Chemistry Data Booklet

Higher and Advanced Higher

For use in National Qualification Courses

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Relationships for Higher and Advanced Higher Chemistry

$E_h = cm\Delta T$

$\%\ \text{yield} = \dfrac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$

$\%\ \text{atom economy} = \dfrac{\text{Mass of desired product(s)}}{\text{Total mass of reactants}} \times 100$

$n = cV$

$\dfrac{c_1V_1}{n_1} = \dfrac{c_2V_2}{n_2}$

$n = \dfrac{m}{GFM}$

$\%\ \text{by mass} = \dfrac{m}{GFM} \times 100$

$average\ rate = \dfrac{\Delta quantity}{\Delta t}$

$reaction\ rate = \dfrac{1}{t}$

$c = f\lambda$

$E = Lhf$

$E = \dfrac{Lhc}{\lambda}$

$K = \dfrac{[C]^c[D]^d}{[A]^a[B]^b}$ for $aA + bB \rightleftharpoons cC + dD$

$\text{pH} = -\log_{10}[H_3O^+]$

$\text{pOH} = -\log_{10}[OH^-]$

$\text{p}K_a = -\log_{10} K_a$

$\text{pH} = \text{p}K_a - \log_{10}\dfrac{[\text{acid}]}{[\text{salt}]}$

$\text{pH} = \frac{1}{2}\text{p}K_a - \frac{1}{2}\log_{10} c$

$K_W = [H_3O^+][OH^-]$

$\text{pH} + \text{pOH} = 14$

$K_{In} = \dfrac{[H_3O^+][In^-]}{[HIn]}$

$\text{pH} = \text{p}K_{In} \pm 1$

$\Delta H° = \sum \Delta H°_f(\text{products}) - \sum \Delta H°_f(\text{reactants})$

$\Delta S° = \sum S°(\text{products}) - \sum S°(\text{reactants})$

$\Delta G° = \sum \Delta G°_f\ (\text{products}) - \sum \Delta G°_f\ (\text{reactants})$

$\Delta G = \Delta H - T\Delta S$

$\Delta G° = \Delta H° - T\Delta S°$

Names, Symbols, Relative Atomic Masses and Densities

(Relative atomic masses, also known as average atomic masses, have been rounded to the nearest 0.1)

Element	Symbol	Relative atomic mass	Density ($g\,cm^{-3}$)
Actinium	Ac	227.0	10.0
Aluminium	Al	27.0	2.70
Americium	Am	243.1	12.0
Antimony	Sb	121.8	6.68
Argon	Ar	39.9	0.0018
Arsenic	As	74.9	5.75
Astatine	At	210.0	unknown
Barium	Ba	137.3	3.62
Berkelium	Bk	247.1	13.3
Beryllium	Be	9.0	1.85
Bismuth	Bi	209.0	9.79
Boron	B	10.8	2.34
Bromine	Br	79.9	3.10
Cadmium	Cd	112.4	8.69
Calcium	Ca	40.1	1.54
Californium	Cf	251.1	15.1
Carbon	C	12.0	*
Cerium	Ce	140.1	6.77
Caesium	Cs	132.9	1.87
Chlorine	Cl	35.5	0.0032
Chromium	Cr	52.0	7.15
Cobalt	Co	58.9	8.86
Copper	Cu	63.5	8.96
Curium	Cm	247.1	13.51
Dysprosium	Dy	162.5	8.55
Einsteinium	Es	252.1	unknown
Erbium	Er	167.3	9.07
Europium	Eu	152.0	5.24
Fluorine	F	19.0	0.0017
Francium	Fr	223.0	unknown
Gadolinium	Gd	157.3	7.90
Gallium	Ga	69.7	5.91
Germanium	Ge	72.6	5.32
Gold	Au	197.0	19.3
Hafnium	Hf	178.5	13.3
Helium	He	4.0	0.0002
Holmium	Ho	164.9	8.80
Hydrogen	H	1.0	0.00009
Indium	In	114.8	7.31
Iodine	I	126.9	4.93
Iridium	Ir	192.2	22.6
Iron	Fe	55.8	7.87
Krypton	Kr	83.8	0.0037
Lanthanum	La	138.9	6.15
Lead	Pb	207.2	11.3
Lithium	Li	6.9	0.53
Lutetium	Lu	175.0	9.84
Magnesium	Mg	24.3	1.74
Manganese	Mn	54.9	7.30
Mercury	Hg	200.6	13.5
Molybdenum	Mo	96.0	10.2
Neodymium	Nd	144.2	7.01
Neon	Ne	20.2	0.0009
Neptunium	Np	237.0	20.2
Nickel	Ni	58.7	8.90
Niobium	Nb	92.9	8.57
Nitrogen	N	14.0	0.0013
Osmium	Os	190.2	22.6
Oxygen	O	16.0	0.0014
Palladium	Pd	106.4	12.0
Phosphorus	P	31.0	1.82
Platinum	Pt	195.1	21.5
Plutonium	Pu	244.1	19.7
Polonium	Po	209.0	9.20
Potassium	K	39.1	0.89
Praseodymium	Pr	140.9	6.77
Promethium	Pm	144.9	7.26
Protactinium	Pa	231.0	15.4
Radium	Ra	226.0	5.00
Radon	Rn	222.0	0.0097
Rhenium	Re	186.2	20.8
Rhodium	Rh	102.9	12.4
Rubidium	Rb	85.5	1.53
Ruthenium	Ru	101.1	12.1
Samarium	Sm	150.4	7.52
Scandium	Sc	45.0	2.99
Selenium	Se	79.0	4.81
Silicon	Si	28.1	2.33
Silver	Ag	107.9	10.5
Sodium	Na	23.0	0.97
Strontium	Sr	87.6	2.64
Sulfur	S	32.1	2.00
Tantalum	Ta	180.9	16.4
Technetium	Tc	97.9	11.0
Tellurium	Te	127.6	6.23
Terbium	Tb	158.9	8.23
Thallium	Tl	204.4	11.8
Thorium	Th	232.0	11.7
Thulium	Tm	168.9	9.32
Tin	Sn	118.7	7.29
Titanium	Ti	47.9	4.51
Tungsten	W	183.8	19.3
Uranium	U	238.0	19.1
Vanadium	V	50.9	6.00
Xenon	Xe	131.3	0.0059
Ytterbium	Yb	173.0	6.90
Yttrium	Y	88.9	4.47
Zinc	Zn	65.4	7.13
Zirconium	Zr	91.2	6.52

*The density of carbon as graphite is 2.27 $g\,cm^{-3}$
The density of carbon as diamond is 3.51 $g\,cm^{-3}$

Melting and Boiling Points of Selected Elements

Group 1	Group 2											Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
1 Hydrogen **–259** *–253*																	2 Helium **–271** *–269*
3 Lithium **181** *1342*	4 Beryllium **1287** *2471**											5 Boron **2077** *4000*	6 Carbon **†3825**	7 Nitrogen **–210** *–196*	8 Oxygen **–219** *–183*	9 Fluorine **–220** *–188*	10 Neon **–249** *–246*
11 Sodium **98** *883*	12 Magnesium **650** *1090*											13 Aluminium **660** *2519*	14 Silicon **1414** *3265*	15 Phosphorus **44** *281*	16 Sulfur **115** *445*	17 Chlorine **–101** *–34*	18 Argon **–189** *–186*
19 Potassium **63** *759*	20 Calcium **842** *1484*	21 Scandium **1541** *2836*	22 Titanium **1670** *3287*	23 Vanadium **1910** *3407*	24 Chromium **1907** *2671*	25 Manganese **1246** *2061*	26 Iron **1538** *2861*	27 Cobalt **1495** *2927*	28 Nickel **1455** *2913*	29 Copper **1085** *2560*	30 Zinc **420** *907*	31 Gallium **30** *2229*	32 Germanium **938** *2833*	33 Arsenic **817** *†616*	34 Selenium **221** *685*	35 Bromine **–7** *59*	36 Krypton **–157** *–153*
37 Rubidium **39** *688*	38 Strontium **777** *1377*	39 Yttrium **1522** *3345*	40 Zirconium **1854** *4406*	41 Niobium **2477** *4741*	42 Molybdenum **2622** *4639*	43 Technetium **2157** *4262*	44 Ruthenium **2333** *4147*	45 Rhodium **1963** *3695*	46 Palladium **1555** *2963*	47 Silver **962** *2162*	48 Cadmium **321** *767*	49 Indium **157** *2072*	50 Tin **232** *2586*	51 Antimony **631** *1587*	52 Tellurium **450** *988*	53 Iodine **114** *184*	54 Xenon **–112** *–108*
55 Caesium **28** *671*	56 Barium **727** *1845*	57 Lanthanum **920** *3464*	72 Hafnium **2233** *4600*	73 Tantalum **3017** *5455*	74 Tungsten **3414** *5555*	75 Rhenium **3185** *5590*	76 Osmium **3033** *5008*	77 Iridium **2446** *4428*	78 Platinum **1768** *3825*	79 Gold **1064** *2836*	80 Mercury **–39** *357*	81 Thallium **304** *1473*	82 Lead **327** *1749*	83 Bismuth **271** *1564*	84 Polonium **254** *962*	85 Astatine **302**	86 Radon **–71** *–62*

Key

Atomic number
Name of element
Melting point (°C)
Boiling point (°C)

* at 28 atmospheres
† sublimes

Covalent Radii of Selected Elements

Key

Atomic number
Name of element
Covalent radius (pm)

Group 1	Group 2										Group 3	Group 4	Group 5	Group 6	Group 7
1 Hydrogen 32															
3 Lithium 130	4 Beryllium 99										5 Boron 84	6 Carbon 75	7 Nitrogen 71	8 Oxygen 64	9 Fluorine 60
11 Sodium 160	12 Magnesium 140										13 Aluminium 124	14 Silicon 114	15 Phosphorus 109	16 Sulfur 104	17 Chlorine 100
19 Potassium 200	20 Calcium 174	21 Scandium 159	22 Titanium 148	23 Vanadium 144	24 Chromium 130	25 Manganese 129	26 Iron 124	27 Cobalt 118	28 Nickel 117	29 Copper 122	30 Zinc 120	31 Gallium 123	32 Germanium 120	33 Arsenic 120	34 Selenium 118	35 Bromine 117
37 Rubidium 215	38 Strontium 190	39 Yttrium 176	40 Zirconium 164	41 Niobium 156	42 Molybdenum 146	43 Technetium 138	44 Ruthenium 136	45 Rhodium 134	46 Palladium 130	47 Silver 136	48 Cadmium 140	49 Indium 142	50 Tin 140	51 Antimony 140	52 Tellurium 137	53 Iodine 136
55 Caesium 238	56 Barium 206	57 Lanthanum 194	72 Hafnium 164	73 Tantalum 158	74 Tungsten 150	75 Rhenium 141	76 Osmium 136	77 Iridium 132	78 Platinum 130	79 Gold 130	80 Mercury 132	81 Thallium 144	82 Lead 145	83 Bismuth 150	84 Polonium 142	85 Astatine 148

Electron Arrangements of Elements

Key

Atomic number
Symbol
Electron arrangement
Name

Group 1 (1)	Group 2 (2)	Transition Elements (3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Group 3 (13)	Group 4 (14)	Group 5 (15)	Group 6 (16)	Group 7 (17)	Group 0 (18)
1 **H** 1 Hydrogen																	2 **He** 2 Helium
3 **Li** 2,1 Lithium	4 **Be** 2,2 Beryllium											5 **B** 2,3 Boron	6 **C** 2,4 Carbon	7 **N** 2,5 Nitrogen	8 **O** 2,6 Oxygen	9 **F** 2,7 Fluorine	10 **Ne** 2,8 Neon
11 **Na** 2,8,1 Sodium	12 **Mg** 2,8,2 Magnesium											13 **Al** 2,8,3 Aluminium	14 **Si** 2,8,4 Silicon	15 **P** 2,8,5 Phosphorus	16 **S** 2,8,6 Sulfur	17 **Cl** 2,8,7 Chlorine	18 **Ar** 2,8,8 Argon
19 **K** 2,8,8,1 Potassium	20 **Ca** 2,8,8,2 Calcium	21 **Sc** 2,8,9,2 Scandium	22 **Ti** 2,8,10,2 Titanium	23 **V** 2,8,11,2 Vanadium	24 **Cr** 2,8,13,1 Chromium	25 **Mn** 2,8,13,2 Manganese	26 **Fe** 2,8,14,2 Iron	27 **Co** 2,8,15,2 Cobalt	28 **Ni** 2,8,16,2 Nickel	29 **Cu** 2,8,18,1 Copper	30 **Zn** 2,8,18,2 Zinc	31 **Ga** 2,8,18,3 Gallium	32 **Ge** 2,8,18,4 Germanium	33 **As** 2,8,18,5 Arsenic	34 **Se** 2,8,18,6 Selenium	35 **Br** 2,8,18,7 Bromine	36 **Kr** 2,8,18,8 Krypton
37 **Rb** 2,8,18,8,1 Rubidium	38 **Sr** 2,8,18,8,2 Strontium	39 **Y** 2,8,18,9,2 Yttrium	40 **Zr** 2,8,18,10,2 Zirconium	41 **Nb** 2,8,18,12,1 Niobium	42 **Mo** 2,8,18,13,1 Molybdenum	43 **Tc** 2,8,18,13,2 Technetium	44 **Ru** 2,8,18,15,1 Ruthenium	45 **Rh** 2,8,18,16,1 Rhodium	46 **Pd** 2,8,18,18,0 Palladium	47 **Ag** 2,8,18,18,1 Silver	48 **Cd** 2,8,18,18,2 Cadmium	49 **In** 2,8,18,18,3 Indium	50 **Sn** 2,8,18,18,4 Tin	51 **Sb** 2,8,18,18,5 Antimony	52 **Te** 2,8,18,18,6 Tellurium	53 **I** 2,8,18,18,7 Iodine	54 **Xe** 2,8,18,18,8 Xenon
55 **Cs** 2,8,18,18,8,1 Caesium	56 **Ba** 2,8,18,18,8,2 Barium	57 **La** 2,8,18,18,9,2 Lanthanum	72 **Hf** 2,8,18,32,10,2 Hafnium	73 **Ta** 2,8,18,32,11,2 Tantalum	74 **W** 2,8,18,32,12,2 Tungsten	75 **Re** 2,8,18,32,13,2 Rhenium	76 **Os** 2,8,18,32,14,2 Osmium	77 **Ir** 2,8,18,32,15,2 Iridium	78 **Pt** 2,8,18,32,17,1 Platinum	79 **Au** 2,8,18,32,18,1 Gold	80 **Hg** 2,8,18,32,18,2 Mercury	81 **Tl** 2,8,18,32,18,3 Thallium	82 **Pb** 2,8,18,32,18,4 Lead	83 **Bi** 2,8,18,32,18,5 Bismuth	84 **Po** 2,8,18,32,18,6 Polonium	85 **At** 2,8,18,32,18,7 Astatine	86 **Rn** 2,8,18,32,18,8 Radon
87 **Fr** 2,8,18,32,18,8,1 Francium	88 **Ra** 2,8,18,32,18,8,2 Radium	89 **Ac** 2,8,18,32,18,9,2 Actinium	104 **Rf** 2,8,18,32,32,10,2 Rutherfordium	105 **Db** 2,8,18,32,32,11,2 Dubnium	106 **Sg** 2,8,18,32,32,12,2 Seaborgium	107 **Bh** 2,8,18,32,32,13,2 Bohrium	108 **Hs** 2,8,18,32,32,14,2 Hassium	109 **Mt** 2,8,18,32,32,15,2 Meitnerium	110 **Ds** 2,8,18,32,32,17,1 Darmstadtium	111 **Rg** 2,8,18,32,32,18,1 Roentgenium	112 **Cn** 2,8,18,32,32,18,2 Copernicium	113 **Nh** 2,8,18,32,32,18,3 Nihonium	114 **Fl** 2,8,18,32,32,18,4 Flerovium	115 **Mc** 2,8,18,32,32,18,5 Moscovium	116 **Lv** 2,8,18,32,32,18,6 Livermorium	117 **Ts** 2,8,18,32,32,18,7 Tennessine	118 **Og** 2,8,18,32,32,18,8 Oganesson

Lanthanides	57 **La** 2,8,18,18,9,2 Lanthanum	58 **Ce** 2,8,18,20,8,2 Cerium	59 **Pr** 2,8,18,21,8,2 Praseodymium	60 **Nd** 2,8,18,22,8,2 Neodymium	61 **Pm** 2,8,18,23,8,2 Promethium	62 **Sm** 2,8,18,24,8,2 Samarium	63 **Eu** 2,8,18,25,8,2 Europium	64 **Gd** 2,8,18,25,9,2 Gadolinium	65 **Tb** 2,8,18,27,8,2 Terbium	66 **Dy** 2,8,18,28,8,2 Dysprosium	67 **Ho** 2,8,18,29,8,2 Holmium	68 **Er** 2,8,18,30,8,2 Erbium	69 **Tm** 2,8,18,31,8,2 Thulium	70 **Yb** 2,8,18,32,8,2 Ytterbium	71 **Lu** 2,8,18,32,9,2 Lutetium
Actinides	89 **Ac** 2,8,18,32,18,9,2 Actinium	90 **Th** 2,8,18,32,18,10,2 Thorium	91 **Pa** 2,8,18,32,20,9,2 Protactinium	92 **U** 2,8,18,32,21,9,2 Uranium	93 **Np** 2,8,18,32,22,9,2 Neptunium	94 **Pu** 2,8,18,32,24,8,2 Plutonium	95 **Am** 2,8,18,32,25,8,2 Americium	96 **Cm** 2,8,18,32,25,9,2 Curium	97 **Bk** 2,8,18,32,27,8,2 Berkelium	98 **Cf** 2,8,18,32,28,8,2 Californium	99 **Es** 2,8,18,32,29,8,2 Einsteinium	100 **Fm** 2,8,18,32,30,8,2 Fermium	101 **Md** 2,8,18,32,31,8,2 Mendelevium	102 **No** 2,8,18,32,32,8,2 Nobelium	103 **Lr** 2,8,18,32,32,9,2 Lawrencium

Formulae of Selected Ions containing more than one kind of Atom

one positive		one negative		two negative		three negative	
Ion	**Formula**	**Ion**	**Formula**	**Ion**	**Formula**	**Ion**	**Formula**
ammonium	NH_4^+	ethanoate	CH_3COO^-	carbonate	CO_3^{2-}	phosphate	PO_4^{3-}
		hydrogencarbonate	HCO_3^-	chromate	CrO_4^{2-}		
		hydrogensulfate	HSO_4^-	dichromate	$Cr_2O_7^{2-}$		
		hydrogensulfite	HSO_3^-	sulfate	SO_4^{2-}		
		hydroxide	OH^-	sulfite	SO_3^{2-}		
		nitrate	NO_3^-	thiosulfate	$S_2O_3^{2-}$		
		permanganate	MnO_4^-				

Solubilities of Selected Compounds in Water

The table shows how some compounds behave in cold water

vs means very soluble (a solubility greater than 10 g l^{-1})
s means soluble (a solubility of between 1 and 10 g l^{-1})
i means insoluble (a solubility of less than 1 g l^{-1})
— no data

	bromide	**carbonate**	**chloride**	**iodide**	**nitrate**	**phosphate**	**sulfate**	**oxide**	**hydroxide**
aluminium	vs	—	vs	vs	vs	i	vs	i	i
ammonium	vs	vs	vs	vs	vs	vs	vs	—	—
barium	vs	i	vs	vs	vs	i	i	vs	vs
calcium	vs	i	vs	vs	vs	i	s	s	s
copper(II)	vs	i	vs	—	vs	i	vs	i	i
iron(II)	vs	i	vs	vs	vs	i	vs	i	i
iron(III)	vs	—	vs	—	vs	i	vs	i	i
lead(II)	s	i	s	i	vs	i	i	i	i
lithium	vs	vs	vs	vs	vs	i	vs	vs	vs
magnesium	vs	i	vs	vs	vs	i	vs	i	i
nickel	vs	i	vs	vs	vs	i	vs	i	i
potassium	vs	vs	vs	vs	vs	vs	vs	vs	vs
silver	i	i	i	i	vs	i	s	i	—
sodium	vs	vs	vs	vs	vs	vs	vs	vs	vs
tin(II)	vs	i	vs	s	—	i	vs	i	i
zinc	vs	i	vs	vs	vs	i	vs	i	i

Note: Some of the compounds in the table hydrolyse significantly in water.

Melting and Boiling Points of Selected Oxides

Element	Formula of oxide	mp (°C)	bp (°C)
hydrogen	H_2O	0	100
lithium	Li_2O	1438	
beryllium	BeO	2578	3900
boron	B_2O_3	450	1860
carbon	CO_2	sublimes at −78	
nitrogen	N_2O_4	−9	21
fluorine	F_2O	−224	−144
sodium	Na_2O	sublimes at 1134	
magnesium	MgO	2825	3600
aluminium	Al_2O_3	2053	2977
silicon	SiO_2	1713	2950
phosphorus	P_4O_{10}	sublimes at 300	
sulfur	SO_2	−75	−10
chlorine	Cl_2O	−121	2
potassium	K_2O	740	
calcium	CaO	2613	

Melting and Boiling Points of Selected Chlorides

Element	Formula of chloride	mp (°C)	bp (°C)
lithium	LiCl	610	1383
beryllium	$BeCl_2$	405	482
boron	BCl_3	−107	12
carbon	CCl_4	−23	77
nitrogen	NCl_3	−40	71
fluorine	FCl	−155	−100
sodium	NaCl	802	1465
magnesium	$MgCl_2$	714	1412
aluminium	Al_2Cl_6	sublimes at 180	
silicon	$SiCl_4$	−69	58
phosphorus	PCl_3	−93	76
sulfur	SCl_2	−122	60
potassium	KCl	771	1680
calcium	$CaCl_2$	775	

Melting and Boiling Points of Selected Organic Compounds

Name of compound	mp (°C)	bp (°C)
methane	−182	−162
ethane	−183	−89
propane	−188	−42
butane	−138	−1
pentane	−130	36
hexane	−95	69
heptane	−90	98
octane	−57	126
cyclobutane	−91	12
cyclopentane	−93	49
cyclohexane	7	81
ethene	−169	−104
propene	−185	−48
but-1-ene	−185	−6
pent-1-ene	−165	30
hex-1-ene	−140	63
benzene	6	80

Name of compound	mp (°C)	bp (°C)
methanol	−98	65
ethanol	−114	78
propan-1-ol	−124	97
propan-2-ol	−88	82
butan-1-ol	−89	118
butan-2-ol	−88	99
methanal	−92	−19
ethanal	−123	21
propanal	−80	48
butanal	−97	75
propanone	−95	56
butanone	−87	80
methanoic acid	8	101
ethanoic acid	17	118
propanoic acid	−20	142
butanoic acid	−5	164
methoxyethane	−113	7
ethoxyethane	−116	34

Enthalpies of Formation and Combustion of Selected Substances

Substance	Standard enthalpy of formation (kJ mol^{-1})	Standard enthalpy of combustion (kJ mol^{-1})
hydrogen	–	−286
carbon (graphite)	–	−394
sulfur (rhombic)	–	−297
methane	−75	−891
ethane	−84	−1561
propane	−104	−2220
butane	−126	−2878
benzene	49	−3268
ethene	52	−1411
ethyne	227	−1300
methanol	−239	−726
ethanol	−278	−1367
propan-1-ol	−303	−2021
methanoic acid	−425	−254
ethanoic acid	−484	−874

Selected Bond and Mean Bond Enthalpies

Bond Enthalpies

Bond	Enthalpy (kJ mol^{-1})
H – H	436
O = O	498
N ≡ N	945
F – F	159
Cl – Cl	243
Br – Br	194
I – I	152
H – F	570
H – Cl	431
H – Br	366
H – I	298

Mean Bond Enthalpies

Bond	Mean Enthalpy (kJ mol^{-1})
Si – Si	226
C – C	346
C = C	614
C ≡ C	839
C – C (aromatic)	507
H – O	463
H – N	388
C – H	412
C – N	296
C ≡ N	937
C – O	360
C = O	804
C – F	484
C – Cl	338
C – Br	276
C – I	238

Enthalpy of Sublimation of Carbon

The energy required to convert 1 mole solid carbon into 1 mole gaseous carbon atoms is 716 kJ at 298 K (25 °C). The equation is

$$C(s) \rightarrow C(g) \quad \Delta H = 716 \text{ kJ}$$

Ionisation Energies and Electronegativities of Selected Elements

Notes: The first ionisation energy for an element E refers to the reaction $E(g) \rightarrow E^+(g) + e^-$; the second ionisation energy refers to $E^+(g) \rightarrow E^{2+}(g) + e^-$; etc.

Element	Symbol	Ionisation Energies ($kJ\,mol^{-1}$)				Electro-negativity (Pauling scale)
		First	Second	Third	Fourth	
hydrogen	H	1312	–	–	–	2.2
helium	He	2372	5251	–	–	–
lithium	Li	520	7298	11 815	–	1.0
beryllium	Be	900	1757	14 849	21 007	1.6
boron	B	801	2427	3660	25 026	2.0
carbon	C	1086	2353	4620	6223	2.6
nitrogen	N	1402	2856	4578	7475	3.0
oxygen	O	1314	3389	5300	7469	3.4
fluorine	F	1681	3374	6050	8408	4.0
neon	Ne	2081	3952	6122	9371	–
sodium	Na	496	4562	6910	9543	0.9
magnesium	Mg	738	1451	7733	10 543	1.3
aluminium	Al	578	1817	2745	11 577	1.6
silicon	Si	787	1577	3232	4356	1.9
phosphorus	P	1012	1908	2914	4964	2.2
sulfur	S	1000	2252	3357	4556	2.6
chlorine	Cl	1251	2298	3822	5159	3.2
argon	Ar	1521	2666	3931	5771	–
potassium	K	419	3052	4420	5877	0.8
calcium	Ca	590	1145	4912	6491	1.0
scandium	Sc	633	1235	2389	7091	1.4
titanium	Ti	659	1310	2653	4175	1.5
vanadium	V	651	1410	2828	4507	1.6
chromium	Cr	653	1591	2987	4743	1.7
manganese	Mn	717	1509	3248	4940	1.6
iron	Fe	762	1562	2957	5287	1.8
cobalt	Co	760	1648	3232	4950	1.9
nickel	Ni	737	1753	3395	5297	1.9
copper	Cu	745	1958	3555	5536	1.9
zinc	Zn	906	1733	3833	5731	1.7
gallium	Ga	579	1979	2965	6102	1.8
germanium	Ge	762	1537	3302	4411	2.0
arsenic	As	944	1794	2735	4837	2.0
bromine	Br	1140	2083	3473	4564	3.0
rubidium	Rb	403	2633	3859	5075	0.8
strontium	Sr	549	1064	4138	5500	1.0
silver	Ag	731	2072	3361	–	1.9
tin	Sn	709	1412	2943	3930	2.0
antimony	Sb	831	1605	2441	4265	2.1
iodine	I	1008	1846	3184	–	2.7
caesium	Cs	376	2234	–	–	0.8
barium	Ba	503	965	–	–	0.9
gold	Au	890	1949	–	–	2.4
lead	Pb	716	1450	3081	4083	1.8

Electrochemical Series: Standard Reduction Potentials

Note: The data given below are reduction potentials applicable to standard state conditions.

Reaction			E° (V)
$Li^+(aq) + e^-$	$\rightleftharpoons$	$Li(s)$	−3.04
$Cs^+(aq) + e^-$	$\rightleftharpoons$	$Cs(s)$	−3.03
$Rb^+(aq) + e^-$	$\rightleftharpoons$	$Rb(s)$	−2.98
$K^+(aq) + e^-$	$\rightleftharpoons$	$K(s)$	−2.93
$Sr^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Sr(s)$	−2.90
$Ca^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Ca(s)$	−2.87
$Na^+(aq) + e^-$	$\rightleftharpoons$	$Na(s)$	−2.71
$Mg^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Mg(s)$	−2.37
$Al^{3+}(aq) + 3e^-$	$\rightleftharpoons$	$Al(s)$	−1.68
$2H_2O(\ell) + 2e^-$	$\rightleftharpoons$	$H_2(g) + 2OH^-(aq)$	−0.83
$Zn^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Zn(s)$	−0.76
$Cr^{3+}(aq) + 3e^-$	$\rightleftharpoons$	$Cr(s)$	−0.74
$Fe^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Fe(s)$	−0.45
$Ni^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Ni(s)$	−0.26
$Sn^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Sn(s)$	−0.14
$Pb^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Pb(s)$	−0.13
$Fe^{3+}(aq) + 3e^-$	$\rightleftharpoons$	$Fe(s)$	−0.04
$2H^+(aq) + 2e^-$	$\rightleftharpoons$	$H_2(g)$	0.00
$S_4O_6^{2-}(aq) + 2e^-$	$\rightleftharpoons$	$2S_2O_3^{2-}(aq)$	0.08
$Sn^{4+}(aq) + 2e^-$	$\rightleftharpoons$	$Sn^{2+}(aq)$	0.15
$Cu^{2+}(aq) + e^-$	$\rightleftharpoons$	$Cu^+(aq)$	0.15
$SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$	$\rightleftharpoons$	$SO_3^{2-}(aq) + H_2O(\ell)$	0.17
$Cu^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34
$O_2(g) + 2H_2O(\ell) + 4e^-$	$\rightleftharpoons$	$4OH^-(aq)$	0.40
$I_2(s) + 2e^-$	$\rightleftharpoons$	$2I^-(aq)$	0.54
$Fe^{3+}(aq) + e^-$	$\rightleftharpoons$	$Fe^{2+}(aq)$	0.77
$Ag^+(aq) + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80
$Hg^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Hg(\ell)$	0.85
$Br_2(\ell) + 2e^-$	$\rightleftharpoons$	$2Br^-(aq)$	1.07
$O_2(g) + 4H^+(aq) + 4e^-$	$\rightleftharpoons$	$2H_2O(\ell)$	1.23
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$	$\rightleftharpoons$	$2Cr^{3+}(aq) + 7H_2O(\ell)$	1.36
$Cl_2(g) + 2e^-$	$\rightleftharpoons$	$2Cl^-(aq)$	1.36
$MnO_4^-(aq) + 8H^+(aq) + 5e^-$	$\rightleftharpoons$	$Mn^{2+}(aq) + 4H_2O(\ell)$	1.51
$H_2O_2(aq) + 2H^+(aq) + 2e^-$	$\rightleftharpoons$	$2H_2O(\ell)$	1.78
$F_2(g) + 2e^-$	$\rightleftharpoons$	$2F^-(aq)$	2.87

Electrolysis of Water

Reduction reactions at the negative electrode

$$2H_2O(\ell) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$$
$$2H^+(aq) + 2e^- \longrightarrow H_2(g)$$

Oxidation reactions at the positive electrode

$$2H_2O(\ell) \longrightarrow O_2(g) + 4H^+(aq) + 4e^-$$
$$4OH^-(aq) \longrightarrow 2H_2O(\ell) + O_2(g) + 4e^-$$

Dissociation Constants of Selected Species

Equilibrium in aqueous solution				K_a	pK_a
methanoic acid	$HCOOH + H_2O$	$\rightleftharpoons$	$H_3O^+ + HCOO^-$	1.8×10^{-4}	3.75
ethanoic acid	$CH_3COOH + H_2O$	$\rightleftharpoons$	$H_3O^+ + CH_3COO^-$	1.7×10^{-5}	4.76
propanoic acid	$CH_3CH_2COOH + H_2O$	$\rightleftharpoons$	$H_3O^+ + CH_3CH_2COO^-$	1.3×10^{-5}	4.87
butanoic acid	$CH_3(CH_2)_2COOH + H_2O$	$\rightleftharpoons$	$H_3O^+ + CH_3(CH_2)_2COO^-$	1.5×10^{-5}	4.83
benzoic acid	$C_6H_5COOH + H_2O$	$\rightleftharpoons$	$H_3O^+ + C_6H_5COO^-$	6.3×10^{-5}	4.20
phenol	$C_6H_5OH + H_2O$	$\rightleftharpoons$	$H_3O^+ + C_6H_5O^-$	1.0×10^{-10}	9.99
hydrofluoric acid	$HF + H_2O$	$\rightleftharpoons$	$H_3O^+ + F^-$	6.3×10^{-4}	3.20
boric acid	$H_3BO_3 + H_2O$	$\rightleftharpoons$	$H_3O^+ + H_2BO_3^-$	5.4×10^{-10}	9.27
hydrocyanic acid	$HCN + H_2O$	$\rightleftharpoons$	$H_3O^+ + CN^-$	6.2×10^{-10}	9.21
carbonic acid	$H_2O + CO_2 + H_2O$	$\rightleftharpoons$	$H_3O^+ + HCO_3^-$	4.5×10^{-7}	6.35
hydrogencarbonate ion	$HCO_3^- + H_2O$	$\rightleftharpoons$	$H_3O^+ + CO_3^{2-}$	4.7×10^{-11}	10.33
sulfurous acid	$H_2SO_3 + H_2O$	$\rightleftharpoons$	$H_3O^+ + HSO_3^-$	1.4×10^{-2}	1.85
hydrogensulfite ion	$HSO_3^- + H_2O$	$\rightleftharpoons$	$H_3O^+ + SO_3^{2-}$	6.3×10^{-8}	7.20
hydrogen sulfide	$H_2S + H_2O$	$\rightleftharpoons$	$H_3O^+ + HS^-$	8.9×10^{-8}	7.05
hydrogensulfide ion	$HS^- + H_2O$	$\rightleftharpoons$	$H_3O^+ + S^{2-}$	1.0×10^{-19}	19.00
phosphoric acid	$H_3PO_4 + H_2O$	$\rightleftharpoons$	$H_3O^+ + H_2PO_4^-$	6.9×10^{-3}	2.16
dihydrogenphosphate ion	$H_2PO_4^- + H_2O$	$\rightleftharpoons$	$H_3O^+ + HPO_4^{2-}$	6.2×10^{-8}	7.21
hydrogenphosphate ion	$HPO_4^{2-} + H_2O$	$\rightleftharpoons$	$H_3O^+ + PO_4^{3-}$	4.8×10^{-13}	12.32
ammonium ion	$NH_4^+ + H_2O$	$\rightleftharpoons$	$H_3O^+ + NH_3$	5.6×10^{-10}	9.25
methylammonium ion	$CH_3NH_3^+ + H_2O$	$\rightleftharpoons$	$H_3O^+ + CH_3NH_2$	2.2×10^{-11}	10.66
phenylammonium ion	$C_6H_5NH_3^+ + H_2O$	$\rightleftharpoons$	$H_3O^+ + C_6H_5NH_2$	1.3×10^{-5}	4.87

Acid-base Indicators

Acid-base indicator	pH range
bromophenol blue	3.0–4.6
methyl orange	3.1–4.4
methyl red	4.4–6.2
phenolphthalein	8.3–10.0
bromocresol green	3.8–5.4
bromocresol purple	5.2–6.8
bromothymol blue	6.0–7.6
cresol red	0.0–1.0; 7.0–8.8
p-nitrophenol	5.4–6.6
phenol red	6.8–8.4
thymol blue	1.2–2.8; 8.0–9.6
thymolphthalein	9.4–10.6
screened methyl orange	2.9–4.4
azolitmin (litmus)	4.5–8.3

Infrared Correlation Table

Wave number range (cm^{-1})	Type of compound	Infrared absorption due to
3600–3200	alcohols and phenols	hydrogen bonded O – H stretch
3650–3590	alcohols and phenols	not hydrogen bonded O – H stretch
3500–3300	amine, not hydrogen bonded	N – H stretch
3300	alkyne	C – H stretch in C ≡ C – H
3095–3010	alkene	C – H stretch in C = C – H
3100–3000	benzene ring	C – H stretch
2962–2853	alkane	C – H stretch
2900–2820	aldehyde	C – H stretch in –CHO
2775–2700	aldehyde	C – H stretch in –CHO
3000–2500	carboxylic acid	hydrogen bonded O – H stretch in –COOH
2260–2215	nitriles	C ≡ N stretch
2260–2100	alkynes	C ≡ C stretch
1750–1735	ester	C = O stretch
1740–1700	aldehyde, ketones	C = O stretch
1730–1717	aromatic ester	C = O stretch
1725–1700	carboxylic acid	C = O stretch
1700–1680	aromatic and alkyl ketones aromatic carboxylic acid	C = O stretch
1680–1620	alkene	C = C stretch
1600, 1580, 1500 and 1450	benzene ring	C = C (aromatic) stretch
1485–1340	alkane	C – H bend
1342–1266	aromatic amine	C – N stretch
1275–1200	aromatic ether	C – O stretch
1250–1020	alkyl amine	C – N stretch
1150–1070	alkyl ether	C – O stretch

Spectral Lines and Flame Colours

Gas Discharge Lamps

Element	Wavelength (nm)	Colour
hydrogen (Balmer series)	656	red
	486	blue-green
	434	blue-green
	410	violet
	397	ultra-violet
	389	ultra-violet
helium	706	red
	667	red
	588	orange-yellow

Metal Vapour Lamps

Element	Wavelength (nm)	Colour
cadmium	644	red
	509	green
	480	blue
mercury	579, 577	yellow doublet
	546	green
	436	blue-violet
	405	violet
	310	ultra-violet
sodium	589.0, 589.6	orange-yellow doublet

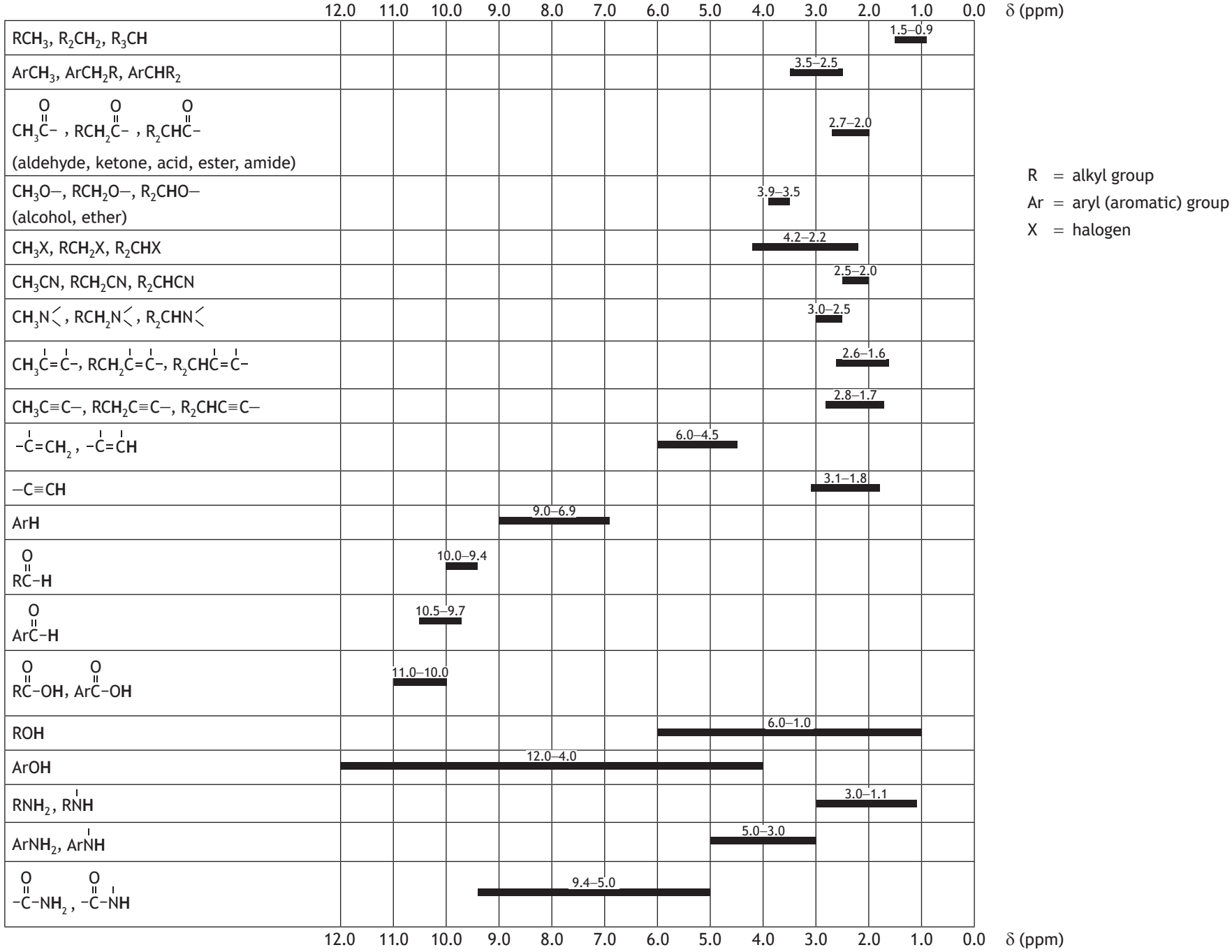
Flame Colours

Note: The data refers to prominent spectral lines.

Element	Wavelength (nm)	Colour
barium	554	green
calcium	620	orange-red
copper	522	blue-green
lithium	671	crimson
potassium	405	lilac
sodium	589	orange-yellow
strontium	650	red

Proton NMR Spectra Correlation Chart

Note: Approximate chemical shift values of hydrogen atoms in different structural environments relative to tetramethylsilane (TMS) for which $\delta = 0$ ppm



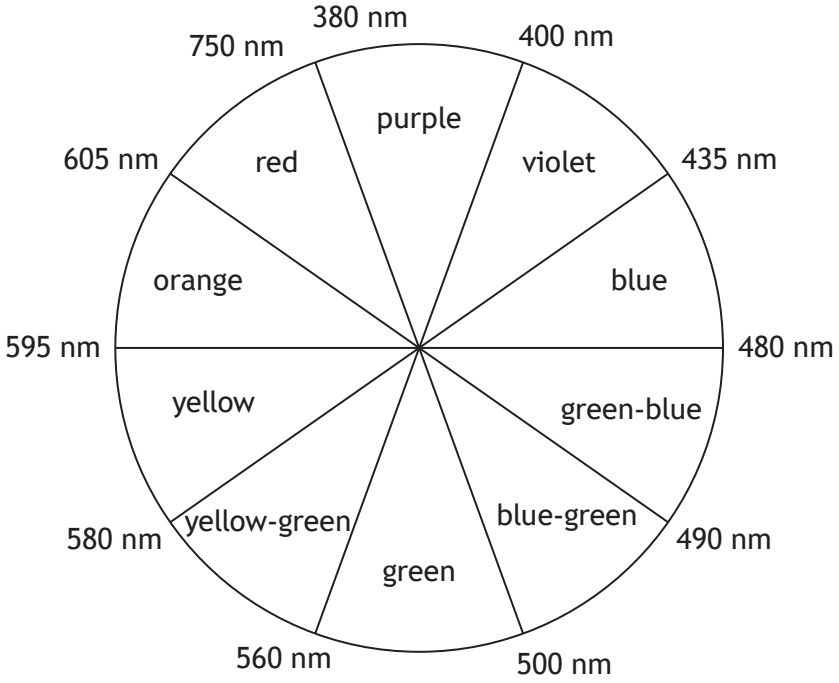
Ionic Radii of Selected Ions

Ion	Radius (pm)
H^-	208
Li^+	76
Be^{2+}	45
N^{3-}	132
O^{2-}	140
F^-	133
Na^+	102
Mg^{2+}	72
Al^{3+}	54
P^{3-}	198
S^{2-}	184
Cl^-	181
K^+	138
Ca^{2+}	100
Ti^{3+}	67
V^{3+}	64
Cr^{2+}	73
Cr^{3+}	62
Mn^{2+}	83
Fe^{2+}	61
Fe^{3+}	55
Co^{2+}	65
Co^{3+}	55
Ni^{2+}	69
Cu^+	77
Cu^{2+}	73
Zn^{2+}	74
Br^-	196
Rb^+	152
Sr^{2+}	118
Ag^+	115
Sn^{2+}	112
I^-	220
Cs^+	167
Ba^{2+}	135
Hg^{2+}	102
Pb^{2+}	119

Standard Entropy Values for Selected Substances

Substance	Standard Entropy ($J\,K^{-1}\,mol^{-1}$)
$H_2(g)$	131
He(g)	126
Li(s)	29
B(s)	5.9
C(s) (graphite)	5.7
C(s) (diamond)	2.4
$N_2(g)$	192
$O_2(g)$	205
$F_2(g)$	203
Na(s)	51
Mg(s)	33
Al(s)	28
Si(s)	19
$Cl_2(g)$	223
K(s)	65
Ca(s)	42
Fe(s)	27
Ni(s)	30
Cu(s)	33
$Br_2(\ell)$	152
Ag(s)	43
$I_2(s)$	116
Cs(s)	85
Ba(s)	63
Au(s)	47
Hg(ℓ)	76
$H_2O(\ell)$	70
$H_2O(g)$	189
$CO_2(g)$	214
MgO(s)	27
$Al_2O_3(s)$	51
$SO_2(g)$	248
CaO(s)	38
BaO(s)	72
NaCl(s)	72
$CaCl_2(s)$	108
CsCl(s)	101

Colour Wheel



Systeme Internationale (SI) Units

Quantity	Name of Unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	degree celsius	°C
energy	joule	J
electric charge	coulomb	C
electric potential difference	volt	V
amount of substance	mole	mol

Physical Constants

Quantity	Symbol	Value
Avogadro constant	L	6.02×10^{23} mol^{-1}
Planck constant	h	6.63×10^{-34} J s
speed of light in vacuum	c	3.00×10^{8} m s^{-1}

Properties of Water

Quantity	Value
specific heat capacity of liquid water	4.18 kJ kg^{-1} °C^{-1}
ionic product of water	1.01×10^{-14} at 25 °C

SI Prefixes and Multiplication Factors

SI Prefix	Symbol	Multiplication
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Conversion Factors

For Volume	For Thermodynamic Temperature
1 litre = 1 dm^3 = 1000 cm^3 1000 litres = 1000 dm^3 = 1 m^3	0 °C = 273 K

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Change since last published:

House style updates.

Data values updated in line with CRC Handbook of Chemistry and Physics 100th ed.

Removal of material no longer in courses.

Solubilities moved to page 09.

Reorganisation of relationships on page 04.

Addition of carbon to nitrogen mean bond enthalpies.

Addition of thiosulfate and hydrogen peroxide to the Electrochemical Series.

H^+ changed to H_3O^+.

C – N stretch added to Infrared Correlation Table.