

# APPENDIX A

## Physical Property Data

### ► A.1 CRITICAL CONSTANTS, ACENTRIC FACTORS, AND ANTOINE COEFFICIENTS:<sup>1</sup>

The Antoine equation is of the form:  $\ln(P^{\text{sat}} \text{ [bar]}) = A - \frac{B}{T[K]} + C$

**TABLE A.1.1 Organic compounds**

Formula	Name	MW[g/mol]	T <sub>c</sub> [K]	P <sub>c</sub> [bar]	ω	A	B	C	T <sub>min</sub>	T <sub>mix</sub>
CH <sub>2</sub> O	Formaldehyde	30.026	408	65.86	0.253	9.8573	2204.13	-30.15	185	271
CH <sub>4</sub>	Methane	16.042	190.6	46.00	0.008	8.6041	897.84	-7.16	93	120
CH <sub>4</sub> O	Methanol	32.042	512.6	80.96	0.559	11.9673	3626.55	-34.29	257	364
C <sub>2</sub> H <sub>4</sub>	Acetylene	26.038	308.3	61.40	0.184	9.7279	1637.14	-19.77	194	202
C <sub>2</sub> H <sub>3</sub> N	Acetonitrile	41.052	548	48.33	0.321	9.6672	2945.47	-49.15	260	390
C <sub>2</sub> H <sub>4</sub>	Ethylene	28.053	282.4	50.36	0.085	8.9166	1347.01	-18.15	120	182
C <sub>2</sub> H <sub>4</sub> O	Acetaldehyde	44.053	461	55.73	0.303	9.6279	2465.15	-37.15	210	320
C <sub>2</sub> H <sub>4</sub> O	Ethylene oxide	44.053	469	71.94	0.200	10.1198	2567.61	-29.01	300	310
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid	60.052	594.4	57.86	0.454	10.1878	3405.57	-56.34	290	430
C <sub>2</sub> H <sub>6</sub>	Ethane	30.069	305.4	48.74	0.099	9.0435	1511.42	-17.16	130	199
C <sub>2</sub> H <sub>6</sub> O	Ethanol	46.068	516.2	63.83	0.635	12.2917	3803.98	-41.68	270	369
C <sub>3</sub> H <sub>6</sub>	Propylene	42.080	365.0	46.20	0.148	9.0825	1807.53	-26.15	160	240
C <sub>3</sub> H <sub>6</sub> O	Acetone	58.079	508.1	47.01	0.309	10.0311	2940.46	-35.93	241	350
C <sub>3</sub> H <sub>8</sub>	Propane	44.096	370.0	42.44	0.152	9.1058	1872.46	-25.16	164	249
C <sub>3</sub> H <sub>8</sub> O	1-Propanol	60.095	536.7	51.68	0.624	10.9237	3166.38	-80.15	285	400
C <sub>4</sub> H <sub>6</sub>	1,3-Butadiene	54.090	425	43.27	0.195	9.1525	2142.66	-34.30	215	290
C <sub>4</sub> H <sub>8</sub>	<i>cis</i> -2-Butene	56.106	435.6	42.05	0.202	9.1969	2210.71	-36.15	200	305
C <sub>4</sub> H <sub>8</sub>	<i>trans</i> -2-Butene	56.106	428.6	41.04	0.214	9.1975	2212.32	-33.15	200	300
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate	88.105	523.2	38.30	0.363	9.5314	2790.50	-57.15	260	385
C <sub>4</sub> H <sub>10</sub>	<i>n</i> -Butane	58.122	425.2	37.90	0.193	9.0580	2154.90	-34.42	195	290
C <sub>4</sub> H <sub>10</sub>	Isobutane	58.122	408.1	36.48	0.176	8.9179	2032.76	-33.15	187	280
C <sub>4</sub> H <sub>10</sub> O	<i>n</i> -Butanol	74.122	562.9	44.18	0.590	10.5958	3137.02	-94.43	288	404
C <sub>5</sub> H <sub>10</sub>	1-Pentene	70.133	464.7	40.53	0.245	9.1444	2405.96	-39.63	220	325
C <sub>5</sub> H <sub>12</sub>	<i>n</i> -Pentane	72.149	469.6	33.74	0.251	9.2131	2477.07	-39.94	220	330
C <sub>6</sub> H <sub>6</sub>	Benzene	78.112	562.1	48.94	0.212	9.2806	2788.51	-52.36	280	377
C <sub>6</sub> H <sub>6</sub> O	Phenol	94.111	694.2	61.30	0.440	9.8077	3490.89	-98.59	345	481
C <sub>6</sub> H <sub>7</sub> N	Aniline	93.127	699	53.09	0.382	10.0546	3857.52	-73.15	340	500
C <sub>6</sub> H <sub>12</sub>	Cyclohexane	84.159	553.4	40.73	0.213	9.1325	2766.63	-50.50	280	380
C <sub>6</sub> H <sub>12</sub>	1-Hexene	84.159	504.0	31.71	0.285	9.1887	2654.81	-47.30	240	360
C <sub>6</sub> H <sub>14</sub>	<i>n</i> -Hexane	86.175	507.4	29.69	0.296	9.2164	2697.55	-48.78	245	370

(Continued)

<sup>1</sup> For a more complete set of compounds, consult ThermoSolver, the text software.

**TABLE A.1.1** Continued

Formula	Name	$MW_{[g/mol]}$	$T_c$ [K]	$P_c$ [bar]	$\omega$	A	B	C	$T_{\min}$	$T_{\max}$
C <sub>7</sub> H <sub>8</sub>	Toluene	92.138	591.7	41.14	0.257	9.3935	3096.52	-53.67	280	410
C <sub>7</sub> H <sub>14</sub>	1-Heptene	98.186	537.2	28.37	0.358	9.2692	2895.51	-53.97	265	400
C <sub>7</sub> H <sub>16</sub>	n-Heptane	100.202	540.2	27.36	0.351	9.2535	2911.32	-56.51	270	400
C <sub>8</sub> H <sub>8</sub>	Styrene	104.149	647.0	39.92	0.257	9.3991	3328.57	-63.72	305	460
C <sub>8</sub> H <sub>10</sub>	<i>o</i> -Xylene	106.165	630.2	37.29	0.314	9.4954	3395.57	-59.46	305	445
C <sub>8</sub> H <sub>10</sub>	<i>m</i> -Xylene	106.165	617.0	35.46	0.331	9.5188	3366.99	-58.04	300	440
C <sub>8</sub> H <sub>10</sub>	<i>p</i> -Xylene	106.165	616.2	35.16	0.324	9.4761	3346.65	-57.84	300	440
C <sub>8</sub> H <sub>10</sub>	Ethylbenzene	106.165	617.1	36.07	0.301	9.3993	3279.47	-59.95	300	450
C <sub>8</sub> H <sub>16</sub>	1-Octene	112.213	566.6	26.24	0.386	9.3428	3116.52	-60.39	288	420
C <sub>8</sub> H <sub>18</sub>	n-Octane	114.229	568.8	24.82	0.394	9.3224	3120.29	-63.63	292	425
C <sub>9</sub> H <sub>20</sub>	n-Nonane	128.255	594.6	23.10	0.444	9.3469	3291.45	-71.33	312	452
C <sub>10</sub> H <sub>8</sub>	Naphthalene	128.171	748.4	40.53	0.302	9.5224	3992.01	-71.29	360	545
C <sub>10</sub> H <sub>22</sub>	<i>n</i> -Decane	142.282	617.6	21.08	0.490	9.3912	3456.80	-78.67	330	476

**TABLE A.1.2** Inorganic Compounds

Formula	Name	$MW_{[g/mol]}$	$T_c$ [K]	$P_c$ [bar]	$\omega$	A	B	C	$T_{\min}$	$T_{\max}$
Ar	Argon	39.948	150.8	48.74	-0.004	8.6128	700.51	-5.84	81	94
BCl <sub>3</sub>	Boron trichloride	117.169	451.95	38.71	0.148	9.0985	2242.71	-38.99	182	286
B <sub>2</sub> H <sub>6</sub>	Diborane	27.670	289.80	40.50	0.138	8.7074	1377.84	-22.18	118	181
Br <sub>2</sub>	Bromine	159.808	584	103.35	0.132	9.2239	2582.32	-51.56	259	354
CCl <sub>3</sub> F	Trichlorofluoromethane	137.367	471.2	44.08	0.188	9.2314	2401.61	-36.3	240	300
CF <sub>4</sub>	Carbon tetrafluoride	88.004	227.6	37.39	0.191	9.4341	1244.55	-13.06	93	148
C <sub>2</sub> F <sub>6</sub>	Hexafluoroethane	138.012	292.8	30.42	0.255	9.1646	1559.11	-24.51	180	195
CHCl <sub>3</sub>	Chloroform	119.377	536.4	54.72	0.216	9.3530	2696.79	-46.16	260	370
CO	Carbon monoxide	28.010	132.9	34.96	0.049	7.7484	530.22	-13.15	63	108
CO <sub>2</sub>	Carbon dioxide	44.010	304.2	73.76	0.225	15.9696	3103.39	-0.16	154	204
CS <sub>2</sub>	Carbon disulfide	76.143	552	79.03	0.115	9.3642	2690.85	-31.62	228	342
Cl <sub>2</sub>	Chlorine	70.905	417	77.01	0.073	9.3408	1978.32	-27.01	172	264
F <sub>2</sub>	Fluorine	37.997	144.3	52.18	0.048	9.0498	714.10	-6.00	59	91
H <sub>2</sub>	Hydrogen	2.016	33.2	12.97	-0.22	7.0131	164.90	3.19	14	25
HBr	Hydrogen bromide	80.912	363.2	85.52	0.063	7.8485	1242.53	-47.86	184	221
HCN	Hydrogen cyanide	27.025	456.8	53.90	0.407	9.8936	2585.80	-37.15	234	330
HCl	Hydrogen chloride	36.461	324.6	83.09	0.12	9.8838	1714.25	-14.45	137	200
H <sub>2</sub> O	Water	18.015	647.3	220.48	0.344	11.6834	3816.44	-46.13	284	441
H <sub>2</sub> S	Hydrogen sulfide	34.082	373.2	89.37	0.100	9.4838	1768.69	-26.06	190	230
NH <sub>3</sub>	Ammonia	17.031	405.6	112.77	0.250	10.3279	2132.50	-32.98	179	261
He	Helium-4	4.003	5.19	2.27	-0.387	5.6312	33.7329	1.79	3.7	4.3
HF	Hydrogen fluoride	20.006	461	64.85	0.372	11.0756	3404.49	15.06	206	313
Kr	Krypton	83.800	209.4	55.02	-0.002	8.6475	958.75	-8.71	113	129
N <sub>2</sub>	Nitrogen	28.013	126.2	33.84	0.039	8.3340	588.72	-6.60	54	90
NF <sub>3</sub>	Nitrogen trifluoride	71.002	234	45.29	0.132	8.9905	1155.69	-15.37	103	155
N <sub>2</sub> O	Nitrous oxide	44.013	309.6	72.45	0.160	9.5069	1506.49	-25.99	144	200
NO	Nitric oxide	30.006	180	64.85	0.607	13.5112	1572.52	-4.88	95	140
NO <sub>2</sub>	Nitrogen dioxide	46.006	431.4	101.33	0.86	13.9122	4141.29	3.65	230	320
Ne	Neon	20.180	44.4	27.56	0.00	7.3897	180.47	-2.61	24	29
O <sub>2</sub>	Oxygen	31.999	154.6	50.46	0.021	8.7873	734.55	-6.45	63	100
PH <sub>3</sub>	Phosphene	33.998	324.45	65.35	0.042	9.2700	1617.91	-11.07	144	186
SF <sub>6</sub>	Sulfur hexafluoride	146.056	318.7	37.59	0.286	12.7583	2524.78	-11.16	159	220
SO <sub>2</sub>	Sulfur dioxide	64.065	430.8	78.83	0.251	10.1478	2302.35	-35.97	195	280

**TABLE A.1.2** Continued

Formula	Name	$MW_{[\text{g/mol}]}$	$T_c [\text{K}]$	$P_c [\text{bar}]$	$\omega$	A	B	C	$T_{\min}$	$T_{\max}$
$\text{SO}_3$	Sulfur trioxide	80.064	491.0	82.07	0.41	14.2201	3995.70	-36.66	290	332
$\text{SiCl}_3\text{H}$	Trichlorosilane	135.452	479.0	41.7	0.203	9.7079	2694.02	-27.00	275	305
$\text{SiCl}_4$	Silicon tetrachloride	169.896	507.0	37.49	0.264	9.1817	2634.16	-43.15	238	364
$\text{SiF}_4$	Silicon tetrafluoride	104.079	259.09	37.15	0.456	16.3709	2810.45	-6.88	129	128
$\text{SiH}_4$	Silane	32.117	269.69	48.43	0.089	9.7222	1620.99	5.35	94	162
$\text{WF}_6$	Tungsten hexafluoride	297.830	444.0	43.40	0.231	10.4899	2351.42	-64.70	202	290

*Sources:* Mostly from R. C. Reid, J. M. Prausnitz, and T. K. Sherwood. *The Properties of Gases and Liquids*, 3rd ed. (New York: McGraw-Hill, 1977). Also from: CRC Handbook of Chemistry and Physics (Boca Raton, FL: CRC Press, (various) years); P. J. Linstrom and W. G. Mallard, Eds., **NIST Chemistry WebBook, NIST Standard Reference Database Number 69**, June 2005, National Institute of Standards and Technology, Gaithersburg MD, 20899 (<http://webbook.nist.gov/chemistry/fluid/>); C. L. Yaws, *Handbook of Vapor Pressure* (vol. 4) (Houston: Gulf Publishing, 1995).

## ► A.2 HEAT CAPACITY DATA

$$\frac{c_p}{R} = A + BT + CT^2 + DT^{-2} + ET^3 \text{ with } T \text{ in [K]}$$

**TABLE A.2.1** Heat Capacity of Ideal gases: Organic Compounds

Formula	Name	A	$B \times 10^3$	$C \times 10^6$	$D \times 10^{-5}$	$E \times 10^9$	$T_{\min}$	$T_{\max}$	Source
$\text{CH}_2\text{O}$	Formaldehyde	2.264	7.022	-1.877			298	1500	1
$\text{CH}_4$	Methane	1.702	9.081	-2.164			298	1500	1
$\text{CH}_4\text{O}$	Methanol	2.211	12.216	-3.45			298	1500	1
$\text{C}_2\text{H}_2$	Acetylene	6.132	1.952		-1.299		298	1500	1
$\text{C}_2\text{H}_4$	Ethylene	1.424	14.394	-4.392			298	1500	1
$\text{C}_2\text{H}_4\text{O}$	Acetaldehyde	1.693	17.978	-6.158			298	1000	1
$\text{C}_2\text{H}_4\text{O}$	Ethylene oxide	-0.385	23.463	-9.296			298	1000	1
$\text{C}_2\text{H}_6$	Ethane	1.131	19.225	-5.561			298	1500	1
$\text{C}_2\text{H}_6\text{O}$	Ethanol	3.518	20.001	-6.002			298	1500	1
$\text{C}_3\text{H}_6$	Propylene	1.637	22.706	-6.915			298	1500	1
$\text{C}_3\text{H}_8$	Propane	1.213	28.785	-8.824			298	1500	1
$\text{C}_4\text{H}_6$	1,3-Butadiene	2.734	26.786	-8.882			298	1500	1
$\text{C}_4\text{H}_8$	1-Butene	1.967	31.63	-9.873			298	1500	1
$\text{C}_4\text{H}_{10}$	n-Butane	1.935	36.915	-11.402			298	1500	1
$\text{C}_4\text{H}_{10}$	Isobutane	1.677	37.853	-11.945			298	1500	1
$\text{C}_5\text{H}_{10}$	1-Pentene	2.691	39.753	-12.447			298	1500	1
$\text{C}_5\text{H}_{12}$	n-Pentane	2.464	45.351	-14.111			298	1500	1
$\text{C}_6\text{H}_6$	Benzene	-0.206	39.064	-13.301			298	1500	1
$\text{C}_6\text{H}_{12}$	Cyclohexane	-3.876	63.249	-20.928			298	1500	1
$\text{C}_6\text{H}_{12}$	1-Hexene	3.220	48.189	-15.157			298	1500	1
$\text{C}_6\text{H}_{14}$	n-Hexane	3.025	53.722	-16.791			298	1500	1
$\text{C}_7\text{H}_8$	Toluene	0.290	47.052	-15.716			298	1500	1
$\text{C}_7\text{H}_{14}$	1-Heptene	3.768	56.588	-17.847			298	1500	1
$\text{C}_7\text{H}_{16}$	n-Heptane	3.570	62.127	-19.468			298	1500	1
$\text{C}_8\text{H}_8$	Styrene	2.050	50.192	-16.662			298	1500	1
$\text{C}_8\text{H}_{10}$	Ethylbenzene	1.124	55.38	-18.476			298	1500	1
$\text{C}_8\text{H}_{16}$	1-Octene	4.324	64.96	-20.521			298	1500	1
$\text{C}_8\text{H}_{18}$	n-Octane	8.163	70.567	-22.208			298	1500	1

*Sources:*

1. J. M. Smith, H. C. Van Ness, and M. M. Abbott, *Introduction to Chemical Engineering Thermodynamics*, 5th ed. (New York: McGraw-Hill, 1996).
2. P. J. Linstrom and W. G. Mallard, Eds., **NIST Chemistry WebBook, NIST Standard Reference Database Number 69**, June 2005, National Institute of Standards and Technology, Gaithersburg MD, 20899 (<http://webbook.nist.gov/chemistry/fluid/>).

**TABLE A.2.2 Heat Capacity of Ideal Gases: Inorganic Compounds**

Formula	Name	A	$B \times 10^3$	$C \times 10^6$	$D \times 10^{-5}$	$E \times 10^9$	$T_{\min}$	$T_{\max}$	Source
BCl <sub>3</sub>	Air	3.355	0.575		-0.016		298	2000	1
	Boron trichloride	4.245	16.539	-18.969	-0.176	8.031	298	700	2
B <sub>2</sub> H <sub>6</sub>	Diborane	9.882	0.078	-0.018	-3.374	0.001	700	6000	2
		-1.494	32.188	-18.314	0.361	3.988	298	1200	2
Br <sub>2</sub>	Bromine	19.440	1.351	-0.262	-44.224	0.018	1200	6000	2
		4.493	0.056		-0.154		298	3000	1
CF <sub>4</sub>	Carbon tetrafluoride	1.921	25.299	-22.789	-0.261	7.482	298	1000	2
		12.776	0.129	-0.027	-10.032	0.002	1000	6000	2
CO	Carbon monoxide	3.376	0.557		-0.031		298	2500	1
CO <sub>2</sub>	Carbon dioxide	5.457	1.045		-1.157		298	2000	1
CS <sub>2</sub>	Carbon disulfide	6.311	0.805		-0.906		298	1800	1
C <sub>2</sub> F <sub>6</sub>	Hexafluoroethane	8.389	27.106	-20.948	-1.751	5.671	298	1400	2
		21.284	0.123	-0.023	-13.447	0.001	1400	6000	2
Cl <sub>2</sub>	Chlorine	4.442	0.089		-0.344		298	3000	1
H <sub>2</sub>	Hydrogen	3.249	0.422		0.083		298	3000	1
HBr	Hydrogen bromide	3.815	-1.648	2.809	-0.035	-1.084	298	1100	2
		3.956	0.339	-0.057	-3.819	0.004	1100	6000	2
HCN	Hydrogen cyanide	4.736	1.359		-0.725		298	2500	1
HCl	Hydrogen chloride	3.156	0.623		0.151		298	2000	1
HF	Hydrogen fluoride	3.622	-0.390	0.345	-0.030	0.055	298	1000	2
		2.955	0.829	-0.150	-0.282	0.010	1000	6000	2
H <sub>2</sub> O	Water	3.470	1.45		0.121		298	2000	1
H <sub>2</sub> S	Hydrogen sulfide	3.931	1.49		-0.232		298	2300	1
N <sub>2</sub>	Nitrogen	3.280	0.593		0.04		298	2000	1
NH <sub>3</sub>	Ammonia	3.5778	3.02		-0.186		298	1800	1
N <sub>2</sub> O	Nitrous oxide	5.328	1.24		-0.928		298	2000	1
NO	Nitric oxide	3.387	0.629		0.014		298	2000	1
NO <sub>2</sub>	Nitrogen dioxide	4.982	1.195		-0.792		298	2000	1
N <sub>2</sub> O <sub>4</sub>	Dinitrogen tetroxide	11.660	2.257		-2.787		298	2000	1
O <sub>2</sub>	Oxygen	3.639	0.506		-0.227		298	2000	1
PH <sub>3</sub>	Phosphene	1.431	10.160	-4.576	0.348	0.685	298	1200	2
SF <sub>6</sub>	Sulfur hexafluoride	7.085	30.736	-30.343	-1.935	10.676	298	1000	2
		18.901	0.058	-0.012	-9.959	0.001	1000	6000	2
SO <sub>2</sub>	Sulfur dioxide	5.699	0.801		-1.015		298	2000	1
SO <sub>3</sub>	Sulfur trioxide	8.06	1.056		-2.028		298	2000	1
SiCl <sub>4</sub>	Tetrachlorosilane	12.700	0.255	-0.069	-1.744	0.006	298	6000	2
SiClH <sub>3</sub>	Chlorosilane	2.977	14.807	-9.231	-0.432	2.242	298	1100	2
		11.954	0.572	-0.114	-17.303	0.008	1100	6000	2
SiCl <sub>2</sub> H <sub>2</sub>	Dichlorosilane	6.026	10.145	-6.014	-0.959	1.328	298	1500	2
		12.603	0.195	-0.035	-15.277	0.002	1500	6000	2
SiCl <sub>3</sub> H	Trichlorosilane	7.732	10.262	-8.671	-0.908	2.818	298	1000	2
		12.552	0.253	-0.052	-7.179	0.004	1000	6000	2
SiF <sub>4</sub>	Silicon tetrafluoride	5.170	19.158	-18.179	-0.514	6.207	298	1000	2
		12.903	0.057	-0.012	-6.482	0.001	1000	6000	2
SiH <sub>4</sub>	Silane	0.729	16.835	-9.368	0.163	1.953	298	1300	2
		12.010	0.511	-0.097	-24.525	0.006	1300	6000	2
WF <sub>6</sub>	Tungsten hexafluoride	18.137	0.730	-0.197	-3.690	0.017	1000	6000	2

**Sources:**

1. J. M. Smith, H. C. Van Ness, and M. M. Abbott, *Introduction to Chemical Engineering Thermodynamics*, 5th ed. (New York: McGraw-Hill, 1996).

2. P. J. Linstrom and W. G. Mallard, Eds., **NIST Chemistry WebBook, NIST Standard Reference Database Number 69**, June 2005, National Institute of Standards and Technology, Gaithersburg MD, 20899 (<http://webbook.nist.gov/chemistry/fluid>).

**TABLE A.2.3 Heat Capacity of Liquids and Solids**

Formula	Name	Phase	A	B × 10 <sup>3</sup>	D × 10 <sup>-5</sup>	Source
CH <sub>4</sub> O	Methanol	L, $\bar{c}_P$	9.815			2
C <sub>2</sub> H <sub>6</sub> O	Ethanol	L, $\bar{c}_P$	13.592			2
C <sub>3</sub> H <sub>6</sub> O	Acetone	L	11.184	13.375		2
C <sub>5</sub> H <sub>12</sub>	Pentane	L	18.691	5.254		3
C <sub>6</sub> H <sub>6</sub>	Benzene	L	16.310	0.000		2
C <sub>6</sub> H <sub>14</sub>	Hexane	L	23.695			2
Al	Aluminum	L	3.819			1
Al	Aluminum	S	2.486	1.490		1
Al <sub>2</sub> O <sub>3</sub>	Aluminum oxide	S	23.154			4
C	Graphite	S	2.063	0.514	-1.057	1
C	Diamond	S	0.782			4
Cu	Copper	L	3.950			4
Cu	Copper	S	2.723			1
Cu <sub>2</sub> O	Cuprous oxide	S, alpha	7.498			1
CuO	Cupric oxide	S	4.666			1
Fe	Iron	S, alpha	2.104	2.979		1
Fe <sub>3</sub> O <sub>4</sub>	Iron oxide	S	11.012	24.260		1
GaAs	Gallium arsenide	S	5.438	0.730		1
Ni	Nickel	S	1.508	4.308	0.297	1
Si	Silicon	L	3.272			4
Si	Silicon	S	2.879	0.297	-0.498	1
SiO <sub>2</sub>	Silicon dioxide	S	5.647	4.127	-1.359	1
SiCl <sub>3</sub> H	Trichlorosilane	L, $\bar{c}_P$	15.678			2
SiCl <sub>4</sub>	Tetrachlorosilane	L, $\bar{c}_P$	16.117			2
H <sub>2</sub> O	Water	L, $\bar{c}_P$	9.069			2
H <sub>2</sub> O	Water (ice)	S, $\bar{c}_P$	4.196			5
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid	L	16.731	1.875		3
HNO <sub>3</sub>	Nitric acid	L, $\bar{c}_P$	13.315			2
NH <sub>3</sub>	Ammonia	L	6.880	9.682		2

Sources:

1. O. Kubaschewski and C. B. Alcock, *Metallurgical Thermochemistry*, 5th ed. (New York: Pergamon Press, 1979).
2. Milan Zabransky et al., *Heat Capacity of Liquids* (Washington, DC: American Chemical Society; Woodbury, NY: National Bureau of Standards, 1996).
3. Richard M. Felder and Ronald W. Rousseau, *Elementary Principles of Chemical Processes*, 3rd ed. (New York: Wiley, 2000).
4. M. W. Chase et al., *JANAF Thermochemical Tables*, 4th ed. (Washington, DC: American Chemical Society; National Bureau of Standards, 1998).
5. K. Ranjevic, *Handbook of Thermodynamic Tables and Charts* (New York: McGraw-Hill, 1976).

## ► A.3 ENTHALPY AND GIBBS ENERGY OF FORMATION AT 298 K AND 1 BAR

**TABLE A.3.1 Organic Compounds**

Formula	Name	Phase	$\Delta h_f^o$ [kJ/mol]	$\Delta g_f^o$ [kJ/mol]	Source
CH <sub>2</sub> O	Formaldehyde	G	-115.97	-109.99	1
CH <sub>4</sub>	Methane	G	-74.81	-50.72	1
CH <sub>4</sub> O	Methanol	L	-238.73	-166.34	1
CH <sub>4</sub> O	Methanol	G	-200.66	-161.96	1
C <sub>2</sub> H <sub>2</sub>	Acetylene	G	226.88	209.24	1
C <sub>2</sub> H <sub>3</sub> N	Acetonitrile	L	53.17	98.93	1
C <sub>2</sub> H <sub>3</sub> N	Acetonitrile	G	87.92	105.67	1
C <sub>2</sub> H <sub>4</sub>	Ethylene	G	52.26	68.15	1

(Continued)

**TABLE A.3.1** Continued

Formula	Name	Phase	$\Delta h_{f,298}^\circ$ [kJ/mol]	$\Delta g_{f,298}^\circ$ [kJ/mol]	Source
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	1,1-Dichloroethane	L	-160.86	-76.20	1
C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	1,1-Dichloroethane	G	-130.00	-73.14	1
C <sub>2</sub> H <sub>4</sub> O	Acetaldehyde	G	-166.47	-133.39	1
C <sub>2</sub> H <sub>4</sub> O	Ethylene oxide	L	-77.46	-11.43	1
C <sub>2</sub> H <sub>4</sub> O	Ethylene oxide	G	-52.67	-13.10	1
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid	L	-484.41	-389.62	1
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	Acetic acid	G	-435.13	-376.94	1
C <sub>2</sub> H <sub>6</sub>	Ethane	G	-84.68	-32.84	1
C <sub>2</sub> H <sub>6</sub> O	Ethanol	L	-277.17	-174.25	1
C <sub>2</sub> H <sub>6</sub> O	Ethanol	G	-234.96	-168.39	1
C <sub>3</sub> H <sub>6</sub>	Propylene	G	20.43	62.76	1
C <sub>3</sub> H <sub>6</sub> O	Acetone	L	-248.28	-155.50	1
C <sub>2</sub> H <sub>6</sub> O	Acetone	G	-217.71	-153.15	1
C <sub>3</sub> H <sub>6</sub> O	Propylene oxide	L	-120.75	-26.75	1
C <sub>3</sub> H <sub>6</sub> O	Propylene oxide	G	-92.82	-25.79	1
C <sub>3</sub> H <sub>8</sub>	Propane	G	-103.85	-23.49	1
C <sub>3</sub> H <sub>8</sub> O	1-Propanol	L	-304.76	-170.78	1
C <sub>3</sub> H <sub>8</sub> O	1-Propanol	G	-257.70	-163.08	1
C <sub>4</sub> H <sub>6</sub>	1,3-Butadiene	L	85.41	149.68	1
C <sub>4</sub> H <sub>6</sub>	1,3-Butadiene	G	110.24	150.77	1
C <sub>4</sub> H <sub>8</sub>	1-Butene	G	-0.13	71.34	1
C <sub>4</sub> H <sub>8</sub>	cis-2-Butene	G	-6.99	65.90	1
C <sub>4</sub> H <sub>8</sub>	trans-2-Butene	G	-11.18	63.01	1
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate	L	-479.35	-332.93	1
C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	Ethyl acetate	G	-443.21	-327.62	1
C <sub>4</sub> H <sub>10</sub>	n-Butane	L	-147.75	-15.07	1
C <sub>4</sub> H <sub>10</sub>	n-Butane	G	-126.23	-17.17	1
C <sub>4</sub> H <sub>10</sub>	Isobutane	L	-158.55	-21.98	1
C <sub>4</sub> H <sub>10</sub>	Isobutane	G	-134.61	-20.89	1
C <sub>4</sub> H <sub>10</sub> O	n-Butanol	L	-326.03	-161.19	1
C <sub>4</sub> H <sub>10</sub> O	n-Butanol	G	-274.61	-150.77	1
C <sub>5</sub> H <sub>10</sub>	1-Pentene	L	-46.72	78.25	1
C <sub>5</sub> H <sub>10</sub>	1-Pentene	G	-20.93	79.17	1
C <sub>5</sub> H <sub>12</sub>	n-Pentane	L	-173.33	-9.46	1
C <sub>5</sub> H <sub>12</sub>	n-Pentane	G	-146.54	-8.37	1
C <sub>6</sub> H <sub>6</sub>	Benzene	L	49.07	124.34	1
C <sub>6</sub> H <sub>6</sub>	Benzene	G	82.98	129.75	1
C <sub>6</sub> H <sub>6</sub> O	Phenol	S	-165.13	-50.45	1
C <sub>6</sub> H <sub>6</sub> O	Phenol	G	-96.42	-32.91	1
C <sub>6</sub> H <sub>7</sub> N	Aniline	L	31.11	149.18	1
C <sub>6</sub> H <sub>7</sub> N	Aniline	G	86.92	166.80	1
C <sub>6</sub> H <sub>12</sub>	Cyclohexane	L	-156.34	26.89	1
C <sub>6</sub> H <sub>12</sub>	Cyclohexane	G	-123.22	31.78	1
C <sub>6</sub> H <sub>12</sub>	1-Hexene	L	-72.43	83.44	1
C <sub>6</sub> H <sub>12</sub>	1-Hexene	G	-41.70	87.50	1
C <sub>6</sub> H <sub>14</sub>	n-Hexane	L	-198.96	-4.35	1
C <sub>6</sub> H <sub>14</sub>	n-Hexane	G	-167.30	-0.25	1
C <sub>7</sub> H <sub>8</sub>	Toluene	L	12.02	113.84	1
C <sub>7</sub> H <sub>8</sub>	Toluene	G	50.03	122.09	1
C <sub>7</sub> H <sub>14</sub>	1-Heptene	L	-98.01	88.84	1
C <sub>7</sub> H <sub>14</sub>	1-Heptene	G	-62.34	95.88	1
C <sub>7</sub> H <sub>16</sub>	n-Heptane	L	-224.54	1.00	1

**TABLE A.3.1** Continued

Formula	Name	Phase	$\Delta h_f^\circ_{298}$ [kJ/mol]	$\Delta g_f^\circ_{298}$ [kJ/mol]	Source
C <sub>7</sub> H <sub>16</sub>	<i>n</i> -Heptane	G	-187.90	8.00	1
C <sub>8</sub> H <sub>10</sub>	<i>o</i> -Xylene	L	-24.45	110.53	1
C <sub>8</sub> H <sub>10</sub>	<i>o</i> -Xylene	G	19.01	122.17	1
C <sub>8</sub> H <sub>10</sub>	<i>m</i> -Xylene	L	-25.41	107.73	1
C <sub>8</sub> H <sub>10</sub>	<i>m</i> -Xylene	G	17.25	118.95	1
C <sub>8</sub> H <sub>10</sub>	<i>p</i> -Xylene	L	-24.45	110.03	1
C <sub>8</sub> H <sub>10</sub>	<i>p</i> -Xylene	G	17.96	121.21	1
C <sub>8</sub> H <sub>10</sub>	Ethylbenzene	L	-12.48	119.78	1
C <sub>8</sub> H <sub>10</sub>	Ethylbenzene	G	29.81	130.67	1
C <sub>8</sub> H <sub>16</sub>	1-Octene	L	-123.59	94.16	1
C <sub>8</sub> H <sub>16</sub>	1-Octene	G	-82.98	104.29	1
C <sub>8</sub> H <sub>18</sub>	<i>n</i> -Octane	L	-250.12	6.49	1
C <sub>8</sub> H <sub>18</sub>	<i>n</i> -Octane	G	-208.59	16.41	1
C <sub>9</sub> H <sub>20</sub>	<i>n</i> -Nonane	L	-275.66	11.76	1
C <sub>9</sub> H <sub>20</sub>	<i>n</i> -Nonane	G	-229.19	24.83	1
C <sub>10</sub> H <sub>8</sub>	Naphthalene	S	78.13	201.18	1
C <sub>10</sub> H <sub>8</sub>	Naphthalene	G	151.06	223.74	1
C <sub>10</sub> H <sub>22</sub>	<i>n</i> -Decane	L	-301.24	17.25	1
C <sub>10</sub> H <sub>22</sub>	<i>n</i> -Decane	G	-249.83	33.24	1

*Sources:*1. Daniel R. Stull, Edgar F. Westrum, and Gerard C. Sinke, *The Chemical Thermodynamics of Organic Compounds*, (New York: Wiley, 1969).**TABLE A.3.2** Inorganic Compounds

Formula	Name	Phase	$\Delta h_f^\circ_{298}$ [kJ/mol]	$\Delta g_f^\circ_{298}$ [kJ/mol]	Source
BCl <sub>3</sub>	Boron trichloride	G	-402.96	-387.96	2
B <sub>2</sub> H <sub>6</sub>	Diborane	G	35.61	86.77	2
BN	Boron nitride	S	-254.387	-228.501	2
B <sub>2</sub> O <sub>3</sub>	Boron oxide	S	-1271.94	-1192.8	2
CCl <sub>3</sub> F	Trichlorofluoromethane	G	-284.70	-245.51	1
CF <sub>4</sub>	Carbon tetrafluoride	G	-975.52	-889.03	1
C <sub>2</sub> F <sub>6</sub>	Hexafluoroethane	G	-1343.06	-1257.3	2
CHCl <sub>3</sub>	Chloroform	L	-132.30	-71.89	1
CHCl <sub>3</sub>	Chloroform	G	-101.32	-68.58	1
CHN	Hydrogen cyanide	G	130.63	120.20	1
CO	Carbon monoxide	G	-110.53	-137.17	2
CO <sub>2</sub>	Carbon dioxide	G	-393.51	-394.36	2
CS <sub>2</sub>	Carbon disulfide	G	116.94	66.82	2
CaS	Calcium sulfide	S	-473.2	-468.178	2
CaSO <sub>4</sub>	Calcium sulfate	S	-1434.11	-1321.68	2
CaO	Calcium oxide	S	-635.09	-603.51	2
CuCl	Copper chloride	S	-155.65	-138.66	2
CuO	Copper monoxide	S	-156.06	-128.29	2
Cu <sub>2</sub> O	Dicopper oxide	S	-170.71	-147.88	2
CuS	Copper sulfide	S	-53.1	-53.47	2
CuSO <sub>4</sub>	Copper sulfate	S	-771.36	-662.08	2
Fe <sub>3</sub> C	Triiron carbide	S	25.104	20.029	2

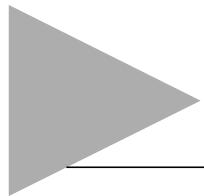
(Continued)

**TABLE A.3.2** Continued

Formula	Name	Phase	$\Delta h_{f,298}^\vartheta$ [kJ/mol]	$\Delta g_{f,298}^\vartheta$ [kJ/mol]	Source
Fe <sub>2</sub> O <sub>3</sub>	Hematite	S	-824.25	-742.29	2
Fe <sub>2</sub> O <sub>4</sub>	Magnetite	S	-1118.38	-1015.23	2
HBr	Hydrogen bromide	G	-36.38	-53.45	2
HCl	Hydrogen chloride	G	-92.312	-95.29	2
HF	Hydrogen fluoride	G	-272.55	-274.65	2
HNO <sub>3</sub>	Nitric acid	G	-134.31	-73.96	2
H <sub>2</sub> O	Water	L	-285.83	-237.14	2
H <sub>2</sub> O	Water	G	-241.82	-228.57	2
H <sub>2</sub> S	Hydrogen sulfide	G	-20.5	-33.33	2
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid	L	-813.99	-689.89	2
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid	G	-735.13	-653.37	2
NH <sub>3</sub>	Ammonia	G	-46.11	-16.45	2
N <sub>2</sub> O	Nitrous oxide	G	82.05	104.17	2
NO	Nitric oxide	G	90.29	86.6	2
NO <sub>2</sub>	Nitrogen dioxide	G	33.1	51.26	2
N <sub>2</sub> O <sub>4</sub>	Dinitrogen tetroxide	L	-19.564	97.51	2
N <sub>2</sub> O <sub>4</sub>	Dinitrogen tetroxide	G	9.079	97.79	2
NaCl	Sodium chloride	S	-411.12	-384.02	2
NaF	Sodium fluoride	S	-573.48	-545.08	2
NaOH	Sodium hydroxide	S	-425.93	-379.73	2
NaOH	Sodium hydroxide	G	-197.49	-200.19	2
O	Oxygen	G	249.17	231.74	2
PH <sub>3</sub>	Phosphene	G	5.57	13.59	2
TaN	Tantalum nitride	S	-252.3	-226.58	2
TiC	Titanium carbide	S	-184.5	-180.84	2
TiN	Titanium nitride	S	-337.86	-309.16	2
SiC	Silicon carbide	S	-73.22	-70.85	2
SiCl <sub>2</sub>	Dichlorosilylene	G	-168.61	-180.36	2
SiCl <sub>4</sub>	Silicon tetrachloride	G	-662.75	-622.76	2
SiF <sub>4</sub>	Silicon tetrafluoride	G	-1614.94	-1572.7	2
SiCl <sub>3</sub> H	Trichlorosilane	G	-496.22	-464.9	3
SiCl <sub>2</sub> H <sub>2</sub>	Dichlorosilane	G	-320.49	-294.9	3
SiH <sub>3</sub> Cl	Chlorosilane	G	-141.838	-119.29	3
SiH <sub>4</sub>	Silane	G	34.31	56.82	2
Si <sub>3</sub> N <sub>4</sub>	Silicon nitride	S	-744.75	-647.34	2
SiO <sub>2</sub>	Silicon dioxide, trigonal	S	-910.86	-856.44	2
SiO <sub>2</sub>	Silicon dioxide, hexagonal	S	-906.34	-757.11	2
SiO <sub>2</sub>	Silicon dioxide, cristobalite	S	-902.53	-716.46	2
SiO <sub>2</sub>	Silicon dioxide	L	-935.34	-551.67	2
SF <sub>6</sub>	Sulfur hexafluoride	G	-1220.47	-1116.5	2
SO <sub>2</sub>	Sulfur dioxide	G	-296.813	-300.1	2
SO <sub>3</sub>	Sulfur trioxide	G	-395.77	-371.02	2
WF <sub>6</sub>	Tungsten hexafluoride	G	-1721.72	-1632.29	2
ZnO	Zinc oxide	S	-350.46	-320.48	2
ZnS	Zinc sulfide, wurtzite	S	-191.84	-190.14	2
ZnS	Zinc sulfide, sphalerite	S	-205.18	-200.4	2
ZnSO <sub>4</sub>	Zinc sulfate	S	-982.8	-871.45	2

*Sources:*

1. Daniel R. Stull, Edgar F. Westrum, and Gerard C. Sinke, *The Chemical Thermodynamics of Organic Compounds* (New York: Wiley, 1969).
2. Ihsan Barin, *Thermochemical Data of Pure Substances*, 3rd ed. (vol. I and II) (New York: VCH, 1995).
3. M. W. Chase et al., *JANAF Thermochemical Tables*, 3rd ed. (Washington, DC: American Chemical Society; (New York: National Bureau of Standards, 1986).



## APPENDIX B

### Steam Tables

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- ▶ TABLE B.1: Saturated Water: Temperature Table [648]
  - ▶ TABLE B.2: Saturated Water: Pressure Table [650]
  - ▶ TABLE B.3: Saturated Water: Solid-Vapor [652]
  - ▶ TABLE B.4: Superheated Water Vapor [653]
  - ▶ TABLE B.5: Subcooled Liquid Water [659]
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#### *Symbols Used in the Steam Tables*

$T$	Temperature	°C
$P$	Pressure	kPa or MPa
$\hat{v}$	Specific volume	m <sup>3</sup> /kg
$\hat{u}$	Specific internal energy	kJ/kg
$\hat{h}$	Specific enthalpy	kJ/kg
$\hat{s}$	Specific entropy	kJ/kg K

#### *Subscripts*

- $l$  Liquid in equilibrium with vapor
- $s$  Solid in equilibrium with vapor
- $v$  Vapor in equilibrium with liquid or solid
- $lv$  Change by evaporation
- $sv$  Change by sublimation

*Source:* New York: Wiley J. H. Keenan, F. G. Keys, P. G. Hill, and J. G. Moore, *Steam Tables* (1969), as used by G. J. Van Wylen, R. E. Sonntag, and C. Borgnakke, *Fundamentals of Classical Thermodynamics*, 4th ed., (New York: Wiley, 1994).

**TABLE B.1 Saturated Water: Temperature Table**

$T$ °C	$P$ kPa, MPa	$\hat{v}_l$ m <sup>3</sup> /kg	$\hat{v}_v$ m <sup>3</sup> /kg	$\hat{u}_l$ kJ/kg	$\Delta\hat{u}_v$ kJ/kg	$\hat{u}_v$ kJ/kg	$\hat{h}_l$ kJ/kg	$\Delta\hat{h}_{lv}$ kJ/kg	$\hat{h}_v$ kJ/kg	$\hat{s}_l$ kJ/kg K	$\Delta\hat{s}_{lv}$ kJ/kg K	$\hat{s}_v$ kJ/kg K
0.01	0.6113 kPa	0.001000	206.132	0.00	2375.3	2375.3	0.00	2501.3	2501.3	0.000	9.1562	9.1562
5	0.8721	0.001000	147.118	20.97	2361.3	2382.2	20.98	2489.6	2510.5	0.0761	8.9496	9.0257
10	1.2276	0.001000	106.377	41.99	2347.2	2389.2	41.99	2477.7	2519.7	0.1510	8.7498	8.9007
15	1.7051	0.001001	77.925	62.98	2333.1	2396.0	62.98	2465.9	2528.9	0.2245	8.5569	8.7813
20	2.3385	0.001002	57.790	83.94	2319.0	2402.9	83.94	2454.1	2538.1	0.2966	8.3706	8.6671
25	3.1691	0.001003	43.359	104.86	2304.9	2409.8	104.87	2442.3	2547.2	0.3673	8.1905	8.5579
30	4.2461	0.001004	32.893	125.77	2290.8	2416.6	125.77	2430.5	2556.2	0.4369	8.0164	8.4533
35	5.6280	0.001006	25.216	146.65	2276.7	2423.4	146.66	2418.6	2565.3	0.5052	7.8478	8.3530
40	7.3837	0.001008	19.523	167.53	2262.6	2430.1	167.54	2406.7	2574.3	0.5724	7.6845	8.2569
45	9.5934	0.001010	15.258	188.41	2248.4	2436.8	188.42	2394.8	2583.2	0.6386	7.5261	8.1647
50	12.350	0.001012	12.032	209.30	2234.2	2443.5	209.31	2382.7	2592.1	0.7037	7.3725	8.0762
55	15.758	0.001015	9.568	230.19	2219.9	2450.1	230.20	2370.7	2600.9	0.7679	7.2234	7.9912
60	19.941	0.001017	7.671	251.09	2205.5	2456.6	251.11	2358.5	2609.6	0.8311	7.0784	7.9095
65	25.033	0.001020	6.197	272.00	2191.1	2463.1	272.03	2346.2	2618.2	0.8934	6.9375	7.8309
70	31.188	0.001023	5.042	292.93	2176.6	2469.5	292.96	2333.8	2626.8	0.9548	6.8004	7.7552
75	38.578	0.001026	4.131	313.87	2162.0	2475.9	313.91	2321.4	2635.3	1.0154	6.6670	7.6824
80	47.390	0.001029	3.407	334.84	2147.4	2482.2	334.88	2308.8	2643.7	1.0752	6.5369	7.6121
85	57.834	0.001032	2.828	355.82	2132.6	2488.4	355.88	2296.0	2651.9	1.1342	6.4102	7.5444
90	70.139	0.001036	2.361	376.82	2117.7	2494.5	376.90	2283.2	2660.1	1.1924	6.2866	7.4790
95	84.554	0.001040	1.982	397.86	2102.7	2500.6	397.94	2270.2	2668.1	1.2500	6.1659	7.4158
100	0.10135 MPa	0.001044	1.6729	418.91	2087.6	2506.5	419.02	2257.0	2676.0	1.3068	6.0480	7.3548
105	0.12082	0.001047	1.4194	440.00	2072.3	2512.3	440.13	2243.7	2683.8	1.3629	5.9328	7.2958
110	0.14328	0.001052	1.2102	461.12	2057.0	2518.1	461.27	2230.2	2691.5	1.4184	5.8202	7.2386
115	0.16906	0.001056	1.0366	482.28	2041.4	2523.7	482.46	2216.5	2699.0	1.4733	5.7100	7.1832
120	0.19853	0.001060	0.8919	503.48	2025.8	2529.2	503.69	2202.6	2706.3	1.5275	5.6020	7.1295
125	0.2321	0.001065	0.77059	524.72	2009.9	2534.6	524.96	2188.5	2713.5	1.5812	5.4962	7.0774
130	0.2701	0.001070	0.66850	546.00	1993.9	2539.9	546.29	2174.2	2720.5	1.6343	5.3925	7.0269
135	0.3130	0.001075	0.58217	567.34	1977.7	2545.0	567.67	2159.6	2727.3	1.6869	5.2907	6.9777
140	0.3613	0.001080	0.50885	588.72	1961.3	2550.0	589.11	2144.8	2733.9	1.7390	5.1908	6.9298
145	0.4154	0.001085	0.44632	610.16	1944.7	2554.9	610.61	2129.6	2740.3	1.7906	5.0926	6.8832
150	0.4759	0.001090	0.39278	631.66	1927.9	2559.5	632.18	2114.3	2746.4	1.8417	4.9960	6.8378
155	0.5431	0.001096	0.34676	653.23	1910.8	2564.0	653.82	2098.6	2752.4	1.8924	4.9010	6.7934
160	0.6178	0.001102	0.30706	674.85	1893.5	2568.4	675.53	2082.6	2758.1	1.9426	4.8075	6.7501
165	0.7005	0.001108	0.27269	696.55	1876.0	2572.5	697.32	2066.2	2763.5	1.9924	4.7153	6.7078
170	0.7917	0.001114	0.24283	718.31	1858.1	2576.5	719.20	2049.5	2768.7	2.0418	4.6244	6.6663

175	0.8920	0.001121	0.21680	740.16	1840.0	2580.2	741.16	2032.4	2773.6	2.0909	4.5347	6.6256
180	1.0022	0.001127	0.19405	762.08	1821.6	2583.7	763.21	2015.0	2778.2	2.1395	4.4461	6.5857
185	1.1227	0.001134	0.17409	784.08	1802.9	2587.0	785.36	1997.1	2782.4	2.1878	4.3586	6.5464
190	1.2544	0.001141	0.15654	806.17	1783.8	2590.0	807.61	1978.8	2786.4	2.2358	4.2720	6.5078
195	1.3978	0.001149	0.14105	828.36	1764.4	2592.8	829.96	1960.0	2790.0	2.2835	4.1863	6.4697
200	1.5538	0.001156	0.12736	850.64	1744.7	2595.3	852.43	1940.7	2793.2	2.3308	4.1014	6.4322
205	1.7230	0.001164	0.11521	873.02	1724.5	2597.5	875.03	1921.0	2796.0	2.3779	4.0172	6.3951
210	1.9063	0.001173	0.10441	895.51	1703.9	2599.4	897.75	1900.7	2798.5	2.4247	3.9337	6.3584
215	2.1042	0.001181	0.09479	918.12	1682.9	2601.1	920.61	1879.9	2800.5	2.4713	3.8507	6.3221
220	2.3178	0.001190	0.08619	940.85	1661.5	2602.3	943.61	1858.5	2802.1	2.5177	3.7683	6.2860
225	2.5477	0.001199	0.07849	963.72	1639.6	2603.3	966.77	1836.5	2803.3	2.5639	3.6863	6.2502
230	2.7949	0.001209	0.07158	986.72	1617.2	2603.9	990.10	1813.8	2803.9	2.6099	3.6047	6.2146
235	3.0601	0.001219	0.06536	1009.88	1594.2	2604.1	1013.61	1790.5	2804.1	2.6557	3.5233	6.1791
240	3.3442	0.001229	0.05976	1033.19	1570.8	2603.9	1037.31	1766.5	2803.8	2.7015	3.4422	6.1436
245	3.6482	0.001240	0.05470	1056.69	1546.7	2603.4	1061.21	1741.7	2802.9	2.7471	3.3612	6.1083
250	3.9730	0.001251	0.05013	1080.37	1522.0	2602.4	1085.34	1716.2	2801.5	2.7927	3.2802	6.0729
255	4.3195	0.001263	0.04598	1104.26	1496.7	2600.9	1109.72	1689.8	2799.5	2.8382	3.1992	6.0374
260	4.6886	0.001276	0.04220	1128.37	1470.6	2599.0	1134.35	1662.5	2796.9	2.8837	3.1181	6.0018
265	5.0813	0.001289	0.03877	1152.72	1443.9	2596.6	1159.27	1634.3	2793.6	2.9293	3.0368	5.9661
270	5.4987	0.001302	0.03564	1177.33	1416.3	2593.7	1184.49	1605.2	2789.7	2.9750	2.9551	5.9301
275	5.9418	0.001317	0.03279	1202.23	1387.9	2590.2	1210.05	1574.9	2785.0	3.0208	2.8730	5.8937
280	6.4117	0.001332	0.03017	1227.43	1358.7	2586.1	1235.97	1543.6	2779.5	3.0667	2.7903	5.8570
285	6.9094	0.001348	0.02777	1252.98	1328.4	2581.4	1262.29	1511.0	2773.3	3.1129	2.7069	5.8198
290	7.4360	0.001366	0.02557	1278.89	1297.1	2576.0	1289.04	1477.1	2766.1	3.1593	2.6227	5.7821
295	7.9928	0.001384	0.02354	1305.21	1264.7	2569.9	1316.27	1441.8	2758.0	3.2061	2.5375	5.7436
300	8.5810	0.001404	0.02167	1331.97	1231.0	2563.0	1344.01	1404.9	2748.9	3.2533	2.4511	5.7044
305	9.2018	0.001425	0.01995	1359.22	1195.9	2555.2	1372.33	1366.4	2738.7	3.3009	2.3633	5.6642
310	9.8566	0.001447	0.01835	1387.03	1159.4	2546.4	1401.29	1326.0	2727.3	3.3492	2.2737	5.6229
315	10.547	0.001472	0.01687	1415.44	1121.1	2536.6	1430.97	1283.5	2714.4	3.3981	2.1821	5.5803
320	11.274	0.001499	0.01549	1444.55	1080.9	2525.5	1461.45	1238.6	2700.1	3.4479	2.0882	5.5361
330	12.845	0.001561	0.012996	1505.24	993.7	2498.9	1525.29	1140.6	2665.8	3.5506	1.8909	5.4416
340	14.586	0.001638	0.010797	1570.26	894.3	2464.5	1594.15	1027.9	2622.0	3.6593	1.6763	5.3356
350	16.514	0.001740	0.008813	1641.81	776.6	2418.4	1670.54	893.4	2563.9	3.7776	1.4336	5.2111
360	18.651	0.001892	0.006945	1725.19	626.3	2351.5	1760.48	720.5	2481.0	3.9146	1.1379	5.0525
370	21.028	0.002213	0.004926	1843.84	384.7	2228.5	1890.37	441.8	2332.1	4.1104	0.6868	4.7972
374.14	22.089	0.003155	0.003155	2029.58	0	2029.6	2099.26	0	2099.3	4.4297	0	4.4297

**TABLE B.2** Saturated Water: Pressure Table

$P$ kPa, MPa	$T$ °C	$\hat{v}_l$ m <sup>3</sup> /kg	$\hat{v}_e$ m <sup>3</sup> /kg	$\hat{u}_l$ kJ/kg	$\Delta\hat{u}_l$ kJ/kg	$\hat{u}_e$ kJ/kg	$\hat{h}_l$ kJ/kg	$\Delta\hat{h}_l$ kJ/kg	$\hat{h}_e$ kJ/kg	$\hat{s}_l$ kJ/kg K	$\Delta\hat{s}_l$ kJ/kg K	$\hat{s}_e$ kJ/kg K
0.6113	0.01	0.001000	206.132	0	2375.3	2375.3	0.00	2501.3	2501.3	0	9.1562	9.1562
1.0	6.98	0.001000	129.208	29.29	2355.7	2385.0	29.29	2484.9	2514.2	0.1059	8.8697	8.9756
1.5	13.03	0.001001	87.980	54.70	2338.6	2393.3	54.70	2470.6	2525.3	0.1956	8.6322	8.8278
2.0	17.50	0.001001	67.004	73.47	2326.0	2399.5	73.47	2460.0	2533.5	0.2607	8.4629	8.7236
2.5	21.08	0.001002	54.254	88.47	2315.9	2404.4	88.47	2451.6	2540.0	0.3120	8.3311	8.6431
3.0	24.08	0.001003	45.665	101.03	2307.5	2408.5	101.03	2444.5	2545.5	0.3545	8.2231	8.5775
4.0	28.96	0.001004	34.800	121.44	2293.7	2415.2	121.44	2432.9	2554.4	0.4226	8.0520	8.4746
5.0	32.88	0.001005	28.193	137.79	2282.7	2420.5	137.79	2423.7	2561.4	0.4763	7.9187	8.3950
7.5	40.29	0.001008	19.238	168.76	2261.7	2430.5	168.77	2406.0	2574.8	0.5763	7.6751	8.2514
10.0	45.81	0.001010	14.674	191.79	2246.1	2437.9	191.81	2392.8	2584.6	0.6492	7.5010	8.1501
15.0	53.97	0.001014	10.022	225.90	2222.8	2448.7	225.91	2373.1	2599.1	0.7548	7.2536	8.0084
20.0	60.06	0.001017	7.649	251.35	2205.4	2456.7	251.38	2358.3	2609.7	0.8319	7.0766	7.9085
25.0	64.97	0.001020	6.204	271.88	2191.2	2463.1	271.90	2346.3	2618.2	0.8930	6.9383	7.8313
30.0	69.10	0.001022	5.229	289.18	2179.2	2468.4	289.21	2336.1	2625.3	0.9439	6.8247	7.7686
40.0	75.87	0.001026	3.993	317.51	2159.5	2477.0	317.55	2319.2	2636.7	1.0258	6.6441	7.6700
50.0	81.33	0.001030	3.240	340.42	2143.4	2483.8	340.47	3205.4	2645.9	1.0910	6.5029	7.5939
75.0	91.77	0.001037	2.217	384.29	2112.4	2496.7	384.36	2278.6	2663.0	1.2129	6.2434	7.4563
0.100	99.62	0.001043	1.694	417.33	2088.7	2506.1	417.44	2258.0	2675.5	1.3025	6.0568	7.3593
0.125	105.99	0.001048	1.3749	444.16	2069.3	2513.5	444.30	2241.1	2685.3	1.3739	5.9104	7.2843
0.150	111.37	0.001053	1.1593	466.92	2052.7	2519.6	467.08	2226.5	2693.5	1.4335	5.7897	7.2232
0.175	116.06	0.001057	1.0036	486.78	2038.1	2524.9	486.97	2213.6	2700.5	1.4848	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.47	2025.0	2529.5	504.68	2202.0	2706.6	1.5300	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.45	2013.1	2533.6	520.69	2191.3	2712.0	1.5705	5.5173	7.0878
0.250	127.43	0.001067	0.7187	535.08	2002.1	2537.2	535.34	2181.5	2716.9	1.6072	5.4455	7.0526
0.275	130.60	0.001070	0.6573	548.57	1992.0	2540.5	548.87	2172.4	2721.3	1.6407	5.3801	7.0208
0.300	133.55	0.001073	0.6058	561.13	1982.4	2543.6	561.45	2163.9	2725.3	1.6717	5.3201	6.9918
0.325	136.30	0.001076	0.562	572.88	1973.5	2546.3	573.23	2155.8	2729.0	1.7005	5.2646	6.9651
0.350	138.88	0.001079	0.5243	583.93	1965	2548.9	584.31	2148.1	2732.4	1.7274	5.2130	6.9404
0.375	141.32	0.001081	0.4914	594.38	1956.9	2551.3	594.79	2140.8	2735.6	1.7527	5.1647	6.9174
0.40	143.63	0.001084	0.4625	604.29	1949.3	2553.6	604.73	2133.8	2738.5	1.7766	5.1193	6.8958
0.45	147.93	0.001088	0.4140	622.75	1934.9	2557.6	623.24	2120.7	2743.9	1.8206	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.66	1921.6	2561.2	640.21	2108.5	2748.7	1.8606	4.9606	6.8212
0.55	155.48	0.001097	0.3427	655.30	1909.2	2564.5	655.91	2097.0	2752.9	1.8972	4.8920	6.7892
0.60	158.85	0.001101	0.3157	669.88	1897.5	2567.4	670.54	2086.3	2756.8	1.9311	4.8289	6.7600
0.65	162.01	0.001104	0.2927	683.55	1886.5	2570.1	684.26	2076.0	2760.3	1.9627	4.7704	6.7330
0.70	164.97	0.001108	0.2729	696.43	1876.1	2572.5	697.20	2066.3	2763.5	1.9922	4.7158	6.7080

0.75	167.77	0.001111	0.2556	708.62	1866.1	2574.7	709.45	2057.0	2766.4	2.0199	4.6647	6.6846
0.80	170.43	0.001115	0.2404	720.20	1856.6	2576.8	721.10	2048.0	2769.1	2.0461	4.6166	6.6627
0.85	172.96	0.001118	0.2270	731.25	1847.4	2578.7	732.20	2039.4	2771.6	2.0709	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.81	1838.7	2580.5	742.82	2031.1	2773.9	2.0946	4.5280	6.6225
0.95	177.69	0.001124	0.2042	751.94	1830.2	2582.1	753.00	2023.1	2776.1	2.1171	4.4869	6.6040
1.00	179.91	0.001127	0.19444	761.67	1822.0	2583.6	762.79	2015.3	2778.1	2.1386	4.4478	6.5864
1.10	184.09	0.001133	0.17753	780.08	1806.3	2586.4	781.32	2000.4	2781.7	2.1791	4.3744	6.5535
1.20	187.99	0.001139	0.16333	797.27	1791.6	2588.8	798.64	1986.2	2784.8	2.2165	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.42	1777.5	2590.9	814.91	1972.7	2787.6	2.2514	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.68	1764.1	2592.8	830.29	1959.7	2790.0	2.2842	4.1850	6.4692
1.50	198.32	0.001154	0.13177	843.14	1751.3	2594.5	844.87	1947.3	2792.1	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.44	1721.4	2597.8	878.48	1918.0	2796.4	2.3851	4.0044	6.3895
2.00	212.42	0.001177	0.09963	906.42	1693.8	2600.3	908.77	1890.7	2799.5	2.4473	3.8935	6.3408
2.25	218.45	0.001187	0.08875	933.81	1668.2	2602.0	936.48	1865.2	2801.7	2.5034	3.7938	6.2971
2.50	223.99	0.001197	0.07998	959.09	1644.0	2603.1	962.09	1841.0	2803.1	2.5546	3.7028	6.2574
2.75	229.12	0.001207	0.07275	982.65	1621.2	2603.8	985.97	1817.9	2803.9	2.6018	3.6190	6.2208
3.00	233.90	0.001216	0.06668	1004.76	1599.3	2604.1	1008.41	1795.7	2804.1	2.6456	3.5412	6.1869
3.25	238.38	0.001226	0.06152	1025.62	1578.4	2604.0	1029.60	1774.4	2804.0	2.6866	3.4685	6.1551
3.5	242.60	0.001235	0.05707	1045.41	1558.3	2603.7	1049.73	1753.7	2803.4	2.7252	3.4000	6.1252
4.0	250.40	0.001252	0.049778	1082.28	1520.0	2602.3	1087.29	1714.1	2801.4	2.7963	3.2737	6.0700
5.0	263.99	0.001286	0.039441	1147.78	1449.3	2597.1	1154.21	1640.1	2794.3	2.9201	3.0532	5.9733
6.0	275.64	0.001319	0.032440	1205.41	1384.3	2589.7	1213.32	1571.0	2784.3	3.0266	2.8625	5.8891
7.0	285.88	0.001351	0.027370	1257.51	1323.0	2580.5	1266.97	1505.1	2772.1	3.1210	2.6922	5.8132
8.0	295.06	0.001384	0.023518	1305.54	1264.3	2569.8	1316.61	1441.3	2757.9	3.2067	2.5365	5.7431
9.0	303.40	0.001418	0.020484	1350.47	1207.3	2557.8	1363.23	1378.9	2742.1	3.2857	2.3915	5.6771
10.0	311.06	0.001452	0.018026	1393.00	1151.4	2544.4	1407.53	1317.1	2724.7	3.3595	2.2545	5.6140
11.0	318.15	0.001489	0.015987	1433.68	1096.1	2529.7	1450.05	1255.5	2705.6	3.4294	2.1233	5.5527
12.0	324.75	0.001527	0.014263	1472.92	1040.8	2513.7	1491.24	1193.6	2684.8	3.4961	1.9962	5.4923
13.0	330.93	0.001567	0.012780	1511.09	985.0	2496.1	1531.46	1130.8	2662.2	3.5604	1.8718	5.4323
14.0	336.75	0.001611	0.011485	1548.53	928.2	2476.8	1571.08	1066.5	2637.5	3.6231	1.7485	5.3716
15.0	342.24	0.001658	0.010338	1585.58	869.8	2455.4	1610.45	1000.0	2610.5	3.6847	1.6250	5.3097
16.0	347.43	0.001711	0.009306	1622.63	809.1	2431.7	1650.00	930.6	2580.6	3.7460	1.4995	5.2454
17.0	352.37	0.001770	0.008365	1660.16	744.8	2405.0	1690.25	856.9	2547.2	3.8078	1.3698	5.1776
18.0	357.06	0.001840	0.007490	1698.86	675.4	2374.3	1731.97	777.1	2509.1	3.8713	1.2330	5.1044
19.0	361.54	0.001924	0.006657	1739.87	598.2	2338.1	1776.43	688.1	2464.5	3.9387	1.0841	5.0227
20.0	365.81	0.002035	0.005834	1785.47	507.6	2293.1	1826.18	583.6	2409.7	4.0137	0.9132	4.9269

**TABLE B.3 Saturated Water: Solid–Vapor**

$T$ °C	$P$ kPa	$\hat{v}_s (\times 10^3)$ m <sup>3</sup> /kg	$\hat{v}_v$ m <sup>3</sup> /kg	$\hat{u}_s$ kJ/kg	$\Delta\hat{u}_{sv}$ kJ/kg	$\hat{u}_v$ kJ/kg	$\hat{h}_s$ kJ/kg	$\Delta\hat{h}_{sv}$ kJ/kg	$\hat{h}_v$ kJ/kg	$\hat{s}_s$ kJ/kg K	$\Delta\hat{s}_{sv}$ kJ/kg K	$\hat{s}_v$ kJ/kg K
0.01	0.6113	1.0908	206.153	-333.40	2708.7	2375.3	-333.40	2834.7	2501.3	-1.2210	10.3772	9.1562
0	0.6108	1.0908	206.315	-333.42	2708.7	2375.3	-333.42	2834.8	2501.3	-1.2211	10.3776	9.1565
-2	0.5177	1.0905	241.663	-337.61	2710.2	2372.5	-337.61	2835.3	2497.6	-1.2369	10.4562	9.2193
-4	0.4376	1.0901	283.799	-341.78	2711.5	2369.8	-341.78	2835.7	2494.0	-1.2526	10.5358	9.2832
-6	0.3689	1.0898	334.139	-345.91	2712.9	2367.0	-345.91	2836.2	2490.3	-1.2683	10.6165	9.3482
-8	0.3102	1.0894	394.414	-350.02	2714.2	2364.2	-350.02	2836.6	2486.6	-1.2839	10.6982	9.4143
-10	0.2601	1.0891	466.757	-354.09	2715.5	2361.4	-354.09	2837.0	2482.9	-1.2995	10.7809	9.4815
-12	0.2176	1.0888	553.803	-358.14	2716.8	2358.7	-358.14	2837.3	2479.2	-1.3150	10.8648	9.5498
-14	0.1815	1.0884	658.824	-362.16	2718.0	2355.9	-362.16	2837.6	2475.5	-1.3306	10.9498	9.6192
-16	0.1510	1.0881	785.907	-366.14	2719.2	2353.1	-366.14	2837.9	2471.8	-1.3461	11.0359	9.6698
-18	0.12521	1.0878	940.183	-370.10	2720.4	2350.3	-370.10	2838.2	2468.1	-1.3617	11.1233	9.7616
-20	0.10355	1.0874	1128.113	-374.03	2721.6	2347.5	-374.03	2838.4	2464.3	-1.3772	11.2120	9.8348
-22	0.08535	1.0871	1357.864	-377.93	2722.7	2344.7	-377.93	2838.6	2460.6	-1.3928	11.3020	9.9093
-24	0.07012	1.0868	1639.753	-381.80	2723.7	2342.0	-381.80	2838.7	2456.9	-1.4083	11.3935	9.9852
-26	0.05741	1.0864	1986.776	-385.64	2724.8	2339.2	-385.64	2838.9	2453.2	-1.4239	11.4864	10.0625
-28	0.04684	1.0861	2415.201	-389.45	2725.8	2336.4	-389.45	2839.0	2449.5	-1.4394	11.5808	10.1413
-30	0.03810	1.0858	2945.228	-393.23	2726.8	2333.6	-393.23	2839.0	2445.8	-1.4550	11.6765	10.2215
-32	0.03090	1.0854	3601.823	-396.98	2727.8	2330.8	-396.98	2839.1	2442.1	-1.4705	11.7733	10.3028
-34	0.02499	1.0851	4416.253	-400.71	2728.7	2328.0	-400.71	2839.1	2438.4	-1.4860	11.8713	10.3853
-36	0.02016	1.0848	5430.116	-404.40	2729.6	2325.2	-404.40	2839.1	2434.7	-1.5014	11.9704	10.4690
-38	0.01618	1.0844	6707.022	-408.06	2730.5	2322.4	-408.06	2839.0	2431.0	-1.5168	12.0714	10.5546
-40	0.01286	1.0841	8366.396	-411.70	2731.3	2319.6	-411.70	2838.9	2427.2	-1.5321	12.1768	10.6447

**TABLE B.4** Superheated Water Vapour

$P = 10 \text{ kPa}$						$P = 50 \text{ kPa}$						$P = 100 \text{ kPa}$							
$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$
sat	14.674	2437.9	2584.6	8.1501	sat	3.240	2483.8	2645.9	7.5939	sat	1.6940	2506.1	2675.5	7.3593					
50	14.869	2443.9	2592.6	8.1749	100	3.418	2511.6	2682.5	7.6947	100	1.6958	2506.6	2676.2	7.3614					
100	17.196	2515.5	2687.5	8.4479	150	3.889	2585.6	2780.1	7.9400	150	1.9364	2582.7	2776.4	7.6133					
150	19.513	2587.9	2783.0	8.6881	200	4.356	2659.8	2877.6	8.1579	200	2.1723	2658.0	2875.3	7.8342					
200	21.825	2661.3	2879.5	8.9037	250	4.821	2735.0	2976.0	8.3555	250	2.4060	2733.7	2974.3	8.0332					
250	24.136	2736.0	2977.3	9.1002	300	5.284	2811.3	3075.5	8.5372	300	2.6388	2810.4	3074.3	8.2157					
300	26.445	2812.1	3076.5	9.2812	400	6.209	2968.4	3278.9	8.8641	400	3.1026	2967.8	3278.1	8.5434					
400	31.063	2968.9	3279.5	9.6076	500	7.134	3131.9	3488.6	9.1545	500	3.5655	3131.5	3488.1	8.8341					
500	35.679	3132.3	3489.0	9.8977	600	8.058	3302.2	3705.1	9.4177	600	4.0278	3301.9	3704.7	9.0975					
600	40.295	3302.5	3705.4	10.1608	700	8.981	3479.5	3928.5	9.6599	700	4.4899	3479.2	3928.2	9.3398					
700	44.911	3479.6	3928.7	10.4028	800	9.904	3663.7	4158.9	9.8852	800	4.9517	3663.5	4158.7	9.5652					
800	49.526	3663.8	4159.1	10.6281	900	10.828	3854.9	4396.3	10.0967	900	5.4135	3854.8	4396.1	9.7767					
900	54.141	3855.0	4396.4	10.8395	1000	11.751	4052.9	4640.5	10.2964	1000	5.8753	4052.8	4640.3	9.9764					
1000	58.757	4053.0	4640.6	11.0392	1100	12.674	4257.4	4891.1	10.4858	1100	6.3370	4257.3	4890.9	10.1658					
1100	63.372	4257.5	4891.2	11.2287	1200	13.597	4467.8	5147.7	10.6662	1200	6.7986	4467.7	5147.6	10.3462					
1200	67.987	4467.9	5147.8	11.4090	1300	14.521	4683.6	5409.6	10.8382	1300	7.2603	4683.5	5409.5	10.5182					
$P = 200 \text{ kPa}$						$P = 300 \text{ kPa}$						$P = 400 \text{ kPa}$							
$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$
sat	0.88573	2529.5	2706.6	7.1271	sat	0.60582	2543.6	2725.3	6.9918	sat	0.46246	2553.6	2738.5	6.8958					
150	0.95964	2576.9	2768.8	7.2795	150	0.63358	2570.8	2761.0	7.0778	150	0.47084	2564.5	2752.8	6.9299					
200	1.08034	2654.4	2870.5	7.5066	200	0.71629	2650.7	2865.5	7.3115	200	0.53422	2646.8	2860.5	7.1706					
250	1.19880	2731.2	2971.0	7.7085	250	0.79636	2728.7	2967.6	7.5165	250	0.59512	2726.1	2964.2	7.3788					
300	1.31616	2808.6	3071.8	7.8926	300	0.87529	2806.7	3069.3	7.7022	300	0.65484	2804.8	3066.7	7.5661					
400	1.54930	2966.7	3276.5	8.2217	400	1.03151	2965.5	3275.0	8.0329	400	0.77262	2964.4	3273.4	7.8984					
500	1.78139	3130.7	3487.0	8.5132	500	1.18669	3130.0	3486.0	8.3250	500	0.88934	3129.2	3484.9	8.1912					
600	2.01297	3301.4	3704.0	8.7769	600	1.34136	3300.8	3703.2	8.5892	600	1.00555	3300.2	3702.4	8.4557					
700	2.24426	3478.8	3927.7	9.0194	700	1.49573	3478.4	3827.1	8.8319	700	1.12147	3477.9	3926.5	8.6987					
800	2.47539	3663.2	4158.3	9.2450	800	1.64994	3662.9	4157.8	9.0575	800	1.23722	3662.5	4157.4	8.9244					
900	2.70643	3854.5	4395.8	9.4565	900	1.80406	3854.2	4395.4	9.2691	900	1.35288	3853.9	4395.1	9.1361					
1000	2.93740	4052.5	4640.0	9.6563	1000	1.95812	4052.3	4639.7	9.4689	1000	1.46847	4052.0	4639.4	9.3360					
1100	3.16834	4257.0	4890.7	9.8458	1100	2.11214	4256.8	4890.4	9.6585	1100	1.58404	4256.5	4890.1	9.5255					
1200	3.39927	4467.5	5147.3	10.0262	1200	2.26614	4467.2	5147.1	9.8389	1200	1.69958	4467.0	5146.8	9.7059					
1300	3.63018	4683.2	5409.3	10.1982	1300	2.42013	4683.0	5409.0	10.0109	1300	1.81511	4682.8	5408.8	9.8780					

(Continued)

**TABLE B.4** Continued

$P = 500 \text{ kPa}$							$P = 600 \text{ kPa}$							$P = 800 \text{ kPa}$										
$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$			$\hat{u}$ $\text{kJ/kg}$			$\hat{h}$ $\text{kJ/kg}$			$\hat{s}$ $\text{kJ/kg K}$	$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$			$\hat{u}$ $\text{kJ/kg}$			$\hat{h}$ $\text{kJ/kg}$			$\hat{s}$ $\text{kJ/kg K}$			
	sat	0.37489	2561.2	2748.7	6.8212	0.31567	2567.4	2756.8	6.7600	sat	0.24043	2576.8	2769.1	6.6627	sat	0.24043	2576.8	2769.1	6.6627	sat	0.24043	2576.8	2769.1	6.6627
200	0.42492	2642.9	2855.4	7.0592	200	0.35202	2638.9	2850.1	6.9665	200	0.26080	2630.6	2839.2	6.8158	200	0.26080	2630.6	2839.2	6.8158	200	0.26080	2630.6	2839.2	6.8158
250	0.47436	2723.5	2960.7	7.2708	250	0.39383	2720.9	2957.2	7.1816	250	0.29314	2715.5	2950.0	7.0384	250	0.29314	2715.5	2950.0	7.0384	250	0.29314	2715.5	2950.0	7.0384
300	0.52256	2802.9	3064.2	7.4598	300	0.43437	2801.0	3061.6	7.3723	300	0.32411	2797.1	3056.4	7.2327	300	0.32411	2797.1	3056.4	7.2327	300	0.32411	2797.1	3056.4	7.2327
350	0.57012	2882.6	3167.6	7.6328	350	0.47424	2881.1	3165.7	7.5463	350	0.35439	2878.2	3161.7	7.4088	350	0.35439	2878.2	3161.7	7.4088	350	0.35439	2878.2	3161.7	7.4088
400	0.61728	2963.2	3271.8	7.7937	400	0.51372	2962.0	3270.2	7.7078	400	0.38426	2959.7	3267.1	7.5715	400	0.38426	2959.7	3267.1	7.5715	400	0.38426	2959.7	3267.1	7.5715
500	0.71093	3128.4	3483.8	8.0872	500	0.59199	3127.6	3482.7	8.0020	500	0.44331	3125.9	3480.6	7.8672	500	0.44331	3125.9	3480.6	7.8672	500	0.44331	3125.9	3480.6	7.8672
600	0.80406	3299.6	3701.7	8.3521	600	0.66974	3299.1	3700.9	8.2673	600	0.50184	3297.9	3699.4	8.1332	600	0.50184	3297.9	3699.4	8.1332	600	0.50184	3297.9	3699.4	8.1332
700	0.89691	3477.5	3926.0	8.5952	700	0.74720	3477.1	3925.4	8.5107	700	0.56007	3476.2	3924.3	8.3770	700	0.56007	3476.2	3924.3	8.3770	700	0.56007	3476.2	3924.3	8.3770
800	0.98959	3662.2	4157.0	8.8211	800	0.82450	3661.8	4156.5	8.7367	800	0.61813	3661.1	4155.7	8.6033	800	0.61813	3661.1	4155.7	8.6033	800	0.61813	3661.1	4155.7	8.6033
900	1.08217	3853.6	4394.7	9.0329	900	0.90169	3853.3	4394.4	8.9485	900	0.67610	3852.8	4393.6	8.8153	900	0.67610	3852.8	4393.6	8.8153	900	0.67610	3852.8	4393.6	8.8153
1000	1.17469	4051.8	4639.1	9.2328	1000	0.97883	4051.5	4638.8	9.1484	1000	0.73401	4051.0	4638.2	9.0153	1000	0.73401	4051.0	4638.2	9.0153	1000	0.73401	4051.0	4638.2	9.0153
1100	1.26718	4256.3	4889.9	9.4224	1100	1.05594	4256.1	4889.6	9.3381	1100	0.79188	4255.6	4889.1	9.2049	1100	0.79188	4255.6	4889.1	9.2049	1100	0.79188	4255.6	4889.1	9.2049
1200	1.35964	4466.8	5146.6	9.6028	1200	1.13302	4466.5	5146.3	9.5185	1200	0.84974	4466.1	5145.8	9.3854	1200	0.84974	4466.1	5145.8	9.3854	1200	0.84974	4466.1	5145.8	9.3854
1300	1.45210	4682.5	5408.6	9.7749	1300	1.21009	4682.3	5408.3	9.6906	1300	0.90758	4681.8	5407.9	9.5575	1300	0.90758	4681.8	5407.9	9.5575	1300	0.90758	4681.8	5407.9	9.5575
$P = 1 \text{ MPa}$							$P = 1.2 \text{ MPa}$							$P = 1.4 \text{ MPa}$										
$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$			$\hat{u}$ $\text{kJ/kg}$			$\hat{h}$ $\text{kJ/kg}$			$\hat{s}$ $\text{kJ/kg K}$	$T$ $^{\circ}\text{C}$	$\hat{v}$ $\text{m}^3/\text{kg}$			$\hat{u}$ $\text{kJ/kg}$			$\hat{h}$ $\text{kJ/kg}$			$\hat{s}$ $\text{kJ/kg K}$			
	sat	0.19444	2583.6	2778.1	6.5864	sat	0.16333	2588.8	2784.8	6.5233	sat	0.14084	2592.8	2790.0	6.4692	sat	0.14084	2592.8	2790.0	6.4692 <th>sat</th> <td>0.14084</td> <td>2592.8</td> <td>2790.0</td> <td>6.4692</td>	sat	0.14084	2592.8	2790.0
200	0.20596	2621.9	2827.9	6.6939	200	0.16930	2612.7	2815.9	6.5898	200	0.14302	2603.1	2803.3	6.4975	200	0.14302	2603.1	2803.3	6.4975	200	0.14302	2603.1	2803.3	6.4975
250	0.23268	2709.9	2942.6	6.9246	250	0.19235	2704.2	2935.0	6.8293	250	0.16350	2698.3	2927.2	6.7467	250	0.16350	2698.3	2927.2	6.7467	250	0.16350	2698.3	2927.2	6.7467
300	0.25794	2793.2	3051.2	7.1228	300	0.21382	2789.2	3045.8	7.0316	300	0.18228	2785.2	3040.4	6.9533	300	0.18228	2785.2	3040.4	6.9533	300	0.18228	2785.2	3040.4	6.9533
350	0.28247	2875.2	3157.7	7.3010	350	0.23452	2872.2	3153.6	7.2120	350	0.20026	2869.1	3149.5	7.1359	350	0.20026	2869.1	3149.5	7.1359	350	0.20026	2869.1	3149.5	7.1359
400	0.30659	2957.3	3263.9	7.4650	400	0.25480	2954.9	3260.7	7.3773	400	0.21780	2952.5	3257.4	7.3025	400	0.21780	2952.5	3257.4	7.3025	400	0.21780	2952.5	3257.4	7.3025
500	0.35411	3124.3	3478.4	7.7621	500	0.29463	3122.7	3476.3	7.6758	500	0.25215	3121.1	3474.1	7.6026	500	0.25215	3121.1	3474.1	7.6026	500	0.25215	3121.1	3474.1	7.6026
600	0.40109	3296.8	3697.9	8.0289	600	0.33393	3295.6	3696.3	7.9434	600	0.28596	3294.4	3694.8	7.8710	600	0.28596	3294.4	3694.8	7.8710	600	0.28596	3294.4	3694.8	7.8710
700	0.44779	3475.4	3923.1	8.2731	700	0.37294	3474.5	3922.0	8.1881	700	0.31947	3473.6	3920.9	8.1160	700	0.31947	3473.6	3920.9	8.1160	700	0.31947	3473.6	3920.9	8.1160
800	0.49432	3660.5	4154.8	8.4996	800	0.41177	3659.8	4153.9	8.4149	800	0.35281	3659.1	4153.0	8.3431	800	0.35281	3659.1	4153.0	8.3431	800	0.35281	3659.1	4153.0	8.3431
900	0.54075	3852.2	4392.9	8.7118	900	0.45051	3851.6	4392.2	8.6272	900	0.38606	3851.0	4391.5	8.5555	900	0.38606	3851.0	4391.5	8.5555	900	0.38606	3851.0	4391.5	8.5555
1000	0.58712	4050.5	4637.6	8.9119	1000	0.48919	4050.0	4637.0	8.8274	1000	0.41924	4049.5	4636.4	8.7558	1000	0.41924	4049.5	4636.4	8.7558	1000	0.41924	4049.5	4636.4	8.7558
1100	0.63345	4255.1	4888.5	9.1016	1100	0.52783	4254.6	4888.0	9.0171	1100	0.45239	4254.1	4887.5	8.9456	1100	0.45239	4254.1	4887.5	8.9456	1100	0.45239	4254.1	4887.5	8.9456
1200	0.67977	4465.6	5145.4	9.2821	1200	0.56646	4465.1	5144.9	9.1977	1200	0.48552	4464.6	5144.4	9.1262	1200	0.48552	4464.6	5144.4	9.1262	1200	0.48552	4464.6	5144.4	9.1262
1300	0.72608	4681.3	5407.4	9.4542	1300	0.60507	4680.9	5406.9	9.3698	1300	0.51864	4680.4	5406.5	9.2983	1300	0.51864	4680.4	5406.5	9.2983	1300	0.51864	4680.4	5406.5	9.2983

$P = 1.6 \text{ MPa}$

T °C	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$
sat	0.12380	2595.9	2794.0	6.4217
225	0.13287	2644.6	2857.2	6.5518
250	0.14184	2692.3	2919.2	6.6732
300	0.15862	2781.0	3034.8	6.8844
350	0.17456	2866.0	3145.4	7.0693
400	0.19005	2950.1	3254.2	7.2573
500	0.22029	3119.5	3471.9	7.5389
600	0.24998	3293.3	3693.2	7.8080
700	0.27937	3472.7	3919.7	8.0535
800	0.30859	3658.4	4152.1	8.2808
900	0.33772	3850.5	4390.8	8.4934
1000	0.36678	4049.0	4635.8	8.6938
1100	0.39581	4253.7	4887.0	8.8837
1200	0.42482	4464.2	5143.9	9.0642
1300	0.45382	4679.9	5406.0	9.2364

$P = 1.8 \text{ MPa}$

T °C	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$
sat	0.11042	2598.4	2797.1	6.3793
225	0.11673	2636.6	2846.7	6.4807
250	0.12497	2686.0	2911.0	6.6066
300	0.14021	2776.8	3029.2	6.8226
350	0.15457	2862.9	3141.2	7.0099
400	0.16847	2947.7	3250.9	7.1793
500	0.19550	3117.8	3469.7	7.4824
600	0.22199	3292.1	3691.7	7.7523
700	0.24818	3471.9	3918.6	7.9983
800	0.27420	3657.7	4151.3	8.2258
900	0.30012	3849.9	4390.1	8.4386
1000	0.32598	4048.4	4635.2	8.6390
1100	0.35180	4253.2	4886.4	8.8290
1200	0.37761	4463.7	5143.4	9.0096
1300	0.40340	4679.4	5405.6	9.1817

$P = 2.5 \text{ MPa}$

T °C	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$
sat	0.06668	2604.1	2804.1	6.1869
225	0.07058	2644.0	2855.8	6.2871
250	0.08114	2750.0	2993.5	6.5389
300	0.09053	2843.7	3115.3	6.7427
350	0.10976	2851.8	3126.2	6.8402
400	0.12010	2939.0	3239.3	7.0147
450	0.13014	3025.4	3350.8	7.1745
500	0.13998	3112.1	3462.0	7.3233
600	0.15930	3288.0	3686.2	7.5960
700	0.17832	3468.8	3914.6	7.8435
800	0.19716	3655.3	4148.2	8.0720
900	0.21590	3847.9	4387.6	8.2853
1000	0.23458	4046.7	4633.1	8.4860
1100	0.25322	4251.5	4884.6	8.6761
1200	0.27185	4462.1	5141.7	8.8569
1300	0.29046	4677.8	5404.0	9.0291

$P = 1.8 \text{ MPa}$

T °C	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$
sat	0.09963	2600.3	2799.5	6.3408
225	0.10377	2628.3	2835.8	6.4146
250	0.11144	2679.6	2902.5	6.5452
300	0.12547	2772.6	3023.5	6.7663
350	0.13857	2859.8	3137.0	6.9562
400	0.15120	2945.2	3247.6	7.1270
500	0.17568	3116.2	3467.6	7.4316
600	0.19960	3290.9	3690.1	7.7023
700	0.22323	3471.0	3917.5	7.9487
800	0.24668	3657.0	4150.4	8.1766
900	0.27004	3849.3	4389.4	8.3895
1000	0.29333	4047.9	4634.6	8.5900
1100	0.31659	4252.7	4885.9	8.7800
1200	0.33984	4463.2	5142.9	8.9606
1300	0.36306	4679.0	5405.1	9.1328

(Continued)

**TABLE B.4** Continued

<i>P</i> = 4 MPa							<i>P</i> = 4.5 MPa							<i>P</i> = 5 MPa																				
T	$\hat{v}$	$\hat{u}$	$\hat{h}$	$\hat{s}$	T	$\hat{v}$	$\hat{u}$	$\hat{h}$	$\hat{s}$	T	$\hat{v}$	$\hat{u}$	$\hat{h}$	$\hat{s}$	T	$\hat{v}$	$\hat{u}$	$\hat{h}$	$\hat{s}$															
°C	m <sup>3</sup> /kg	kJ/kg	kJ/kg	kJ/kg K	°C	m <sup>3</sup> /kg	kJ/kg	kJ/kg	kJ/kg K	°C	m <sup>3</sup> /kg	kJ/kg	kJ/kg	kJ/kg K	°C	m <sup>3</sup> /kg	kJ/kg	kJ/kg	kJ/kg K															
sat	0.04978	2602.3	2801.4	6.0700	sat	0.04406	2600.0	2798.3	6.0198	sat	0.03944	2597.1	2794.3	5.9733	275	0.04730	2650.3	2863.1	6.1401	275	0.04141	2631.2	2838.3	6.0543										
275	0.05457	2667.9	2886.2	6.2284	275	0.04730	2650.3	2863.1	6.1401	300	0.05135	2712.0	2943.1	6.2827	300	0.04532	2697.9	2906.6	6.2083	350	0.05194	2817.8	3080.6	6.5130	350	0.05781	2808.7	3068.4	6.4492					
300	0.05884	2725.3	2960.7	6.3614	300	0.05135	2712.0	2943.1	6.2827	400	0.06475	2913.3	3204.7	6.7046	400	0.05781	2906.6	3195.6	6.6458	450	0.07074	3004.9	3323.2	6.8745	450	0.06330	2999.6	3316.1	6.8185					
350	0.06645	2826.6	3092.4	6.5820	350	0.05840	2817.8	3080.6	6.5130	500	0.07651	3095.2	3439.5	7.0300	500	0.06857	3090.9	3433.8	6.9758	600	0.08765	3276.0	3670.5	7.3109	600	0.07869	3273.0	3666.5	7.2588					
400	0.07341	2919.9	3213.5	6.7689	700	0.09847	3459.9	3903.0	7.5631	700	0.08849	3457.7	3900.1	7.5122	800	0.10911	3648.4	4139.4	7.7942	800	0.09811	3646.6	4137.2	7.7440	900	0.11965	3842.1	4380.6	8.0091	900	0.10762	3840.7	4378.8	7.9593
450	0.08003	3010.1	3330.2	6.9362	1000	0.13013	4041.6	4627.2	8.2108	1000	0.11707	4040.3	4625.7	8.1612	1100	0.14056	4246.8	4879.3	8.4014	1100	0.12648	4245.6	4878.0	8.3519	1200	0.15098	4457.4	5136.9	8.5824	1200	0.13587	4456.3	5135.7	8.5330
500	0.08643	3099.5	3445.2	7.0900	1200	0.15381	4458.6	5137.6	8.6376	1300	0.16139	4673.1	5399.4	8.7548	1300	0.14526	4672.0	5398.2	8.7055	1300	0.09885	3279.1	3674.4	7.3688	1300	0.08769	3273.0	3666.5	7.2588					
600	0.13469	3843.6	4382.3	8.0647	1000	0.14645	4042.9	4628.7	8.2661	1100	0.15817	4248.0	4880.6	8.4566	1200	0.16987	4458.6	5138.1	8.6376	1300	0.18156	4674.3	5400.5	8.8099	1300	0.16139	4673.1	5399.4	8.7548					
700	0.11095	3462.1	3905.9	7.6198	1100	0.12287	3650.1	4141.6	7.8502	1200	0.13469	3843.6	4382.3	8.0647	1300	0.14645	4042.9	4628.7	8.2661	1300	0.13469	3843.6	4382.3	8.0647	1300	0.12287	3650.1	4141.6	7.8502					
800	0.12287	3650.1	4141.6	7.8502	900	0.13469	3843.6	4382.3	8.0647	1000	0.14645	4042.9	4628.7	8.2661	1100	0.15817	4248.0	4880.6	8.4566	1200	0.16987	4458.6	5138.1	8.6376	1300	0.18156	4674.3	5400.5	8.8099					
900	0.14645	4042.9	4628.7	8.2661	1000	0.15817	4248.0	4880.6	8.4566	1100	0.16987	4458.6	5138.1	8.6376	1200	0.18156	4674.3	5400.5	8.8099	1300	0.18156	4674.3	5400.5	8.8099	1300	0.18156	4674.3	5400.5	8.8099					
1000	0.16987	4458.6	5138.1	8.6376	1100	0.18156	4674.3	5400.5	8.8099	1200	0.19324	4882.3	5540.6	9.4500	1300	0.21591	5299.7	5958.0	10.1594	1300	0.20373	5299.7	5958.0	9.4500	1300	0.19324	4882.3	5540.6	9.4500					
1100	0.18156	4674.3	5400.5	8.8099	1200	0.19324	4882.3	5540.6	9.4500	1300	0.21591	5299.7	5958.0	10.1594	1300	0.20373	5299.7	5958.0	9.4500	1300	0.19324	4882.3	5540.6	9.4500	1300	0.19324	4882.3	5540.6	9.4500					
1200	0.19324	4882.3	5540.6	9.4500	1300	0.21591	5299.7	5958.0	10.1594	1300	0.20373	5299.7	5958.0	10.1594	1300	0.19324	4882.3	5540.6	9.4500	1300	0.19324	4882.3	5540.6	9.4500	1300	0.19324	4882.3	5540.6	9.4500					
1300	0.21591	5299.7	5958.0	10.1594	1300	0.20373	5299.7	5958.0	10.1594	1300	0.19324	4882.3	5540.6	9.4500	1300	0.19324	4882.3	5540.6	9.4500	1300	0.19324	4882.3	5540.6	9.4500	1300	0.19324	4882.3	5540.6	9.4500					
<i>P</i> = 6 MPa							<i>P</i> = 7 MPa							<i>P</i> = 8 MPa																				
T	$\hat{v}$	$\hat{u}$	$\hat{h}$	$\hat{s}$	T	$\hat{v}$	$\hat{u}$	$\hat{h}$	$\hat{s}$	T	$\hat{v}$	$\hat{u}$	$\hat{h}$	$\hat{s}$	T	$\hat{v}$	$\hat{u}$	$\hat{h}$	$\hat{s}$															
°C	m <sup>3</sup> /kg	kJ/kg	kJ/kg	kJ/kg K	°C	m <sup>3</sup> /kg	kJ/kg	kJ/kg	kJ/kg K	°C	m <sup>3</sup> /kg	kJ/kg	kJ/kg	kJ/kg K	°C	m <sup>3</sup> /kg	kJ/kg	kJ/kg	kJ/kg K															
sat	0.03244	2589.7	2784.3	5.8891	sat	0.02737	2580.5	2772.1	5.8132	sat	0.02352	2569.8	2757.9	5.7431	300	0.02947	2632.1	2838.4	5.9304	300	0.02426	2590.9	2785.0	5.7905										
300	0.03616	2667.2	2884.2	6.0673	350	0.03524	2769.3	3016.0	6.2282	350	0.02995	2747.7	2987.3	6.1300	400	0.03993	2878.6	3158.1	6.4477	400	0.03432	2863.8	3138.3	6.3633										
350	0.04223	2759.6	3043.0	6.3334	400	0.04416	2077.9	3287.0	6.6326	450	0.03817	2966.7	3272.0	6.5550	500	0.04814	3073.3	3410.3	6.7974	500	0.04175	3064.3	3398.3	6.7239										
400	0.04739	2892.8	3177.2	6.5407	450	0.04416	2077.9	3287.0	6.6326	500	0.04814	3073.3	3410.3	6.7974	550	0.04516	3159.8	3521.0	6.8778	600	0.04845	3254.4	3642.0	7.0205										
450	0.05214	2988.9	3301.8	6.7192	500	0.04814	3073.3	3410.3	6.7974	550	0.04814	3073.3	3410.3	6.7974	600	0.05481	3444.0	3882.5	7.2812	650	0.05195	3167.2	3530.9	6.9486										
500	0.05665	3082.2	3422.1	6.8802	550	0.05195	3167.2	3530.9	6.9486	600	0.05565	3260.7	3650.3	7.0894	650	0.05195	3167.2	3530.9	6.9486	700	0.05027	3437.1	3835.0	7.7991	700	0.05481	3444.0	3882.5	7.2812					
550	0.06101	3174.6	3540.6	7.0287	600	0.05565	3260.7	3650.3	7.0894	650	0.05195	3167.2	3530.9	6.9486	700	0.05027	3437.1	3832.1	7.7350	700	0.05481	3444.0	3882.5	7.2812	700	0.05027	3437.1	3832.1	7.7350					
600	0.06525	3266.9	3658.4	7.1676	700	0.06283	3448.6	3888.4	7.3476	700	0.06283	3448.6	3888.4	7.3476	750	0.06981	3639.6	4128.3	7.5822	750	0.06097	3636.1	4123.8	7.5173	750	0.06981	3639.6	4128.3	7.5173					
700	0.07352	3453.2	3894.3	7.4234	800	0.06981	3639.6	4128.3	7.5822	800	0.06981	3639.6	4128.3	7.5822	900	0.07669	3835.0	4371.8	7.7991	900	0.06702	3832.1	4368.3	7.7350	900	0.07669	3835.0	4371.8	7.7991					
1000	0.09749	4037.8	4632.7	8.0751	1000	0.08350	4035.3	4619.8	8.0020	1000	0.09027	4240.9	4872.8	8.1933	1100	0.07896	4238.6	4870.3	8.1299	1100	0.07301	4032.8	4616.9	7.9384	1100	0.07896	4238.6	4870.3	8.1299					
1100	0.10536	4243.3	4875.4	8.2661	1200	0.09703	4451.7	5130.9	8.3747	1200	0.09703	4451.7	5130.9	8.3747	1300	0.10377	4667.3	5393.7	8.5472	1300	0.09080	4665.0	5391.5	8.4842	1300	0.10377	4667.3	5393.7	8.5472					

$P = 15 \text{ MPa}$						
T	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	T	$\hat{v}$ $\text{m}^3/\text{kg}$
sat	.010338	2455.4	2610.5	5.3097	sat	.0079204
350	.011470	2520.4	2692.4	5.4420	400	.0124477
400	.015649	2740.7	2975.4	5.8810	450	.0151740
450	.018446	2879.5	3156.2	6.1403	500	.0173585
500	.020800	2996.5	3308.5	6.3442	550	.0192877
550	.022927	3104.7	3448.6	6.5198	600	.0210640
600	.024911	3208.6	3582.3	6.6775	650	.0227372
650	.026797	3310.4	3712.3	6.8223	700	.0243365
700	.028612	3410.9	3840.1	6.9572	800	.0273849
800	.032096	3611.0	4092.4	7.2040	900	.0303071
900	.035457	3811.9	4343.8	7.4279	1000	.0331580
1000	.038748	4015.4	4596.6	7.6347	1100	.0359695
1100	.042001	4222.6	4852.6	7.8282	1200	.0387605
1200	.045233	4433.8	5112.3	8.0108	1300	.0415417
1300	.048455	4649.1	5375.9	8.1839		

$P = 9 \text{ MPa}$						
T	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	T	$\hat{v}$ $\text{m}^3/\text{kg}$
sat	0.02048	2357.8	2742.1	5.6771	sat	0.01803
325	0.02327	2646.5	2855.9	5.8711	325	0.01986
350	0.02580	2724.4	2956.5	6.0361	350	0.02242
400	0.02993	2848.4	3117.8	6.2853	400	0.02641
450	0.03350	2955.1	3256.6	6.4843	450	0.02975
500	0.03677	3055.1	3386.1	6.6575	500	0.03279
550	0.03987	3152.2	3511.0	6.8141	550	0.03564
600	0.04285	3248.1	3633.7	6.9588	600	0.03837
650	0.04574	3343.7	3755.3	7.0943	650	0.04101
700	0.04857	3439.4	3876.5	7.2221	700	0.04358
800	0.05409	3632.5	4119.4	7.4597	800	0.04859
900	0.05950	3829.2	4364.7	7.6782	900	0.05349
1000	0.06485	4030.3	4613.9	7.8821	1000	0.05832
1100	0.07016	4236.3	4867.7	8.0739	1100	0.06312
1200	0.07544	4447.2	5126.2	8.2556	1200	0.06789
1300	0.08072	4662.7	5339.2	8.4283	1300	0.07265
					1300	0.07664
						0.3783

$P = 10 \text{ MPa}$						
T	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	T	$\hat{v}$ $\text{m}^3/\text{kg}$
sat	0.02048	2357.8	2742.1	5.6771	sat	0.01803
325	0.02327	2646.5	2855.9	5.8711	325	0.01986
350	0.02580	2724.4	2956.5	6.0361	350	0.02242
400	0.02993	2848.4	3117.8	6.2853	400	0.02641
450	0.03350	2955.1	3256.6	6.4843	450	0.02975
500	0.03677	3055.1	3386.1	6.6575	500	0.03279
550	0.03987	3152.2	3511.0	6.8141	550	0.03564
600	0.04285	3248.1	3633.7	6.9588	600	0.03837
650	0.04574	3343.7	3755.3	7.0943	650	0.04101
700	0.04857	3439.4	3876.5	7.2221	700	0.04358
800	0.05409	3632.5	4119.4	7.4597	800	0.04859
900	0.05950	3829.2	4364.7	7.6782	900	0.05349
1000	0.06485	4030.3	4613.9	7.8821	1000	0.05832
1100	0.07016	4236.3	4867.7	8.0739	1100	0.06312
1200	0.07544	4447.2	5126.2	8.2556	1200	0.06789
1300	0.08072	4662.7	5339.2	8.4283	1300	0.07265
					1300	0.07664
						0.3783

$P = 12.5 \text{ MPa}$						
T	$\hat{v}$ $\text{m}^3/\text{kg}$	$\hat{u}$ $\text{kJ/kg}$	$\hat{h}$ $\text{kJ/kg}$	$\hat{s}$ $\text{kJ/kg K}$	T	$\hat{v}$ $\text{m}^3/\text{kg}$
sat	0.02048	2357.8	2742.1	5.6771	sat	0.01803
325	0.02327	2646.5	2855.9	5.8711	325	0.01986
350	0.02580	2724.4	2956.5	6.0361	350	0.02242
400	0.02993	2848.4	3117.8	6.2853	400	0.02641
450	0.03350	2955.1	3256.6	6.4843	450	0.02975
500	0.03677	3055.1	3386.1	6.6575	500	0.03279
550	0.03987	3152.2	3511.0	6.8141	550	0.03564
600	0.04285	3248.1	3633.7	6.9588	600	0.03837
650	0.04574	3343.7	3755.3	7.0943	650	0.04101
700	0.04857	3439.4	3876.5	7.2221	700	0.04358
800	0.05409	3632.5	4119.4	7.4597	800	0.04859
900	0.05950	3829.2	4364.7	7.6782	900	0.05349
1000	0.06485	4030.3	4613.9	7.8821	1000	0.05832
1100	0.07016	4236.3	4867.7	8.0739	1100	0.06312
1200	0.07544	4447.2	5126.2	8.2556	1200	0.06789
1300	0.08072	4662.7	5339.2	8.4283	1300	0.07265
					1300	0.07664
						0.3783

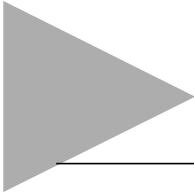
(Continued)

**TABLE B.4** *Continued*

<i>P</i> = 25 MPa							<i>P</i> = 30 MPa							<i>P</i> = 35 MPa						
T	$\hat{v}$ m <sup>3</sup> /kg	$\hat{u}$ kJ/kg	$\hat{h}$ kJ/kg	$\hat{s}$ kJ/kg K	T	$\hat{v}$ m <sup>3</sup> /kg	$\hat{u}$ kJ/kg	$\hat{h}$ kJ/kg	$\hat{s}$ kJ/kg K	T	$\hat{v}$ m <sup>3</sup> /kg	$\hat{u}$ kJ/kg	$\hat{h}$ kJ/kg	$\hat{s}$ kJ/kg K	T	$\hat{v}$ m <sup>3</sup> /kg	$\hat{u}$ kJ/kg	$\hat{h}$ kJ/kg	$\hat{s}$ kJ/kg K	
375	.001973	1798.6	1847.9	4.0319	375	.001789	1737.8	1791.4	3.9303	375	.001700	1702.9	1762.4	3.8721						
400	.006004	2430.1	2580.2	5.1418	400	.002790	2067.3	2151.0	4.4728	400	.002100	1914.0	1987.5	4.2124						
450	.009162	2720.7	2949.7	5.6743	450	.006735	2619.3	2821.4	5.4423	450	.004962	2498.7	2672.4	5.1962						
500	.011124	2884.3	3162.4	5.9592	500	.008679	2820.7	3081.0	5.7904	500	.006927	2751.9	2994.3	5.6281						
550	.012724	3017.5	3335.6	6.1764	550	.010168	2970.3	3275.4	6.0342	550	.008345	2920.9	3213.0	5.9025						
600	.014138	3137.9	3491.4	6.3602	600	.011446	3100.5	3443.9	6.2330	600	.009527	3062.0	3395.5	6.1178						
650	.015433	3251.6	3637.5	6.5229	650	.012596	3221.0	3598.9	6.4057	650	.010575	3189.8	3559.9	6.3010						
700	.016647	3361.4	3777.6	6.6707	700	.013661	3335.8	3745.7	6.5606	700	.011533	3309.9	3713.5	6.4631						
800	.018913	3574.3	4047.1	6.9345	800	.015623	3555.6	4024.3	6.8332	800	.013278	3536.8	4001.5	6.7450						
900	.021045	3783.0	4309.1	7.1679	900	.017448	3768.5	4291.9	7.0717	900	.014883	3754.0	4274.9	6.9886						
1000	.023102	3990.9	4568.5	7.3801	1000	.019196	3978.8	4554.7	7.2867	1000	.016410	3966.7	4541.1	7.2063						
1100	.025119	4200.2	4828.2	7.5765	1100	.020903	4189.2	4816.3	7.4845	1100	.017895	4178.3	4804.6	7.4056						
1200	.027115	4412.0	5089.9	7.7604	1200	.022589	4401.3	5079.0	7.6691	1200	.019360	4390.7	5068.4	7.5910						
1300	.029101	4626.9	5354.4	7.9342	1300	.024266	4616.0	5344.0	7.8432	1300	.020815	4605.1	5333.6	7.7652						
<i>P</i> = 40 MPa							<i>P</i> = 50 MPa							<i>P</i> = 60 MPa						
T	$\hat{v}$ m <sup>3</sup> /kg	$\hat{u}$ kJ/kg	$\hat{h}$ kJ/kg	$\hat{s}$ kJ/kg K	T	$\hat{v}$ m <sup>3</sup> /kg	$\hat{u}$ kJ/kg	$\hat{h}$ kJ/kg	$\hat{s}$ kJ/kg K	T	$\hat{v}$ m <sup>3</sup> /kg	$\hat{u}$ kJ/kg	$\hat{h}$ kJ/kg	$\hat{s}$ kJ/kg K	T	$\hat{v}$ m <sup>3</sup> /kg	$\hat{u}$ kJ/kg	$\hat{h}$ kJ/kg	$\hat{s}$ kJ/kg K	
375	.0016406	1677.1	1742.7	3.8289	375	.0015593	1638.6	1716.5	3.7638	375	.0015027	1609.3	1699.5	3.7140						
400	.0019017	1854.5	1930.8	4.1134	400	.0017309	1788.0	1874.6	4.0030	400	.0016335	1745.3	1843.4	3.9317						
450	.0036931	2365.1	2512.8	4.9459	450	.0024862	2159.6	2283.9	4.5883	450	.0020850	2053.9	2179.0	4.4119						
500	.0056225	2678.4	2903.3	5.4699	500	.0038924	2525.5	2720.1	5.1725	500	.0029557	2390.5	2567.9	4.9320						
600	.0080943	3022.6	3346.4	6.0113	600	.0061123	2942.0	3247.6	5.8177	600	.0048345	2861.1	3151.2	5.6451						
700	.0099415	3283.6	3681.3	6.3750	700	.0077274	3230.5	3616.9	6.2189	700	.0062719	3177.3	3553.6	6.0824						
800	.0115228	3517.9	3978.8	6.6662	800	.0090761	3479.8	3933.6	6.5290	800	.0074588	3441.6	3889.1	6.4110						
900	.0129626	3739.4	4257.9	6.9150	900	.0102831	3710.3	4224.4	6.7382	900	.0085083	3681.0	4191.5	6.6805						
1000	.0143238	3954.6	4527.6	7.1356	1000	.0114113	3930.5	4501.1	7.0146	1000	.0094800	3906.4	4475.2	6.9126						
1100	.0156426	4167.4	4793.1	7.3364	1100	.0124966	4145.7	4770.6	7.2183	1100	.0104091	4124.1	4748.6	7.1194						
1200	.0169403	4380.1	5057.7	7.5224	1200	.0135606	4359.1	5037.2	7.4058	1200	.0113167	4338.2	5017.2	7.3082						
1300	.0182292	4594.3	5323.5	7.6969	1300	.0146159	4572.8	5303.6	7.5807	1300	.0122155	4551.4	5284.3	7.4837						

**TABLE B.5 Subcooled Liquid Water**

$P = 5 \text{ MPa}$							$P = 10 \text{ MPa}$							$P = 15 \text{ MPa}$							$P = 5 \text{ MPa}$																				
				$T$			$\hat{v}$			$\hat{u}$			$\hat{h}$			$\hat{\dot{v}}$			$\hat{u}$			$\hat{h}$			$\hat{\dot{v}}$																
$T$	$\hat{v}$	$\text{m}^3/\text{kg}$	$\hat{u}$	$\text{kJ/kg}$	$\hat{h}$	$\text{kJ/kg}$	$\hat{s}$	$\text{kJ/kg K}$	$T$	$\hat{v}$	$\text{m}^3/\text{kg}$	$\hat{u}$	$\text{kJ/kg}$	$\hat{h}$	$\text{kJ/kg}$	$\hat{s}$	$\text{kJ/kg K}$	$T$	$\hat{v}$	$\text{m}^3/\text{kg}$	$\hat{u}$	$\text{kJ/kg}$	$\hat{h}$	$\text{kJ/kg}$	$\hat{s}$	$\text{kJ/kg K}$															
0	.0009977	0.03	5.02	0.0001	0	.0009952	0.10	10.05	0.0003	0	.0009928	0.15	15.04	0.0004	0	.0009950	83.05	97.97	0.2934	20	.0010034	40	.0010013	165.73	180.75	0.5665															
20	.0009995	83.64	88.64	0.2955	20	.0009972	83.35	93.32	0.2945	20	.0009950	83.05	97.97	0.2934	40	.0010127	60	.0010105	248.49	263.65	0.8231	60	.0010127	60	.0010105	248.49	263.65	0.8231													
40	.0010056	166.93	171.95	0.5705	40	.0010034	166.33	176.36	0.5685	40	.0010034	40	.0010013	165.73	180.75	0.5665	60	.0010245	80	.0010222	331.46	346.79	1.0655	60	.0010245	80	.0010222	331.46	346.79	1.0655											
60	.0010149	250.21	255.28	0.8284	60	.0010127	249.34	259.47	0.8258	60	.0010127	60	.0010105	248.49	263.65	0.8231	80	.0010245	342.81	1.0687	331.46	346.79	1.0655	80	.0010245	342.81	1.0687	331.46	346.79	1.0655											
80	.0010268	333.69	338.83	1.0719	80	.0010245	332.56	342.81	1.0687	80	.0010245	80	.0010222	331.46	346.79	1.0655	100	.0010385	416.09	426.48	1.2992	100	.0010361	414.72	430.26	1.2954	100	.0010385	416.09	426.48	1.2992	100	.0010361	414.72	430.26	1.2954					
100	.0010410	417.50	422.71	1.3030	100	.0010385	410.00	426.48	1.2992	100	.0010385	100	.0010361	414.72	430.26	1.2954	120	.0010549	500.07	510.61	1.5188	120	.0010522	498.39	514.17	1.5144	120	.0010549	500.07	510.61	1.5188	120	.0010522	498.39	514.17	1.5144					
120	.0010576	501.79	507.07	1.5232	120	.0010549	500.07	510.61	1.5188	120	.0010549	120	.0010522	498.39	514.17	1.5144	140	.0010737	584.67	595.40	1.7291	140	.0010707	582.64	598.70	1.7241	140	.0010737	584.67	595.40	1.7291	140	.0010707	582.64	598.70	1.7241					
140	.0010768	586.74	592.13	1.7342	140	.0010737	584.67	595.40	1.7291	140	.0010737	140	.0010707	582.64	598.70	1.7241	160	.0010953	670.11	681.07	1.9316	160	.0010918	667.69	684.07	1.9259	160	.0010953	670.11	681.07	1.9316	160	.0010918	667.69	684.07	1.9259					
160	.0010988	672.61	678.10	1.9374	160	.0010953	670.11	681.07	1.9316	160	.0010953	160	.0010918	667.69	684.07	1.9259	180	.0011199	756.63	767.83	2.1274	180	.0011159	753.74	770.48	2.1209	180	.0011199	756.63	767.83	2.1274	180	.0011159	753.74	770.48	2.1209					
180	.0011240	759.62	765.24	2.1341	180	.0011199	756.63	767.83	2.1274	180	.0011199	180	.0011159	753.74	770.48	2.1209	200	.0011480	844.49	855.97	2.3178	200	.0011433	841.04	858.18	2.3103	200	.0011480	844.49	855.97	2.3178	200	.0011433	841.04	858.18	2.3103					
200	.0011530	848.08	853.85	2.3254	200	.0011480	844.49	855.97	2.3178	200	.0011480	200	.0011433	841.04	858.18	2.3103	220	.0011866	938.43	944.36	2.5128	220	.0011866	934.07	945.88	2.5038	220	.0011866	934.07	945.88	2.5038	220	.0011866	934.07	945.88	2.5038					
220	.0011866	938.43	944.36	2.5128	220	.0011866	934.07	945.88	2.5038	220	.0011866	220	.0011821	929.89	947.52	2.4952	240	.0012264	1031.34	1037.47	2.6978	240	.0012264	1025.94	1038.13	2.6872	240	.0012264	1025.94	1038.13	2.6872	240	.0012264	1025.94	1038.13	2.6872					
240	.0012264	1031.34	1037.47	2.6978	240	.0012264	1025.94	1038.13	2.6872	240	.0012264	240	.0012187	1020.82	1038.99	2.6770	260	.0012645	1124.30	1134.30	2.8829	260	.0012645	1121.03	1133.68	2.8698	260	.0012645	1121.03	1133.68	2.8698	260	.0012645	1121.03	1133.68	2.8698					
260	.0012748	1127.92	1134.30	2.8829	260	.0012645	1121.03	1133.68	2.8698	260	.0012645	260	.0013216	1120.90	1134.11	3.0547	280	.0013216	1234.11	1243.11	3.0547	280	.0013216	1234.11	1243.11	3.0547	280	.0013216	1234.11	1243.11	3.0547	280	.0013216	1234.11	1243.11	3.0547					
300	.0013596	1306.10	1333.29	3.2071	300	.0013304	1287.89	1327.80	3.1740	300	.0013304	300	.0013097	1306.84	1042.60	2.6489	320	.0013997	1390.64	1432.63	3.3538	320	.0013997	1306.84	1042.60	2.6489	320	.0013997	1390.64	1432.63	3.3538	320	.0013997	1306.84	1042.60	2.6489					
320	.0014437	1415.66	1444.53	3.3978	320	.0013997	1390.64	1432.63	3.3538	320	.0013997	320	.0014191	1501.71	1546.47	3.5425	340	.0016074	1571.01	1626.57	1626.57	340	.0016074	1571.01	1626.57	1626.57	340	.0016074	1571.01	1626.57	1626.57	340	.0016074	1571.01	1626.57	1626.57					
340	.0015683	1539.64	1571.01	3.6074	340	.0014919	1501.71	1546.47	3.5425	340	.0014919	340	.0014724	1520.69	1621.35	3.7492	360	.0016265	1739.23	1837.70	3.8770	360	.0016265	1781.35	1837.43	4.0010	360	.0016265	1781.35	1837.43	4.0010	360	.0016265	1781.35	1837.43	4.0010	360	.0016265	1781.35	1837.43	4.0010
360	.0018226	1702.78	1739.23	3.8770	360	.0018691	1781.35	1837.43	4.0010	360	.0018691	360	.0018483	1667.13	1746.54	3.6545	380	.0018691	1667.13	1746.54	3.6545	380	.0018691	1667.13	1746.54	3.6545	380	.0018691	1667.13	1746.54	3.6545	380	.0018691	1667.13	1746.54	3.6545	380	.0018691	1667.13	1746.54	3.6545



# APPENDIX C

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## Lee-Kesler Generalized Correlation Tables<sup>1</sup>

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**TABLE C.1** Values for  $z^{(0)}$

$T_r$	$P_r$	0.025	0.05	0.075	0.1	0.25	0.5	0.6	0.7	0.8	0.9	1	1.1
	0.01												
0.3	0.0029	0.0072	0.0145	0.0217	0.0290	0.0724	0.1447	0.1737	0.2026	0.2315	0.2604	0.2892	0.3181
0.35	0.0026	0.0065	0.0130	0.0196	0.0261	0.0652	0.1303	0.1564	0.1824	0.2084	0.2344	0.2604	0.2863
0.4	0.0024	0.0060	0.0119	0.0179	0.0239	0.0596	0.1191	0.1429	0.1667	0.1904	0.2142	0.2379	0.2616
0.45	0.0022	0.0055	0.0110	0.0166	0.0221	0.0552	0.1102	0.1322	0.1542	0.1762	0.1981	0.2200	0.2420
0.5	0.0021	0.0052	0.0103	0.0155	0.0207	0.0516	0.1031	0.1236	0.1441	0.1647	0.1851	0.2056	0.2261
0.55	0.9804	0.0049	0.0098	0.0146	0.0195	0.0487	0.0972	0.1166	0.1360	0.1553	0.1746	0.1939	0.2131
0.6	0.9849	0.9614	0.0093	0.0139	0.0186	0.0463	0.0925	0.1109	0.1293	0.1476	0.1660	0.1842	0.2025
0.65	0.9881	0.9697	0.9377	0.0134	0.0178	0.0445	0.0887	0.1063	0.1239	0.1415	0.1590	0.1765	0.1939
0.7	0.9904	0.9757	0.9504	0.9238	0.8958	0.0430	0.0857	0.1027	0.1197	0.1366	0.1535	0.1703	0.1871
0.75	0.9922	0.9802	0.9598	0.9386	0.9165	0.0420	0.0836	0.1001	0.1166	0.1330	0.1493	0.1656	0.1819
0.8	0.9935	0.9837	0.9669	0.9497	0.9319	0.8093	0.0823	0.0985	0.1147	0.1307	0.1467	0.1626	0.1784
0.85	0.9946	0.9864	0.9725	0.9582	0.9436	0.8465	0.0823	0.0983	0.1143	0.1301	0.1458	0.1614	0.1769
0.9	0.9954	0.9885	0.9768	0.9649	0.9528	0.8739	0.7019	0.1006	0.1164	0.1321	0.1476	0.1630	0.1783
0.93	0.9959	0.9896	0.9790	0.9683	0.9573	0.8871	0.7420	0.6635	0.1204	0.1359	0.1512	0.1664	0.1814
0.95	0.9961	0.9902	0.9803	0.9703	0.9600	0.8948	0.7637	0.6967	0.6107	0.1410	0.1557	0.1705	0.1852
0.97	0.9963	0.9908	0.9815	0.9721	0.9625	0.9018	0.7825	0.7240	0.6538	0.5580	0.1648	0.1779	0.1916
0.98	0.9965	0.9911	0.9821	0.9730	0.9637	0.9051	0.7910	0.7360	0.6714	0.5887	0.1748	0.1844	0.1966
0.99	0.9966	0.9914	0.9826	0.9738	0.9648	0.9082	0.7990	0.7471	0.6873	0.6138	0.5070	0.1959	0.2041
1	0.9967	0.9916	0.9832	0.9746	0.9659	0.9112	0.8065	0.7574	0.7017	0.6353	0.5477	0.2918	0.2167
1.01	0.9968	0.9919	0.9837	0.9754	0.9669	0.9141	0.8136	0.7671	0.7149	0.6542	0.5785	0.4648	0.2486
1.02	0.9969	0.9921	0.9842	0.9761	0.9679	0.9168	0.8204	0.7761	0.7271	0.6710	0.6038	0.5146	0.3597
1.03	0.9969	0.9924	0.9846	0.9768	0.9689	0.9194	0.8267	0.7846	0.7383	0.6863	0.6256	0.5501	0.4439
1.05	0.9971	0.9928	0.9855	0.9781	0.9707	0.9243	0.8385	0.8002	0.7586	0.7130	0.6618	0.6026	0.5312
1.1	0.9975	0.9937	0.9874	0.9811	0.9747	0.9350	0.8634	0.8323	0.7996	0.7649	0.7278	0.6880	0.6449
1.15	0.9978	0.9945	0.9891	0.9835	0.9780	0.9438	0.8833	0.8576	0.8309	0.8032	0.7744	0.7443	0.7129
1.2	0.9981	0.9952	0.9904	0.9856	0.9808	0.9511	0.8994	0.8779	0.8557	0.8330	0.8097	0.7858	0.7613
1.3	0.9985	0.9963	0.9926	0.9889	0.9852	0.9626	0.9240	0.9083	0.8924	0.8764	0.8602	0.8438	0.8275
1.4	0.9988	0.9971	0.9942	0.9913	0.9884	0.9710	0.9416	0.9298	0.9180	0.9062	0.8945	0.8827	0.8710
1.5	0.9991	0.9977	0.9954	0.9932	0.9909	0.9772	0.9546	0.9456	0.9367	0.9278	0.9190	0.9103	0.9018
1.6	0.9993	0.9982	0.9964	0.9946	0.9928	0.9820	0.9644	0.9575	0.9507	0.9439	0.9373	0.9308	0.9243
1.7	0.9994	0.9986	0.9971	0.9957	0.9943	0.9858	0.9721	0.9667	0.9614	0.9563	0.9512	0.9463	0.9414
1.8	0.9995	0.9989	0.9977	0.9966	0.9955	0.9888	0.9780	0.9739	0.9698	0.9659	0.9620	0.9583	0.9546
1.9	0.9996	0.9991	0.9982	0.9973	0.9964	0.9912	0.9828	0.9796	0.9765	0.9735	0.9706	0.9678	0.9650
2	0.9997	0.9993	0.9986	0.9979	0.9972	0.9931	0.9866	0.9842	0.9819	0.9796	0.9774	0.9754	0.9734
2.25	0.9999	0.9996	0.9993	0.9989	0.9986	0.9965	0.9935	0.9924	0.9913	0.9904	0.9895	0.9887	0.9879
2.5	0.9999	0.9999	0.9997	0.9996	0.9994	0.9987	0.9977	0.9975	0.9972	0.9971	0.9970	0.9969	0.9969
2.75	1.0000	1.0000	1.0000	1.0000	1.0000	1.0001	1.0005	1.0008	1.0011	1.0014	1.0018	1.0022	1.0027
3	1.0000	1.0001	1.0002	1.0003	1.0004	1.0011	1.0024	1.0030	1.0036	1.0043	1.0050	1.0057	1.0065
3.5	1.0001	1.0002	1.0004	1.0006	1.0008	1.0022	1.0045	1.0055	1.0065	1.0075	1.0086	1.0097	1.0108
4	1.0001	1.0003	1.0005	1.0008	1.0010	1.0027	1.0055	1.0066	1.0078	1.0090	1.0102	1.0115	1.0127
5	1.0001	1.0003	1.0006	1.0009	1.0012	1.0030	1.0060	1.0073	1.0085	1.0098	1.0111	1.0124	1.0137

<sup>1</sup> As calculated by text software.

**TABLE C.1 Continued**

$T_r$	$P_r$	1.2	1.3	1.4	1.5	1.75	2	2.5	3	4	5	7.5	10
0.3	0.3470	0.3758		0.4047	0.4335	0.5055	0.5775	0.7213	0.8648	1.1512	1.4366	2.1463	2.8507
0.35	0.3123	0.3382		0.3642	0.3901	0.4549	0.5195	0.6487	0.7775	1.0344	1.2902	1.9251	2.5539
0.4	0.2853	0.3090		0.3327	0.3563	0.4154	0.4744	0.5921	0.7095	0.9433	1.1758	1.7519	2.3211
0.45	0.2638	0.2857		0.3076	0.3294	0.3840	0.4384	0.5470	0.6551	0.8704	1.0841	1.6128	2.1338
0.5	0.2465	0.2669		0.2873	0.3077	0.3585	0.4092	0.5103	0.6110	0.8110	1.0094	1.4989	1.9801
0.55	0.2323	0.2515		0.2707	0.2899	0.3377	0.3853	0.4803	0.5747	0.7620	0.9475	1.4042	1.8520
0.6	0.2207	0.2390		0.2571	0.2753	0.3206	0.3657	0.4554	0.5446	0.7213	0.8959	1.3247	1.7440
0.65	0.2113	0.2287		0.2461	0.2634	0.3065	0.3495	0.4349	0.5197	0.6872	0.8526	1.2573	1.6519
0.7	0.2038	0.2205		0.2372	0.2538	0.2952	0.3364	0.4181	0.4991	0.6588	0.8161	1.1999	1.5729
0.75	0.1981	0.2142		0.2303	0.2464	0.2863	0.3260	0.4046	0.4823	0.6352	0.7854	1.1508	1.5047
0.8	0.1942	0.2099		0.2255	0.2411	0.2798	0.3182	0.3942	0.4690	0.6160	0.7598	1.1087	1.4456
0.85	0.1924	0.2077		0.2230	0.2382	0.2759	0.3132	0.3868	0.4591	0.6007	0.7388	1.0727	1.3943
0.9	0.1935	0.2085		0.2235	0.2383	0.2751	0.3114	0.3828	0.4527	0.5892	0.7220	1.0421	1.3496
0.93	0.1963	0.2112		0.2259	0.2405	0.2766	0.3122	0.3822	0.4507	0.5841	0.7138	1.0261	1.3257
0.95	0.1998	0.2144		0.2288	0.2432	0.2787	0.3138	0.3827	0.4501	0.5815	0.7092	1.0164	1.3108
0.97	0.2055	0.2195		0.2334	0.2474	0.2821	0.3164	0.3841	0.4504	0.5796	0.7052	1.0073	1.2968
0.98	0.2097	0.2231		0.2366	0.2503	0.2843	0.3182	0.3851	0.4508	0.5789	0.7035	1.0030	1.2901
0.99	0.2154	0.2278		0.2407	0.2538	0.2871	0.3204	0.3864	0.4514	0.5784	0.7018	0.9989	1.2835
1	0.2237	0.2342		0.2459	0.2583	0.2904	0.3229	0.3880	0.4522	0.5780	0.7004	0.9949	1.2772
1.01	0.2370	0.2432		0.2529	0.2640	0.2944	0.3260	0.3899	0.4533	0.5778	0.6991	0.9912	1.2710
1.02	0.2629	0.2568		0.2624	0.2715	0.2993	0.3297	0.3921	0.4547	0.5778	0.6980	0.9875	1.2650
1.03	0.3168	0.2793		0.2760	0.2813	0.3053	0.3340	0.3948	0.4563	0.5780	0.6970	0.9841	1.2592
1.05	0.4437	0.3630		0.3246	0.3131	0.3219	0.3452	0.4014	0.4604	0.5790	0.6956	0.9776	1.2481
1.1	0.5984	0.5492		0.5003	0.4580	0.4026	0.3953	0.4277	0.4770	0.5851	0.6950	0.9639	1.2232
1.15	0.6803	0.6468		0.6129	0.5798	0.5116	0.4760	0.4718	0.5042	0.5972	0.6987	0.9538	1.2021
1.2	0.7363	0.7110		0.6856	0.6605	0.6029	0.5605	0.5295	0.5425	0.6155	0.7069	0.9471	1.1844
1.3	0.8111	0.7947		0.7784	0.7624	0.7243	0.6908	0.6467	0.6344	0.6681	0.7358	0.9427	1.1580
1.4	0.8595	0.8480		0.8367	0.8256	0.7992	0.7753	0.7387	0.7202	0.7299	0.7761	0.9486	1.1419
1.5	0.8933	0.8850		0.8768	0.8689	0.8499	0.8328	0.8052	0.7887	0.7884	0.8200	0.9619	1.1339
1.6	0.9180	0.9119		0.9059	0.9000	0.8863	0.8738	0.8537	0.8410	0.8386	0.8617	0.9795	1.1320
1.7	0.9367	0.9321		0.9277	0.9234	0.9133	0.9043	0.8899	0.8809	0.8798	0.8984	0.9986	1.1343
1.8	0.9511	0.9477		0.9444	0.9413	0.9339	0.9275	0.9176	0.9118	0.9129	0.9297	1.0174	1.1391
1.9	0.9624	0.9599		0.9575	0.9552	0.9500	0.9456	0.9391	0.9359	0.9396	0.9557	1.0348	1.1452
2	0.9715	0.9697		0.9680	0.9664	0.9628	0.9599	0.9561	0.9550	0.9611	0.9772	1.0503	1.1516
2.25	0.9873	0.9867		0.9861	0.9857	0.9849	0.9846	0.9854	0.9880	0.9986	1.0157	1.0805	1.1661
2.5	0.9970	0.9971		0.9973	0.9976	0.9984	0.9996	1.0031	1.0080	1.0215	1.0395	1.1003	1.1763
2.75	1.0033	1.0038		1.0045	1.0051	1.0070	1.0092	1.0143	1.0205	1.0357	1.0543	1.1125	1.1823
3	1.0074	1.0082		1.0091	1.0101	1.0126	1.0153	1.0215	1.0284	1.0446	1.0635	1.1196	1.1848
3.5	1.0120	1.0131		1.0143	1.0156	1.0187	1.0221	1.0292	1.0368	1.0537	1.0723	1.1249	1.1834
4	1.0140	1.0153		1.0166	1.0179	1.0214	1.0249	1.0323	1.0401	1.0567	1.0747	1.1239	1.1773
5	1.0150	1.0163		1.0176	1.0190	1.0224	1.0259	1.0331	1.0405	1.0559	1.0722	1.1153	1.1611

**TABLE C.2** Values for  $z^{(t)}$ 

$T_r$	$P_r$	0.01	0.025	0.05	0.075	0.1	0.25	0.5	0.6	0.7	0.8	0.9	1	1.1
0.3	-0.0008	-0.0020	-0.0040	-0.0061	-0.0081	-0.0202	-0.0403	-0.0484	-0.0645	-0.0725	-0.0806	-0.0886		
0.35	-0.0009	-0.0023	-0.0046	-0.0069	-0.0093	-0.0231	-0.0462	-0.0554	-0.0646	-0.0738	-0.0830	-0.0921	-0.1013	
0.4	-0.0010	-0.0024	-0.0048	-0.0071	-0.0095	-0.0238	-0.0475	-0.0570	-0.0664	-0.0758	-0.0852	-0.0946	-0.1040	
0.45	-0.0009	-0.0023	-0.0047	-0.0070	-0.0094	-0.0234	-0.0467	-0.0560	-0.0652	-0.0745	-0.0837	-0.0929	-0.1021	
0.5	-0.0009	-0.0023	-0.0045	-0.0068	-0.0090	-0.0226	-0.0450	-0.0539	-0.0628	-0.0716	-0.0805	-0.0893	-0.0981	
0.55	-0.0314	-0.0022	-0.0043	-0.0065	-0.0086	-0.0215	-0.0428	-0.0513	-0.0598	-0.0682	-0.0766	-0.0849	-0.0932	
0.6	-0.0205	-0.0543	-0.0041	-0.0062	-0.0082	-0.0204	-0.0406	-0.0487	-0.0566	-0.0646	-0.0725	-0.0803	-0.0882	
0.65	-0.0137	-0.0357	-0.0772	-0.0059	-0.0078	-0.0194	-0.0385	-0.0461	-0.0536	-0.0611	-0.0685	-0.0759	-0.0833	
0.7	-0.0093	-0.0240	-0.0507	-0.0809	-0.1161	-0.0185	-0.0366	-0.0438	-0.0509	-0.0579	-0.0649	-0.0718	-0.0787	
0.75	-0.0064	-0.0163	-0.0359	-0.0531	-0.0744	-0.0178	-0.0350	-0.0417	-0.0484	-0.0550	-0.0616	-0.0681	-0.0745	
0.8	-0.0044	-0.0111	-0.0228	-0.0353	-0.0487	-0.0150	-0.0337	-0.0401	-0.0464	-0.0526	-0.0588	-0.0648	-0.0708	
0.85	-0.0029	-0.0075	-0.0152	-0.0234	-0.0319	-0.0063	-0.0331	-0.0391	-0.0451	-0.0509	-0.0566	-0.0622	-0.0677	
0.9	-0.0019	-0.0049	-0.0099	-0.0151	-0.0205	-0.0077	-0.0177	-0.0396	-0.0451	-0.0503	-0.0554	-0.0604	-0.0653	
0.93	-0.0015	-0.0037	-0.0075	-0.0114	-0.0154	-0.0420	-0.1088	-0.1662	-0.0469	-0.0514	-0.0558	-0.0602	-0.0645	
0.95	-0.0012	-0.0031	-0.0062	-0.0093	-0.0126	-0.0336	-0.0805	-0.1110	-0.1747	-0.0540	-0.0572	-0.0607	-0.0642	
0.97	-0.0010	-0.0025	-0.0050	-0.0075	-0.0101	-0.0264	-0.0594	-0.0770	-0.1023	-0.1647	-0.2166	-0.0623	-0.0643	
0.98	-0.0009	-0.0022	-0.0044	-0.0067	-0.0090	-0.0233	-0.0507	-0.0641	-0.0812	-0.1100	-0.1690	-0.2141	-0.0644	
0.99	-0.0008	-0.0020	-0.0039	-0.0059	-0.0079	-0.0203	-0.0429	-0.0531	-0.0646	-0.0796	-0.1143	-0.2180	-0.0641	
1	-0.0007	-0.0017	-0.0034	-0.0052	-0.0069	-0.0176	-0.0360	-0.0435	-0.0511	-0.0588	-0.1665	-0.2789	-0.0607	
1.01	-0.0006	-0.0015	-0.0030	-0.0045	-0.0060	-0.0151	-0.0297	-0.0351	-0.0398	-0.0429	-0.1223	-0.2082	-0.0623	
1.02	-0.0005	-0.0013	-0.0026	-0.0039	-0.0051	-0.0127	-0.0241	-0.0277	-0.0301	-0.0303	-0.0256	-0.0662	-0.0895	
1.03	-0.0004	-0.0011	-0.0022	-0.0033	-0.0043	-0.0105	-0.0190	-0.0211	-0.0217	-0.0198	-0.0130	-0.0553	-0.0588	
1.05	-0.0003	-0.0007	-0.0017	-0.0034	-0.0052	-0.0069	-0.0176	-0.0360	-0.0435	-0.0511	-0.0588	-0.1665	-0.2789	-0.0607
1.1	0.0000	0.0000	0.0000	0.0001	0.0001	0.0012	0.0066	0.0160	0.0161	0.0236	0.0338	0.0476	0.0659	
1.15	0.0002	0.0005	0.0011	0.0017	0.0023	0.0068	0.0177	0.0237	0.0309	0.0396	0.0500	0.0625	0.0772	
1.2	0.0004	0.0009	0.0019	0.0029	0.0040	0.0108	0.0254	0.0326	0.0407	0.0499	0.0603	0.0719	0.0848	
1.3	0.0006	0.0015	0.0030	0.0045	0.0061	0.0159	0.0345	0.0429	0.0518	0.0612	0.0713	0.0819	0.0931	
1.4	0.0007	0.0018	0.0036	0.0054	0.0072	0.0185	0.0390	0.0477	0.0567	0.0661	0.0757	0.0857	0.0959	
1.5	0.0008	0.0019	0.0039	0.0058	0.0078	0.0198	0.0409	0.0497	0.0586	0.0677	0.0770	0.0864	0.0959	
1.6	0.0008	0.0020	0.0040	0.0060	0.0080	0.0204	0.0415	0.0501	0.0589	0.0677	0.0766	0.0855	0.0945	
1.7	0.0008	0.0020	0.0040	0.0061	0.0081	0.0204	0.0413	0.0497	0.0582	0.0667	0.0752	0.0838	0.0923	
1.8	0.0008	0.0020	0.0040	0.0060	0.0081	0.0202	0.0406	0.0488	0.0570	0.0652	0.0734	0.0816	0.0897	
1.9	0.0008	0.0020	0.0040	0.0059	0.0079	0.0199	0.0397	0.0477	0.0556	0.0635	0.0714	0.0792	0.0870	
2	0.0008	0.0019	0.0039	0.0058	0.0078	0.0194	0.0387	0.0464	0.0541	0.0617	0.0692	0.0767	0.0842	
2.25	0.0007	0.0018	0.0036	0.0055	0.0073	0.0181	0.0360	0.0431	0.0501	0.0570	0.0640	0.0708	0.0776	
2.5	0.0007	0.0017	0.0034	0.0051	0.0068	0.0168	0.0334	0.0399	0.0464	0.0528	0.0591	0.0654	0.0716	
2.75	0.0006	0.0016	0.0032	0.0047	0.0063	0.0156	0.0310	0.0370	0.0430	0.0490	0.0548	0.0607	0.0664	
3	0.0006	0.0015	0.0029	0.0044	0.0059	0.0146	0.0289	0.0345	0.0401	0.0456	0.0511	0.0565	0.0619	
3.5	0.0005	0.0013	0.0026	0.0039	0.0052	0.0128	0.0254	0.0303	0.0352	0.0401	0.0449	0.0497	0.0544	
4	0.0005	0.0012	0.0023	0.0034	0.0046	0.0114	0.0226	0.0270	0.0314	0.0357	0.0400	0.0443	0.0485	
5	0.0004	0.0009	0.0028	0.0038	0.0058	0.0019	0.0019	0.0019	0.0022	0.0025	0.0029	0.0035	0.0040	

$T_r$	$P_r$	1.2	1.3	1.4	1.5	1.75	2	2.5	3	4	5	7.5	10
0.3	-0.0966	-0.1047	-0.1127	-0.1207	-0.1408	-0.1608	-0.2008	-0.2407	-0.3203	-0.3996	-0.5965	-0.7915	
0.35	-0.1105	-0.1196	-0.1287	-0.1379	-0.1607	-0.1834	-0.2287	-0.2738	-0.3634	-0.4523	-0.6713	-0.8863	
0.4	-0.1134	-0.1228	-0.1321	-0.1414	-0.1647	-0.1879	-0.2341	-0.2799	-0.3707	-0.4603	-0.6799	-0.8936	
0.45	-0.1113	-0.1204	-0.1296	-0.1387	-0.1614	-0.1840	-0.2289	-0.2734	-0.3612	-0.4475	-0.6577	-0.8606	
0.5	-0.1069	-0.1156	-0.1243	-0.1330	-0.1547	-0.1762	-0.2189	-0.2611	-0.3440	-0.4253	-0.6216	-0.8099	
0.55	-0.1015	-0.1098	-0.1180	-0.1263	-0.1467	-0.1669	-0.2070	-0.2465	-0.3238	-0.3991	-0.5800	-0.7521	
0.6	-0.0960	-0.1037	-0.1115	-0.1192	-0.1383	-0.1572	-0.1945	-0.2312	-0.3026	-0.3718	-0.5369	-0.6929	
0.65	-0.0906	-0.0978	-0.1051	-0.1123	-0.1301	-0.1476	-0.1822	-0.2160	-0.2816	-0.3447	-0.4943	-0.6346	
0.7	-0.0855	-0.0923	-0.0990	-0.1057	-0.1222	-0.1385	-0.1703	-0.2013	-0.2611	-0.3184	-0.4531	-0.5785	
0.75	-0.0808	-0.0871	-0.0934	-0.0996	-0.1149	-0.1298	-0.1590	-0.1872	-0.2414	-0.3299	-0.4134	-0.5250	
0.8	-0.0767	-0.0825	-0.0883	-0.0940	-0.1080	-0.1217	-0.1481	-0.1736	-0.2222	-0.2682	-0.3752	-0.4740	
0.85	-0.0731	-0.0784	-0.0837	-0.0888	-0.1015	-0.1138	-0.1375	-0.1602	-0.2032	-0.2439	-0.3383	-0.4254	
0.9	-0.0701	-0.0748	-0.0795	-0.0840	-0.0951	-0.1059	-0.1265	-0.1463	-0.1839	-0.2195	-0.3022	-0.3788	
0.93	-0.0687	-0.0729	-0.0770	-0.0810	-0.0910	-0.1007	-0.1194	-0.1374	-0.1718	-0.2045	-0.2808	-0.3516	
0.95	-0.0678	-0.0715	-0.0751	-0.0788	-0.0878	-0.0967	-0.1141	-0.1310	-0.1634	-0.1943	-0.2666	-0.3339	
0.97	-0.0669	-0.0698	-0.0728	-0.0759	-0.0840	-0.0921	-0.1082	-0.1240	-0.1545	-0.1837	-0.2524	-0.3163	
0.98	-0.0661	-0.0685	-0.0712	-0.0740	-0.0816	-0.0893	-0.1049	-0.1202	-0.1499	-0.1783	-0.2452	-0.3075	
0.99	-0.0646	-0.0665	-0.0688	-0.0715	-0.0787	-0.0861	-0.1013	-0.1162	-0.1451	-0.1728	-0.2381	-0.2989	
1	-0.0609	-0.0628	-0.0652	-0.0678	-0.0750	-0.0824	-0.0972	-0.1118	-0.1401	-0.1672	-0.2309	-0.2902	
1.01	-0.0473	-0.0545	-0.0586	-0.0621	-0.0702	-0.0778	-0.0927	-0.1072	-0.1349	-0.1615	-0.2237	-0.2816	
1.02	0.0227	-0.0310	-0.0452	-0.0524	-0.0635	-0.0722	-0.0876	-0.1021	-0.1295	-0.1556	-0.2165	-0.2731	
1.03	0.1159	0.0318	-0.0152	-0.0343	-0.0540	-0.0649	-0.0818	-0.0966	-0.1239	-0.1495	-0.2092	-0.2646	
1.05	0.1059	0.1357	0.0951	0.0451	-0.0195	-0.0432	-0.0671	-0.0838	-0.1118	-0.1370	-0.1946	-0.2476	
1.1	0.0897	0.1185	0.1468	0.1630	0.1300	0.0698	-0.0033	-0.0373	-0.0751	-0.1021	-0.1572	-0.2056	
1.15	0.0943	0.1137	0.1345	0.1548	0.1835	0.1667	0.0906	0.0332	-0.0272	-0.0611	-0.1185	-0.1642	
1.2	0.0991	0.1146	0.1310	0.1477	0.1840	0.1990	0.1651	0.1095	0.0304	-0.0141	-0.0782	-0.1231	
1.3	0.1048	0.1169	0.1294	0.1420	0.1729	0.1991	0.2223	0.2079	0.1435	0.0875	0.0053	-0.0423	
1.4	0.1063	0.1169	0.1276	0.1383	0.1648	0.1894	0.2259	0.2397	0.2171	0.1737	0.0870	0.0350	
1.5	0.1055	0.1152	0.1248	0.1345	0.1582	0.1806	0.2186	0.2433	0.2525	0.2309	0.1584	0.1058	
1.6	0.1035	0.1124	0.1214	0.1303	0.1521	0.1729	0.2098	0.2381	0.2654	0.2631	0.2147	0.1673	
1.7	0.1008	0.1092	0.1176	0.1259	0.1463	0.1658	0.2013	0.2305	0.2672	0.2788	0.2556	0.2179	
1.8	0.0978	0.1058	0.1137	0.1216	0.1408	0.1593	0.1932	0.2224	0.2639	0.2846	0.2834	0.2576	
1.9	0.0947	0.1023	0.1099	0.1173	0.1356	0.1532	0.1858	0.2144	0.2582	0.2848	0.3013	0.2876	
2	0.0916	0.0989	0.1061	0.1133	0.1307	0.1476	0.1789	0.2069	0.2517	0.2820	0.3120	0.3096	
2.25	0.0843	0.0909	0.0975	0.1039	0.1198	0.1350	0.1638	0.1901	0.2346	0.2691	0.3198	0.3392	
2.5	0.0778	0.0839	0.0899	0.0958	0.1104	0.1245	0.1511	0.1757	0.2189	0.2542	0.3146	0.3475	
2.75	0.0721	0.0778	0.0833	0.0888	0.1023	0.1154	0.1403	0.1635	0.2049	0.2399	0.3045	0.3454	
3	0.0672	0.0724	0.0776	0.0828	0.0954	0.1076	0.1310	0.1529	0.1925	0.2268	0.2930	0.3385	
3.5	0.0591	0.0637	0.0683	0.0728	0.0840	0.0949	0.1158	0.1356	0.1719	0.2042	0.2700	0.3194	
4	0.0527	0.0569	0.0610	0.0651	0.0751	0.0849	0.1038	0.1219	0.1554	0.1857	0.2493	0.2994	
5	0.0434	0.0469	0.0503	0.0537	0.0621	0.0703	0.0863	0.1016	0.1306	0.1573	0.2155	0.2637	

**TABLE C.3** Values for  $\left[ \frac{h_{T_r, P_r} - h_{T_c, P_r}^{\text{ideal gas}}}{RT_c} \right]^{(0)}$

$T_r$	$P_r$	0.01	0.025	0.05	0.075	0.1	0.25	0.5	0.6	0.7	0.8	0.9	1	1.1
0.3	-6.046	-6.045	-6.043	-6.042	-6.040	-6.031	-6.017	-6.011	-6.005	-5.999	-5.993	-5.987	-5.981	
0.35	-5.907	-5.906	-5.904	-5.903	-5.901	-5.892	-5.876	-5.870	-5.864	-5.858	-5.852	-5.845	-5.839	
0.4	-5.763	-5.762	-5.761	-5.759	-5.757	-5.748	-5.732	-5.726	-5.719	-5.713	-5.707	-5.700	-5.694	
0.45	-5.615	-5.614	-5.612	-5.611	-5.609	-5.600	-5.583	-5.577	-5.571	-5.564	-5.558	-5.551	-5.545	
0.5	-5.465	-5.464	-5.462	-5.461	-5.459	-5.450	-5.434	-5.427	-5.421	-5.414	-5.408	-5.401	-5.395	
0.55	-0.032	-5.314	-5.312	-5.311	-5.309	-5.300	-5.284	-5.277	-5.271	-5.265	-5.258	-5.252	-5.245	
0.6	-0.027	-0.068	-5.162	-5.161	-5.159	-5.150	-5.135	-5.129	-5.122	-5.116	-5.110	-5.104	-5.098	
0.65	-0.023	-0.058	-0.118	-0.117	-0.115	-0.109	-0.100	-0.098	-0.095	-0.092	-0.088	-0.082	-0.076	
0.7	-0.020	-0.050	-0.101	-0.156	-0.213	-0.287	-0.339	-0.393	-0.431	-0.435	-0.431	-0.426	-0.416	
0.75	-0.017	-0.043	-0.088	-0.135	-0.183	-0.241	-0.315	-0.379	-0.431	-0.464	-0.499	-0.501	-0.504	
0.8	-0.015	-0.038	-0.078	-0.118	-0.160	-0.214	-0.287	-0.351	-0.411	-0.464	-0.501	-0.535	-0.561	
0.85	-0.014	-0.034	-0.069	-0.105	-0.141	-0.209	-0.287	-0.351	-0.411	-0.464	-0.501	-0.535	-0.561	
0.9	-0.012	-0.031	-0.062	-0.094	-0.126	-0.194	-0.262	-0.329	-0.389	-0.449	-0.499	-0.535	-0.561	
0.93	-0.011	-0.029	-0.058	-0.088	-0.118	-0.186	-0.254	-0.320	-0.380	-0.440	-0.490	-0.530	-0.560	
0.95	-0.011	-0.028	-0.056	-0.084	-0.113	-0.181	-0.249	-0.315	-0.375	-0.435	-0.485	-0.525	-0.555	
0.97	-0.011	-0.027	-0.054	-0.081	-0.109	-0.178	-0.247	-0.313	-0.373	-0.433	-0.483	-0.523	-0.553	
0.98	-0.010	-0.026	-0.053	-0.079	-0.107	-0.176	-0.245	-0.311	-0.371	-0.431	-0.481	-0.521	-0.551	
0.99	-0.010	-0.026	-0.052	-0.078	-0.105	-0.175	-0.244	-0.309	-0.369	-0.429	-0.479	-0.519	-0.549	
1	-0.010	-0.026	-0.051	-0.076	-0.103	-0.174	-0.243	-0.308	-0.368	-0.428	-0.478	-0.518	-0.548	
1.01	-0.010	-0.025	-0.050	-0.075	-0.101	-0.173	-0.242	-0.307	-0.367	-0.427	-0.477	-0.517	-0.547	
1.02	-0.010	-0.024	-0.049	-0.074	-0.099	-0.172	-0.241	-0.306	-0.366	-0.426	-0.476	-0.516	-0.546	
1.03	-0.009	-0.024	-0.048	-0.072	-0.097	-0.171	-0.240	-0.305	-0.365	-0.425	-0.475	-0.515	-0.545	
1.05	-0.009	-0.023	-0.046	-0.070	-0.094	-0.169	-0.238	-0.304	-0.364	-0.424	-0.474	-0.514	-0.544	
1.1	-0.008	-0.021	-0.042	-0.064	-0.086	-0.168	-0.237	-0.303	-0.363	-0.423	-0.473	-0.513	-0.543	
1.15	-0.008	-0.019	-0.039	-0.059	-0.079	-0.167	-0.236	-0.302	-0.362	-0.422	-0.472	-0.512	-0.542	
1.2	-0.007	-0.018	-0.036	-0.054	-0.073	-0.166	-0.235	-0.301	-0.361	-0.421	-0.471	-0.511	-0.541	
1.3	-0.006	-0.016	-0.031	-0.047	-0.063	-0.165	-0.234	-0.300	-0.360	-0.420	-0.469	-0.510	-0.539	
1.4	-0.005	-0.014	-0.027	-0.041	-0.055	-0.164	-0.233	-0.299	-0.359	-0.419	-0.468	-0.508	-0.538	
1.5	-0.005	-0.012	-0.024	-0.036	-0.048	-0.163	-0.232	-0.298	-0.358	-0.418	-0.467	-0.507	-0.537	
1.6	-0.004	-0.011	-0.021	-0.032	-0.043	-0.162	-0.231	-0.297	-0.357	-0.417	-0.466	-0.506	-0.536	
1.7	-0.004	-0.010	-0.019	-0.029	-0.038	-0.161	-0.230	-0.296	-0.356	-0.416	-0.465	-0.505	-0.535	
1.8	-0.003	-0.009	-0.017	-0.026	-0.034	-0.160	-0.229	-0.295	-0.355	-0.415	-0.464	-0.504	-0.534	
1.9	-0.003	-0.008	-0.015	-0.023	-0.031	-0.159	-0.228	-0.294	-0.354	-0.414	-0.463	-0.503	-0.533	
2	-0.003	-0.007	-0.014	-0.021	-0.028	-0.158	-0.227	-0.293	-0.353	-0.413	-0.462	-0.502	-0.532	
2.25	-0.002	-0.006	-0.011	-0.017	-0.022	-0.157	-0.226	-0.292	-0.352	-0.412	-0.461	-0.501	-0.531	
2.5	-0.002	-0.004	-0.009	-0.013	-0.018	-0.156	-0.225	-0.291	-0.351	-0.411	-0.460	-0.500	-0.530	
2.75	-0.001	-0.004	-0.007	-0.011	-0.014	-0.155	-0.224	-0.290	-0.350	-0.410	-0.459	-0.500	-0.529	
3	-0.001	-0.003	-0.006	-0.009	-0.011	-0.154	-0.223	-0.289	-0.349	-0.409	-0.449	-0.499	-0.528	
3.5	-0.001	-0.002	-0.004	-0.006	-0.007	-0.153	-0.222	-0.288	-0.348	-0.408	-0.448	-0.498	-0.527	
4	0.000	-0.001	-0.002	-0.003	-0.005	-0.152	-0.221	-0.287	-0.347	-0.407	-0.447	-0.497	-0.526	
5	0.000	0.000	0.000	-0.001	-0.002	-0.151	-0.220	-0.286	-0.346	-0.406	-0.446	-0.496	-0.525	

$T_r$	$P_r$	1.2	1.3	1.4	1.5	1.75	2	2.5	3	4	5	7.5	10
0.3	-5.975	-5.969	-5.963	-5.957	-5.942	-5.927	-5.898	-5.868	-5.808	-5.748	-5.598	-5.446	
0.35	-5.833	-5.827	-5.821	-5.814	-5.799	-5.783	-5.752	-5.721	-5.658	-5.595	-5.437	-5.278	
0.4	-5.687	-5.681	-5.675	-5.668	-5.652	-5.636	-5.604	-5.572	-5.507	-5.442	-5.278	-5.113	
0.45	-5.538	-5.532	-5.525	-5.519	-5.502	-5.486	-5.453	-5.420	-5.354	-5.288	-5.120	-4.950	
0.5	-5.388	-5.382	-5.375	-5.369	-5.352	-5.336	-5.303	-5.270	-5.203	-5.135	-4.964	-4.791	
0.55	-5.239	-5.233	-5.226	-5.220	-5.203	-5.187	-5.154	-5.121	-5.054	-4.986	-4.814	-4.638	
0.6	-5.091	-5.085	-5.079	-5.073	-5.057	-5.041	-5.008	-4.976	-4.909	-4.842	-4.669	-4.492	
0.65	-4.945	-4.939	-4.933	-4.927	-4.911	-4.896	-4.865	-4.833	-4.769	-4.702	-4.531	-4.353	
0.7	-4.797	-4.792	-4.786	-4.781	-4.767	-4.752	-4.723	-4.693	-4.631	-4.566	-4.397	-4.221	
0.75	-4.646	-4.641	-4.637	-4.632	-4.620	-4.607	-4.581	-4.554	-4.495	-4.434	-4.269	-4.095	
0.8	-4.488	-4.485	-4.481	-4.478	-4.469	-4.459	-4.437	-4.413	-4.361	-4.303	-4.145	-3.974	
0.85	-4.316	-4.315	-4.314	-4.312	-4.308	-4.302	-4.287	-4.269	-4.225	-4.173	-4.024	-3.857	
0.9	-4.118	-4.121	-4.125	-4.127	-4.131	-4.132	-4.129	-4.119	-4.086	-4.043	-3.905	-3.744	
0.93	-3.976	-3.985	-3.993	-4.000	-4.012	-4.020	-4.026	-4.024	-4.001	-3.963	-3.834	-3.678	
0.95	-3.865	-3.880	-3.893	-3.904	-3.925	-3.939	-3.959	-3.958	-3.943	-3.910	-3.788	-3.634	
0.97	-3.732	-3.758	-3.779	-3.796	-3.830	-3.853	-3.879	-3.890	-3.883	-3.856	-3.741	-3.591	
0.98	-3.652	-3.686	-3.714	-3.736	-3.778	-3.806	-3.840	-3.854	-3.853	-3.829	-3.717	-3.569	
0.99	-3.558	-3.605	-3.641	-3.670	-3.723	-3.758	-3.799	-3.818	-3.823	-3.801	-3.694	-3.548	
1	-3.441	-3.510	-3.560	-3.598	-3.664	-3.706	-3.757	-3.782	-3.774	-3.767	-3.670	-3.526	
1.01	-3.283	-3.395	-3.465	-3.516	-3.600	-3.652	-3.713	-3.744	-3.760	-3.746	-3.647	-3.505	
1.02	-3.039	-3.246	-3.352	-3.422	-3.530	-3.595	-3.668	-3.705	-3.729	-3.718	-3.624	-3.484	
1.03	-2.657	-3.043	-3.213	-3.313	-3.454	-3.534	-3.621	-3.665	-3.696	-3.690	-3.600	-3.462	
1.05	-2.034	-2.497	-2.831	-3.030	-3.277	-3.398	-3.521	-3.583	-3.630	-3.632	-3.553	-3.420	
1.1	-1.487	-1.709	-1.955	-2.203	-2.686	-2.965	-3.231	-3.353	-3.456	-3.484	-3.435	-3.315	
1.15	-1.239	-1.389	-1.550	-1.719	-2.139	-2.479	-2.888	-3.091	-3.268	-3.329	-3.315	-3.211	
1.2	-1.076	-1.193	-1.315	-1.443	-1.770	-2.079	-2.537	-2.807	-3.065	-3.166	-3.194	-3.107	
1.3	-0.860	-0.943	-1.029	-1.116	-1.338	-1.560	-1.964	-2.274	-2.645	-2.825	-2.947	-2.899	
1.4	-0.716	-0.782	-0.848	-0.915	-1.084	-1.253	-1.576	-1.857	-2.255	-2.486	-2.696	-2.692	
1.5	-0.611	-0.665	-0.719	-0.774	-0.910	-1.046	-1.309	-1.549	-1.926	-2.175	-2.449	-2.486	
1.6	-0.531	-0.576	-0.622	-0.667	-0.781	-0.894	-1.114	-1.318	-1.659	-1.904	-2.213	-2.285	
1.7	-0.466	-0.505	-0.544	-0.583	-0.681	-0.777	-0.964	-1.139	-1.441	-1.672	-1.994	-2.091	
1.8	-0.413	-0.447	-0.481	-0.515	-0.600	-0.683	-0.844	-0.996	-1.264	-1.476	-1.794	-1.908	
1.9	-0.368	-0.398	-0.429	-0.458	-0.533	-0.606	-0.747	-0.880	-1.117	-1.309	-1.614	-1.736	
2	-0.330	-0.357	-0.384	-0.411	-0.476	-0.541	-0.665	-0.782	-0.993	-1.167	-1.453	-1.577	
2.25	-0.257	-0.277	-0.297	-0.318	-0.367	-0.416	-0.509	-0.597	-0.755	-0.889	-1.120	-1.232	
2.5	-0.203	-0.219	-0.234	-0.250	-0.289	-0.326	-0.398	-0.465	-0.585	-0.687	-0.866	-0.954	
2.75	-0.162	-0.174	-0.187	-0.199	-0.229	-0.258	-0.314	-0.365	-0.457	-0.534	-0.667	-0.729	
3	-0.129	-0.139	-0.149	-0.159	-0.182	-0.205	-0.248	-0.288	-0.357	-0.415	-0.509	-0.545	
3.5	-0.081	-0.087	-0.093	-0.099	-0.113	-0.127	-0.152	-0.174	-0.211	-0.239	-0.272	-0.264	
4	-0.048	-0.051	-0.054	-0.065	-0.072	-0.085	-0.095	-0.109	-0.116	-0.105	-0.061	-0.017	
5	-0.004	-0.004	-0.003	-0.002	-0.001	0.003	0.009	0.024	0.045	0.05	0.117	0.213	

**TABLE C.4** Values for  $\left[ \frac{h_{T,P_r} - h_{T,P_r}^{\text{ideal gas}}}{RT_c} \right]^{(1)}$

$T_r$	$P_r$	0.01	0.025	0.05	0.075	0.1	0.25	0.5	0.6	0.7	0.8	0.9	1	1.1
0.3	-11.101	-11.101	-11.100	-11.099	-11.098	-11.093	-11.084	-11.081	-11.078	-11.074	-11.071	-11.067	-11.064	
0.35	-10.652	-10.652	-10.651	-10.651	-10.651	-10.648	-10.645	-10.643	-10.642	-10.640	-10.639	-10.637	-10.636	
0.4	-10.120	-10.120	-10.120	-10.120	-10.120	-10.120	-10.120	-10.120	-10.120	-10.120	-10.120	-10.120	-10.120	
0.45	-9.513	-9.514	-9.514	-9.514	-9.514	-9.516	-9.519	-9.520	-9.521	-9.522	-9.523	-9.525	-9.526	
0.5	-8.867	-8.867	-8.868	-8.868	-8.869	-8.872	-8.877	-8.879	-8.881	-8.883	-8.885	-8.887	-8.889	
0.55	-8.080	-8.212	-8.213	-8.213	-8.214	-8.218	-8.224	-8.227	-8.230	-8.232	-8.235	-8.238	-8.241	
0.6	-7.059	-7.565	-7.568	-7.569	-7.570	-7.574	-7.582	-7.585	-7.588	-7.592	-7.595	-7.598	-7.601	
0.65	-6.945	-6.116	-0.247	-6.948	-6.949	-6.954	-6.962	-6.966	-6.969	-6.973	-6.976	-6.980	-6.984	
0.7	-0.034	-0.088	-0.185	-0.292	-0.415	-6.361	-6.370	-6.373	-6.377	-6.381	-6.385	-6.388	-6.392	
0.75	-0.027	-0.068	-0.142	-0.220	-0.306	-5.798	-5.806	-5.809	-5.813	-5.816	-5.820	-5.824	-5.828	
0.8	-0.021	-0.054	-0.110	-0.170	-0.234	-0.753	-0.753	-0.768	-0.771	-0.774	-0.777	-0.785	-0.788	
0.85	-0.017	-0.043	-0.087	-0.134	-0.182	-0.534	-0.753	-0.754	-0.756	-0.758	-0.760	-0.763	-0.767	
0.9	-0.014	-0.034	-0.070	-0.106	-0.144	-0.400	-1.133	-1.133	-1.254	-1.250	-1.248	-1.249	-1.251	
0.93	-0.012	-0.030	-0.061	-0.093	-0.126	-0.341	-0.855	-0.855	-1.236	-1.236	-1.236	-1.236	-1.236	
0.95	-0.011	-0.028	-0.056	-0.085	-0.115	-0.309	-0.736	-0.736	-0.994	-0.994	-0.994	-0.994	-0.994	
0.97	-0.010	-0.026	-0.052	-0.078	-0.105	-0.280	-0.643	-0.643	-0.837	-0.837	-1.100	-1.100	-1.100	
0.98	-0.010	-0.025	-0.050	-0.075	-0.101	-0.267	-0.603	-0.603	-0.776	-0.776	-0.994	-0.994	-0.994	
0.99	-0.009	-0.024	-0.048	-0.072	-0.097	-0.254	-0.568	-0.568	-0.722	-0.722	-0.908	-0.908	-0.908	
1	-0.009	-0.023	-0.046	-0.069	-0.093	-0.243	-0.535	-0.535	-0.675	-0.675	-0.836	-0.836	-0.836	
1.01	-0.009	-0.022	-0.044	-0.066	-0.089	-0.232	-0.505	-0.505	-0.632	-0.632	-0.775	-0.775	-0.775	
1.02	-0.008	-0.021	-0.042	-0.063	-0.085	-0.221	-0.478	-0.478	-0.594	-0.594	-0.721	-0.721	-0.721	
1.03	-0.008	-0.020	-0.040	-0.061	-0.082	-0.211	-0.452	-0.452	-0.559	-0.559	-0.674	-0.674	-0.674	
1.05	-0.007	-0.019	-0.037	-0.056	-0.075	-0.193	-0.406	-0.406	-0.498	-0.498	-0.593	-0.593	-0.593	
1.1	-0.006	-0.015	-0.030	-0.046	-0.061	-0.155	-0.316	-0.316	-0.381	-0.381	-0.445	-0.445	-0.445	
1.15	-0.005	-0.012	-0.025	-0.037	-0.050	-0.124	-0.248	-0.248	-0.296	-0.296	-0.342	-0.342	-0.342	
1.2	-0.004	-0.010	-0.020	-0.030	-0.040	-0.100	-0.196	-0.196	-0.232	-0.232	-0.266	-0.266	-0.266	
1.3	-0.003	-0.007	-0.013	-0.020	-0.026	-0.064	-0.122	-0.122	-0.142	-0.142	-0.161	-0.161	-0.161	
1.4	-0.002	-0.004	-0.008	-0.012	-0.016	-0.039	-0.072	-0.072	-0.083	-0.083	-0.093	-0.093	-0.093	
1.5	-0.001	-0.002	-0.005	-0.007	-0.009	-0.022	-0.022	-0.022	-0.038	-0.038	-0.042	-0.042	-0.042	
1.6	0.000	-0.001	-0.002	-0.003	-0.004	-0.009	-0.013	-0.013	-0.013	-0.013	-0.012	-0.012	-0.012	
1.7	0.000	0.000	0.000	0.000	0.000	0.001	0.006	0.006	0.009	0.009	0.012	0.012	0.012	
1.8	0.000	0.001	0.001	0.002	0.003	0.008	0.019	0.025	0.031	0.031	0.037	0.044	0.051	
1.9	0.001	0.001	0.003	0.004	0.005	0.014	0.030	0.037	0.045	0.045	0.053	0.061	0.070	
2	0.001	0.002	0.004	0.005	0.007	0.018	0.039	0.047	0.056	0.065	0.075	0.085	0.094	
2.25	0.001	0.003	0.005	0.008	0.010	0.026	0.053	0.064	0.075	0.087	0.098	0.110	0.121	
2.5	0.001	0.003	0.006	0.009	0.012	0.031	0.062	0.075	0.087	0.100	0.112	0.125	0.138	
2.75	0.001	0.003	0.007	0.010	0.014	0.034	0.068	0.081	0.095	0.108	0.122	0.135	0.149	
3	0.001	0.004	0.007	0.011	0.014	0.036	0.072	0.086	0.100	0.114	0.128	0.142	0.156	
3.5	0.002	0.004	0.008	0.012	0.016	0.039	0.077	0.092	0.107	0.122	0.137	0.152	0.167	
4	0.002	0.004	0.008	0.012	0.016	0.04	0.08	0.096	0.112	0.127	0.143	0.158	0.173	
5	0.002	0.004	0.009	0.013	0.017	0.042	0.084	0.101	0.117	0.133	0.15	0.166	0.182	

$T_r$	$P_r$	1.2	1.3	1.4	1.5	1.75	2	2.5	3	4	5	7.5	10
0.3	-11.061	-11.057	-11.054	-11.051	-11.042	-11.034	-11.017	-11.001	-10.968	-10.936	-10.857	-10.782	
0.35	-10.634	-10.633	-10.632	-10.630	-10.627	-10.623	-10.616	-10.610	-10.597	-10.584	-10.555	-10.529	
0.4	-10.120	-10.120	-10.120	-10.120	-10.121	-10.121	-10.121	-10.122	-10.127	-10.127	-10.137	-10.150	
0.45	-9.527	-9.528	-9.529	-9.531	-9.534	-9.537	-9.544	-9.550	-9.564	-9.579	-9.619	-9.663	
0.5	-8.891	-8.893	-8.895	-8.897	-8.903	-8.908	-8.919	-8.931	-8.954	-8.979	-9.043	-9.111	
0.55	-8.243	-8.246	-8.249	-8.252	-8.259	-8.266	-8.281	-8.296	-8.327	-8.359	-8.444	-8.531	
0.6	-7.605	-7.608	-7.611	-7.615	-7.623	-7.632	-7.650	-7.668	-7.705	-7.744	-7.845	-7.950	
0.65	-6.987	-6.991	-6.995	-6.999	-7.008	-7.018	-7.038	-7.059	-7.102	-7.147	-7.263	-7.383	
0.7	-6.396	-6.400	-6.404	-6.408	-6.419	-6.430	-6.452	-6.475	-6.523	-6.573	-6.703	-6.837	
0.75	-5.832	-5.836	-5.841	-5.845	-5.856	-5.868	-5.892	-5.918	-5.971	-6.027	-6.170	-6.317	
0.8	-5.292	-5.297	-5.301	-5.306	-5.317	-5.330	-5.356	-5.384	-5.444	-5.506	-5.664	-5.824	
0.85	-4.771	-4.775	-4.779	-4.784	-4.796	-4.810	-4.840	-4.871	-4.939	-5.008	-5.184	-5.358	
0.9	-4.255	-4.258	-4.263	-4.268	-4.282	-4.298	-4.333	-4.371	-4.450	-4.530	-4.727	-4.916	
0.93	-3.937	-3.940	-3.945	-3.951	-3.968	-3.987	-4.029	-4.073	-4.163	-4.251	-4.463	-4.662	
0.95	-3.713	-3.717	-3.723	-3.730	-3.750	-3.773	-3.822	-3.873	-3.972	-4.068	-4.291	-4.498	
0.97	-3.467	-3.473	-3.482	-3.492	-3.521	-3.551	-3.611	-3.670	-3.782	-3.886	-4.122	-4.336	
0.98	-3.327	-3.337	-3.349	-3.363	-3.399	-3.434	-3.503	-3.568	-3.686	-3.795	-4.039	-4.257	
0.99	-3.164	-3.183	-3.203	-3.222	-3.270	-3.313	-3.392	-3.464	-3.591	-3.705	-3.956	-4.178	
1	-2.952	-2.997	-3.033	-3.065	-3.131	-3.186	-3.279	-3.355	-3.495	-3.615	-3.874	-4.100	
1.01	-2.595	-2.743	-2.824	-2.880	-2.979	-3.051	-3.162	-3.251	-3.399	-3.525	-3.792	-4.023	
1.02	-1.723	-2.326	-2.537	-2.650	-2.809	-2.906	-3.041	-3.142	-3.303	-3.435	-3.711	-3.947	
1.03	-0.978	-1.630	-2.108	-2.345	-2.612	-2.748	-2.915	-3.031	-3.206	-3.346	-3.631	-3.871	
1.05	-0.878	-0.835	-1.113	-1.496	-2.110	-2.381	-2.645	-2.800	-3.010	-3.167	-3.473	-3.722	
1.1	-0.673	-0.662	-0.631	-0.617	-0.854	-1.261	-1.853	-2.167	-2.507	-2.720	-3.086	-3.362	
1.15	-0.503	-0.509	-0.502	-0.487	-0.474	-0.604	-1.083	-1.497	-1.990	-2.275	-2.713	-3.019	
1.2	-0.381	-0.388	-0.388	-0.381	-0.353	-0.361	-0.591	-0.934	-1.489	-1.840	-2.355	-2.692	
1.3	-0.218	-0.221	-0.221	-0.218	-0.200	-0.178	-0.182	-0.300	-0.693	-1.066	-1.691	-2.086	
1.4	-0.115	-0.115	-0.112	-0.108	-0.092	-0.070	-0.034	-0.044	-0.228	-0.504	-1.117	-1.547	
1.5	-0.046	-0.042	-0.038	-0.032	-0.014	0.008	0.052	0.078	0.023	-0.142	-0.654	-1.080	
1.6	0.004	0.009	0.016	0.023	0.043	0.065	0.113	0.151	0.163	0.082	-0.299	-0.689	
1.7	0.040	0.047	0.055	0.063	0.085	0.109	0.158	0.202	0.248	0.223	-0.036	-0.369	
1.8	0.067	0.076	0.084	0.094	0.117	0.143	0.194	0.241	0.306	0.317	0.157	-0.112	
1.9	0.088	0.098	0.107	0.117	0.143	0.169	0.221	0.271	0.347	0.381	0.299	0.092	
2	0.105	0.115	0.125	0.136	0.163	0.190	0.244	0.295	0.379	0.428	0.406	0.255	
2.25	0.133	0.145	0.156	0.168	0.197	0.227	0.284	0.338	0.433	0.505	0.578	0.534	
2.5	0.150	0.163	0.176	0.188	0.219	0.250	0.310	0.367	0.469	0.552	0.678	0.704	
2.75	0.162	0.175	0.189	0.202	0.234	0.266	0.328	0.387	0.494	0.585	0.744	0.817	
3	0.170	0.184	0.198	0.211	0.245	0.278	0.342	0.403	0.514	0.611	0.793	0.899	
3.5	0.181	0.196	0.210	0.224	0.260	0.294	0.361	0.425	0.544	0.650	0.864	1.015	
4	0.188	0.203	0.218	0.233	0.27	0.306	0.375	0.442	0.567	0.68	0.917	1.097	
5	0.198	0.214	0.229	0.245	0.283	0.321	0.395	0.466	0.601	0.726	0.997	1.219	

**TABLE C.5** Values for  $\left[ \frac{s_{T_r} p_r - s_{T_r}^{\text{ideal gas}}}{R} \right]^{(0)}$

$T_r$	$p_r$	0.01	0.025	0.05	0.075	0.1	0.25	0.5	0.6	0.7	0.8	0.9	1	1.1	
0.3	-11.613	-10.699	-10.008	-9.605	-9.319	-8.417	-7.747	-7.574	-7.429	-7.304	-7.196	-7.099	-7.013	-6.976	
0.35	-11.185	-10.270	-9.579	-9.176	-8.890	-7.986	-7.314	-7.140	-6.995	-6.869	-6.760	-6.663	-6.576	-6.500	
0.4	-10.802	-9.887	-9.196	-8.792	-8.506	-7.602	-6.929	-6.755	-6.608	-6.483	-6.373	-6.275	-6.188	-6.094	
0.45	-10.453	-9.538	-8.847	-8.443	-8.158	-7.253	-6.579	-6.405	-6.258	-6.132	-6.022	-5.924	-5.837	-5.746	
0.5	-10.137	-9.222	-8.531	-8.127	-7.842	-6.937	-6.263	-6.089	-5.942	-5.816	-5.706	-5.608	-5.520	-5.432	
0.55	-0.038	-8.936	-8.245	-7.841	-7.555	-6.651	-5.978	-5.803	-5.657	-5.531	-5.421	-5.324	-5.236	-5.145	
0.6	-0.029	-0.075	-0.059	-0.053	-0.053	-0.391	-0.579	-0.571	-0.544	-0.539	-0.523	-0.513	-0.497	-0.481	
0.65	-0.023	-0.059	-0.122	-0.122	-0.122	-0.150	-0.5479	-0.5306	-0.5161	-0.5036	-0.4927	-0.4830	-0.4743	-0.4656	
0.7	-0.018	-0.047	-0.096	-0.149	-0.206	-0.222	-0.5254	-0.5082	-0.4938	-0.4814	-0.4706	-0.4610	-0.4524	-0.4438	
0.75	-0.015	-0.038	-0.078	-0.120	-0.164	-0.200	-0.5036	-0.4866	-0.4723	-0.4600	-0.4494	-0.4399	-0.4314	-0.4228	
0.8	-0.013	-0.032	-0.064	-0.098	-0.134	-0.188	-0.390	-0.4817	-0.4649	-0.4508	-0.4388	-0.4283	-0.4191	-0.4108	-0.4025
0.85	-0.011	-0.027	-0.054	-0.082	-0.111	-0.182	-0.312	-0.4581	-0.4418	-0.4282	-0.4166	-0.4065	-0.3976	-0.3897	-0.3798
0.9	-0.009	-0.023	-0.046	-0.069	-0.094	-0.158	-0.257	-0.648	-0.615	-0.5919	-0.5912	-0.5820	-0.5738	-0.5655	-0.5573
0.93	-0.008	-0.021	-0.042	-0.063	-0.085	-0.151	-0.231	-0.5556	-0.5231	-0.5006	-0.4785	-0.4641	-0.4569	-0.4493	-0.4418
0.95	-0.008	-0.019	-0.039	-0.059	-0.080	-0.148	-0.215	-0.5058	-0.5058	-0.5058	-0.4897	-0.4756	-0.4643	-0.4533	-0.4453
0.97	-0.007	-0.018	-0.037	-0.056	-0.075	-0.148	-0.202	-0.467	-0.607	-0.787	-1.056	-3.286	-3.259	-3.224	-3.197
0.98	-0.007	-0.018	-0.036	-0.054	-0.073	-0.195	-0.449	-0.580	-0.743	-0.971	-3.116	-3.142	-3.129	-3.105	-3.078
0.99	-0.007	-0.017	-0.035	-0.053	-0.071	-0.189	-0.432	-0.555	-0.705	-0.903	-1.228	-2.972	-3.011	-3.053	-3.095
1	-0.007	-0.017	-0.034	-0.051	-0.069	-0.183	-0.416	-0.532	-0.671	-0.847	-1.104	-2.167	-2.846	-3.378	-3.745
1.01	-0.007	-0.016	-0.033	-0.050	-0.067	-0.178	-0.401	-0.510	-0.640	-0.799	-1.015	-1.391	-2.535	-3.224	-3.978
1.02	-0.006	-0.016	-0.032	-0.049	-0.065	-0.172	-0.386	-0.449	-0.580	-0.743	-0.945	-1.225	-1.850	-2.575	-3.224
1.03	-0.006	-0.015	-0.031	-0.047	-0.063	-0.167	-0.373	-0.432	-0.555	-0.705	-0.903	-1.228	-2.972	-3.011	-3.053
1.05	-0.006	-0.015	-0.030	-0.045	-0.060	-0.158	-0.349	-0.439	-0.540	-0.656	-0.945	-1.194	-1.493	-2.045	-2.745
1.1	-0.005	-0.013	-0.026	-0.039	-0.053	-0.138	-0.298	-0.371	-0.450	-0.537	-0.633	-0.742	-0.867	-1.095	-1.493
1.15	-0.005	-0.011	-0.023	-0.035	-0.047	-0.121	-0.258	-0.319	-0.383	-0.452	-0.527	-0.607	-0.695	-0.845	-1.095
1.2	-0.004	-0.010	-0.021	-0.031	-0.042	-0.107	-0.226	-0.277	-0.331	-0.389	-0.449	-0.512	-0.580	-0.735	-0.985
1.3	-0.003	-0.008	-0.017	-0.025	-0.033	-0.086	-0.178	-0.217	-0.257	-0.298	-0.341	-0.385	-0.431	-0.535	-0.735
1.4	-0.003	-0.007	-0.017	-0.021	-0.027	-0.070	-0.144	-0.174	-0.205	-0.237	-0.270	-0.303	-0.337	-0.435	-0.635
1.5	-0.002	-0.006	-0.011	-0.017	-0.023	-0.058	-0.118	-0.143	-0.168	-0.194	-0.220	-0.246	-0.272	-0.370	-0.570
1.6	-0.002	-0.005	-0.010	-0.015	-0.019	-0.049	-0.099	-0.120	-0.141	-0.162	-0.183	-0.204	-0.225	-0.323	-0.523
1.7	-0.002	-0.004	-0.008	-0.012	-0.017	-0.042	-0.085	-0.102	-0.119	-0.137	-0.154	-0.172	-0.190	-0.288	-0.488
1.8	-0.001	-0.004	-0.007	-0.011	-0.014	-0.036	-0.073	-0.088	-0.102	-0.117	-0.132	-0.147	-0.162	-0.262	-0.462
1.9	-0.001	-0.003	-0.006	-0.009	-0.013	-0.032	-0.063	-0.076	-0.089	-0.102	-0.115	-0.127	-0.140	-0.240	-0.440
2	-0.001	-0.003	-0.006	-0.008	-0.011	-0.028	-0.056	-0.067	-0.078	-0.089	-0.100	-0.111	-0.123	-0.238	-0.438
2.25	-0.001	-0.002	-0.004	-0.006	-0.008	-0.021	-0.041	-0.050	-0.058	-0.066	-0.074	-0.083	-0.091	-0.208	-0.408
2.5	-0.001	-0.002	-0.003	-0.005	-0.006	-0.016	-0.032	-0.038	-0.045	-0.051	-0.057	-0.064	-0.070	-0.180	-0.380
2.75	-0.001	-0.001	-0.003	-0.004	-0.005	-0.013	-0.026	-0.031	-0.036	-0.041	-0.046	-0.050	-0.055	-0.158	-0.358
3	0.000	-0.001	-0.002	-0.003	-0.004	-0.010	-0.021	-0.025	-0.029	-0.033	-0.037	-0.041	-0.045	-0.145	-0.345
3.5	0.000	-0.001	-0.001	-0.002	-0.003	-0.007	-0.015	-0.020	-0.023	-0.026	-0.031	-0.036	-0.041	-0.136	-0.336
4	0.000	-0.001	-0.001	-0.002	-0.002	-0.005	-0.011	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	-0.126	-0.326
5	0.000	0.000	-0.001	-0.001	-0.001	-0.003	-0.007	-0.008	-0.009	-0.010	-0.012	-0.013	-0.014	-0.114	-0.314

$P_r$	1.2	1.3	1.4	1.5	1.75	2	2.5	3	4	5	7.5	10
0.3	-6.935	-6.864	-6.799	-6.740	-6.608	-6.497	-6.319	-6.182	-5.983	-5.847	-5.657	-5.578
0.35	-6.497	-6.426	-6.360	-6.299	-6.165	-6.052	-5.870	-5.728	-5.521	-5.376	-5.163	-5.060
0.4	-6.109	-6.036	-5.970	-5.909	-5.774	-5.660	-5.475	-5.330	-5.117	-4.967	-4.738	-4.619
0.45	-5.757	-5.685	-5.618	-5.557	-5.421	-5.306	-5.120	-4.974	-4.757	-4.603	-4.364	-4.234
0.5	-5.441	-5.368	-5.302	-5.240	-5.05	-4.989	-4.802	-4.656	-4.438	-4.282	-4.036	-3.899
0.55	-5.157	-5.084	-5.018	-4.956	-4.821	-4.706	-4.519	-4.373	-4.154	-3.998	-3.750	-3.607
0.6	-4.900	-4.828	-4.762	-4.700	-4.566	-4.451	-4.266	-4.120	-3.902	-3.747	-3.498	-3.353
0.65	-4.665	-4.593	-4.527	-4.467	-4.333	-4.220	-4.036	-3.892	-3.677	-3.523	-3.276	-3.131
0.7	-4.446	-4.375	-4.310	-4.250	-4.118	-4.007	-3.826	-3.684	-3.473	-3.322	-3.079	-2.935
0.75	-4.238	-4.168	-4.104	-4.046	-3.916	-3.807	-3.630	-3.491	-3.286	-3.138	-2.902	-2.761
0.8	-4.034	-3.966	-3.904	-3.846	-3.721	-3.615	-3.444	-3.310	-3.112	-2.970	-2.741	-2.605
0.85	-3.825	-3.760	-3.701	-3.646	-3.526	-3.425	-3.262	-3.135	-2.947	-2.812	-2.594	-2.463
0.9	-3.599	-3.539	-3.484	-3.434	-3.324	-3.231	-3.081	-2.963	-2.789	-2.663	-2.458	-2.334
0.93	-3.444	-3.390	-3.341	-3.295	-3.194	-3.108	-3.018	-2.969	-2.860	-2.696	-2.577	-2.381
0.95	-3.326	-3.279	-3.235	-3.193	-3.102	-3.023	-2.893	-2.790	-2.634	-2.520	-2.331	-2.215
0.97	-3.188	-3.151	-3.115	-3.081	-3.002	-2.932	-2.814	-2.719	-2.572	-2.463	-2.283	-2.170
0.98	-3.106	-3.078	-3.049	-3.019	-2.949	-2.884	-2.774	-2.682	-2.541	-2.436	-2.259	-2.148
0.99	-3.010	-2.995	-2.975	-2.953	-2.893	-2.835	-2.732	-2.646	-2.510	-2.405	-2.235	-2.126
1	-2.893	-2.900	-2.893	-2.879	-2.834	-2.784	-2.690	-2.609	-2.479	-2.380	-2.211	-2.105
1.01	-2.736	-2.785	-2.799	-2.798	-2.770	-2.730	-2.647	-2.571	-2.448	-2.352	-2.188	-2.083
1.02	-2.495	-2.639	-2.688	-2.706	-2.702	-2.673	-2.602	-2.533	-2.416	-2.325	-2.165	-2.062
1.03	-2.122	-2.441	-2.552	-2.599	-2.628	-2.614	-2.556	-2.494	-2.385	-2.297	-2.142	-2.042
1.05	-1.523	-1.915	-2.185	-2.328	-2.457	-2.483	-2.461	-2.415	-2.322	-2.242	-2.097	-2.001
1.1	-1.012	-1.180	-1.368	-1.557	-1.908	-2.081	-2.191	-2.202	-2.159	-2.104	-1.987	-1.903
1.15	-0.790	-0.894	-1.007	-1.126	-1.421	-1.649	-1.885	-1.968	-1.992	-1.966	-1.881	-1.810
1.2	-0.651	-0.727	-0.807	-0.890	-1.106	-1.308	-1.587	-1.727	-1.820	-1.827	-1.777	-1.722
1.3	-0.478	-0.527	-0.576	-0.628	-0.759	-0.891	-1.127	-1.299	-1.484	-1.554	-1.580	-1.556
1.4	-0.372	-0.407	-0.442	-0.478	-0.570	-0.663	-0.839	-0.990	-1.194	-1.303	-1.394	-1.402
1.5	-0.299	-0.326	-0.353	-0.381	-0.450	-0.520	-0.654	-0.777	-0.967	-1.088	-1.223	-1.260
1.6	-0.247	-0.268	-0.290	-0.312	-0.367	-0.421	-0.528	-0.628	-0.794	-0.913	-1.071	-1.130
1.7	-0.208	-0.225	-0.243	-0.261	-0.306	-0.350	-0.437	-0.519	-0.662	-0.773	-0.938	-1.013
1.8	-0.177	-0.192	-0.207	-0.222	-0.259	-0.296	-0.369	-0.438	-0.561	-0.661	-0.824	-0.908
1.9	-0.153	-0.166	-0.179	-0.191	-0.223	-0.255	-0.316	-0.375	-0.481	-0.570	-0.726	-0.815
2	-0.134	-0.145	-0.156	-0.167	-0.194	-0.221	-0.274	-0.325	-0.417	-0.497	-0.644	-0.733
2.25	-0.099	-0.107	-0.115	-0.123	-0.143	-0.162	-0.200	-0.237	-0.305	-0.366	-0.486	-0.570
2.5	-0.076	-0.082	-0.088	-0.094	-0.109	-0.124	-0.153	-0.181	-0.233	-0.281	-0.379	-0.453
2.75	-0.060	-0.065	-0.070	-0.075	-0.087	-0.098	-0.121	-0.143	-0.184	-0.222	-0.303	-0.367
3	-0.049	-0.053	-0.057	-0.061	-0.070	-0.080	-0.098	-0.116	-0.150	-0.181	-0.248	-0.303
3.5	-0.034	-0.037	-0.040	-0.042	-0.049	-0.056	-0.068	-0.081	-0.104	-0.126	-0.175	-0.216
4	-0.025	-0.027	-0.029	-0.031	-0.036	-0.041	-0.050	-0.059	-0.077	-0.093	-0.130	-0.162
5	-0.015	-0.017	-0.018	-0.019	-0.022	-0.025	-0.031	-0.036	-0.047	-0.057	-0.080	-0.100

**TABLE C.6** Values for  $\left[ \frac{s_{T_r P_r} - s_{T_r P_r}^{\text{ideal gas}}}{R} \right]^{(1)}$

$T_r$	$P_r$	0.01	0.025	0.05	0.075	0.1	0.25	0.5	0.6	0.7	0.8	0.9	1	1.1
0.3	-16.790	-16.787	-16.783	-16.778	-16.773	-16.744	-16.695	-16.675	-16.656	-16.637	-16.617	-16.598	-16.578	
0.35	-15.408	-15.406	-15.402	-15.399	-15.395	-15.375	-15.341	-15.328	-15.314	-15.301	-15.288	-15.274	-15.261	
0.4	-13.989	-13.987	-13.985	-13.983	-13.980	-13.966	-13.942	-13.932	-13.923	-13.914	-13.904	-13.895	-13.885	
0.45	-12.562	-12.561	-12.559	-12.557	-12.556	-12.545	-12.528	-12.521	-12.514	-12.508	-12.501	-12.494	-12.488	
0.5	-11.201	-11.200	-11.198	-11.197	-11.196	-11.188	-11.176	-11.171	-11.166	-11.161	-11.156	-11.151	-11.146	
0.55	-0.115	-0.950	-0.949	-0.948	-0.947	-0.941	-0.932	-0.928	-0.924	-0.921	-0.917	-0.914	-0.910	
0.6	-0.078	-0.207	-0.828	-0.827	-0.822	-0.812	-0.814	-0.811	-0.808	-0.806	-0.803	-0.800	-0.798	
0.65	-0.055	-0.143	-0.309	-0.833	-0.832	-0.782	-0.782	-0.7819	-0.7815	-0.7812	-0.7810	-0.7808		
0.7	-0.040	-0.102	-0.216	-0.343	-0.491	-0.6949	-0.6943	-0.6941	-0.6939	-0.6937	-0.6935	-0.6933	-0.6932	
0.75	-0.029	-0.075	-0.156	-0.244	-0.340	-0.6172	-0.6165	-0.6160	-0.6158	-0.6156	-0.6155	-0.6153		
0.8	-0.022	-0.056	-0.116	-0.179	-0.246	-0.812	-0.5471	-0.5467	-0.5465	-0.5462	-0.5460	-0.5458	-0.5456	
0.85	-0.017	-0.043	-0.088	-0.135	-0.183	-0.545	-0.846	-0.841	-0.836	-0.832	-0.829	-0.826	-0.824	
0.9	-0.013	-0.033	-0.068	-0.103	-0.140	-0.392	-1.137	-4.269	-4.258	-4.250	-4.243	-4.238	-4.235	
0.93	-0.011	-0.029	-0.058	-0.089	-0.120	-0.328	-0.834	-1.219	-3.933	-3.914	-3.902	-3.893	-3.888	
0.95	-0.010	-0.026	-0.053	-0.081	-0.109	-0.293	-0.706	-0.961	-1.418	-3.697	-3.672	-3.658	-3.650	
0.97	-0.010	-0.024	-0.048	-0.073	-0.099	-0.263	-0.609	-0.797	-1.055	-1.570	-3.438	-3.406	-3.394	
0.98	-0.009	-0.023	-0.046	-0.070	-0.094	-0.250	-0.569	-0.734	-0.946	-1.270	-3.337	-3.264	-3.248	
0.99	-0.009	-0.022	-0.044	-0.067	-0.090	-0.237	-0.533	-0.680	-0.859	-1.098	-1.556	-1.556	-3.093	
1	-0.008	-0.021	-0.042	-0.064	-0.086	-0.225	-0.500	-0.632	-0.787	-0.977	-1.242	-2.311	-2.810	
1.01	-0.008	-0.020	-0.040	-0.061	-0.082	-0.214	-0.470	-0.590	-0.726	-0.883	-1.074	-1.306	-1.795	
1.02	-0.008	-0.019	-0.039	-0.058	-0.078	-0.204	-0.443	-0.552	-0.673	-0.807	-0.958	-1.113	-1.015	
1.03	-0.007	-0.018	-0.037	-0.056	-0.075	-0.194	-0.418	-0.518	-0.627	-0.744	-0.868	-0.989	-1.017	
1.05	-0.007	-0.017	-0.034	-0.051	-0.069	-0.177	-0.374	-0.460	-0.549	-0.642	-0.735	-0.820	-0.872	
1.1	-0.005	-0.014	-0.028	-0.041	-0.055	-0.141	-0.289	-0.350	-0.411	-0.470	-0.527	-0.577	-0.617	
1.15	-0.005	-0.011	-0.023	-0.034	-0.045	-0.114	-0.229	-0.275	-0.319	-0.361	-0.401	-0.437	-0.467	
1.2	-0.004	-0.009	-0.019	-0.028	-0.037	-0.094	-0.185	-0.220	-0.254	-0.286	-0.316	-0.343	-0.366	
1.3	-0.003	-0.007	-0.013	-0.020	-0.026	-0.065	-0.125	-0.148	-0.170	-0.190	-0.209	-0.226	-0.241	
1.4	-0.002	-0.005	-0.010	-0.014	-0.019	-0.046	-0.089	-0.104	-0.119	-0.133	-0.146	-0.158	-0.168	
1.5	-0.001	-0.004	-0.007	-0.011	-0.014	-0.034	-0.065	-0.076	-0.087	-0.097	-0.106	-0.115	-0.123	
1.6	-0.001	-0.003	-0.005	-0.008	-0.011	-0.026	-0.049	-0.057	-0.065	-0.073	-0.080	-0.086	-0.092	
1.7	-0.001	-0.002	-0.004	-0.006	-0.008	-0.020	-0.038	-0.044	-0.050	-0.056	-0.061	-0.067	-0.071	
1.8	0.001	-0.002	-0.003	-0.005	-0.006	-0.016	-0.030	-0.035	-0.040	-0.044	-0.049	-0.053	-0.057	
1.9	0.001	-0.001	-0.003	-0.004	-0.005	-0.013	-0.024	-0.028	-0.032	-0.036	-0.039	-0.043	-0.046	
2	0.000	-0.001	-0.002	-0.003	-0.004	-0.011	-0.019	-0.023	-0.026	-0.029	-0.032	-0.035	-0.038	
2.25	0.000	-0.001	-0.001	-0.002	-0.003	-0.007	-0.013	-0.015	-0.017	-0.019	-0.021	-0.023	-0.025	
2.5	0.000	0.000	-0.001	-0.001	-0.002	-0.005	-0.010	-0.012	-0.014	-0.015	-0.017	-0.018	-0.018	
2.75	0.000	0.000	-0.001	-0.001	-0.001	-0.003	-0.007	-0.008	-0.009	-0.010	-0.012	-0.013	-0.014	
3	0.000	0.000	-0.001	-0.001	-0.001	-0.003	-0.005	-0.006	-0.007	-0.008	-0.009	-0.010	-0.011	
3.5	0.000	0.000	0.000	-0.001	-0.001	-0.002	-0.004	-0.004	-0.005	-0.006	-0.007	-0.008	-0.008	
4	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.003	-0.003	-0.004	-0.005	-0.006	-0.006	-0.006	
5	0.000	0.000	0.000	0.000	0.000	-0.001	-0.002	-0.002	-0.003	-0.003	-0.004	-0.004	-0.004	

$T_r$	$P_r$	1.2	1.3	1.4	1.5	1.75	2	2.5	3	4	5	7.5	10
0.3	-16.559	-16.540	-16.521	-16.501	-16.453	-16.405	-16.310	-16.214	-16.025	-15.838	-15.377	-14.927	
0.35	-15.248	-15.234	-15.221	-15.208	-15.175	-15.142	-15.077	-15.012	-14.884	-14.757	-14.450	-14.154	
0.4	-13.876	-13.867	-13.858	-13.848	-13.825	-13.803	-13.757	-13.713	-13.626	-13.540	-13.337	-13.144	
0.45	-12.481	-12.475	-12.468	-12.461	-12.445	-12.429	-12.398	-12.367	-12.308	-12.251	-12.119	-11.998	
0.5	-11.142	-11.137	-11.132	-11.128	-11.116	-11.105	-11.083	-11.063	-11.023	-10.986	-10.905	-10.836	
0.55	-9.907	-9.903	-9.900	-9.897	-9.889	-9.881	-9.866	-9.853	-9.828	-9.806	-9.763	-9.732	
0.6	-8.795	-8.793	-8.790	-8.788	-8.783	-8.777	-8.768	-8.759	-8.746	-8.735	-8.721	-8.720	
0.65	-7.807	-7.805	-7.803	-7.801	-7.798	-7.794	-7.789	-7.784	-7.779	-7.778	-7.788	-7.811	
0.7	-6.930	-6.929	-6.928	-6.926	-6.924	-6.922	-6.919	-6.919	-6.921	-6.928	-6.959	-7.002	
0.75	-6.152	-6.151	-6.150	-6.149	-6.147	-6.146	-6.147	-6.149	-6.150	-6.174	-6.224	-6.285	
0.8	-5.455	-5.454	-5.453	-5.452	-5.452	-5.452	-5.455	-5.461	-5.478	-5.501	-5.570	-5.648	
0.85	-4.822	-4.821	-4.820	-4.820	-4.820	-4.822	-4.828	-4.839	-4.866	-4.898	-5.083	-5.083	
0.9	-4.232	-4.231	-4.230	-4.230	-4.232	-4.236	-4.250	-4.267	-4.307	-4.351	-4.465	-4.578	
0.93	-3.885	-3.883	-3.883	-3.883	-3.886	-3.896	-3.917	-3.941	-3.993	-4.046	-4.177	-4.300	
0.95	-3.647	-3.646	-3.646	-3.648	-3.657	-3.669	-3.697	-3.728	-3.790	-3.851	-3.994	-4.125	
0.97	-3.391	-3.392	-3.396	-3.401	-3.418	-3.437	-3.477	-3.517	-3.592	-3.661	-3.818	-3.957	
0.98	-3.247	-3.252	-3.259	-3.268	-3.293	-3.318	-3.366	-3.412	-3.494	-3.569	-3.732	-3.875	
0.99	-3.082	-3.096	-3.111	-3.126	-3.162	-3.195	-3.254	-3.306	-3.397	-3.477	-3.648	-3.795	
1	-2.868	-2.908	-2.940	-2.967	-3.022	-3.067	-3.140	-3.200	-3.301	-3.387	-3.565	-3.717	
1.01	-2.513	-2.657	-2.732	-2.784	-2.871	-2.933	-3.024	-3.094	-3.206	-3.297	-3.484	-3.640	
1.02	-1.655	-2.246	-2.450	-2.557	-2.703	-2.790	-2.904	-2.986	-3.110	-3.209	-3.405	-3.565	
1.03	-0.927	-1.567	-2.031	-2.259	-2.512	-2.636	-2.781	-2.878	-3.016	-3.121	-3.326	-3.492	
1.05	-0.831	-0.800	-1.073	-1.443	-2.030	-2.283	-2.522	-2.655	-2.827	-2.949	-3.174	-3.348	
1.1	-0.640	-0.639	-0.620	-0.618	-0.857	-1.241	-1.786	-2.067	-2.360	-2.534	-2.814	-3.013	
1.15	-0.489	-0.502	-0.506	-0.502	-0.518	-0.654	-1.100	-1.471	-1.900	-2.138	-2.483	-2.708	
1.2	-0.385	-0.399	-0.408	-0.412	-0.415	-0.447	-0.680	-0.991	-1.473	-1.767	-2.178	-2.430	
1.3	-0.254	-0.265	-0.275	-0.282	-0.292	-0.300	-0.351	-0.481	-0.835	-1.147	-1.646	-1.944	
1.4	-0.178	-0.186	-0.194	-0.200	-0.212	-0.220	-0.240	-0.290	-0.488	-0.730	-1.220	-1.544	
1.5	-0.130	-0.136	-0.142	-0.147	-0.158	-0.166	-0.181	-0.206	-0.315	-0.479	-0.900	-1.222	
1.6	-0.098	-0.103	-0.108	-0.112	-0.121	-0.129	-0.142	-0.159	-0.224	-0.334	-0.671	-0.969	
1.7	-0.076	-0.080	-0.084	-0.087	-0.095	-0.102	-0.114	-0.127	-0.173	-0.248	-0.511	-0.775	
1.8	-0.060	-0.064	-0.067	-0.070	-0.077	-0.083	-0.094	-0.105	-0.140	-0.195	-0.401	-0.628	
1.9	-0.049	-0.052	-0.054	-0.057	-0.063	-0.069	-0.079	-0.089	-0.117	-0.160	-0.323	-0.518	
2	-0.040	-0.043	-0.045	-0.048	-0.053	-0.058	-0.067	-0.077	-0.101	-0.136	-0.269	-0.434	
2.25	-0.027	-0.029	-0.031	-0.032	-0.036	-0.040	-0.048	-0.056	-0.075	-0.100	-0.187	-0.302	
2.5	-0.020	-0.021	-0.022	-0.024	-0.027	-0.031	-0.037	-0.044	-0.060	-0.080	-0.145	-0.230	
2.75	-0.015	-0.016	-0.017	-0.019	-0.021	-0.024	-0.030	-0.037	-0.050	-0.067	-0.120	-0.187	
3	-0.012	-0.013	-0.014	-0.015	-0.018	-0.020	-0.026	-0.031	-0.044	-0.058	-0.103	-0.158	
3.5	-0.009	-0.010	-0.011	-0.013	-0.015	-0.019	-0.024	-0.034	-0.046	-0.081	-0.122	-0.122	
4	-0.007	-0.008	-0.009	-0.010	-0.012	-0.016	-0.020	-0.028	-0.038	-0.066	-0.100	-0.100	
5	-0.005	-0.005	-0.006	-0.006	-0.007	-0.009	-0.011	-0.020	-0.028	-0.048	-0.073	-0.073	

**TABLE C.7** Values for  $\log[\varphi^{(0)}]$

$T_r$	$P_r$	0.01	0.025	0.05	0.075	0.1	0.25	0.5	0.6	0.7	0.8	0.9	1	1.1
0.3	-3.708	-4.104	-4.402	-4.575	-4.697	-5.076	-5.346	-5.412	-5.467	-5.512	-5.551	-5.584	-5.613	
0.35	-2.472	-2.868	-3.166	-3.339	-3.461	-3.842	-4.115	-4.183	-4.239	-4.285	-4.325	-4.359	-4.390	
0.4	-1.566	-1.962	-2.261	-2.434	-2.557	-2.939	-3.214	-3.283	-3.340	-3.387	-3.428	-3.464	-3.495	
0.45	-0.879	-1.276	-1.574	-1.748	-1.871	-2.254	-2.531	-2.601	-2.658	-2.707	-2.748	-2.784	-2.816	
0.5	-0.344	-0.741	-1.040	-1.214	-1.336	-1.721	-1.999	-2.070	-2.128	-2.177	-2.219	-2.256	-2.288	
0.55	-0.008	-0.315	-0.614	-0.788	-0.911	-1.296	-1.576	-1.647	-1.705	-1.755	-1.798	-1.835	-1.868	
0.6	-0.007	-0.016	-0.269	-0.443	-0.566	-0.952	-1.233	-1.304	-1.363	-1.413	-1.456	-1.494	-1.527	
0.65	-0.005	-0.013	-0.026	-0.160	-0.283	-0.670	-0.951	-1.023	-1.082	-1.132	-1.176	-1.214	-1.248	
0.7	-0.004	-0.010	-0.021	-0.032	-0.043	-0.435	-0.717	-0.789	-0.848	-0.899	-0.942	-0.981	-1.015	
0.75	-0.003	-0.009	-0.017	-0.026	-0.035	-0.237	-0.520	-0.592	-0.652	-0.703	-0.746	-0.785	-0.819	
0.8	-0.003	-0.007	-0.014	-0.021	-0.029	-0.076	-0.354	-0.426	-0.486	-0.537	-0.581	-0.619	-0.654	
0.85	-0.002	-0.006	-0.012	-0.018	-0.024	-0.062	-0.213	-0.285	-0.345	-0.396	-0.440	-0.479	-0.513	
0.9	-0.002	-0.005	-0.010	-0.015	-0.020	-0.052	-0.111	-0.166	-0.225	-0.276	-0.320	-0.359	-0.393	
0.93	-0.002	-0.005	-0.009	-0.014	-0.018	-0.047	-0.099	-0.122	-0.163	-0.214	-0.258	-0.296	-0.330	
0.95	-0.002	-0.004	-0.008	-0.013	-0.017	-0.044	-0.092	-0.113	-0.136	-0.176	-0.220	-0.258	-0.292	
0.97	-0.002	-0.004	-0.008	-0.012	-0.016	-0.041	-0.086	-0.105	-0.126	-0.148	-0.185	-0.223	-0.256	
0.98	-0.002	-0.004	-0.008	-0.012	-0.016	-0.040	-0.083	-0.101	-0.121	-0.142	-0.168	-0.206	-0.240	
0.99	-0.001	-0.004	-0.007	-0.011	-0.015	-0.038	-0.080	-0.098	-0.117	-0.137	-0.159	-0.191	-0.224	
1	-0.001	-0.004	-0.007	-0.011	-0.015	-0.037	-0.077	-0.095	-0.113	-0.132	-0.152	-0.176	-0.209	
1.01	-0.001	-0.004	-0.007	-0.011	-0.014	-0.036	-0.075	-0.091	-0.109	-0.127	-0.146	-0.168	-0.195	
1.02	-0.001	-0.003	-0.007	-0.010	-0.014	-0.035	-0.073	-0.088	-0.105	-0.122	-0.141	-0.161	-0.184	
1.03	-0.001	-0.003	-0.007	-0.010	-0.013	-0.034	-0.070	-0.086	-0.101	-0.118	-0.136	-0.154	-0.175	
1.05	-0.001	-0.003	-0.006	-0.009	-0.013	-0.032	-0.066	-0.080	-0.095	-0.110	-0.126	-0.143	-0.161	
1.1	-0.001	-0.003	-0.005	-0.008	-0.011	-0.028	-0.057	-0.069	-0.081	-0.093	-0.106	-0.120	-0.133	
1.15	-0.001	-0.002	-0.005	-0.007	-0.009	-0.024	-0.049	-0.059	-0.069	-0.080	-0.091	-0.102	-0.113	
1.2	-0.001	-0.002	-0.004	-0.006	-0.008	-0.021	-0.042	-0.051	-0.060	-0.069	-0.078	-0.088	-0.097	
1.3	-0.001	-0.002	-0.003	-0.006	-0.009	-0.013	-0.032	-0.046	-0.059	-0.066	-0.073	-0.081	-0.090	
1.4	-0.001	-0.001	-0.003	-0.004	-0.005	-0.013	-0.025	-0.030	-0.035	-0.040	-0.046	-0.051	-0.056	
1.5	0.000	-0.001	-0.002	-0.003	-0.004	-0.010	-0.020	-0.024	-0.028	-0.032	-0.035	-0.039	-0.043	
1.6	0.000	-0.001	-0.002	-0.004	-0.006	-0.008	-0.016	-0.019	-0.022	-0.025	-0.028	-0.031	-0.034	
1.7	0.000	-0.001	-0.002	-0.003	-0.005	-0.016	-0.033	-0.039	-0.046	-0.052	-0.059	-0.066	-0.073	
1.8	0.000	0.000	-0.001	-0.001	-0.002	-0.005	-0.010	-0.012	-0.014	-0.015	-0.017	-0.019	-0.021	
1.9	0.000	0.000	-0.001	-0.001	-0.002	-0.004	-0.008	-0.009	-0.011	-0.012	-0.014	-0.015	-0.016	
2	0.000	0.000	-0.001	-0.001	-0.002	-0.003	-0.006	-0.007	-0.008	-0.009	-0.011	-0.012	-0.013	
2.25	0.000	0.000	0.000	0.000	0.000	-0.001	-0.002	-0.003	-0.004	-0.005	-0.005	-0.006	-0.006	
2.5	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	-0.002	-0.002	
2.75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
3	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002	0.002	
3.5	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.003	0.003	0.004	0.004	
4	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.004	0.005	0.005	
5	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.003	0.004	0.005	0.005	0.006	

TABLE C.7 Continued

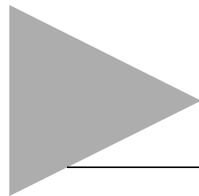
$T_r$	$P_r$	1.2	1.3	1.4	1.5	1.75	2	2.5	3	4	5	7.5	10
0.3	-5.638	-5.660	-5.680	-5.697	-5.733	-5.759	-5.793	-5.810	-5.810	-5.792	-5.647	-5.462	
0.35	-4.416	-4.440	-4.460	-4.479	-4.518	-4.548	-4.588	-4.611	-4.623	-4.608	-4.505	-4.352	
0.4	-3.522	-3.546	-3.568	-3.588	-3.629	-3.661	-3.707	-3.735	-3.757	-3.752	-3.673	-3.545	
0.45	-2.845	-2.870	-2.892	-2.913	-2.956	-2.990	-3.039	-3.071	-3.101	-3.104	-3.046	-2.938	
0.5	-2.317	-2.343	-2.366	-2.387	-2.432	-2.468	-2.520	-2.555	-2.592	-2.601	-2.559	-2.468	
0.55	-1.897	-1.924	-1.947	-1.969	-2.015	-2.052	-2.107	-2.145	-2.187	-2.201	-2.173	-2.095	
0.6	-1.557	-1.584	-1.608	-1.630	-1.677	-1.715	-1.773	-1.812	-1.859	-1.878	-1.861	-1.795	
0.65	-1.278	-1.305	-1.329	-1.352	-1.400	-1.439	-1.498	-1.539	-1.589	-1.612	-1.604	-1.549	
0.7	-1.045	-1.073	-1.097	-1.120	-1.169	-1.208	-1.269	-1.312	-1.365	-1.391	-1.391	-1.344	
0.75	-0.850	-0.877	-0.902	-0.925	-0.974	-1.015	-1.076	-1.121	-1.176	-1.204	-1.212	-1.172	
0.8	-0.684	-0.712	-0.737	-0.760	-0.810	-0.851	-0.913	-0.958	-1.016	-1.046	-1.060	-1.026	
0.85	-0.544	-0.572	-0.597	-0.620	-0.670	-0.711	-0.774	-0.820	-0.879	-0.911	-0.929	-0.901	
0.9	-0.424	-0.452	-0.477	-0.500	-0.550	-0.591	-0.654	-0.700	-0.761	-0.794	-0.817	-0.793	
0.93	-0.361	-0.389	-0.414	-0.437	-0.486	-0.527	-0.591	-0.637	-0.698	-0.732	-0.756	-0.735	
0.95	-0.322	-0.350	-0.375	-0.398	-0.447	-0.488	-0.552	-0.598	-0.659	-0.693	-0.719	-0.699	
0.97	-0.287	-0.314	-0.339	-0.362	-0.411	-0.452	-0.515	-0.561	-0.622	-0.657	-0.683	-0.665	
0.98	-0.270	-0.297	-0.322	-0.344	-0.393	-0.434	-0.497	-0.543	-0.604	-0.639	-0.666	-0.649	
0.99	-0.254	-0.281	-0.305	-0.328	-0.377	-0.417	-0.480	-0.526	-0.587	-0.622	-0.650	-0.633	
1	-0.238	-0.265	-0.289	-0.312	-0.360	-0.401	-0.463	-0.509	-0.570	-0.605	-0.634	-0.617	
1.01	-0.224	-0.250	-0.274	-0.297	-0.345	-0.385	-0.447	-0.493	-0.554	-0.589	-0.618	-0.602	
1.02	-0.210	-0.236	-0.260	-0.282	-0.330	-0.370	-0.432	-0.477	-0.538	-0.573	-0.603	-0.588	
1.03	-0.199	-0.223	-0.246	-0.268	-0.315	-0.355	-0.417	-0.462	-0.523	-0.558	-0.588	-0.573	
1.05	-0.180	-0.201	-0.222	-0.242	-0.288	-0.327	-0.388	-0.433	-0.493	-0.529	-0.559	-0.546	
1.1	-0.148	-0.163	-0.178	-0.193	-0.232	-0.267	-0.324	-0.368	-0.427	-0.462	-0.493	-0.482	
1.15	-0.125	-0.136	-0.148	-0.160	-0.191	-0.220	-0.272	-0.312	-0.369	-0.403	-0.435	-0.426	
1.2	-0.106	-0.116	-0.126	-0.135	-0.160	-0.184	-0.229	-0.266	-0.319	-0.352	-0.384	-0.377	
1.3	-0.080	-0.086	-0.093	-0.100	-0.117	-0.134	-0.167	-0.195	-0.239	-0.269	-0.299	-0.293	
1.4	-0.061	-0.066	-0.071	-0.076	-0.089	-0.101	-0.125	-0.146	-0.181	-0.205	-0.231	-0.226	
1.5	-0.047	-0.051	-0.055	-0.068	-0.077	-0.095	-0.111	-0.138	-0.157	-0.178	-0.173	-0.173	
1.6	-0.037	-0.040	-0.043	-0.046	-0.053	-0.060	-0.073	-0.085	-0.105	-0.120	-0.136	-0.129	
1.7	-0.029	-0.031	-0.033	-0.036	-0.041	-0.046	-0.056	-0.065	-0.081	-0.092	-0.102	-0.094	
1.8	-0.023	-0.024	-0.026	-0.028	-0.032	-0.036	-0.044	-0.050	-0.061	-0.069	-0.075	-0.066	
1.9	-0.018	-0.019	-0.020	-0.022	-0.025	-0.028	-0.033	-0.038	-0.046	-0.052	-0.054	-0.043	
2	-0.014	-0.015	-0.016	-0.017	-0.019	-0.021	-0.025	-0.029	-0.034	-0.037	-0.036	-0.024	
2.25	-0.007	-0.007	-0.008	-0.008	-0.009	-0.010	-0.011	-0.012	-0.013	-0.013	-0.005	0.010	
2.5	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.003	-0.002	0.000	0.003	0.014	0.031	
2.75	0.001	0.001	0.001	0.001	0.001	0.002	0.003	0.004	0.008	0.012	0.026	0.044	
3	0.003	0.003	0.003	0.003	0.004	0.005	0.007	0.009	0.013	0.018	0.034	0.053	
3.5	0.005	0.005	0.006	0.006	0.007	0.008	0.011	0.013	0.019	0.025	0.042	0.061	
4	0.006	0.006	0.007	0.007	0.009	0.010	0.013	0.016	0.022	0.028	0.045	0.064	
5	0.006	0.007	0.007	0.008	0.009	0.011	0.014	0.016	0.022	0.029	0.045	0.062	

**TABLE C.8** Values for  $\log[\varphi^{(1)}]^*$ 

$T_r$	$P_r$	0.01	0.025	0.05	0.075	0.1	0.25	0.5	0.6	0.7	0.8	0.9	1	1.1
0.3	-8.779	-8.779	-8.780	-8.781	-8.782	-8.787	-8.796	-8.799	-8.803	-8.806	-8.810	-8.813	-8.817	
0.35	-6.526	-6.527	-6.528	-6.529	-6.530	-6.536	-6.546	-6.550	-6.554	-6.558	-6.562	-6.566	-6.570	
0.4	-4.912	-4.913	-4.914	-4.915	-4.916	-4.922	-4.932	-4.936	-4.941	-4.945	-4.949	-4.953	-4.957	
0.45	-3.726	-3.726	-3.727	-3.728	-3.729	-3.736	-3.746	-3.750	-3.754	-3.758	-3.762	-3.766	-3.770	
0.5	-2.838	-2.838	-2.839	-2.840	-2.841	-2.847	-2.857	-2.861	-2.865	-2.868	-2.872	-2.876	-2.880	
0.55	-0.013	-2.163	-2.164	-2.165	-2.166	-2.171	-2.181	-2.184	-2.188	-2.192	-2.196	-2.199	-2.203	
0.6	-0.009	-0.023	-1.644	-1.645	-1.646	-1.651	-1.660	-1.664	-1.667	-1.671	-1.674	-1.678	-1.681	
0.65	-0.006	-0.015	-0.031	-1.241	-1.241	-1.247	-1.255	-1.258	-1.262	-1.265	-1.268	-1.272	-1.275	
0.7	-0.004	-0.010	-0.021	-0.032	-0.044	-0.929	-0.937	-0.940	-0.943	-0.946	-0.949	-0.952	-0.955	
0.75	-0.003	-0.007	-0.014	-0.022	-0.030	-0.677	-0.685	-0.688	-0.691	-0.694	-0.697	-0.700	-0.703	
0.8	-0.002	-0.005	-0.010	-0.015	-0.020	-0.056	-0.484	-0.487	-0.490	-0.493	-0.496	-0.498	-0.501	
0.85	-0.001	-0.003	-0.006	-0.010	-0.013	-0.036	-0.324	-0.327	-0.330	-0.332	-0.335	-0.338	-0.341	
0.9	-0.001	-0.002	-0.004	-0.006	-0.009	-0.023	-0.053	-0.053	-0.053	-0.053	-0.053	-0.056	-0.059	
0.93	-0.001	-0.002	-0.002	-0.003	-0.005	-0.007	-0.017	-0.037	-0.048	-0.138	-0.141	-0.143	-0.146	-0.149
0.95	-0.001	-0.001	-0.003	-0.004	-0.005	-0.014	-0.030	-0.037	-0.046	-0.103	-0.106	-0.108	-0.111	
0.97	0.000	-0.001	-0.002	-0.003	-0.004	-0.011	-0.023	-0.029	-0.034	-0.042	-0.042	-0.072	-0.075	
0.98	0.000	-0.001	-0.002	-0.003	-0.004	-0.010	-0.020	-0.025	-0.030	-0.035	-0.035	-0.056	-0.062	
0.99	0.000	-0.001	-0.002	-0.003	-0.003	-0.009	-0.018	-0.021	-0.025	-0.030	-0.034	-0.044	-0.047	
1	0.000	-0.001	-0.001	-0.002	-0.003	-0.008	-0.015	-0.018	-0.022	-0.025	-0.028	-0.031	-0.034	
1.01	0.000	-0.001	-0.001	-0.002	-0.003	-0.007	-0.013	-0.016	-0.018	-0.021	-0.023	-0.024	-0.023	
1.02	0.000	-0.001	-0.001	-0.002	-0.002	-0.006	-0.011	-0.013	-0.015	-0.017	-0.018	-0.019	-0.018	
1.03	0.000	0.000	-0.001	-0.001	-0.002	-0.005	-0.009	-0.011	-0.012	-0.013	-0.014	-0.014	-0.013	
1.05	0.000	0.000	-0.001	-0.001	-0.002	-0.003	-0.008	-0.015	-0.018	-0.022	-0.025	-0.028	-0.031	
1.1	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.004	0.005	0.007	0.009	
1.15	0.000	0.000	0.000	0.001	0.001	0.003	0.006	0.008	0.009	0.011	0.014	0.016	0.019	
1.2	0.000	0.000	0.000	0.001	0.001	0.002	0.004	0.009	0.012	0.014	0.017	0.020	0.023	0.026
1.3	0.000	0.001	0.001	0.001	0.002	0.003	0.007	0.014	0.017	0.020	0.023	0.027	0.030	0.034
1.4	0.000	0.001	0.001	0.002	0.002	0.003	0.008	0.016	0.020	0.023	0.027	0.030	0.034	0.038
1.5	0.000	0.001	0.001	0.002	0.003	0.008	0.017	0.021	0.024	0.028	0.032	0.036	0.039	
1.6	0.000	0.001	0.001	0.002	0.003	0.009	0.018	0.021	0.025	0.029	0.032	0.036	0.040	
1.7	0.000	0.001	0.001	0.002	0.003	0.004	0.009	0.018	0.021	0.025	0.029	0.032	0.036	0.039
1.8	0.000	0.001	0.001	0.002	0.003	0.008	0.018	0.021	0.025	0.028	0.032	0.035	0.039	
1.9	0.000	0.001	0.001	0.002	0.003	0.009	0.017	0.021	0.024	0.028	0.031	0.034	0.038	
2	0.000	0.001	0.001	0.002	0.003	0.008	0.017	0.020	0.024	0.027	0.030	0.034	0.037	
2.25	0.000	0.001	0.001	0.002	0.003	0.008	0.016	0.019	0.022	0.025	0.028	0.031	0.034	
2.5	0.000	0.001	0.001	0.002	0.003	0.007	0.015	0.018	0.020	0.023	0.026	0.029	0.032	
2.75	0.000	0.001	0.001	0.002	0.003	0.007	0.014	0.016	0.019	0.022	0.024	0.027	0.030	
3	0.000	0.001	0.001	0.002	0.003	0.006	0.013	0.015	0.018	0.020	0.023	0.025	0.028	
3.5	0.000	0.001	0.001	0.002	0.003	0.006	0.011	0.013	0.016	0.018	0.020	0.022	0.024	
4	0.000	0.001	0.001	0.002	0.003	0.005	0.010	0.014	0.016	0.018	0.020	0.022	0.024	
5	0.000	0.000	0.000	0.001	0.001	0.002	0.008	0.010	0.013	0.015	0.016	0.016	0.016	

\* Many of these values have a different last decimal place from those published by Lee-Kesler.

$P_r$	1.2	1.3	1.4	1.5	1.75	2	2.5	3	4	5	5	7.5	10
$T_r$	-8.820	-8.824	-8.827	-8.831	-8.840	-8.848	-8.866	-8.883	-8.918	-8.953	-9.039	-9.126	
0.3	-6.574	-6.578	-6.582	-6.586	-6.606	-6.625	-6.645	-6.685	-6.724	-6.822	-6.919		
0.35	-4.961	-4.965	-4.969	-4.973	-4.984	-4.994	-5.014	-5.034	-5.075	-5.115	-5.214	-5.312	
0.4	-3.774	-3.778	-3.782	-3.786	-3.796	-3.806	-3.826	-3.846	-3.885	-3.924	-4.020	-4.115	
0.45	-2.884	-2.888	-2.892	-2.896	-2.905	-2.915	-2.934	-2.953	-2.990	-3.027	-3.119	-3.208	
0.5	-2.207	-2.210	-2.214	-2.218	-2.227	-2.236	-2.254	-2.272	-2.307	-2.342	-2.427	-2.510	
0.55	-1.685	-1.688	-1.692	-1.695	-1.704	-1.712	-1.729	-1.746	-1.779	-1.812	-1.891	-1.967	
0.6	-1.278	-1.281	-1.285	-1.288	-1.296	-1.304	-1.320	-1.336	-1.367	-1.397	-1.470	-1.540	
0.65	-0.959	-0.962	-0.965	-0.968	-0.975	-0.983	-0.998	-1.013	-1.041	-1.069	-1.137	-1.201	
0.7	-0.705	-0.708	-0.711	-0.714	-0.721	-0.728	-0.742	-0.756	-0.783	-0.809	-0.870	-0.929	
0.75	-0.504	-0.507	-0.510	-0.512	-0.519	-0.526	-0.539	-0.551	-0.576	-0.600	-0.656	-0.709	
0.8	-0.343	-0.346	-0.348	-0.351	-0.357	-0.364	-0.376	-0.388	-0.410	-0.432	-0.483	-0.530	
0.85	-0.215	-0.217	-0.220	-0.222	-0.228	-0.234	-0.245	-0.256	-0.277	-0.296	-0.342	-0.384	
0.9	-0.151	-0.154	-0.156	-0.158	-0.164	-0.170	-0.180	-0.191	-0.210	-0.228	-0.270	-0.310	
0.93	-0.114	-0.116	-0.118	-0.121	-0.126	-0.132	-0.142	-0.151	-0.170	-0.187	-0.227	-0.265	
0.95	-0.080	-0.082	-0.084	-0.087	-0.092	-0.097	-0.107	-0.116	-0.133	-0.150	-0.188	-0.223	
0.97	-0.064	-0.067	-0.069	-0.071	-0.076	-0.081	-0.090	-0.099	-0.116	-0.132	-0.169	-0.203	
0.98	-0.050	-0.052	-0.054	-0.056	-0.061	-0.066	-0.075	-0.084	-0.100	-0.115	-0.151	-0.184	
1	-0.036	-0.038	-0.040	-0.042	-0.047	-0.052	-0.060	-0.069	-0.084	-0.099	-0.134		
1.01	-0.024	-0.026	-0.028	-0.030	-0.034	-0.038	-0.047	-0.054	-0.069	-0.084	-0.117	-0.149	
1.02	-0.015	-0.016	-0.018	-0.020	-0.022	-0.026	-0.033	-0.041	-0.055	-0.069	-0.102	-0.132	
1.03	-0.010	-0.007	-0.007	-0.008	-0.011	-0.014	-0.021	-0.028	-0.042	-0.055	-0.086	-0.116	
1.05	-0.002	0.002	0.006	0.008	0.009	0.007	0.001	-0.005	-0.017	-0.029	-0.058	-0.085	
1.1	0.012	0.016	0.020	0.025	0.035	0.041	0.044	0.042	0.035	0.026	0.004	-0.019	
1.15	0.022	0.026	0.030	0.034	0.046	0.056	0.069	0.074	0.074	0.069	0.054	0.036	
1.2	0.029	0.033	0.037	0.041	0.052	0.064	0.082	0.093	0.101	0.102	0.093	0.081	
1.3	0.038	0.041	0.045	0.049	0.060	0.071	0.091	0.109	0.131	0.142	0.150	0.148	
1.4	0.041	0.045	0.049	0.053	0.063	0.074	0.094	0.112	0.141	0.161	0.183	0.191	
1.5	0.043	0.047	0.051	0.055	0.064	0.074	0.094	0.112	0.143	0.167	0.202	0.218	
1.6	0.043	0.047	0.051	0.055	0.064	0.074	0.092	0.110	0.142	0.167	0.210	0.234	
1.7	0.043	0.047	0.050	0.054	0.063	0.072	0.090	0.107	0.138	0.165	0.213	0.242	
1.8	0.042	0.046	0.049	0.053	0.062	0.070	0.087	0.104	0.134	0.161	0.212	0.246	
1.9	0.041	0.045	0.048	0.052	0.060	0.068	0.085	0.101	0.130	0.157	0.209	0.246	
2	0.040	0.044	0.047	0.050	0.058	0.066	0.082	0.097	0.126	0.152	0.205	0.244	
2.25	0.037	0.040	0.043	0.046	0.054	0.061	0.076	0.090	0.116	0.141	0.193	0.234	
2.5	0.035	0.037	0.040	0.043	0.050	0.057	0.070	0.083	0.108	0.130	0.181	0.222	
2.75	0.032	0.035	0.037	0.040	0.046	0.053	0.065	0.077	0.100	0.121	0.169	0.210	
3	0.030	0.032	0.035	0.037	0.043	0.049	0.061	0.072	0.093	0.114	0.159	0.199	
3.5	0.026	0.028	0.031	0.033	0.038	0.043	0.053	0.063	0.082	0.101	0.142	0.179	
4	0.023	0.025	0.027	0.029	0.034	0.038	0.048	0.057	0.074	0.090	0.128	0.163	
5	0.019	0.021	0.022	0.024	0.028	0.032	0.039	0.047	0.061	0.075	0.108		



## APPENDIX D

# Unit Systems

The most common system of units for scientific work is the *Système Internationale*, or SI. The SI unit system uses seven *primary* dimensions:  $m$ ,  $s$ ,  $kg$ ,  $kgmol$ ,  $K$ , *amp*, and  $cd$ . These are presented in Table D.1. Each of these primary dimensions is defined in terms of some measured standard. For example, the length of a meter is defined as the length given by 1,650,763.73 times the wavelength of a particular emission in the spectrum of  $^{86}Kr$ . Additionally, the derived *secondary* units are also presented in terms of the primary dimensions of that measuring system, in the column labeled “SI units.” There are several other unit systems we encounter as engineers. The units of common thermodynamic variables for three common unit systems are presented in Table D.1: SI, CGS, and English units.

**TABLE D.1 Common Variables Used in Thermodynamics and Their Associated Units**

Variable	SI Units	Primary SI Dimensions	CGS Units	English Units
Length	meter [m]	M	centimeter [cm]	foot [ft]
Time	second [s]	S	second [s]	second [s]
Mass	kilogram [kg]	kg	gram [g]	pound mass [ $lb_m$ ] or slug [sl]
Moles	kgmole	kgmol	gmole	lb mole
Temperature				
Absolute	Kelvin [K]	K	Kelvin [K]	Rankine [ $^{\circ}R$ ]
Relative	Celsius [ $^{\circ}C$ ]		Celsius [ $^{\circ}C$ ]	Fahrenheit [ $^{\circ}F$ ]
Force	newton [N]	$kgm/s^2$	dyne [dyne]	pound force [ $lb_F$ ]
energy	joule	$kgm^2/s^2$	erg	foot pound [ $ft lb_F$ ] or British Thermal Unit [BTU]
pressure	pascal [Pa]	$kg/ms^2$	dyne/cm <sup>2</sup>	pound force per square inch [PSI]
power	watt [W]	$kgm^2/s^3$	erg/s	$ft lb_F/s$ BTU/s
concentration		$kgmol/m^3$	$gmol/cm^3$	$lbmol/ft^3$
density		$kg/m^3$	$g/cm^3$	$lb/ft^3$

In most cases, it is easy to convert between SI and CGS unit systems. For example, the form of Newton's second law that force,  $F$ , equals mass,  $m$ , times acceleration,  $a$ , is the same in either system:

$$F = ma \quad \text{SI or CGS units} \quad (\text{D.1})$$

Thus the fundamental unit for force is defined in the SI system as  $1[\text{N}] = 1[\text{kg m/s}^2]$ , as shown in Table D.1. Similarly, in the CGS system, it is defined as  $1[\text{dyne}] = 1[\text{g cm/s}^2]$ . With electric and magnetic units, however, changing between the two unit systems is not as straight-forward. The physical laws of nature can actually change form. For example Coulomb's law presented in Chapter 4 has a different form depending on what unit system is used. In the SI system of units, we have:

$$F_{12} = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2} \quad \text{SI units} \quad (\text{D.2})$$

On the other hand, the CGS unit system gives a simpler form:

$$F_{12} = \frac{Q_1 Q_2}{r^2} \quad \text{CGS units} \quad (\text{D.3})$$

The forces affecting the behavior of molecules are often caused by electric interactions. In this section, we explore the differences that manifest in the SI and CGS unit systems when we treat electric and magnetic quantities. The origin of the differences lies in how units are defined, and it actually leads to different forms of the fundamental equations, as illustrated above. The premise is that by understanding these differences, you will make fewer mistakes when calculating quantities associated with electric or magnetic properties. We further specify the unit system associated with CGS as *Gaussian* units to distinguish it from other ways electric and magnetic units have been incorporated into the CGS unit system. For electromagnetics, the Gaussian unit system is simpler and better pedagogically than SI units. Thus, we use Gaussian units when we relate the electrical characteristics of matter to thermodynamic properties in Chapter 4—unlike the rest of the text where SI units are employed.

The two basic forces on charges are electric and magnetic in nature. The electric force given by Coulomb's law can be written in general as:

$$F_{12} = k_E \frac{Q_1 Q_2}{r^2} \quad (\text{D.4})$$

where  $k_E$  is a proportionality constant. Similarly, the magnetic force per length,  $f$ , between two wires carrying currents  $I_1$  and  $I_2$  is given by:

$$f_{12} = 2k_M \frac{I_1 I_2}{r} \quad (\text{D.5})$$

where  $k_M$  is a proportionality constant. The two proportionality constants,  $k_E$  and  $k_M$  determine the system of units, i.e., they relate units of charge and current on the right hand side of Equations D.4 and D.5, respectively, to units of force. Moreover, their ratio is fixed by the laws of physics to be:

$$\frac{k_E}{k_M} = c^2 \quad (\text{D.6})$$

where  $c$  is the speed of light. In both SI and CGS (Gaussian) units systems, units of force and distance are well defined. Furthermore, we choose the unit of current to be charge

per second, or vice versa; thus, Equations D.4 – D.6 have only one parameter left to specify. The difficulty in converting between SI vs. CGS (Gaussian) unit systems is that each system chooses a different parameter to specify these equations. *In CGS units,  $k_E$  has a value of 1 and is unitless.* Inspection of Equation D.4 shows the units of charge are then defined as:

$$\text{unit of charge in cgs system} = \sqrt{\text{dyne cm}} = \text{g}^{1/2} \text{cm}^{3/2}/\text{s} = \text{esu}$$

The definition above defines the unit of charge as the electrostatic unit [esu]<sup>1</sup>. It is directly related to the primary units in the CGS unit system. Equation D.4 reduces to:

$$F_{12} = \frac{Q_1 Q_2}{r^2} \quad \text{CGS units} \quad (\text{D.7})$$

Equation D.7 is identical to Equation 4.8 in the text. In this unit system, currents are 1 esu/s. Using Equation D.6, the magnetic force per length  $f$  between two wires carrying currents  $I_1$  and  $I_2$  is given by:

$$f_{12} = \frac{2I_1 I_2}{C^2 r} \quad \text{CGS units} \quad (\text{D.8})$$

On the other hand, in order to specify the one remaining parameter in Equations D.4 – D.6, the SI unit system defines a *new* unit for current, the ampere [A]. The ampere is defined so that the proportionality constant in Equation D.5 becomes:

$$k_M = 10^{-7} [\text{N/A}^2] \equiv \frac{\mu_0}{4\pi} \quad \text{SI units} \quad (\text{D.9})$$

The definition given in Equation D.9 also includes the value of  $k_M$  in terms of the permeability of free space,  $\mu_0$ . The unit for charge in the SI unit system becomes 1 [As] and is defined as the coulomb [C]. Using Equation D.6, the proportionality constant in Equation D.4 becomes:

$$k_E = c^2(10^{-7} [\text{N/A}^2]) \equiv \frac{1}{4\pi\epsilon_0} \quad \text{SI units} \quad (\text{D.10})$$

The definition in Equation D.10 includes the value of the permittivity of free space,  $\epsilon_0$ <sup>2</sup>. Thus, in the SI system, Equation D.4 become:

$$F_{12} = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2} \quad \text{SI units} \quad (\text{D.11})$$

while the magnetic force per length  $f$  between two wires carrying currents  $I_1$ , and  $I_2$  is given by:

$$f_{12} = \frac{2\mu_0 I_1 I_2}{4\pi r} \quad \text{SI units} \quad (\text{D.12})$$

Example D.1 illustrates calculations for of the Coulombic potential energy in each unit system and shows the two unit systems are, indeed, consistent.

<sup>1</sup> This unit is often alternatively called the “statcoulomb.”

<sup>2</sup> The terms permeability and permittivity of free space have their origins back when scientists viewed space as containing a material-type substance called “ether.”

**TABLE D.2 Conversion between CGS (Gaussian) units and SI units**

Quantity	CGS (Gaussian) Units	SI Units	Conversion Factor: SI = CGS multiplied by
Charge	$Q \sqrt{\text{dyne}} \text{ cm} = g^{1/2} \text{ cm}^{3/2}/\text{s} \equiv \text{esu}$	C	$3.34 \times 10^{-10}$
Current	$I \sqrt{\text{dyne}} \text{ cm/s} = g^{1/2} \text{ cm}^{3/2}/\text{s}^2 = \text{esu/s}$	A = C/s	$3.34 \times 10^{-10}$
Power	$\dot{W} \text{ erg/s} = \text{dyne cm/s} = \text{gcm}^2/\text{s}^3$	J/s = W	$1.00 \times 10^{-7}$
Electric potential	$E \sqrt{\text{dyne}}$	V = J/C	300
Resistance	R s/cm	$\Omega = V/J$	$8.99 \times 10^{11}$
Dipole moment	$\mu^* g^{1/2} \text{ cm}^{5/2}/\text{s} = \text{esu cm}$	Cm	$3.34 \times 10^{-12}$
Polarizability	$\alpha \text{ cm}^3$	$\text{C}^2\text{m}^2/\text{J}$	$1.11 \times 10^{-16}$
Magnetic Field	$B \sqrt{\text{dyne}/\text{cm}} \equiv \text{gauss}$	Tesla	$1.00 \times 10^{-4}$

\*The commonly used unit for the dipole moment is the Debye [D]. 1 [D] =  $10^{-18}$  [esu cm].

For free space, it is straight-forward to translate between CGS (Gaussian) and SI units, by substituting  $\epsilon_0 \rightarrow 1/(4\pi)$  and  $\mu_0 \rightarrow 4\pi/c^2$ . For dielectric and magnetic materials, conversion between the two quantities is not so easy. For details, see a treatise on electromagnetism.<sup>3</sup> An abbreviated set of conversion factors between CGS and SI units that are relevant to the quantities of interest in this text is given in Table D.2. The convenience of Gaussian units is illustrated by the fact that all quantities presented in Table D.2 can be related to the three fundamental units of the CGS system—cm, g, and s.

### EXAMPLE D.1

Electrostatic calculations in Gaussian and SI units

Consider a singly ionized negative ion and a singly ionized positive ion that are separated by 1 nm. Calculate the potential energy between the two ions using SI units and CGS (Gaussian) units

**SOLUTION** In SI units, the charge of a singly ionized ion is approximately  $1.60 \times 10^{-19}$  [C]. The permittivity of free space has the value,  $\epsilon_0 = 8.85 \times 10^{-12}$  [ $\text{C}^2/(\text{Jm})$ ]. Thus, Equation D.11 becomes:

$$\Gamma_{12} = \frac{Q_1 Q_2}{4\pi\epsilon_0 r} = \frac{(1.60 \times 10^{-19} [\text{C}])(1.60 \times 10^{-19} [\text{C}])}{(4\pi)(8.85 \times 10^{-12} [\text{C}^2/(\text{Jm})])(10^{-9} [\text{m}])} = -2.30 \times 10^{-19} [\text{J}] \quad (\text{ED.1})$$

The charge of a singly ionized ion in CGS units can be found from Table D.2:

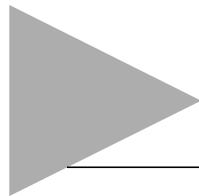
$$(1.60 \times 10^{-19} [\text{C}]) \left( \frac{[\text{esu}]}{3.34 \times 10^{-10} [\text{C}]} \right) = 4.80 \times 10^{-10} [\text{esu}]$$

Thus, Equation D.7 becomes:

$$\Gamma_{12} = \frac{Q_1 Q_2}{r} = \frac{(-4.80 \times 10^{-10} [\text{esu}])(4.80 \times 10^{-10} [\text{esu}])}{10^{-7} [\text{cm}]} = -2.30 \times 10^{-12} [\text{erg}] \quad (\text{ED.2})$$

Since  $1 [\text{erg}] = 1 \text{ g cm}^2/\text{s}^2 = 1 \times 10^{-7} [\text{J}]$ , Expressions ED.1 and ED.2 are equivalent.

<sup>3</sup> John D. Jackson, *Classical Electrodynamics*, 3rd ed., New York: Wiley (1999).



## APPENDIX E

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# ThermoSolver Software

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### ► E.1 SOFTWARE DESCRIPTION

#### Program Installation

*Requirements:* Windows Operating System

##### Features

- Thermodynamic properties of 300+ compounds are provided.
- Saturation pressure calculator is provided for any species in the database.
- Solver for the Peng–Robinson and Lee–Kesler equations of state is provided.
- Fugacity coefficients can be solved for pure species or mixtures.
- Models for Gibbs energy can be fit to isobaric or isothermal vapor–liquid equilibrium data. Sample data sets are provided. The results can be plotted.
- Bubble-point and dew-point calculations are provided.
- Equilibrium constant ( $K_T$ ) solver is provided.
- General chemical reaction equilibria calculations are provided.
- Equations used in the calculation process can be viewed.

Installation is a one-time process. Simply download the software from <http://www.wiley.com/college/koretsky>. If the setup process does not start automatically, double-click **Setup.exe**. Once the setup process has started, follow the on-screen instructions. This process needs to be completed only for the first-time installation. Once the software has been installed, you may consult the Documentation program for more detailed documentation, including screenshots and descriptions of the numerical methods used to solve these problems.

#### Program Usage

Click **Start, Programs, ThermoSolver**, and click the ThermoSolver program icon to begin. The Thermodynamics Menu will appear. From here, eight programs are available to choose from:

##### Species Database

The thermodynamic properties of more than 300 species are available from here. Choose a species from the drop-down list at the top of the screen; the list is sorted by reduced chemical formula, so “Ethanol” will be found under “C<sub>2</sub>H<sub>6</sub>O.” *Use the scrollbar at the side of the drop-down list to choose a species quickly.*

The Species Database provides all of the thermodynamic data used by the rest of the software. Thus, if a species is not available elsewhere in ThermoSolver, there are two causes: Either the given species does not have all of the fields filled in that are required for the calculation, or the species is not in the database. Edits can be made to the database. The program will ask if the changes are to be saved when the Species Database is closed.

Once a species is chosen, the thermodynamic properties are displayed. Choose one of the three tabs to view **General Properties**, **Energy Properties**, or **Heat Capacity Properties**. If a field is blank, it is not provided for the given species.

In the **General Properties** tab, the Antoine constants are shown for the chosen logarithm base and units. Click the **Antoine Eqn** button at the bottom of the window to be shown the general form of the Antoine equation. The critical temperature, critical pressure, and acentric factor are also reported.

In the **Heat Capacity** tab, the heat capacity constants are reported for a generalized heat capacity equation. Click the **Cp/R Eqn** button at the bottom of the view to display the general heat capacity equation. The quantity  $c_p/R$  is unitless and the temperature has units of K.

#### Saturation Pressure Calculator

This program uses the Antoine equation to calculate either a saturation pressure at a given temperature or a saturation temperature at a given pressure. Select a species, enter either a pressure or temperature, and click **Solve** next to the unspecified variable.

#### Equation of State Solver

The equation of state solver uses two of the measure properties ( $P, v, T$ ) to solve for the third, using either the Peng–Robinson or Lee–Kesler equation of state. For example, given the pressure and temperature of a species, the molar volume can be found. To use the program, first choose a species, enter two of the values out of ( $P, v, T$ ), and click **Solve** next to the third value.

#### EXAMPLE E.1

##### Using Equation of State Solver to find $v$

Find the molar volume of helium at 0°C and 1 atm.

**SOLUTION** From the Select a Species drop-down list, scroll down and select **He—Helium-4**. Enter “1” for pressure and choose the units **atm**. Enter “273.15 K” for temperature. Choose **L/mol** for the molar volume unit and click **Solve** next to the molar volume field. The result is 22.4201 L/mol. This is expected, since ideal gases at STP should have molar volumes of 22.4 L/mol.

#### Departure Functions

This program calculates departure functions of enthalpy and entropy for a pure species given a known set of dependent properties. You may choose  $T$  and  $P$  as dependent properties to give  $h_{T,P} - h_{T,P}^{\text{ideal gas}}$  and  $s_{T,P} - s_{T,P}^{\text{ideal gas}}$  or  $T$  and  $v$  as dependent properties to give  $h_{T,v} - h_{T,v}^{\text{ideal gas}}$  and  $s_{T,v} - s_{T,v}^{\text{ideal gas}}$ . If you specify both the initial state (1) and the final state (2), the difference in the departure functions between states will also be provided. You may select either the Lee–Kesler equation or the Peng–Robinson equation to perform the calculations.

#### Fugacity Coefficient Solver

The fugacity coefficient solver uses either the Peng–Robinson or the Lee–Kesler equation of state to calculate fugacity coefficients. At the main Fugacity Coefficient Solver window, add one or more species by clicking the **Add** button. The program will prompt for the number of moles and allow the species to be chosen from a drop-down list. Continue to add species until the entire-system is represented. Now choose a temperature and pressure at the bottom of the Fugacity Coefficient Solver window. On the right side of the window, the fugacity coefficients will be displayed for the current system. The mole values can be changed directly in the summary table.

If the Peng–Robinson option is selected, the Peng–Robinson equation of state will be used to calculate both the pure species fugacity coefficients ( $\phi_i$ ) and the fugacity coefficients in the mixture ( $\hat{\phi}_i$ ). The Lee–Kesler equation of state can calculate only pure fugacity coefficients.

### Models for $g^e$ —Parameter Fitting

This software program solves for the parameters of two-suffix Margules, three-suffix Margules, van Laar, Wilson, and NRTL models. First, choose whether  $P$  or  $T$  will be held constant in the data. At the next window, the experimental data are listed on the left, and the activity coefficient model and parameters are listed on the right.

Any one of the currently saved data sets can be selected in the Experimental Data frame, via a drop-down list. To create a new data set, click **New**, and enter the data in the table. Data can be copied and pasted to and from Microsoft Excel. Make sure to select the appropriate units and enter the constant pressure or temperature at the bottom of the window. Choose **Save** to save an entered data set—saved data sets will be available in the drop-down list of experimental data in all future sessions of the program. The built-in data sets are read-only and cannot be saved.

### EXAMPLE E.2

#### Example 8.9 Using ThermoSolver

Verify the activity coefficient parameter for the two-suffix Margules equation found for the binary system benzene (*a*) and cyclohexane (*b*) found in Example 8.9.

**SOLUTION** Choose the **Isothermal** button since constant temperature data will be used. The main binary mixture VLE coefficient solver window will appear next. From the drop-down list in the upper-left corner of the window, select **Benzene (a) and Cyclohexane (b)**. The pressure,  $x_a$ , and  $y_a$  data will load into the data grid. Click **Solve**. Coefficient A is now 1400.75 J/mol, which is the optimal two-suffix Margules parameter for objective function pressure. To plot the curve that was just fit to the data, click **Plot Data**. Choose **Pressure vs Xa** as the property to plot, and then click **OK**.

### Bubble-Point / Dew-Point Calculations

This program performs bubble-point and dew-point calculations, with various fugacity and activity coefficient corrections. After the appropriate bubble-point or dew-point calculation type has been selected, the main window will be presented.

Add a species to the mixture by using the **Add** button. Choose the desired fugacity and activity coefficient corrections at the bottom of the window. If the multicomponent Wilson model is used, the model parameters should be entered by choosing **Edit** in the Wilson Model Parameters frame. Once everything is set, choose **Solve Unknowns** to perform the bubble-point or dew-point calculation. Choose **More Information** to see the values of the correction factors at equilibrium.

### EXAMPLE E.3

#### Dew-Point Calculation

A system with vapor contains 30% *n*-pentane (1), 30% cyclohexane (2), 20% *n*-hexane (3), and 20% *n*-heptane (4) at 1 bar. Determine the temperature and liquid composition at which the vapor develops the first drop of liquid.

**SOLUTION** This system corresponds to quadrant IV, since the vapor composition and pressure are known. Choose **Add**, select **C5H12—n-Pentane**, and enter “0.3” for the vapor mole fraction. Next, choose **Add**, select **C6H12—Cyclohexane**, and enter “0.3” for the mole fraction. Add **C6H14—n-Hexane** with 0.2 mole fraction and, finally, **C7H16—n-Heptane** with a mole fraction of 0.2. Enter “1 bar” for the pressure, and click **Solve Unknowns**. The liquid mole fractions and equilibrium temperature will be displayed. The dew point temperature is 75.7° C, and the liquid composition is:

Species	<i>n</i> -Pentane	Cyclohexane	<i>n</i> -Hexane	<i>n</i> -Heptane
$x_i$	0.10	0.35	0.16	0.40

### Equilibrium Constant ( $K_T$ ) Calculator

Choose **Chemical Reaction Equilibria** from the ThermoSolver main menu, then choose the **Equilibrium Constant Calculation**. The equilibrium constant calculator solves for the equilibrium constant  $K$  at a given temperature, as described in Section 9.4. The reactants and products for an equation can be added by choosing the **Add** button on either the reactant or product side of the window. *Make sure to specify the stoichiometric coefficient of each species as it is added.*

Once all reactants and products have been added, the correct chemical equation should be displayed at the bottom of the window, and the equation status should read “Balanced.” If not, select a reactant or product and choose **Edit** to adjust the stoichiometric coefficient. Fractions may be used for stoichiometric coefficients. Finally, enter a temperature, and the corresponding equilibrium constant will be displayed.

### Reaction Equilibria Calculations

Choose **Chemical Reaction Equilibria** from the ThermoSolver main menu, then choose the **Reaction Equilibria Calculations**. The reaction equilibria program solves for the composition of a reacting system at equilibrium, using the Gibbs energy minimization method discussed in Section 9.6. The software is limited to gases and solids.

Click the **Add** button to add one or more species to the reaction. In the **Add** dialog box, a method is needed to calculate the Gibbs energy of formation at a particular temperature. If the species is selected from the database, the Gibbs energy of formation will be computed automatically. If the species is manually entered, its Gibbs energy of formation must be known for the temperature at which the reaction takes place. Enter the number of moles initially present, and click **Add** to add the species to the reaction.

At the main window, the temperature and pressure of the reaction can be adjusted, and the vapor phase correction can be chosen. Click **Calculate EQ** when everything is set. The results of the equilibrium calculation will be displayed in a pop-up window.

## ► E.2 CORRESPONDING STATES USING THE LEE–KESLER EQUATION OF STATE<sup>1</sup>

Below the solution algorithm to the Lee–Kesler equation of state is described. Pick a reduced temperature and pressure:

$$P_r = \frac{P}{P_c} \quad \text{and} \quad T_r = \frac{T}{T_c}$$

Solve for  $v^*$ :

$$z = \frac{Pv}{RT} = \frac{P_r v^*}{T_r} = 1 + \frac{B}{v^*} + \frac{C}{(v^*)^2} + \frac{D}{(v^*)^5} + \frac{c_4}{T_r^3(v^*)^2} \left( \beta + \frac{\gamma}{(v^*)^2} \right) \exp \left( -\frac{\gamma}{(v^*)^2} \right)$$

$$\text{where,} \quad v^* = \frac{P_c v}{R T_c}$$

$$B = b_1 - \frac{b_2}{T_r} - \frac{b_3}{T_r^2} - \frac{b_4}{T_r^3}, \quad C = c_1 - \frac{c_2}{T_r} + \frac{c_3}{T_r^3}, \quad D = d_1 + \frac{d_2}{T_r}$$

$$\text{Simple:} \quad z = z^{(0)}$$

<sup>1</sup> From B. I. Lee and M. G. Kesler, *AICHE Journal*, **21**, 510 (1975).

Correction:

$$z^{(1)} = \frac{z^{(c)} - z^{(0)}}{0.3978}$$

Departure functions:

$$\begin{aligned} \frac{h_{T_r, P_r} - h_{T_r, P_r}^{\text{ideal gas}}}{RT_c} &= T_r \left\{ z - 1 - \frac{1}{T_r v^*} \left( b_2 + \frac{2b_3}{T_r} + \frac{3b_4}{T_r^2} \right) \right. \\ &\quad \left. - \frac{1}{2T_r(v^*)^2} \left( c_2 - \frac{3c_3}{T_r^2} \right) + \frac{d_2}{5T_r(v^*)^5} + \frac{3c_4}{2T_r^3\gamma} \right. \\ &\quad \left. \times \left[ \beta + 1 - \left( \beta + 1 + \frac{\gamma}{(v^*)^2} \right) \exp \left( -\frac{\gamma}{(v^*)^2} \right) \right] \right\} \\ \frac{s_{T_r, P_r} - s_{T_r, P_r}^{\text{ideal gas}}}{R} &= \ln \frac{z}{P[\text{atm}]} - \frac{1}{v^*} \left( b_1 + \frac{b_3}{T_r^2} + \frac{2b_4}{T_r^3} \right) \\ &\quad - \frac{1}{2(v^*)^2} \left( c_1 - \frac{2c_3}{T_r^2} \right) - \frac{d_1}{5(v^*)^5} + \frac{c_4}{T_r^3\gamma} \\ &\quad \times \left[ \beta + 1 - \left( \beta + 1 + \frac{\gamma}{(v^*)^2} \right) \exp \left( -\frac{\gamma}{(v^*)^2} \right) \right] \end{aligned}$$

Fugacity coefficient:

$$\begin{aligned} \ln \varphi &= z - 1 - \ln z + \frac{B}{v^*} + \frac{C}{2(v^*)^2} + \frac{D}{5(V^*)^5} + \frac{c_4}{2T_r^3\gamma} \\ &\quad \times \left[ \beta + 1 - \left( \beta + 1 + \frac{\gamma}{(v^*)^2} \right) \exp \left( -\frac{\gamma}{(v^*)^2} \right) \right] \end{aligned}$$

	Simple (0)	Correction (c)
$b_1$	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	0.06901
$c_4$	0.042724	0.041577
$d_1$	$1.55488 \times 10^{-5}$	$4.8736 \times 10^{-5}$
$d_2$	$6.23689 \times 10^{-5}$	$7.40336 \times 10^{-6}$
$\beta$	0.65392	1.226
$\gamma$	0.060167	0.03754