

Chemistry Data Booklet

Higher and Advanced Higher

For use in National Qualification Courses

Publication date: 2016
Publication code: BB6753
ISBN: 978 1 910180 00 6

Published by the Scottish Qualifications Authority
The Optima Building, 58 Robertson Street, Glasgow G2 8DQ
Lowden, 24 Wester Shawfair, Dalkeith, Midlothian EH22 1FD

www.sqa.org.uk

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Relationships for Higher and Advanced Higher Chemistry

$$E_h = cm\Delta T$$

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

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

$$n = cV$$

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

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

$$\text{rate} = \frac{\Delta \text{quantity}}{\Delta t}$$

$$\text{reaction rate} = \frac{1}{t}$$

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

$$c = f\lambda$$

$$E = Lhf$$

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

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

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

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

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

$$K_w = [\text{H}^+][\text{OH}^-]$$

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

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

$$K_{\text{in}} = \frac{[\text{H}_3\text{O}^+][\text{In}^-]}{[\text{HIn}]}$$

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

$$\Delta H^\circ = \sum \Delta H_f^\circ (\text{products}) - \sum \Delta H_f^\circ (\text{reactants})$$

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

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

$$\Delta G^\circ = \sum \Delta G_f^\circ (\text{products}) - \sum \Delta G_f^\circ (\text{reactants})$$

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

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	10.1
Aluminium	Al	27.0	2.70
Americium	Am	243.1	13.7
Antimony	Sb	121.8	6.68
Argon	Ar	39.9	0.0018
Arsenic	As	74.9	5.78
Astatine	At	210.0	unknown
Barium	Ba	137.3	3.62
Berkelium	Bk	247.1	14.8
Beryllium	Be	9.0	1.85
Bismuth	Bi	209.0	9.79
Boron	B	10.8	2.47
Bromine	Br	79.9	3.12
Cadmium	Cd	112.4	8.69
Calcium	Ca	40.1	1.54
Californium	Cf	251.1	unknown
Carbon	C	12.0	*
Cerium	Ce	140.1	6.77
Caesium	Cs	132.9	1.93
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	13.3
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	4.95
Iridium	Ir	192.2	22.5
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

Element	Symbol	Relative atomic mass	Density (g cm ⁻³)
Manganese	Mn	54.9	7.47
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	2.09
Tantalum	Ta	180.9	16.4
Technetium	Tc	97.9	11
Tellurium	Te	127.6	6.25
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	7.26
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	7.14
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 -272 -269
3 Lithium 181 1342	4 Beryllium 1287 2471*											5 Boron 2075 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 44 280	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 1668 3287	23 Vanadium 1910 3407	24 Chromium 1907 2672	25 Manganese 1246 2061	26 Iron 1538 2861	27 Cobalt 1495 2927	28 Nickel 1455 2913	29 Copper 1085 2562	30 Zinc 420 907	31 Gallium 30 2204	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 1382	39 Yttrium 1522 3345	40 Zirconium 1855 4409	41 Niobium 2477 4744	42 Molybdenum 2623 4639	43 Technetium 2157 4265	44 Ruthenium 2333 4150	45 Rhodium 1964 3695	46 Palladium 1555 2963	47 Silver 962 2162	48 Cadmium 321 767	49 Indium 157 2072	50 Tin 232 2602	51 Antimony 631 1587	52 Tellurium 449 988	53 Iodine 114 184	54 Xenon -112 -108	
55 Caesium 28 671	56 Barium 727 1897	57 Lanthanum 920 3464	72 Hafnium 2223 4602	73 Tantalum 3017 5458	74 Tungsten 3422 5555	75 Rhenium 3185 5596	76 Osmium 3033 5012	77 Iridium 2446 4428	78 Platinum 1768 3825	79 Gold 1064 2856	80 Mercury -39 357	81 Thallium 304 1473	82 Lead 328 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

Group 1 **Group 2**

Group 3 **Group 4** **Group 5** **Group 6** **Group 7**

1 Hydrogen 37	
3 Lithium 134	4 Beryllium 129
11 Sodium 154	12 Magnesium 145
19 Potassium 196	20 Calcium 174
37 Rubidium 216	38 Strontium 191
55 Caesium 235	56 Barium 198

Key

Atomic number
Name of element
Covalent radius/pm

21 Scandium 141	22 Titanium 132	23 Vanadium 122	24 Chromium 119	25 Manganese 116	26 Iron 114	27 Cobalt 114	28 Nickel 113	29 Copper 118	30 Zinc 120
39 Yttrium 162	40 Zirconium 147	41 Niobium 133	42 Molybdenum 127	43 Technetium —	44 Ruthenium 122	45 Rhodium 122	46 Palladium 126	47 Silver 136	48 Cadmium 140
57 Lanthanum 169	72 Hafnium 142	73 Tantalum 133	74 Tungsten 131	75 Rhenium 128	76 Osmium 126	77 Iridium 124	78 Platinum 127	79 Gold 130	80 Mercury 141

5 Boron 90	6 Carbon 77	7 Nitrogen 75	8 Oxygen 73	9 Fluorine 71
13 Aluminium 130	14 Silicon 117	15 Phosphorus 110	16 Sulfur 102	17 Chlorine 99
31 Gallium 120	32 Germanium 122	33 Arsenic 121	34 Selenium 117	35 Bromine 114
49 Indium 150	50 Tin 140	51 Antimony 143	52 Tellurium 135	53 Iodine 133
81 Thallium 157	82 Lead 155	83 Bismuth 151	84 Polonium —	85 Astatine 140

Electron Arrangements of Elements

Group 1 Group 2

Group 3 Group 4 Group 5 Group 6 Group 7 Group 0

(1)

(18)

Key

Atomic number
Symbol
Electron arrangement
Name

1 H 1 Hydrogen	(2)
3 Li 2,1 Lithium	4 Be 2,2 Beryllium
11 Na 2,8,1 Sodium	12 Mg 2,8,2 Magnesium
19 K 2,8,8,1 Potassium	20 Ca 2,8,8,2 Calcium
37 Rb 2,8,18,8,1 Rubidium	38 Sr 2,8,18,8,2 Strontium
55 Cs 2,8,18,18,8,1 Caesium	56 Ba 2,8,18,18,8,2 Barium
87 Fr 2,8,18,32,18,8,1 Francium	88 Ra 2,8,18,32,18,8,2 Radium

Transition Elements

(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
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
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
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

(13)	(14)	(15)	(16)	(17)	2 He 2 Helium
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
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
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
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
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

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
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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
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Melting and Boiling Points of Selected Oxides

Element	Formula of oxide	mp/°C	bp/°C
hydrogen	H ₂ O	0	100
lithium	Li ₂ O	1438	
beryllium	BeO	2578	3900
boron	B ₂ O ₃	450	1860
carbon	CO ₂	sublimes at -78.5	
nitrogen	N ₂ O ₄	-9	21
fluorine	F ₂ O	-224	-144
sodium	Na ₂ O	sublimes at 1134	
magnesium	MgO	2825	3600
aluminium	Al ₂ O ₃	2054	2977
silicon	SiO ₂	1713	2950
phosphorus	P ₄ O ₁₀	sublimes at 300	
sulfur	SO ₂	-75	-10
chlorine	Cl ₂ O	-121	2
potassium	K ₂ O	740	
calcium	CaO	2614	2850

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	
carbon	CCl ₄	-23	
nitrogen	NCl ₃	-40	
fluorine	FCl	-155	-100
sodium	NaCl	801	1465
magnesium	MgCl ₂	714	1412
aluminium	Al ₂ Cl ₆	Sublimes at 180	
silicon	SiCl ₄	-70	57.6
phosphorus	PCl ₃	-93	75.5
sulfur	SCl ₂	-78	decomposes at 59
potassium	KCl	770	1680
calcium	CaCl ₂	775	1935

Melting and Boiling Points of Selected Organic Compounds

Name of compound	mp/°C	bp/°C
methane	-182.5	-162
ethane	-183	-89
propane	-188	-42
butane	-138	-1
pentane	-130	36
hexane	-95	69
heptane	-91	98
octane	-57	126
cyclobutane	-91	13
cyclopentane	-93	49
cyclohexane	6.5	81
ethene	-169	-104
propene	-185	-48
but-1-ene	-185	-6
pent-1-ene	-165	30
hex-1-ene	-140	63
benzene	5.5	80

Name of compound	mp/°C	bp/°C
methanol	-97.5	65
ethanol	-114	78
propan-1-ol	-124	97
propan-2-ol	-88	82
butan-1-ol	-84	118
butan-2-ol	-89	100
methanal	-92	-19
ethanal	-123	20
propanal	-81	49
butanal	-97	75
propanone	-95	56
butanone	-86.5	79.5
methanoic acid	8	101
ethanoic acid	17	118
propanoic acid	-21	141
butanoic acid	-5	164
methoxyethane	-139	7.5
ethoxyethane	-116	34.5

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	-2219
butane	-126	-2878
benzene	49	-3268
ethene	52	-1411
ethyne	227	-1301
methanol	-239	-726
ethanol	-278	-1367
propan-1-ol	-303	-2021
methanoic acid	-425	-255
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	151
H - F	570
H - Cl	432
H - Br	366
H - I	298

Mean Bond Enthalpies

Bond	Mean Enthalpy/ kJ mol ⁻¹
Si - Si	226
C - C	348
C = C	612
C ≡ C	838
C - C (aromatic) }	518
H - O	463
H - N	388
C - H	412
C - O	360
C = O	743
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

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

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	11815	—	1.0
beryllium	Be	900	1757	14849	21007	1.5
boron	B	801	2427	3660	25026	2.0
carbon	C	1086	2353	4620	6223	2.5
nitrogen	N	1402	2856	4578	7475	3.0
oxygen	O	1314	3389	5300	7469	3.5
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	10543	1.2
aluminium	Al	578	1817	2745	11577	1.5
silicon	Si	787	1577	3232	4356	1.9
phosphorus	P	1012	1907	2914	4964	2.2
sulfur	S	1000	2252	3357	4556	2.5
chlorine	Cl	1251	2298	3822	5159	3.0
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	1.3
titanium	Ti	659	1310	2653	4175	1.5
vanadium	V	651	1410	2828	4507	1.6
chromium	Cr	653	1591	2987	4743	1.6
manganese	Mn	717	1509	3248	4940	1.5
iron	Fe	762	1562	2957	5287	1.8
cobalt	Co	760	1648	3232	4950	1.8
nickel	Ni	737	1753	3395	5297	1.9
copper	Cu	745	1958	3555	5536	1.9
zinc	Zn	906	1733	3833	5731	1.6
gallium	Ga	579	1979	2965	6102	1.8
germanium	Ge	762	1537	3302	4411	2.0
arsenic	As	944	1794	2735	4837	2.2
bromine	Br	1140	2083	3473	4564	2.8
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	1.8
antimony	Sb	831	1605	2441	4260	2.1
iodine	I	1008	1846	3184	—	2.6
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
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li}(\text{s})$	-3.04
$\text{Cs}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cs}(\text{s})$	-3.03
$\text{Rb}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Rb}(\text{s})$	-2.98
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.93
$\text{Sr}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sr}(\text{s})$	-2.90
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ca}(\text{s})$	-2.87
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s})$	-2.71
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$	-2.37
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.66
$2\text{H}_2\text{O}(\ell) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Cr}(\text{s})$	-0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.45
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	-0.26
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$\text{Fe}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.04
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}(\text{aq})$	0.15
$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cu}^+(\text{aq})$	0.15
$\text{SO}_4^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{SO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell)$	0.17
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	0.34
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\ell) + 4\text{e}^- \rightleftharpoons 4\text{OH}^-(\text{aq})$	0.40
$\text{I}_2(\text{s}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-(\text{aq})$	0.54
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	0.77
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	0.80
$\text{Hg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Hg}(\ell)$	0.85
$\text{Br}_2(\ell) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-(\text{aq})$	1.07
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\ell)$	1.23
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\ell)$	1.36
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	1.36
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\ell)$	1.51
$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-(\text{aq})$	2.87

Electrolysis of Water

<p>Reduction reactions at the negative electrode</p> $2\text{H}_2\text{O}(\ell) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$ $2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g})$
<p>Oxidation reactions at the positive electrode</p> $2\text{H}_2\text{O}(\ell) \longrightarrow \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^-$ $4\text{OH}^-(\text{aq}) \longrightarrow 2\text{H}_2\text{O}(\ell) + \text{O}_2(\text{g}) + 4\text{e}^-$

Dissociation Constants of Selected Species

Equilibrium in aqueous solution			K_a	pK_a
methanoic acid	HCOOH	$\rightleftharpoons \text{H}^+ + \text{HCOO}^-$	1.8×10^{-4}	3.75
ethanoic acid	CH_3COOH	$\rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^-$	1.7×10^{-5}	4.76
propanoic acid	$\text{CH}_3\text{CH}_2\text{COOH}$	$\rightleftharpoons \text{H}^+ + \text{CH}_3\text{CH}_2\text{COO}^-$	1.3×10^{-5}	4.87
butanoic acid	$\text{CH}_3(\text{CH}_2)_2\text{COOH}$	$\rightleftharpoons \text{H}^+ + \text{CH}_3(\text{CH}_2)_2\text{COO}^-$	1.5×10^{-5}	4.83
benzoic acid	$\text{C}_6\text{H}_5\text{COOH}$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{COO}^-$	6.3×10^{-5}	4.20
phenol	$\text{C}_6\text{H}_5\text{OH}$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{O}^-$	1.0×10^{-10}	9.99
hydrofluoric acid	HF	$\rightleftharpoons \text{H}^+ + \text{F}^-$	6.8×10^{-4}	3.17
boric acid	H_3BO_3	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{BO}_3^-$	5.4×10^{-10}	9.27
hydrocyanic acid	HCN	$\rightleftharpoons \text{H}^+ + \text{CN}^-$	6.2×10^{-10}	9.21
carbonic acid	$\text{H}_2\text{O} + \text{CO}_2$	$\rightleftharpoons \text{H}^+ + \text{HCO}_3^-$	4.5×10^{-7}	6.35
hydrogencarbonate ion	HCO_3^-	$\rightleftharpoons \text{H}^+ + \text{CO}_3^{2-}$	4.7×10^{-11}	10.33
sulfurous acid	H_2SO_3	$\rightleftharpoons \text{H}^+ + \text{HSO}_3^-$	1.4×10^{-2}	1.85
hydrogensulfite ion	HSO_3^-	$\rightleftharpoons \text{H}^+ + \text{SO}_3^{2-}$	6.3×10^{-8}	7.19
hydrogen sulfide	H_2S	$\rightleftharpoons \text{H}^+ + \text{HS}^-$	8.9×10^{-8}	7.05
hydrogensulfide ion	HS^-	$\rightleftharpoons \text{H}^+ + \text{S}^{2-}$	2.73×10^{-20}	19.00
phosphoric acid	H_3PO_4	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{PO}_4^-$	6.9×10^{-3}	2.16
dihydrogenphosphate ion	H_2PO_4^-	$\rightleftharpoons \text{H}^+ + \text{HPO}_4^{2-}$	6.2×10^{-8}	7.21
hydrogenphosphate ion	HPO_4^{2-}	$\rightleftharpoons \text{H}^+ + \text{PO}_4^{3-}$	4.8×10^{-13}	12.32
ammonium ion	NH_4^+	$\rightleftharpoons \text{H}^+ + \text{NH}_3$	5.8×10^{-10}	9.24
methylammonium ion	CH_3NH_3^+	$\rightleftharpoons \text{H}^+ + \text{CH}_3\text{NH}_2$	2.2×10^{-11}	10.66
phenylammonium ion	$\text{C}_6\text{H}_5\text{NH}_3^+$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{NH}_2$	1.3×10^{-5}	4.87

Infra-red Correlation Table

Wave number range/cm ⁻¹	Type of compound	Infra-red absorption due to
3570–3200	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
3500–2500	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
1740–1720	aldehyde	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
1275–1200	aromatic ether	C – O 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

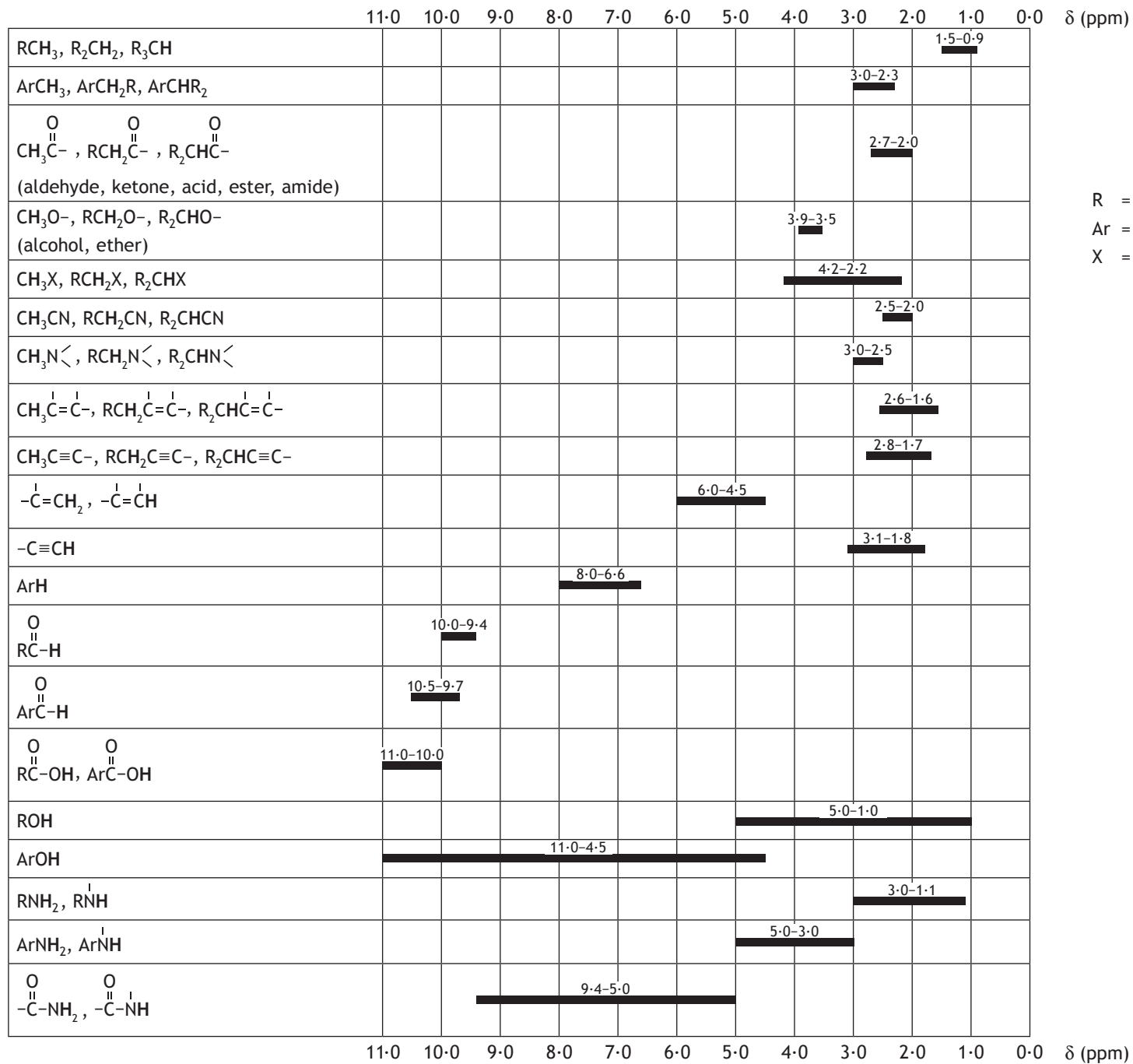
Flame Colours

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



R = alkyl group
 Ar = aryl (aromatic) group
 X = halogen

Ionic Radii of Selected Ions

Ion	Radius/pm
H ⁻	208
Li ⁺	76
Be ²⁺	27
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 ⁺	60
Cu ²⁺	73
Zn ²⁺	74
Br ⁻	196
Rb ⁺	152
Sr ²⁺	126
Ag ⁺	115
Sn ²⁺	112
I ⁻	220
Cs ⁺	174
Ba ²⁺	135
Hg ²⁺	102
Pb ²⁺	120

Standard Entropy Values for Selected Substances

Substance	Standard Entropy /JK ⁻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 (ℓ)	152
Ag(s)	43
I ₂ (s)	116
Cs(s)	85
Ba(s)	63
Au(s)	47
Hg(ℓ)	76
H ₂ O(ℓ)	70
H ₂ O(g)	189
CO ₂ (g)	214
MgO(s)	27
Al ₂ O ₃ (s)	51
SO ₂ (g)	248
CaO(s)	38
BaO(s)	72
NaCl(s)	72
CaCl ₂ (s)	108
CsCl(s)	99

**Standard Molar Enthalpies of Atomisation
of Selected Elements**

Element	$\Delta H^\circ/\text{kJ mol}^{-1}$
H	218
Li	159
Be	326
B	565
C	716
N	472
O	249
F	79
Na	107
Mg	147
Al	330
Si	450
P	317
S	277
Cl	121
K	88
Ca	178
Sc	378
Ti	473
V	515
Cr	397
Mn	283
Fe	414
Co	427
Ni	430
Cu	337
Zn	130
Br	112
Rb	81
Sr	163
Ag	285
Sn	301
I	107
Cs	77
Ba	178

Lattice Enthalpies of Selected Compounds

Compound	Lattice Enthalpy/ kJ mol^{-1}
Li_2O	-2799
BeO	-4514
Na_2O	-2481
MgO	-3795
Al_2O_3	-15916
K_2O	-2238
CaO	-3414
FeO	-3795
CoO	-3837
NiO	-3908
CuO	-4135
ZnO	-4142
SrO	-3217
Ag_2O	-3002
BaO	-3029
LiCl	-834
NaCl	-769
MgCl_2	-2477
KCl	-701
CaCl_2	-2268
CoCl_2	-2707
NiCl_2	-2753
CuCl	-992
CuCl_2	-2774
SrCl_2	-2142
AgCl	-910
BaCl_2	-2046
LiF	-1030
NaF	-910
MgF_2	-2926
KF	-808
CaF_2	-2640
NiF_2	-3098
SrF_2	-2476
AgF	-953
BaF_2	-2347
MgS	-3406
CaS	-3002
BaS	-2713
NiS	-3528
ZnS	-3692
LiBr	-730
NaBr	-732
KBr	-671
NiBr_2	-2729
CuBr_2	-2715
AgBr	-897

Electron Affinities of Selected Elements

Element	Electron Affinity/ kJ mol ⁻¹
H	-72
O	-141
(O ⁻)	+844
F	-328
S	-201
(S ⁻)	+456
Cl	-349
Br	-324
I	-295

The electron affinity for an element E refers to the reaction $E(g) + e^- \rightarrow E^-(g)$.

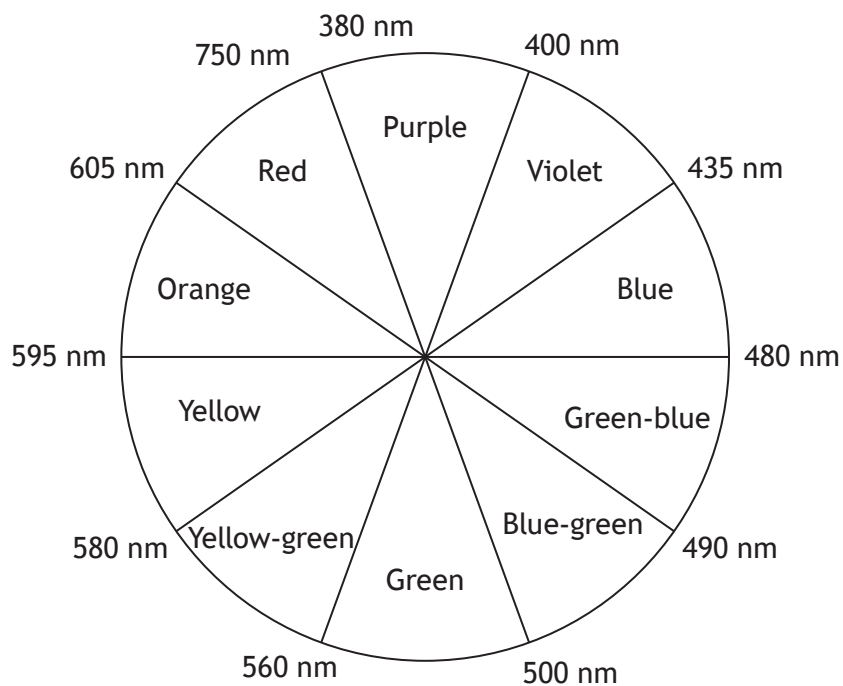
The second electron affinity refers to the reaction $E^-(g) + e^- \rightarrow E^{2-}(g)$.

Hydration Enthalpies of Selected Ions

Ion	Hydration Enthalpy/kJ mol ⁻¹
Li ⁺	-520
Na ⁺	-405
K ⁺	-321
Mg ²⁺	-1920
Al ³⁺	-4690
Ca ²⁺	-1650
Fe ²⁺	-1950
Fe ³⁺	-4430
Cu ²⁺	-2100
Zn ²⁺	-2050
Rb ⁺	-300
Sr ²⁺	-1480
Ag ⁺	-446
Cs ⁺	-277
Ba ²⁺	-1360
OH ⁻	-460
F ⁻	-506
Cl ⁻	-364
Br ⁻	-337
I ⁻	-296

The hydration enthalpy for the ion of an element E refers to the changes represented by $E^{n+}(g) \rightarrow E^{n+}(aq)$ and $E^{n-}(g) \rightarrow E^{n-}(aq)$.

Colour Wheel



Acid-base Indicators

Acid-base indicator	pH range
bromophenol blue	3.0–4.6
methyl orange	3.2–4.4
methyl red	4.8–6.0
phenolphthalein	8.2–10.0
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
<i>p</i> -nitrophenol	5.4–6.6
phenol red	6.6–8.0
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

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 ₃ COO ⁻	carbonate	CO ₃ ²⁻	phosphate	PO ₄ ³⁻
		hydrogencarbonate	HCO ₃ ⁻	chromate	CrO ₄ ²⁻		
		hydrogensulfate	HSO ₄ ⁻	dichromate	Cr ₂ O ₇ ²⁻		
		hydrogensulfite	HSO ₃ ⁻	sulfate	SO ₄ ²⁻		
		hydroxide	OH ⁻	sulfite	SO ₃ ²⁻		
		nitrate	NO ₃ ⁻	thiosulfate	S ₂ O 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.

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
charge on electron	e^-	$1.60 \times 10^{-19} \text{ C}$
Avogadro constant	L	$6.02 \times 10^{23} \text{ mol}^{-1}$
Faraday constant	F	$9.65 \times 10^4 \text{ C mol}^{-1}$
Planck constant	h	$6.63 \times 10^{-34} \text{ Js}$
speed of light in vacuum	c	$3.00 \times 10^8 \text{ m s}^{-1}$

Properties of Water

Quantity	Value
specific heat capacity of liquid water	$4.18 \text{ kJ kg}^{-1} \text{ }^\circ\text{C}^{-1}$
ionic product of water	10^{-14} at 24°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 = $1 \text{ dm}^3 = 1000 \text{ cm}^3$ 1000 litres = $1000 \text{ dm}^3 = 1 \text{ m}^3$	$0^\circ\text{C} = 273 \text{ K}$

Published: September 2016

Change since last published:

Correction to standard enthalpy of combustion for benzene on page 10; correction to wavelength for copper in flame colours table on page 15; updated colour wheel on page 20.