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Higher and Advanced Higher

For use in National Qualification Courses
leading to the 2007 examinations and beyond.

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Contents

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	Group 2										Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
(1)																(18)
1 **H** 1 Hydrogen	(2)															2 **He** 2 Helium
3 **Li** 2, 1 Lithium	4 **Be** 2, 2 Beryllium										(13) 5 **B** 2, 3 Boron	(14) 6 **C** 2, 4 Carbon	(15) 7 **N** 2, 5 Nitrogen	(16) 8 **O** 2, 6 Oxygen	(17) 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 Sulphur	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	(3) 21 **Sc** 2, 8, 9, 2 Scandium	(4) 22 **Ti** 2, 8, 10, 2 Titanium	(5) 23 **V** 2, 8, 11, 2 Vanadium	(6) 24 **Cr** 2, 8, 13, 1 Chromium	(7) 25 **Mn** 2, 8, 13, 2 Manganese	(8) 26 **Fe** 2, 8, 14, 2 Iron	(9) 27 **Co** 2, 8, 15, 2 Cobalt	(10) 28 **Ni** 2, 8, 16, 2 Nickel	(11) 29 **Cu** 2, 8, 18, 1 Copper	(12) 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, 18, 1 Rubidium	38 **Sr** 2, 8, 18, 18, 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 Antimomy	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 **Ti** 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								

Key

Atomic number
Symbol
Electron arrangement
Name

Transition Elements

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

Densities of Selected Elements

Group 1	Group 2										Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
1 Hydrogen 0·00009																2 Helium 0·0002
3 Lithium 0·53	4 Beryllium 1·85										5 Boron 2·34	6 Carbon *	7 Nitrogen 0·0013	8 Oxygen 0·0014	9 Fluorine 0·0017	10 Neon 0·0009
11 Sodium 0·97	12 Magnesium 1·74										13 Aluminium 2·70	14 Silicon 2·33	15 Phosphorus 1·82	16 Sulphur 2·07	17 Chlorine 0·0032	18 Argon 0·0018
19 Potassium 0·86	20 Calcium 1·54	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	31 Gallium 5·90	32 Germanium 5·35	33 Arsenic 5·73	34 Selenium 4·81	35 Bromine 3·12	36 Krypton 0·0037
37 Rubidium 1·53	38 Strontium 2·60	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	49 Indium 7·31	50 Tin 7·28	51 Antimony 6·68	52 Tellurium 6·25	53 Iodine 4·93	54 Xenon 0·0059
55 Caesium 1·93	56 Barium 3·51	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	81 Thallium 11·8	82 Lead 11·3	83 Bismuth 9·80	84 Polonium 9·4	85 Astatine –	86 Radon 0·0097

Key

Atomic number
Name of element
Density/g cm^{-3}
measured at s.t.p.

***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

Key

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

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 0
							2 **Helium** **–*272** *–269*
3 **Lithium** **181** *1342*	**4** **Beryllium** **1278** *2471*						
11 **Sodium** **98** *883*	**12** **Magnesium** **649** *1090*						
19 **Potassium** **64** *759*	**20** **Calcium** **842** *1484*	**21** **Scandium** **1541** *2831*	**22** **Titanium** **1660** *3287*	**23** **Vanadium** **1890** *3380*	**24** **Chromium** **1857** *2672*	**25** **Manganese** **1244** *1962*	**26** **Iron** **1535** *2750*	**27** **Cobalt** **1495** *2927*	**28** **Nickel** **1453** *2913*	**29** **Copper** **1083** *2567*	**30** **Zinc** **420** *907*	**31** **Gallium** **30** *2403*	**32** **Germanium** **937** *2830*	**33** **Arsenic** ***817** *†613*	**34** **Selenium** **217** *685*	**35** **Bromine** **–7** *59*	**36** **Krypton** **–157** *–152*
37 **Rubidium** **39** *688*	**38** **Strontium** **769** *1384*	**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*	**49** **Indium** **157** *2080*	**50** **Tin** **232** *2602*	**51** **Antimony** **631** *1750*	**52** **Tellurium** **452** *988*	**53** **Iodine** **114** *184*	**54** **Xenon** **–112** *–107*
55 **Caesium** **28** *671*	**56** **Barium** **725** *1640*	**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*	**81** **Thallium** **304** *1457*	**82** **Lead** **328** *1749*	**83** **Bismuth** **271** *1560*	**84** **Polonium** **254** *962*	**85** **Astatine** **302**	**86** **Radon** **–71** *–62*

* **not at standard pressure**

† **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									5 Boron 90	6 Carbon 77	7 Nitrogen 75	8 Oxygen 73	9 Fluorine 71
11 Sodium 154	12 Magnesium 145									13 Aluminium 130	14 Silicon 117	15 Phosphorus 110	16 Sulphur 102	17 Chlorine 99
19 Potassium 196	20 Calcium 174	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	31 Gallium 120	32 Germanium 122	33 Arsenic 121	34 Selenium 117	35 Bromine 114
37 Rubidium 216	38 Strontium 191	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	49 Indium 150	50 Tin 140	51 Antimony 143	52 Tellurium 135	53 Iodine 133
55 Caesium 235	56 Barium 198	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	81 Thallium 157	82 Lead 155	83 Bismuth 151	84 Polonium –	85 Astatine 140

Key

Atomic number
Name of element
Convalent radius/pm

Melting and Boiling Points of Selected Oxides

Element	Formula of oxide	mp/°C	bp/°C
hydrogen	H_2O	0	100
lithium	Li_2O	sublimes at 1200	
beryllium	BeO	2530	3900
boron	B_2O_3	450	1860
carbon	CO_2	sublimes at –78·5	
nitrogen	N_2O_2	-9	21
fluorine	F_2O	–224	–145
sodium	Na_2O	sublimes at 1275	
magnesium	MgO	2852	3600
aluminium	Al_2O_3	2072	2980
silicon	SiO_2	1610	2230
phosphorus	P_4O_{10}	sublimes at 300	
sulphur	SO_2	–72·7	–10
chlorine	Cl_2O	–20	decomposes at 4
potassium	K_2O	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_2Cl_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	$Cr_2O_7^{2-}$		
		hydrogensulphite	HSO_3^-	sulphate	SO_4^{2-}		
		hydroxide	OH^-	sulphite	SO_3^{2-}		
		nitrate	NO_3^-	thiosulphate	$S_2O_3^{2-}$		
		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	$3{\cdot}79 \times 10^{5}$ years
uranium	U	238	92	α	$4{\cdot}51 \times 10^{9}$ years
thorium	Th	234	90	β	24·1 days
protactinium	Pa	234	91	β	6·75 hours
uranium	U	234	92	α	$2{\cdot}47 \times 10^{5}$ years
thorium	Th	230	90	α	$8{\cdot}0 \times 10^{4}$ years
radium	Ra	226	88	α	$1{\cdot}62 \times 10^{3}$ 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 / α	19·7 minutes
polonium	Po	214	84	α	$1{\cdot}6 \times 10^{-4}$ 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	$1{\cdot}41 \times 10^{10}$ 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 / α	60·6 minutes
polonium	Po	212	84	α	$3{\cdot}04 \times 10^{-7}$ 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
$C(s) \rightarrow C(g) \quad \Delta H = 715$ 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**
$Li^+(aq) + e^-$	$\rightleftharpoons$	$Li(s)$	–3·02
$Cs^+(aq) + e^-$	$\rightleftharpoons$	$Cs(s)$	–2·92
$Rb^+(aq) + e^-$	$\rightleftharpoons$	$Rb(s)$	–2·92
$K^+(aq) + e^-$	$\rightleftharpoons$	$K(s)$	–2·92
$Sr^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Sr(s)$	–2·89
$Ca^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2·76
$Na^+(aq) + e^-$	$\rightleftharpoons$	$Na(s)$	–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
$Fe^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0·44
$Ni^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0·23
$Sn^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–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
$Sn^{4+}(aq) + 2e^-$	$\rightleftharpoons$	$Sn^{2+}(aq)$	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
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$	$\rightleftharpoons$	$2Cr^{3+}(aq) + 7H_2O(\ell)$	1·33
$Cl_2(g) + 2e^-$	$\rightleftharpoons$	$2Cl^-(aq)$	1·36
$MnO_4^-(aq) + 8H^+(aq) + 5e^-$	$\rightleftharpoons$	$Mn^{2+}(aq) + 4H_2O(\ell)$	1·51
$F_2(g) + 2e^-$	$\rightleftharpoons$	$2F^-(aq)$	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/mol l^{-1}	pK_a
methanoic acid	$HCOOH$	$\rightleftharpoons$	$H^+ + HCOO^-$	$1{\cdot}8 \times 10^{-4}$	3·75
ethanoic acid	CH_3COOH	$\rightleftharpoons$	$H^+ + CH_3COO^-$	$1{\cdot}7 \times 10^{-5}$	4·76
propanoic acid	CH_3CH_2COOH	$\rightleftharpoons$	$H^+ + CH_3CH_2COO^-$	$1{\cdot}3 \times 10^{-5}$	4·87
butanoic acid	$CH_3(CH_2)_2COOH$	$\rightleftharpoons$	$H^+ + CH_3(CH_2)_2COO^-$	$1{\cdot}5 \times 10^{-5}$	4·83
benzoic acid	C_6H_5COOH	$\rightleftharpoons$	$H^+ + C_6H_5COO^-$	$6{\cdot}3 \times 10^{-5}$	4·20
phenol	C_6H_5OH	$\rightleftharpoons$	$H^+ + C_6H_5O^-$	$1{\cdot}0 \times 10^{-10}$	9·99
hydrofluoric acid	HF	$\rightleftharpoons$	$H^+ + F^-$	$6{\cdot}8 \times 10^{-4}$	3·17
boric acid	H_3BO_3	$\rightleftharpoons$	$H^+ + H_2BO_3$	$5{\cdot}4 \times 10^{-10}$	9·27
hydrocyanic acid	HCN	$\rightleftharpoons$	$H^+ + CN^-$	$6{\cdot}2 \times 10^{-10}$	9·21
carbonic acid	$H_2O + CO_2$	$\rightleftharpoons$	$H^+ + HCO_3^-$	$4{\cdot}5 \times 10^{-7}$	6·35
hydrogencarbonate ion	HCO_3^-	$\rightleftharpoons$	$H^+ + CO_3^{2-}$	$4{\cdot}7 \times 10^{-11}$	10·33
sulphurous acid	H_2SO_3	$\rightleftharpoons$	$H^+ + HSO_3^-$	$1{\cdot}4 \times 10^{-2}$	1·85
hydrogensulphite ion	HSO_3^-	$\rightleftharpoons$	$H^+ + SO_3^{2-}$	$6{\cdot}3 \times 10^{-8}$	7·19
hydrogen sulphide	H_2S	$\rightleftharpoons$	$H^+ + HS^-$	$8{\cdot}9 \times 10^{-8}$	7·05
hydrogensulphide ion	HS^-	$\rightleftharpoons$	$H^+ + S^{2-}$	$1{\cdot}3 \times 10^{-4}$	13·90
phosphoric acid	H_3PO_4	$\rightleftharpoons$	$H^+ + H_2PO_4^-$	$6{\cdot}9 \times 10^{-3}$	2·16
dihydrogenphosphate ion	$H_2PO_4^-$	$\rightleftharpoons$	$H^+ + HPO_4^{2-}$	$6{\cdot}2 \times 10^{-8}$	7·21
hydrogenphosphate ion	HPO_4^{2-}	$\rightleftharpoons$	$H^+ + PO_4^{3-}$	$4{\cdot}8 \times 10^{-13}$	12·32
ammonium ion	NH_4^+	$\rightleftharpoons$	$H^+ + NH_3$	$5{\cdot}8 \times 10^{-10}$	9·24
methylammonium ion	$CH_3NH_3^+$	$\rightleftharpoons$	$H^+ + CH_3NH_2$	$2{\cdot}2 \times 10^{-11}$	10·66
phenylammonium ion	$C_6H_5NH_3^+$	$\rightleftharpoons$	$H^+ + C_6H_5NH_2$	$1{\cdot}3 \times 10^{-5}$	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

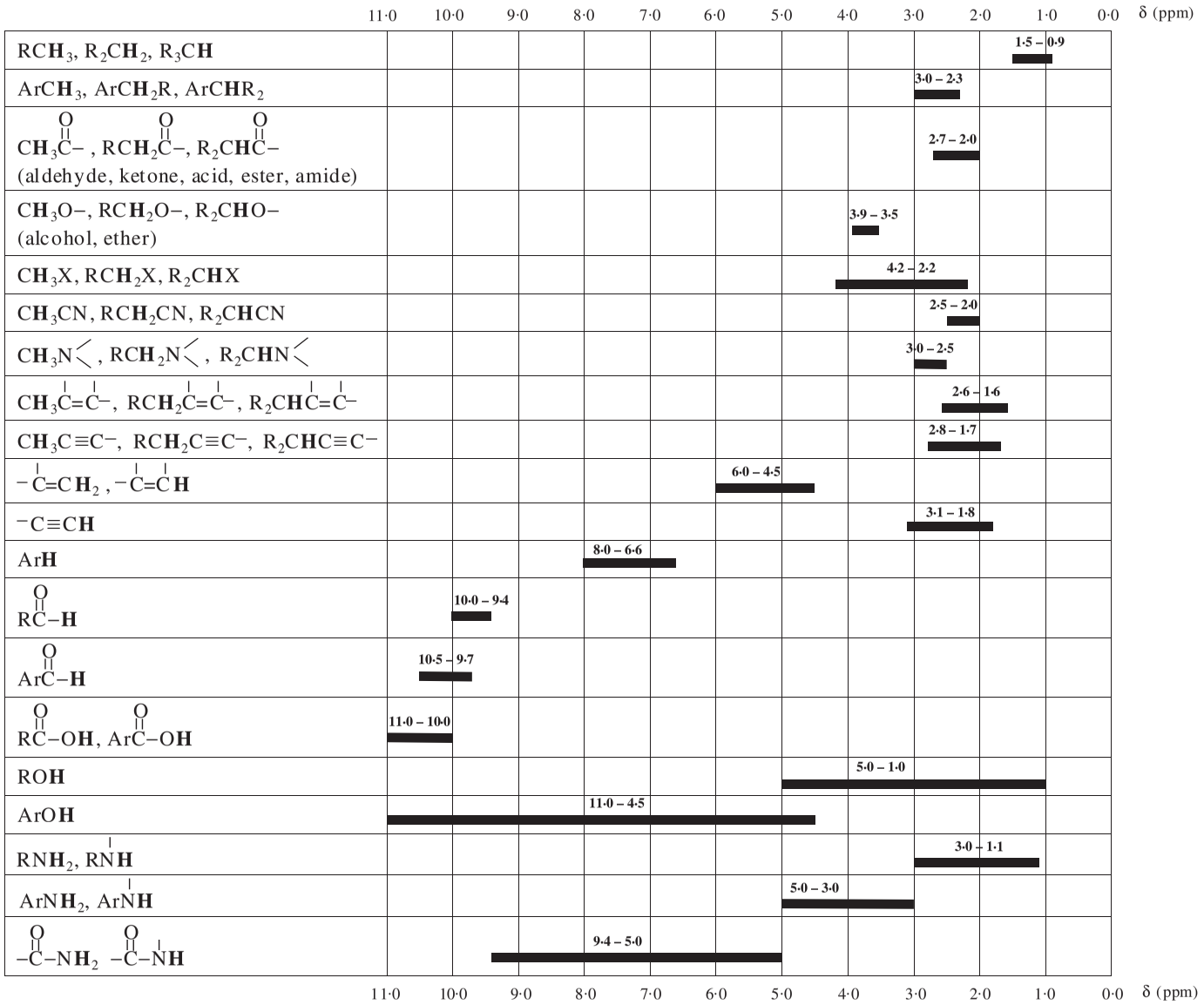
Flame Colours

Note: The data refers to prominent spectral lines.

Element	Wavelength/nm	Colour
barium	554	green
calcium	620	orange-red
copper	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 δ = 0 ppm



R = alkyl group

Ar = aryl (aromatic) group

X = halogen

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
$Br_2(\ell)$	152
Ag(s)	43
$I_2(s)$	116
Cs(s)	85
Ba(s)	63
Au(s)	47
$Hg(\ell)$	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)	99

Standard Molar Enthalpies of Atomisation of Selected Elements

Element	ΔH°/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_2O	–2799
BeO	–4293
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
$MgCl_2$	–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^-	$1{\cdot}60 \times 10^{-19}$ C
Avogadro constant	L	$6{\cdot}02 \times 10^{23}$ mol^{-1}
Faraday constant	F	$9{\cdot}65 \times 10^{4}$ C mol^{-1}
Planck constant	h	$6{\cdot}63 \times 10^{-34}$ J s
speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}$ 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	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 dm^3 = 1000 cm^3 1000 litres = 1000 dm^3 = 1 m^3	0°C = 273 K