Alyn G McFarland
Nora Henry

CCEA AS

CHEMISTRY EXAM PRACTICE

MARK SCHEME

This mark scheme is for use in conjunction with the book *Chemistry Exam Practice for CCEA AS*,
ISBN: 978 1 78073 034 9

Colourpoint Educational
An imprint of Colourpoint Creative Ltd
Colourpoint House
Jubilee Business Park
21 Jubilee Road
Newtownards
County Down
Northern Ireland
BT23 4YH

Tel: 028 9182 0505
E-mail: sales@colourpoint.co.uk
Web site: www.colourpoint.co.uk

Updated with a minor corrections 2024.

Publisher's Note: These answers have been written to help students preparing for the AS Chemistry specification from CCEA. While Colourpoint Educational and the author have taken every care in its production, we are not able to guarantee that it is completely error-free. Additionally, while the mark scheme has been written to closely match the CCEA specification, it is the responsibility of each candidate to satisfy themselves that they have fully met the requirements of the CCEA specification prior to sitting an exam set by that body. For this reason, and because specifications change with time, we strongly advise every candidate to avail of a qualified teacher and to check the contents of the most recent specification for themselves prior to the exam. Colourpoint Creative Ltd therefore cannot be held responsible for any errors or omissions in this mark scheme or any consequences thereof.

v7

Unit AS 1:

Basic Concepts in Physical and Inorganic Chemistry

Answers

1.1 Formulae, Equations and Amounts of Substance

1

Name	Formula
potassium carbonate	K_2CO_3 [1]
silver(I) nitrate	$AgNO_3$ [1]
ammonium chloride	NH_4Cl [1]
sodium thiosulfate	$Na_2S_2O_3$ [1]
copper(II) chloride–2–water	$CuCl_2.2H_2O$ [1]
ammonium nitrate	NH_4NO_3 [1]
sodium hypochlorite	NaClO [1]
aluminium sulfate	$Al_2(SO_4)_3$ [1]
lithium nitrite	$LiNO_2$ [1]
zinc hydroxide	$Zn(OH)_2$ [1]
sodium hydrogensulfate	$NaHSO_4$ [1]
sodium chlorate	$NaClO_3$ [1]
ammonium carbonate	$(NH_4)_2CO_3$
potassium phosphate	K_3PO_4 [1]
chromium(III) nitrate	$Cr(NO_3)_3$ [1]
sodium sulfite	Na_2SO_3 [1]
potassium hydrogencarbonate	$KHCO_3$ [1]
sodium chromate	Na_2CrO_4 [1]
ammonium sulfate	$(NH_4)_2SO_4$ [1]
potassium permanganate	$KMnO_4$ [1]

[20]

Equations

2 **(a)** $K_2CO_3 + 2HNO_3 \rightarrow 2KNO_3 + CO_2 + H_2O$ [1]

(b) $ZnO + 2HCl \rightarrow ZnCl_2 + H_2O$ [1]

(c) $2Ca + O_2 \rightarrow 2CaO$ [1]

The answer $Ca + \frac{1}{2}O_2 \rightarrow CaO$ is equally acceptable and expected if 1 mole of Ca or 1 mole of CaO is required in the question. You will be required to write equations of this type in enthalpy work in AS2.

(d) $H_2 + Cl_2 \rightarrow 2HCl$ [1]

(e) $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$ [2]

(f) $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$ [2]

(g) $4K_2Cr_2O_7 \rightarrow 4K_2CrO_4 + 2Cr_2O_3 + 3O_2$ [2]

(h) $3Cl_2 + 6NaOH \rightarrow NaClO_3 + 5NaCl + 3H_2O$ [2]

(i) $Br_2 + 2KI \rightarrow 2KBr + I_2$ [1]

(j) $(NH_4)_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2NH_3 + 2H_2O$ [2]

(k) $BaCl_2 + K_2CrO_4 \rightarrow BaCrO_4 + 2KCl$ [1]

(l) $Fe(NO_3)_3 + 3NaOH \rightarrow Fe(OH)_3 + 3NaNO_3$ [2]

(m) $2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$ [2]

(n) $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$ [1]

(o) $N_2 + 3H_2 \rightarrow 2NH_3$ [1]

(p) $2SO_2 + O_2 \rightarrow 2SO_3$ [1]

(q) $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$ [1]

(r)

3 **(a)** $OH^- + H^+ \rightarrow H_2O$ [1]

(b) $Ag^+ + I^- \rightarrow AgI$ [1]

(c) $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$ [1]

(d) $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ [1]

(e) $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ [1]

(f) $O^{2-} + 2H^+ \rightarrow H_2O$ [1]

4 **(a)** $Cl_2(g) + 2NaI(aq) \rightarrow 2NaCl(aq) + I_2(aq)$ [2]

(b) $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ [2]

(c) $NH_4NO_3(s) + KOH(aq) \rightarrow NH_3(g) + KNO_3(aq) + H_2O(l)$ [2]

(d) $2AgNO_3(aq) + MgCl_2(aq) \rightarrow Mg(NO_3)_2(aq) + 2AgCl(s)$ [2]

(e) $CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$ [2]

(f) $KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$ [2]

Avogadro's constant, the mole and molar mass

5 **(a)** moles of Mg = $\frac{0.240}{24}$ = 0.01 mol

atoms of Mg = $0.01 \times 6.02\times10^{23} = 6.02\times10^{21}$ [1]

(b) moles of Ne = $\frac{14.0}{20}$ = 0.7 mol

atoms of Ne = $0.7 \times 6.02\times10^{23} = 4.214\times10^{23}$ [1]

(c) moles of H_2O = $\frac{0.270}{18}$ = 0.015 mol

atoms of $H_2O = 0.015 \times 6.02\times10^{23} \times 3 = 2.709\times10^{22}$ [1]

6 moles of CO_2 = $\frac{1.10}{44}$ = 0.0250 mol

molecules of $CO_2 = 0.0250 \times 6.02\times10^{23} = 1.505\times10^{22}$

atoms of $O = 1.505\times10^{22} \times 2 = 3.01\times10^{22}$ [2]

7 **(a)** moles of H_2O = $\frac{9.24}{18}$ = 0.5133 mol

molecules of $H_2O = 0.5133 \times 6.02\times10^{23} = 3.09\times10^{23}$ [1]

(b) moles of C_3H_8 = $\frac{11.2}{44}$ = 0.2545 mol

molecules of $C_3H_8 = 0.2545 \times 6.02\times10^{23} = 1.53\times10^{23}$ [1]

8 Relative molecular mass of $C_8H_{10}N_4O_2$ = 194

moles of $C_8H_{10}N_4O_2$ = $\frac{0.0948}{194}$ = 4.887×10^{-4} mol

molecules of $C_8H_{10}N_4O_2 = 4.887\times10^{-4} \times 6.02\times10^{23} = 2.942\times10^{20}$

atoms = $2.942\times10^{20} \times 24 = 7.06\times10^{21}$ [3]

9 **(a)** moles of $C_4H_{10}O$ = $\frac{14.88}{74}$ = 0.2011 mol

molecules of $C_4H_{10}O = 0.2011 \times 6.02\times10^{23} = 1.21\times10^{23}$ [1]

(b) atoms of carbon = $1.21\times10^{23} \times 4 = 4.84\times10^{23}$ [1]

(c) atoms of hydrogen = $1.21\times10^{23} \times 10 = 1.21\times10^{24}$ [1]

(d) atoms of oxygen = 1.21×10^{23} [1]

10 mass of water = 200×1.00 = 200 g

moles of water = $\frac{200}{18}$ = 11.11 mol

molecules of water = $11.11 \times 6.02\times10^{23} = 6.69\times10^{24}$ [2]

11 moles of glucose = $\frac{1.0\times10^{20}}{6.02\times10^{23}} = 1.661\times10^{-4}$ mol

mass of glucose = $1.661\times10^{-4} \times 180 = 0.0299$ g

mass of glucose = 30 mg [3]

12 Answer is D [1]

A contains 2.4×10^{24} atoms (4 mol of atoms)
B contains 9.03×10^{23} atoms (1.5 mol of atoms)
C contains 1.204×10^{24} atoms (2 mol of atoms)
D contains 6.02×10^{23} atoms (1 mol of atoms)

13 Answer is A [1]

moles of K = $\frac{0.390}{39} = 0.0100$ mol

moles of O_2 required = $\frac{0.0100}{4} = 2.50\times10^{-3}$ mol

number of molecules of $O_2 = 2.50\times10^{-3} \times 6.02\times10^{23} = 1.51\times10^{21}$

Mass and moles

14

Substance	Formula	Relative formula mass	Mass	Moles
sodium oxide	**Na_2O**	**62**	15.2 g	**0.245**
zinc hydroxide	**$Zn(OH)_2$**	**99**	**0.198 g**	0.002
aluminium sulfate	$Al_2(SO_4)_3$	**342**	7.35 kg	**21.5**
iron(III) oxide	**Fe_2O_3**	**160**	250 mg	**1.56×10^{-3}**
hydrated copper(II) sulfate	$CuSO_4.5H_2O$	**250**	**2.05 g**	0.0820
glucose	$C_6H_{12}O_6$	**180**	**36.9 tonnes**	2.05×10^{5}
potassium dichromate	**$K_2Cr_2O_7$**	**294**	14.7 kg	**50**
lithium carbonate	**Li_2CO_3**	**74**	**274 µg**	3.70×10^{-6}
paracetamol	$C_8H_9NO_2$	**151**	500 mg	**3.31×10^{-3}**

[1] per row [9]

Reacting mass calculations

15 moles of $NaHCO_3$ = $\frac{1.20}{84} = 0.01429$ mol

moles of Na_2CO_3 = $\frac{0.01429}{2} = 7.145\times10^{-3}$ mol

mass of $Na_2CO_3 = 7.145\times10^{-3} \times 106 = 0.757$ g [2]

Note: The answer kept on your calculator would give the same final answer to 3 significant figures. The number of moles of $NaHCO_3$ (0.01429) is rounded to 4 significant figures and this number is taken through in the calculation here.

16 moles of $Cu(NO_3)_2 = \frac{4.3}{188} = 0.02287$ mol

moles of $Na_2CO_3 = 0.02287 \times 2 = 0.04574$ mol

mass of $Na_2CO_3 = 0.04574 \times 46 = 2.1$ g [2]

17 moles of $MnO_2 = \frac{24.7}{87} = 0.2839$ mol

moles of $Mn_2O_3 = \frac{0.2839}{2} = 0.14195$ mol

mass of $Mn_2O_3 = 0.14195 \times 158 = 22.4$ g [2]

18 moles of $KI = \frac{5.28}{166} = 0.03181$ mol

moles of $I_2 = \frac{0.03181}{2} = 0.015905$ mol

mass of $I_2 = 0.015905 \times 254 = 4.04$ g [3]

19 (a) moles of $CuO = \frac{0.84}{80} = 0.0105$ mol

moles of $CuSO_4.5H_2O = 0.0105$ mol

mass of $CuSO_4.5H_2O = 0.0105 \times 250 = 2.6$ g [3]

(b) not all crystallised from solution/loss by mechanical transfer [1]

20 (a) $2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 2N_2O_4(l) + O_2(g)$ [2]

(b) U–tube [1]

(c) condense the NO_2 [1]

(d) brown colour [1]

(e) moles of $N_2O_4 = \frac{2.24}{92} = 0.02435$ mol

moles of $Pb(NO_3)_2 = 0.02435$ mol

mass of $Pb(NO_3)_2 = 0.02435 \times 331 = 8.06$ g [3]

21 Answer is C [1]

moles of $Mg = \frac{9000}{92} = 375$ mol

moles of $Fe = \frac{375}{3} \times 2 = 250$ mol

mass of $Fe = 250 \times 56 = 14000$ g $= 14$ kg

Limiting reactant

22 **(a)** moles of $SiO_2 = \frac{15.0}{60} = 0.25$ mol [1]

(b) moles of $C = \frac{8.5}{12} = 0.7083$ mol [1]

(c) silicon dioxide [1]

(d) moles of $SiC = \frac{0.7083}{3} = 0.2361$ mol

mass of $SiC = 0.2361 \times 40 = 9.4$ g [2]

23 moles of $Fe_2O_3 = \frac{600000}{160} = 3750$ mol

moles of $C = \frac{63000}{12} = 5250$ mol

limiting reactant is C

moles of $Fe = \frac{5250}{3} \times 4 = 7000$ mol

mass of $Fe = 7000 \times 56 = 392\,000$ g $= 392$ kg [5]

24 moles of $H_2SO_4 = \frac{2.1}{98} = 0.02143$ mol

moles of $NH_3 = \frac{0.150}{17} = 0.00882$ mol

limiting reactant is NH_3

moles of $(NH_4)_2SO_4 = \frac{0.00882}{2} = 0.00441$ mol

mass of $(NH_4)_2SO_4 = 0.00441 \times 132 = 0.58$ g [3]

25 moles of $NH_4Cl = \frac{1000}{53.5} = 18.69$ mol

moles of $CaO = \frac{510}{56} = 9.107$ mol

limiting reactant is CaO

moles of $NH_3 = 9.107 \times 2 = 18.214$

mass of $NH_3 = 18.214 \times 17 = 310$ g (0.310 kg) [3]

26 moles of Mg $= \frac{100}{24} = 4.167$ mol

moles of $Cr_2O_3 = \frac{400}{152} = 2.632$ mol

limiting reactant is Mg

moles of Cr $= \frac{4.167}{3} \times 2 = 2.778$

mass of Cr $= 2.778 \times 52 = 144$ g [3]

27 (a) moles of $NH_3 = \frac{2.10 \times 10^6}{17} = 123529.4$ mol

moles of $O_2 = \frac{4.15 \times 10^6}{32} = 129687.5$ mol

limiting reactant is O_2

moles of NH_3 used $= \frac{129687.5}{5} \times 4 = 103750$

moles of NH_3 remaining $= 123529.4 - 103750 = 19779.4$ mol

mass of NH_3 remaining $= 19779.4 \times 17 = 336249$ g $= 336$ kg [3]

(b) moles of NO formed $= \frac{129687.5}{5} \times 4 = 103750$

mass of NO formed $= 103750 \times 30 = 3112500$ g $= 3.11$ tonnes [2]

28 Answer is B [1]

moles of Na $= \frac{6.0}{23} = 0.2609$ mol

moles of $N_2 = \frac{1.4}{28} = 0.05$ mol

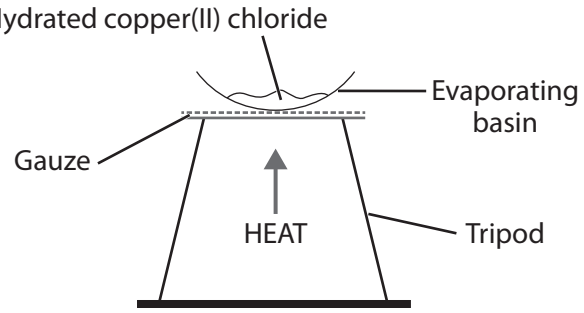
limiting reactant is Na

moles of Na_3N formed $= \frac{0.2609}{3} = 0.08696$ mol

mass of Na_3N formed $= 0.08696 \times 83 = 7.2$ g

Water of crystallisation

29 (a)



evaporating basin containing hydrated copper(II) chloride [1]
evaporating basin on a gauze placed on a tripod [1]
heat/Bunsen burner [1] [3]

(b) heat and weigh [1] repeat until mass does not change/consecutive measurements are the same [1] [2]

(c) mass of empty evaporating basin [1]
mass of evaporating basin and hydrated copper(II) chloride [1] [2]

(d) (i) mass of water = 8.21 – 6.48 = 1.73 g [1]

(ii) moles of water $= \frac{1.73}{18} = 0.0961$ mol [1]

(iii) moles of anhydrous salt $= \frac{6.48}{135} = 0.048$ mol [1]

(iv) $x = \frac{0.0961}{0.048} = 2$ [1]

30 (a) mass of anhydrous aluminium nitrate = 46.26 – 42.72 = 3.54 g

moles of anhydrous aluminium nitrate $= \frac{3.54}{213} = 0.01662$ mol

mass of water of crystallisation = 48.96 – 46.26 = 2.70 g (or 2.7 g)

moles of water of crystallisation $= \frac{2.70}{18} = 0.015$ mol

$n = \frac{0.015}{0.01662} = 9$ [5]

(b) aluminium nitrate may decompose [1]

31 mass of $Na_2CO_3.10H_2O = 22.11 - 21.25 = 0.86$ g

moles of $Na_2CO_3.10H_2O = \frac{0.86}{286} = 3.007\times10^{-3}$ mol

moles of $Na_2CO_3 = 3.007\times10^{-3}$ mol

mass of $Na_2CO_3 = 3.007\times10^{-3} \times 106 = 0.3187$ g

mass after heating to constant mass = 21.25 + 0.3187 = 21.57 g [4]

32 moles of water $= \frac{45.4}{18} = 2.522$ mol

moles of $CoCl_2 = \frac{54.6}{130} = 0.42$ mol

$x = \frac{2.522}{0.42} = 6$ [3]

33 Answer is B [1]

moles of $Zn(NO_3)_2.6H_2O = \frac{5.94}{297} = 0.02$ mol

moles of ZnO = 0.02 × 81 = 1.62 g

1.2 Atomic Structure

Atoms and ions

1

Species	Number of protons	Number of neutrons	Number of electrons
Al	**13**	**14**	**13**
Rb	**37**	**48**	**37**
N^{3-}	7	**7**	10
Fe^{2+}	**26**	30	**24**
Cr^{3+}	24	**28**	21
Ba	**56**	**81**	**56**
Se^{2-}	**34**	**45**	**36**
Mn^{2+}	25	**30**	23

[7]

2 **(a)**

Species	Mass number	Atomic number	Number of protons	Number of neutrons	Number of electrons
Mo	96	**42**	**42**	**54**	**42**
Mo^{2+}	96	42	**42**	**54**	**40**

[2]

(b) atomic number is the number of protons in an atom [1]
mass number is the total number of protons and neutrons in an atom [1] [2]

(c) 1 [1]

3 2, 8, 8 drawn [1] 15 p 18 n in nucleus [1] 3– charge [1] [3]

4 Answer is A [1]

5 protons = 1 + 35 = 36 [1]
neutrons = 0 + 45 = 45 [1]
electrons = 1 + 35 = 36 [1] [3]

6 Answer is D [1]

7 Answer is C [1]

8 1 proton and 1 neutron in nucleus [1]
1 electron in shell [1] [2]

Relative atomic mass and isotopes

9 **(a)** they have the same atomic number (37) [1]
different number of neutrons 48 and 50/rubidium–87 has 2 more neutrons [1] [2]

(b) mass of an atom of an isotope of an element relative to one twelfth of the mass of an atom of carbon–12 [2]

(c) ram $= \frac{(85 \times 72.15) + (87 \times 27.85)}{100} = 85.557$ 85.56 (2dp) [2]

(d) no difference as they have the same number of electrons in the outer shell [1]

10 **(a)** average (weighted mean) mass of an atom of an element relative to one twelfth of the mass of an atom of carbon–12 [2]

(b) $121.8 = \frac{(60 \times 121) + (x \times 40)}{100}$ $x = 123$ ^{123}Sb [2]

(c) atoms which have the same number of protons but a different number of neutrons [2]

11 **(a)** $\frac{(64 \times 49.0) + (66 \times 27.9) + (67 \times 4.3) + (68 \times 18.8)}{100} = 65.439 = 65.4$ [2]

(b) atomic masses are measured relative to carbon 12 which has a mass of 12.000 [2]

12 $10.8 = \frac{(10 \times x) + (11 \times y)}{(x + y)}$ if $x + y = 100$ then $x = 100 - y$

$10.8 = \frac{(10 \times (100 - y)) + (11y)}{100}$

$1080 = 1000 - 10y + 11y$

$80 = y$ 80% [2]

13 let the abundance of the 113 isotope equal x and the abundance of the 115 isotope equal y.

$114.5 = \frac{(113 \times x) + (115 \times y)}{(x + y)}$

$114.5x + 114.5y = 113x + 115y$

$1.5x = 0.5y$

Ratio is 1.5:0.5 = 3 :1 [2]

14 ram $= \frac{(114 \times 20) + (0.2 \times 21) + (11.2 \times 22)}{(114 + 0.2 + 11.2)} = 20.180 = 20.2$ [2] neon [1] [3]

15 Answer is B [1]

Electronic configuration

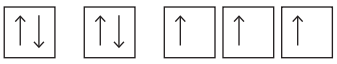
16

Element	Atomic number	Electronic configuration
potassium	19	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
fluorine	9	$1s^2\ 2s^2\ 2p^5$
magnesium	12	$1s^2\ 2s^2\ 2p^6\ 3s^2$
selenium	34	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^4$
titanium	22	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$
sulfur	16	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
iron	26	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$
gallium	31	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^1$
bromine	35	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^5$
nitrogen	7	$1s^2\ 2s^2\ 2p^3$
krypton	36	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$

[10]

17 **(a)** $1s^2$
(b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
(c) $1s^2\ 2s^2\ 2p^6$
(d) $1s^2\ 2s^2\ 2p^6$
(e) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$
(f) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$
(g) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8$
(h) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$
(i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$
(j) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$ [10]

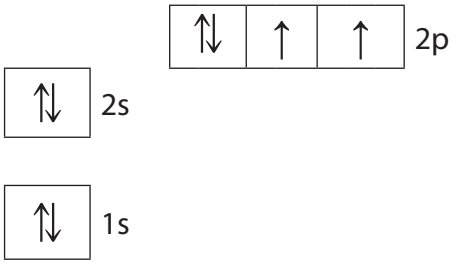
18 Answer is B [1]

19 **(a)** 

[1]

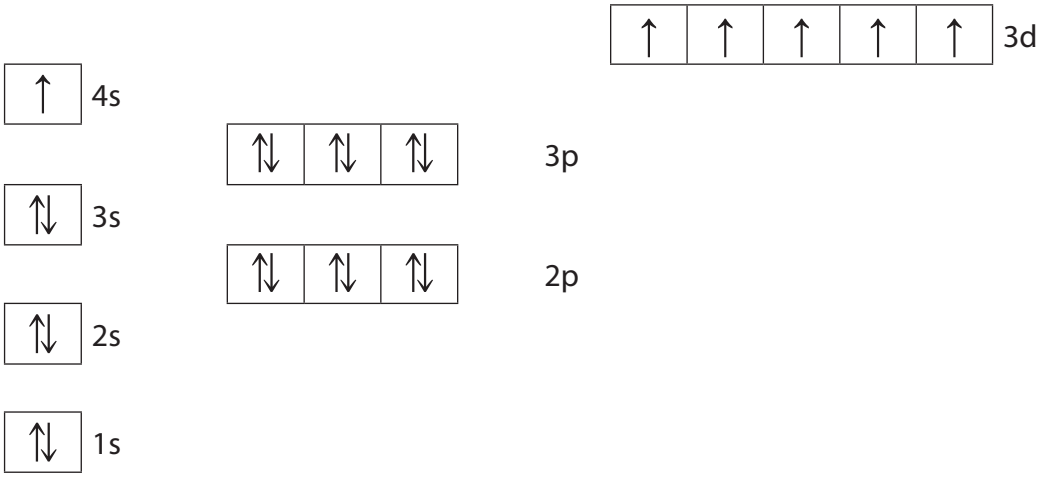
(b) electrons spin in opposite directions [1]

20 (a)



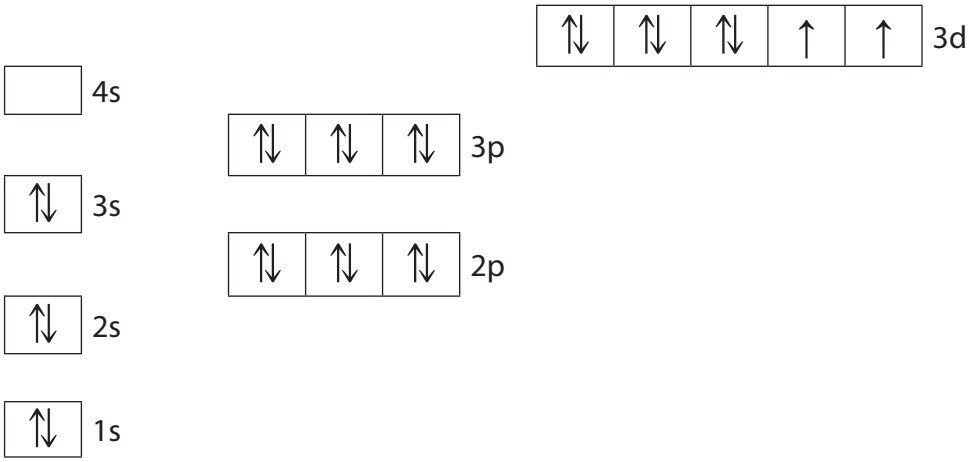
[1]

(b)



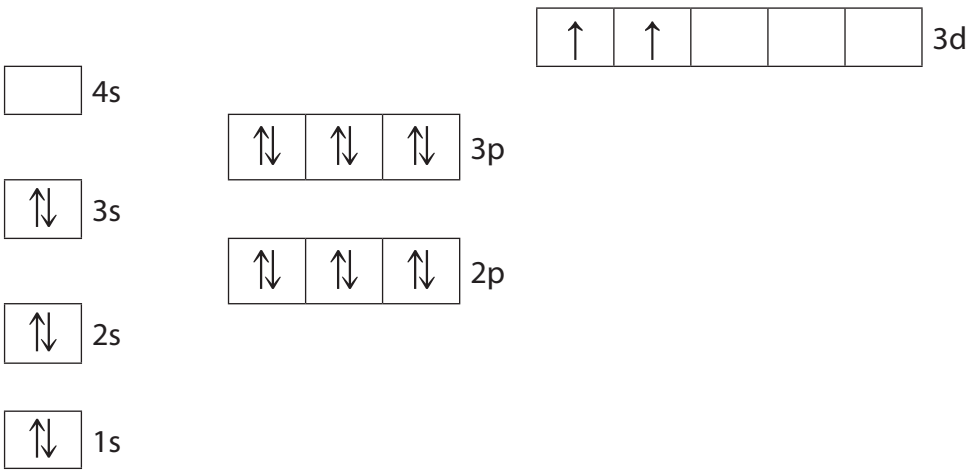
[1]

(c)



[1]

(d)



[1]
[4]

21 Answer is B [1]

22 **(a)** B [1]
(b) C [1]
(c) C [1]
(d) D [1]
(e) A [1]
(f) E [1]

23

Atom/ion	Electronic configuration	s, p or d block
W	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$	s
X^+	$1s^2\ 2s^2\ 2p^6$	s
Y^{2-}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	p
Z	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$	d

[4]

24 **(a)**

Region	Number of electrons
a 2p orbital	2 [1]
a 3s subshell	2 [1]
the 3rd energy level	18 [1]

[3]

(b) an orbital is a region within an atom that can hold up to two electrons with opposite spin [2]

(c) 
s orbital [1] p orbital [1] [2]

(d) outer electrons/highest energy electrons are in an s sub shell [1]

(e) p block [1] outer electrons are in a p sub–shell [1] [2]

(f) 9 [1]

Ionisation energy

25 (a) $Cs(g) \rightarrow Cs^{+}(g) + e^{-}$ [1]

(b) $Cl^{+}(g) \rightarrow Cl^{2+}(g) + e^{-}$ [1]

(c) $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^{-}$ [1]

(d) $Zn(g) \rightarrow Zn^{+}(g) + e^{-}$ [1]

(e) $Ga(g) \rightarrow Ga^{+}(g) + e^{-}$ [1]

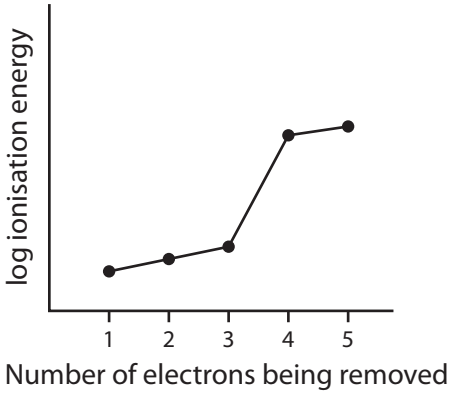
(f) $Mn^{2+}(g) \rightarrow Mn^{3+}(g) + e^{-}$ [1]

(g) $Na^{+}(g) \rightarrow Na^{2+}(g) + e^{-}$ [1]

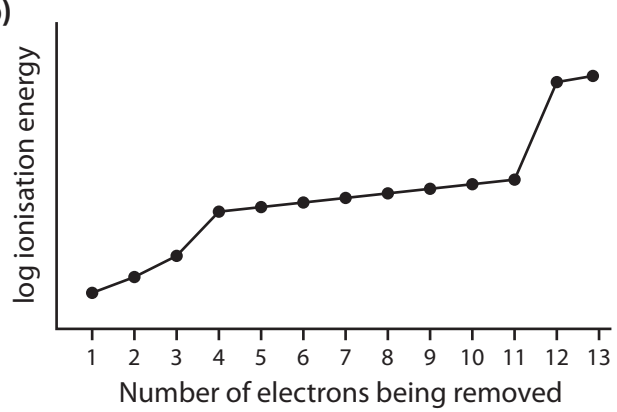
26 (a) first ionisation energy is the energy required to covert one mole of gaseous atoms into gaseous ions with a single positive charge [2]

(b) third ionisation energy is the energy required to covert one mole of gaseous ions with a double positive charge into gaseous ions with a triple positive charge [2]

27 (a)



(b)



(c) general increase as effective nuclear charge increase [1]
large increase between 3 and 4 as the electron is removed from a full $1s^2$ which is closer to the nucleus with less shielding [1] [2]

28 (a) outer electron is further from the nucleus in magnesium so weaker nuclear attraction on outer electron [1]
more shielding of nuclear charge by inner shells in magnesium [1] [2]

(b) $Be^{3+}(g) \rightarrow Be^{4+}(g) + e^{-}$ [1]

(c) it only has 4 electrons [1]

(d) first electron is further from the nucleus than second / it takes more energy to remove an electron from a positively charge ion / greater effective nuclear charge (ratio of protons to electrons) for removal of second electron [1]

29 **(a)** Z [1]

(b) W [1]

(c) Y_2O_3 [1]

(d) X [1] as it has a large increase in ionisation energy after the fourth electron has been removed [1] [2]

30 XCl_3 [1]

31 M_2O_3 [1]

32 **(a)** $Na(g) \rightarrow Na^+(g) + e^-$ [1]

(b) outer electron is further from the attraction of the nucleus in sodium [1]
outer electron is more shielded from the nuclear charge in sodium [1] [2]

(c) nitrogen has a $2p^3$ half–filled subshell which is more stable [1]
oxygen has a $2p^4$ arrangement and the repulsion of two electrons in the same p orbital leads to less energy being required to remove the outer electron [1] [2]

(d) line goes up for Mg but less than Be [1]
down again for Al but less than B [1]
up again for Si bit less than C [1] [3]

(e) they have the highest nuclear charge in a period so greater attraction on outer electron [1]
full outer subshell is stable [1] [2]

(f) in fluorine outer electron is closer to the nucleus and held more tightly by larger nuclear charge [1] shielding effect is constant in the same shell [1] [2]

(g) Be has full $2s^2$ subshell which is stable [1]
outer electron is further from the nucleus in B and is held less tightly by the nuclear charge [1] [2]

33 **(a)** **(i)** C [1]
(ii) H [1]

(b) shielding constant/electron added to same shell [1]
nuclear charge increases giving greater attraction for outer electron [1] [2]

34 **(a)** $Sr^+(g) \rightarrow Sr^{2+}(g) + e^-$ [1]

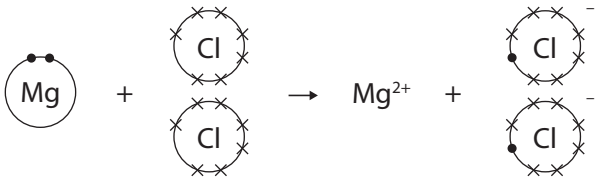
(b) Sr has a greater nuclear charge giving greater attraction for the outer electron / filled s^2 is stable [1]
outer electrons are in the same shell/experience same shielding [1] [2]

(c) second ionisation energy of Rb involves removing electron from a shell closer to nucleus and there is a stronger nuclear attraction on outer electron [1]
stability of full outer subshell in Rb^+ [1] [2]

1.3 Bonding

1 **(a)** 

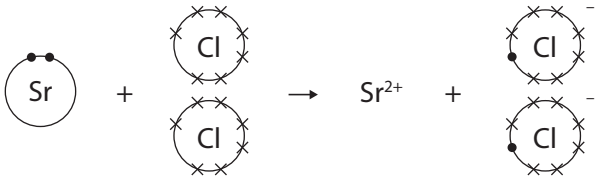
[2]

(b) 

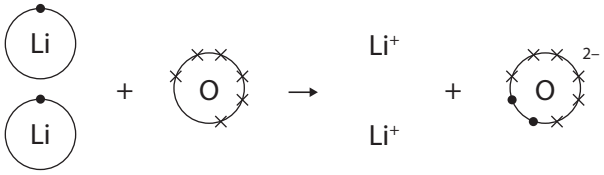
[2]

(c) 

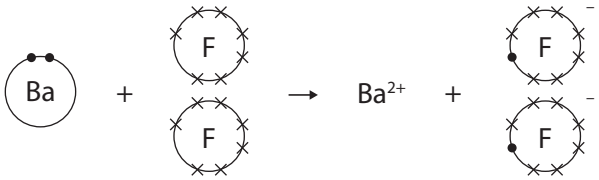
[2]

(d) 

[2]

(e) 

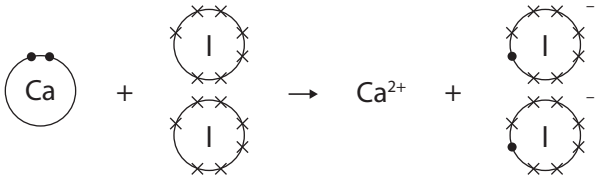
[2]

(f) 

[2]

(g) 

[2]

(h) 

[2]

2 XY_2 [1]

3 Ionic bonding – attraction between oppositely charged positive copper ions and negative chloride ions [2]

4 **(a)** $Na^+ + e- \rightarrow Na$ [1]

(b) $2Cl^- \rightarrow Cl_2 + 2e^-$ [1]

(c) $4e^- + O_2 \rightarrow 2O^{2-}$ [1]

(d) $Ca^{2+} + 2e^- \rightarrow Ca$ [1]

(e) $Al \rightarrow Al^{3+} + 3e^-$ [1]

(f) $Br_2 + 2e^- \rightarrow 2Br^-$ [1]

(g) $H_2 \rightarrow 2H^+ + 2e^-$ [1]

5 Ionic bonding – Attraction between oppositely charged positive ammonium ions and negative chloride ions [2]

6 AB_2 [1]

7 the electrostatic attraction between a shared pair of electrons and the nuclei of bonded atoms [2]

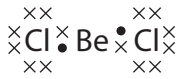
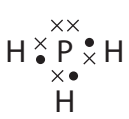
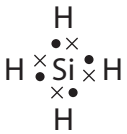
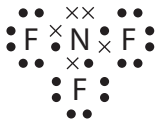
8 **(a)**

[1]

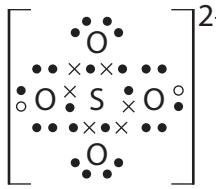
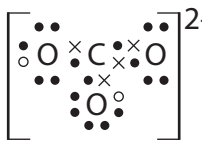
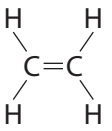
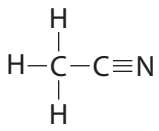
(b) a lone pair of electrons is a pair of unshared electrons in the outer shell of an atom [1]

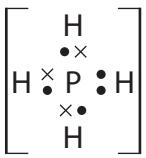
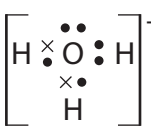
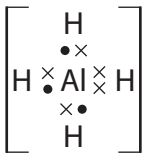
(c) 3 covalent bonds/3 pairs of electrons shared [1]

9

Molecule	Dot and cross diagram	Molecule	Dot and cross diagram
H_2S		$BeCl_2$	
PH_3		SiH_4	
NF_3		CS_2	

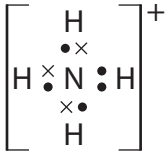
[6]

10 (a)  [1] **(b)**  [1] **(c)**  [1] **(d)**  [1]

11 (a)  [1] **(b)**  [1] **(c)**  [1] [3]

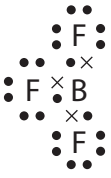
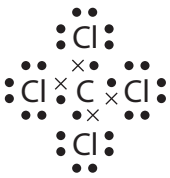
12 (a) $NH_3 + H^+ \rightarrow NH_4^+$ [1]

(b) a shared pair of electrons between two atoms. One atom provides both electrons. [2]

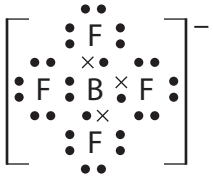
(c)  [1]

13 (a) $2F_2 + C \rightarrow CF_4$ [1]

$B + 1½F_2 \rightarrow BF_3$ [1] [2]

(b)  [1]  [1] [2]

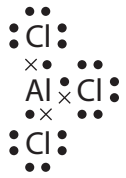
(c) when reacting, an atom tends to gain, lose or share electrons to achieve eight in its outer shell
B does not obey octet as 6 electrons in outer shell. F has 8 and does [1]
C does as 8 electrons in outer shell F has 8 and does [1] [4]

(d)  [1]

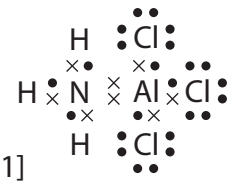
coordinate [1] [2]

14 Answer is C [1]

15 (a)



[1]



[1] [2]

(b) co–ordinate [1]
the lone pair of electrons is shared with the aluminium chloride [1] [2]

16 (a) yes, chlorine 8 electrons in outer shell, oxygen has 8 in outer shell [1] [2]

(b) no, sulfur has 12 in outer shell, not 8, fluorine has 8 in outer shell [1] [2]

(c) yes, sulfur has 8 in outer shell, chlorine has 8 in outer shell [1] [2]

17 (a) electronegativity is the extent to which an atom attracts the bonding electrons in a covalent bond [2]

(b) the nuclear charge is greater in fluorine / fluorine atom smaller than aluminium atom [1]
greater attraction between the nucleus of the bonding atom and the bonding electrons [1] [2]

(c) atomic radius increases down the group [1]
decreasing attraction between the nucleus and the bonding electrons [1] [2]

18 Cl
O
F
O [2]

19 Answer is D [1]

20 (a) a polar bond is a covalent bond in which there is unequal sharing of the bonding electrons [2]

(b) $\overset{\delta+}{C}-\overset{\delta-}{Cl}$ $\overset{\delta+}{H}-\overset{\delta-}{F}$ $\overset{\delta+}{C}=\overset{\delta-}{O}$ $\overset{\delta+}{N}=\overset{\delta-}{O}$ [2]

(c) there is a small difference in electronegativity between C and O [1]

(d) there is a very small difference in electronegativity between C and H [1]

(e) the Cl is delta – and P is delta + [1]
the electrons in the covalent bond are towards Cl as it is more electronegative than P [1] [2]

21 Answer is A [1]

1.4 Intermolecular Forces

1 Answer is C [1]

2 attraction between the lone pair on the fluorine [1]
and the delta plus hydrogen on a neighbouring molecule [1] [2]

3 Answer is D [1]

4 **(a)** van der Waals' forces [1]

(b) van der Waals' forces, dipole–dipole attractions [1]

(c) van der Waals' forces, hydrogen bonds [1]

(d) van der Waals' forces [1]

5 **(a)** iodine has a greater relative molecular mass/ more electrons [1]
stronger van der Waals' forces between molecules [1] [2]

(b) hydrogen bonds between molecules of hydrogen fluoride are stronger [1]
than the van der Waals' forces and dipole–dipole attractions between HCl molecules [1] [2]

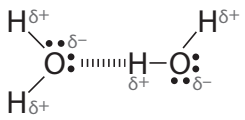
(c) HBr has a greater relative molecular mass/ more electrons [1]
stronger van der Waals' forces between molecules [1] [2]

(d) fluorine is more electronegative than hydrogen [1]
electrons in the covalent bond are attracted to F and it has a delta minus charge [1] [2]

6 **(a)** increasing relative molecular mass/more electrons [1]
stronger van der Waals' forces between molecules [1] [2]

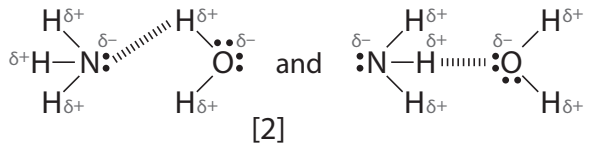
(b) in water there are hydrogen bonds between molecules [1]
These are stronger than the van der Waals' forces and dipole–dipole attractions
between H_2S and H_2Se molecules so higher boiling point [1] [2]

(c)



7 **(a)** the attraction between instantaneous and induced dipoles on neighbouring molecules [2]

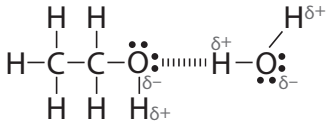
(b)



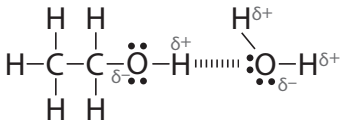
[2] [2] [4]

(c) hydrogen bonds between molecules of ammonia are stronger [1]
than the van der Waals' forces and dipole–dipole attractions between PH_3 molecules [1] [2]

8 (a)



[2]



[2]

[4]

(b) indicative content

- place the hexane in one burette and ethanol in another and place beakers underneath the jet
- at the same time open the tap and allow a small stream of liquid to run from the burette and hold a charged polythene rod close to the stream of liquid
- charged rod should be same distance from liquid for each and compare any deflection
- hexane will not deflect and ethanol will deflect
- hexane is non–polar and ethanol is polar
- polar liquid has dipoles which are attracted to the charged rod

5–6 indicative points = [5]–[6]
3–4 indicative points = [3]–[4]
1–2 indicative points = [1]–[2] [6]

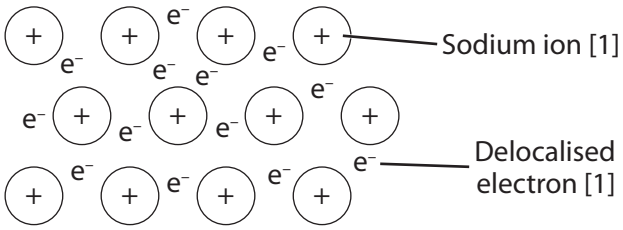
1.5 Structures

1 **(a)** attraction between positive ions and delocalised electrons [2]

(b) delocalised electrons [1]
can move and carry charge [1] [2]

(c) aluminium has more delocalised electrons / aluminum has 3 decloalised electrons sodium has only one per atom [1]
(delocalised electrons) which can move and carry charge [1] [2]

(d) [1] drawing [2] labels



[3]

2 **(a)** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$ [1]

(b) strong attraction between positive ions and delocalised electrons [1]
requires substantial energy to break [1] [2]

(c) Cu has more delocalised electrons/Cu produces 2 delocalised electrons compared to 1 with Li [1]

(d) outer electrons do not have fixed positions but move freely [1]

3 **(a)** a three–dimensional regular structure of oppositely charged ions held by ionic bonding [1]

(b) the ions cannot move to carry charge [1]

(c) dissolve in water or heat to melt [1]

(d) magnesium oxide has a greater melting point as there is a greater attraction between ions [1]
ions have greater charge [1]

4 **(a)** weak forces [1] between the layers [1] [2]

(b) many strong covalent bonds between carbon atoms [1]
3d tetrahedral arrangement [1] [2]

(c) many strong covalent bonds [1] which require substantial energy to break [1] [2]

(d) weak van der Waals' forces between molecules [1]

5 indicative content

- giant covalent structure
- each carbon atom covalently bonded to 3 others
- hexagonal layers
- weak forces between the layers
- delocalised electrons can move and carry charge
- many strong covalent bonds require substantial energy to break

5–6 indicative points = [5]–[6]
3–4 indicative points = [3]–[4]
1–2 indicative points = [1]–[2] [6]

6 indicative content

- melting point of graphite is higher
- more energy needed to break strong covalent bonds in graphite
- than energy needed to break the weak van der Waals' forces in iodine
- graphite conducts iodine does not
- each carbon in graphite has a delocalised electron which moves and carries charge
- iodine has no delocalised electrons or ions to carry charge

5–6 indicative points = [5]–[6]
3–4 indicative points = [3]–[4]
1–2 indicative points = [1]–[2] [6]

7 (a) giant ionic lattice, ions [1]

(b) giant covalent, atoms [1]

(c) metallic, positive ions and delocalised electrons [1]

(d) molecular covalent, molecules [1]

(e) molecular covalent , molecules [1]

(f) giant ionic lattice, ions [1]

(g) molecular covalent, molecules [1]

(h) metallic, positive ions delocalised electrons [1]

(i) giant ionic lattice , ions [1]

(j) giant covalent, atoms [1]

8 **(a)** covalent as low boiling point/liquid at room temp [1]

(b) covalent as low melting point does not conduct when molten/dissolved and dissolves better in covalent solid [1]

(c) ionic as high melting point/conducts in solution and dissolves in water [1]

9 Answer is C [1]

10 chlorine has van der Waals' forces between molecules [1]
Si has covalent bonds between atoms [1]
van der Waals' forces are weaker than covalent bonds [1]
less energy need to break forces in chlorine [1] [4]

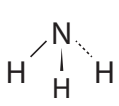
11 **(a)** increasing number of delocalised electrons/increasing charge on cation [1]
greater attraction between cation and delocalised electrons [1]
more energy required to break attractions [1] [3]

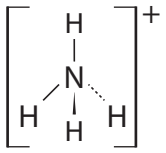
(b) many strong covalent bonds [1]
require substantial energy to break [1] [2]

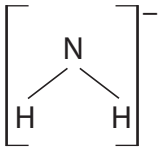
(c) S_8 has more electrons than P_4 / higher rmm [1]
greater van der Waals' forces between molecules require more energy to break [1] [2]

1.6 Shapes of Molecules and Ions

1 **(a)**







pyramidal [2] tetrahedral [2] bent [2] [6]

(b) NH_3 has one lone pair of electrons and 3 bonding pairs of electrons [1]
NH_4^+ has 4 bonding pairs of electrons [1]
lone pairs of electrons repel more than bonding pairs of electrons [1] [3]

(c) NH_2^- has two lone pairs of electrons and 2 bonding pairs of electrons and NH_3 has one lone pair of electrons and 3 bonding pairs of electrons [1]
so greater repulsion from extra lone pair of electrons [1] [2]

2

Substance	Shape	Explanation
BF_3	trigonal planar	3 bonding pairs of electrons repel each other equally
CH_4	tetrahedral	4 bonding pairs of electrons repel each other equally
H_3O^+	pyramidal	3 bonding pairs of electrons and 1 lone pair of electrons. The repulsion between the lone pair and the bonding pair is greater than the bonding pair bonding pair repulsion and the molecule is pyramidal to minimise repulsions
BrF_4^-	square planar	4 bonding pairs of electrons and 2 lone pairs of electrons. The 2 lone pairs repel each other more than the lone pair bonding pairs which repel more than the bonding pair bonding pairs and the molecule is square planar to minimise repulsions.

[1] each shape [2] each explanation [12]

3 **(a)** linear [1]

(b) bent [1]

(c) trigonal planar [1]

(d) tetrahedral [1]

(e) octahedral [1]

(f) trigonal bipyramidal [1]

(g) tetrahedral [1]

4 3 bonding pairs of electrons, 1 lone pair of electrons [1]
lone pair–bonding pair repulsion is greater than bonding pair–bonding pair repulsion [1]
pyramidal [1] with angle decreased to 107° [1] [4]

5 indicative content

Each box in table is an indicative content mark

	$BeCl_2$	CCl_4	ClF_2^+
name	linear	tetrahedral	bent
explanation	2 lone pairs of electrons repel equally.	4 lone pairs of electrons repel equally.	2 lone pairs of electrons and 2 bonding pairs of electrons. greater repulsion between lone pair–lone pair than lone pair–bonding pair and greater than bonding pair–bonding pair, so it is bent to minimise repulsions
angle	180	109.5	104.5

8–10 indicative points = [5]–[6]
4–7 indicative points = [3]–[4]
1–3 indicative points = [1]–[2] [6]

6 (a) octahedral [1]
6 bonding pairs of electrons [1]
repel each other equally [1] [3]

(b) fluorine is more electronegative than sulfur [1]
electrons in covalent bond are closer to F and so partial charges occur [1] [2]

(c) equally polar bonds are arranged symmetrically (in tetrahedral shape) [1]
dipoles cancel [1] [2]

7 (a) CBr_4 [1]
CO_2 [1]
BF_3 [1] [3]

(b) fluorine [1]
methane [1] [2]

(c) $\overset{\delta+}{C}—\overset{\delta-}{Cl}$

(d) equally polar bonds are arranged symmetrically (in tetrahedral shape) [1]
dipoles cancel [1] [2]

1.7 Redox

Oxidation numbers (states)

1

Species	Element	Oxidation state
Cl_2O_7	Cl	+7 [1]
$KMnO_4$	Mn	+7 [1]
Na_2HPO_4	P	+5 [1]
VO_2^+	V	+5 [1]
K_2MnO_4	Mn	+6 [1]
ClO^-	Cl	+1 [1]
NH_3	N	−3 [1]
HSO_4^-	S	+6 [1]
H_3PO_4	P	+5 [1]
VO_3^-	V	+5 [1]
$LiAlH_4$	H	−1 [1]
P_4O_{10}	P	+5 [1]
VO^{2+}	V	+4 [1]
MnO_2	Mn	+4 [1]
Na_3PO_4	P	+5 [1]
KCl	Cl	−1 [1]
Li_2CO_3	C	+4 [1]
SF_6	F	−1 [1]
KIO_3	I	+5 [1]
NaBrO	Br	+1 [1]

[20]

2 (a) $x = 3$ [1]; (b) $x = 3$ [1]; (c) $x = 4$ [1]; (d) $x = 2$ [1]

3 Answer is C [1]
Oxidation states in A +5, +3, –3, 0
Oxidation states in B +3, –3, 0, +5
Oxidation states in C –3, 0, +3, +5
Oxidation states in D 0, +3, –3, +5

4 Answer is C [1]

Redox and disprortionation

5 **(a)** +3, +1, +6, –1 all correct [2] each error –1 [2]

(b) Fe oxidation number changes from +3 to +6 = oxidation [1]
Cl oxidation number changes from +1 to –1 = reduction [1]
redox is oxidation and reduction occurring in the same reaction [1] [3]

6. S oxidation number changes from 0 in S to +2 in $Na_2S_2O_3$ = oxidation [1]
S oxidation number changes from 0 in S to –2 in Na_2S = reduction [1]
disproportionation is oxidation and reduction of the same element in the same reaction [1] [3]

7 **(a)** Fe oxidation number changes from +2 in $FeSO_4$ to +3 in $Fe_2(SO_4)_3$ = oxidation [1]
O oxidation number changes from –1 in H_2O_2 to –2 in H_2O = reduction [1]
redox is oxidation and reduction occurring in the same reaction [1] [3]

(c) hydrogen peroxide/H_2O_2 [1]

8 **(a)** N oxidation number changes from +3 in NO_2^- to +5 in NO_3^- = oxidation [1]
Mn oxidation number changes from +7 in MnO_4^- to +2 in Mn^{2+} = reduction [1]
redox is oxidation and reduction occurring in the same reaction [1] [3]

(d) nitrite ion/ NO_2^- [1]

9 **(a)** O oxidation number changes from –2 in Mn_2O_7 to 0 in O_2 = oxidation [1]
Mn oxidation number changes from +7 in Mn_2O_7 to +4 in MnO_2 = reduction [1]
redox is oxidation and reduction occurring in the same reaction [1] [3]

(b) chlorine/Cl_2 [1]

(c) iodate(V) ions gain electrons (supplied by the reducing agent) [1]

(d) Cl oxidation number changes from 0 in Cl_2 to +5 in $NaClO_3$ = oxidation [1]
Cl oxidation number changes from 0 in Cl_2 to –1 in NaCl = reduction [1]
disproportionation is oxidation and reduction of the same element in the same reaction [1] [3]

10 Answer is D [1]

Half–equations

11 (a) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ [1]

(b) $Cl_2 + 2e^- \rightarrow 2Cl^-$ [1]

(c) $Al \rightarrow Al^{3+} + 3e^-$ [1]

(d) $2H^+ + 2e^- \rightarrow H_2$ [1]

(e) $NO_2 + H_2O \rightarrow NO_3^- + 2H^+ + e^-$ [2]

(f) $VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$ [2]

(g) $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ [2]

(h) $2IO_3^- + 12H^+ + 10e^- \rightarrow I_2 + 6H_2O$ [2]

(i) $Cl_2 + 2H_2O \rightarrow 2ClO^- + 4H^+ + 2e^-$ [2]

(j) $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ [2]

12 (a) 8, 6, 4 [1]

(b) sulfate(VI) gains electrons and gain of electrons is reduction [1]

(c) S oxidation number changes from +6 in SO_4^{2-} to 0 in S [1]
decrease in oxidation number is reduction [1] [2]

Balanced redox ionic equations

13 (a) 14, 6, 2, 7 [1]

(b) (i) $2I^- \rightarrow I_2 + 2e^-$ [1]

(ii) $Cr_2O_7^{2-} + 6I^- + 14H^+ \rightarrow 2Cr^{3+} + 3I_2 + 7H_2O$ [2]

14 (a) $Fe^{3+} + e^- \rightarrow Fe^{2+}$ [1]

(b) (i) $2Fe^{3+} + SO_2 + 2H_2O \rightarrow 2Fe^{2+} + SO_4^{2-} + 4H^+$ [2]

(ii) SO_2 loses electrons and reducing agents lose electrons (given to the oxidising agent) [1]
S oxidation number changes from +4 in SO_2 to +6 in SO_4^{2-} [1]
increase in oxidation number is oxidation [1] [3]

15 (a) $3NaClO \rightarrow 2NaCl + NaClO_3$ [2]

(b) Cl oxidation number changes from +1 in NaClO to +5 in $NaClO_3$ = oxidation [1]
Cl oxidation number changes from +1 in NaClO to −1 in NaCl = reduction [1]
disproportionation is oxidation and reduction of the same element in the same reaction [1] [3]

16 (a) $VO_3^- + 6H^+ + 3e^- \rightarrow V^{2+} + 3H_2O$ [1]

(b) $Zn \rightarrow Zn^{2+} + 2e^-$ [1]

(c) $2VO_3^- + 12H^+ + 3Zn \rightarrow 2V^{2+} + 6H_2O + 3Zn^{2+}$ [2]

(d) zinc [1]

1.8 Halogens

The elements

1

Halogen	State at room temperature	Colour	Colour of aqueous solution
fluorine	gas	yellow	
iodine	solid	grey–black/ black–grey	yellow/brown
bromine	liquid	red–brown	yellow/orange/brown
chlorine	gas	green/yellow–green/ green–yellow	green/colourless

[1] per column [3]

2 **(a)** boiling point increases [1]
molecules have more electrons (down the group) [1]
increased van der Waals' forces between the molecules [1] [3]

(b) mix bromine water and hexane in a test tube [1]
stopper and shake [1]
yellow/orange/brown colour of bromine moves into hexane layer [1] [3]

3 **indicative content**

- yellow/brown iodine solution
- two layers
- top layer colourless
- yellow/brown colour in bottom layer fades
- top layer becomes purple
- iodine more soluble in hexane than water
- iodine is non–polar and hexane is non–polar

6–7 indicative points = [5]–[6]
3–5 indicative points = [3]–[4]
1–2 indicative points = [1]–[2] [6]

4 Answer is B [1]

Reactions of halogens

5 **(a)** $Cl_2 + H_2O \rightarrow HOCl + HCl$ [1]
Cl oxidised from 0 in Cl_2 to +1 in HOCl and reduced from 0 in Cl_2 to –1 in HCl [1]
disproportionation is oxidation and reduction of the same element in the same reaction [1] [3]

(b) ozone breaks down to oxygen [1]
chlorine remains in the water when it reaches the consumer [1] [2]

(c) no taste/no residual chemicals in water/kills more different types of micro–organisms/removes metal and organic chemicals from water [1]

6 **(a)** **(i)** $Cl_2(g) + 2OH^-(aq) \rightarrow ClO^-(aq) + Cl^-(aq) + H_2O(l)$ [2]

(ii) +1 in ClO^-
–1 in Cl^- [1]

(b) $3Cl_2 + 6NaOH \rightarrow NaClO_3 + 5NaCl + 3H_2O$ [2]
Cl oxidised from 0 in Cl_2 to +5 in $NaClO_3$ and reduced from 0 in Cl_2 to –1 in NaCl [1]
disproportionation is oxidation and reduction of the same element in the same reaction [1] [4]

7 **(a)** (as group descended) outer shell further from the nucleus [1]
incoming electron less attracted to nucleus/more shielding [1]
atoms gain electron less readily [1] [3]

(b) **(i)** $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$ [1]

(ii) colourless solution changes to yellow/brown [1]

(iii) displacement [1]

(c) **(i)** $2Cl_2 + 2H_2O \rightarrow 4HCl + O_2$ [1]

(ii) decreased levels of chlorine so micro–organisms not killed [1]

8 **(a)** $2Br^- \rightarrow Br_2 + 2e^-$ [1]

(b) iodine is darker than bromine [1]

(c) $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$ [1]

(d) chlorine gains electrons [1]

(e) chlorine outer shell closer to nucleus [1]
incoming electron more attracted to nucleus/less shielding [1]
chlorine atom gains electron more readily than bromine [1] [3]

9 Answer is C [1]

Reactions of halides

10 (a) misty/steamy fumes [1]

(b) red–brown vapour [1]

(c) $NaBr + H_3PO_4 \rightarrow NaH_2PO_4 + HBr$ [1]

(d) sodium hydrogensulfate
hydrogen bromide
bromine
sulfur dioxide
water
all correct [2]; one missing [1] [2]

(e) HCl cannot reduce H_2SO_4/HCl cannot act as a reducing agent [2]

11 (a) sulfur [1]

(b) misty fumes
purple vapour
grey–black solid
all correct [1]; one missing [1] [2]

(c) $NaI + H_2SO_4 \rightarrow NaHSO_4 + HI$ [1]

(d) (i) I oxidation number changes from –1 in HI to 0 in I_2 = oxidation [1]
S oxidation number changes from +6 in H_2SO_4 to +4 in SO_2 = reduction [1]
redox is oxidation and reduction occurring in the same reaction [1] [3]

(ii) $2I^- \rightarrow I_2 + 2e^-$ oxidation [1]
$H_2SO_4 + 2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$ reduction [1]
(or $SO_4^{2-} + 4H^+ + 2e^- \rightarrow SO_2 + 2H_2O$) [2]

(d) $8HI + H_2SO_4 \rightarrow 4I_2 + H_2S + 4H_2O$ [2]

(e) outer electrons in chloride ions are closer to the nucleus/less shielded [1]
chloride ions cannot lose electrons as readily as iodide ions [1] [2]

12 (a) $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$ [1]

(b) dry the gas/remove water/moisture [1]

(c) denser than air [1]

(d) (i) outer electrons in the bromide ion further from nucleus/more shielded [1]
bromide ions can lose electrons more readily than chloride ions [1] [2]

(ii) $2HBr + H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_2O$ [2]

13 (a) no change in oxidation number [1]

(b) $2KI + 3H_2SO_4 \rightarrow 2KHSO_4 + I_2 + SO_2 + 2H_2O$ [2]

(c)

Observation	Product
steamy fumes	hydrogen iodide
smell of rotten eggs	hydrogen sulfide
violet vapour	iodine
yellow solid	sulfur
grey–black solid	iodine

all correct [3] each missing/error [–1] [3]

(d) $H_2SO_4 + 6H^+ + 6e^- \rightarrow S + 4H_2O$
(or $SO_4^{2-} + 8H^+ + 6e^- \rightarrow S + 4H_2O$) [2]

(e) I oxidation number changes from –1 in HI to 0 in I_2 = oxidation [1]
S oxidation number changes from +6 in H_2SO_4 to –2 in H_2S = reduction [1]
redox is oxidation and reduction occurring in the same reaction [1] [3]

14 Answer is C [1]

15 Answer is C [1]

1.9 Acid–Base Titrations

Titration techniques

1 indicative content

- moles required = 0.00625 mol
- mass required = 0.00625 × 106 = 0.6625/0.663 g
- weigh out accurately 0.66(25) g of solid
- dissolve solid in a small volume of deionised water
- add solution to a 250 cm^3 volumetric flask
- rinse the beaker and glass rod with deionised water and add washings to volumetric flask
- make up to mark by adding deionised water until the bottom of the meniscus is on the mark
- stopper and invert to mix

7–8 indicative points = [5]–[6]
3–6 indicative points = [3]–[4]
1–2 indicative points = [1]–[2] [6]

2 (a) dilution factor = $\frac{0.125}{0.0250} = 5$

final total volume = 20 × 5 = 100 cm^3
volume of water added = 100 – 20 = 80 cm^3 [3]

(b) rinse pipette with the undiluted acid [1]
use pipette and pipette filler to transfer 20.0 cm^3 of acid into a 100 cm^3 volumetric flask [1]
fill volumetric flask with deionised water until the bottom of the meniscus is on the line [1]
stopper and invert to mix [1] [4]

(c) (i) 27.2 cm^3 [1]

(ii) $\frac{0.1}{27.1} \times 100 = 0.4\ \%$ [1]

(iii) phenolphthalein [1] pink to colourless [1]
or methyl orange [1] yellow to red [1] [2]

(iv) moles of HCl = $\frac{27.2 \times 0.0250}{1000} = 6.8\times10^{-4}$ mol

moles of NaOH = 6.8×10^{-4} mol
concentration of NaOH = $6.8\times10^{-4} \times 40 = 0.0272$ mol dm^{-3} [3]

(v) higher titre values as acid is more dilute [1]

3 (a) to obtain an estimate of the end–point enabling faster subsequent titrations [1]

(b) calculated using titrations 1 and 3 which are concordant [1]

(c) weak acid–strong base titration/rapid change in pH not in range where indicator changes colour [1]

(d) colourless to pink [1]

(e) $0.95 = \frac{2 \times \text{uncertainty}}{10.5} \times 100$

uncertainty = 0.05 [1]

(f) more dilute solution of sodium hydroxide to obtain higher titre [1]

(g) moles of NaOH = $\frac{10.6 \times 0.085}{1000} = 9.01 \times 10^{-4}$ mol

moles of CH_3COOH in 25.0 $cm^3 = 9.01 \times 10^{-4}$ mol

moles of CH_3COOH in 10.0 $cm^3 = 9.01 \times 10^{-3}$ mol

concentration of undiluted = $9.01 \times 10^{-3} \times 100 = 0.901$ mol dm^{-3}

concentration of undiluted = $0.901 \times 60 = 54$ g dm^{-3} [5]

4 moles of HCl used = $\frac{26.0 \times 0.0450}{1000} = 0.00117$ mol

moles of $Ca(OH)_2$ in 25.0 $cm^3 = \frac{0 \times 0.0117}{2} = 5.85 \times 10^{-4}$ mol

moles of $Ca(OH)_2$ in 100 $cm^3 = 5.85 \times 10^{-4} \times 4 = 0.00234$ mol

mass of $Ca(OH)_2$ in 100 $cm^3 = 0.00234 \times 74 \times 1000 = 173$ mg [4]

5 Answer is C

moles of NaOH = $\frac{25.0 \times 0.120}{1000} = 3.00 \times 10^{-3}$ mol

A 1.50×10^{-3} mol HCl present and 3.00×10^{-3} mol required as 1:1 ratio

B 7.50×10^{-4} mol H_2SO_4 present and 1.50×10^{-3} required as 1:2 ratio

C 1.50×10^{-3} mol H_2SO_4 present and 1.50×10^{-3} required as 1:2 ratio

D 6.00×10^{-3} mol HCl present and 3.00×10^{-3} required as 1:1 ratio

Further titrations

6 **(a)** methyl orange [1]
yellow to red [1] [2]

(b) moles of HCl = $\frac{16.35 \times 0.140}{1000} = 2.289 \times 10^{-3}$ mol

moles of Na_2CO_3 in 25.0 $cm^3 = \frac{2.289 \times 10^{-3}}{1000} = 1.1445 \times 10^{-3}$ mol

moles of Na_2CO_3 in 250.0 $cm^3 = 1.1445 \times 10^{-3} \times 10 = 0.01145$ mol

mass of Na_2CO_3 in 250.0 $cm^3 = 0.01145 \times 106 = 1.213$ g

mass of water = 2.45 – 1.213 = 1.237 g

moles of water = $\frac{1.237}{18} = 0.06872$ mol

$x = \frac{0.06872}{0.01145} = 6$ [5]

(c) heating to constant mass [1]

7 **(a)** 20.15 cm^3 [1]
titrations 2 and 3 [1] [2]

(b) pink to colourless [1]

(c) moles of $H_2SO_4 = \frac{20.15 \times 0.450}{1000} = 9.0675 \times 10^{-4}$ mol
moles of MOH in 25.0 $cm^3 = 9.0675 \times 10^{-4} \times 2 = 1.8135 \times 10^{-3}$ mol
moles of MOH in 500.0 $cm^3 = 1.8135 \times 10^{-3} \times 20 = 0.03627$ mol
relative formula mass $= \frac{3.70}{0.03627} = 102$
relative atomic mass = 102 – 17 = 85 identity = Rb [5]

8 moles of HCl $= \frac{26.15 \times 0.0500}{1000} = 0.0013075$ mol
moles of $Ba(OH)_2$ in 25.0 $cm^3 = \frac{0.0013075}{2} = 6.5375 \times 10^{-4}$ mol
moles of $Ba(OH)_2$ in 1 $dm^3 = 6.5375 \times 10^{-4} \times 40 = 0.02615$ mol
relative formula mass of $Ba(OH)_2.xH_2O = \frac{8.24}{0.02615} = 315$
$xH_2O = 315 - 171 = 144$
$x = \frac{144}{18} = 8$ [5]

9 moles of $Na_2CO_3.10H_2O = \frac{14.2}{286} = 0.04965$ mol
moles of Na_2CO_3 in 25.0 $cm^3 = \frac{0.04965}{40} = 1.24125 \times 10^{-3}$ mol
moles of HCl required $= 1.24125 \times 10^{-3} \times 2 = 2.4825 \times 10^{-3}$ mol
volume of HCl $= \frac{2.4825 \times 10^{-3} \times 1000}{0.100} = 24.8$ cm^3 [4]

10 **(a)** completely dissociated in solution/water [1]

(b) moles of NaOH $= \frac{18.2 \times 0.0450}{1000} = 8.19 \times 10^{-4}$ mol
moles of HX $= 8.19 \times 10^{-4}$ mol
concentration of HX $= 8.19 \times 10^{-4} \times 40 = 0.03276$ mol dm^{-3}
relative formula mass $= \frac{2.65}{0.03279} = 81$
X = bromine/Br [5]

(c) concentration of HCl = $\frac{2.65}{36.5}$ = 0.0726 mol dm^{-3}

moles of HCl = $\frac{25.0 \times 0.0726}{1000}$ = 1.815×10^{-3} mol

moles of NaOH = 1.815×10^{-3} mol

volume of NaOH = $\frac{1.815 \times 10^{-3} \times 1000}{0.0450}$ = 40.3 cm^3 [4]

11 (a) moles of $C_2H_2O_4.2H_2O$ in 250.0 cm^3 = $\frac{4.25}{126}$ = 0.03373 mol

moles of $C_2H_2O_4$ in 25.0 cm^3 = $\frac{0.03373}{10}$ = 3.3373×10^{-3} mol

moles of NaOH = $3.3373 \times 10^{-3} \times 2 = 6.746 \times 10^{-3}$ mol

volume of NaOH = $\frac{6.746 \times 10^{-3} \times 1000}{0.580}$ = 11.6 cm^3 [4]

(b) burette not rinsed with sodium hydroxide solution
solid has lost water of crystallisation
jet not filled
overshot the end–point
any [2]

12 Answer is D [1]

A 0.005 mol $NaHCO_3$ present; 0.005 mol required as 1:1 ratio
B 0.005 mol KOH present and 0.005 mol required as 1:1 ratio
C 0.0025 mol $Na_2CO_3.10H_2O$ present; 0.0025 required as 1:2 ratio
D 0.01 mol $Ba(OH)_2$ present; 0.0025 required as 1:2 ratio

13 Answer is C [1]

moles of $Sr(OH)_2$ = $\frac{0.549}{122}$ = 0.0045 mol

moles of HCl = 0.0045 × 2 = 0.009 mol

volume of 0.2 mol dm^{-3} HCl required = $\frac{0.009 \times 1000}{0.2}$ = 45.0 cm^3

1.10 Qualitative Tests

1 **(a)** $Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$ [2]

(b) apply a lit splint; popping sound [1]

(c) add silver nitrate solution [1]
white ppt [1]
add dilute ammonia solution and ppt disappears [1] [3]

(d) nichrome wire [1]
dipped in concentrated hydrochloric acid and into solid [1]
into a blue Bunsen burner flame [1]
red/brick–red flame [1] [4]

2 **(a)** $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$ [1]

(b) add excess silver nitrate solution [1]
(white) precipitate [1]
add dilute ammonia solution [1]
no precipitate remaining [1] [4]

3 **(a)** ammonia/NH_3 [1]

(b) alkaline gas [1]

(c) white smoke/fumes/solid [1]
$NH_3 + HCl \rightarrow NH_4Cl$ [1] [2]

(d) silver iodide/AgI [1]

(e) SO_4^{2-} [1]

(f) $NH_4I/(NH_4)_2SO_4$ [1]

4 **(a)** $2KMnO_4 \rightarrow K_2MnO_4 + MnO_2 + O_2$ [2]

(b) pink flame [1]

(c) glowing splint; relights [1]

(d) **(i)** remove hydrogen chloride gas [1]

(ii) remove water [1]

(iii) denser than air [1]

(iv) bleaches damp universal indicator/litmus paper [1]

5 **(a)** effervescence [1]
limewater changes from colourless to milky [1] [2]

(b) blue–green/green–blue flame [1]

(c) blue–black solution [1]

(d) white smoke/fumes/solid [1]

6

Ion	Flame test colour
Li^+	crimson
K^+	**lilac**
Ba^{2+}	**apple green/green**
Cu^{2+}	**blue–green/green–blue**
Na^+	yellow

[3]

7 add excess silver nitrate solution [1]
precipitate formed [1]
add dilute ammonia solution [1]
cream precipitate remains [1]
filter solution and wash with deionised water [1]
dry in low temperature oven/desiccator [1] [6]

8 Answer is C [1]

9 Answer is D [1]

Unit AS 2: Answers

2.1 Formulae and Amounts of Substance

Empirical and molecular formulae

1 **(a)** moles of P $= \frac{43.7}{31} = 1.4097$ mol

moles of O $= \frac{56.3}{16} = 3.51875$ mol

ratio = 1:2.5 = 2:5

P_2O_5 [3]

(b) $\frac{284}{142} = 2$

P_4O_{10} [1]

2 mass of carbon = $0.12 \times 12 = 1.44$ g
mass of hydrogen = 1.71 – 1.44 = 0.27 g
moles of hydrogen = 0.27 mol
ratio 4:9
empirical formula C_4H_9
molecular formula C_8H_{18} [3]

3 moles of C $= \frac{16.8}{12} = 1.4$ mol

moles of H $= \frac{2.8}{1} = 2.8$ mol

moles of O $= \frac{22.4}{16} = 1.4$ mol

empirical formula CH_2O

RMM $= \frac{42}{0.70} = 60$

molecular formula = $C_2H_4O_2$ [3]

4 moles of H $= \frac{1.12}{1} = 1.12$ mol

moles of O $= \frac{62.92}{16} = 3.93$ mol

moles of S $= \frac{35.96}{32} = 1.12$ mol

empirical formula = $H_2S_2O_7$ [3]

5 **(a)** heating and weighing until two consecutive mass measurements are the same [1]

(b) mass of iron = 17.48 – 15.24 = 2.24 g

moles of iron = $\frac{2.24}{56}$ = 0.04 mol

mass of oxygen = 18.33 – 17.48 = 0.85 g

moles of oxygen = $\frac{0.85}{16}$ = 0.053125 mol

ratio 1:1.33 so empirical formula = Fe_3O_4 [5]

6 Answer is C [1]

moles of C = $\frac{5}{6} \div 12$ = 0.0694 mol

moles of H = $\frac{1}{6} \div 1$ = 0.1667 mol

ratio C:H ratio 1:2.4 = 5:12 so C_5H_{12}

7 Answer is B [1]

$\frac{3.2}{A_r \text{ of X}} = \frac{0.8}{16}$ so A_r of X = 64

moles of X = $\frac{8}{64}$ = 0.125 mol

moles of O = $\frac{1}{16}$ = 0.0625 mol

ratio X:O = 2:1 so X_2O

Gas calculations

8 **(a)** volume of $CO_2 = \frac{1.05}{44} \times 24000 = 573\ cm^3$ [1]

(b) volume of $H_2O = \frac{15.4}{18} \times 24 = 20.5\ dm^3$ [1]

(c) volume of $NH_3 = \frac{200\,000}{17} \times 0.024 = 282\ m^3$ [1]

9 **(a)** moles of gas = $\frac{196}{24000} = 8.167 \times 10^{-3}$ mol

RMM of gas = $\frac{0.580}{8.167 \times 10^{-3}} = 71$ [2]

(b) chlorine [1]

(c) $8.167 \times 10^{-3} \times 84 \times 1000 = 686$ mg [1]

10 volume of O_2 left over = 30 cm^3
volume of CO_2 formed = 80 cm^3
total volume = 110 cm^3 [2]

11 moles of $Cu(NO_3)_2.3H_2O = \frac{6.00}{242} = 0.02479$ mol

moles of NO_2 and O_2 formed $= \frac{0.02479}{2} \times 5 = 0.06198$ mol

(Note H_2O is (l) at 20°C)

volume of gas = $0.06198 \times 24 = 1.49$ dm^3 [3]

12 moles of $NH_3 = \frac{200\,000}{17} = 11764.71$ mol

moles of $O_2 = \frac{11764.71}{4} \times 3 = 8823.53$ mol

volume of $O_2 = 8823.53 \times 0.024 = 212$ m^3 [3]

13 moles of gas $= \frac{450}{24000} = 0.01875$ mol

moles of $X_2CO_3 = \frac{0.01875}{3} \times 2 = 0.0125$ mol

RFM of $X_2CO_3 = \frac{3.45}{0.0125} = 276$

RAM of X = 108
Identity = silver/Ag [3]

14 **(a)** have MCO_3 in a separate container in flask and shake to mix [1]
use a gas syringe [1] [2]

(b) no more fizzing/no more gas collected/solid disappears [1]

(c) volume before error = 180 cm^3

moles of $CO_2 = \frac{180}{24000} = 7.5 \times 10^{-3}$ mol

RFM of $MCO_3 = \frac{0.93}{7.5 \times 10^{-3}} = 124$

RAM of M = 64
M is copper/Cu [3]

(d) moles of HCl = $7.5 \times 10^{-3} \times 2 = 0.015$ mol

volume of HCl $= \frac{0.015 \times 1000}{0.5} = 30$ cm^3 [1]

15 Answer is D [1]

volume of unreacted oxygen = 50 cm^3

volume of carbon dioxide = 30 cm^3

$C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$

$1 : x + \frac{y}{4} : x = 10:50:30 = 1:5:3$

x = 3; x + y/4 = 5 so y = 8

16 Answer is B [1]

$2H_2 + O_2 \rightarrow 2H_2O$

40 cm^3 of hydrogen reacts with 20 cm^3 of oxygen

H_2O liquid under these conditions

volume of gas remaining = 50 – 20 = 30 cm^3

Percentage yield

17 moles of 1–bromobutane = $\frac{12.0}{137} = 0.08759$ mol

theoretical yield of butan–1–ol = 0.08759 × 74 = 6.482 g

percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{5.24}{6.482} \times 100 = 80.8\ \%$ [3]

18 (a) mass of propan–1–ol = 15.7 × 0.80 = 12.56 g

moles of propan–1–ol = $\frac{12.56}{60} = 0.2093$ mol

theoretical yield of propanal = 0.2093 × 58 = 12.14 g

percentage yield = $\frac{8.40}{12.14} \times 100 = 69.2\ \%$ [4]

(b) side reactions/not all propan–1–ol oxidised [1]
loss during transfer [1] [2]

19 (a) moles of 2–hydroxybenzoic acid = $\frac{11.04}{138} = 0.08$ mol

theoretical yield of aspirin = 0.08 × 180 = 14.4 g

mass of aspirin formed = 0.225 × 14.4 = 3.24 g [3]

(b) mass of ethanoic acid = 0.08 × 60 = 4.8 g

volume of ethanoic acid = $\frac{4.8}{1.05} = 4.57$ cm^3 [2]

20 mass of 1,2–dibromohexane produced = $20.0 \times 1.58 = 31.6$ g

theoretical yield of 1,2–dibromohexane = $\frac{31.6}{0.78} = 40.51$ g

moles of 1,2–dibromohexane = $\frac{40.51}{244} = 0.166$ mol

mass of hex–1–ene = $0.166 \times 84 = 13.95$ g [4]

21 theoretical yield of ethanoic acid = $\frac{10.0}{0.725} = 13.79$ g

moles of ethanoic acid = $\frac{13.79}{60} = 0.2299$ mol

mass of ethanol required = $0.2299 \times 46 = 10.57$ g

volume of ethanol required = $\frac{10.75}{0.79} = 13.4$ cm^3 [4]

22 (a) moles of NaI = $\frac{25.0 \times 0.125}{1000} = 3.125 \times 10^{-3}$ mol

moles of $Pb(NO_3)_2$ = $\frac{25.0 \times 0.0800}{1000} = 2.00 \times 10^{-3}$ mol

limiting reactant is NaI

theoretical yield of PbI_2 in moles = $\frac{3.125 \times 10^{-3}}{2} = 1.5625 \times 10^{-3}$ mol

theoretical yield of PbI_2 in milligrams = $1.5625 \times 10^{-3} \times 461 = 720$ mg

percentage yield = $\frac{663}{720} \times 100 = 92.1$ % [5]

(b) lead(II) iodide not dried fully [1]

(c) side reactions/not all precipitated/
loss during transfer or filtration/decomposition on drying [1]

23 Answer is B [1]

mass of butan–1–ol = $7.5 \times 0.81 = 6.075$ g

moles of butan–1–ol = $\frac{6.075}{74} = 0.0821$ mol

theoretical yield of 1–bromobutane = $0.0821 \times 137 = 11.25$ g

percentage yield = $\frac{5.5}{11.25} \times 100 = 49$ %

24 Answer is A [1]

moles of methyl propanoate = $\frac{1.00}{88} = 0.01136$ mol

theoretical yield of methanol = 0.01136×0.364 g

actual yield of methanol = $0.55 \times 0.364 = 0.20$ g

Atom economy

25 mass of desired product = $2 \times 28 = 56$
total mass of products = $56 + 6 \times 18 = 164$
atom economy = $\frac{56}{164} \times 100 = 34.1\ \%$ [2]

26 **(a)** mass of desired product = $2 \times 64 = 128$
total mass of products = $128 + 44 = 172$
atom economy = $\frac{128}{172} \times 100 = 74.4\ \%$ [2]

(b) less waste/other product mass less/atom economy 78% [1]
hydrogen flammable/hydrogen storage/hydrogen production causes more waste [1] [2]

27 mass of desired product = $2 \times 46 = 92$
total mass of products = $92 + 2 \times 44 = 180$
atom economy = $\frac{92}{180} \times 100 = 51.1\ \%$ [2]

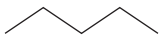
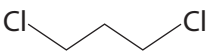
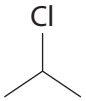
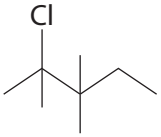
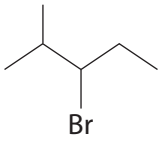
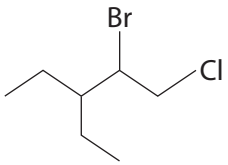
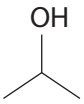
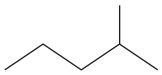
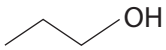
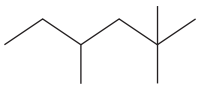
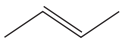
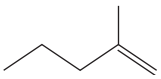
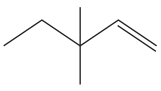
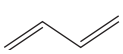
28 Answer is B [1]
atom economy of A = 2.06 %
atom economy of B = 17.6 %
atom economy of C = 15.4 %
atom economy of D = 1.45 %

2.2 Nomenclature and Isomerism in Organic Compounds

Nomenclature

1 **(a)** pentane [1]
(b) 1,3–dichloropropane [1]
(c) 2–chloropropane [1]
(d) 2–methylpropane [1]
(e) 2–chloro–2,3,3–trimethylpentane [1]
(f) 3–bromo–2–methylpentane [1]
(g) 2-bromo-1-chloro–3–ethylpentane [1]
(h) propan–2–ol [1]
(i) 2,2–dimethylpropane [1]
(j) 2–methylpentane [1]
(k) propan–1–ol [1]
(l) 2,2,4–trimethylhexane [1]
(m) but–2–ene [1]
(n) 2–methylpent–1–ene [1]
(o) propene [1]
(p) 2–methylpropene [1]
(q) 3,3–dimethylpent–1–ene [1]
(r) buta–1,3–diene [1] [18]

2

(a) 	**(b)** 	**(c)** 
(d) 	**(e)** 	**(f)** 
(g) 	**(h)** 	**(i)** 
(j) 	**(k)** 	**(l)** 
(m) 	**(n)** 	**(o)** 
(p) 	**(q)** 	**(r)** 

[1] for each [18]

3 **(a)** butane [1]
(b) but–1–ene [1]
(c) butan–1–ol [1]
(d) pentan–2–ol [1]
(e) propan–2–ol [1]
(f) 2,3–dibromohexane [1]
(g) 4–bromo–1–chloro–2–methylpentane [1]
(h) 3–bromo–1,1,1–trichloropentane [1]
(i) 2,2–dimethylpentane [1]
(j) pent–2–ene [1]
(k) 2,3–dibromopent–1–ene [1]
(l) pent–1–en–3–ol [1] [12]

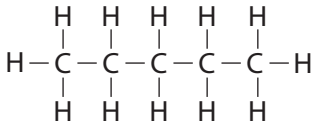
4 **(a)** 2–methylbutane [1]
(b) 2,5–dimethylhexane [1]
(c) propan–2–ol [1]
(d) pent–2–ene [1]
(e) 3–methylbutan–1–ol [1]
(f) 1,1,2–trichloro–1,2,2–trifluoroethane [1]
(g) 3–ethyl–2–methylhexane [1] [7]

5 Answer is B [1]

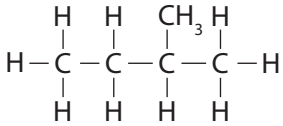
Isomers

6 structural isomers are molecules with the same molecular formula but with a different structural formula [2]

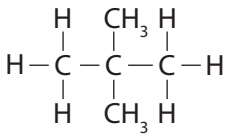
7 pentane



2–methylbutane

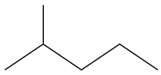


2,2–dimethylpropane

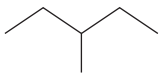


[3]

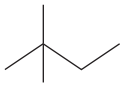
8



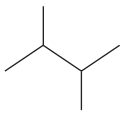
2–methylpentane



3–methylpentane



2,2–dimethylbutane

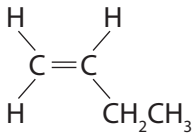


2,3–dimethylbutane

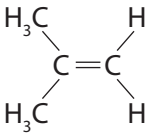
[1] mark for each correct name and structure [4]

9 Answer is B [1]

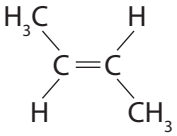
10 but–1–ene



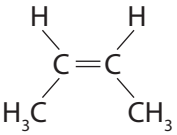
2–methylpropene



E–but–2–ene



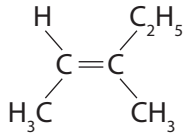
Z–but–2–ene



[1] each name with structure [4]

11 **(a)** restricted rotation about C=C [1]
both carbons in C=C have 2 different atoms/groups attached [1] [2]

(b)

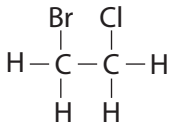


[1]

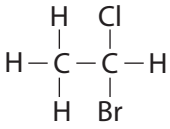
(c) hex–1–ene / 2-methylpent-2-ene [1]

12 **(a)** Z **(b)** E **(c)** E **(d)** E [2]

13 **(a)**



1–bromo–2–chloroethane [1]

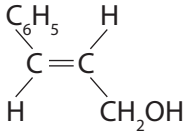


1–bromo–1–chloroethane [1] [2]

(b) No, two hydrogens are the same atom, bonded to the same carbon. [1]

14 **(a)** C=C/carbon–carbon double bond [1]
OH/hydroxyl [1] [2]

(b)



[1]

15 right hand carbon of the C=C, C has a higher atomic number than H [1]
CH_2CH_2OH has highest priority [1]
left hand carbon of the C=C, (C has higher atomic number than H) CH_2CH_3 has higher priority [1]
higher priority groups are on opposite sides of C=C so E isomer [1] [3]

2.3 Alkanes

Physical properties

1 (a)

Name	Formula
hexane	**$CH_3CH_2CH_2CH_2CH_2CH_3$**
3–methylpentane	$CH_3CH_2CH(CH_3)CH_2CH_3$
2–methylpentane	**$CH_3CH(CH_3)CH_2CH_2CH_3$**
2,3–dimethylbutane	$CH_3CH(CH_3)CH(CH_3)CH_3$
2,2–dimethylbutane	$CH_3C(CH_3)_2CH_2CH_3$

[4]

(a) contains no C=C or C≡C bond [1]
and contains carbon and hydrogen only [1] [2]

(b) it is nonpolar/cannot form hydrogen bonds with water [1]

(c) branched molecules cannot pack so tightly together [1]
van der Waals' forces between molecules are weaker [1] [2]

2 (a) C_3H_8 and C_4H_{10} [1]

(b) propane has lower formula mass/fewer electrons [1]
weaker van der Waals' forces between the molecules [1] [2]

3 (a) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ [2]

(b) $C_6H_{14} + 9½O_2 \rightarrow 6CO_2 + 7H_2O$ [2]

(c) $C_2H_6 + 2½O_2 \rightarrow 2CO + 3H_2O$ [2]

(d) $C_4H_{10} + 6½O_2 \rightarrow 4CO_2 + 5H_2O$ [2]

(e) $C_{10}H_{22} + 5½O_2 \rightarrow 10C + 11H_2O$ [2]

[1] for correct formula [1] balancing

4 Answer is C [1]

5 (a) higher formula mass/more electrons [1]
stronger van der Waals' forces between the molecules [1] [2]

(b) high carbon content/incomplete combustion [1]

6 **(a)** incomplete combustion of alkanes in limited oxygen produces carbon monoxide [1]
nitrogen from air reacts with oxygen at high temperatures in engine [1] [2]

(b) carbon monoxide is toxic and prevents the blood carrying oxygen [1]
nitrogen monoxide forms smog/dissolve in water to form nitric acid (acid rain) [1] [2]

(c) carbon monoxide is oxidised to carbon dioxide [1]
nitrogen monoxide is reduced to nitrogen and oxygen [1] [2]

7 **(a)** increase of 0.01% / from 0.03 to 0.04% [1]

(b) $C_8H_{18} + 12½O_2 \rightarrow 8CO_2 + 9H_2O$ [2]

(c) $C_8H_{18} + 8½O_2 \rightarrow 8CO + 9H_2O$ [2]

(d) limited oxygen present [1]

(e) carbon [1]
exacerbates asthma/smog/global dimming [1] [2]

8 **(a)** platinum–rhodium [1]

(b) it provides a large surface area [1]
reactions occur faster [1] [2]

(c) reactants are gases catalyst is solid [1]
reactants and catalyst in different states [1] [2]

(d) carbon dioxide [1]
carbon dioxide and water [1]
nitrogen and oxygen [1] [3]

(e) nitrogen monoxide = nitrogen(II) oxide [1]
nitrogen dioxide = nitrogen(IV) oxide [1] [2]

(f) **(i)** $CH_3SH + 3O_2 \rightarrow CO_2 + SO_2 + 2H_2O$ [2]

(ii) causes acid rain/ sulfur dioxide causes respiratory problems [1]

9 Answer is B [1]

10 Answer is D [1]

11 (a) $C_3H_8 + Br_2 \rightarrow C_3H_7Br + HBr$ [1]

(b) a hydrogen atom is replaced by a bromine atom [1]

(c) $Br_2 \rightarrow 2Br^{\bullet}$ [1]

$C_3H_8 + Br^{\bullet} \rightarrow C_3H_7^{\bullet} + HBr$ [1]

$C_3H_7^{\bullet} + Br_2 \rightarrow Br^{\bullet} + C_3H_7Br$ [1] [2]

$2C_3H_7^{\bullet} \rightarrow C_6H_{14}$ [1]

12 (a) uv light [1]

(b) $Cl_2 \rightarrow 2Cl^{\bullet}$ [1]

(c) homolytic [1]
one of the shared chlorine electrons in the bond goes to each atom [1] [2]

(d) $Cl^{\bullet} + CH_2Cl_2 \rightarrow HCl + CHCl_2^{\bullet}$ [1]

$CHCl_2^{\bullet} + Cl_2 \rightarrow CHCl_3 + Cl^{\bullet}$ [1] [2]

(e) any one of [1]

$2Cl^{\bullet} \rightarrow Cl_2$

$Cl^{\bullet} + CHCl_2^{\bullet} \rightarrow CHCl_3$

$2CHCl_2^{\bullet} \rightarrow C_2H_2Cl_4$ [1]

(f) $Cl_2 + CHCl_3 \rightarrow CCl_4 + HCl$ [1]

13 (a) a particle with an unpaired electron [1]

(b) initiation $Cl_2 \rightarrow 2Cl^{\bullet}$ [1]

propagation $Cl^{\bullet} + CHF_3 \rightarrow HCl + CF_3^{\bullet}$ [1]

$CF_3^{\bullet} + Cl_2 \rightarrow CClF_3 + Cl^{\bullet}$ [1] [2]

termination $2CF_3^{\bullet} \rightarrow C_2F_6$ or $2CF_3^{\bullet} \rightarrow CF_3CF_3$ [1]

14 (a) one of the shared chlorine electrons in the bond goes to each atom [1]

(b) $Br^{\bullet} + H_2 \rightarrow H^{\bullet} + HBr$ [1]

$H^{\bullet} + Br_2 \rightarrow Br^{\bullet} + HBr$ [1] [2]

(c) any two from

$2Br^{\bullet} \rightarrow Br_2$

$2H^{\bullet} \rightarrow H_2$

$Br^{\bullet} + H^{\bullet} \rightarrow HBr$ [2]

2.4 Alkenes

1 **(a)** hex–2–ene [1]

(b) 2,5–dimethylhex–2–ene [1]

(c) 2–chloropent–2–ene [1]

(d) 3–chlorobut–1–ene [1]

(e) 2–chloropent–1–ene [1]

(f) hexa–1,4–diene [1]

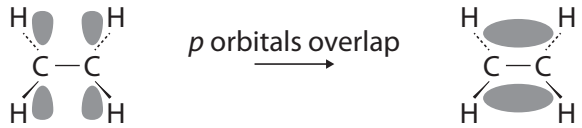
(g) buta–1,2–diene [1]

2 **(a)** a covalent bond formed by the linear overlap of atomic orbitals [1]

(b) a covalent bond formed by the sideways overlap of p orbitals [1]

(c) pi bond is a weaker bond than sigma [1]
pi bond has high electron density [1]
prone to attack by electrophiles [1] any [2]

(d)

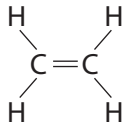
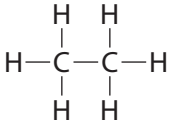
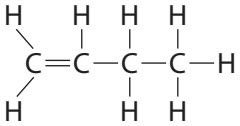
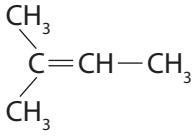
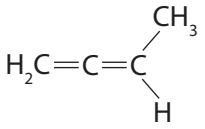


[2]

(e) contains hydrogen and carbon only [1]
contains at least one C=C or C≡C bond [1] [2]

3 **(a)** in ethene the bond is C=C and composed of a sigma and a pi bond [1]
in ethane the bond is C–C and composed of sigma only [1] [2]

(b)

Compound	Structural formula	Number of pi bonds present in compound	Number of sigma bonds present in compound
ethene		1	5
ethane		0	7
but–1–ene		1	11
2–methylbut–2–ene		1	14
buta–1,2–diene		2	9

[1] per correct column [4]

(c) shake with bromine water [1] orange/yellow/brown to colourless [1] [2]

(d) pi bond in ethene has high electron density/pi bond projects out of molecule [1]
prone to attack by electrophiles [1] [2]

Reactions

4 **(a)** $CH_3C(CH_3)CHCH_3 + H_2 \rightarrow CH_3CH(CH_3)CH_2CH_3$ [1]
2–methylbutane [1] [2]

(b) $CH_3CHCHCH_3 + Cl_2 \rightarrow CH_3CHClCHClCH_3$ [1]
2,3–dichlorobutane [1] [2]

(c) $C_2H_4 + HBr \rightarrow C_2H_5Br$ [1]
bromoethane [1] [2]

(d) $CH_3CHCHCH_2CH_3 + Br_2 \rightarrow CH_3CHBrCHBrCH_2CH_3$ [1]
2,3–dibromopentane [1] [2]

(e) $Br_2 \rightarrow Br^- + Br^+$ [1]

(f) $Br_2 \rightarrow 2Br^{\bullet}$ [1]

5 **(a)** addition of a hydrogen molecule across a double bond [1]

(b) finely divided nickel [1]
180°C [1] [2]

(c) $C_5H_{10} + H_2 \rightarrow C_5H_{12}$ [1]
pentane[1] [2]

(d) $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH + H_2 \rightarrow CH_3(CH_2)_7CH_2CH_2(CH_2)_7COOH$ / $CH_3(CH_2)_{16}COOH$ [1]

6 **indicative content**

- **ethane**
  - mechanism is free radical substitution
  - products are bromoethane and hydrogen bromide
  - mixture of brominated ethanes may form due to chain reaction
  - uv light

- **ethene**
  - mechanism is electrophilic addition
  - product is 1,2–dibromoethane
  - room temperature with bromine water

5 or more indicative content [5]– [6]
3–4 indicative content [3]–[4]
1–2 indicative content [1]–[2]

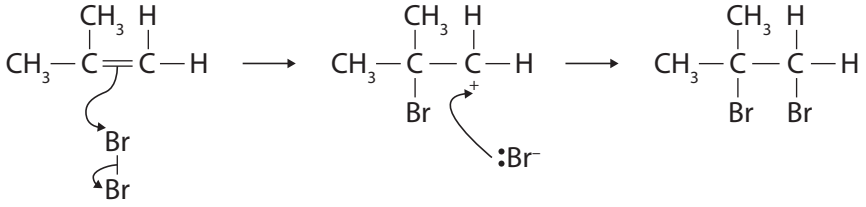
7 **(a)** A (2–)methylpropene [1]
B 1,2–dibromo–2–methylpropane [1] [2]

(b) orange/yellow/brown to colourless [1]

(c) double bonds are electron–rich/centres of electron density. [1]
bromine becomes polarised/forms an induced dipole/becomes δ+/ δ– [1] [2]

(d) electrophilic addition [1]

(e)



[4]

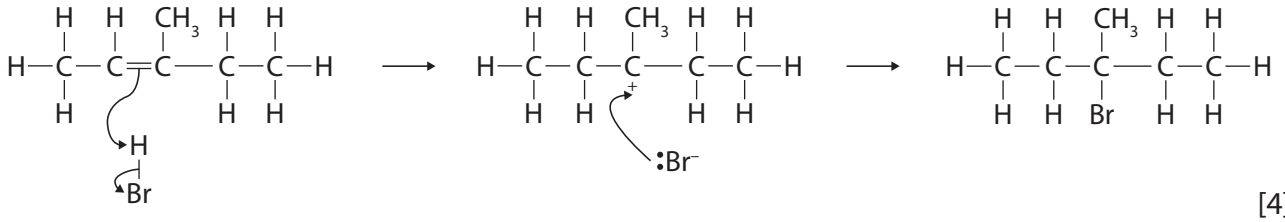
8 **(a)** $CH_3CHClCHClCHClCHCl_2$ [1]

(b) $CH_3CH_2CH_2CH_2CH_2Cl$ [2]

9 **(a)** an ion or molecule that attacks regions of high electron density [2]

(b) 3–bromo–3–methylpentane [1]

(c)



[4]

(d) reaction goes via tertiary carbocation [1]
which is more stable than the secondary carbocation [1] [2]

(e) C=C/carbon–carbon double bond [1]

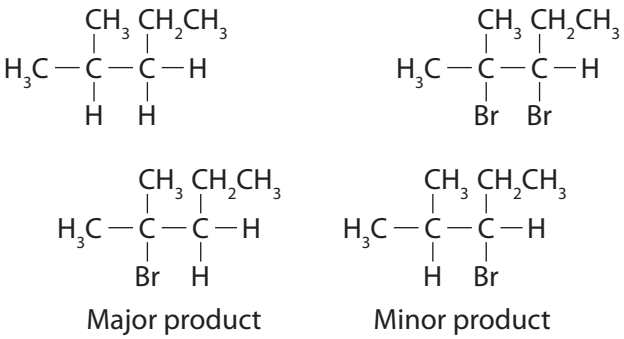
(f) 3–methylpentane [1]

10 **indicative content**

- major product 2–bromobutane minor product 1–bromobutane [1]
- but–2–ene product is 2–bromobutane [1]
- mechanism is via intermediate carbocations [1]
- for but-2-ene the carbocation is secondary [1]
- for but–1–ene a primary or secondary carbocation can form [1]
- major product is formed via the more stable secondary carbocation [1]

5 or more indicative content [5]– [6]
3–4 indicative content [3]–[4]
1–2 indicative content [1]–[2]

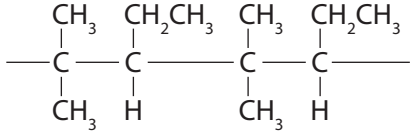
11 **(a)**



[4]

(b) 2–methylpent–2–ene [1]

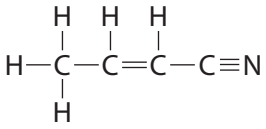
(c)



[1]

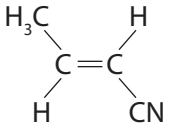
12 (a) C_4H_5N [1]

(b)



[1]

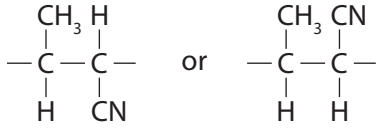
(c)



[1]

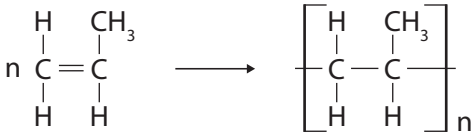
(d) restricted rotation about double bond [1]
different atoms/groups on each carbon [1] [2]

(e)



[1]

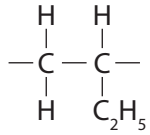
13 (a)



[1]

(b) addition [1]

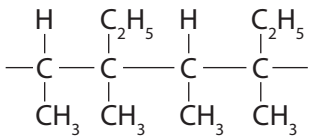
(c)



[1]

14 (a) joining together of many small molecules(monomers) to form a large molecule. [2]

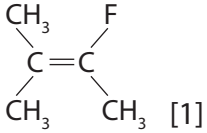
(b)



[1]

(c) C=C/ carbon–carbon double bond [1]

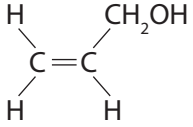
15 (a) 2-fluoro-3-methylbut-2-ene [1]



[1]

[2]

(b) prop–2–en–1–ol [1]



[1]

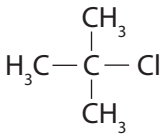
[2]

2.5 Halogenoalkanes

Nomenclature and physical properties

1 **(a)** 1–iodo–3–methylbutane [1]
(b) 1,1,3–trichloro–2–methylbutane [1]
(c) 3–fluorohex–3–ene [1]
(d) 2–bromobut–1–ene [1]
(e) 1,1,1–trichloro–2,2–difluoroethane [1]
(f) tribromochloromethane [1]
(g) 1,2–dichloro–2–methylpropane [1] [7]

2 **(a)**



[1]

(b) $\overset{\delta+}{C}—\overset{\delta-}{Cl}$ [1]

(c) chlorine is more electronegative than carbon [1]
electrons in the covalent bond are attracted more to the chlorine and form a partial negative charge [1] [2]

(d) a halogenoalkane which has three carbon atoms directly bonded to the carbon atom that is bonded to the halogen [2]

(e) 1–chlorobutane and $CH_3CH_2CH_2CH_2Cl$ [1]
1–chlorobutane has no branching/greater contact between molecules [1]
stronger van der Waals' forces between molecules [1] [3]

3 higher formula mass/more electrons [1]
stronger van der Waals' forces between molecules [1] [2]

4 2–chloropropane as Cl is in the middle of the chain [1]
this reduces the contact between the molecules so weaker van der Waals' forces between molecules [1] [2]

5 **(a)**

2–chloro–2–methylpropane [1]	tertiary [1]
1–chlorobutane [1]	primary [1]
1–chloro–2–methylpropane [1]	primary [1]

[6]

(b) straight chain packs together closely [1]
stronger van der Waals' forces between molecules [1] [2]

(c) a halogenoalkane which has one carbon atom directly bonded to the carbon atom that is bonded to the halogen [2]

6 **(a)** triiodomethane [1]

(b) triiodomethane has a higher formula mass/more electrons [1]
stronger van der Waals' forces between molecules [1] [2]

Reactions

7 **(a)** ethanol [1]
$CH_3CH_2Br + NaOH \rightarrow CH_3CH_2OH + NaBr$ [1] [2]

(b) pentanenitrile [1]
$CH_3CH_2CH_2CH_2Cl + KCN \rightarrow CH_3CH_2CH_2CH_2CN + KCl$ [1] [2]

(c) butylamine/butan–1–amine/1–aminobutane [1]
$CH_3CH_2CH_2CH_2I + NH_3 \rightarrow CH_3CH_2CH_2CH_2NH_2 + HI$ [1] [2]

(d) butan–2–ol [1]
$CH_3CH_2CHBrCH_3 + NaOH \rightarrow CH_3CH_2CH(OH)CH_3 + NaBr$ [1] [2]

(e) butanenitrile [1]
$CH_3CH_2CH_2Cl + KCN \rightarrow CH_3CH_2CH_2CN + KCl$ [1] [2]

(f) ethylamine/ethanamine/aminoethane [1]
$CH_3CH_2Br + NH_3 \rightarrow CH_3CH_2NH_2 + HBr$ [1] [2]

8 **(a)** $CH_3CH_2CH_2CH_2CH(OH)CH_2OH$ [1]

(b) $CH_3CH_2CH_2CH_2CH(NH_2)CH_2NH_2$ [1]

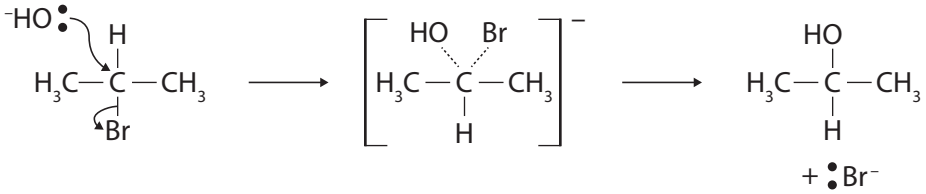
(c) $CH_3CH_2CH_2CH_2CH(CN)CH_2CN$ [1]

(d) $CH_3CH_2CH_2CH_2CH{=}CH_2 + Cl_2 \rightarrow CH_3CH_2CH_2CH_2CHClCH_2Cl$ [1]

9 **(a)** **(i)** 2–bromopropane [1]

(ii) nucleophilic substitution [1]

(iii)



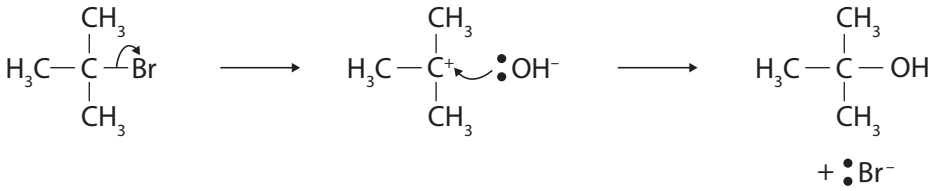
[4]

(b) **(i)** KOH in ethanol [1]

(ii) elimination [1]

10 Answer is B [1]
B has no lone pair

11 (a)



[4]

(b) (i) $CH_3CBr(CH_3)CH_3 + KOH \rightarrow CH_2=C(CH_3)CH_3 + KBr + H_2O$ [1]

(ii) 2–methylpropene [1]

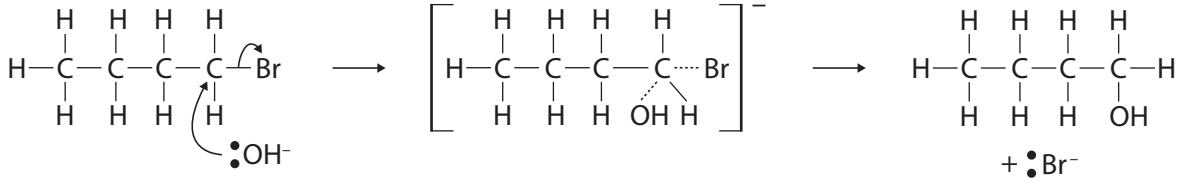
(iii) a reaction in which a small molecule is removed from a larger molecule [1]
HBr is removed (from 2–bromo–2–methylpropane) [1] [2]

12 (a) 1–iodobutane [1]
the C–I bond has the lowest bond enthalpy/weakest bond [1] [2]

(b) $CH_3CH_2CH_2CH_2Br + NaOH \rightarrow CH_3CH_2CH=CH_2 + NaBr + H_2O$ [1]
but–1–ene [1] [2]

(c) $CH_3CH_2CH_2CH_2Br + NaOH \rightarrow CH_3CH_2CH_2CH_2OH + NaBr$ [1]
butan–1–ol [1] [2]

(d) nucleophilic substitution [1]



[4] [5]

(e) 2–methylbut–1–ene [1]
2–methylbut–2–ene [1] [2]

13 (a) breaking up molecules by reaction with water [1]

(b) equal amounts of each halogenoalkane [1]
use halogenoalkanes with the same chain length [1]
equal amounts of ethanol [1]
same temperature [1] [4]

(c) silver chloride white [1]
silver bromide cream [1]
silver iodide yellow[1] [3]

(d) halogenoalkane is hydrolysed and halide ions are released [1]
the halide ions react with the silver ions in silver nitrate [1]
an insoluble ppt is formed [1]
$Ag^+ + X^- \rightarrow AgX$ X = Cl, Br or I [1] [4]

(e) chloroalkane [1]
the C–Cl bond is strongest/C–Cl has highest bond enthalpy [1] [2]

(f) ethanol is the solvent for the halogenoalkane/mutual solvent [1]

14 **(a)** dichlorodifluoromethane [1]

(b) uv light [1]

(c) $CF_2Cl_2 \rightarrow CF_2Cl\bullet + Cl\bullet$ [1]

(d) $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ [1]
$ClO\bullet + O_3 \rightarrow 2O_2 + Cl\bullet$ [1] [2]

(e) removal of ozone means more harmful uv radiation reaches earth [1]
causes sunburn/skin cancer/skin aging [1] [2]

(f)  [1]

(g) the C–Br bond enthalpy/bond strength is less than that for C–Cl [1]

(h) pentane does not contain chlorine/no C–Cl/pentane does not release chlorine radicals [1]

15 **(a)** reaction is exothermic [1]
controls the reaction and prevents dangerous spitting [1] [2]

(b) bromine [1]
hydrogen bromide is oxidised to bromine by concentrated sulfuric acid [1] [2]

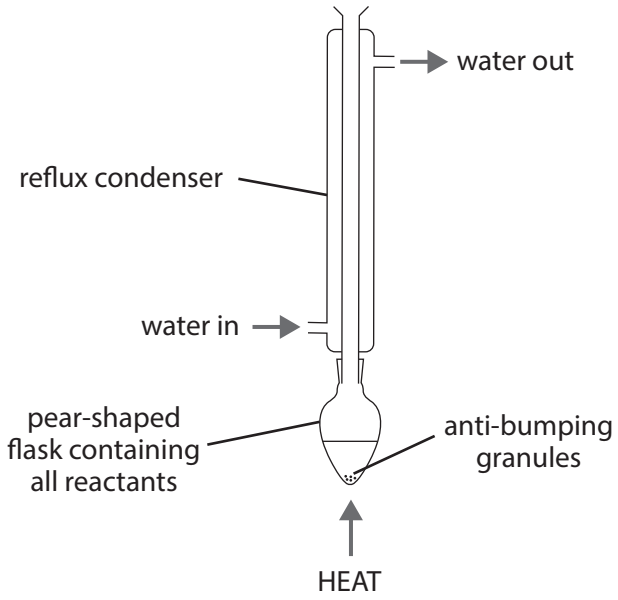
(c) repeated boiling and condensing of a reaction mixture [1]

(d) to remove acidic impurities [1]

(e) shake in a separating funnel [1]
invert and release the pressure periodically [1]
allow to settle and run off bottom layer; discard the aqueous layer [1] [3]

(f) to remove water [1]

16 (a)



[3]

(b) distil off the impure brombutane [1]
shake with concentrated hydrochloric acid in a separating funnel [1]
shake with sodium hydrogencarbonate solution in a separating funnel, releasing pressure [1]
add anhydrous calcium chloride and swirl, repeat until changes from cloudy to clear [1]
distil and collect at boiling point [1] [5]

2.6 Alcohols

1 **(a)** propan–1–ol
(b) 2–methylpropan–1–ol
(c) butan–2–ol
(d) 1–chloro– 4–methylpentan–2–ol
(e) methanol
(f) propan–2–ol
(g) 2–methylpropan–2–ol
(h) butane–1,2–diol
(i) pent–4–en–2–ol [8]

2 **(a)** primary
(b) primary
(c) secondary
(d) secondary
(e) primary
(f) secondary
(g) tertiary [7]

3 **(a)** P
(b) P
(c) T
(d) T
(e) T
(f) P
(g) S
(h) S [8]

4 **(a)** hydrogen bonds, van der Waals' forces, permanent dipole-dipole attractions [1]

(b) liquids which mix in all proportions/liquids form a single layer [1]

(c) hydrogen bonds form between the lone pair on oxygen of water [1]
and the delta plus hydrogen on the ethanol molecule [1]
or hydrogen bond between lone pair on oxygen of ethanol [1] and delta plus of H on water [1] [2]

(d) an alcohol which has one carbon atom directly bonded to the carbon atom that is bonded to the –OH group [2]

(e) less soluble due to long non–polar hydrocarbon chain [1]

5 **indicative content**
- all have similar van der Waals' forces between molecules (due to same number of electrons) [1]
- pentane is low as only weak van der Waals' forces between molecules [1]
- butan–1–ol hydrogen bonds between molecules [1]
- hydrogen bonds are stronger than van der Waals' [1]
- 2–methylpropan–1–ol has hydrogen bonds between molecules [1]
- 2–methylpropan–1–ol has branching so the molecules do not pack as closely and intermolecular forces are weaker than in butan–1–ol [1]

5–6 indicative points = [5]–[6]
3–4 indicative points = [3]–[4]
1–2 indicative points = [1]–[2] [6]

6 fractional distillation [1]

7 similar van der Waals' forces between molecules [1]
heptan–1–ol also has hydrogen bonds between molecules [1]
these are stronger than van der Waals' forces [1] [3]

Reactions

8 **(a)** $C_3H_7OH + 4½O_2 \rightarrow 3CO_2 + 4H_2O$ [1]

(b) $C_3H_7OH + 3O_2 \rightarrow 3CO + 4H_2O$ [1]

(c) $C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$ [1]

9 **(a)** **(i)** $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ [1]

(ii) $C_2H_5OH + 2O_2 \rightarrow 2CO + 3H_2O$ [1]

(iii) produces less carbon dioxide for every mole of water formed than alkane fuels/conserves fossil fuels/no sulfur impurities/renewable any [2]

(b) **(i)** $2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2$ [1]

(ii) solid disappears/fizzing/mixture warms up any [2]

(iii) sodium ethoxide [1]

(c) **(i)** $C_2H_5OH + PCl_5 \rightarrow C_2H_5Cl + HCl + POCl_3$ [1]

(ii) solid disappears/steamy or misty fumes/mixture warms up/hissing noise any [2]

(iii) chloroethane [1]

10 A CH_2ClCH_2Cl [1]
B CH_2ClCH_2Br [1]
C CH_2ClCHO [1]
D $CH_2ClCOOH$ [1] [4]

11 A pentan-3-one $CH_3CH_2COCH_2CH_3$ [1]
B butanal $CH_2CH_2CH_2CHO$ [1]
C hexanoic acid $CH_3CH_2CH_2CH_2CH_2COOH$ [1] [3]

12 (a)

Name	Structure	Classification – primary, secondary or tertiary
butan–1–ol	$CH_3CH_2CH_2CH_2OH$	primary
butan–2–ol	$CH_3CH_2CH(OH)CH_3$	secondary
2–methylpropan–2–ol	$CH_3C(OH)(CH_3)CH_3$	tertiary
2–methylpropan–1–ol	$CH_3CH(CH_3)CH_2OH$	primary

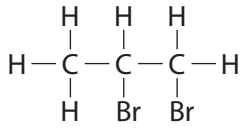
[1] each correct structure [1] correct name and classification [6]

(b) 2–methylpropan–2–ol [1]

(c) orange to green [1]

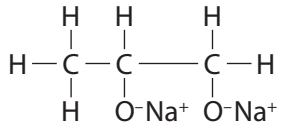
13 (a) propane–1,2–diol [1]

(b) (i)



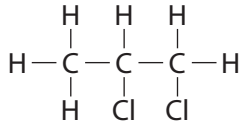
[1]

(ii)



(the charges can be omitted) [1]

(iii)



[1]

[3]

(b) two OH groups in propylene glycol [1]
more hydrogen bonds between molecules [1] [2]

14 Answer is C [1]

15 (a) repeated boiling and condensing of a reaction mixture [1]
keeps reactants in contact so complete oxidation of propan–1–ol/propanal occurs [1] [2]

(b) $CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ [1]

(c) acidified potassium dichromate (VI) [1] orange to green [1] [2]

(d) change the apparatus for distillation [1]
use a still head containing a thermometer with the condenser horizontal [1]
collect sample at the boiling point of propanal [1] [3]

(e) propan–2–ol [1]

16 indicative content

- warm
- with acidified potassium dichromate(VI)
- orange to green with pentan–1–ol
- pentan–1–ol is primary can be oxidised
- stays orange with 2–methylbutan–2–ol
- 2–methylbutan–2–ol is tertiary and cannot be oxidised

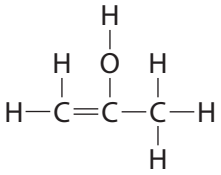
5–6 indicative points = [5]–[6]
3–4 indicative points = [3]–[4]
1–2 indicative points = [1]–[2] [6]

2.7 Infrared Spectroscopy

1 **(a)** no absorption between 3200 and 3600 cm^{-1} for OH of alcohol [1]
no absorption between 1650 and 1800 for C=O of carbonyl [1] [2]

(b) absorption at 2850 to 3000 cm^{-1} due to C–H bond of hydrocarbons [1]

2 **(a)**



[1]

(b) C=C 1600–1700 cm^{-1} [1]
O–H 3200–3500 cm^{-1} [1] [2]

3 **(a)** O—H [1]

(b) A = butan–1–ol [1]
B = butan–2–ol [1] [2]

(c) 2–methylpropan–2–ol [1] $CH_3C(OH)(CH_3)CH_3$ [1] [2]

(d) **(i)** 2–methylpropan–1–ol [1] $CH_3CH(CH_3)CH_2OH$ [1] [2]

(ii) E has C=O [1] F has COOH [1] [2]

(iii) still contains peak at 3030–3600 cm^{-1} due to O–H/alcohol [1]
does not contain peak at 2500–3200 cm^{-1} due to O–H/carboxylic acid [1]
does not contain peak at 1650–1800 cm^{-1} due to C=O [1] any [2]

4 Answer is B [1]

5 **(a)** bonds vibrate and absorb the infrared radiation [1]
(b) absorption at 3000/2500–3200cm^{-1} [1] due to OH [1] [2]
(c) match with a database spectra [1]

6 **(a)** absence of OH absorption [1] at 2500–3200cm^{-1} [1] [2]
(b) same bonds present/C–C, C–H, C–O and O–H [1]
same absorptions in same places [1] [2]
(c) run a infrared spectrum and compare to data base spectrum of propan–2–ol [1]
if spectra match exactly then the sample is pure [1] [2]

7 no OH at 3200–3600cm^{-1} [1] not an alcohol [1]
no OH at 2500–3200 [1] not a carboxylic acid [1]
C=O absorption at 1650–1800 [1] aldehyde or ketone [1] [6]

8 monitor absorption of alcohol O–H at 3200–3600 cm^{-1} [1]
all alcohol has reacted when O–H peak has disappeared [1] [2]

2.8 Energetics

Enthalpy level diagrams and enthalpy changes

1 **(a)** $Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$ [1]

(b) $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ [1]

(c) $Na(s) + \frac{1}{2}Cl_2(g) \rightarrow NaCl(s)$ [1]

(d) $C_4H_{10}(g) + 6\frac{1}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$ [1]

(e) $H_2(g) + O_2(g) \rightarrow H_2O_2(l)$ [1]

(f) $\frac{1}{2}H_2SO_4(aq) + NaOH(aq) \rightarrow \frac{1}{2}Na_2SO_4(aq) + H_2O(l)$ [1]

(g) $C(s) + O_2(g) \rightarrow CO_2(g)$ [1]

(h) $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ [1]

(i) $2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(l)$ [1]

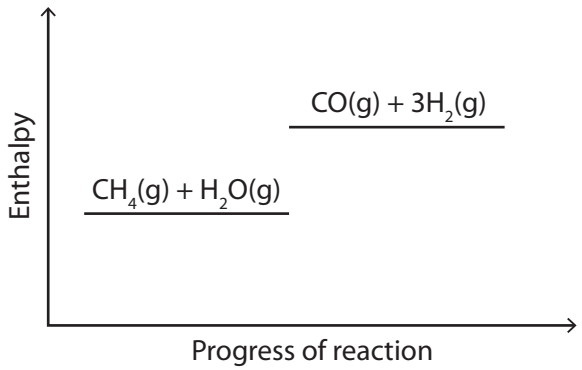
(j) $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ [1]

(k) $Fe(s) + 1\frac{1}{2}O_2(g) + 1\frac{1}{2}H_2(g) \rightarrow Fe(OH)_3(s)$ [1]

(l) $Ca(s) + C(s) + 1\frac{1}{2}O_2(g) \rightarrow CaCO_3(s)$ [1]

(m) $C_2H_6(g) + 3\frac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ [1]

2 **(a)**



[3]

(b) $-206\ kJ\ mol^{-1}$ [1]

(c) **(i)** the enthalpy change when one mole of a compound is formed from its elements under standard conditions [2]

(ii) $C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ [1]

(iii) $C(s) + 2H_2(g) \rightarrow CH_4(g)$ [1]

(d) **(i)** 298 K and 100 kPa [1]

(ii) more energy released forming water than steam/more bonds form between water molecules releasing more energy [2]

(iii) $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ [1]

3 **(a)** enthalpy of products lower than enthalpy of reactants [1]

(b) energy released when bonds form in CO_2 and H_2O [1]
is more than the energy taken in to break bonds in CH_4 and O_2 [1] [2]

(c) label between the two enthalpy levels [1]

4 **(a)**

Enthalpy change	Equation	Value of enthalpy change /kJ mol^{-1}
Standard enthalpy of formation of carbon monoxide	$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$	–99
Standard enthalpy of combustion of propane	$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$	–2200
standard enthalpy of formation of silver chloride	$Ag(s) + \frac{1}{2}Cl_2(g) \rightarrow AgCl(s)$	–127
Standard enthalpy of combustion of potassium	$K(s) + \frac{1}{4}O_2(g) \rightarrow \frac{1}{2}K_2O(s)$	–363
Standard enthalpy of formation of iron(III) oxide	$2Fe(s) + 1\frac{1}{2}O_2(g) \rightarrow Fe_2O_3(s)$	–824
standard enthalpy of formation of sodium nitrate	$Na(s) + \frac{1}{2}N_2(g) + 1\frac{1}{2}O_2(g) \rightarrow NaNO_3(s)$	–468

[5]

(b) **(i)** –254 kJ [1]
(ii) +198 kJ [1]
(iii) –1452 kJ [1]

(c) the enthalpy change when one mole of a substance is completely burnt in oxygen under standard conditions [2]

5 **(a)** $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ [2]

(b) less exothermic [1]
weak acid/some energy used dissociating the acid [1] [2]

(c) Reaction D [1]
strong acid–strong base and 1 mole of water formed [1] [2]

6 Answer is C [1]

Hess's Law

7 $\Delta H = 2(-602) - (-394) = -810$ kJ (mol^{-1}) [2]

8 $\Delta_f H = 5(-394) + 6(-286) - (-3323) = -363$ kJ mol^{-1} [3]

9 **(a)** the enthalpy change when one mole of a compound is formed from its elements under standard conditions [2]

(b) $CH_3OH(l) + 1½O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ [2]

(c) $\Delta_c H = -394 + 2(-286) - \Delta_f H(CH_3OH) = -727$
$\Delta_f H = -394 + 2(-286) + 727 = -239$ kJ mol^{-1} [3]

(d) oxygen is an element in its standard state [1]

(e) (If these elements were reacted together) other products would form/carbon does not react with hydrogen/oxygen under standard conditions [1]

10 **(a)** the enthalpy change for a reaction is independent of the route taken, provided the initial and final conditions are the same [2]

(b) energy cannot be created or destroyed but it can change from one form to another [1]

(c) $2Na(s) + H_2(g) + 2C(s) + 3O_2(g) \rightarrow 2NaHCO_3(s)$
$2Na(s) + C(s) + 1½O_2(g) \rightarrow Na_2CO_3(s)$
$C(s) + O_2(g) \rightarrow CO_2(g)$
$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$

(d) ΔH for $2NaHCO_3 = -1131 + (-394) + (-286) - 2(-948) = +85$
ΔH for 1 mol of $NaHCO_3 = +42.5$ kJ mol^{-1} [4]

11 (a) $\Delta H = -1271 - 6(-394) - 6(-286) = +2809$ kJ mol^{-1} [3]

(b) – 2809 kJ mol^{-1} [1]

12 (a) $-1532 = -4\Delta_f(NH_3) + 6(-286)$

$4\Delta_f H(NH_3) = -184$ kJ

$\Delta_f H(NH_3) = -46$ kJ mol^{-1} [3]

(c) (i) $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ [1]

(ii) $-928 = 4(90) + 6\Delta_f H(H_2O(g)) - 4(-46)$
$6\Delta_f H(H_2O(g)) = -928 - 4(90) + 4(-46) = -1472$ kJ
$\Delta_f H(H_2O(g)) = -245.3$ kJ mol^{-1} [3]

(iii) $\Delta H = -245.3 - (-286) = +40.7$ kJ mol^{-1} [2]

13 Answer is C [1]
$\Delta H = -2542 + 2(-286) - (-2877) = -237$ kJ mol^{-1}

14 (a) $\Delta H = (2(803) + 4(436)) - (4(412) + 4(463))$
$\Delta H = 3350 - 3500 = -150$ kJ mol^{-1} [3]

(b) average bond enthalpy values give an estimate of the value as they are not specific to the compounds involved in the reaction/water is a gas and under standard conditions water is a liquid [1]

15 $\Delta H = (3(146) + 6(463) + (242)) - (2(496) + 2(431) + 4(463))$
$\Delta H = 3458 - 3706 = -248$ kJ (mol^{-1}) [3]

16 $\Delta H = (2(611) + 4(412) + 4(496)) - (6(803) + 4(463))$
$\Delta H = 4854 - 6670 = -1816$ kJ mol^{-1} [3]

17 $-2503 = (3(C—H) + 9(412) + (360) + (463) + 6(496)) - (8(803) + 10(463))$
$-2503 = 3(C—H) + 7507 - 11054$
$3(C—H) = 1044$
C—H = 348 kJ mol^{-1} [4]

18 $-46 = ((611) + 4(412) + 2\Delta H(O—H)) - ((348) + 5(412) + (360) + \Delta H(O—H))$
$-46 = 2259 - 2768 + \Delta H(O—H)$
$\Delta H(O—H) = 463$ kJ mol^{-1} [4]

19 (a) $\Delta H = (12(386) + 3(496)) - (2(916) + 12(463))$
$\Delta H = 6120 - 7388 = -1268$ kJ (mol^{-1}) [3]

(b) $-1268 = 6(-242) - 4\Delta_f H(NH_3)$
$4\Delta_f H(NH_3) = -184$ kJ
$\Delta_f H(NH_3) = -46$ kJ mol^{-1} [3]

20 (a) $\Delta H = 4(-394) + 5(-286) - (-126) = -2880\ kJ\ mol^{-1}$ [3]

(b) the energy required to break one mole of a given bond averaged over many compounds [1]

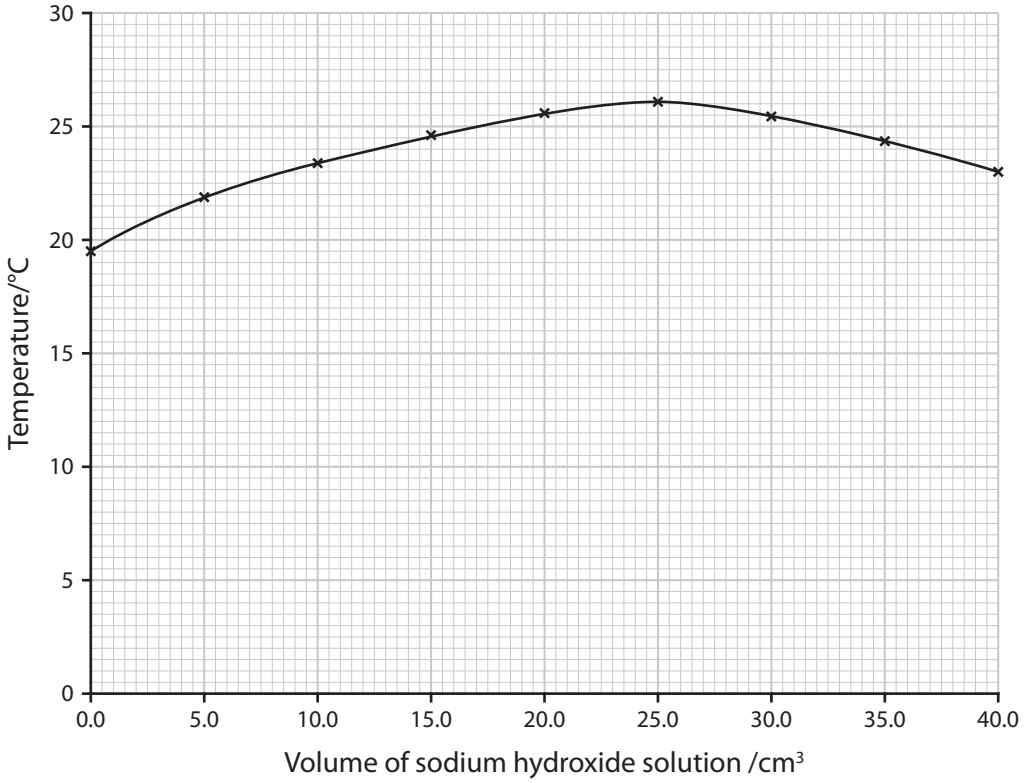
(c) $\Delta H = (3(348) + 10(412) + 6.5(496)) - (8(803) + 10(463))$
$\Delta H = 8388 - 11054 = -2666\ kJ\ mol^{-1}$ [3]

(d) average bond enthalpy values give an estimate of the value as they are not specific to the compounds involved in the reaction/water is a gas and under standard conditions water is a liquid [1]

21 Answer is C [1]
$\Delta H = ((916) + 2(436)) - ((163) + 4(386))$
$\Delta H = 1788 - 1707 = +81\ kJ\ mol^{-1}$

Experimental enthalpy change determination

22 (a)



[3]

(b) moles of NaOH $= \frac{25.0 \times 1.00}{1000} = 0.025$ mol

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

moles of $H_2O = 0.025$ mol [1]

(c) $\Delta T = 26.2 - 19.5 = 6.7\ °C$
$c = 50 \times 4.2 \times 6.7 = 1407\ J$ [2]

(d) $\Delta_n H = \frac{1407}{0.025 \times 1000} = -56.3 \text{ kJ mol}^{-1}$ [2]

(e) no further reaction/excess solution dissipates the heat/larger volume with same heat energy [1]

23 **(a)** better conductor of heat [1]

(b) $C_3H_7OH(l) + 4½O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ [2]

(c) mass of propan–2–ol burned = 142.8 – 141.9 = 0.9 g

moles of propan–2–ol burned = $\frac{0.9}{60} = 0.015$ mol

temperature change = 65.2 – 20.4 = 44.8 °C

energy = $125 \times 4.2 \times 44.8 = 23520$ J

enthalpy of combustion = $\frac{23520}{0.015 \times 1000} = -1568 \text{ kJ mol}^{-1}$ [5]

(d) **(i)** any **two** from:
heat loss of surroundings
heat loss by evaporation
heat energy used to heat the copper can
water is not a gas under standard conditions [2]

(ii) different enthalpies of formation of the alcohols/different bond enthalpies for bonds in propan–1–ol compared to propan–2–ol [1]

24 moles of NaOH = moles of HCl = moles of $H_2O = \frac{25.0 \times 1.00}{1000} = 0.025$ mol

heat energy released in J = 57900 ×0.025 = 1447.5 J

temperature change = $\frac{1447.5}{4.2 \times 50} = 6.9$ °C [3]

25 moles of $C_6H_{14} = \frac{0.24}{86} = 0.002791$ mol

heat energy released = $4195000 \times 0.002791 = 11707$ J

temperature change = $\frac{11707}{4.2 \times 100} = 27.9$ °C [4]

26 **(a)** 33.5 °C [1]

(b) maximum temperature achieved before cooling [1]

(c) moles of HCl = $\frac{50.0 \times 0.250}{1000} = 0.0125$ mol

moles of Mg = $\frac{0.200}{24} = 0.00833$ mol

moles of HCl required for 0.00833 mol of Mg = 0.01667 mol
HCl limiting reactant [3]

(d) $\Delta T = 33.5 - 20 = 13.5\ ^\circ C$

heat energy $= 50 \times 4.18 \times 13.5 = 2821.5$ J

enthalpy change $= \dfrac{2821.5}{0.0125 \times 1000} = -226$ kJ mol^{-1} [3]

2.9 Kinetics

Kinetics of a reaction

1 **(a)** reaction rate increases [1]
reactant particles have more energy [1]
more collisions per unit time and more successful collisions per unit time [1] [3]

(b) reaction rate increases [1]
particles closer together/smaller volume [1]
more collisions per unit time and more successful collisions per unit time [1] [3]

(c) reaction rate increases [1]
catalyst provides an alternative reaction pathway [1]
(of) lower activation energy [1] [3]

(d) reaction rate increases [1]
more reactant particles [1]
more collisions per unit time and more successful collisions per unit time [1] [3]

2 **(a)** exothermic as ΔH is negative/enthalpy of products lower than enthalpy of reactants [1]

(b) reaction pathway for uncatalysed reaction = C
activation energy for catalysed reaction = D
enthalpy change = E
activation energy for uncatalysed reaction = B
reaction pathway for catalysed reaction = A [3]

(c) provides an alternative reaction pathway of lower activation energy [1]

3 Answer is C [1]

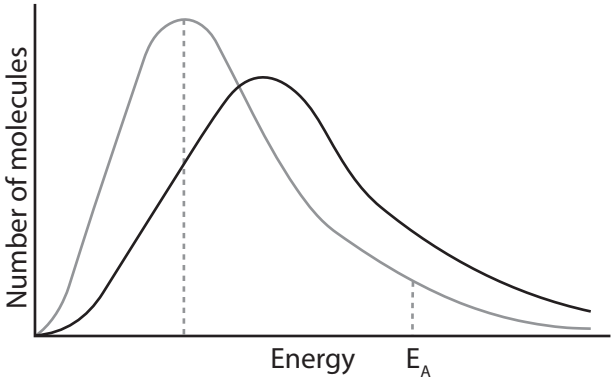
Maxwell–Boltzmann distribution

4 **(a)** no molecules have zero energy [1]
there is no upper limit to the energy of the molecules [1] [2]

(b) label below right hand vertical line as shown below [1]

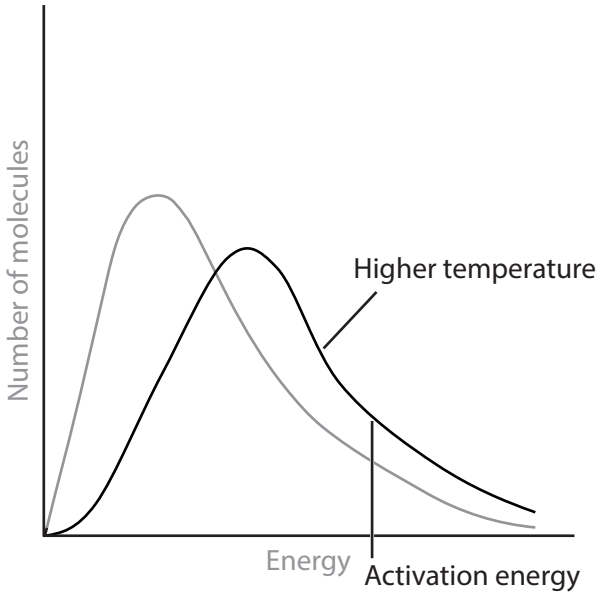
(c) start at origin, lower peak moved to the right, crosses other line once as shown below [1]

(d)



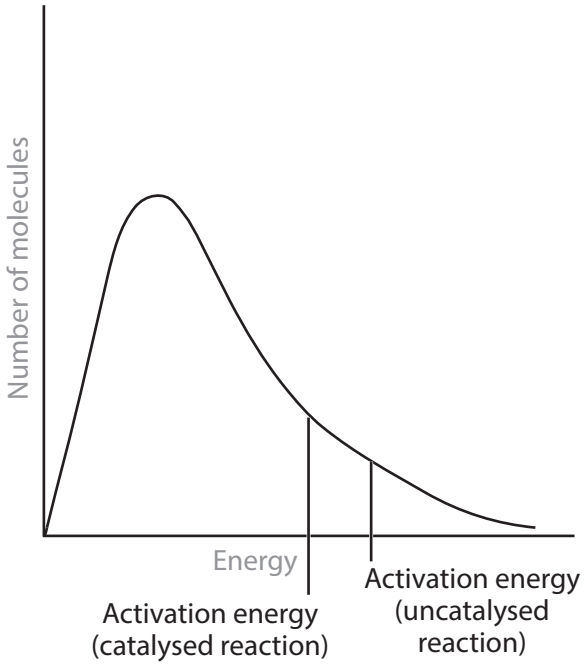
(d) more molecules with energy greater than the activation energy [1]

5 **(a)** start at origin, lower peak moved to the right, crosses other line once as shown below [1]



higher temperature gives a higher rate of reaction [1]
activation energy labelled [1]
more molecules have energy greater than activation energy at higher temperature [1] [4]

(b)



activation energy for uncatalysed reaction labelled [1]
lower activation energy for catalysed reaction labelled [1]
more molecules have energy greater than activation energy in the presence of a catalyst [1] [3]

6 **(a)** B [1]

(b) C [1]

(c) A and B [1]

(d) lower activation energy [1]
more molecules have energy greater than the activation energy in presence of a catalyst [1] [2]

2.10 Equilibrium

Equilibria and industrial conditions

1 **(a)** a reversible reaction in which the amount of each reactant/product remains constant [1]
rate of forward reaction is equal to the rate of the backward reaction [1] [2]

(b) a reaction in which all the reactants and products are in the same physical state [1]
all are gases in this reaction [1] [2]

(c) yield of SO_3 increases [1]
reaction is exothermic [1]
position of equilibrium shifts to the right [1] [3]

(d) yield of SO_3 increases [1]
3 moles of gas on left hand side (LHS) → 2 moles of gas on right hand side (RHS) [1]
position of equilibrium shifts to the right [1] [3]

(e) compromise temperature [1]
compromise between rate and yield [1] [2]

(f) too expensive as thicker pipes are required/more steel [1]

2 **(a)**

(i) reaction exothermic [1]
position of equilibrium shifts to the right at lower temperatures [1] [2]

(ii) compromise temperature [1]
compromise between rate and yield [1] [2]

(b) increase rate of reaction [1]

(c) no effect [1]
catalyst speeds up forward and reverse reactions equally [1] [2]

3 **(a)** $\Delta H = -(-75) - (-242) + (-111) = +206$ kJ (mol^{-1}) [2]

(b) high temperature as forward reaction is endothermic [1]
position of equilibrium shifts to the right [1] [2]

(c) low pressure as 2 moles of gas on LHS → 4 moles of gas on RHS [1]
position of equilibrium shifts to right [1] [2]

(d) cheaper than methane [1]

4 **(a)** $N_2 + 3H_2 \rightleftharpoons 2NH_3$ [2]

(b) compromise between rate and yield [1]

(c) 4 moles of gas on LHS → 2 moles of gas on RHS [1]
position of equilibrium moves to right at high pressure [1] [2]

(d) no effect [1]

5 **(a)** increase in temperature shifts position of equilibrium to left [1]
reverse reaction is endothermic so forward reaction is exothermic [1] [2]

(b) yield of CH_3OH decreases [1]
3 moles of gas on LHS and 1 mole of gas on RHS [1]
position of equilibrium shifts to the left [1] [3]

(c) yield of CH_3OH increases [1]
position of equilibrium shifts to the right [1]
to remove the added hydrogen [1] [3]

6 Answer is C [1]

The equilibrium constant, K_c

7 **(a)** $K_c = \frac{[NO_2]^2}{[NO]^2[O_2]}$ [1] units: $mol^{-1}\ dm^3$ [1] [2]

(b) $K_c = \frac{[NO_2]^2}{[N_2O_4]}$ [1] units: $mol\ dm^{-3}$ [1] [2]

(c) $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$ [1] units: $mol^{-2}\ dm^6$ [1] [2]

(d) $K_c = \frac{[CO_2][H_2]^4}{[CH_4][H_2O]^2}$ [1] units: $mol^2\ dm^{-6}$ [1] [2]

(e) $K_c = \frac{[H_2][I_2]}{[HI]^2}$ [1] units: none [1] [2]

8 **(a)** $K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$ [1] units: mol dm^{-3} [1] [2]

(b) position of equilibrium shifts to the left [1]
1 mole of gas on LHS and 2 moles of gas on RHS [1] [2]

(c) forward reaction is endothermic [1]
position of equilibrium shifts to the right [1] [2]

(d) position of equilibrium unchanged [1]
catalyst speeds up forwards and reverse reactions equally [1] [2]

9 **(a)** concentrations cancel out in K_c expression [1]

(b) K_c decreases as temperature increases [1]
forward reaction is exothermic [1] [2]

10 Answer is B [1]

2.11 Group II Elements and Their Compounds

Group II metals

1 **(a)** an element which has an atom with highest energy/outer electrons in an s–subshell [1]

(b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 5s^2$ [1]

(c) **(i)** outer electron further from nucleus/atomic radius increases [1]
more shielding by inner electrons [1]
less energy required to remove an electron [1] [3]

(ii) outer electrons in energy levels/shells further from nucleus [1]

2 **(a)** $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$ [1]

(b) calcium hydroxide slightly soluble in water [1]
initial solution of calcium hydroxide colourless [1]
when saturated white solid calcium hydroxide appears [1] [3]

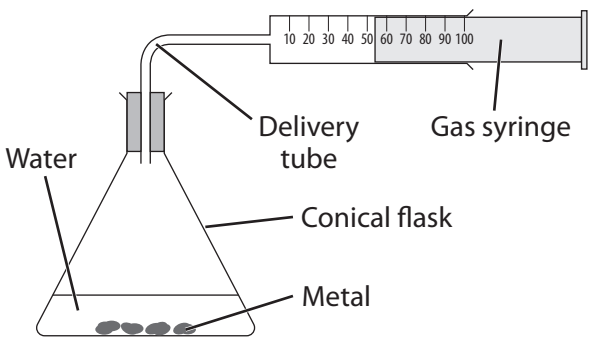
(c) **(i)** $2Ca + O_2 \rightarrow 2CaO$ [1]

(ii) red/brick red flame [1]
explosive [1]
white solid formed [1] any [2]

(iii) surface layer of calcium oxide prevents immediate reaction [1]

(d) magnesium = white
strontium = red
barium =green/apple green [2]

3 **(a)**



[3]

(b) moles of $H_2 = \frac{45}{24000} = 1.875\times10^{-3}$ mol

moles of M = 1.875×10^{-3} mol

relative atomic mass of M = $\frac{0.165}{1.875 \times 3} = 88$

identity = strontium [3]

(c) too small to be accurately measurable/very low mass of H_2 lost [1]

Group II metal compounds and solubility

4 **(a)** $SrCO_3 \rightarrow SrO + CO_2$ [1]

(b) thermal stability increases down the group [1]
cation size increases/charge density of cation decreases [1]
down the group cation has less polarising effect on carbonate ion [1] [3]

5 **(a)** $CaCO_3 \rightarrow CaO + CO_2$ [1]

$CaO + H_2O \rightarrow Ca(OH)_2$ [1] [2]

(b) moles of CaO = $\frac{8.00}{56} = 0.1429$ mol

energy released = $65000 \times 0.01429 = 9285.7$ J

$\Delta T = \frac{9285.7}{100 \times 4.2} = 22.1$ °C [3]

(c) **(i)** reacts with acids [1]

(ii) cement/concrete/slaked lime manufacture [1]

(d) **(i)** $Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$ [1]

(ii) $H^+ + OH^- \rightarrow H_2O$ [1]

(iii) $Ca^{2+} + SO_4^{2-} \rightarrow CaSO_4$ [1]

(e) solubility of sulfates decreases and solubility of hydroxides increases [1]

6 **(a)** the maximum mass of a solute that will dissolve in 100 g of solvent at a stated temperature [2]

(b) moles = $\frac{0.255}{136}$ = 0.001875 mol

concentration = 0.001875 × 10 = 0.0188 mol dm^{-3} [2]

(c) **(i)** solubility at 30 °C = 40 g/100 g water

$\frac{16}{40} \times 100 = 40$ g water [2]

(ii) solubility at 50 °C = 50 g/100 g water
solubility at 20 °C = 36 g/100 g water
difference in solubility = 50 – 36 = 14 g

for 28 g water: mass of solid = $\frac{28}{100} \times 14 = 3.92$ g [2]

(iii) contains water of crystallisation/water lost by evaporation [1]

(iv) solubility at 26 °C = 38 g/100 g water
mass in 250 g of water = 38 × 2.5 = 95 g
125 – 95 = 30 g [2]

7 Answer is C [1]