

Chemistry Data Booklet

Higher and Advanced Higher

For use in National Qualification Courses
leading to the 2008 examinations and beyond.

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Relative Atomic Masses of Selected Elements

Element	Symbol	Relative atomic mass
Aluminium	Al	27.0
Antimony	Sb	121.8
Argon	Ar	40.0
Arsenic	As	74.9
Barium	Ba	137.3
Beryllium	Be	9.0
Bismuth	Bi	209.0
Boron	B	10.8
Bromine	Br	79.9
Cadmium	Cd	112.4
Calcium	Ca	40.0
Carbon	C	12.0
Cerium	Ce	140.1
Caesium	Cs	132.9
Chlorine	Cl	35.5
Chromium	Cr	52.0
Cobalt	Co	58.9
Copper	Cu	63.5
Fluorine	F	19.0
Gallium	Ga	69.7
Germanium	Ge	72.6
Gold	Au	197.0
Hafnium	Hf	178.5
Helium	He	4.0
Hydrogen	H	1.0
Indium	In	114.8
Iodine	I	126.9
Iridium	Ir	192.2
Iron	Fe	55.8
Krypton	Kr	83.8
Lead	Pb	207.2
Lithium	Li	6.9
Magnesium	Mg	24.3
Manganese	Mn	54.9
Mercury	Hg	200.6

Element	Symbol	Relative atomic mass
Molybdenum	Mo	95.9
Neon	Ne	20.2
Nickel	Ni	58.7
Niobium	Nb	92.9
Nitrogen	N	14.0
Osmium	Os	190.2
Oxygen	O	16.0
Palladium	Pd	106.4
Phosphorus	P	31.0
Platinum	Pt	195.1
Potassium	K	39.1
Rhenium	Re	186.2
Rhodium	Rh	102.9
Rubidium	Rb	85.5
Ruthenium	Ru	101.1
Scandium	Sc	45.0
Selenium	Se	79.0
Silicon	Si	28.1
Silver	Ag	107.9
Sodium	Na	23.0
Strontium	Sr	87.6
Sulphur	S	32.1
Tantalum	Ta	181.0
Tellurium	Te	127.6
Thallium	Tl	204.4
Thorium	Th	232.0
Tin	Sn	118.7
Titanium	Ti	47.9
Tungsten	W	183.9
Uranium	U	238.0
Vanadium	V	51.0
Xenon	Xe	131.3
Zinc	Zn	65.4
Zirconium	Zr	91.2

Electron Arrangements of Elements

Group 1
2

1 H 1 Hydrogen	(1)	2 He 2 Helium	(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	

Group 3
4
5
6
7
0
(18)

5 B 2, 3 Boron	(13)	6 C 2, 4 Carbon	(14)	7 N 2, 5 Nitrogen	(15)	8 O 2, 6 Oxygen	(16)	9 F 2, 7 Fluorine	(17)	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 Sulphur		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, 3 Indium		50 Sn 2, 8, 18, 4 Tin		51 Sb 2, 8, 18, 5 Antimony		52 Te 2, 8, 18, 6 Tellurium		53 I 2, 8, 18, 7 Iodine		54 Xe 2, 8, 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

Key

Atomic number Symbol Electron arrangement Name

Transition Elements

21 Sc 2, 8, 9, 2 Scandium	(3)	22 Ti 2, 8, 10, 2 Titanium	(4)	23 V 2, 8, 11, 2 Vanadium	(5)	24 Cr 2, 8, 13, 1 Chromium	(6)	25 Mn 2, 8, 13, 2 Manganese	(7)	26 Fe 2, 8, 14, 2 Iron	(8)	27 Co 2, 8, 15, 2 Cobalt	(9)	28 Ni 2, 8, 16, 2 Nickel	(10)	29 Cu 2, 8, 18, 1 Copper	(11)	30 Zn 2, 8, 18, 2 Zinc	(12)												
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	
57 La 2, 8, 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	
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, 16, 2 Darmstadtium		111 Rg 2, 8, 18, 32, 32, 17, 2 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
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

Actinides

Densities of Selected Elements

Group 1
2

1 Hydrogen 0-00009	4 Beryllium 1-85
3 Lithium 0-53	12 Magnesium 1-74
11 Sodium 0-97	20 Calcium 1-54
37 Rubidium 1-53	38 Strontium 2-60
55 Caesium 1-93	56 Barium 3-51

Key

Atomic number Name of element Density/g cm ⁻³ <i>measured at s.t.p.</i>

Group 3
4
5
6
7
0

5 Boron 2-34	6 Carbon *	7 Nitrogen 0-0013	8 Oxygen 0-0014	9 Fluorine 0-0017	10 Neon 0-0009
13 Aluminium 2-70	14 Silicon 2-33	15 Phosphorus 1-82	16 Sulphur 2-07	17 Chlorine 0-0032	18 Argon 0-0018
31 Gallium 5-90	32 Germanium 5-35	33 Arsenic 5-73	34 Selenium 4-81	35 Bromine 3-12	36 Krypton 0-0037
49 Indium 7-31	50 Tin 7-28	51 Antimony 6-68	52 Tellurium 6-25	53 Iodine 4-93	54 Xenon 0-0059
81 Thallium 11-8	82 Lead 11-3	83 Bismuth 9-80	84 Polonium 9-4	85 Astatine -	86 Radon 0-0097

21 Scandium 2-99	22 Titanium 4-50	23 Vanadium 5-96	24 Chromium 7-20	25 Manganese 7-20	26 Iron 7-86	27 Cobalt 8-90	28 Nickel 8-90	29 Copper 8-92	30 Zinc 7-14
39 Yttrium 4-47	40 Zirconium 6-52	41 Niobium 8-57	42 Molybdenum 10-2	43 Technetium 11-5	44 Ruthenium 12-3	45 Rhodium 12-4	46 Palladium 12-0	47 Silver 10-5	48 Cadmium 8-64
57 Lanthanum 6-15	72 Hafnium 13-3	73 Tantalum 16-6	74 Tungsten 19-4	75 Rhenium 20-5	76 Osmium 22-5	77 Iridium 22-4	78 Platinum 21-5	79 Gold 19-3	80 Mercury 13-6

*The density of carbon as graphite is 2-25 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

1 Hydrogen -259 -253	4 Beryllium 1278 2471
3 Lithium 181 1342	12 Magnesium 649 1090
11 Sodium 98 883	20 Calcium 842 1484
19 Potassium 64 759	38 Strontium 769 1384
37 Rubidium 688	56 Barium 725 1640

Key

Atomic number
Name of element
Melting point/°C
Boiling Point/°C

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

5 Boron 2300 4000	6 Carbon †3642	7 Nitrogen -210 -196	8 Oxygen -218 -183	9 Fluorine -220 -188	10 Neon -249 -246
13 Aluminium 660 2467	14 Silicon 1410 2355	15 Phosphorus 44 280	16 Sulphur 113 445	17 Chlorine -101 -35	18 Argon -189 -186
31 Gallium 30 2403	32 Germanium 937 2830	33 Arsenic *817 †613	34 Selenium 217 685	35 Bromine -7 59	36 Krypton -157 -152
49 Indium 157 2080	50 Tin 232 2602	51 Antimony 631 1750	52 Tellurium 452 988	53 Iodine 114 184	54 Xenon -112 -107
81 Thallium 304 1457	82 Lead 328 1749	83 Bismuth 271 1560	84 Polonium 254 962	85 Astatine 302	86 Radon -71 -62

21 Scandium 1541 2831	22 Titanium 1660 3287	23 Vanadium 1890 3380	24 Chromium 1857 2672	25 Manganese 1244 1962	26 Iron 1535 2730	27 Cobalt 1495 2927	28 Nickel 1453 2913	29 Copper 1083 2567	30 Zinc 420 907
39 Yttrium 1522 3338	40 Zirconium 1852 4377	41 Niobium 2477 4742	42 Molybdenum 2623 4639	43 Technetium 2157 4265	44 Ruthenium 2310 3900	45 Rhodium 1966 3695	46 Palladium 1552 2963	47 Silver 962 2212	48 Cadmium 321 765
57 Lanthanum 921 3457	72 Hafnium 2227 4602	73 Tantalum 2996 5425	74 Tungsten 3410 5660	75 Rhenium 3180 5627	76 Osmium 3033 5012	77 Iridium 2410 4130	78 Platinum 1772 3827	79 Gold 1064 2856	80 Mercury -39 357

* not at standard pressure

† Sublimes.

Covalent Radii of Selected Elements

Group 1
2

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

Group 3
4
5
6
7

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 Sulphur 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

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

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	sublimes at 1200	
beryllium	BeO	2530	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	-145
sodium	Na ₂ O	sublimes at 1275	
magnesium	MgO	2852	3600
aluminium	Al ₂ O ₃	2072	2980
silicon	SiO ₂	1610	2230
phosphorus	P ₄ O ₁₀	sublimes at 300	
sulphur	SO ₂	-72.7	-10
chlorine	Cl ₂ O	-20	decomposes at 4
potassium	K ₂ O	decomposes at 350	
calcium	CaO	2614	2850

Melting and Boiling Points of Selected Chlorides

Element	Formula of chloride	mp/°C	bp/°C
lithium	LiCl	605	1350
beryllium	BeCl ₂	405	520
boron	BCl ₃	-107	12.5
carbon	CCl ₄	-23	76.8
nitrogen	NCl ₃	-40	71
fluorine	FCl	-154	-101
sodium	NaCl	801	1413
magnesium	MgCl ₂	714	1412
aluminium	Al ₂ Cl ₆	sublimes at 178	
silicon	SiCl ₄	-70	57.6
phosphorus	PCl ₃	-112	75.5
sulphur	SCl ₂	-78	decomposes at 59
potassium	KCl	770	1680
calcium	CaCl ₂	782	>1600

Melting and Boiling Points of Selected Organic Compounds

Name of compound	mp/°C	bp/°C
methane	-182.5	-164
ethane	-183	-89
propane	-190	-42
butane	-138	-1
pentane	-130	36
hexane	-95	69
heptane	-91	98
octane	-57	126
cyclobutane	-50	12
cyclopentane	-94	49
cyclohexane	7	81
ethene	-169	-104
propene	-185	-47
but-1-ene	-185	-6
pent-1-ene	-138	30
hex-1-ene	-140	63
benzene	6	80

Name of compound	mp/°C	bp/°C
methanol	-94	65
ethanol	-117	79
propan-1-ol	-127	97
propan-2-ol	-90	82
butan-1-ol	-90	117
butan-2-ol	-100	100
methanal	-92	-21
ethanal	-121	21
propanal	-81	49
butanal	-99	76
propanone	-95	56
butanone	-86	80
methanoic acid	8	101
ethanoic acid	17	118
propanoic acid	-21	141
butanoic acid	-4	164
methoxyethane	-113	7
ethoxyethane	-116	34.5

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	sulphate	oxide	hydroxide
aluminium	vs	i	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.

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-}		
		hydrogensulphate	HSO_4^-	dichromate	$\text{Cr}_2\text{O}_7^{2-}$		
		hydrogensulphite	HSO_3^-	sulphate	SO_4^{2-}		
		hydroxide	OH^-	sulphite	SO_3^{2-}		
		nitrate	NO_3^-	thiosulphate	$\text{S}_2\text{O}_3^{2-}$		
		permanganate	MnO_4^-				

Radioactive Decay Series

Note: In both tables γ emissions have been omitted.

Table 1 (Plutonium-Uranium)

Element	Symbol	Mass Number	Atomic Number	Type of Radiation	Half-life Period
plutonium	Pu	242	94	α	3.79×10^5 years
uranium	U	238	92	α	4.51×10^9 years
thorium	Th	234	90	β	24.1 days
protactinium	Pa	234	91	β	6.75 hours
uranium	U	234	92	α	2.47×10^5 years
thorium	Th	230	90	α	8.0×10^4 years
radium	Ra	226	88	α	1.62×10^3 years
radon	Rn	222	86	α	3.82 days
polonium	Po	218	84	α	3.05 minutes
lead	Pb	214	82	β	26.8 minutes
bismuth	Bi	214	83	β	19.7 minutes
polonium	Po	214	84	α	1.6×10^{-4} seconds
thallium	Tl	210	81	β	1.3 minutes
lead	Pb	210	82	β	21 years
bismuth	Bi	210	83	β	5.01 days
polonium	Po	210	84	α	138 days
lead	Pb	206	82	stable	

Table 2 (Thorium)

Element	Symbol	Mass Number	Atomic Number	Type of Radiation	Half-life Period
thorium	Th	232	90	α	1.41×10^{10} years
radium	Ra	228	88	β	5.8 years
actinium	Ac	228	89	β	6.13 hours
thorium	Th	228	90	α	1.91 years
radium	Ra	224	88	α	3.64 days
radon	Rn	220	86	α	55 seconds
polonium	Po	216	84	α	0.15 seconds
lead	Pb	212	82	β	10.6 hours
bismuth	Bi	212	83	β	60.6 minutes
polonium	Po	212	84	α	3.04×10^{-7} seconds
thallium	Tl	208	81	β	3.10 minutes
lead	Pb	208	82	stable	

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
sulphur (rhombic)	–	–297
methane	–75	–891
ethane	–85	–1560
propane	–104	–2220
butane	–125	–2877
benzene	49	–3268
ethene	52	–1411
ethyne	227	–1300
methanol	–239	–727
ethanol	–278	–1367
propan-1-ol	–306	–2020
methanoic acid	–409	–255
ethanoic acid	–487	–876

Selected Bond and Mean Bond Enthalpies

Bond Enthalpies

Bond	Enthalpy /kJ mol ⁻¹
H – H	432
O = O	497
N ≡ N	941
F – F	155
Cl – Cl	243
Br – Br	194
I – I	149
H – F	569
H – Cl	428
H – Br	362
H – I	295

Mean Bond Enthalpies

Bond	Mean Enthalpy /kJ mol ⁻¹
Si – Si	222
C – C	346
C = C	602
C ≡ C	835
C ≡ C (aromatic) }	519
H – O	458
H – N	387
C – H	414
C – O	358
C = O	798
C – F	486
C – Cl	326
C – Br	285
C – I	213

Enthalpy of Sublimation of Carbon

The energy required to convert 1 mole solid carbon into 1 mole gaseous carbon atoms is 715 kJ at 298 K (25°C). The equation is

$$\text{C(s)} \rightarrow \text{C(g)} \quad \Delta H = 715 \text{ kJ}$$

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	1311	–	–	–	2.2
helium	He	2380	5260	–	–	–
lithium	Li	526	7310	11800	–	1.0
beryllium	Be	905	1770	14800	–	1.5
boron	B	807	2440	3660	25000	2.0
carbon	C	1090	2360	4640	6220	2.5
nitrogen	N	1410	2860	4580	7470	3.0
oxygen	O	1320	3400	5320	7470	3.5
fluorine	F	1690	3380	6060	8410	4.0
neon	Ne	2090	3960	6140	9360	–
sodium	Na	502	4560	6920	9540	0.9
magnesium	Mg	744	1460	7750	10500	1.2
aluminium	Al	584	1830	2760	11600	1.5
silicon	Si	792	1590	3250	4350	1.9
phosphorus	P	1020	1920	2930	4950	2.2
sulphur	S	1010	2260	3380	4560	2.5
chlorine	Cl	1260	2310	3840	5160	3.0
argon	Ar	1530	2670	3950	5770	–
potassium	K	425	3060	4440	5880	0.8
calcium	Ca	596	1160	4930	6470	1.0
scandium	Sc	637	1250	2410	7130	1.3
titanium	Ti	664	1320	2670	4170	1.5
vanadium	V	656	1430	2850	4600	1.6
chromium	Cr	659	1600	3000	4800	1.6
manganese	Mn	723	1520	3270	5000	1.5
iron	Fe	766	1570	2970	5480	1.8
cobalt	Co	764	1660	3250	–	1.8
nickel	Ni	743	1770	3410	5400	1.9
copper	Cu	751	1970	3570	5700	1.9
zinc	Zn	913	1740	3850	5990	1.6
arsenic	As	947	1798	2736	4838	2.2
bromine	Br	1150	2100	3480	4560	2.8
rubidium	Rb	409	2670	3880	–	0.8
strontium	Sr	556	1080	4120	5500	1.0
silver	Ag	731	2073	3361	–	1.9
tin	Sn	709	1412	2942	3930	1.8
antimony	Sb	834	1595	2439	4265	2.1
iodine	I	1020	1850	2040	–	2.6
caesium	Cs	382	2440	–	–	0.8
barium	Ba	509	979	3420	–	0.9
gold	Au	890	1979	–	–	2.4
lead	Pb	716	1450	3081	4084	1.8

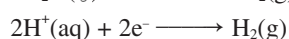
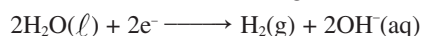
Electrochemical Series: Standard Reduction Potentials

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

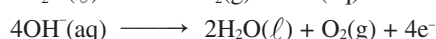
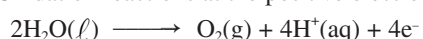
Reaction	E°/V
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li}(\text{s})$	-3.02
$\text{Cs}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cs}(\text{s})$	-2.92
$\text{Rb}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Rb}(\text{s})$	-2.92
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.92
$\text{Sr}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sr}(\text{s})$	-2.89
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ca}(\text{s})$	-2.76
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s})$	-2.71
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$	-2.37
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.68
$2\text{H}_2\text{O}(\ell) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-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
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.44
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	-0.23
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-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
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\ell)$	1.33
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	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

Reduction reactions at the negative electrode



Oxidation reactions at the positive electrode



Dissociation Constants of Selected Species

Equilibrium in aqueous solution				K_a	pK_a
methanoic acid	HCOOH	\rightleftharpoons	$H^+ + HCOO^-$	1.8×10^{-4}	3.75
ethanoic acid	CH ₃ COOH	\rightleftharpoons	$H^+ + CH_3COO^-$	1.7×10^{-5}	4.76
propanoic acid	CH ₃ CH ₂ COOH	\rightleftharpoons	$H^+ + CH_3CH_2COO^-$	1.3×10^{-5}	4.87
butanoic acid	CH ₃ (CH ₂) ₂ COOH	\rightleftharpoons	$H^+ + CH_3(CH_2)_2COO^-$	1.5×10^{-5}	4.83
benzoic acid	C ₆ H ₅ COOH	\rightleftharpoons	$H^+ + C_6H_5COO^-$	6.3×10^{-5}	4.20
phenol	C ₆ H ₅ OH	\rightleftharpoons	$H^+ + C_6H_5O^-$	1.0×10^{-10}	9.99
hydrofluoric acid	HF	\rightleftharpoons	$H^+ + F^-$	6.8×10^{-4}	3.17
boric acid	H ₃ BO ₃	\rightleftharpoons	$H^+ + H_2BO_3^-$	5.4×10^{-10}	9.27
hydrocyanic acid	HCN	\rightleftharpoons	$H^+ + CN^-$	6.2×10^{-10}	9.21
carbonic acid	H ₂ O + CO ₂	\rightleftharpoons	$H^+ + HCO_3^-$	4.5×10^{-7}	6.35
hydrogencarbonate ion	HCO ₃ ⁻	\rightleftharpoons	$H^+ + CO_3^{2-}$	4.7×10^{-11}	10.33
sulphurous acid	H ₂ SO ₃	\rightleftharpoons	$H^+ + HSO_3^-$	1.4×10^{-2}	1.85
hydrogensulphite ion	HSO ₃ ⁻	\rightleftharpoons	$H^+ + SO_3^{2-}$	6.3×10^{-8}	7.19
hydrogen sulphide	H ₂ S	\rightleftharpoons	$H^+ + HS^-$	8.9×10^{-8}	7.05
hydrogensulphide ion	HS ⁻	\rightleftharpoons	$H^+ + S^{2-}$	1.3×10^{-4}	13.90
phosphoric acid	H ₃ PO ₄	\rightleftharpoons	$H^+ + H_2PO_4^-$	6.9×10^{-3}	2.16
dihydrogenphosphate ion	H ₂ PO ₄ ⁻	\rightleftharpoons	$H^+ + HPO_4^{2-}$	6.2×10^{-8}	7.21
hydrogenphosphate ion	HPO ₄ ²⁻	\rightleftharpoons	$H^+ + PO_4^{3-}$	4.8×10^{-13}	12.32
ammonium ion	NH ₄ ⁺	\rightleftharpoons	$H^+ + NH_3$	5.8×10^{-10}	9.24
methylammonium ion	CH ₃ NH ₃ ⁺	\rightleftharpoons	$H^+ + CH_3NH_2$	2.2×10^{-11}	10.66
phenylammonium ion	C ₆ H ₅ NH ₃ ⁺	\rightleftharpoons	$H^+ + C_6H_5NH_2$	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	yellow doublet
	577	
	546	green
	436	blue-violet
	405	violet
	310	ultra-violet
sodium	589.0	orange-yellow doublet
	589.6	

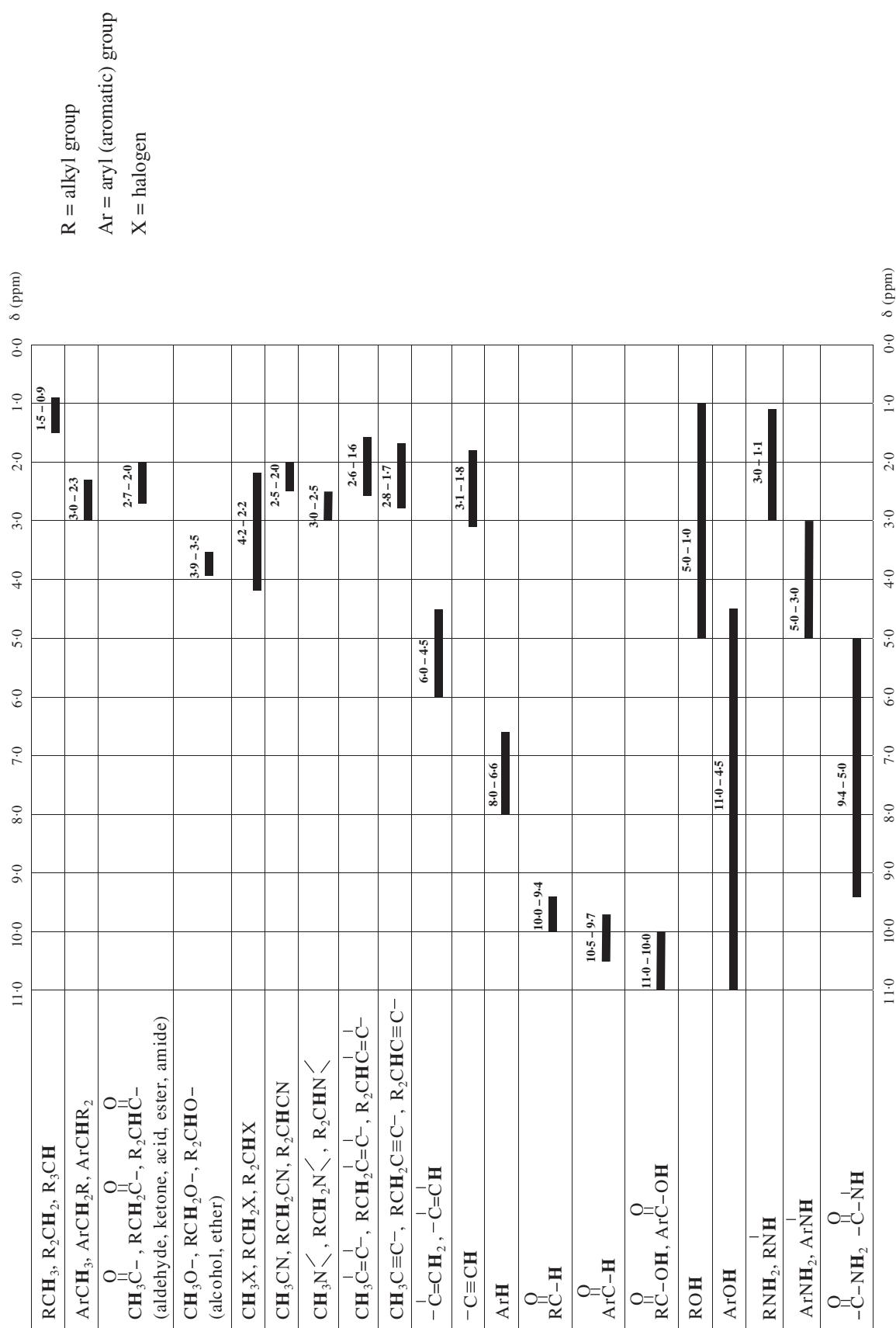
Flame Colours

Note: The data refers to prominent spectral lines.

Element	Wavelength/nm	Colour
barium	554	green
calcium	620	orange-red
copper	325	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 ⁺	68
Be ²⁺	31
N ³⁻	142
O ²⁻	136
F ⁻	133
Na ⁺	95
Mg ²⁺	65
Al ³⁺	50
P ³⁻	198
S ²⁻	184
Cl ⁻	181
K ⁺	133
Ca ²⁺	100
Ti ³⁺	67
V ³⁺	64
Cr ²⁺	73
Cr ³⁺	62
Mn ²⁺	67
Fe ²⁺	61
Fe ³⁺	55
Co ²⁺	65
Co ³⁺	55
Ni ²⁺	69
Cu ⁺	60
Cu ²⁺	72
Zn ²⁺	74
Br ⁻	196
Rb ⁺	161
Sr ²⁺	126
Ag ⁺	126
Sn ²⁺	101
I ⁻	220
Cs ⁺	174
Ba ²⁺	135
Hg ²⁺	110
Pb ²⁺	120

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 (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	216
Li	159
Be	326
B	565
C	715
N	471
O	249
F	78
Na	109
Mg	147
Al	330
Si	450
P	317
S	227
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 ₂ O	-2799
BeO	-4293
Na ₂ O	-2481
MgO	-3795
Al ₂ O ₃	-15916
K ₂ O	-2238
CaO	-3414
FeO	-3795
CoO	-3837
NiO	-3908
CuO	-4135
ZnO	-4142
SrO	-3217
Ag ₂ O	-3002
BaO	-3029
LiCl	-834
NaCl	-769
MgCl ₂	-2326
KCl	-701
CaCl ₂	-2223
CoCl ₂	-2709
NiCl ₂	-2753
CuCl	-921
CuCl ₂	-2774
SrCl ₂	-2127
AgCl	-864
BaCl ₂	-2033
LiF	-1030
NaF	-910
MgF ₂	-2913
KF	-808
CaF ₂	-2609
NiF ₂	-2845
SrF ₂	-2476
AgF	-953
BaF ₂	-2341
MgS	-3274
CaS	-3002
BaS	-2713
NiS	-3528
ZnS	-3692
LiBr	-788
NaBr	-732
KBr	-671
NiBr ₂	-2699
CuBr ₂	-2711
AgBr	-830

Electron Affinities of Selected Elements

Element	Electron Affinity/kJ mol ⁻¹
H	-73
O	-141
(O ⁻)	+844
F	-328
S	-200
(S ⁻)	+456
Cl	-349
Br	-325
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 ⁺	-464
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 $E^{n-}(g) \rightarrow E^{n-}(aq)$.

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	$6.63 \times 10^{-34} \text{ J s}$
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 $24 \text{ }^\circ\text{C}$

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
$1 \text{ litre} = 1 \text{ dm}^3 = 1000 \text{ cm}^3$ $1000 \text{ litres} = 1000 \text{ dm}^3 = 1 \text{ m}^3$	$0^\circ\text{C} = 273 \text{ K}$

