Chemistry

2026 Data Book

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Version 2 – February 2026

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

VICTORIA State Government

1. Names of selected elements

Element	Symbol	Atomic number	Relative atomic mass (amu)
aluminium	Al	13	27.0
argon	Ar	18	40.0
arsenic	As	33	74.9
barium	Ba	56	137.3
beryllium	Be	4	9.0
boron	B	5	10.8
bromine	Br	35	79.9
cadmium	Cd	48	112.4
caesium	Cs	55	132.9
calcium	Ca	20	40.1
carbon	C	6	12.0
chlorine	Cl	17	35.5
chromium	Cr	24	52.0
cobalt	Co	27	58.9
copper	Cu	29	63.5
fluorine	F	9	19.0
gallium	Ga	31	69.7
germanium	Ge	32	72.6
gold	Au	79	197.0
helium	He	2	4.0
hydrogen	H	1	1.0
iodine	I	53	126.9
iron	Fe	26	55.8
krypton	Kr	36	83.8
lead	Pb	82	207.2
lithium	Li	3	6.9

Element	Symbol	Atomic number	Relative atomic mass (amu)
magnesium	Mg	12	24.3
manganese	Mn	25	54.9
mercury	Hg	80	200.6
neon	Ne	10	20.2
nickel	Ni	28	58.7
nitrogen	N	7	14.0
oxygen	O	8	16.0
phosphorus	P	15	31.0
platinum	Pt	78	195.1
potassium	K	19	39.1
rubidium	Rb	37	85.5
scandium	Sc	21	45.0
selenium	Se	34	79.0
silicon	Si	14	28.1
silver	Ag	47	107.9
sodium	Na	11	23.0
strontium	Sr	38	87.6
sulfur	S	16	32.1
tin	Sn	50	118.7
titanium	Ti	22	47.9
tungsten	W	74	183.8
vanadium	V	23	50.9
xenon	Xe	54	131.3
yttrium	Y	39	88.9
zinc	Zn	30	65.4
zirconium	Zr	40	91.2

2. Electrochemical series

Standard reduction potentials, $E^{\ominus}$, are listed at SLC (25 °C and 100 kPa). The concentration of all soluble species is assumed to be 1.00 M.

Reaction	$E^{\ominus}$(V)
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.89
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.76
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$PbO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Pb^{2+}(aq) + 2H_2O(l)$	+1.46
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.36
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.08
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+ 0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+ 0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+ 0.70
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+ 0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+ 0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+ 0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+ 0.15
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	− 0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	− 0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	− 0.24
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	− 0.28
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	− 0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	− 0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	− 0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.18
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	−1.68
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	−2.36
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	−2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	−2.94
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	−3.04

3. Chemical relationships

Name	Formula
amount of substance (number of moles)	$n = \frac{m}{M}; \quad n = cV; \quad n = \frac{N}{N_A}; \quad n = \frac{V}{V_m}$
concentration (parts per million)	$c_{ppm} = \frac{\text{mass of solute (in mg)}}{\text{mass of solution (in kg)}}$
density	$\rho = \frac{m}{V}$
ideal gas equation	$pV = nRT$
enthalpy change of a reaction	$\Delta H = H_{products} - H_{reactants}$
heat gained or lost	$q = mc\Delta T$
molar enthalpy change	$\Delta H = \frac{q}{n}$
electric charge	$Q = It$
amount of electrons (number of moles)	$n(e^-) = \frac{Q}{F}$
electrical energy	$E = VIt$
calibration factor (CF) for general calorimetry	$\text{CF} = \frac{E}{\Delta T}$
calibration factor (CF) for reaction calorimetry	$\text{CF} = \frac{n\Delta H}{\Delta T}$
standard cell potential	$E^\ominus_{cell} = E^\ominus_{(\text{reduction half-cell})} - E^\ominus_{(\text{oxidation half-cell})}$
percentage atom economy	$\%\text{ atom economy} = \frac{\text{molar mass of desired product}}{\text{molar mass of all atoms in reactants}} \times \frac{100}{1}$
percentage yield	$\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times \frac{100}{1}$
equilibrium constant	$K_c = \frac{[C]^y \times [D]^z \times \ldots}{[A]^w \times [B]^x \times \ldots}$ for the equation $wA + xB + \ldots \rightleftharpoons yC + zD + \ldots$

4. Physical constants and standard values

Name	Symbol	Value
Avogadro constant	N_A or L	6.02×10^{23} mol^{-1}
Faraday constant	F	96 500 C mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
molar volume of an ideal gas at SLC (25 °C and 100 kPa)	V_m	24.8 L mol^{-1}
specific heat capacity of water	c_w	4.18 kJ kg^{-1} K^{-1} or 4.18 J g^{-1} K^{-1}
density of water at 25 °C	ρ	1.0 g mL^{-1}
molar latent heat of vaporisation of water at 25 °C	$\Delta H_{vap}(H_2O)$	+44.0 kJ mol^{-1}
molar latent heat of vaporisation of water at 100 °C	$\Delta H_{vap}(H_2O)$	+40.7 kJ mol^{-1}

5. Unit conversions

Measured value	Conversion
0 °C	273 K
100 kPa	0.987 atm
1 litre (L)	1 dm^3 or 1×10^{-3} m^3 or 1×10^3 cm^3 or 1×10^3 mL
1 tonne (t)	1×10^3 kg or 1×10^6 g

6. Metric prefixes

The following prefixes are commonly used within the International System of Units (SI) to modify the base units and express quantities in multiples or fractions of those units.

Prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	1 000 000 000
mega (M)	10^6	1 000 000
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000 001
nano (n)	10^{-9}	0.000 000 001
pico (p)	10^{-12}	0.000 000 000 001

7. Acid-base indicators

Name	pH range	Colour change from lower pH to higher pH in range
thymol blue (1st change)	1.2 – 2.8	red → yellow
methyl orange	3.1 – 4.4	red → orange
bromophenol blue	3.0 – 4.6	yellow → blue-violet
bromocresol green	4.0 – 5.6	yellow → blue
methyl red	4.4 – 6.2	red → yellow
bromothymol blue	6.0 – 7.6	yellow → blue
phenol red	6.4 – 8.0	yellow → red
thymol blue (2nd change)	8.0 – 9.6	yellow → blue
phenolphthalein	8.0 – 10.0	colourless → pink (dilute) colourless → red (concentrated)

8. Colours of selected oxidising agents and their conjugate reducing agents

The listed conjugate reducing agents are formed only under appropriate reaction conditions, particularly with respect to solution acidity. Under different conditions, alternative products may be formed. Solution concentrations may also influence observed colours.

Oxidising agent			**Conjugate reducing agent**		
Name	**Formula**	**Colour of aqueous solution**	**Name**	**Formula**	**Colour of solid or aqueous solution**
bromine	Br_2	reddish-brown	bromide ion	Br^-	colourless solution
chlorine	Cl_2	pale yellow-green	chloride ion	Cl^-	colourless solution
cobalt ion	Co^{2+}	pink	cobalt metal	Co	silver solid
copper(II) ion	Cu^{2+}	blue	copper metal	Cu	red-brown solid
dichromate ion	$Cr_2O_7^{2-}$	orange	chromium(III) ion	Cr^{3+}	green solution
iodine	I_2	brown in aqueous solutions	iodide ion	I^-	colourless solution
iron(III) ion	Fe^{3+}	yellow/brown	iron(II) ion	Fe^{2+}	pale green solution
iron(II) ion	Fe^{2+}	pale green	iron metal	Fe	silver solid
manganese(IV) dioxide	MnO_2	black/brown	manganese(II) ion	Mn^{2+}	colourless solution (dilute) very pale pink solution (concentrated)
nickel ion	Ni^{2+}	green	nickel metal	Ni	silver solid
permanganate ion	MnO_4^-	intense purple	manganese(II) ion	Mn^{2+}	colourless solution (dilute) very pale pink solution (concentrated)

Note: Starch solution can be added to a reaction mixture to detect the presence of iodine at low concentrations. This forms a blue-black starch-iodine complex, which is easier to see than the very pale brown colour of a dilute iodine solution.

9. Formulas and charges for selected ions

Cations

1+		2+		3+	
Name	**Formula**	**Name**	**Formula**	**Name**	**Formula**
ammonium	NH_4^+	barium	Ba^{2+}	aluminium	Al^{3+}
copper(I)	Cu^+	calcium	Ca^{2+}	chromium(III)	Cr^{3+}
hydronium	H_3O^+	copper(II)	Cu^{2+}	iron(III)	Fe^{3+}
lithium	Li^+	iron(II)	Fe^{2+}	**4+**	
potassium	K^+	lead(II)	Pb^{2+}	titanium(IV)	Ti^{4+}
silver	Ag^+	magnesium	Mg^{2+}		
sodium	Na^+	mercury(II)	Hg^{2+}		
		nickel(II)	Ni^{2+}		
		tin(II)	Sn^{2+}		
		zinc	Zn^{2+}		

Anions

1−			
Name	**Formula**	**Name**	**Formula**
bromide	Br^-	hydrogensulfide	HS^-
chlorate	ClO_3^-	hydrogensulfite	HSO_3^-
chloride	Cl^-	hydroxide	OH^-
chlorite	ClO_2^-	hypochlorite	ClO^-
cyanide	CN^-	iodide	I^-
dihydrogenphosphate	$H_2PO_4^-$	nitrate	NO_3^-
ethanoate	CH_3COO^-	nitrite	NO_2^-
fluoride	F^-	perchlorate	ClO_4^-
hydrogencarbonate	HCO_3^-	permanganate	MnO_4^-
hydrogensulfate	HSO_4^-		

2−			
Name	**Formula**	**Name**	**Formula**
carbonate	CO_3^{2-}	peroxide	O_2^{2-}
chromate	CrO_4^{2-}	sulfate	SO_4^{2-}
dichromate	$Cr_2O_7^{2-}$	sulfide	S^{2-}
monohydrogenphosphate	HPO_4^{2-}	sulfite	SO_3^{2-}
oxide	O^{2-}	thiosulfate	$S_2O_3^{2-}$

3−	
Name	**Formula**
citrate	$C_6H_5O_7^{3-}$
nitride	N^{3-}
phosphate	PO_4^{3-}

10. Qualitative solubilities of selected ionic salts in water

Solubility data in the table below is based on mass, in grams, of anhydrous substance per 100 g water required to prepare a saturated solution at 298 K.

Anion / Cation	bromide Br^-	carbonate CO_3^{2-}	chloride Cl^-	hydroxide OH^-	iodide I^-	nitrate NO_3^-	oxide O^{2-}	phosphate PO_4^{3-}	sulfate SO_4^{2-}
aluminium Al^{3+}	s		s	i	s	s	i	i	s
ammonium NH_4^+	s	s	s		s	s		s	s
barium Ba^{2+}	s	i	s	s	s	s	s	i	i
calcium Ca^{2+}	s	i	s	ss	s	s	s	i	ss
cobalt(II) Co^{2+}	s	i	s	i	s	s	i	i	s
copper(II) Cu^{2+}	s	i	s	i		s	i	i	s
iron(II) Fe^{2+}	s	ss	s	i	s	s	i	i	s
iron(III) Fe^{3+}	s		s	i		s	i	i	s
lead(II) Pb^{2+}	ss	i	ss	ss	ss	s	i	i	i
magnesium Mg^{2+}	s	ss	s	i	s	s	i	i	s
manganese(II) Mn^{2+}	s	i	s	i	s	s	i	i	s
nickel(II) Ni^{2+}	s	i	s	i	s	s	i	i	s
potassium K^+	s	s	s	s	s	s	s	s	s
silver Ag^+	i	i	i		i	s	i	i	ss
sodium Na^+	s	s	s	s	s	s		s	s
strontium Sr^{2+}	s	i	s	ss	s	s	ss	ss	ss
zinc Zn^{2+}	s	ss	s	i	s	s	i	i	s

Key

Abbreviation	Description
s	soluble in water (more than 3 g of solute will dissolve in 100 mL of water)
ss	sparingly soluble in water (between 0.01 g and 3 g of solute will dissolve in 100 mL of water)
i	insoluble in water (less than 0.01 g of solute will dissolve in 100 mL of water)
(blank)	no reliable data (salt decomposes or reacts in water before dissolving)

11. Energy content of biomolecules in food

The energy that is typically available for the body to use as a result of the digestion and absorption of fats and oils, proteins and carbohydrates is shown in the table below. These values may vary based on the specific composition of foods and individual metabolic factors.

Biomolecules	Energy content (kJ g^{-1})
fats and oils	37
proteins	17
carbohydrates	16

12. Molar enthalpies of combustion

The molar enthalpies of combustion in the following table are calculated at SLC (25 °C and 100 kPa) with combustion products being $CO_2(g)$ and $H_2O(l)$. Enthalpies of combustion, ΔH, for the substances in this table are reported for one mole of fuel and are shown as negative values, indicating the exothermic nature of the combustion reaction.

ΔH values are equation-dependent.

$$C_2H_6(g) + 3\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) \qquad \Delta H = -1560 \text{ kJ}$$

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l) \qquad \Delta H = -3120 \text{ kJ}$$

Fuel	Formula	Molar enthalpy of combustion (kJ mol^{-1})
hydrogen	$H_2(g)$	−286
methane	$CH_4(g)$	−890
ethane	$C_2H_6(g)$	−1560
propane	$C_3H_8(g)$	−2220
butane	$C_4H_{10}(g)$	−2877
octane	$C_8H_{18}(l)$	−5470
methanol	$CH_3OH(l)$	−726
ethanol	$C_2H_5OH(l)$	−1367
carbon (graphite)	C(s)	−394
glucose	$C_6H_{12}O_6(s)$	−2803

13. Heats of combustion of selected fossil fuels

The following table provides typical values for the heats of combustion of selected fossil fuels at SLC (25 °C and 100 kPa), with the combustion products being $CO_2(g)$ and $H_2O(l)$. The values for the heats of combustion will vary due to the composition of the different fuels. The listed fossil fuels are mixtures of compounds, so the molar composition is variable. Additionally, for natural gas, the values may vary based on the source and processing.

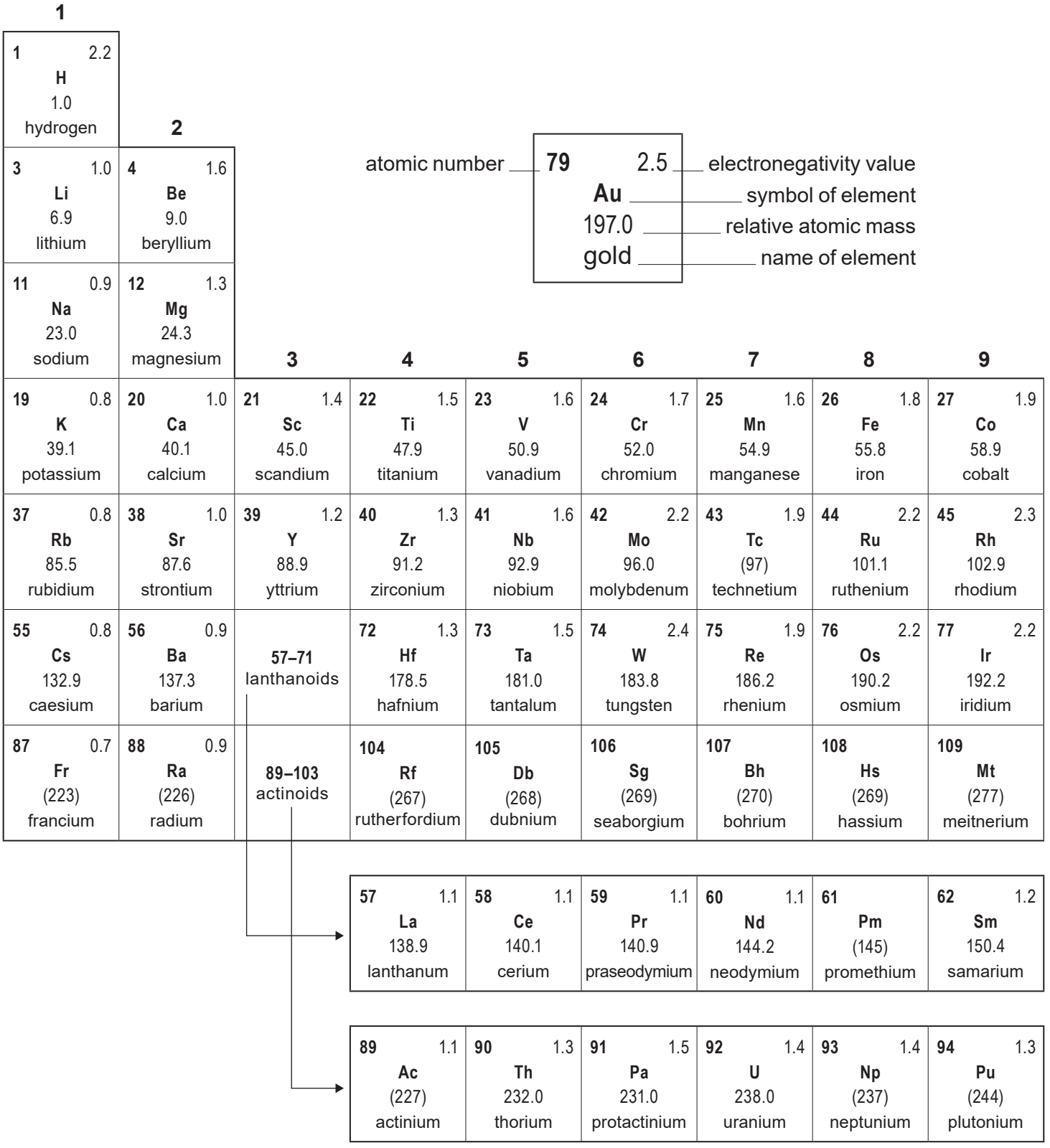
Fuel	State	Heat of combustion ($kJ\ g^{-1}$)	Heat of combustion ($kJ\ mL^{-1}$)
diesel	liquid	45	37
kerosene	liquid	46	37
natural gas	gas	54	0.035
petrol	liquid	45	34

14. Heats of combustion of selected biofuels

The following table provides typical values for the heats of combustion of selected biofuels. The values for the heats of combustion may vary significantly, particularly for biogas, depending on the source of the biofuel and, hence, its composition. The amount of energy consumed during any purification process must also be considered when determining the net energy obtained from a biofuel.

Fuel	State	Heat of combustion ($kJ\ g^{-1}$)
biodiesel	liquid	approximately 37 This varies slightly depending on the feedstock used to produce it.
bioethanol	liquid	29.7
biogas	gas	14–24 This depends on its methane content, which can vary from 45% to 75% methane by volume, depending on its source. The other main constituent is CO_2, which does not burn. Some samples may also contain a small amount of gases, such as H_2S and water vapour.

15. Periodic table of the elements



								18
			13	14	15	16	17	**2** 1.3 **He** 4.0 helium
			5 2.0 **B** 10.8 boron	**6** 2.6 **C** 12.0 carbon	**7** 3.0 **N** 14.0 nitrogen	**8** 3.4 **O** 16.0 oxygen	**9** 4.0 **F** 19.0 fluorine	**10** **Ne** 20.2 neon
10	11	12	**13** 1.6 **Al** 27.0 aluminium	**14** 1.9 **Si** 28.1 silicon	**15** 2.2 **P** 31.0 phosphorus	**16** 2.6 **S** 32.1 sulfur	**17** 3.2 **Cl** 35.5 chlorine	**18** **Ar** 40.0 argon
28 1.9 **Ni** 58.7 nickel	**29** 1.9 **Cu** 63.5 copper	**30** 1.7 **Zn** 65.4 zinc	**31** 1.8 **Ga** 69.7 gallium	**32** 2.0 **Ge** 72.6 germanium	**33** 2.2 **As** 74.9 arsenic	**34** 2.6 **Se** 79.0 selenium	**35** 3.0 **Br** 79.9 bromine	**36** 3.0 **Kr** 83.8 krypton
46 2.2 **Pd** 106.4 palladium	**47** 1.9 **Ag** 107.9 silver	**48** 1.7 **Cd** 112.4 cadmium	**49** 1.8 **In** 114.8 indium	**50** 2.0 **Sn** 118.7 tin	**51** 2.1 **Sb** 121.8 antimony	**52** 2.1 **Te** 127.6 tellurium	**53** 2.7 **I** 126.9 iodine	**54** 2.6 **Xe** 131.3 xenon
78 2.3 **Pt** 195.1 platinum	**79** 2.5 **Au** 197.0 gold	**80** 2.0 **Hg** 200.6 mercury	**81** 1.6 **Tl** 204.4 thallium	**82** 2.3 **Pb** 207.2 lead	**83** 2.0 **Bi** 209.0 bismuth	**84** 2.0 **Po** (209) polonium	**85** 2.2 **At** (210) astatine	**86** **Rn** (222) radon
110 **Ds** (281) darmstadtium	**111** **Rg** (282) roentgenium	**112** **Cn** (285) copernicium	**113** **Nh** (286) nihonium	**114** **Fl** (290) flerovium	**115** **Mc** (290) moscovium	**116** **Lv** (293) livermorium	**117** **Ts** (294) tennessine	**118** **Og** (294) oganesson

63 **Eu** 152.0 europium	**64** 1.2 **Gd** 157.3 gadolinium	**65** **Tb** 158.9 terbium	**66** 1.2 **Dy** 162.5 dysprosium	**67** 1.2 **Ho** 164.9 holmium	**68** 1.2 **Er** 167.3 erbium	**69** 1.3 **Tm** 168.9 thulium	**70** **Yb** 173.1 ytterbium	**71** 1.3 **Lu** 175.0 lutetium

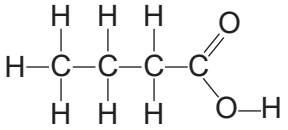
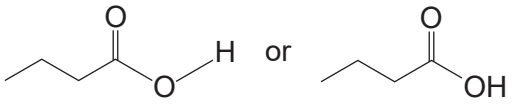
95 1.3 **Am** (243) americium	**96** 1.3 **Cm** (247) curium	**97** 1.3 **Bk** (247) berkelium	**98** 1.3 **Cf** (251) californium	**99** 1.3 **Es** (252) einsteinium	**100** 1.3 **Fm** (257) fermium	**101** 1.3 **Md** (258) mendelevium	**102** 1.3 **No** (259) nobelium	**103** 1.3 **Lr** (262) lawrencium

Notes

- Groups are numbered according to IUPAC convention.
- Values in brackets indicate the mass number of the longest-lived isotope of that element.

16. Formats for representing organic molecules

The following table shows different representations of organic molecules, using butanoic acid as an example.

Formula	Representation
molecular formula	$C_4H_8O_2$
structural formula	
semi-structural (condensed) formula	$CH_3CH_2CH_2COOH$ or $CH_3(CH_2)_2COOH$
skeletal structure	

17. Functional group and substituent nomenclature in organic chemistry

The following table shows the most common functional groups and substituents, categorised by their priority according to IUPAC rules for naming organic compounds with multiple functional groups. The table also shows their suffixes and prefixes, where relevant for VCE Chemistry. The functional group with the highest priority determines the compound's suffix. Lower-priority functional groups and substituents may be indicated as prefixes.

IUPAC class	IUPAC functional group structure	Prefix	Suffix
carboxylic acid	−COOH	*	-oic acid
ester	−COOR (where R is an alkyl group)−	*	-oate
aldehyde	−CHO	*	-al
ketone	−CO−	*	-one
alcohol	−OH	hydroxy-	-ol
amine	$-NH_2$	amino-	-amine
alkene	>C=C<	*	-ene
halogen and alkyl substituents	−X (where X = F, Cl, Br or I) −R (where R is an alkyl group)	fluoro-, chloro-, bromo-, iodo- methyl-, ethyl-, propyl-, butyl-, pentyl-, hexyl-, heptyl-, octyl-	–

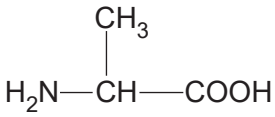
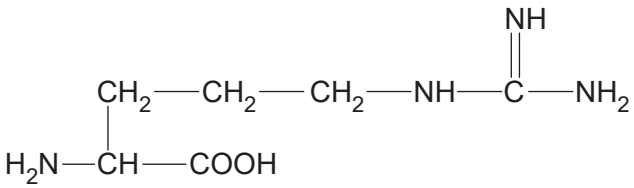
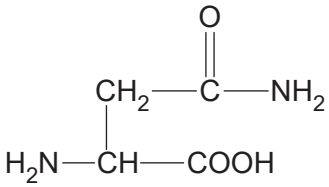
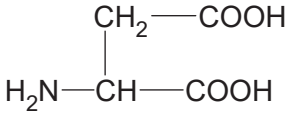
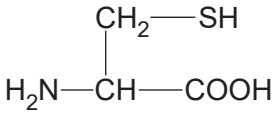
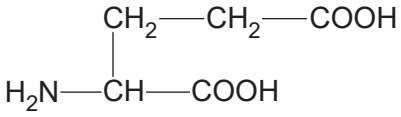
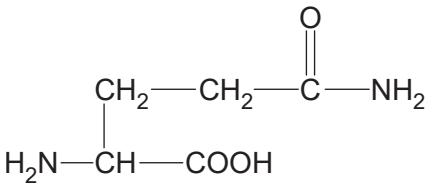
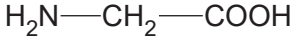
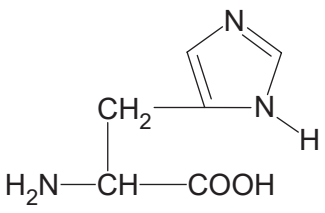
Note: The * indicates that use of this prefix is beyond the scope of VCE Chemistry.

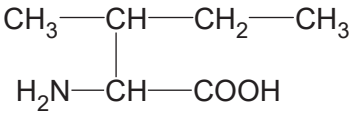
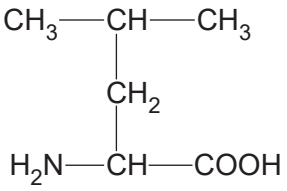
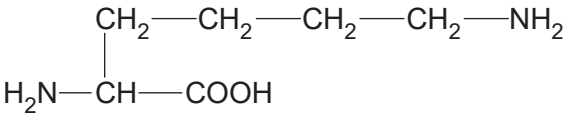
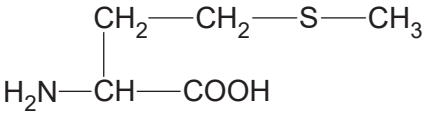
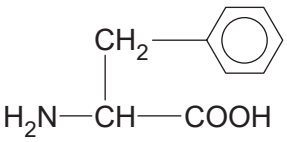
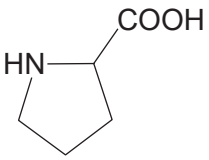
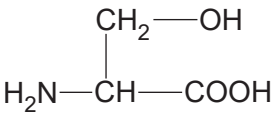
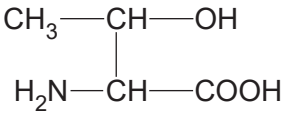
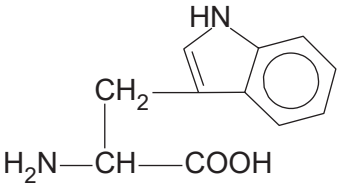
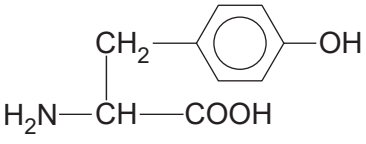
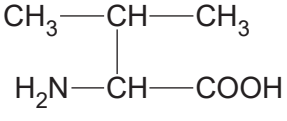
18. Formulas of selected fatty acids

Name	Molecular formula	State at SLC	Representation
caproic	$C_6H_{12}O_2$	liquid	$CH_3(CH_2)_4COOH$
capric	$C_{10}H_{20}O_2$	solid	$CH_3(CH_2)_8COOH$
lauric	$C_{12}H_{24}O_2$	solid	$CH_3(CH_2)_{10}COOH$
myristic	$C_{14}H_{28}O_2$	solid	$CH_3(CH_2)_{12}COOH$
palmitic	$C_{16}H_{32}O_2$	solid	$CH_3(CH_2)_{14}COOH$
palmitoleic	$C_{16}H_{30}O_2$	liquid	$CH_3(CH_2)_5CH=CH(CH_2)_7COOH$
stearic	$C_{18}H_{36}O_2$	solid	$CH_3(CH_2)_{16}COOH$
oleic	$C_{18}H_{34}O_2$	liquid	$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$
linoleic	$C_{18}H_{32}O_2$	liquid	$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7COOH$
linolenic	$C_{18}H_{30}O_2$	liquid	$CH_3(CH_2CH=CH)_3(CH_2)_7COOH$
arachidic	$C_{20}H_{40}O_2$	solid	$CH_3(CH_2)_{18}COOH$
arachidonic	$C_{20}H_{32}O_2$	liquid	$CH_3(CH_2)_4(CH=CHCH_2)_3CH=CH(CH_2)_3COOH$

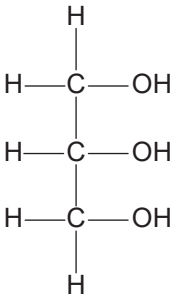
19. 2-amino acids

The following table provides simplified structures for amino acids. These amino acids may all be classified as 2-amino acids since the amino group ($-NH_2$) is attached to the second carbon atom in the carbon chain, numbered from the carboxyl ($-COOH$) end. These structures may be used as the basis for drawing zwitterions, identifying the products of protein hydrolysis and drawing the structures formed in the condensation polymerisation of amino acid monomers.

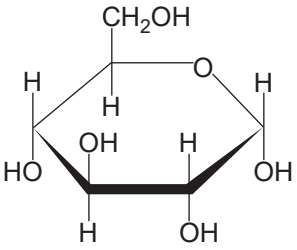
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamic acid	Glu	
glutamine	Gln	
glycine	Gly	
histidine	His	

Name	Symbol	Structure
isoleucine	Ile	
leucine	Leu	
lysine	Lys	
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

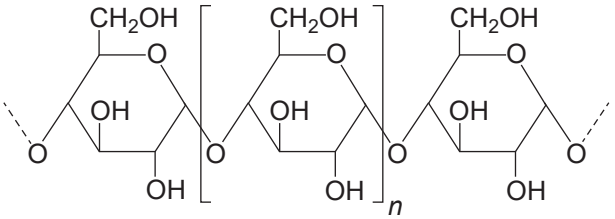
20. Representation of selected biomolecules



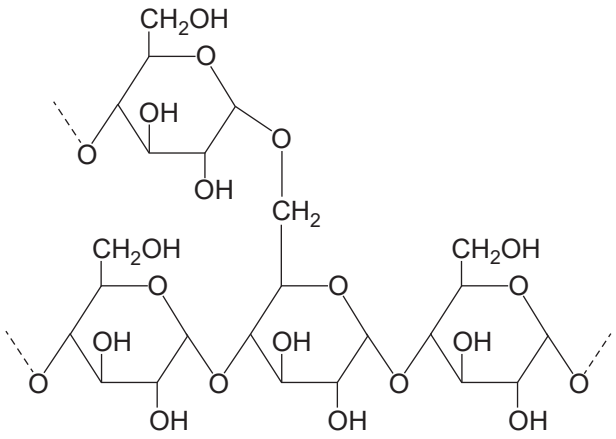
Glycerol



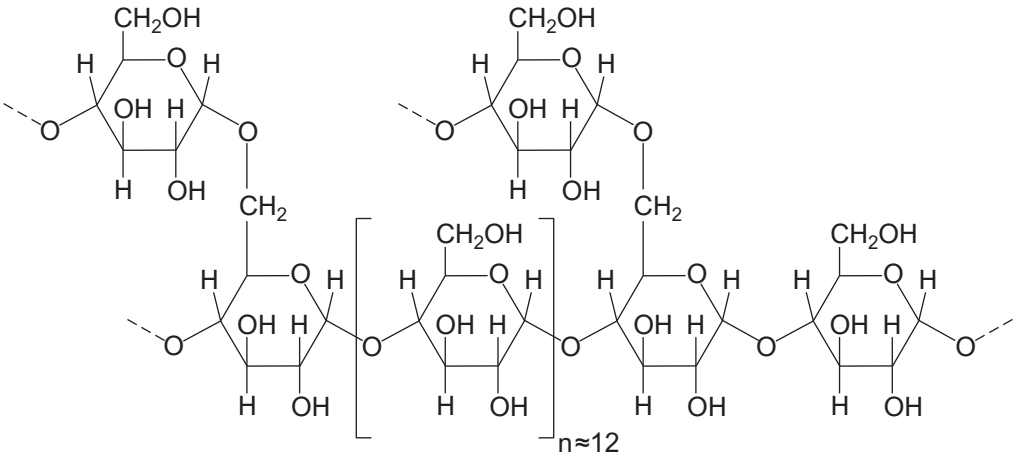
α-D-glucose



Amylose (starch)



Amylopectin (starch)



Glycogen

21. Characteristic ranges for infrared absorption

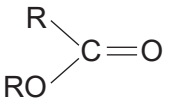
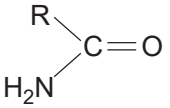
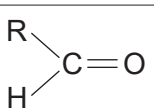
Bond	Wavenumber (cm^{-1})
C=O (amides)	1630–1680
C=O (aldehydes)	1660–1745
C=O (acids)	1680–1740
C=O (ketones)	1680–1700
C=O (esters)	1720–1750

Bond	Wavenumber (cm^{-1})
C–H (alkanes, alkenes, arenes)	2850–3090
O–H (acids)	2500–3500
O–H (alcohols)	3200–3600
N–H (amines and amides)	3300–3500

22. ^{13}C-NMR data

Typical ^{13}C shift values relative to TMS = 0

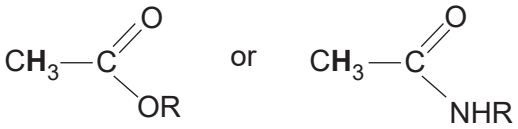
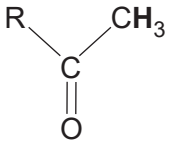
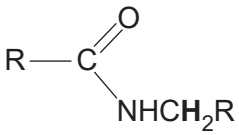
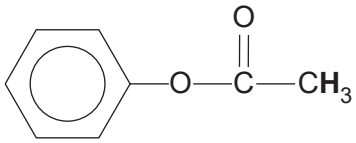
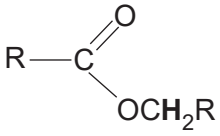
The values depend on the chemical environment and may vary with solvent choice.

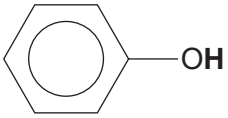
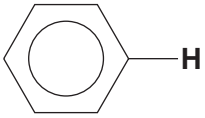
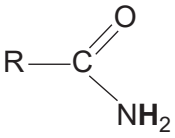
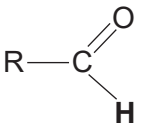
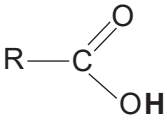
Type of carbon	Chemical shift (ppm)
$R-CH_3$	8–25
$R-CH_2-R$	20–45
R_3-CH	40–60
R_4-C	36–45
$R-CH_2-X$	15–80
R_3C-NH_2, R_3C-NR	35–70
$R-CH_2-OH$	50–90
$R_2C=CR_2$	110–150
C_6H_5-R (arenes)	110–150
RCOOH	160–185
	165–175
	165–185
	190–200
$R_2C=O$	205–220

23. ^{1}H-NMR data

Typical proton shift values relative to TMS = 0

The values depend on the chemical environment and may vary with solvent choice. The shift refers to the proton environment that is indicated in bold font in the formula.

Type of proton	Chemical shift (ppm)
R–C**H**$_3$	0.9–1.0
R–C**H**$_2$–R	1.3–1.4
RHC=CH–C**H**$_3$	1.6–1.9
R$_3$–C**H**	1.5
	2.0
	2.1–2.7
R–C**H**$_2$–X (X = F, Cl, Br or I)	3.0–4.5
R–C**H**$_2$–OH, R$_2$–C**H**–OH	3.3–4.5
	3.2
R—O—C**H**$_3$ or R—O—C**H**$_2$R	3.3–3.7
	2.3
	3.7–4.8
R–O**H**	1–6 (varies considerably under different conditions)
R–N**H**$_2$	1–5
RHC=C**H**R	4.5–7.0

Type of proton	Chemical shift (ppm)
	4.0–12.0
	6.9–9.0
	6.0–8.0
	9.4–10.0
	9.0–13.0

24. Sustainability

Sustainability is considered in terms of the United Nations Sustainable Development Goals and green chemistry principles, along with linear and circular economies.

i. United Nations Sustainable Development Goals

The following nine goals are relevant to VCE Chemistry:

- Goal 2: Zero hunger
- Goal 6: Clean water and sanitation
- Goal 7: Affordable and clean energy
- Goal 9: Industry, innovation and infrastructure
- Goal 11: Sustainable cities and communities
- Goal 12: Responsible consumption and production
- Goal 13: Climate action
- Goal 14: Life below water
- Goal 15: Life on land

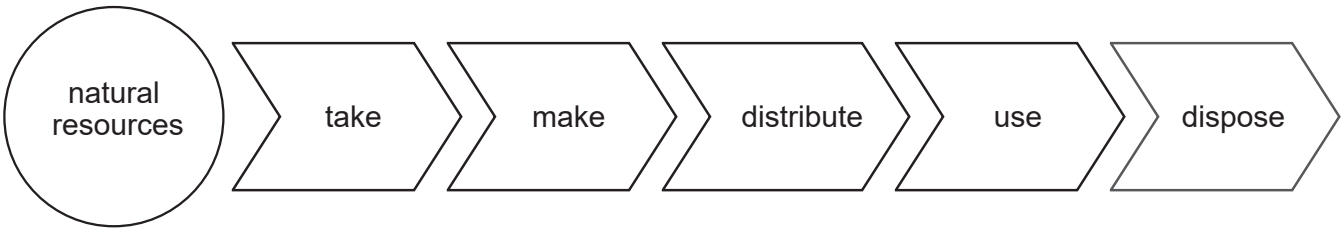
ii. Green chemistry principles

The following seven green chemistry principles are relevant to VCE Chemistry:

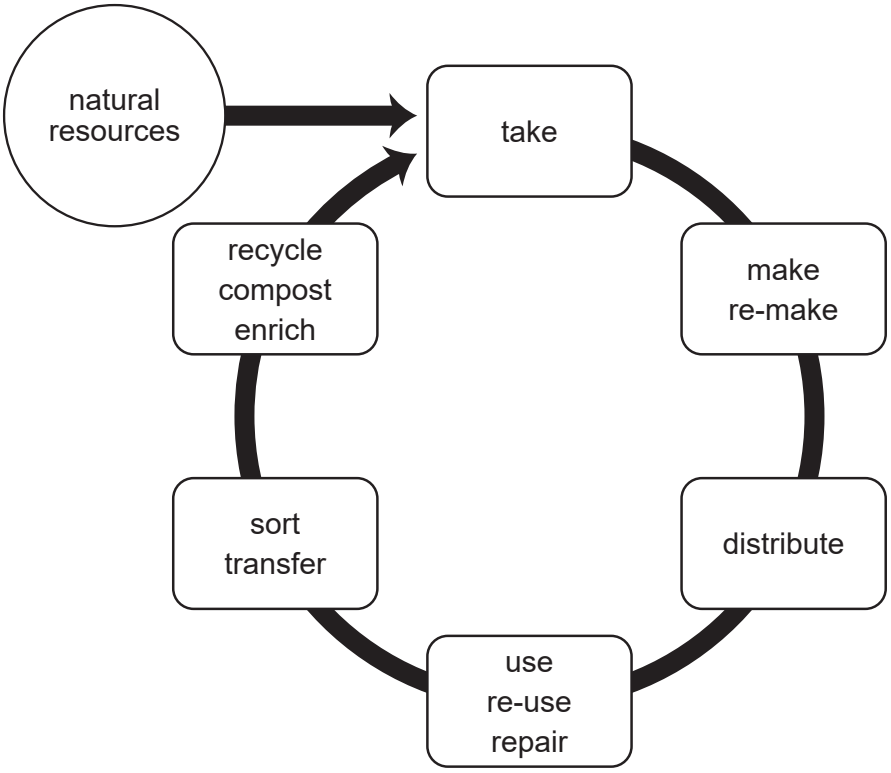
- Atom economy
  Processes/pathways should be designed to maximise incorporation of all reactant materials used in the process into the final product.
- Catalysis
  Catalysts should be selected to generate the same desired product(s) with less waste and using less energy and reagents in reaction processes/pathways.
- Design for degradation
  Chemical products should be designed so that at the end of their use they break down into harmless degradation products and do not persist in the environment.
- Design for energy efficiency
  Processes/pathways should be designed for maximum energy efficiency and with minimal negative environmental and economic impacts.
- Designing safer chemicals
  Chemical products should be designed to achieve their intended function while minimising toxicity.
- Prevention of wastes
  It is better to prevent waste than to treat or clean up waste after it has been produced.
- Use of renewable feedstocks
  Raw materials or feedstocks should be made from renewable (mainly plant-based) materials, rather than from fossil fuels, whenever practicable.

iii. Types of economies

Linear



Circular



25. References

Data for Items 2, 3, 4, 5, 6, 7, 9, 10, 12, 18, 21, 22 and 23 was taken fully or in part from:

A Blackman and LR Gahan, *Aylward and Findlay's SI Chemical Data*, 7th edition, John Wiley and Sons, Milton, 2013

NG Connelly et al. (eds), *Nomenclature of Inorganic Chemistry: IUPAC Recommendations 2005*, RSC Publishing, Cambridge, 2005 <iupac.org/wp-content/uploads/2016/07/Red_Book_2005.pdf>

J McMurry, *Organic Chemistry: A Tenth Edition*, OpenStax, Houston, 2023 <openstax.org/details/books/organic-chemistry>

JR Rumble (ed), *CRC Handbook of Chemistry and Physics*, 106th edition, CRC Press, 2025

Data for Item 11 was obtained from:

Food Standards Australia New Zealand, *Australian Food Composition Database – Release 3.0*, Food Standards Australia New Zealand <afcd.foodstandards.gov.au/nutrientsearch.aspx> 2023

Data for Items 1 and 15 was obtained from:

National Center for Biotechnology Information, 'Electronegativity in the periodic table of elements', *PubChem*, 2026 <pubchem.ncbi.nlm.nih.gov/periodic-table/electronegativity>

International Union of Pure and Applied Chemistry (IUPAC), *Periodic Table of Elements*, IUPAC <iupac.org/what-we-do/periodic-table-of-elements> 2022
*with relative atomic masses rounded to one decimal place where applicable

Data for Items 16, 17, 19 and 20 was obtained from:

GJ Leigh et al., *Principles of Chemical Nomenclature: A Guide to IUPAC Recommendations 2011 Edition*, RSC Publishing, UK, 2011 <iupac.org/what-we-do/books/principles>

J McMurry, *Organic Chemistry: A Tenth Edition*, OpenStax, Houston, 2023 <openstax.org/details/books/organic-chemistry>

CL Perrin et al., 'Glossary of terms used in physical organic chemistry (IUPAC Recommendations 2021)', *Pure and Applied Chemistry*, vol. 94, no. 4, 2022, pp. 353–534 <doi.org/10.1515/pac-2018-1010>

Information for Item 24 was adapted from:

Department of Economic and Social Affairs: Sustainable Development, *The 17 Goals*, United Nations <sdgs.un.org/goals>

PT Anastas and JC Warner, *Green Chemistry: Theory and practice*, Oxford University Press, Oxford, 1998, p. 30

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