SCIENCE

Data Booklet

Updated 2010

Government of Alberta

Alberta

Freedom To Create. Spirit To Achieve.

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Cover design interpretation of DNA in the presence of electromagnetic energy by Nathan A. Smith of Alberta Education.

General Formulas and Data

Formulas and Data

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\begin{array}{c}\text{percent difference}\\ \text{from theoretical value}\end{array} = \frac{|\text{experimental value} - \text{theoretical value}|}{|\text{theoretical value}|} \times 100\%$$

$$\text{percent efficiency} = \left(\frac{\text{output}}{\text{input}}\right) \times 100\%$$

$$\text{magnification} = \left(\begin{array}{l}\text{power of}\\ \text{ocular lens}\end{array}\right) \times \left(\begin{array}{l}\text{power of}\\ \text{objective lens}\end{array}\right)$$

Distilled Water at Room Temperature (25°C) and Standard Pressure (101.325 kPa)

Volume	Mass	Density
1.0 mL or 1.0 cm^3	1.0 g	1.0 g/cm^3
1.0 L or 1.0 dm^3	1.0 kg	1.0 kg/dm^3

Units and Prefixes

Prefix	Symbol	Factor by Which Base Unit Is Multiplied	
tera	T	1 000 000 000 000	$= 10^{12}$
giga	G	1 000 000 000	$= 10^{9}$
mega	M	1 000 000	$= 10^{6}$
kilo	k	1 000	$= 10^{3}$
hecto	h	100	$= 10^{2}$
deca	da	10	$= 10^{1}$
Common Base Units*		1	$= 10^{0}$
deci	d	0.1	$= 10^{-1}$
centi	c	0.01	$= 10^{-2}$
milli	m	0.001	$= 10^{-3}$
micro	μ	0.000 001	$= 10^{-6}$
nano	n	0.000 000 001	$= 10^{-9}$
pico	p	0.000 000 000 001	$= 10^{-12}$

*metre (m), gram (g), litre (L), mole (mol)

Some Non-SI Units Used with SI

Quantity	Unit Name	Symbol	Definition
Time	minute	min	1 min = 60 s
	hour	h	1 h = 3 600 s
	day	d	1 d = 86 400 s
	year (annum)	a	1 a = 31 557 600 s
Area	hectare	ha	1 ha = 1 hm^2 = 10 000 m^2
Volume	litre	L	1 L = 1 000 cm^3
Mass	metric ton or tonne	t	1 t = 1 000 kg = 1 Mg
Pressure	standard atmosphere	atm	1 atm = 101.325 kPa

Kinematics and Dynamics Formulas

$$v = \frac{\Delta d}{\Delta t}$$

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$$

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

$$\vec{F}_{net} = m\vec{a}$$

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$

$$W = F\Delta d$$

$$P = \frac{W}{t}$$

$$\Delta \vec{d} = \vec{v}_i \Delta t + \tfrac{1}{2}\vec{a}(\Delta t)^2$$

$$\Delta \vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)\Delta t$$

$$\vec{p} = m\vec{v}$$

$$\Delta \vec{p} = \vec{F}\Delta t, \;\; \Delta \vec{p} = \vec{p}_f - \vec{p}_i$$

$$\vec{F} = \frac{m(\vec{v}_f - \vec{v}_i)}{\Delta t}$$

$$E_p = mgh$$

$$E_k = \tfrac{1}{2}mv^2$$

v = average speed (m/s)

$\vec{v}$ = average velocity (m/s)

d = distance (m)

$\vec{d}$ = displacement (m)

t = time elapsed (s)

$\vec{a}$ = acceleration (m/s^2)

$\vec{F}$ = force ($kg{\cdot}m/s^2$ or N)

$\vec{F}_{net}$ = net force (N)

$\vec{F}_a$ = applied force (N)

$\vec{F}_f$ = force of friction (N)

F = magnitude of a force (N)

m = mass (kg)

W = work (N·m or J)

P = power (J/s or W)

Δ = change in

$\vec{F}\Delta t$ = impulse

$\vec{p}$ = momentum (kg·m/s)

E_p = gravitational potential energy (J)

g = magnitude of acceleration due to gravity (m/s^2)

E_k = kinetic energy (J)

Collisions

Hit and rebound:

$$m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}\,'_1 + m_2\vec{v}\,'_2$$

Hit and stick:

$$m_1\vec{v}_1 + m_2\vec{v}_2 = (m_1 + m_2)\vec{v}\,'_{1 \text{ and } 2}$$

Explosion:

$$(m_1 + m_2)\vec{v}_{1 \text{ and } 2} = m_1\vec{v}\,'_1 + m_2\vec{v}\,'_2$$

Gravitational and Electric Fields

$$\vec{F}_g = m\vec{g}$$

$$g = \frac{Gm}{r^2}$$

$$|\vec{E}| = \frac{kq}{r^2}$$

$\vec{F}_g$ = force due to gravity (N)

m = mass (kg)

G = gravitational constant = $6.67 \times 10^{-11}\ N{\cdot}m^2/kg^2$

r = radius or centre-to-centre distance (m)

g = magnitude of gravitational field strength (N/kg)

k = Coulomb's law constant = $8.99 \times 10^{9}\ N{\cdot}m^2/C^2$

q = electrostatic charge in coulombs (C)

$|\vec{E}|$ = electric field strength (N/C)

Astronomy Data

Mass of Earth = 5.98×10^{24} kg

Radius of Earth = 6.37×10^{6} m

Mass of sun = 1.99×10^{30} kg

1 light-year = 9.47×10^{15} m

1 AU (astronomical unit) = 1.50×10^{11} m

Average acceleration due to gravity on surface of Earth = $9.81\ m/s^2$

Average gravitational field strength on surface of Earth = 9.81 N/kg

Electricity Formulas

$P = IV, \quad P = I^2R$

$V = IR$

$E = Pt$

R = resistance (Ω)

P = power (W)

I = current (A)

V = voltage (V)

E = energy (J)

t = time elapsed (s)

For resistances connected in series

$$R_T = R_1 + R_2 + R_3 + \ldots R_n$$

For resistances connected in parallel

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \frac{1}{R_n}$$

Ideal Transformers

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}, \quad \frac{N_p}{N_s} = \frac{I_s}{I_p}, \quad \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

N = number of turns

p = primary

s = secondary

Related value: 1.00 kilowatt hour = 1.00 kW•h = 3.60×10^6 J

Wave Formulas

$v = f\lambda$

$c = f\lambda$

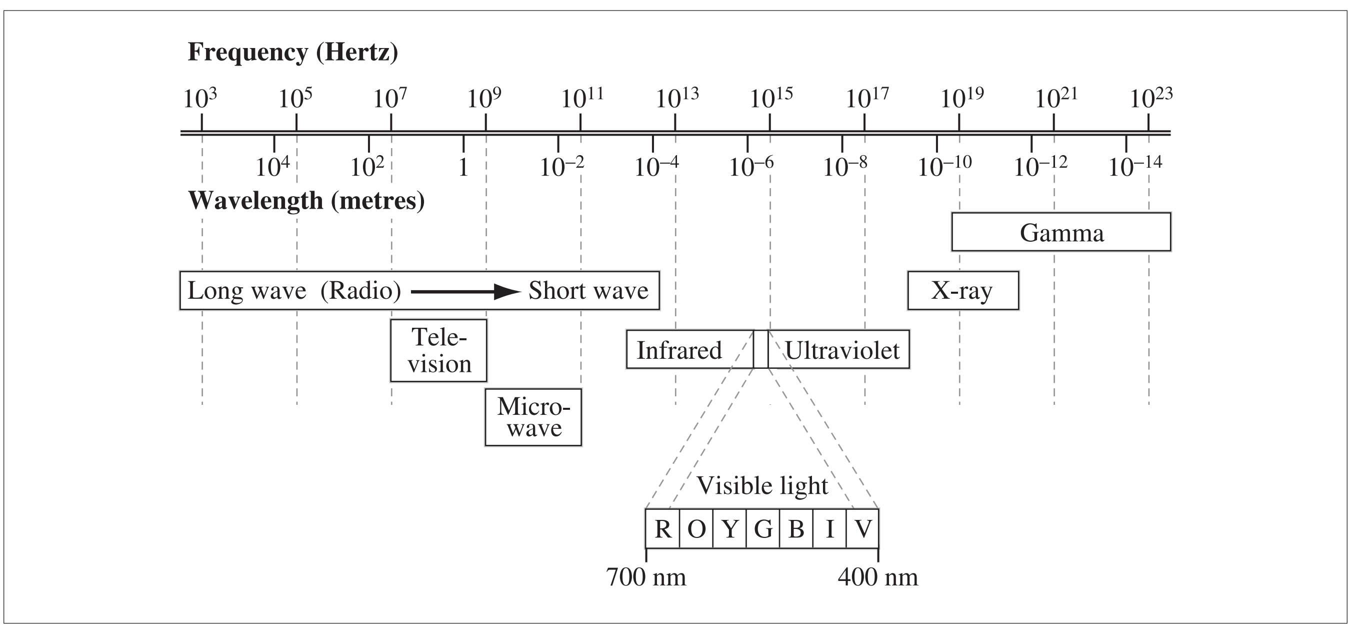
v = speed of wave (m/s)

c = speed of electromagnetic radiation in air or vacuum (3.00×10^8 m/s)

f = frequency (Hz or 1/s)

λ = wavelength (m)

Electromagnetic Spectrum



Electrochemistry

Activity Series for 1.0 mol/L Solution at 25 °C and 101.325 kPa

Increasing strength of reactant as an oxidizing agent ↑

Reduction Half-Reaction				
$Au^{3+}(aq)$	+	$3\,e^-$	→	$Au(s)$
$Hg^{2+}(aq)$	+	$2\,e^-$	→	$Hg(l)$
$Ag^{+}(aq)$	+	e^-	→	$Ag(s)$
$Cu^{2+}(aq)$	+	$2\,e^-$	→	$Cu(s)$
$2\,H^{+}(aq)$	+	$2\,e^-$	→	$H_2(g)$
$Pb^{2+}(aq)$	+	$2\,e^-$	→	$Pb(s)$
$Sn^{2+}(aq)$	+	$2\,e^-$	→	$Sn(s)$
$Ni^{2+}(aq)$	+	$2\,e^-$	→	$Ni(s)$
$Cd^{2+}(aq)$	+	$2\,e^-$	→	$Cd(s)$
$Fe^{2+}(aq)$	+	$2\,e^-$	→	$Fe(s)$
$Zn^{2+}(aq)$	+	$2\,e^-$	→	$Zn(s)$
$Cr^{2+}(aq)$	+	$2\,e^-$	→	$Cr(s)$
$Al^{3+}(aq)$	+	$3\,e^-$	→	$Al(s)$
$Mg^{2+}(aq)$	+	$2\,e^-$	→	$Mg(s)$
$Na^{+}(aq)$	+	e^-	→	$Na(s)$
$Ca^{2+}(aq)$	+	$2\,e^-$	→	$Ca(s)$
$Li^{+}(aq)$	+	e^-	→	$Li(s)$

Increasing strength of reactant as a reducing agent ↓

Thermodynamics

Heat Capacities of Selected Substances at 25°C

Compound		Specific Heat Capacity (J/g·°C) or (kJ/kg·°C)
water	$H_2O(l)$	4.19
ice (at 0 °C)	$H_2O(s)$	2.10
water vapour (at 100 °C)	$H_2O(g)$	2.08
methanol	$CH_3OH(l)$	2.53
ethanol	$C_2H_5OH(l)$	2.44
hexane	$C_6H_{14}(l)$	2.27
toluene	$C_7H_8(l)$	1.71
air	mixture of $N_2(g)$, $O_2(g)$, $CO_2(g)$, and trace gases	1.01

Thermodynamic Properties of Selected Compounds

Compound		Melting Point (°C)	Boiling Point (°C)	Heat of Fusion (kJ/mol)	Heat of Vaporization (kJ/mol)
water	$H_2O(l)$	0.00	100.00	6.01	40.66
hexane	$C_6H_{14}(l)$	–95.35	68.73	13.08	28.85
ethanol	$C_2H_5OH(l)$	–114.14	78.29	4.93	38.56
methanol	$CH_3OH(l)$	–97.53	64.6	3.22	35.21
toluene	$C_7H_8(l)$	–94.95	110.63	6.64	33.18

Geological Time-Line

Millions of Years Ago	Era	Period	Epoch
	Cenozoic	Quaternary	Holocene
			Pleistocene
1.7			
		Tertiary	
65			
	Mesozoic	Cretaceous	
140			
		Jurassic	
210			
		Triassic	
250			
	Paleozoic	Permian	
290			
		Carboniferous	
360			
		Devonian	
410			
		Silurian	
440			
		Ordovician	
500			
		Cambrian	
590			
	Precambrian		
4 600			

*Current research suggests that the start of the Quaternary period is earlier.

Standard Heats of Formation of Selected Compounds at 25°C

Compound	Formula	$\Delta_f H°$(kJ/mol)
ammonia	$NH_3(g)$	−45.9
benzene	$C_6H_6(l)$	+49.1
butane	$C_4H_{10}(g)$	−125.7
calcium carbonate	$CaCO_3(s)$	−1 207.6
calcium hydroxide	$Ca(OH)_2(s)$	−985.2
carbon dioxide	$CO_2(g)$	−393.5
carbon monoxide	$CO(g)$	−110.5
ethane	$C_2H_6(g)$	−84.0
ethanoic acid (acetic acid)	$CH_3COOH(l)$	−484.3
ethanol	$C_2H_5OH(l)$	−277.6
ethene (ethylene)	$C_2H_4(g)$	+52.4
ethyne (acetylene)	$C_2H_2(g)$	+227.4
glucose	$C_6H_{12}O_6(s)$	−1 273.3
hydrogen sulfide	$H_2S(g)$	−20.6
methane	$CH_4(g)$	−74.6
methanol	$CH_3OH(l)$	−239.2
nitrogen dioxide	$NO_2(g)$	+33.2
nitrogen monoxide	$NO(g)$	+91.3
octane	$C_8H_{18}(l)$	−250.1
pentane	$C_5H_{12}(l)$	−173.5
propane	$C_3H_8(g)$	−103.8
sucrose	$C_{12}H_{22}O_{11}(s)$	−2 226.1
sulfur dioxide	$SO_2(g)$	−296.8
sulfur trioxide	$SO_3(g)$	−395.7
water (liquid)	$H_2O(l)$	−285.8
water (gas)	$H_2O(g)$	−241.8

Note: Elements are given a value of zero.
Negative sign (–) denotes exothermic change.
Positive sign (+) denotes endothermic change.

Energy Formulas

$$Q = mc\Delta t$$

$$\Delta_{fus} H = \frac{Q}{n}$$

$$\Delta_{vap} H = \frac{Q}{n}$$

$$\Delta_r H = \sum n\Delta_f H° \text{ products} - \sum n\Delta_f H° \text{ reactants}$$

Q = quantity of heat energy (J or kJ)
m = mass (g or kg)
$\Delta_{fus} H$ = heat of fusion (kJ/mol)
$\Delta_{vap} H$ = heat of vaporization (kJ/mol)
c = specific heat capacity (J/g•°C or kJ/kg•°C)
Δt = change in temperature (°C)
n = amount in moles (mol)
$\Delta_r H$ = energy change of reaction (kJ)
$\sum$ = the sum of
$\Delta_f H°$ = standard molar heat (enthalpy) of formation (kJ/mol)

Periodic Chart of the Elements and Ions

Note: The legend at the right denotes the physical state of the elements at 101.325 kPa and 298.15 K (25°C).

Legend for the Elements

Solid	Liquid	Gas	Seldom forms ions

Table of Polyatomic Ions

Polyatomic ions

acetate	CH_3COO^-	chlorate	ClO_3^-	iodate	IO_3^-	permanganate	MnO_4^-	sulfite	SO_3^{2-}
ammonium	NH_4^+	chlorite	ClO_2^-	nitrate	NO_3^-	phosphate	PO_4^{3-}	hydrogen sulfide	HS^-
benzoate	$C_6H_5COO^-$	hypochlorite	ClO^-	nitrite	NO_2^-	hydrogen phosphate	HPO_4^{2-}	hydrogen sulfate	HSO_4^-
borate	BO_3^{3-}	chromate	CrO_4^{2-}	methanoate	$CHOO^-$	dihydrogen phosphate	$H_2PO_4^-$	hydrogen sulfite	HSO_3^-
carbonate	CO_3^{2-}	dichromate	$Cr_2O_7^{2-}$	oxalate	$OOCCOO^{2-}$	silicate	SiO_3^{2-}	thiocyanate	SCN^-
hydrogen carbonate	HCO_3^-	cyanide	CN^-	hydrogen oxalate	$HOOCCOO^-$	sulfate	SO_4^{2-}	thiosulfate	$S_2O_3^{2-}$
perchlorate	ClO_4^-	hydroxide	OH^-						

1	2	3	4	5	6	7	8	9
1 H hydrogen 1.01 H^+ hydrogen								
3 Li lithium 6.94 Li^+ lithium	4 Be beryllium 9.01 Be^{2+} beryllium							
11 Na sodium 22.99 Na^+ sodium	12 Mg magnesium 24.31 Mg^{2+} magnesium							
19 K potassium 39.10 K^+ potassium	20 Ca calcium 40.08 Ca^{2+} calcium	21 Sc scandium 44.96 Sc^{3+} scandium	22 Ti titanium 47.87 Ti^{4+} titanium(IV) Ti^{3+} titanium(III)	23 V vanadium 50.94 V^{5+} vanadium(V) V^{4+} vanadium(IV)	24 Cr chromium 52.00 Cr^{3+} chromium(III) Cr^{2+} chromium(II)	25 Mn manganese 54.94 Mn^{2+} manganese(II) Mn^{4+} manganese(IV)	26 Fe iron 55.85 Fe^{3+} iron(III) Fe^{2+} iron(II)	27 Co cobalt 58.93 Co^{2+} cobalt(II) Co^{3+} cobalt(III)
37 Rb rubidium 85.47 Rb^+ rubidium	38 Sr strontium 87.62 Sr^{2+} strontium	39 Y yttrium 88.91 Y^{3+} yttrium	40 Zr zirconium 91.22 Zr^{4+} zirconium	41 Nb niobium 92.91 Nb^{5+} niobium(V) Nb^{3+} niobium(III)	42 Mo molybdenum 95.94 Mo^{6+} molybdenum	43 Tc technetium (98) Tc^{7+} technetium	44 Ru ruthenium 101.07 Ru^{3+} ruthenium(III)	45 Rh rhodium 102.91 Rh^{3+} rhodium
55 Cs cesium 132.91 Cs^+ cesium	56 Ba barium 137.33 Ba^{2+} barium	57 La lanthanum 138.91 La^{3+} lanthanum	72 Hf hafnium 178.49 Hf^{4+} hafnium	73 Ta tantalum 180.95 Ta^{5+} tantalum	74 W tungsten 183.84 W^{6+} tungsten	75 Re rhenium 186.21 Re^{7+} rhenium	76 Os osmium 190.23 Os^{4+} osmium	77 Ir iridium 192.22 Ir^{4+} iridium
87 Fr francium (223) Fr^+ francium	88 Ra radium (226) Ra^{2+} radium	89 Ac actinium (227) Ac^{3+} actinium	104 Rf rutherfordium (261)	105 Db dubnium (262)	106 Sg seaborgium (266)	107 Bh bohrium (264)	108 Hs hassium (277)	109 Mt meitnerium (268)

Lanthanide and Actinide Series Begins

58 Ce cerium 140.12 Ce^{3+} cerium	59 Pr praseodymium 140.91 Pr^{3+} praseodymium	60 Nd neodymium 144.24 Nd^{3+} neodymium	61 Pm promethium (145) Pm^{3+} promethium	62 Sm samarium 150.36 Sm^{3+} samarium(III) Sm^{2+} samarium(II)
90 Th thorium 232.04 Th^{4+} thorium	91 Pa protactinium 231.04 Pa^{5+} protactinium(V) Pa^{4+} protactinium(IV)	92 U uranium 238.03 U^{6+} uranium(VI) U^{4+} uranium(IV)	93 Np neptunium (237) Np^{5+} neptunium	94 Pu plutonium (244) Pu^{4+} plutonium(IV) Pu^{6+} plutonium(VI)

Key

Atomic number	91
Symbol of the element	Pa
Name of the element	protactinium
Atomic mass	231.04
Ion charge	Pa^{5+}
Stock name (IUPAC)	protactinium(V)
	Pa^{4+} protactinium(IV)

Based on $^{12}_{6}C$

Most stable or common ion is listed above dotted line. Atomic mass in parentheses indicates mass of the most stable isotope.

10	11	12	13	14	15	16	17	18
							1 H hydrogen 1.01 H^- hydride	2 He helium 4.00 He helium
			5 B boron 10.81 B boron	6 C carbon 12.01 C carbon	7 N nitrogen 14.01 N^{3-} nitride	8 O oxygen 16.00 O^{2-} oxide	9 F fluorine 19.00 F^- fluoride	10 Ne neon 20.18 Ne neon
			13 Al aluminium 26.98 Al^{3+} aluminium	14 Si silicon 28.09 Si silicon	15 P phosphorus 30.97 P^{3-} phosphide	16 S sulfur 32.07 S^{2-} sulfide	17 Cl chlorine 35.45 Cl^- chloride	18 Ar argon 39.95 Ar argon
28 Ni nickel 58.69 Ni^{2+} nickel(II) Ni^{3+} nickel(III)	29 Cu copper 63.55 Cu^{2+} copper(II) Cu^+ copper(I)	30 Zn zinc 65.41 Zn^{2+} zinc	31 Ga gallium 69.72 Ga^{3+} gallium	32 Ge germanium 72.64 Ge^{4+} germanium	33 As arsenic 74.92 As^{3-} arsenide	34 Se selenium 78.96 Se^{2-} selenide	35 Br bromine 79.90 Br^- bromide	36 Kr krypton 83.80 Kr krypton
46 Pd palladium 106.42 Pd^{2+} palladium(II) Pd^{3+} palladium(III)	47 Ag silver 107.87 Ag^+ silver	48 Cd cadmium 112.41 Cd^{2+} cadmium	49 In indium 114.82 In^{3+} indium	50 Sn tin 118.71 Sn^{4+} tin(IV) Sn^{2+} tin(II)	51 Sb antimony 121.76 Sb^{3+} antimony(III) Sb^{5+} antimony(V)	52 Te tellurium 127.60 Te^{2-} telluride	53 I iodine 126.90 I^- iodide	54 Xe xenon 131.29 Xe xenon
78 Pt platinum 195.08 Pt^{4+} platinum(IV) Pt^{2+} platinum(II)	79 Au gold 196.97 Au^{3+} gold(III) Au^+ gold(I)	80 Hg mercury 200.59 Hg^{2+} mercury(II) Hg^+ mercury(I)	81 Tl thallium 204.38 Tl^+ thallium(I) Tl^{3+} thallium(III)	82 Pb lead 207.2* Pb^{2+} lead(II) Pb^{4+} lead(IV)	83 Bi bismuth 208.98 Bi^{3+} bismuth(III) Bi^{5+} bismuth(V)	84 Po polonium (209) Po^{2+} polonium(II) Po^{4+} polonium(IV)	85 At astatine (210) At^- astatide	86 Rn radon (222) Rn radon
110 Ds darmstadtium (271)	111 Rg roentgenium (272)							

Polyatomic Elements

Elements			
astatine	At_2	iodine	I_2
bromine	Br_2	nitrogen	N_2
chlorine	Cl_2	oxygen	O_2
fluorine	F_2	phosphorus	P_4
hydrogen	H_2	sulfur	S_8

* The isotopic mix of naturally occurring lead is more variable than that of other elements, preventing precision to greater than tenths of a gram per mole.

63 Eu europium 151.96 Eu^{3+} europium(III) Eu^{2+} europium(II)	64 Gd gadolinium 157.25 Gd^{3+} gadolinium	65 Tb terbium 158.93 Tb^{3+} terbium	66 Dy dysprosium 162.50 Dy^{3+} dysprosium	67 Ho holmium 164.93 Ho^{3+} holmium	68 Er erbium 167.26 Er^{3+} erbium	69 Tm thulium 168.93 Tm^{3+} thulium	70 Yb ytterbium 173.04 Yb^{3+} ytterbium(III) Yb^{2+} ytterbium(II)	71 Lu lutetium 174.97 Lu^{3+} lutetium
95 Am americium (243) Am^{3+} americium(III) Am^{4+} americium(IV)	96 Cm curium (247) Cm^{3+} curium	97 Bk berkelium (247) Bk^{3+} berkelium(III) Bk^{4+} berkelium(IV)	98 Cf californium (251) Cf^{3+} californium	99 Es einsteinium (252) Es^{3+} einsteinium	100 Fm fermium (257) Fm^{3+} fermium	101 Md mendelevium (258) Md^{2+} mendelevium(II) Md^{3+} mendelevium(III)	102 No nobelium (259) No^{2+} nobelium(II) No^{3+} nobelium(III)	103 Lr lawrencium (262) Lr^{3+} lawrencium

Nuclear Chemistry

Masses of Subatomic Particles and Radiation

Subatomic Particle or Radiation		Mass (10^{-3} kg/mol)	Subatomic Particle or Radiation		Mass (10^{-3} kg/mol)
alpha particle (helium nucleus)	${}^{4}_{2}He$ or α	4.001 51	positron	${}^{0}_{+1}e$	0.000 549
			gamma radiation	${}^{0}_{0}\gamma$	—
beta particle (electron)	${}^{0}_{-1}e$ or β	0.000 549	neutron	${}^{1}_{0}n$	1.008 66
			proton	${}^{1}_{1}p$	1.007 28

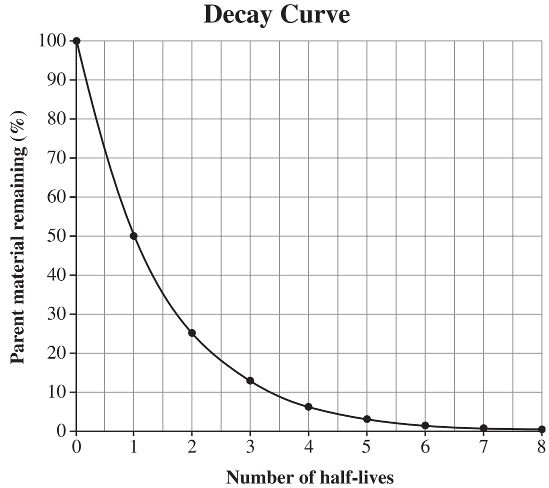
Masses of Selected Nuclides

Nuclide		Mass (10^{-3} kg/mol)	Nuclide		Mass (10^{-3} kg/mol)
barium-141	${}^{141}_{56}Ba$	140.914 41	nitrogen-15	${}^{15}_{7}N$	15.000 11
beryllium-7	${}^{7}_{4}Be$	7.016 93	oxygen-15	${}^{15}_{8}O$	15.003 07
beryllium-8	${}^{8}_{4}Be$	8.005 31	oxygen-16	${}^{16}_{8}O$	15.994 91
boron-8	${}^{8}_{5}B$	8.024 61	oxygen-18	${}^{18}_{8}O$	17.999 16
carbon-14	${}^{14}_{6}C$	14.003 24	phosphorus-31	${}^{31}_{15}P$	30.973 76
cesium-144	${}^{144}_{55}Cs$	143.932 02	plutonium-239	${}^{239}_{94}Pu$	239.052 16
fluorine-17	${}^{17}_{9}F$	17.002 10	polonium-210	${}^{210}_{84}Po$	209.982 86
helium-3	${}^{3}_{2}He$	3.016 03	polonium-218	${}^{218}_{84}Po$	218.008 97
hydrogen-1	${}^{1}_{1}H$	1.007 83	potassium-40	${}^{40}_{19}K$	39.964 00
hydrogen-2 (deuterium)	${}^{2}_{1}H$	2.014 10	radium-226	${}^{226}_{88}Ra$	226.025 40
hydrogen-3 (tritium)	${}^{3}_{1}H$	3.016 03	radon-222	${}^{222}_{86}Rn$	222.017 57
krypton-92	${}^{92}_{36}Kr$	91.926 11	rubidium-90	${}^{90}_{37}Rb$	89.914 81
lanthanum-146	${}^{146}_{57}La$	145.925 8	ruthenium-107	${}^{107}_{44}Ru$	106.909 9
lead-206	${}^{206}_{82}Pb$	205.974 5	strontium-95	${}^{95}_{38}Sr$	94.919 31
lead-208	${}^{208}_{82}Pb$	207.976 64	sulfur-31	${}^{31}_{16}S$	30.979 56
neon-20	${}^{20}_{10}Ne$	19.992 44	thorium-230	${}^{230}_{90}Th$	230.033 13
nitrogen-13	${}^{13}_{7}N$	13.005 74	uranium-235	${}^{235}_{92}U$	235.043 92
nitrogen-14	${}^{14}_{7}N$	14.003 07			

Elements for Radioactive Dating

Radioisotope (Parent Nuclide)		Final Decay Nuclide		Approximate Half-Life (annum—a)
carbon-14	${}^{14}_{6}C$	nitrogen-14	${}^{14}_{7}N$	5.73×10^{3}
potassium-40	${}^{40}_{19}K$	argon-40	${}^{40}_{18}Ar$	1.26×10^{9}
rubidium-87	${}^{87}_{37}Rb$	strontium-87	${}^{87}_{38}Sr$	4.88×10^{10}
uranium-235	${}^{235}_{92}U$	lead-207	${}^{207}_{82}Pb$	7.04×10^{8}
uranium-238	${}^{238}_{92}U$	lead-206	${}^{206}_{82}Pb$	4.47×10^{9}

Decay Curve



Energy Change Formula

$\Delta E = \Delta mc^2$

ΔE = change in energy (J)
Δm = mass converted to energy (kg)
c = speed of EMR (3.00×10^{8} m/s)

Organic Chemistry

Homologous Series of Alkanes at 25°C and 101.325 kPa

Name*	Formula	Name*	Formula
*meth*ane	$CH_4(g)$	*hex*ane	$C_6H_{14}(l)$
*eth*ane	$C_2H_6(g)$	*hept*ane	$C_7H_{16}(l)$
*prop*ane	$C_3H_8(g)$	*oct*ane	$C_8H_{18}(l)$
*but*ane	$C_4H_{10}(g)$	*non*ane	$C_9H_{20}(l)$
*pent*ane	$C_5H_{12}(l)$	*dec*ane	$C_{10}H_{22}(l)$

*Note: Italics indicate organic nomenclature prefixes.

Prefixes for Molecular Compounds

1 = *mono-*	6 = *hexa-*
2 = *di-*	7 = *hepta-*
3 = *tri-*	8 = *octa-*
4 = *tetra-*	9 = *ennea- (nona-)*
5 = *penta-*	10 = *deca-*

Types of Reactions

Formation (Synthesis)
element + element → compound

Decomposition
compound → element + element

Single Replacement
compound + element → new compound + new element

Double Replacement
compound + compound → new compound + new compound

Complete Hydrocarbon Combustion
hydrocarbon + oxygen → carbon dioxide + water

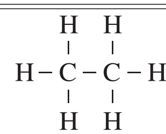
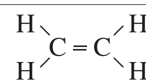
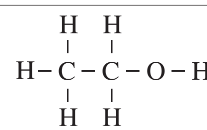
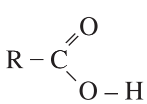
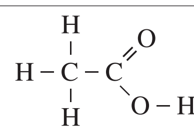
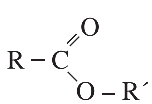
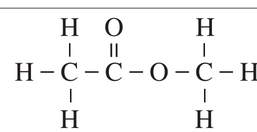
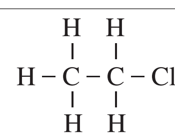
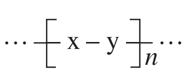
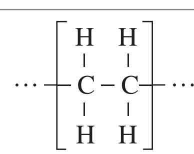
Addition
alkene or alkyne + excess hydrogen → alkane
alkene or alkyne + halogen → halogenated hydrocarbon

Cracking
large hydrocarbon → small hydrocarbons

Polymerization
monomer + monomer → polymer

Esterification
alcohol + carboxylic acid → ester + water

General Formulas and Names of Some Organic Compounds

General Formula	Classification	Example Formula	Example Name
$C_nH_{(2n+2)}$	alkane		ethane
$C_nH_{(2n)}$	alkene		ethene
$C_nH_{(2n-2)}$	alkyne	$H-C \equiv C-H$	ethyne
R − O − H	alcohol		ethanol
	carboxylic acid		ethanoic acid
	ester		methyl ethanoate
R − Q	halogenated hydrocarbon		chloroethane
	polymer		polyethene

R usually represents a carbon group
R´ usually represents a different carbon group
Q represents a halogen (fluoro-, chloro-, bromo-, iodo-)
x–y represents the monomer unit
n represents a whole number

Solutions

Solubility of Selected Ionic Compounds in Aqueous Solutions at 25°C

Ion	Group 1 ions NH_4^+ NO_3^- ClO_3^- ClO_4^- CH_3COO^-	F^-	Cl^- Br^- I^-	SO_4^{2-}	CO_3^{2-} PO_4^{3-} SO_3^{2-}	IO_3^- $OOCCOO^{2-}$	OH^-
Solubility greater than or equal to 0.1 mol/L (very soluble) **(aq)**	most	most	most	most	Group 1 ions NH_4^+	Group 1 ions NH_4^+ $Co(IO_3)_2$ $Fe_2(OOCCOO)_3$	Group 1 ions NH_4^+
Solubility less than 0.1 mol/L (slightly soluble) **(s)**	$RbClO_4$ $CsClO_4$ $AgCH_3COO$	Li^+ Mg^{2+} Ca^{2+} Sr^{2+} Ba^{2+} Fe^{2+} Pb^{2+}	Cu^+ Ag^+ Pb^{2+} Tl^+	Ca^{2+} Sr^{2+} Ba^{2+} Ag^+ Pb^{2+} Ra^{2+}	most	most	most

Note: This solubility table is only a guideline that was established using the K_{sp} values. A concentration of 0.1 mol/L corresponds to approximately 10 g/L to 30 g/L, depending on molar mass.

Stoichiometry and Solution Formulas

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

$$C = \frac{n}{V}$$

$$C_iV_i = C_fV_f$$

$$\frac{coefficient_r}{coefficient_g} = \frac{n_r}{n_g} \quad \text{or} \quad n_r = n_g \times \frac{coefficient_r}{coefficient_g}$$

$$(\% \ V/V) = \frac{V_{solute}}{V_{solution}} \times 100\%$$

$$\text{parts per million} = \frac{m_{solute}}{m_{solution}} \times 10^6 \text{ ppm}$$

n = number of moles (mol)

m = mass (g)

M = molar mass (g/mol)

C = molar concentration (mol/L)

V = volume (L)

i = initial solution

f = final solution

r = required substance

g = given substance

% V/V = percent by volume concentration

Identification of Selected Ions in 1.0 mol/L Aqueous Solutions

Ion	Symbol	Colour in Solution
chromate	$CrO_4^{2-}(aq)$	yellow
chromium(III)	$Cr^{3+}(aq)$	blue-green
chromium(II)	$Cr^{2+}(aq)$	dark blue
cobalt(II)	$Co^{2+}(aq)$	red
copper(I)	$Cu^{+}(aq)$	blue-green
copper(II)	$Cu^{2+}(aq)$	blue
dichromate	$Cr_2O_7^{2-}(aq)$	orange
iron(II)	$Fe^{2+}(aq)$	lime green
iron(III)	$Fe^{3+}(aq)$	orange-yellow
manganese(II)	$Mn^{2+}(aq)$	pale pink
nickel(II)	$Ni^{2+}(aq)$	blue-green
permanganate	$MnO_4^{-}(aq)$	deep purple

Flame Colour of Elements

Element	Symbol	Colour
barium	Ba	yellowish-green
calcium	Ca	yellowish red
cesium	Cs	violet
copper	Cu	blue to green
lead	Pb	blue-white
lithium	Li	red
potassium	K	violet
rubidium	Rb	violet
sodium	Na	yellow
strontium	Sr	scarlet red

Note: The flame test can be used to determine the identity of a metal or a metal ion. Blue to green indicates a range of colours that might appear.

Acids and Bases

Rules for Naming Acids

Compound Name	Classical System Example				IUPAC System Example
	Acid Name	Formula	Compound Name	Acid Name	Acid Name
hydrogen *–ide*	*hydro–ic* acid	$HCl(aq)$	hydrogen chlor*ide*	*hydro*chlor*ic* acid	aqueous hydrogen chloride
hydrogen *–ate*	*–ic* acid	$H_3PO_4(aq)$	hydrogen phosph*ate*	phosphor*ic* acid	aqueous hydrogen phosphate
hydrogen *–ite*	*–ous* acid	$H_3PO_3(aq)$	hydrogen phosph*ite*	phosphor*ous* acid	aqueous hydrogen phosphite

IUPAC Rules for Naming Inorganic Bases

Base Name	Example	
	Formula	Base Name
cation + anion	$NaOH(aq)$	sodium hydroxide

pH Formulas

$pH = -\log_{10}[H_3O^+(aq)]$ $[H_3O^+(aq)] = 10^{(-pH)}$ [ ] = concentration (mol/L)

Relative Strengths of Selected Acids and Bases for 0.10 mol/L Solution at 25°C

Increasing strength of acid ↑

Increasing strength of base ↓

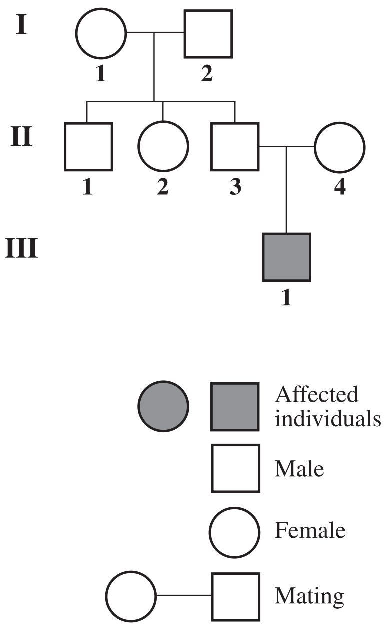
Acid Name	Acid Formula	Conjugate Base Formula
hydrochloric acid	$HCl(aq)$	$Cl^{-}(aq)$
sulfuric acid	$H_2SO_4(aq)$	$HSO_4^{-}(aq)$
nitric acid	$HNO_3(aq)$	$NO_3^{-}(aq)$
hydronium ion	$H_3O^{+}(aq)$	$H_2O(l)$
oxalic acid	$HOOCCOOH(aq)$	$HOOCCOO^{-}(aq)$
sulfurous acid	$H_2SO_3(aq)$	$HSO_3^{-}(aq)$
hydrogen sulfate ion	$HSO_4^{-}(aq)$	$SO_4^{2-}(aq)$
phosphoric acid	$H_3PO_4(aq)$	$H_2PO_4^{-}(aq)$
orange IV	$HOr(aq)$	$Or^{-}(aq)$
nitrous acid	$HNO_2(aq)$	$NO_2^{-}(aq)$
hydrofluoric acid	$HF(aq)$	$F^{-}(aq)$
methanoic (formic) acid	$HCOOH(aq)$	$HCOO^{-}(aq)$
methyl orange	$HMo(aq)$	$Mo^{-}(aq)$
benzoic acid	$C_6H_5COOH(aq)$	$C_6H_5COO^{-}(aq)$
ethanoic (acetic) acid	$CH_3COOH(aq)$	$CH_3COO^{-}(aq)$
carbonic acid ($CO_2(g) + H_2O(l)$)	$H_2CO_3(aq)$	$HCO_3^{-}(aq)$
bromothymol blue	$HBb(aq)$	$Bb^{-}(aq)$
hydrosulfuric acid	$H_2S(aq)$	$HS^{-}(aq)$
phenolphthalein	$HPh(aq)$	$Ph^{-}(aq)$
ammonium ion	$NH_4^{+}(aq)$	$NH_3(aq)$
hydrogen carbonate ion	$HCO_3^{-}(aq)$	$CO_3^{2-}(aq)$
indigo carmine	$HIc(aq)$	$Ic^{-}(aq)$
water (55.5 mol/L)	$H_2O(l)$	$OH^{-}(aq)$

Acid–Base Indicators at 25°C

Indicator	Abbreviation (acid/conjugate base)	pH Range	Colour Change as pH Increases
methyl violet	$HMv(aq)$ / $Mv^{-}(aq)$	0.0 – 1.6	yellow to blue
thymol blue	$H_2Tb(aq)$ / $HTb^{-}(aq)$	1.2 – 2.8	red to yellow
thymol blue	$HTb^{-}(aq)$ / $Tb^{2-}(aq)$	8.0 – 9.6	yellow to blue
orange IV	$HOr(aq)$ / $Or^{-}(aq)$	1.4 – 2.8	red to yellow
methyl orange	$HMo(aq)$ / $Mo^{-}(aq)$	3.2 – 4.4	red to yellow
bromocresol green	$HBg(aq)$ / $Bg^{-}(aq)$	3.8 – 5.4	yellow to blue
litmus	$HLt(aq)$ / $Lt^{-}(aq)$	4.5 – 8.3	red to blue
methyl red	$HMr(aq)$ / $Mr^{-}(aq)$	4.8 – 6.0	red to yellow
chlorophenol red	$HCh(aq)$ / $Ch^{-}(aq)$	5.2 – 6.8	yellow to red
bromothymol blue	$HBb(aq)$ / $Bb^{-}(aq)$	6.0 – 7.6	yellow to blue
phenol red	$HPr(aq)$ / $Pr^{-}(aq)$	6.6 – 8.0	yellow to red
phenolphthalein	$HPh(aq)$ / $Ph^{-}(aq)$	8.2 – 10.0	colourless to pink
thymolphthalein	$HTh(aq)$ / $Th^{-}(aq)$	9.4 – 10.6	colourless to blue
alizarin yellow R	$HAy(aq)$ / $Ay^{-}(aq)$	10.1 – 12.0	yellow to red
indigo carmine	$HIc(aq)$ / $Ic^{-}(aq)$	11.4 – 13.0	blue to yellow
1,3,5–trinitrobenzene	$HNb(aq)$ / $Nb^{-}(aq)$	12.0 – 14.0	colourless to orange

Genetics

Pedigree Chart



- Offspring listed in birth order.
- Roman numerals symbolize generations.
- Arabic numbers symbolize individuals within a given generation.

DNA Nitrogen Bases

Nitrogen Base	Abbreviation
adenine	A
cytosine	C
guanine	G
thymine	T

Alleles

Upper case—dominant
Lower case—recessive
Sex linked—$X^?Y$ or $X^?X^?$

DNA Base Triplets and Their Corresponding Amino Acids

FIRST BASE	SECOND BASE: T	SECOND BASE: C	SECOND BASE: A	SECOND BASE: G	THIRD BASE
T	TTT phenylalanine	TCT serine	TAT tyrosine	TGT cysteine	T
T	TTC phenylalanine	TCC serine	TAC tyrosine	TGC cysteine	C
T	TTA leucine	TCA serine	TAA STOP**	TGA STOP**	A
T	TTG leucine	TCG serine	TAG STOP**	TGG tryptophan	G
C	CTT leucine	CCT proline	CAT histidine	CGT arginine	T
C	CTC leucine	CCC proline	CAC histidine	CGC arginine	C
C	CTA leucine	CCA proline	CAA glutamine	CGA arginine	A
C	CTG leucine	CCG proline	CAG glutamine	CGG arginine	G
A	ATT isoleucine	ACT threonine	AAT asparagine	AGT serine	T
A	ATC isoleucine	ACC threonine	AAC asparagine	AGC serine	C
A	ATA isoleucine	ACA threonine	AAA lysine	AGA arginine	A
A	ATG methionine or START*	ACG threonine	AAG lysine	AGG arginine	G
G	GTT valine	GCT alanine	GAT aspartate	GGT glycine	T
G	GTC valine	GCC alanine	GAC aspartate	GGC glycine	C
G	GTA valine	GCA alanine	GAA glutamate	GGA glycine	A
G	GTG valine	GCG alanine	GAG glutamate	GGG glycine	G

Note: This table uses base triplets from the "complementary" (5´ → 3´) strand of DNA.
***Note:** ATG is an initiator base triplet but also codes for the amino acid methionine.
****Note:** TAA, TAG, and TGA are terminator base triplets.

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1 Important values, constants and standards

molar gas constant	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Faraday constant	$F = 9.65 \times 10^{4}\ \mathrm{C\,mol^{-1}}$
the Avogadro constant	$L = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Planck constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
rest mass of proton, ${}^{1}_{1}\mathrm{H}$	$m_\mathrm{p} = 1.67 \times 10^{-27}\ \mathrm{kg}$
rest mass of neutron, ${}^{1}_{0}\mathrm{n}$	$m_\mathrm{n} = 1.67 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron, ${}^{0}_{-1}\mathrm{e}$	$m_\mathrm{e} = 9.11 \times 10^{-31}\ \mathrm{kg}$
electronic charge	$e = -1.60 \times 10^{-19}\ \mathrm{C}$
molar volume of gas	$V_\mathrm{m} = 22.4\ \mathrm{dm^{3}\,mol^{-1}}$ at s.t.p. $V_\mathrm{m} = 24.0\ \mathrm{dm^{3}\,mol^{-1}}$ under room conditions (where s.t.p. is expressed as 101 kPa, approximately, and 273 K [0 °C])
ionic product of water	$K_\mathrm{w} = 1.00 \times 10^{-14}\ \mathrm{mol^{2}\,dm^{-6}}$ (at 298 K [25 °C])
specific heat capacity of water	$= 4.18\ \mathrm{kJ\,kg^{-1}\,K^{-1}}$ $(= 4.18\ \mathrm{J\,g^{-1}\,K^{-1}})$

2 Ionisation energies (1st, 2nd, 3rd and 4th) of selected elements, in kJ mol^{-1}

	Proton number	First	Second	Third	Fourth
H	1	1310	–	–	–
He	2	2370	5250	–	–
Li	3	519	7300	11800	–
Be	4	900	1760	14800	21000
B	5	799	2420	3660	25000
C	6	1090	2350	4610	6220
N	7	1400	2860	4590	7480
O	8	1310	3390	5320	7450
F	9	1680	3370	6040	8410
Ne	10	2080	3950	6150	9290
Na	11	494	4560	6940	9540
Mg	12	736	1450	7740	10500
Al	13	577	1820	2740	11600
Si	14	786	1580	3230	4360
P	15	1060	1900	2920	4960
S	16	1000	2260	3390	4540
Cl	17	1260	2300	3850	5150
Ar	18	1520	2660	3950	5770
K	19	418	3070	4600	5860
Ca	20	590	1150	4940	6480
Sc	21	632	1240	2390	7110
Ti	22	661	1310	2720	4170
V	23	648	1370	2870	4600
Cr	24	653	1590	2990	4770
Mn	25	716	1510	3250	5190
Fe	26	762	1560	2960	5400
Co	27	757	1640	3230	5100
Ni	28	736	1750	3390	5400
Cu	29	745	1960	3350	5690
Zn	30	908	1730	3828	5980
Ga	31	577	1980	2960	6190
Br	35	1140	2080	3460	4850
Rb	37	403	4632	3900	5080
Sr	38	548	1060	4120	5440
Ag	47	731	2074	3361	–
I	53	1010	1840	2040	4030
Cs	55	376	2420	3300	–
Ba	56	502	966	3390	–

3 Bond Energies

3(a) Bond energies in diatomic molecules (these are exact values)

Homonuclear

Bond	**Energy / kJ mol^{-1}**
H—H	436
D—D	442
N≡N	944
O=O	496
P≡P	485
S=S	425
F—F	158
C*l*—C*l*	242
Br—Br	193
I—I	151

Heteronuclear

Bond	**Energy / kJ mol^{-1}**
H—F	562
H—C*l*	431
H—Br	366
H—I	299
C≡O	1077

3(b) Bond energies in polyatomic molecules (these are average values)

Homonuclear

Bond	Energy / $kJ\,mol^{-1}$
C—C	350
C=C	610
C≡C	840
C⎓C (benzene)	520
N—N	160
N=N	410
O—O	150
Si—Si	222
P—P	200
S—S	264

Heteronuclear

Bond	Energy / $kJ\,mol^{-1}$
C—H	410
C—Cl	340
C—Br	280
C—I	240
C—N	305
C=N	610
C≡N	890
C—O	360
C=O	740
C=O in CO_2	805
N—H	390
N—Cl	310
O—H	460
Si—Cl	359
Si—H	320
Si—O (in $SiO_2(s)$)	460
Si=O (in $SiO_2(g)$)	640
P—H	320
P—Cl	330
P—O	340
P=O	540
S—H	347
S—Cl	250
S—O	360
S=O	500

4 Standard electrode potential and redox potentials, $E^\ominus$ at 298 K (25 °C)

For ease of reference, two tables are given:

(a) an extended list in alphabetical order;
(b) a shorter list in decreasing order of magnitude, i.e. a redox series.

(a) $E^\ominus$ in alphabetical order

Electrode reaction			$E^\ominus$/V
$Ag^+ + e^-$	$\rightleftharpoons$	Ag	+0.80
$Al^{3+} + 3e^-$	$\rightleftharpoons$	Al	–1.66
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	Ba	–2.90
$Br_2 + 2e^-$	$\rightleftharpoons$	$2Br^-$	+1.07
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	Ca	–2.87
$Cl_2 + 2e^-$	$\rightleftharpoons$	$2Cl^-$	+1.36
$2HOCl + 2H^+ + 2e^-$	$\rightleftharpoons$	$Cl_2 + 2H_2O$	+1.64
$ClO^- + H_2O + 2e^-$	$\rightleftharpoons$	$Cl^- + 2OH^-$	+0.89
$Co^{2+} + 2e^-$	$\rightleftharpoons$	Co	–0.28
$Co^{3+} + e^-$	$\rightleftharpoons$	Co^{2+}	+1.82
$[Co(NH_3)_6]^{2+} + 2e^-$	$\rightleftharpoons$	$Co + 6NH_3$	–0.43
$Cr^{2+} + 2e^-$	$\rightleftharpoons$	Cr	–0.91
$Cr^{3+} + 3e^-$	$\rightleftharpoons$	Cr	–0.74
$Cr^{3+} + e^-$	$\rightleftharpoons$	Cr^{2+}	–0.41
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	+1.33
$Cu^+ + e^-$	$\rightleftharpoons$	Cu	+0.52
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	Cu	+0.34
$Cu^{2+} + e^-$	$\rightleftharpoons$	Cu^+	+0.15
$[Cu(NH_3)_4]^{2+} + 2e^-$	$\rightleftharpoons$	$Cu + 4NH_3$	–0.05
$F_2 + 2e^-$	$\rightleftharpoons$	$2F^-$	+2.87
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	Fe	–0.44
$Fe^{3+} + 3e^-$	$\rightleftharpoons$	Fe	–0.04
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	+0.77
$[Fe(CN)_6]^{3-} + e^-$	$\rightleftharpoons$	$[Fe(CN)_6]^{4-}$	+0.36
$Fe(OH)_3 + e^-$	$\rightleftharpoons$	$Fe(OH)_2 + OH^-$	–0.56
$2H^+ + 2e^-$	$\rightleftharpoons$	H_2	0.00
$2H_2O + 2e^-$	$\rightleftharpoons$	$H_2 + 2OH^-$	–0.83
$I_2 + 2e^-$	$\rightleftharpoons$	$2I^-$	+0.54
$K^+ + e^-$	$\rightleftharpoons$	K	–2.92
$Li^+ + e^-$	$\rightleftharpoons$	Li	–3.04
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	Mg	–2.38
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	Mn	–1.18
$Mn^{3+} + e^-$	$\rightleftharpoons$	Mn^{2+}	+1.49
$MnO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Mn^{2+} + 2H_2O$	+1.23
$MnO_4^- + e^-$	$\rightleftharpoons$	MnO_4^{2-}	+0.56
$MnO_4^- + 4H^+ + 3e^-$	$\rightleftharpoons$	$MnO_2 + 2H_2O$	+1.67
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	+1.52
$NO_3^- + 2H^+ + e^-$	$\rightleftharpoons$	$NO_2 + H_2O$	+0.81
$NO_3^- + 3H^+ + 2e^-$	$\rightleftharpoons$	$HNO_2 + H_2O$	+0.94
$NO_3^- + 10H^+ + 8e^-$	$\rightleftharpoons$	$NH_4^+ + 3H_2O$	+0.87

Electrode reaction			$E^{\ominus}$/V
$Na^+ + e^-$	$\rightleftharpoons$	Na	–2.71
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	Ni	–0.25
$[Ni(NH_3)_6]^{2+} + 2e^-$	$\rightleftharpoons$	$Ni + 6NH_3$	–0.51
$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	$2H_2O$	+1.77
$HO_2^- + H_2O + 2e^-$	$\rightleftharpoons$	$3OH^-$	+0.88
$O_2 + 4H^+ + 4e^-$	$\rightleftharpoons$	$2H_2O$	+1.23
$O_2 + 2H_2O + 4e^-$	$\rightleftharpoons$	$4OH^-$	+0.40
$O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O_2	+0.68
$O_2 + H_2O + 2e^-$	$\rightleftharpoons$	$HO_2^- + OH^-$	–0.08
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	Pb	–0.13
$Pb^{4+} + 2e^-$	$\rightleftharpoons$	Pb^{2+}	+1.69
$PbO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Pb^{2+} + 2H_2O$	+1.47
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2 + 2H_2O$	+0.17
$S_2O_8^{2-} + 2e^-$	$\rightleftharpoons$	$2SO_4^{2-}$	+2.01
$S_4O_6^{2-} + 2e^-$	$\rightleftharpoons$	$2S_2O_3^{2-}$	+0.09
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	Sn	–0.14
$Sn^{4+} + 2e^-$	$\rightleftharpoons$	Sn^{2+}	+0.15
$V^{2+} + 2e^-$	$\rightleftharpoons$	V	–1.20
$V^{3+} + e^-$	$\rightleftharpoons$	V^{2+}	–0.26
$VO^{2+} + 2H^+ + e^-$	$\rightleftharpoons$	$V^{3+} + H_2O$	+0.34
$VO_2^+ + 2H^+ + e^-$	$\rightleftharpoons$	$VO^{2+} + H_2O$	+1.00
$VO_3^- + 4H^+ + e^-$	$\rightleftharpoons$	$VO^{2+} + 2H_2O$	+1.00
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	–0.76

All ionic states refer to aqueous ions but other state symbols have been omitted.

(b) $E^{\ominus}$ in decreasing order of oxidising power

(a selection only – see also the extended alphabetical list on the previous pages)

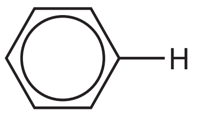
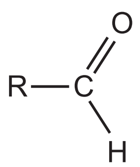
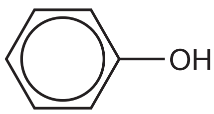
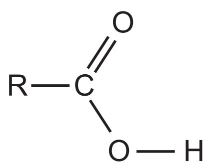
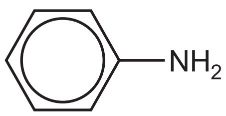
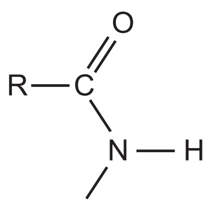
Electrode reaction			$E^{\ominus}$/V
$F_2 + 2e^-$	$\rightleftharpoons$	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	$\rightleftharpoons$	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	$2H_2O$	+1.77
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	+1.52
$PbO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Pb^{2+} + 2H_2O$	+1.47
$Cl_2 + 2e^-$	$\rightleftharpoons$	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	+1.33
$O_2 + 4H^+ + 4e^-$	$\rightleftharpoons$	$2H_2O$	+1.23
$Br_2 + 2e^-$	$\rightleftharpoons$	$2Br^-$	+1.07
$ClO^- + H_2O + 2e^-$	$\rightleftharpoons$	$Cl^- + 2OH^-$	+0.89
$NO_3^- + 10H^+ + 8e^-$	$\rightleftharpoons$	$NH_4^+ + 3H_2O$	+0.87
$NO_3^- + 2H^+ + e^-$	$\rightleftharpoons$	$NO_2 + H_2O$	+0.81
$Ag^+ + e^-$	$\rightleftharpoons$	Ag	+0.80
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	+0.77
$I_2 + 2e^-$	$\rightleftharpoons$	$2I^-$	+0.54
$O_2 + 2H_2O + 4e^-$	$\rightleftharpoons$	$4OH^-$	+0.40
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	Cu	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2 + 2H_2O$	+0.17
$Sn^{4+} + 2e^-$	$\rightleftharpoons$	Sn^{2+}	+0.15
$S_4O_6^{2-} + 2e^-$	$\rightleftharpoons$	$2S_2O_3^{2-}$	+0.09
$2H^+ + 2e^-$	$\rightleftharpoons$	H_2	0.00
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	Pb	–0.13
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	Sn	–0.14
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	Fe	–0.44
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	–0.76
$2H_2O + 2e^-$	$\rightleftharpoons$	$H_2 + 2OH^-$	–0.83
$V^{2+} + 2e^-$	$\rightleftharpoons$	V	–1.20
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	Mg	–2.38
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	Ca	–2.87
$K^+ + e^-$	$\rightleftharpoons$	K	–2.92

5 Atomic and ionic radii

		atomic / nm		ionic / nm			
(a)	**Period 1**	**atomic / nm**		**ionic / nm**			
	single covalent	H	0.037	H^-	0.208		
	van der Waals	He	0.140				
(b)	**Period 2**	**atomic / nm**		**ionic / nm**			
	metallic	Li	0.152	Li^+	0.060		
		Be	0.112	Be^{2+}	0.031		
	single covalent	B	0.080	B^{3+}	0.020		
		C	0.077	C^{4+}	0.015	C^{4-}	0.260
		N	0.074			N^{3-}	0.171
		O	0.073			O^{2-}	0.140
		F	0.072			F^-	0.136
	van der Waals	Ne	0.160				
(c)	**Period 3**	**atomic / nm**		**ionic / nm**			
	metallic	Na	0.186	Na^+	0.095		
		Mg	0.160	Mg^{2+}	0.065		
		Al	0.143	Al^{3+}	0.050		
	single covalent	Si	0.117	Si^{4+}	0.041		
		P	0.110			P^{3-}	0.212
		S	0.104			S^{2-}	0.184
		Cl	0.099			Cl^-	0.181
	van der Waals	Ar	0.190				
(d)	**Group 2**	**atomic / nm**		**ionic / nm**			
	metallic	Be	0.112	Be^{2+}	0.031		
		Mg	0.160	Mg^{2+}	0.065		
		Ca	0.197	Ca^{2+}	0.099		
		Sr	0.215	Sr^{2+}	0.113		
		Ba	0.217	Ba^{2+}	0.135		
		Ra	0.220	Ra^{2+}	0.140		

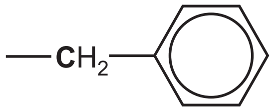
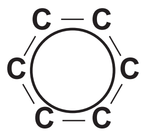
		atomic/nm		ionic/nm			
(e)	**Group 14**	**atomic / nm**		**ionic / nm**			
	single covalent	C	0.077	C^{4+}	0.015		
		Si	0.117	Si^{4+}	0.041		
		Ge	0.122	Ge^{2+}	0.093		
	metallic	Sn	0.162	Sn^{2+}	0.112		
		Pb	0.175	Pb^{2+}	0.120		
(f)	**Group 17**	**atomic / nm**		**ionic / nm**			
	single covalent	F	0.072	F^{-}	0.136		
		Cl	0.099	Cl^{-}	0.181		
		Br	0.114	Br^{-}	0.195		
		I	0.133	I^{-}	0.216		
		At	0.140				
(g)	**First row transition elements**	**atomic / nm**		**ionic / nm**			
	metallic	Sc	0.164			Sc^{3+}	0.081
		Ti	0.146	Ti^{2+}	0.090	Ti^{3+}	0.067
		V	0.135	V^{2+}	0.079	V^{3+}	0.064
		Cr	0.129	Cr^{2+}	0.073	Cr^{3+}	0.062
		Mn	0.132	Mn^{2+}	0.067	Mn^{3+}	0.062
		Fe	0.126	Fe^{2+}	0.061	Fe^{3+}	0.055
		Co	0.125	Co^{2+}	0.078	Co^{2+}	0.053
		Ni	0.124	Ni^{2+}	0.070	Ni^{3+}	0.056
		Cu	0.128	Cu^{2+}	0.073		
		Zn	0.135	Zn^{2+}	0.075		

6 Typical proton (^1H) chemical shift values (δ) relative to TMS = 0

type of proton	environment of proton	example structures	chemical shift range (δ)
C–H	alkane	$-CH_3$, $-CH_2-$, $>CH-$	0.9–1.7
	alkyl next to C=O	$CH_3-C=O$, $-CH_2-C=O$, $>CH-C=O$	2.2–3.0
	alkyl next to aromatic ring	CH_3-Ar, $-CH_2-Ar$, $>CH-Ar$	2.3–3.0
	alkyl next to electronegative atom	CH_3-O, $-CH_2-O$, $-CH_2-Cl$, $>CH-Br$	3.2–4.0
	attached to alkyne	$\equiv C-H$	1.8–3.1
	attached to alkene	$=CH_2$, $=CH-$	4.5–6.0
	attached to aromatic ring		6.0–9.0
	aldehyde		9.3–10.5
O-H (see note below)	alcohol	RO–H	0.5–6.0
	phenol		4.5–7.0
	carboxylic acid		9.0–13.0
N-H (see note below)	alkyl amine	R–NH–	1.0–5.0
	aryl amine		3.0–6.0
	amide		5.0–12.0

Note: δ values for –O-H and –N-H protons can vary depending on solvent and concentration

7 Typical carbon (^{13}C) chemical shift values (δ) relative to TMS = 0

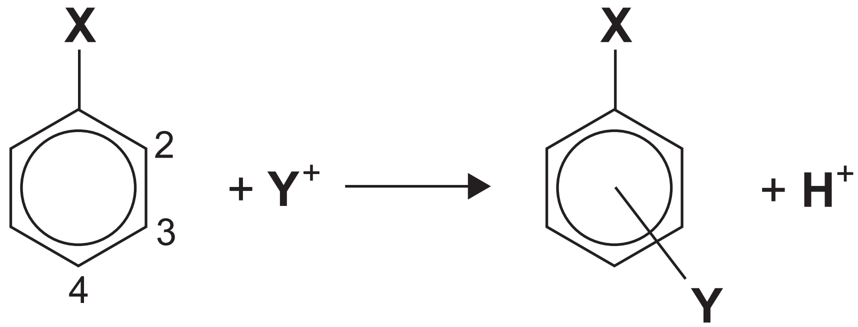
hybridisation of the carbon atom	environment of carbon atom	example structures	chemical shift range (δ)
sp^3	alkyl	**C**H_3–, –**C**H_2–, –**C**H<	0–50
sp^3	next to alkene/arene	–**C**H_2–C=C, 	10–40
sp^3	next to carbonyl/carboxyl	–**C**H_2–COR, –**C**H_2–CO_2R	25–50
sp^3	next to nitrogen	–**C**H_2–NH_2, –**C**H_2–NR_2, –**C**H_2–NHCO	30–65
sp^3	next to chlorine (-CH_2-Br and -CH_2-I are in the same range as alkyl)	–**C**H_2–C*l*	30–60
sp^3	next to oxygen	–**C**H_2–OH, –**C**H_2–O–CO–	50–70
sp^2	alkene or arene	>**C**=**C**<, 	110–160
sp^2	carboxyl	R–**C**O_2H, R–**C**O_2R	160–185
sp^2	carbonyl	R–**C**HO, R–**C**O–R	190–220
sp	alkyne	R–**C**≡**C**–	65–85
sp	nitrile	R–**C**≡N	100–125

8 Characteristic infra-red absorption frequencies for some selected bonds

bond	functional groups containing the bond	absorption range (in wavenumbers) /cm^{-1}	appearance of peak (*s* = strong, *w* = weak)
C–O	alcohols, ethers, esters	1040–1300	***s***
C=C	aromatic compounds, alkenes	1500–1680	***w*** unless conjugated
C=O	amides, ketones and aldehydes esters,	1640–1690 1670–1740 1710–1750	***s*** ***s*** ***s***
C≡C	alkynes	2150–2250	***w*** unless conjugated
C≡N	nitriles	2200–2250	***w***
C–H	alkanes, CH_2–H alkenes/arenes, =C–H	2850–2950 3000–3100	***s*** ***w***
N–H	amines, amides	3300–3500	***w***
O–H	carboxylic acids, RCO_2–H H–bonded alcohol, RO–H free alcohol, RO–H	2500–3000 3200–3600 3580–3650	***s*** and very broad ***s*** ***s*** and sharp

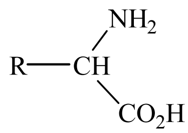
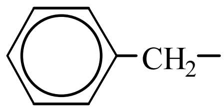
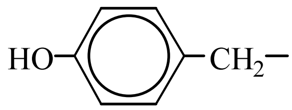
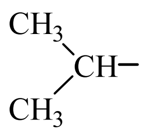
9 The orientating effect of groups in aromatic substitution reactions.

The position of the incoming group, **Y**, is determined by the nature of the group, **X**, already bonded to the ring, and not by the nature of the incoming group **Y**.



X- groups that direct the incoming **Y** group to the 2- or 4- positions	**X**- groups that direct the incoming **Y** group to the 3- position
$–NH_2$, –NHR or $–NR_2$	$–NO_2$
–OH or –OR	$–NH_3$
–NHCOR	–CN
$–CH_3$, –alkyl	–CHO, –COR
$–Cl$	$–CO_2H$, $–CO_2R$

10 Names, structures and abbreviations of some amino acids

name	3-letter abbreviation	1-letter symbol	structure of side chain R- in 
alanine	Ala	A	CH_3–
aspartic acid	Asp	D	HO_2CCH_2–
cysteine	Cys	C	$HSCH_2$–
glutamic acid	Glu	E	$HO_2CCH_2CH_2$–
glycine	Gly	G	H–
lysine	Lys	K	$H_2NCH_2CH_2CH_2CH_2$–
phenylalanine	Phe	F	
serine	Ser	S	$HOCH_2$–
tyrosine	Tyr	Y	
valine	Val	V	

The Periodic Table of Elements

Key

atomic number atomic symbol name relative atomic mass

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1.0										2 He helium 4.0
3 Li lithium 6.9	4 Be beryllium 9.0											5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
11 Na sodium 23.0	12 Mg magnesium 24.3	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 116.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cr copernicium –		114 Fl flerovium –		116 Lv livermorium –		

lanthanoids	57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.4	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
actinoids	89 Ac actinium –	90 Th thorium 232.0	91 Pa protactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

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