RV Educational Institutions®
RV College of Engineering®
Autonomous Institution Affiliated to Visvesvaraya Technological University, Belagavi
Approved by AICTE, New Delhi

CHEMISTRY HANDBOOK

RV College Of Engineering

CHEMISTS HAVE ALL THE SOLUTIONS

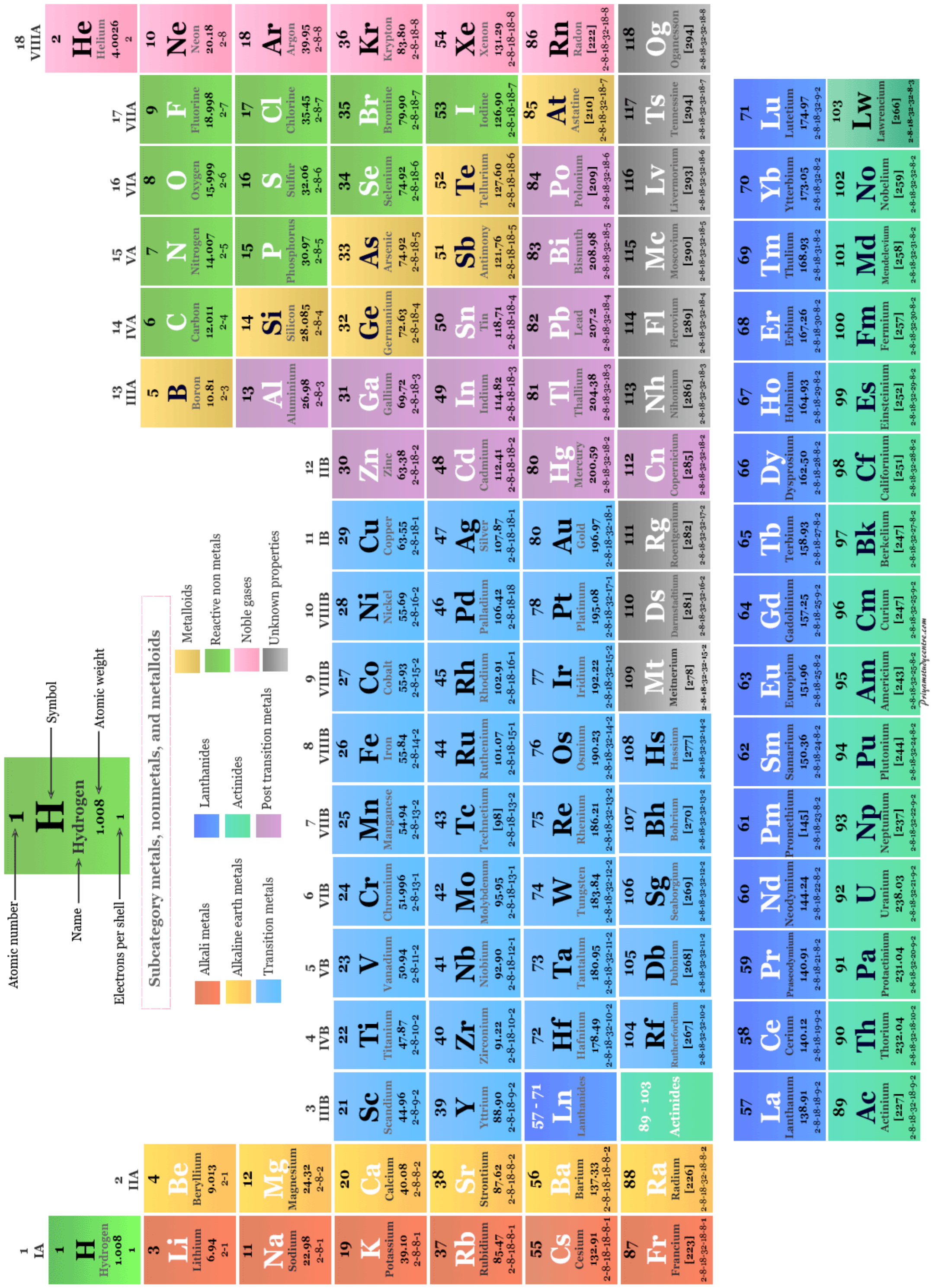
DEPARTMENT OF CHEMISTRY
RV College of Engineering®
(Autonomous Institution affiliated to VTU, Belagavi)
RV Vidyaniketan Post, 8th Mile, Mysuru Road
Bengaluru – 560 059
Ph: 080 68188228
Email ID: hod.chemistry@rvce.edu.in

DECLARATION

All the data in this Chemistry Handbook is taken from CRC Handbook of Chemistry and Physics 97th Edition for the use of chemistry calculations and experiments.

Index

PERIODIC TABLE



INTERNATIONAL SYSTEM OF UNITS (SI)

Quantity	Name	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Area	Square meter	m^2
Volume	Cubic meter	m^3
Speed/Velocity	Meter per second	m/s
Density	kilogram per cubic meter	kg/m^3
Amount of Substance	Mole	mol

CONVERSION FACTORS

To convert from	To	Multiply by
Ampere-hour	Coloumb	3.6×10^3
Angstrong	Meter	10^{-10}
Angstrong	Nanometer	10^{-1}
Fermi meter	Meter	10^{-15}
Atmosphere, standard(atm)	Pascal	1.01325×10^5
Calorie	Joule	4.184

CONVERSION OF TEMPERATURES

From	to	Conversion formula
Celsius	Fahrenheit	T/˚F = (9/5)t/˚C + 32
	Kelvin	T/K = t/˚C + 273.15
	Rankine	T/˚R = (9/5) (t/˚C + 273.15)
Fahrenheit	Celsius	T/˚C = (5/9) [(t/˚F) - 32
	Kelvin	T/K = (5/9)[(t/˚F) - 32] + 273.15
	Rankine	T/˚R = t/˚F + 459.67
Kelvin	Celsius	t/˚C = T/K - 273.15
	Rankine	T/˚R = (9/5)T/K
Rankine	Fahrenheit	T/˚F = T/˚R - 459.67
	Kelvin	T/K = (5/9)T/˚R

VALUES OF GAS CONSTANT IN DIFFERENT TERMS

In SI Units: R = 8.314472 Pa m3 K^{-1} mol^{-1}

= 8314.472 Pa L K^{-1} mol^{-1}

= 0.08314472 bar L K^{-1} mol^{-1}

MELTING, BOILING, TRIPLE, AND CRITICAL POINTS OF SOME ELEMENTS

Element	t_m(°C)	t_b(°C)	t_c(°C)
Aluminium	1050	≈3200	6427
Carbon (graphite)	4489	3825	-
Carbon (diamond)	4440	-	-
Copper	1084.62	2560	-
Hydrogen (H_2)	-259.16	-252.879	-240.212
Iodine (I_2)	113.7	184.4	546
Iron	1538	2861	9067
Mercury (Hg)	-38.8290	356.619	1491
Nitrogen (N_2)	-210.00	-195.795	-146.958
Oxygen (O_2)	-218.79	-182.962	-118.569

ENTHALPY OF HYDRATION OF GASES (at 298.15 K)

Name	Mol. form	$\Delta_{hyd}H^{\infty}$/ kJ mol^{-1}
Acetic acid	$C_2H_4O_2$	-52.8
Acetone	C_3H_6O	-39.7
Acetonitrile	C_2H_3N	-34.9
Ammonia	H_3N	-35.4
Aniline	C_6H_7N	-56.5
Anisole	C_7H_8O	-41.4
Argon	Ar	-12.2
Benzaldehyde	C_7H_6O	-42.1
Benzene	C_6H_6	-28.1
Benzyl alcohol	C_7H_8O	-66.9
Butane	C_4H_{10}	-24.8
1-Butanol	$C_4H_{10}O$	-61.9
2-Butanol	$C_4H_{10}O$	-62.7
2-Butanone	C_4H_8O	-41.9
1-Butene	C_4H_8	-24.1
Butyl acetate	$C_6H_{12}O_2$	-52.7
Carbon dioxide	CO_2	-17.9
Carbon monoxide	CO	-11.1
Dichloromethane	CH_2Cl_2	-30.3
Diethyl amine	$C_4H_{11}N$	-64.3
Diethyl ether	$C_4H_{10}O$	-46.4
Ethane	C_2H_6	-17.9
Ethanol	C_2H_6O	-50.6
Ethyl acetate	$C_4H_8O_2$	-45.3
Glycerol	$C_3H_8O_3$	-103.5
Helium	He	-0.67
Hexane	C_6H_{14}	-31.9
Hydrogen	H_2	-0.402

Methane	CH_4	-12
Methanol	CH_4O	-52
Phenol	C_6H_6O	-57.7

PHYSICAL CONSTANTS AND UNIT CONVERSIONS	
Absolute zero	0 K = -273 ° C
Atomic mass unit	1 amu = 1.66 x10^{-27} kg
Avogadro's constant	NA = 6.02 x 10^{23} $mo1^{-1}$
Ideal gas constant	R = 8.31 J mori K^{-1}
Ionic product constant for water (at 298 K)	Kw =1.00 x10^{-14} mol^2 dm^{-6}
Molar volume of an ideal gas (at STP)	2.27 x10^{-2} m^3 $mo1^{-1}$ = 22.7 dm^3
Specific heat capacity of water (at 298 K)	cw = 4.18 J g^{-1} K^{-1}
Standard temperature and pressure (STP)	273 K and 100 kPa
Volume and capacity conversions	1 dm^3 =1x10^{-3} m^3 .1x10^3 cm^3 =1 L
Faraday constant (F)	96,500 C $mo1^{-1}$
Electronic charge (e)	1.6023 x 10^{19}C
1 calorie	4.184 joule
Ideal gas Law	PV =nRT, P=pressure, V=volume, R=ideal gas constant, n=no of moles of gas, T=Absolute temperature

IMPORTANT PROPERTIES OF SOLUTIONS

Descriptive term	Parts of solvent required for 1 part of solute
Very soluble	Less than 1
Freely soluble	From 1 to 10
Soluble	From 10 to 30
Sparingly soluble	From 30 to 100
Slightly soluble	From 100 to 1000
Very slightly soluble	From 1000 to 10000
Practically insoluble, or Insoluble	Greater than or equal to 10000

SOLUBILITY OF SELECTED COMPOUNDS AT 298K

	bromide	carbonate	chloride	hydroxide	Iodide	Nitrate	oxide	Phosphorous	sulphate
Aluminium	S	-	S	I	S	S	I	I	S
Ammonium	S	S	S	S	S	S	-	S	S
Barium	S	I	S	S	S	S	S	I	I
Calcium	S	I	S	P	S	S	P	I	P
Cobalt(II)	S	I	S	I	S	S	I	I	S
Copper(II)	S	-	S	I	I	S	I	I	S
Iron(II)	S	I	S	I	S	S	I	I	S
Iron(III)	S	-	S	I	S	S	I	I	S
Lead(II)	P	I	S	I	I	S	I	I	I
Lithium	S	S	S	S	S	S	S	-	S
Magnesium	S	I	S	I	S	S	I	P	S
Silver	I	I	I	I	S	S	I	I	P
Sodium	S	S	S	S	S	S	I	S	S
Zinc	S	I	S	I	S	S	I	I	S

Abbreviation	**Explanation**
S	Soluble in Water (solubility greater than 10 g L^{-1})
P	Partially soluble in Water (solubility between 1 and 10 g L^{-1})
I	Insoluble in Water (solubility less than 1 g L^{-1})
-	No Data

INDEX OF REFRACTION OF INORGANIC LIQUIDS

(All values refer to a wavelength of 589 nm)

Name	Formula	Refractive Index
Ammonia	NH_3	1.3944
Carbon dioxide	CO_2	1.6630
Carbon disulphide	CS_2	1.6277
Hydrogen	H_2	1.1096
Nitric acid	HNO_3	1.393
Nitrogen	N_2	1.19876
Oxygen	O_2	1.2243
Perchloric acid	$HClO_4$	1.3819
Water	H_2O	1.33336

STANDARD KCl SOLUTIONS FOR CALIBRATING CONDUCTIVITY CELLS

(Conductivity of Aqueous Potassium Chloride at Various Concentrations and Temperatures)

T(ºC)	$10^4 x$(0.01 m)/ S m^{-1}	$10^4 x$(0.1 m)/ S m^{-1}	$10^4 x$(1.0 m)/ S m^{-1}	$10^4 x(H_20)$/ S m^{-1}
0	772.92	7116.85	63488	0.58
5	890.96	8183.70	72030	0.68
10	1013.95	9291.72	80844	0.79
15	1141.45	10437.1	89900	0.89
18	1219.93	11140.6	-	0.95
20	1273.03	11615.9	99170	0.99
25	1408.23	12824.6	108620	1.10
30	1546.63	14059.2	118240	1.20
35	1687.79	15316.0	127970	1.30

IONIC CONDUCTIVITY AND DIFFUSION AT INFINITE DILUTION

General Formula

$\Lambda° = v_+ \Lambda_+ + v_- \Lambda_-$, where v_+ and v_- refer to the number of moles of cations and anions to which one mole of the electrolyte gives a rise in the solution.

$\Lambda° = \Lambda_+ + \Lambda_-$, where Λ_+ and Λ_- are equivalent ionic conductivities of the cation and anion

Ion	$\Lambda \pm\ 10^{-4} m^2 S mol^-$	$D 10^{-5} cm^2 s^-$
1/2Malate^{2-}	58.8	0.783
1/2Maleate^{2-}	61.9	0.824
1/2Malonate^{2-}	63.5	0.845
Methylsulfate$^-$	48.8	1.299
Naphthylacetate$^-$	28.4	0.756
1/2Oxalate^{2-}	74.11	0.987

VAPOUR PRESSURES (Temperature at Which Pressure Reaches Indicated Value), BOILING POINTS, AND HEATS OF SUBLIMATION OF RARE EARTH METALS

Rare earth metal	10^{-8} atm (0.001 Pa)	10^{-6} atm (0.101 Pa)	10^{-4} atm (10.1Pa)	10^{-2} atm (1013 Pa)	Boiling point[a] ("C)	Heat of sublimation at 25 "C (kJ/mol)
Sc	1036	1243	1533	1999	2836	377.8
Y	1222	1460	1812	2360	3345	424.7
La	1301	1566	1938	2506	3464	431.0
Ce	1290	1554	1926	2487	3443	422.6
Pr	1083	1333	1701	2305	3520	355.6
Sm	508	642	835	1150	1794	206.7
Eu	399	515	685	964	1529	175.3
Gd	1167	1408	1760	2306	3273	397.5
Tb	1124	1354	1698	2237	3230	388.7
Dy	804	988	1252	1685	2567	290.4
Ho	845	1036	1313	1771	2700	300.8
Er	908	1113	1405	1896	2868	317.1
Tm	599	748	964	1300	1950	232.2
Yb	301	400	541	776	1196	152.1
Lu	1241	1483	1832	2387	3402	427.6

VALUES OF $pK_W(H_2O)$ AND $pK_W(D_2O)$

$pK_w = -\log10(K_w)$		
t/"C	$pK_W(H_2O)$	$pK_W(D_2O)$
0	14.947	15.972
5	14.734	15.743
10	14.534	15.527
15	14.344	15.324
20	14.165	15.132
25	13.995	14.951
30	13.833	14.779
35	13.680	14.616

FIXED-POINT PROPERTIES OF H_2O AND D_2O

Properties	Unit	H_2O	D_2O
Molar mass	G mol^{-1}	18.015268	20.02751
Melting point (101.325 kPa)	°C	0.0025	3.81
Boiling point (101.325 kPa)	°C	99.974	101.40
Triple-point temperature	°C	0.01	3.82
Triple-point pressure	Pa	611.657	661
Triple-point density (liquid)	g cm^{-3}	0.99979	1.1055
Critical temperature	°C	373.946	370.697
Critical pressure	MPa	22.064	21.671

SOLUBILITY OF SELECTED GASES IN WATER

1. Carbon monoxide (CO) Mr = 28.0104

T/K	Solubility(X_1)	Equations Constant
288.15	2.095 * $10^{(-5)}$	Derived from Henry 's Law
293.15	1.918 * $10^{(-5)}$	Constant Equation
298.15	1.774 * $10^{(-5)}$	
303.15	1.657 * $10^{(-5)}$	Std. dev.= ± 0.043%
308.15	1.562 * $10^{(-5)}$	Temp. range = 273.15—328.15

2. Carbon dioxide (CO2) Mr = 44.0098

T/K	Solubility(X_1)	Equations Constant
288.15	8.21 * $10^{(-4)}$	Derived from Henry 's Law
293.15	7.07 * $10^{(-4)}$	Constant Equation
298.15	6.15 * $10^{(-4)}$	
303.15	5.41 * $10^{(-4)}$	Std. dev.= ± 1.1%
308.15	4.80* $10^{(-4)}$	Temp. range = 273.15—353.15

3. Methane (CH4) Mr = 16.0428

T/K	Solubility(X_1)	Equations Constant
288.15	3.122 * $10^{(-5)}$	C=65.2553
293.15	2.806 * $10^{(-5)}$	D=-6.1698
298.15	2.552 * $10^{(-5)}$	Std. dev.= ± 0.056%
303.15	2.346 * $10^{(-5)}$	Temp. range = 273.15—328.15
308.15	2.180 * $10^{(-5)}$	

4. Ethane (C2H6) Mr = 30.069

T/K	Solubility(X_1)	Equations Constant
288.15	4.556 * $10^{(-5)}$	A=-90.8225
293.15	3.907 * $10^{(-5)}$	B=126.9559
298.15	3.401 * $10^{(-5)}$	C=34.7413
303.15	3.002 * $10^{(-5)}$	Std. dev.= ± 0.012%
308.15	308.15 * $10^{(-5)}$	Temp. range = 273.15—328.15

5. Butane ($C4H10$) Mr = 58.123

T/K	Solubility(X_1)	Equations Constant
288.15	$3.274 * 10^{(-5)}$	A=-102.029 B=146.040 C=53.4651 Std. dev.= ± 0.34% Temp. range = 273.15—349.15
293.15	$2.687 * 10^{(-5)}$	
298.15	$2.244 * 10^{(-5)}$	
303.15	$1.906 * 10^{(-5)}$	
308.15	$1.645 * 10^{(-5)}$	

6. Isobutene ($C4H10$) Mr = 58.123

T/K	Solubility(X_1)	Equations Constant
288.15	$2.333 * 10^{(-5)}$	A=-129.714 B=183.044 C=53.4651 Std. dev.= ± 0.034% Temp. range = 278.15—318.15
293.15	$1.947 * 10^{(-5)}$	
298.15	$1.659 * 10^{(-5)}$	
303.15	$1.443 * 10^{(-5)}$	
308.15	$1.278 * 10^{(-5)}$	

VAPOUR PRESSURE, ENTHALPY OF VAPORIZATION, AND SURFACE TENSION OF WATER

t/°C	P/kPa	$\Delta_{vap}H$/kJ kg^{-1}	γ/mN m^{-1}
0.01	0.61165	2500.9	75.65
2	0.70599	2496.2	75.37
4	0.81355	2491.4	75.08
6	0.93536	2486.7	74.80
8	1.0730	2481.9	74.51
10	1.2282	2477.2	74.22
12	1.4028	2472.5	73.93
14	1.5990	2467.7	73.63

THERMOPHYSICAL PROPERTIES

Temperature (°C)	(MPa)	ρ (Kgm^{-3})	u (ms^{-1})	H (kJ kg^{-1})	S (kJ kg^{-1} K^{-1})
0.01	0.1	999.84	1402.4	0.10186	0.000007
10	0.1	999.70	1447.3	42.118	0.15108
20	0.1	998.21	1482.3	84.006	0.29646
25	0.1	997.05	1496.7	104.92	0.36720
30	0.1	995.65	1509.2	125.82	0.43673
40	0.1	992.22	1528.9	167.62	0.57237
50	0.1	988.03	1542.6	209.42	0.70377
60	0.1	983.20	1551.0	251.25	0.83125

70	0.1	977.76	1554.7	293.12	0.95509
80	0.1	971.79	1554.4	335.05	1.0755
90	0.1	965.31	1550.4	377.06	1.1928
100	0.1	0.58967	472.28	2675.8	7.3610

DENSITY OF WATER AT DIFFERENT TEMPERATURES

Temperature (ºC)	Density(kg/m^3)
0	917.00
1	999.82
2	999.94
3	999.98
4	1000.00
5	1000.00
6	999.99
7	999.96
8	999.91
9	999.85
10	999.77

IMPORTANT PROPERTIES OF VARIOUS AQUEOUS IONS

Electrical Conductivity of Aqueous Ions

Electrical Conductivity κ in mS/cm for the Indicated Concentration in Mass Percent

Name	Formula	κ (0.5%)	κ (1%)	κ (5%)	κ (10%)	κ (15%)	κ (20%)	κ (25%)	κ (30%)	κ (50%)
Acetic acid	CH_3COOH	0.3	0.6	1.2	1.5	1.7	1.7	1.6	1.4	0.8
Ammonia	NH_3	0.5	0.7	1.1	1.0	0.7	0.5	0.4		
Ammonium chloride	NH4Cl	10.5	20.4	95.3	180					
Ammonium sulfate	$(NH_4)_2SO_4$	7.4	14.2	57.4	105	147	185	215		
Barium chloride	$BaCl_2$	4.7	9.1	40.4	76.7	109.0	137.0			
Calcium chloride	$CaCl_2$	8.1	15.7	67.0	117	157	177	183	172	
Cesium chloride	CsCl	3.8	7.4	32.9	65.8	102	142			
Citric acid	$C(OH)(COOH)_3$	1.2	2.1	4.7	6.2	7.0	7.2	7.1		
Copper(II) sulfate	$CuSO_4$	2.9	5.4	19.0	32.2	42.3				

Formic acid	$HCOOH$	1.4	2.4	5.6	7.8	9.0	9.9	10.4	10.5	8.6
Hydrogen chloride	HCl	45.1	92.9							
Lithium chloride	$LiCl$	10.1	19.0	76.4	127	155	170	165	146	
Magnesium chloride	$MgCl_2$	8.6	16.6	66.9	108	129	134	122	98	
Magnesium sulfate	$MgSO_4$	4.1	7.6	27.4	42.7	54.2	51.1	44.1		
Manganese(II) sulfate	$MnSO_4$		6.2	21.6	34.5	43.7	47.6			
Nitric acid	HNO_3	28.4	56.1							
Oxalic acid	$H_2C_2O_4$	14.0	21.8	65.6						
Phosphoric acid	H_3PO_4	5.5	10.1	31.5	59.4	88.4	118	146	173	
Potassium chloride	KCl	8.2	15.7	71.9	143	208				
Potassium iodide	KI	3.8	7.5	35.2	71.8	110	188	224		
Potassium nitrate	KNO_3	5.5	10.7	47.0	87.3	124	157	182		
Potassium permanganate	$KMnO_4$	3.5	6.9	30.5						
Silver(I) nitrate 30.2 70.1 126 171 204 222	$AgNO_3$	3.1	6.1	26.7	49.8	72.0	92.8	112	129	
Sodium acetate	$NaC_2H_3O_2$	3.9	7.6	30.9	53.4	64.1	69.3	69.2	64.3	
Sodium bromide	$NaBr$	5.0	9.7	44.0	84.6	122	157	191	216	
Sodium carbonate	Na_2CO_3	7.0	13.1	47.0	74.4	88.6				
Sodium chloride	$NaCl$	8.2	16.0	70.1	126	171	204	222		
Sodium hydroxide	$NaOH$	24.8	48.6	206						
Sodium nitrate	$NaNO_3$	5.4	10.6	46.2	82.6	111	134	152	165	

THERMODYNAMIC PROPERTIES OF SOME AQUEOUS IONS

(All values refer to standard conditions of 25 °C and 100 kPa pressure)

Cations	$\Delta_f H°$/kJ mol^{-1}	$\Delta_f G°$/kJ mol^{-1}	S°/J mol^{-1}K^{-1}	C_p/ J mol^{-1}K^{-1}
Ag^+	105.6	77.1	72.7	21.8
Al^{3+}	-531.0	-485.0	-321.8	
Be^{2+}	-382.8	-379.7	-129.7	
Ca^{+2}	-542.8	-553.6	-53.1	
K^+	−252.4	−283.3	102.5	21.8
Mn^{+2}	−220.8	−228.1	−73.6	50.0
NH^{4+}	−132.5	−79.3	113.4	79.9
Na^+	−240.1	−261.9	59.0	46.4
HSO3$^-$	−626.2	−527.7	139.7	
N3$^-$	275.1	348.2	107.9	

MOLAR IONIC CONDUCTIVITY

Name	Symbol	Molar ionic conductivity ($S.m^2.mol^{-1}$).10^{-4}
Potassium	K^+	73.5
Nitrate	NO_3^-	71.4
Hydroxide	OH^-	198.6
Sodium	Na^+	50.1
Ammonium	NH_4^+	73.5
Silver	Ag^+	69.1
Bromide	Br^-	78.1
Iodide	I^-	76.8
Chloride	Cl^-	76.3
Fluoride	F^-	54.4

ELECTRON AFFINITIES AND 1ST IONIZATION ENERGY OF ELEMENTS

The electron affinities and 1st ionization energies of a few important elements

Element	Electron Affinity	1st Ionization Energy
H	0.75420817	13.598443
He	not stable	24.587387
Li	0.618049(0.000020)	5.391719
Be	not stable	9.32270
B	0.279723(0.000025)	8.29802
C	1.262119(0.000020)	11.26030
N	not stable	14.5341
O	1.4611135(0.0000009)	13.61805
Na	0.547926(0.000025)	5.139076
Al	0.43283(0.00005)	5.985768
Cl	3.612725(0.000027)	12.96763
Mg	not stable	7.646235
K	0.50147(0.00010)	4.3406633
Ca	0.02455(0.00010)	6.11316
Cr	0.666(0.012)	6.76651

ELECTRICAL CONDUCTIVITY AND RESISTIVITY OF PURE METALS

The resistivity of a conductor is defined as the resistance of the conductor of length and unit area of cross-section, the following table gives the values of the electrical conductivity and resistivity of metals at room temperature:

Metal	Electrical Conductivity in 10^{-8} Sm^{-1}	Electrical Resistivity in 10^{-8} Ω-m
Be	0.27027	3.70
Li	0.105597	9.47
Al	0.36914	2.709
Ca	0.292398	3.42
Cr	0.079365	12.6
Cu	0.584112	1.712
Fe	0.101317	9.87
Ba	0.029412	34.0
Mg	0.223214	4.48
Mn	0.006944	144
Pb	0.047393	21.1
Au	0.443459	2.255
Hf	0.029674	33.7
Ni	0.140449	7.12
Pd	0.093197	10.73
K	0.135318	7.39
Ag	0.618429	1.617

CALCULATION OF EQUIVALENT MASS

Chemical Entity	Equivalent Factor	Formula for calculating equivalent mas
Acids	Basicity (number of moles of ionisable H^+ ions present in 1 mole of Acid)	E= Molar mass of acid/ Basicity of acid
Bases	Acidity (number of moles of ionisable OH^- ions present in 1 mole of Acid)	E= Molar mass of acid/ Acidity of acid
Oxidising agent or reducing agent	No. of moles of electrons gained or lost by one mole of the reagent during redox reaction	E=Molar mass of oxidising agent or reducing agent/ No. of moles of electrons gained or lost by one mole of oxidising or reducing agent

MEAN ACTIVITY COEFFICIENTS AT 25 °C

Electrolyte	m/mol kg^{-1}	γ_{mean}
$AgNO_3$	0.001	0.964
	0.002	0.950
	0.005	0.924
	0.010	0.896
	0.020	0.859
	0.050	0.794
	0.100	0.732
	0.200	0.656
	0.500	0.536
$BaCl_2$	0.001	0.887
	0.002	0.849
	0.005	0.782
	0.010	0.721
	0.020	0.653
	0.050	0.559
HCl	0.001	0.965
	0.002	0.952
	0.005	0.929
	0.010	0.905
	0.020	0.876
	0.050	0.832
KNO_3	0.001	0.964
	0.002	0.95
	0.005	0.924

ELECTROCHEMICAL SERIES

Element	Electrode Reaction	E°(V)
Li	$Li^+ + e^- \rightarrow Li$	-3.045
K	$K^+ + e^- \rightarrow K$	-2.925
Cs	$Cs^+ + e^- \rightarrow Cs$	-2.923
Ba	$Ba^{2+} + 2e^- \rightarrow Ba$	-2.906
Ca	$Ca^{2+} + 2e^- \rightarrow Ca$	-2.866
Na	$Na^+ + e \rightarrow Na$	-2.714
Mg	$Mg^{2+} + 2e^- \rightarrow Mg$	-2.363
Al	$Al^{3+} + 3e^- \rightarrow Al$	-1.662
Zn	$Zn^{2+} + 2e^- \rightarrow Zn$	-0.763
Fe	$Fe^{2+} + 2e^- \rightarrow Fe$	-0.440
Cd	$Cd^{2+} + 2e^- \rightarrow Cd$	-0.403
Pb	$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	-0.310
Ni	$Ni^{2+} + 2e^- \rightarrow Ni$	-0.250
Sn	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.136
Pb	$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
Fe	$Fe^{3+} + 3e^- \rightarrow Fe$	-0.036
H	$2H^+ + 2e \rightarrow H_2$ (SHE)	0
Cu	$Cu^{2+} + e- \rightarrow Cu^+$	+0.153
Cu	$Cu^{2+} + 2e^- \rightarrow Cu$	+0.337
Ag	$Ag^+ + e^- \rightarrow Ag$	+0.799
Hg	$Hg^{++} + 2e^- \rightarrow Hg$	+0.854
Br_2	$Br_2 + 2e^- \rightarrow 2Br$	+1.066
F_2	$F_2 + 2e^- \rightarrow 2F^-$	+2.870

REDUCTION REACTIONS HAVING E° VALUES MORE POSITIVE THAN THAT OF THE STANDARD HYDROGEN ELECTRODE

Reaction	E°/V
$2 H^+ + 2 e \rightleftharpoons H_2$	0.00000
$CuI_2^- + e \rightleftharpoons Cu + 2 I^-$	0.00
$NO_3^- + H_2O + 2 e \rightleftharpoons NO_2^- + 2 OH^-$	0.01
$AgBr + e \rightleftharpoons Ag + Br^-$	0.07133
$HgO + H_2O + 2 e \rightleftharpoons Hg + 2 OH^-$	0.0977
$Hg_2Br_2 + 2 e \rightleftharpoons 2 Hg + 2 Br^-$	0.13923
$Pt(OH)_2 + 2 e \rightleftharpoons Pt + 2 OH^-$	0.14
$Ag_4[Fe(CN)_6] + 4 e \rightleftharpoons 4 Ag + [Fe(CN)_6]^{4-}$	0.1478

$2\ NO_2- + 3\ H_2O + 4\ e \rightleftharpoons N_2O + 6\ OH^-$	0.15
$Sn^{4+} + 2\ e \rightleftharpoons Sn^{2+}$	0.151
$Cu^{2+} + e \rightleftharpoons Cu^+$	0.153
$AgCl + e \rightleftharpoons Ag + Cl^-$	0.22233
$Ge^{2+} + 2\ e \rightleftharpoons Ge$	0.24
$PbO_2 + H_2O + 2\ e \rightleftharpoons PbO + 2\ OH^-$	0.247
$MnO_4- + 4\ H_2O + 5\ e \rightleftharpoons Mn(OH)_2 + 6OH^-$	0.34
$Cu_2^+ + 2\ e \rightleftharpoons Cu$	0.3419
$Cu^+ + e \rightleftharpoons Cu$	0.521
$I_2 + 2\ e \rightleftharpoons 2\ I^-$	0.5355
$I^-_3 + 2\ e \rightleftharpoons 3\ I^-$	0.536
$MnO_4- + e \rightleftharpoons MnO_4^-$	0.558
$Hg_2^{\ 2+} + 2\ e \rightleftharpoons 2\ Hg$	0.7973
$Ag^+ + e \rightleftharpoons Ag$	0.7996
$Hg^{2+} + 2\ e \rightleftharpoons Hg$	0.851
$Br_2(l) + 2\ e \rightleftharpoons 2Br^-$	1.066
$PbO_2 + 4\ H^+ + 2\ e \rightleftharpoons Pb^{2+} + 2\ H_2O$	1.455
$CrO_2 + 4\ H^+ + e \rightleftharpoons Cr^{3+} + 2\ H_2O$	1.48
$Au^{3+} + 3\ e \rightleftharpoons Au$	1.498
$MnO_4- + 4\ H^+ + 3\ e \rightharpoonup MnO_2 + 2\ H_2O$	1.679
$Au^+ + e \rightleftharpoons Au$	1.692
$Ag^{3+} + e \rightleftharpoons Ag^{2+}$	1.8
$Au^{2+} + e \rightleftharpoons Au^+$	1.8
$Ag^{3+} + 2\ e \rightleftharpoons Ag^+$	1.9
$Co^{3+} + e \rightleftharpoons Co^{2+}$	1.92
$Ag^{2+} + e \rightleftharpoons Ag^+$	1.980
$OH + e \rightleftharpoons OH^-$	2.02

PROPERTIES THAT OCCUR DURING EQUILIBRIUM

Chemical Equilibrium Systems

$K_c=[C]^C\ [D]^D/[A]^a\ [B]^b$, For the reaction: $aA + bB \rightleftharpoons cC + dD$

$K_w = [H^+][OH^-]$ $\quad K_w = K_a * K_b$

$pH=-log_{10}[H^+]$

$poH=-log_{10}[OH^-]$

$K_a=[H_3O^+]\ [A^-]/[HA]$

$K_b=[BH^+]\ [OH^-]/[B]$

DISSOCIATION CONSTANTS OF INORGANIC ACIDS AND BASES

Negative Logarithm of the Acid Dissociation Constant at the Indicated Temperature

Name	Formula	Step	t/ºC	pKa
Aluminium ion [Al^{+3}]	Al^{+3}		25	5.0
Ammonia	NH_3		25	9.25
Barium ion [Ba^{+2}]	Ba^{+2}		25	13.4
Boric acid	H_3BO_3	1	20	9.27
Hydrazine	N_2H_4		25	8.1
Hydrazoic acid	HN_3		25	4.6
Hydrogen cyanide	HCN		25	9.21
Hydrogen fluoride	HF		25	3.20
Hydrogen peroxide	H_2O_2		25	11.62
Hydrogen sulphide	H_2S	1	25	7.05
Phosphonic acid	H_3PO_3	1	20	1.3
		2	20	6.70
Phosphoric acid	H_3PO_4	1	25	2.16
		2	25	7.21
		3	25	12.32

IMPORTANT FORMULAS

$\% \; yield = \frac{Actual\; yield\; of\; the\; product}{Theoretical\; yield\; of\; the\; product} X\; 100$
$\boldsymbol{atom\; economy} = \frac{\boldsymbol{molecular\; weight\; (MW)\; of\; desired\; product}}{\boldsymbol{Sum\; of\; MW's\; of\; all\; materials\; produced}} \times 100$
$\boldsymbol{E\; factor} = \frac{\boldsymbol{mass\; of\; total\; waste}}{\boldsymbol{mass\; of\; product}}$
Poiseuille's formula is given by, V = π P ɲ ^ 4 / 8 η l Here, the viscous liquid's flow rate through a tube of length 'l' and radius 'ɲ' is proportional to the applied pressure P.
Nernst's equation $E_{cell} = E^0 - [RT/nF] \ln Q$, Where E_{cell} = cell potential of the cell, E^0 = cell potential under standard conditions, R = universal gas constant, T = temperature, n = number of electrons transferred in the redox reaction, F = Faraday constant, Q = reaction quotient
Normality (N) = No. of equivalents of solute / Volume of the solution in litre
Molarity (M) = No of moles of solute/volume of solution in litre
Molality (m) =No of Moles of solute / Weight of solvent in kg

pH SCALE FOR AQUEOUS SOLUTIONS

For Primary Standards at 0–50 °C

	Temperature in °C										
Primary standards (PS)	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**37**	**40**	**50**
Sat. potassium hydrogen tartrate (at 25 °C)						3.55	3.55	3.54	3.54	3.54	3.54
0.05 mol kg^{-1} potassium dihydrogen citrate	3.86	3.84	3.82	3.80	3.78	3.77	3.76	3.75	3.75	3.75	3.74
0.05 mol kg^{-1} potassium hydrogen phthalate	4.00	3.99	3.99	3.99	4.00	4.00	4.01	4.01	4.02	4.02	4.05
0.025 mol kg^{-1} disodium hydrogen phosphate + 0.025 mol kg^{-1} potassium dihydrogen phosphate	6.98	6.95	6.92	6.900	6.881	6.865	6.853	6.844	6.841	6.838	6.833
0.03043 mol kg^{-1} disodium hydrogen phosphate + 0.008695 mol kg^{-1} potassium dihydrogen phosphate	7.534	7.5	7.472	7.448	7.429	7.413	7.400	7.389	7.386	7.38	7.367
0.01 mol kg^{-1} disodium tetraborate	9.46	9.3	9.33	9.27	9.22	9.18	9.13	9.10	9.08	9.06	9.01

INDICATORS FOR ACIDS AND BASES

The following table lists the most common indicators together with their pH range and colours in acidic and basic media. Since the colour change is not instantaneous at the pKa value, a pH range is given where a combination of colours is present. The list is as follows:

Sl. No	Indicator	pH Range	Solvent	Colour change (Acidic to basic)
1	Penta methoxy Red	1.2-2.3	70% ethanol	red-violet to colorless
2	Thymol Blue	1.2-2.8	Aqueous	red to yellow
3	2,4-Dinitrophenol	2.4-4.0	50% ethanol	colourless to yellow
4	Methyl Orange	3.1-4.4	Aqueous	red to orange
5	Congo Red	3.0-4.6	Aqueous	yellow to blue
6	Bromocresol Green	4.0-5.6	Aqueous	yellow to blue
7	4-Nitrophenol	5.2-6.8	Aqueous	yellow to purple
8	Bromophenol Blue	6.2-7.6	Aqueous	yellow to blue

9	Phenol Red	6.4-8.0	Aqueous	yellow to red
10	Cresol Red	7.2-8.8	Aqueous	yellow to red
11	Orange I	7.6-8.9	Aqueous	yellow to rose-red
12	Phenolphthalein	8.0-10.0	70% ethanol	colourless to red
13	Alizarin Yellow R	10.0-12.0	Aqueous	yellow to lilac

PROPERTIES OF CARRIER GASES FOR GAS CHROMATOGRAPHY

The following is a list of carrier gases sometimes used in gas chromatography, with properties relevant to the design of chromatographic systems. All data refer to normal atmospheric pressure (101.325 kPa).

M_r : Molecular weight (relative molar mass)

ρ_{25}: Density at 25 °C in g L^{-1}

λ: Thermal conductivity in mW m^{-1} $°C^{-1}$

η: Viscosity in µPa s (equal to 10^{-3} cP)

cp : Specific heat at 25 °C in J g^{-1} $°C^{-1}$

Gas	M	ρ_{25} (gL^{-1})	At 25 °C		At 250 *C		c_r (25 *C)
			λ mW $m^{-'}$ *$C^{-'}$	**η µPa s**	**λ mW $m^{-'}$ *$C^{-'}$**	**η µPa s a**	
Hydrogen	2.016	0.082	185.9	8.9	280	13.1	14.3
Helium	4.003	0.163	154.6	19.9	230	29.5	5.20
Argon	39.95	1.632	17.8	22.7	27.7	35.3	0.521
Nitrogen	28.01	1.144	25.9	17.9	39.6	26.8	1.039
Oxygen	32.00	1.308	26.2	20.7	42.6	31.8	0.919
Carbon monoxide	28.01	1.144	24.8	17.8	40.7	26.5	1.039
Carbon dioxide	44.01	1.798	16.7	14.9	35.5	24.9	0.843
Sulfur	146.05	5.969	13.1	28.1	15.3	24.8	0.664
Methane	16.04	0.655	34.5	11.1	75.0	17.6	2.23
Ethane	30.07	1.229	20.9	9.4	57.7	15.5	1.75
Ethylene	28.05	1.146	20.5	10.3	53.8	17.2	1.53
Propane	44.10	1.802	17.9	8.3	49.2	14.0	1.67

PROPERTIES OF CRYOGENIC FLUIDS

This table gives physical and thermodynamic properties of ten cryogenic fluids.
The properties are:

- M Molar mass
- T_t Triple-point temperature
- P_t Triple-point pressure
- ρ_t (l) Liquid density at the triple point
- $\Delta_{fus}H$ at Tt Enthalpy of fusion at the triple point
- T_b Normal boiling point at a pressure of 101.325 kPa (760 mmHg)
- ΔvapH at Tb Enthalpy of vaporization at the normal boiling point
- At T_b Density at the normal boiling point for the liquid (l) or vapour (v)
- C_p at T_b Heat capacity at constant pressure at the normal boiling point for the liquid (l) or vapour (v)
- u at Tb Speed of sound at the normal boiling point for the liquid (l) or vapour (v)
- Tc Critical temperature
- P_c Critical pressure , ρ_c Critical density

The references for all fluids except air, helium, neon, krypton, and xenon are given in the thermophysical properties of fluids table. The properties of hydrogen are given for the para form of the molecule. The triple-point temperature of air is the solidification temperature of the liquid. The boiling-point temperature for air is the bubble-point temperature (i.e., the temperature at which boiling begins as the pressure of the liquid is lowered). The dew-point (vapour) properties of air at 101.325 kPa are calculated at a temperature of 81.72 K; the liquid and vapour properties of these two state points are not in equilibrium. The triple-point properties of helium are given at the temperature of the lambda line (change from normal-to-superfluid helium) for the saturated-liquid state.

Property	Units	Air	N,	0_2	H	He	Ar	CH_4
M	g	28.9655	28.0134	31.9988	2.01588	4.0026	39.948	16.0428
T_t	K	59.75	63.151	54.361	13.8033	2.1768	83.8058	90.6941
P_t	kPa	5.265	12.52	0.1463	7.041	5.043	68.89	11.70
ρ_t(l)	g cm^{-3}	0.9578	0.8672	1.306	0.07698	0.1459	1.417	0.4515
Enthalpy of fusion	J g^{-1}		25.3	13.7	59.5		28.0	58.41
T_b	K	78.903	77.355	90.188	20.271	4.222	87.302	111.667
Enthalpy of vaporiza	J g^{-1}	204.8	199.2	213.1	446.1	20.91	161.1	510.8
ρ (l)@ T_b	g cm^{-3}	0.8752	0.8061	1.141	0.07083	0.1250	1.395	0.4224

ρ (v)@ T_b	g dm^{-3}	4.497	4.612	4.467	1.339	16.70	5.774	1.816
C_p (l)@ T_b	J g^{-1} K^{-1}	1.933	2.041	1.699	9.729	5.105	1.117	3.481
C_p (v)@ T_b	J g^{-1} K^{-1}	1.090	1.124	0.9707	12.03	9.327	0.5658	2.218
u (l)@ T_b	m s^{-1}	865.5	851.4	904.3	1111	177.3	838.3	1338
u (l)@ T_b	m s^{-1}	177.1	174.8	177.5	355.0	101.5	170.9	271.5
T_C	K	131530	126.192	154.581	32.938	5.1953	150.687	190.564
P_C	MPa	3.7860	33958	5.0430	1.2858	0.22746	4.8630	4.5992
ρ_c	g cm^{-3}	0.3426	0.3133	0.4361	0.03132	0.06958	0.5356	0.1627

PROPERTIES OF LIQUID HELIUM

The following data were obtained by a critical evaluation of all existing experimental measurements on liquid helium, using a fitting procedure described in the reference. All values refer to liquid helium at saturated vapor pressure; temperatures are on the ITS-90 scale. Several properties show a singularity at the lambda point (2.1768 K).

T/K	p/kPa	p/g cm^{-3}	C./J mo1^4 K"	$\Delta vapH(J)$	ε	σ *($mN\ m^{-1}$)*	$10^3\alpha_v$ (K^{-1})	η/μPa s	λ/W $(cm\text{-}K)^{-1}$
0.0		0.1451	0.00	59.83	1.05725		0.000		
0.5		0.1451	0.010	70.24	1.057254	0.3530	0.107		
1.0	0.01558	0.1451	0.415	80.33	1.057246	0.3471	0.309	3.873	
1.5	0.4715	0.1451	4.468	89.35	1.057265	0.3322	-2.36	1.346	
2.0	3.130	0.1456	21.28	93.07	1.057449	0.3021	-12.2	1.468	
2.5	10.23	0.1448	9.083	92.50	1.057135	0.2623	39.4	3.259	0.1497
3.0	24.05	0.1412	9.944	94.11	1.055683	0.2161	61	3.517	0.1717
3.5	47.05	0.1360	12.37	92.84	1.053615	0.1626	88.7	3.509	0.1868
4.0	81.62	0.1289	15.96	87.00	1.050770	0.1095	129	3.319	0.1965
4.5	130.3	0.1188	21.8	75.86	1.046725	0.0609	211		
5.0	196.0		44.7	47.67		0.0157			

PROPETRTIES OF FLUIDS

The absolute viscosity of some common liquids at temperatures between –25 °C and 100 °C is given in this table. Values were derived by fitting experimental data to suitable expressions for the temperature dependence. All values are given in units of milli pascal seconds (mPa s); this unit is identical to centipoise (cp).

Name	Mol. Fom.	η(-25°C)/ mPas	η(0 °C)/ mPas	η(025°C)/ mPas	η(50 °C)/ mPas	η(100 °C)/ mPas
Acetic acid	$C_2H_4O_2$			1.056	0.786	0.464
Acetic anhydride	$C_4H_6O_3$		1.241	0.843	0.614	0.377
Acetone	C_3H_6O	0.540	0.39	0.306	0.247	
Acetonitrile	C_2H_3N		0.40	0.369	0.284	
Acetophenone	C_5H_5O			1.681		0.634
Acetyl chloride	C_2H_3ClO			0.368	0.294	
Allyl alcohol	C_3H_6O			1.218	0.759	
Aniline	C_6H_7N			3.85	2.03	0.850
Anisole	C_7H_8O			1.056	0.747	0.427
Benzene	C_6H_6			0.604	0.436	
Benzonitrile	C_7H_5N			1.267	0.883	0.524
Benzyl alcohol	C_7H_8O			5.47	2.76	1.055
Benzylamine	C_7H_9N			1.624	1.080	0.577
Bromoethane	C_2H_5Br	0.635	0.47	0.374		
1-Bromopropane	C_3H_3Br		0.64	0.489	0.387	
2-Bromopropane	C_3H_7Br		0.61	0.458	0.359	
3-Bromopropene	C_3H_5Br		0.62	0.471	0.373	
Butanenitrile	C_4H_7N			0.553	0.418	0.268
Butanoic acid	C_4H_8O		2.22	1.426	0.982	0.542
2-Butanone	C_4H_8O	0.720	0.53	0.405	0.315	
Butyl acetate	$C_6H_{12}O_2$		1.00	0.685	0.500	0.305
Butylamine	$C_4H_{11}N$		0.83	0.574	0.409	
Butylbenzene	$C_{10}H_{14}$			0.950	0.683	
Butyl formate	$C_5H_{10}O_2$		0.93	0.644	0.472	0.289

LISTS OF DIFFUSION COEFFICIENTS D_{AB} AT INFINITE DILUTION FOR SOME BINARY LIQUID MIXTURES

Solute	Solvent	t/°C	$D_{AB}/10^{-5}\ cm^2 s^{-1}$
Acetic Acid	Acetone	25	3.31
Benzene	Acetone	25	4.25
Benzoic Acid	Acetone	25	2.62
Formic Acid	Acetone	25	3.77
Nitrobenzene	Acetone	20	2.94
Water	Acetone	25	4.56
Acetic Acid	Benzene	25	2.09
Bromobenzene	Benzene	8	1.45
Chloroethene	Benzene	8	1.77
Cyclohexane	Benzene	25	2.09
Chlorobenzene	Cyclohexane	25	1.34
Perylene	Cyclohexane	25	0.79
Pyrene	Cyclohexane	25	0.95
Allyl Alcohol	Ethanol	20	0.98
Toluene	Decane	25	1.93
Iodine	Ethanol	25	1.32
Benzene	Ethanol	25	1.88
Water	Ethanol	25	1.24

BOND LENGTHS IN ORGANOMETALLIC COMPOUNDS

This table summarizes the average values of interatomic distances of representative metal–ligand bonds. Sigma bonds between d- and f-block metals and the elements C, O and N are included. If four or more measurements are available, the standard deviation is given in parentheses. All values are in Angstrom units (10–10 m).[M here is the metal]

Cr	2.168	NCF	NCF	2.035(0.009)
Fe	2.074	2.091(0.030)	2.044	1.991(0.039)
Metal (M)	M-CH_3 (Methyl group attached)	M-CH_2-R (Alkyl group attached)	M-C-(=O)R (Carbonyl group)	M–CR=CR2 (Alkene group)
Co	2.014(0.023)	2.039(0.032)	1.990	1.934(0.019)
Ni	2.029	1.964	1.850(0.059)	1.892(0.017)
Zn	NCF	1.964	NCF	NCF
Hf	2.275(0.049)	NCF	NCF	2.205
W	2.189(0.039)	2.175	NCF	2.224
Zr	2.292(0.049)	NCF	NCF	2.257
Pt	2.083(0.045)	2.062(0.031)	2.019	2.024(0.037)
Ta	2.217(0.035)	2.225(0.056)	NCF	NCF
Hg	2.072(0.026	2.125	NCF	2.042
Pd	NCF	2.028	1.982(0.029)	2.000(0.024)

NCF stands for No Compound Formed

PROPERTIES OF SEMICONDUCTORS

The major properties of a few important semiconductors are:

- Density: It is defined as weight per volume of the semiconductor
- Thermal Conductivity: It is defined as the rate at which heat is transferred by conduction through a unit cross-section area of a material, when a temperature gradient exits perpendicular to the area.

Semiconductor	Density (g/cm^3)	Thermal Conductivity [mW/cm-K (300K)]
Si	2.329	1240
Ge	5.323	640
Sn	5.769	67
CuCl	3.53	8.4
AgBr	6.473	0.15
AgI	5.67	4.2
ZnS	5. 4.079	251
CdS	4.826	200
ZnSe	5.42	140
ZnTe	6.34	108

PROPERTIES OF SUPERCONDUCTORS

The two major properties of a superconductor are:

- Critical Temperature: It is denoted by T_c and is defined at which the resistivity of the superconductor tends to zero.
- Electronic Specific Heat: It is denoted by γ and is defined as the amount of heat energy required to raise the temperature of one mole of electrons by one degree Celsius.

The following table gives the information about the important elemental superconductors:

Metal	Critical Temperature(K)	Electron Heat Capacity (mJ $mol^{-1}K^{-1}$)
Al	1.175 ± 0.002	1.35
Be	0.026	0.21
Cd	0.517 ± 0.002	0.69
Ga	1.083 ± 0.001	0.60
Hf	0.128	2.21
In	3.408 ± 0.001	1.672
Mo	0.915 ± 0.005	1.83
Nb	9.25 ± 0.02	7.80
Os	0.66 ± 0.03	2.35
Pb	7.196 ± 0.006	3.1
Th	1.38 ± 0.02	4.32
V	5.40 ± 0.05	9.82

PROPERTIES OF SELECTED POLYMERS

The following are the properties of a few selected polymers that are to be discussed:

- The coefficient of linear thermal expansion is the fractional change in length per °C change in temperature at constant pressure.
- The flexural strength, or cross-breaking strength, of a material is a measure of the bending strength or stiffness.
- The heat deflection temperature (HDT), or heat distortion temperature, is the temperature at which a polymer or plastic sample deforms under a specified load.

These properties are listed in the table below:

Polymer	Coefficient of linear expansion (10^{-5}/°C)	Flexural Strength (kPa)	Heat Deflection Temperature (°C)
PET	6.5	1.1×10^5	100
PBC	7.0	9.6×10^4	65
PT	6.8	9.3×10^4	130
Nylon 6,6	8.0	1×10^5	75
Nylon 6	8.0	9.7×10^4	80
iPP	9.0	5×10^4	55
Plasticized PVC	12.0	Not fixed	Not fixed
Rigid PVC	6.0	9×10^4	75
PET: poly (ethylene terephthalate) PBC: poly (butylene terephthalate) PC: polycarbonate iPP: isotactic polypropylene PVC: Poly Vinyl Chloride			

ADVERSE EFFECTS OF GLOBAL WARMING

Adverse effects of Greenhouse effect

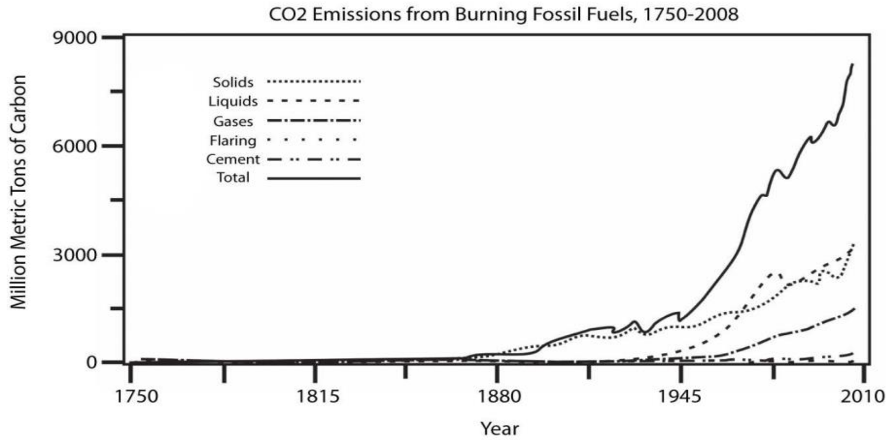
In the greenhouse effect, gases like carbon dioxide and methane entrap the heat from the Sun and does not let it escape out of the atmosphere. This results in effects like:

- Increase in heat in the surroundings,
- Extreme weather conditions, like heavy floods and draughts,
- Migration of species

The following table indicates the concentration of CO_2 in the atmosphere increased from 1961 to 2011, expressed in parts per million:

Year	Presence of CO_2 (ppm)
1961	317.61
1971	326.62
1981	340.10
1991	355.5
2001	371.13
2011	391.63

The following graph indicates the production of carbon dioxide in the atmosphere:



The following table expresses the rise in the annual mean global surface temperature, and can be expressed as in terms of every decade below:

Year	Global Mean Surface Temperature(°C)
1961	14.05
1971	13.91
1981	14.33
1991	14.42
2001	14.54
2011	14.60

As we can see, mainly due to global warming, there has been an overall rise in the temperature of the surface of the Earth. A graph can show the exact depiction: