurately predicted as vapor diffusivities, and specialized methods have been developed. References to each method determined to be accurate are given, but only the most common methods will be presented.

For predicting liquid diffusivities of **binary nonpolar liquid systems at high solute dilution**, Umesi¹²⁰ developed a method that only depends on the viscosity of the solvent (2) and the radius of gyration of the solvent (2) and the solute (1). The *Technical Data Book—Petroleum Refining* gives the method and values of the radii of gyration for common hydrocarbons. Errors average 16 percent but reach 30 percent at times.

For predicting diffusivities in **binary polar or associating liquid systems at high solute dilution**, the method of Wilke and Chang¹²⁹ defined in Eq. (2-156) can be utilized. The Tyn and Calus equation (2-152) can be used to determine the molar volume of the solute at the normal boiling point. Errors average 20 percent, with occasional errors of 35 percent. The method is not considered to be accurate above a solute concentration of 5 mole percent.

For **concentrated binary nonpolar liquid systems** (more than 5 mole percent solute), the diffusivity can be estimated by a molar average mixing rule developed by Caldwell and Babb,¹⁴ Eq. (2-156).

$$D_{1m} = x_1 D_{21} + (1 - x_1) D_{12} \quad (2-156)$$

D_{21} and D_{12} are dilute solution binary diffusivities. Errors depend on the procedure used to determine the dilute solution diffusivities.

For **multicomponent nonpolar liquid systems**, Leffler and Cullinan⁵⁶ developed a mixing rule, Eq. (2-157).

$$D_{1m}\mu_m = (D_{12}\mu_2)^{x_2}(D_{13}\mu_3)^{x_3} \dots \quad (2-157)$$

The diffusivity of solute 1 in the mixture is related to the binary infinite dilution diffusivities for each of the other components calculated from Eq. (2-155) or the Umesi method. The viscosities are calculated by the methods in the previous section. Errors are not quantifiable, as little experimental data exist, although these errors would be related to those assumed for the binary pairs.

For **concentrated binary liquid nonhydrocarbon systems**, the method of Caldwell and Babb,¹⁴ Eq. (2-156) has been modified by introduction of a thermodynamic correction term as shown in Eq. (2-158).

$$D_{1m}\mu_m = [x_1 D_{21} + (1 - x_1) D_{12}] \left(1 + \frac{d \ln \gamma_1}{d \ln x_1} \right) \quad (2-158)$$

The activity coefficient (γ) based corrector is calculated using any applicable activity correlating equation such as the van Laar (slightly polar) or Wilson (more polar) equations. The average absolute error is 20 percent.

An alternate method for **binary concentrated liquid systems** where activity coefficients are not available or estimable is the method of Leffler and Cullinan⁵⁶ previously given in Eq. (2-156). Absolute errors average 25 percent.

For estimating the diffusivity of the **dilute solute (10 mole percent) in water**, the method of Hayduk and Laudie,³⁷ Eq. (2-159), applies.

$$D_{12} = \frac{8.621 \times 10^{-14}}{\mu_2^{1.14} V_1^{0.589}} \quad (2-159)$$

Component 1 is the solute, while component 2 is water. The molar volume of the solute in m^3/kmole is at the solute normal boiling point, while the viscosity of water in Pa sec is at the temperature of the system resulting in a diffusivity in m^2/sec . The average error is about 9 percent when tested on 36 experimental systems.

For estimating the diffusivity of a **dilute solute (<10 mole percent) in any solvent except water**, the method of King et al.,⁴⁹ Eq. (2-160), applies.

$$D_{12} = 4.4 \times 10^{-15} \frac{T}{\mu_2} \left(\frac{V_2}{V_1} \right)^{1/6} \left(\frac{\lambda_2}{\lambda_1} \right)^{1/2} \quad (2-160)$$

Component 1 is the solute, while component 2 is the solvent. The latent heats, λ , are at the normal boiling point, as are the molar volumes. Using T in K and μ in Pa sec yields a diffusivity in m^2/sec . The average error is 21 percent when tested on 237 experimental systems.

For prediction of the **liquid diffusivity of a solute in a pair of mixed solvents**, the method of Tang and Himmelblau,¹¹¹ Eq. (2-161), is recommended.

$$\ln(D_{1m}\mu_m^{1/2}) = x_2 \ln(D_{12}^* \mu_2^{1/2}) + x_3 \ln(D_{13}^* \mu_3^{1/2}) \quad (2-161)$$

The solute 1 is dissolved in a solvent pair of 2 and 3. D^* are infinite dilution binary diffusivities estimated by the proper method discussed previously. The mixture viscosity can be predicted by methods of the previous section. The average absolute error when tested on 40 systems is 25 percent. The method gives higher errors if the solute is gaseous.

SURFACE TENSION

The molecules in a gas-liquid interface are in tension and tend to contract to a minimum surface area. This tension may be quantified by the surface tension, which is defined as the force in the plane of the surface per unit length. Jasper⁴³ has made a critical evaluation of experimental surface tension data for approximately 2200 pure chemicals. He correlates surface tension σ (mN/m or dyn/cm) with temperature T ($^\circ\text{C}$) over a specified temperature range as

$$\sigma = a - bT \quad (2-162)$$

where a and b are listed for most of the substances. To obtain values at a higher temperature than the upper temperature limit indicated by Jasper, the following expression may be used:

$$\sigma = d(1 - T_r)^e \quad (2-163)$$

where d and e are determined such that σ and $d\sigma/dT$ at the upper temperature limit T_{HI} have the same values when calculated from both Eqs. (2-162) and (2-163):

$$e = \frac{b(T_c - T_{HI})}{a - bT_{HI}} \quad (2-164)$$

$$d = (a - bT_{HI})(1 - T_{HI})^{-e} \quad (2-165)$$

where T_c = critical temperature, $^\circ\text{C}$

T_r = reduced temperature = $(T + 273.15)/(T_c + 273.15)$

Eq. (2-163) correctly predicts that the surface tension becomes zero at the critical point.⁵⁷

For **nonpolar, nonhydrocarbon** chemicals not found in Jasper,⁴³ use can be made of the corresponding states approach of Brock and Bird⁵⁸ as modified by Miller⁶⁹ at temperature T (K):

$$\sigma = 4.601 \times 10^{-4} P_c^{2/3} T_c^{1/3} Q (1 - T_r)^{11/9} \quad (2-166)$$

$$Q = 0.1207 \left[1 + \frac{T_{br}(\ln P_c - 11.5261)}{1 - T_{br}} \right] - 0.281 \quad (2-167)$$

where σ = surface tension, mN/m

P_c = critical pressure, Pa

T_c = critical temperature, K
 T_r = reduced temperature, T/T_c
 T_b = normal boiling temperature, K
 T_{br} = reduced normal boiling temperature, T_b/T_c

Errors are usually less than 5 percent.

Example 40 Estimate surface tension for ethyl mercaptan. The required properties from Daubert et al.²⁴ are $P_c = 5.49 \times 10^6 \text{ Pa}$, $T_c = 499.15 \text{ K}$, and $T_b = 308.15 \text{ K}$. For $T = 303.15 \text{ K}$, $T_r = 303.15/499.15 = 0.6073$, and $T_{br} = 308.15/499.15 = 0.6173$. Substituting into Eqs. (2-167) and (2-166):

$$Q = 0.1207 \left[1 + \frac{0.6173 (\ln 5.49 \times 10^6 - 11.5261)}{1 - 0.6173} \right] - 0.281$$

$$Q = 0.6170$$

$$\sigma = 4.601 \times 10^{-4} (5.49 \times 10^6)^{2/3} (499.15)^{1/3} (0.6170) (1 - 0.6073)^{11/9}$$

$$\sigma = 22.36 \text{ mN/m}$$

The reported experimental value is 22.68 mN/m.⁴³

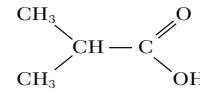
For **hydrocarbon and polar** chemicals, the approach originally suggested by Macleod⁶⁵ as further developed by Sugden^{106,107} can be used:

$$\sigma = \left\{ \frac{[P]}{1000} (\rho_L - \rho_G) \right\}^4 \quad (2-168)$$

where σ = surface tension, mN/m
 ρ_L = liquid density, kmol/m^3
 ρ_G = vapor density, kmol/m^3

The temperature-independent parachor [P] may be calculated by the additive scheme proposed by Quale.⁸³ The atomic group contributions for this method, with contributions for silicon, boron, and aluminum from Myers,⁷⁵ are shown in Table 2-402. At low pressures, where $\rho_L \gg \rho_G$, the vapor density term may be neglected. Errors using Eq. (2-168) are normally less than 5 to 10 percent.

Example 41 Estimate surface tension for isobutyric acid. For isobutyric acid, the liquid density from Daubert et al.²⁴ is 10.77 kmol/m^3 at 293.15 K. [P] is determined from Table 2-402:



is made up of the two groups $\text{CH}_3-\text{CH}(\text{CH}_3)-$ and $-\text{COOH}$. Therefore, $[P] = 133.3 + 73.8 = 207.1$. With Eq. (2-168), neglecting the vapor density,

$$\sigma = \left[\frac{207.1}{1000} (10.77) \right]^4 = 24.75 \text{ mN/m}$$

Jasper⁴³ quotes a value of 25.04 mN/m at 293.15 K.

In general, the surface tension of a **liquid mixture** is not a simple function of the pure component surface tensions because the composition of the mixture surface is not the same as the bulk. For **nonaqueous** solutions of n components, the method of Winterfeld, Scriven, and Davis¹³⁰ is applicable:

$$\sigma_m = \sum_{i=1}^n \sum_{j=1}^n \rho_{i,j}^2 \left(\frac{x_i}{\rho_{Li}} \right) \left(\frac{x_j}{\rho_{Lj}} \right) (\sigma_i \sigma_j)^{1/2} \quad (2-169)$$

$$\frac{1}{\rho} = \sum_{i=1}^n \frac{x_i}{\rho_{Li}} \quad (2-170)$$

where σ_m = mixture surface tension, mN/m

$x_{i,j}$ = mole fraction of component i or j in the liquid mixture

$\rho_{Li,j}$ = pure component liquid density of component i or j , kmol/m^3

$\sigma_{i,j}$ = pure component surface tension of component i or j , mN/m

Accuracies of 3–4 percent average deviation are typical when using this method.

Example 42 Estimate surface tension of a mixture. At 298.15 K, Daubert et al.²⁴ report the liquid density of *n*-pentane to be 8.617 kmol/m^3 and its surface tension to be 15.47 mN/m. From the same source, the corresponding values for dichloromethane are 15.52 kmol/m^3 and 27.22 mN/m. Using Eqs. (2-170) and (2-169) for a mixture of 0.1606 mole fraction *n*-pentane and 0.8394 mole fraction dichloromethane:

$$\begin{aligned} \frac{1}{\rho} &= \frac{0.1606}{8.617} + \frac{0.8394}{15.52} \\ \rho &= 13.75 \text{ kmol/m}^3 \end{aligned}$$

TABLE 2-402 Atomic Group Contributions for Calculation of the Parachor [P]

Atomic group	[P]	Atomic group	[P]
Carbon-hydrogen		Special Groups (Cont.)	
C	9.0	B	13.2
H	15.5	Al	34.9
CH ₃ —	55.5	F	26.1
(—CH ₂ —) _n		Cl	55.2
n = 1–12	40.0	Br	68.0
n > 12	40.3	I	90.3
CH ₃ —CH(CH ₃)—	133.3	Ethylenic Bond	
CH ₃ —CH ₂ —CH(CH ₃)—	171.9	Terminal ^o	19.1
CH ₃ —CH ₂ —CH ₂ —CH(CH ₃)—	211.7	2,3-position	17.7
CH ₃ —CH(CH ₃)—CH ₂ —	173.3	3,4-position [†]	16.3
CH ₃ —CH ₂ —CH(C ₂ H ₅)—	209.5	Triple Bond	40.6
CH ₃ —C(CH ₃) ₂ —	170.4	Ring Closure	
CH ₃ —CH ₂ —C(CH ₃) ₂ —	207.5	3-membered	12.5
CH ₃ —CH(CH ₃)—CH(CH ₃)—	207.9	4-membered	6.0
CH ₃ —CH(CH ₃)—C(CH ₃) ₂ —	243.5	5-membered	3.0
C ₆ H ₅ —	189.6	6-membered	0.8
		7-membered	4.0
Special Groups		=O (ketone)	
H in OH	10.0	3 carbon atoms	22.3
H in HN	12.5	4 carbon atoms	20.0
O	19.8	5 carbon atoms	18.5
—OH	29.8	6 carbon atoms	17.3
O ₂ in acids, esters	54.8	7 carbon atoms	17.3
—COO—	63.8	8 carbon atoms	15.1
—COOH	73.8	9 carbon atoms	14.1
N	17.5	10 carbon atoms	13.0
—NH ₂	42.5	11 carbon atoms	12.6
S	49.1		
P	40.5		
Si	30.3		
Si (silanes)	43.3		

^o Use the value for double bonds in cyclic compound. Assume 3 double bonds for the aromatic ring.[†] Use 16.3 for double bonds in the 3, 4 or higher positions.

$$\begin{aligned}\sigma_m &= (13.75)^2 \left(\frac{0.1606}{8.617} \right)^2 (15.47) \\ &\quad + 2(13.75)^2 \left(\frac{0.1606}{8.617} \right) \left(\frac{0.8394}{15.52} \right) [(15.47)(27.22)]^{1/2} \\ &\quad + (13.75)^2 \left(\frac{0.8394}{15.52} \right)^2 (27.22)\end{aligned}$$

$$\sigma_m = 23.89 \text{ mN/m}$$

De Soria et al.²⁶ give an experimental value of 24.24 mN/m for this mixture. Surface tensions for **aqueous** solutions are more difficult to predict than those for nonaqueous mixtures because of the nonlinear dependence on mole fraction. Small concentrations of the organic material may significantly affect the mixture surface tension value. For many binary organic-water mixtures, the method of Tamura, Kurata, and Odani¹¹⁰ may be used:

$$\sigma_m^{1/4} = \Psi_w \sigma_w^{1/4} + \Psi_o \sigma_o^{1/4} \quad (2-171)$$

where σ_m = mixture surface tension, mN/m
 σ_w = surface tension of pure water, mN/m
 σ_o = surface tension of pure organic component, mN/m
 $\Psi_w = 1 - \Psi_o$ (2-172)

Ψ_w is defined by the relation:

$$\log_{10} \frac{(\Psi_w)^q}{(1 - \Psi_w)} = \log_{10} \left[\frac{(x_w V_w)^q}{x_o V_o} (x_w V_w + x_o V_o)^{1-q} \right] + 44.1 \frac{q}{T} \left[\frac{\sigma_o V_o^{2/3}}{q} - \sigma_w V_w^{2/3} \right] \quad (2-173)$$

where x_w = bulk mole fraction of pure water
 x_o = bulk mole fraction of pure organic component
 V_w = molar volume of pure water, m³/kmol
 V_o = molar volume of pure organic component, m³/kmol
 T = temperature, K
 q = constant depending upon the size and type of the organic component; see table:

Organic component	q	Example
Fatty acids, alcohols	Number of carbon atoms	Acetic acid: q = 2
Ketones	One less than the number of carbon atoms	Acetone: q = 2
Halogen derivatives of fatty acids	Number of carbon atoms times the ratio of the molar volume of the halogen derivative to the parent fatty acid	Chloroacetic acid

$$q = 2 \frac{V(\text{chloroacetic acid})}{V(\text{acetic acid})}$$

Expected errors are less than 10 percent when q is less than 5 and within 20 percent when q is greater than 5.

Example 43 Estimate surface tension of a water-methanol mixture. Equation (2-171) can be used with a water-methanol mixture at 303.15 K when the methanol mole fraction is 0.122. From Jasper,⁴³ $\sigma_w = 71.40 \text{ mN/m}$, and $\sigma_o = 21.73 \text{ mN/m}$. The density of water (per Ref. 24) is 55.16 kmol/m³; $V_w = 0.01813 \text{ m}^3/\text{kmol}$. The density of methanol is 24.49 kmol/m³ (Ref. 24); $V_o = 0.04083 \text{ m}^3/\text{kmol}$. For methanol, $q = 1$. Using Eq. (2-173) to obtain Ψ_w :

$$\begin{aligned}\log_{10} \frac{\Psi_w}{1 - \Psi_w} &= \log_{10} \left[\frac{(0.878)(0.01813)}{(0.122)(0.04083)} \right] \\ &\quad + \frac{44.1}{303.15} [(21.73)(0.04083)^{2/3} - (71.40)(0.01813)^{2/3}] \\ &= 0.505 - 0.342 = 0.163 \\ \frac{\Psi_w}{1 - \Psi_w} &= 10^{0.163} = 1.455 \\ \Psi_w &= \frac{1.455}{2.455} = 0.593\end{aligned}$$

Using Eq. (2-172): $\psi_o = 1 - 0.593 = 0.407$. Substituting into Eq. (2-171):

$$\sigma_m^{1/4} = (0.593)(71.40)^{1/4} + (0.407)(21.73)^{1/4}$$

$$\sigma_m^{1/4} = 2.603$$

$$\sigma_m = 45.91 \text{ mN/m}$$

The reported experimental value is 46.1 mN/m.¹¹⁰

FLAMMABILITY PROPERTIES

Flash points, lower and upper flammability limits, and autoignition temperatures are the three properties used to indicate safe operating limits of temperature when processing organic materials. Prediction methods are somewhat erratic, but, together with comparisons with reliable experimental values for families or similar compounds, they are valuable in setting a conservative value for each of the properties. The DIPPR compilation includes evaluated values for over 1000 common organics. Detailed examples of most of the methods discussed are available in Danner and Daubert.²²

The flash point is the lowest temperature at which a liquid gives off sufficient vapor to form an ignitable mixture with air near the surface of the liquid or within the vessel used. ASTM test methods include procedures using a closed cup (ASTM D56, ASTM D93, and ASTM D3828), which is preferred, and an open cup (ASTM D92 and ASTM D1310). When several values are available, the *lowest* temperature is usually taken in order to assure safe operation of the process.

The method of Shebeko et al.⁹⁶ is the preferred flash point prediction method. The formula of the compound, the system pressure, and vapor pressure data for the compound must be available or estimable. Equation (2-174) is the basic equation.

$$P^{\text{sat}} = \frac{P}{1 + 4.76(2\beta - 1)} = 0 \quad (2-174)$$

$$\beta = N_C + N_S + \frac{(N_H - N_X)}{4} - \frac{N_O}{2}$$

N 's are the numbers of atoms of carbon (C), sulfur (S), hydrogen (H), halogens (X), and oxygen (O) in the molecule. P is the total system pressure. P^{sat} is the vapor pressure of the compound at the flash point temperature.

If P^{sat} is available as a function of temperature, Eq. (2-174) can be solved directly for the flash point temperature. Otherwise, trial and error with a table of P^{sat} vs. T is required. Errors average about 5°C but may be as much as 15°C.

An alternate method for flash point prediction is the method of Gmehling and Rasmussen³³ and depends on the lower flammability limit (discussed later). Vapor pressure as a function of temperature is also required. The method is generally not as accurate as the preceding method as flammability limit errors are propagated. The authors have also extended the method to defined mixtures of organics.

The upper and lower flammability limits are the boundary-line mixtures of vapor or gas with air, which, if ignited, will just propagate flame and are given in terms of percent by volume of gas or vapor in the air. Each of these limits also has a temperature at which the flammability limits are reached. The temperature corresponding to the lower-limit partial vapor pressure should equal the flash point. The

temperature corresponding to the upper-limit partial vapor pressure is somewhat above the lower limit and is usually considerably below the autoignition temperature. Flammability limits are calculated at one atmosphere total pressure and normally are considered synonymous with explosive limits. Limits in oxygen rather than air are sometimes measured and available. Limits are generally reported at 298 K and 1 atm. If temperature or pressure are increased, the lower limit will decrease while the upper limit will increase, giving a wider range of compositions over which flame will propagate.

The most generally applicable method for prediction of the property is the method of Seaton,⁹⁵ which depends only on the molecular structure of the molecule and utilizes second order (Benson-type) groups to construct the molecule. Equation (2-175) sums the groups' number of each type group (n_i) to get both the upper and lower limits.

$$z_u \quad \text{or} \quad z_l = \frac{\sum (n_i f_i)}{\sum \left(\frac{n_i f_i}{g_i} \right)} \quad (2-175)$$

Two sets of f_i and g_i are given in the article for each second-order group to cover both upper (u) and lower (l) limits (z) in volume percent units. A study of this method for about 80 organic compounds in 14 families shows absolute errors of 0.15 percent and 2.3 percent for the lower and upper limits, respectively. The upper limit prediction should not be used for ethers.

Alternate group contribution methods dependent only on molecular structure are the method of Shebeko et al.⁹⁷ modified by High and Siegel³⁹ for lower flammability limit and the method of High and Danner³⁸ for upper flammability limit. Both methods are detailed by Danner and Daubert.²² A study comparing these methods with the Seaton method shows slightly higher absolute errors of 0.23 percent and 2.9 percent for the lower and upper limits, respectively. The upper limit prediction should not be used for ethers. Both methods are recommended to be used only for qualitative guidance. Lower flammability limits can also be back-calculated from a known flash point by the method of Gmehling and Rasmussen³³ discussed earlier.

The autoignition temperature is the minimum temperature for a substance to initiate self-combustion in air in the absence of a spark or flame. The temperature is no lower than and is generally considerably higher than the temperature corresponding to the upper flammability limit. Large differences can occur in reported values determined by different procedures. The lowest reasonable value should be accepted in order to assure safety. Values are also sometimes given in oxygen rather than in air.

Values for hydrocarbons other than alkynes and alkadienes can be predicted by the method of Suzuki et al.¹⁰⁸ The best model includes the descriptors T_c , P_c , the parachor, the molecular surface area (which can be approximated by the van der Waals area), and the zero-order connectivity index. Excluding alkynes and alkadienes, a study for 58 alkanes, aromatics, and cycloalkanes showed an average deviation from experimental values of about 30 K.

Another method of estimating autoignition temperatures is to compare values for a compound with other members of its homologous series on a plot vs. carbon number as the temperature decreases and carbon number increases. Affens¹ gives a formal procedure for such estimation.