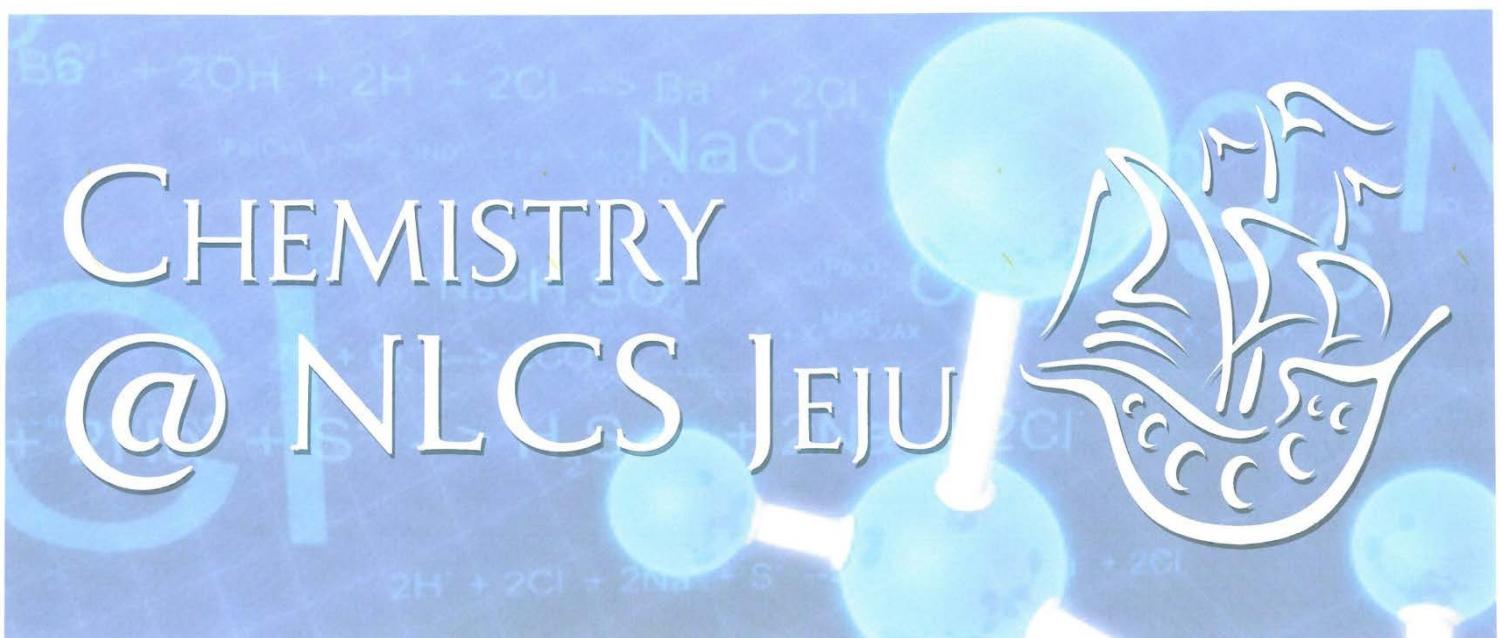


# IB Past Paper 2

# Standard Level



**Summer Papers**  
**2013 to 2001**

Name: \_\_\_\_\_

Class: \_\_\_\_\_ Teacher: \_\_\_\_\_

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## Topic 1 Questions

SL A 13s

1. A student decided to determine the molecular mass of a solid monoprotic acid, HA, by titrating a solution of a known mass of the acid.

The following recordings were made.

Mass of bottle / g $\pm 0.001\text{ g}$	1.737	-
Mass of bottle + acid HA / g $\pm 0.001\text{ g}$	2.412	

- (a) Calculate the mass of the acid and determine its absolute and percentage uncertainty. [2]

$$\text{Mass of acid HA} = 0.675 \pm 0.002\text{ g} \quad \text{uncertainties add up}$$

$$\text{Absolute Uncertainty} = \frac{0.002}{0.675} = 0.001481 \approx 0.003$$

$$\text{Percentage Uncertainty} = \frac{0.001481}{0.675} \cdot 100 = 1.181\% \approx 3\%$$

- (b) This known mass of acid, HA, was then dissolved in distilled water to form a  $100.0\text{ cm}^3$  solution in a volumetric flask. A  $25.0\text{ cm}^3$  sample of this solution reacted with  $12.1\text{ cm}^3$  of a  $0.100\text{ mol dm}^{-3}$  NaOH solution. Calculate the molar mass of the acid. [3]

$$n_{\text{NaOH}} = \frac{12.1 \cdot 10^{-3}\text{ dm}^3 \cdot 0.100\text{ mol dm}^{-3}}{100} = 1.21 \cdot 10^{-3}\text{ mol}$$

$$1.21 \cdot 10^{-3}\text{ mol} = \frac{25.0 \cdot 10^{-3}\text{ dm}^3}{C_{\text{HA}}} \quad n_{\text{NaOH} \text{ 100.0 cm}^3} = 1.21 \cdot 10^{-3}\text{ mol} \cdot 4 = 4.84 \cdot 10^{-3}\text{ mol}$$

$$C_{\text{HA}} = \frac{1.21 \cdot 10^{-3}\text{ mol}}{25.0 \cdot 10^{-3}\text{ dm}^3} \quad \text{unlabelled, and this is the concentration for the 25.0 cm}^3 \text{ sample.}$$

$$M_{\text{HA}} = \frac{0.675\text{ g}}{\frac{1.21 \cdot 10^{-3}\text{ mol}}{4.84}} = 558\text{ g mol}^{-1}$$

- (c) The percentage composition of HA is 70.56% carbon, 23.50% oxygen and 5.94% hydrogen. Determine its empirical formula. [2]

Let  $m_{\text{HA}} = 100 \text{ g}$

$$\frac{70.56 \text{ g}}{12.01 \text{ g/mol}^{-1}} = 5.875 \text{ mol C} \quad | \quad \frac{23.50 \text{ g}}{16 \text{ g/mol}^{-1}} = 1.46875 \text{ mol O} \quad | \quad \frac{5.94 \text{ g}}{1.01 \text{ g/mol}^{-1}} = 5.8819 \text{ mol H}$$

$$\frac{5.875 \text{ mol}}{1.46875 \text{ mol}} = 4 \text{ C} \quad | \quad \frac{5.8819 \text{ mol}}{1.46875 \text{ mol}} = 4 \text{ H} \quad | \quad 1 \text{ Oxygen}$$

Empirical Formula =  $\text{C}_4\text{H}_4\text{O}$

2. In 1921 Thomas Midgley discovered that the addition of a lead compound could improve the combustion of hydrocarbons in automobile (car) engines. This was the beginning of the use of leaded gasoline (petrol).

The percentage composition, by mass, of the lead compound used by Midgley is shown below.

	Pb	C	H
Mass composition / %	64.052	29.703	6.245

- (a) (i) Determine the empirical formula of the lead compound.

[3]

Let m = 100g

$$29.703 \text{ g} / 12.01 \text{ g mol}^{-1} = 2.4731 \text{ mol C}$$

$$64.052 \text{ g} / 207.20 \text{ g mol}^{-1} = 0.3091 \text{ mol Pb}$$

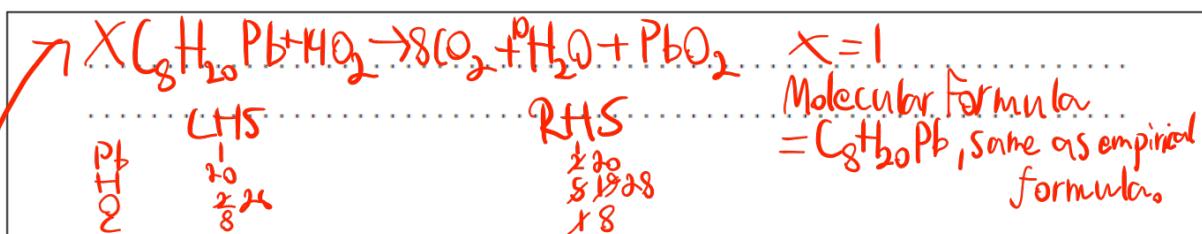
$$6.245 \text{ g} / 1.01 \text{ g mol}^{-1} = 6.1831 \text{ mol H}$$

Empirical Formula =  $\text{C}_8\text{H}_{20}\text{Pb}$

- (ii) Leaded gasoline has been phased out because the lead(IV) oxide,  $\text{PbO}_2$ , produced as a side product in the combustion reaction, may cause brain damage in children.

0.01 mol of Midgley's lead compound produces 0.01 mol of lead(IV) oxide. Deduce the molecular formula of Midgley's compound.

[1]



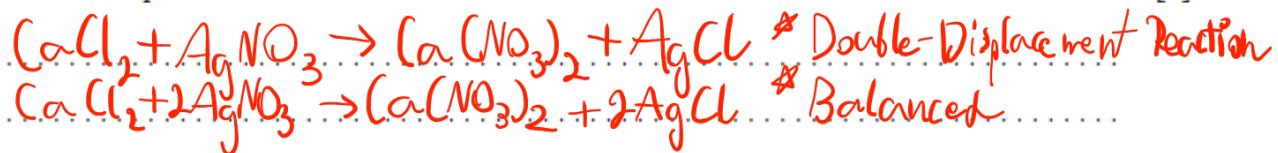
- (iii) Determine the equation for the complete combustion of Midgley's compound.

[2]

I should've been able to tell directly from the 1:1 ratio between the only two elements in the reaction equation that contain Pb that the molecular mass = the empirical mass.

1. A 0.265 g sample of a mixture of calcium chloride,  $\text{CaCl}_2$ , and potassium nitrate,  $\text{KNO}_3$ , is dissolved in  $50.0 \text{ cm}^3$  of water. This mixture is titrated with  $0.100 \text{ mol dm}^{-3}$  silver nitrate,  $\text{AgNO}_3$ , which reacts with the chloride ions present to form insoluble silver chloride,  $\text{AgCl}$ . The titration required  $38.5 \text{ cm}^3$  of silver nitrate.

- (a) Write an equation for the reaction between calcium chloride and silver nitrate. [2]



- (b) Calculate the amount, in moles, of silver nitrate used in the reaction. [2]

$$38.5 \cdot 10^{-3} \text{ dm}^3 \text{ AgNO}_3 \cdot 0.100 \text{ mol dm}^{-3} \text{ AgNO}_3 = 3.85 \cdot 10^{-3} \text{ mol AgNO}_3$$

- (c) Calculate the amount, in moles, of calcium chloride titrated and the mass of calcium chloride present in the original sample. [3]

$$\text{CaCl}_2 : \text{AgNO}_3 = 1 : 2$$

$$n_{\text{CaCl}_2 \text{ titrated}} = 3.85 \cdot 10^{-3} \text{ mol CaCl}_2 / 2 = 1.925 \cdot 10^{-3} \text{ mol CaCl}_2$$

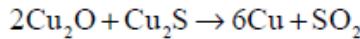
$$m_{\text{CaCl}_2 \text{ og}} = \frac{(1.925 \cdot 10^{-3} \text{ mol CaCl}_2) (50)}{1000} (40.08 + 35.45(2)) \text{ g/mol} \quad \text{CaCl}_2$$

$$m_{\text{CaCl}_2 \text{ og}} = 0.214 \text{ g}$$

- (d) Calculate the percentage of calcium chloride in the original sample. [1]

$$\frac{0.214}{0.265} \cdot 100 \approx 80.6\%$$

3. Copper metal may be produced by the reaction of copper(I) oxide and copper(I) sulfide according to the below equation.



A mixture of 10.0 kg of copper(I) oxide and 5.00 kg of copper(I) sulfide was heated until no further reaction occurred.

- (a) Determine the limiting reagent in this reaction, showing your working.

[3]

$$63.55(2) + 16 = 143.1 \text{ g mol}^{-1} \text{ Cu}_2\text{O}$$

$$63.55(2) + 32.07 = 159.17 \text{ g mol}^{-1} \text{ Cu}_2\text{S}$$

$$143.1 \text{ g mol}^{-1} \text{ Cu}_2\text{O} / 2 = 71.55 \text{ g mol}^{-1} \text{ Cu}_2\text{O}$$

$$71.55 \text{ g mol}^{-1} \text{ Cu}_2\text{O} < 159.17 \text{ g mol}^{-1} \text{ Cu}_2\text{S}$$

Therefore, copper(I) oxide is the limiting reagent.

- (b) Calculate the maximum mass of copper that could be obtained from these masses of reactants.

[2]

$$\text{Cu}_2\text{O} : \text{Cu} = 2 : 6 = 1 : 3$$

$$n_{\text{Cu}_2\text{O}} = \frac{10,000 \text{ g Cu}_2\text{O}}{143.1 \text{ g mol}^{-1} \text{ Cu}_2\text{O}} = 69.88/2 \text{ mol Cu}_2\text{O} \rightarrow n_{\text{Cu}} = 69.88/2 \cdot 3 \text{ mol Cu}$$

$$m_{\text{Cu max}} = 209.644 \text{ mol Cu} \cdot 63.55 \text{ g mol}^{-1} \text{ Cu} = 13,322.9 \text{ g Cu}$$

$$m_{\text{Cu max}} \approx 13.3 \text{ kg Cu}$$

SL A 05s

(a) Find num. of moles for each with mass and molar mass and compare; the smaller of the two is the limiting reagent.

$$n_{\text{Cu}_2\text{O}} = \frac{10,000 \text{ g Cu}_2\text{O}}{143.1 \text{ g mol}^{-1} \text{ Cu}_2\text{O}} \approx 69.9 \text{ mol Cu}_2\text{O} \quad \left| \begin{array}{l} n_{\text{Cu}_2\text{S}} = \frac{5,000 \text{ g Cu}_2\text{S}}{159.17 \text{ g mol}^{-1}} \approx 31.4 \text{ mol Cu}_2\text{S} \\ \text{Smaller} \end{array} \right.$$

Therefore, copper(I) sulfide is the limiting reagent.

(b) Same methodology with new limiting reagent:

$$\text{Cu}_2\text{S} : \text{Cu} = 1 : 6$$

$$n_{\text{Cu}} = 31.4 \text{ mol Cu}_2\text{S} \cdot 6 \approx 188.5 \text{ mol Cu}$$

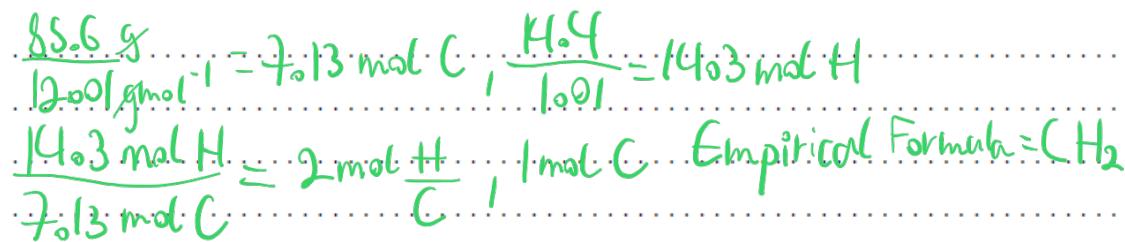
$$m_{\text{Cu max}} = 188.5 \text{ mol Cu} \cdot 63.55 \text{ g mol}^{-1} \text{ Cu} = 11,977.8 \text{ g Cu}$$

$$\approx 12 \text{ kg Cu}$$

2. The percentage composition by mass of a hydrocarbon is C = 85.6 % and H = 14.4 %.

- (a) Calculate the empirical formula of the hydrocarbon.

[2]



- (b) A 1.00 g sample of the hydrocarbon at a temperature of 273 K and a pressure of  $1.01 \times 10^5$  Pa (1.00 atm) has a volume of 0.399 dm<sup>3</sup>.

- (i) Calculate the molar mass of the hydrocarbon.

[2]

$$\begin{aligned} PV &= \frac{m}{M} RT \quad M_{\text{CH}_2} = \frac{1.00\text{ g} \cdot 8.31 \cdot 273\text{ K}}{1.01 \cdot 10^5 \text{ Pa} \cdot 0.399\text{ dm}^3} \approx 56.3 \text{ g mol}^{-1} \text{ CH}_2 \\ M &= \frac{mRT}{PV} \end{aligned}$$

- (ii) Deduce the molecular formula of the hydrocarbon.

[1]

$$\begin{aligned} M_{\text{CH}_2} &= 12.01 + 1.01(2) = 14.03 \text{ g mol}^{-1} \text{ CH}_2 \\ \frac{56.3}{14.03} &\approx 4 \quad \text{Molecular Formula: } \text{C}_4\text{H}_8 \end{aligned}$$

SL A 02s

3. A student was asked to make some copper(II) sulfate-5-water ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) by reacting copper(II) oxide ( $\text{CuO}$ ) with sulfuric acid.

- (a) Calculate the molar mass of copper(II) sulfate-5-water.

[1]

$$63.55 + 32.07 + 16(4) + 5[1.01(2) + 16] = 249.72 \text{ g mol}^{-1} (\text{CuSO}_4 \cdot 5\text{H}_2\text{O})$$

- (b) Calculate the amount (in mol) of copper(II) sulfate-5-water in a 10.0 g sample.

[1]

$$n = \frac{10.0\text{ g}}{249.72 \text{ g mol}^{-1}} \approx 4 \cdot 10^{-2} \text{ mol}$$

- (c) Calculate the mass of copper(II) oxide needed to make this 10.0 g sample.

[1]

## Topic 1 Mark Scheme

SL A 13s

1. (a)  $0.675 \text{ (g)} \pm 0.002 \text{ (g)}$ ;  
*Percentage uncertainty: 0.3 %;*  
*Accept answers correct to one, two or three significant figures for percentage uncertainty.* [2]

(b) In  $25.0 \text{ cm}^3$ :  $n_{\text{HA}} = 1.21 \times 10^{-3} \text{ (mol)}$ ;  
In  $100 \text{ cm}^3$ :  $n_{\text{HA}} = 4.84 \times 10^{-3} \text{ (mol)}$ ;  
 $M = \frac{0.675}{4.84 \times 10^{-3}} = 139 \text{ (g mol}^{-1}\text{)}$ ; [3]

*Award [3] for correct final answer.*  
*Accept suitable alternative methods.*

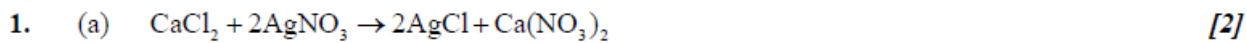
(c)  $n_{\text{C}}: \left( \frac{70.56}{12.01} = \right) 5.88$  and  $n_{\text{O}}: \left( \frac{23.50}{16} = \right) 1.47$  and  $n_{\text{H}}: \left( \frac{5.94}{1.01} = \right) 5.88$ ;  
 $\text{C}_4\text{H}_8\text{O}$ ; [2]

*Award [2] for correct final answer.*  
*Accept answers using integer values of molar mass.*

### SL A 12s

2. (a) (i)  $n(\text{Pb}): \left( \frac{64.052}{207.19} \right) = 0.30915 \text{ (mol)}$   
 $n(\text{C}): \left( \frac{29.703}{12.01} \right) = 2.473 \text{ (mol)}$   
 $n(\text{H}): \left( \frac{6.245}{1.01} \right) = 6.18 \text{ (mol)}$   
*Do not penalize if integer values of atomic masses used.*  
*Accept alternative calculation method.*  
*Award [2] for three correct.*  
*Award [1] for any two correct.*
- PbC<sub>8</sub>H<sub>20</sub>; [3]
- (ii) PbC<sub>8</sub>H<sub>20</sub>; [1]
- (iii) PbC<sub>8</sub>H<sub>20</sub> + 14O<sub>2</sub> → PbO<sub>2</sub> + 8CO<sub>2</sub> + 10H<sub>2</sub>O  
correct reactants and products;  
correct coefficients; [2]  
*M2 can only be scored if M1 correct.*

### SL A 08s



*Allow a correct ionic equation*

*Award [1] for correct reactants and products and [1] for balanced equation.*

(b)  $0.100 \times 0.0385 \text{ dm}^3;$   
 $= 3.85 \times 10^{-3} \text{ mol};$  [2]

(c)  $1.92 \times 10^{-3} \text{ mol} / 1.93 \times 10^{-3} \text{ mol};$   
 $1.92 \times 10^{-3} \times 110.98 / 111;$   
 $= 0.214 / 0.213 \text{ (g);}$  [3]

(d)  $\frac{0.214}{0.265} \times 100 / \frac{0.213}{0.265} \times 100 = 80.7 / 80.8 / 80.4 \text{ (%);}$  [1]

*Allow ECF throughout question one.*

SL A 06s

3. (a)  $n(\text{Cu}_2\text{O}) = 10.0 \times 10^3 \div 143.1 = 69.9 \text{ mol;}$

$n(\text{Cu}_2\text{S}) = 5.00 \times 10^3 \div 159.16 = 31.4 \text{ mol;}$

*Penalise failure to convert kg → g once only.*

$\text{Cu}_2\text{S}$  is the limiting reagent; [3]  
*ECF from above answers.*

(b)  $n(\text{Cu}) = 6 \times n(\text{Cu}_2\text{S}) = 6 \times 31.4 = 188 \text{ mol;}$   
 $m(\text{Cu}) = 188 \times 63.55 = 11900 - 12000 \text{ g} / 11.9 - 12.0 \text{ kg;}$  [2]

*If Cu<sub>2</sub>O given in (a), allow 3 × n(Cu<sub>2</sub>O) and 3 × n(Cu<sub>2</sub>O) × 63.55.*

*Allow ECF from (a).*

SL A 05s

2. (a) mole ratio C : H =  $\frac{85.6}{12.01} : \frac{14.4}{1.01} = 7.13 : 14.3$ ;

No penalty for using integer atomic masses.

empirical formula is CH<sub>2</sub>;

[2]

(b) (i) number of moles of gas n =  $\frac{PV}{RT} = \frac{\text{mass}}{\text{molar mass}} ; \frac{1.01 \times 10^2 \text{kPa} (.399 \text{ dm}^3)}{8.314 \frac{\text{J}}{\text{mol K}} (273 \text{ K})}$ ;

$$\frac{1.00 \text{ g}}{.017 \text{ mol}} = 56.3 \text{ (g mol}^{-1}\text{)}$$

[2]

OR

molar mass is the  $\frac{\text{mass of the molar volume}}{22.4 \text{ dm}^3}$  at STP;

$$= \frac{1.00 \times 22.4}{0.399} = 56.1 \text{ (g mol}^{-1}\text{)}$$

Accept answers in range 56.0 to 56.3.

Accept two, three or four significant figures.

(ii) C<sub>4</sub>H<sub>8</sub>;

No ECF.

[1]

SL A 02s

3. (a) 249.71 (allow 249–250)

[1]

(b) 0.04005 (accept 0.04)

[1]

(c) 3.19 (g)

[1]

## Topic 10 Questions

SL B 13s

8. Ethene belongs to the homologous series of the alkenes.

- (a) (i) Outline **three** features of a homologous series.

[3]

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- (ii) Describe a test to distinguish ethene from ethane, including what is observed in **each** case.

[2]

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- (iii) Bromoethane can be produced either from ethene or from ethane. State an equation for **each** reaction.

[2]

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(b) A bromoalkane,  $\text{C}_4\text{H}_9\text{Br}$ , reacts with a warm, aqueous sodium hydroxide solution, NaOH.

(i) State the equation for the reaction of  $\text{C}_4\text{H}_9\text{Br}$  with NaOH.

[1]

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(ii) Suggest what would happen to the pH of the solution as the reaction proceeds.

[1]

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(c) The time taken to produce a certain amount of product using different initial concentrations of  $\text{C}_4\text{H}_9\text{Br}$  and NaOH is measured. The results are shown in the following table.

Reaction	$[\text{C}_4\text{H}_9\text{Br}] / 10^{-2} \text{ mol dm}^{-3}$	$[\text{NaOH}] / 10^{-3} \text{ mol dm}^{-3}$	$t / \text{s}$
A	1.0	2.0	46
B	2.0	2.0	23
C	2.0	4.0	23

(i) Deduce the effect of the concentration of  $\text{C}_4\text{H}_9\text{Br}$  and NaOH on the rate of reaction. [2]

$\text{C}_4\text{H}_9\text{Br}$ :

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NaOH:

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(ii) Suggest why **warm** sodium hydroxide solution is used. [1]

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(iii) Deduce whether  $C_4H_9Br$  is a primary or tertiary halogenoalkane. [2]

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(iv) Determine the structural formula of  $C_4H_9Br$ . [1]

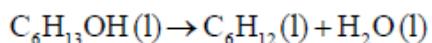
(v) Describe, using an equation, how  $C_4H_9Br$  can be converted into  $C_4H_8Br_2$ . [1]

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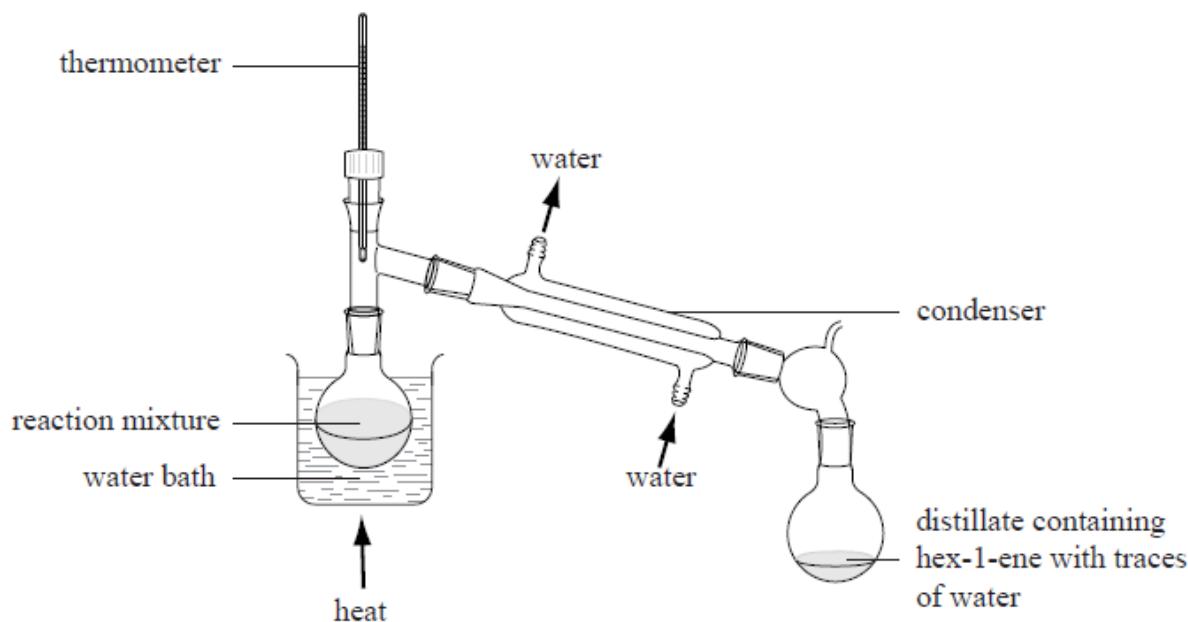
- (d) Explain the mechanism for the reaction in (c) of C<sub>4</sub>H<sub>9</sub>Br with NaOH, using curly arrows to represent the movement of electron pairs. [4]

SL B 12s

7. A student prepared hex-1-ene,  $C_6H_{12}$ , from hexan-1-ol,  $C_6H_{13}OH$ , by a dehydration reaction.



The apparatus for this preparation is shown below. The reaction mixture contains 5.00 g of hexan-1-ol and an excess of concentrated sulfuric acid, which removes the water from the organic compound.



The distillate was dried to obtain 2.62 g of hex-1-ene.

- (a) (i) Determine the amount, in mol, of hexan-1-ol present in the reaction mixture.

[2]

(ii) Calculate the percentage yield of hex-1-ene produced.

[2]

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(iii) Another student repeated the experiment and reported a yield of 5.24 g of organic product. Comment on this result.

[2]

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(b) Hex-1-ene can be converted to hexane in a single step.

(i) State the reagent and conditions needed and draw the structural formula of the product. [2]

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- (ii) Deduce the names of three isomers of hexane.

[3]

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- (iii) Identify the compound with the molecular formula  $C_6H_{14}$  which has the highest boiling point and explain your choice.

[3]

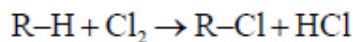
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- (iv) The conversion of carbon-carbon double bonds to carbon-carbon single bonds is an important stage in the synthesis of a commercial product. Identify this commercial product.

[1]

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- (c) (i) Hexane reacts with chlorine to form different products. The reactions can be represented by the following equation, where R is an alkyl chain.



Describe the stepwise mechanism by giving **one** equation for each step and state the essential condition in the initiation step. [4]

Initiation:

.....

Essential condition:

.....

Propagation:

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Termination:

.....

- (ii) Deduce the number of straight-chain structural isomers produced with the molecular formula  $\text{C}_6\text{H}_{13}\text{Cl}$ . [1]

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6. Alkenes are important starting materials for a variety of products.

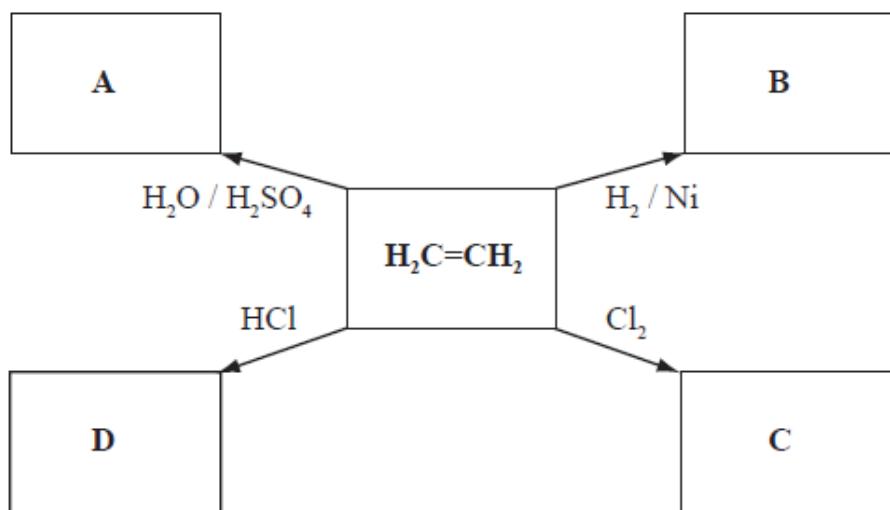
- (a) State and explain the trend of the boiling points of the first five members of the alkene homologous series. [3]

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- (b) Describe **two** features of a homologous series. [2]

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- (c) Below is a schematic diagram representing some reactions of ethene. The letters A–D represent the organic compounds formed from the reactants and catalysts shown.



Deduce the structural formulas of compounds A, B, C, and D and state the IUPAC name of compound C.

[5]

A:

B:

C:

IUPAC name: .....

D:

(d) Describe a chemical test that could be used to distinguish between pent-1-ene and pentane. [2]

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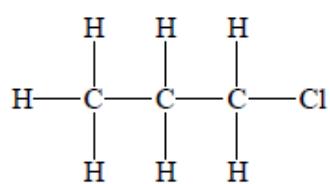
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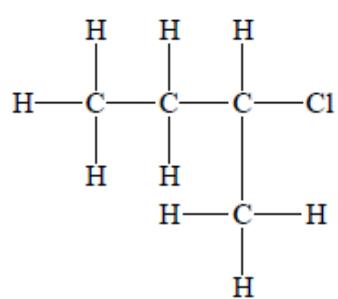
- (e) State and explain whether the following molecules are primary, secondary or tertiary halogenoalkanes.

[4]

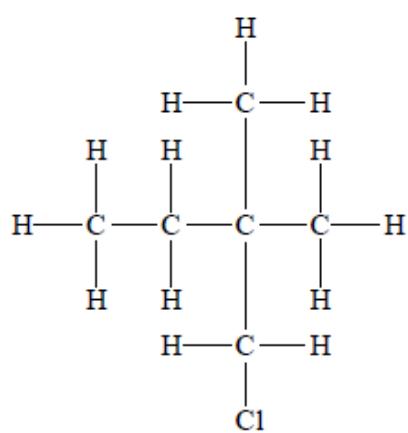
E:



F:



G:



- (f) Explain, using equations, the following steps in the free-radical mechanism of the reaction of methane with chlorine. [4]

  - Initiation
  - Propagation
  - Termination

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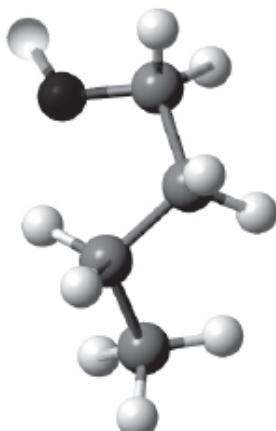
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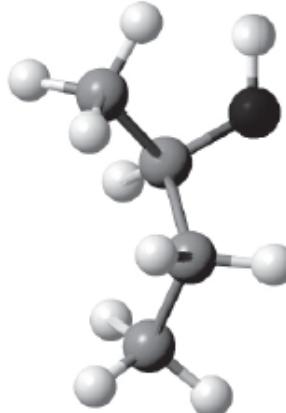
- (b) Ethanol is part of the homologous series of alcohols. Describe two features of a homologous series. [2]

- (c) (i) Below are four structural isomers of alcohols with molecular formula  $C_4H_{10}O$ . State the name of each of the isomers A, B, C and D.

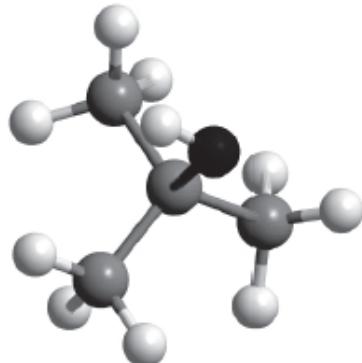
[4]



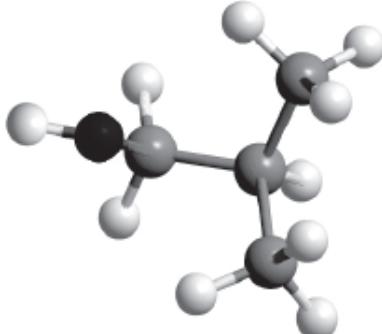
A



B



C



D

Key:

- Oxygen
- Carbon
- Hydrogen

- (ii) Determine the isomer that cannot be oxidized by acidified potassium dichromate(VI),  $K_2Cr_2O_7$ .

[1]

- (iii) Determine the isomer which can be oxidized to butanal.

[1]

- (iv) Determine the isomer which can be oxidized to butanone.

[1]

- (v) Suggest the structural formula of another isomer of  $C_4H_{10}O$ .

[1]

- (d) (i) Isomer A is formed by reacting 1-bromobutane with aqueous sodium hydroxide. State whether the reaction would proceed via an  $S_N1$  or  $S_N2$  mechanism.

[1]

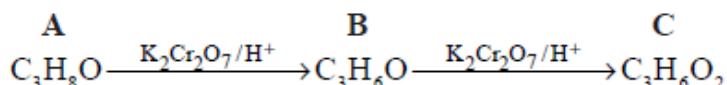
- (ii) Explain the mechanism named in part (d) (i) using curly arrows to represent the movement of electron pairs.

[3]

7. (a) Three compounds with similar relative molecular masses are butane, propanal and propan-1-ol.
- List the three compounds in order of increasing boiling point (lowest first) and explain the differences in their boiling points. [4]
  - Predict, with an explanation, which of the three compounds is least soluble or miscible in water. [2]
  - When propan-1-ol is oxidized using a warm acidified solution of potassium dichromate(VI) two different organic products can be obtained. Deduce the name and structural formula for each of these two products. [3]
  - Propan-2-ol is an isomer of propan-1-ol. Draw the structure of propan-2-ol. [1]
  - Identify the class of alcohols that propan-2-ol belongs to and state the name of the organic product formed when it is oxidized by an acidified solution of potassium dichromate(VI). [2]
- (b) Ethanol can be formed from ethene in a two step reaction:
- 
- (i) State the name of the reagent used for step 1. [1]
- (ii) State the name of the reagent and the conditions used for step 2. [2]
- (iii) The mechanism involved in step 2 is S<sub>N</sub>2. Explain how the reaction proceeds using curly arrows to represent the movement of electron pairs. [3]
- (iv) Outline how ethanol is manufactured from ethene in industry and state one important commercial use of ethanol. [2]

SL B 08sQ8

- (c) The sequence shows some reactions of organic compounds.



- (i) Describe the colour change that occurs when  $\text{K}_2\text{Cr}_2\text{O}_7$  acts as an oxidizing agent. [1]
- (ii) Deduce the names of compounds A, B and C. [3]
- (iii) Compound A reacts with ethanoic acid to form compound D with molecular formula  $\text{C}_5\text{H}_{10}\text{O}_2$ . State the type of reaction occurring and deduce the name of compound D. [2]
- (iv) Explain, with reference to the intermolecular forces present, why compound A has a higher boiling point than compound B. [2]

SL B 07s

5. Ethene is an unsaturated hydrocarbon used as a starting material for many organic chemicals.

- (a) Draw the structural formula of ethene and state the meaning of the term *unsaturated hydrocarbon*. [2]
- (b) State an equation for the conversion of ethene to ethanol and identify the type of reaction. [2]
- (c) Describe the complete oxidation of ethanol and name the product. Include the conditions, reagents required and any colour changes. [4]
- (d) State an equation for the reaction between ethanol and the product of complete oxidation in (c). Include any other reagent required for this reaction. Name the organic product and state one possible use of this product. [4]
- (e) Explain why ethene undergoes addition polymerisation but not condensation polymerisation. [2]
- (f) (i) State the meaning of the term *isomers*. [1]
- (ii) Draw the functional group isomers of  $\text{C}_3\text{H}_6\text{O}$ . [2]

SL B 06sQ8

- (e) Given the structures of the repeating units of the polymers below, identify the monomers from which they are formed.
- (i)  $\text{--CH}_2\text{---CH}_2\text{--}$  [1]

- (g) Many organic compounds can exist as isomers. Draw and name an isomer of ethanoic acid,  $\text{CH}_3\text{COOH}$ . [2]

SL B 06sQ7

- (c) (i) Draw a Lewis structure of a water molecule, name the shape of the molecule and state and explain why the bond angle is less than the bond angle in a tetrahedral molecule such as methane. [4]

- (ii) Explain why water is a suitable solvent for ethanol, but not for ethane. [2]

- (d) Predict and explain the order of the melting point for propanol, butane and propanone with reference to their intermolecular forces. [4]

SL B 05s

8. Several compounds have the molecular formula  $\text{C}_3\text{H}_6\text{O}_2$ .

Three of them, A, B and C, have the following properties:

A is soluble in water and is acidic

B and C are neutral and do not react with bromine.

- (a) Give a structural formula for each of these compounds and name them. [6]

- (b) (i) Explain the solubility and acidity of A in water. [2]

- (ii) Write an equation for the reaction of A with sodium hydroxide solution. [1]

- (iii) Explain why B and C do not react with bromine. [1]

- (c) State and explain which one of A, B or C has the highest boiling point. [2]

- (d) (i) Name the class of compounds to which B and C belong and state a use of this class of compounds. [2]

- (ii) Name the two classes of compounds used to form B or C, and state the other product formed in this reaction. [3]

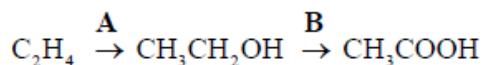
- (e) Suggest the structural formula of an isomer of  $\text{C}_3\text{H}_6\text{O}_2$  which does react rapidly with bromine. Name this type of reaction, and describe an observation that can be made during the reaction. [3]

SL B 04s

7. The compound  $C_2H_4$  can be used as a starting material for the preparation of many substances.

(a) Name the compound  $C_2H_4$  and draw its structural formula. [2]

(b) In the scheme below, state the type of reaction and identify the reagent needed for each reaction.



[4]

(c)  $C_2H_4$  can be converted into one of the compounds below in a single step reaction.



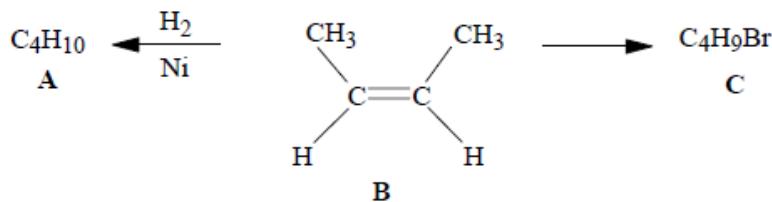
Draw the structural formula for each of these compounds and identify the compound which can be formed directly from  $C_2H_4$ . [3]

(d) One of the two compounds in (c) has an isomer. Draw the structural formula of the isomer and explain why it can not be formed directly from  $C_2H_4$ . [2]

(e)  $C_2H_4$  can also react to form a polymer. Name this type of polymer and draw the structural formula of a section of this polymer consisting of three repeating units. [2]

SL B 03s

8. Two reactions of an alkene, B, are shown below.



(a) (i) State the name of A and write an equation for its complete combustion. Explain why the incomplete combustion of A is dangerous. [5]

(ii) Outline a test to distinguish between A and B, stating the result in each case. [3]

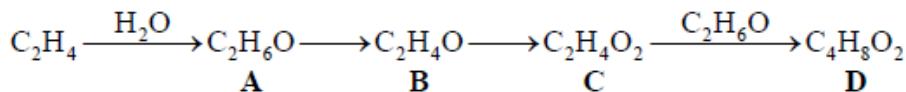
(iii) Write an equation for the conversion of B to C. State the type of reaction taking place and draw the structure of C. [3]

(b) (i) A compound D has the molecular formula  $C_2H_4O_2$  and is obtained from a reaction between methanoic acid and methanol. Write an equation for this reaction and state the name of D. [3]

(ii) A second compound, E, has the same molecular formula as D and has acidic properties. State the name of compound E. [1]

SL B 02sQ4

4. This question is about four compounds A, B, C and D, which can be made from ethene by the following reactions. All four compounds are liquid at room temperature, and each compound's molecular formula is shown. Two of the reagents needed for the reactions are shown on the arrows.



- (c) Identify the gas formed when C reacts with magnesium and write an equation for the reaction occurring. Name the other product of the reaction. [3]
- (e) Compound C has another isomer. Name and give the structural formula of this isomer. [2]

SL B 01sQ6

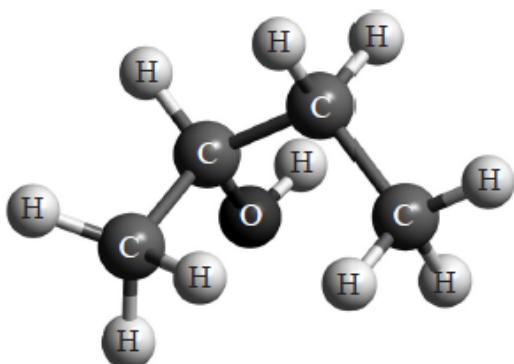
- (b) Explain at the molecular level why ethanol ( $\text{C}_2\text{H}_5\text{OH}$ ) is soluble in water, but cholesterol ( $\text{C}_{27}\text{H}_{45}\text{OH}$ ) and ethane ( $\text{C}_2\text{H}_6$ ) are not. [4]
- (c) Give an equation for the complete combustion of methane,  $\text{CH}_4$ . Identify two products formed by the incomplete combustion of methane and identify one harmful effect caused by one of the products. [3]
- (d) Polyunsaturated oils contain many  $\text{C}=\text{C}$  bonds and react with hydrogen to yield fats. Using the simplified structure of an oil provided below, give the formula of the product formed by reacting this oil with excess hydrogen, and identify this type of reaction.



[2]

SL A 13s

5. The following diagram shows the three-dimensional structure of a molecule.



- (a) Apply IUPAC rules to state the name of this molecule.

[1]

.....  
.....

- (b) Deduce the structural formula of **two** isomers of the molecule above with the same functional group.

[2]

- (c) Describe, using an equation, the oxidation by acidified potassium dichromate(VI) of the substance shown in the diagram. Use the symbol [O] to represent the oxidizing agent.

[1]

.....  
.....

- (b) The combustion of unleaded gasoline still produces pollution with both local and global consequences. Identify **one** exhaust gas which causes local pollution and **one** exhaust gas which causes global pollution.

[2]

Local pollutant:

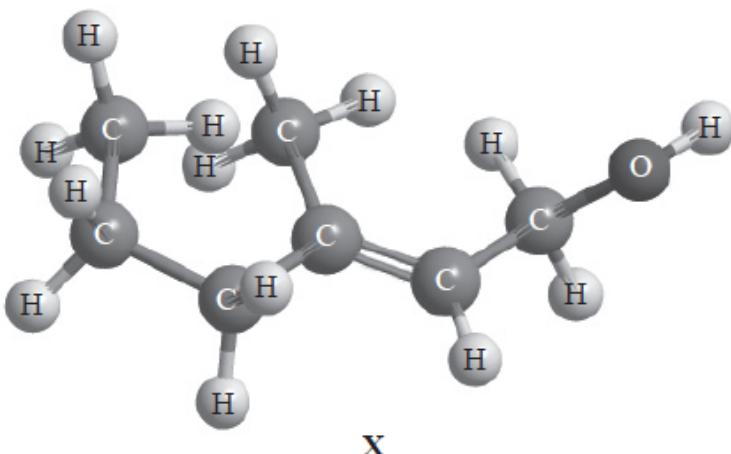
.....

Global pollutant:

.....

3. Compound X (shown below) is produced by bacteria living in human armpits and is thought to be partly responsible for unpleasant body smells.

- (a) Bromine water can be used to test for the presence of one of the functional groups in X. Identify this functional group and describe the colour change observed. [2]



X

- (b) The other functional group changes when X is refluxed with acidified excess potassium dichromate(VI) to produce a compound Y.

- (i) Identify the functional group present in Y but not in X. [1]

.....  
.....  
.....

- (ii) State the type of reaction that X undergoes to form Y. [1]

.....  
.....  
.....

(c) A different compound is produced if excess **X** is heated with acidified potassium dichromate(VI) and the product **Z** is distilled off as it forms.

(i) Identify the functional group present in **Z** but not in **X**.

[1]

.....  
.....

(ii) Predict the order of increasing boiling point of the compounds **X**, **Y** and **Z** and explain your answer.

[3]

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3. (a) Chloroethene,  $C_2H_3Cl$ , is an important organic compound used to manufacture the polymer poly(chloroethene).

(i) Draw the Lewis structure for chloroethene and predict the H–C–Cl bond angle. [2]

.....

(ii) Draw a section of poly(chloroethene) containing six carbon atoms. [1]

.....  
.....  
.....  
.....

- (b) (i) Chloroethene can be converted to ethanol in two steps. For each step deduce an overall equation for the reaction taking place. [2]

Step 1:

.....  
.....

Step 2:

.....  
.....

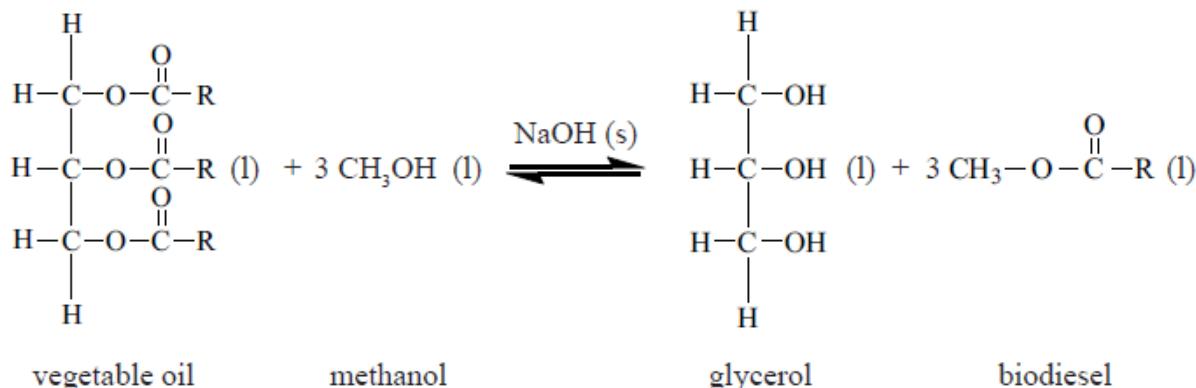
- (ii) State the reagents and conditions necessary to prepare ethanoic acid from ethanol in the laboratory.

[2]

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SL A 09s

1. Biodiesel makes use of plants' ability to fix atmospheric carbon by photosynthesis. Many companies and individuals are now using biodiesel as a fuel in order to reduce their carbon footprint. Biodiesel can be synthesized from vegetable oil according to the following reaction.



- (a) Identify the organic functional group present in both vegetable oil and biodiesel. [1]

.....

- (b) For part of her extended essay investigation into the efficiency of the process, a student reacted a pure sample of a vegetable oil (where  $\text{R}=\text{C}_{17}\text{H}_{33}$ ) with methanol. The raw data recorded for the reaction is below.

Mass of oil	= 1013.0 g
Mass of methanol	= 200.0 g
Mass of sodium hydroxide	= 3.5 g
Mass of biodiesel produced	= 811.0 g

The relative molecular mass of the oil used by the student is 885.6. Calculate the amount (in moles) of the oil and the methanol used, and hence the amount (in moles) of excess methanol.

[3]

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- (d) The reactants had to be stirred vigorously because they formed two distinct layers in the reaction vessel. Explain why they form two distinct layers and why stirring increases the rate of reaction.

[2]

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- (e) Calculate the percentage yield of biodiesel obtained in this process.

[2]

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- (f) When biodiesel is combusted it produces carbon dioxide. Explain why the use of biodiesel as a fuel does not significantly contribute to global warming.

[1]

.....  
.....

SL A 08s

5. (a) The compound  $C_3H_6$  reacts with bromine. Write an equation and state an observation for this reaction.

[2]

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.....  
.....

- (c) Suggest the type of polymerization reaction that  $C_3H_6$  undergoes and draw the structure of a section of the polymer chain formed from three monomer molecules.

[2]

Type of polymerization . . . . .

SL A 06s

5. (a) State two characteristics of a homologous series. [2]

.....

- (b) Describe a chemical test to distinguish between alkanes and alkenes, giving the result in each case. [3]

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SL A 05sQ2

- (c) Explain why the incomplete combustion of hydrocarbons is harmful to humans. [2]

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SL A 05s

5. Give the structural formulas for the isomers of molecular formula  $C_4H_{10}$  and state the name of each one. [4]

## Topic 10 Mark Scheme

SL B 13s

8. (a) (i) same functional group / same general formula;  
difference between successive members is  $\text{CH}_2$ ;  
similar chemical properties;  
*Do not accept "same" chemical properties.*
- gradually changing physical properties; [3 max]
- (ii) adding bromine (water);  
*ethene:* brown/orange to colourless / decolourizes bromine water **and**  
*ethane:* does not change colour; [2]
- OR**
- adding acidified potassium permanganate solution/ $\text{KMnO}_4(\text{aq})$ ;  
*ethene:* purple to colourless/brown **and**  
*ethane:* does not change colour;
- OR**
- adding Baeyer's reagent;  
*ethene:* purple/pink to brown **and**  
*ethane:* does not change colour;
- Do not accept "clear" or "transparent" for "colourless".*
- (iii)  $\text{C}_2\text{H}_4 + \text{HBr} \rightarrow \text{C}_2\text{H}_5\text{Br}$  ;  
 $\text{C}_2\text{H}_6 + \text{Br}_2 \rightarrow \text{C}_2\text{H}_5\text{Br} + \text{HBr}$  ; [2]  
*Accept structural formulas.*  
*Penalise missing H atoms or incorrect bonds (such as C-HO, C-H<sub>2</sub>C) in structural formulas only once in the paper.*
- (b) (i)  $\text{C}_4\text{H}_9\text{Br} + \text{OH}^- \rightarrow \text{C}_4\text{H}_9\text{OH} + \text{Br}^-$  ; [1]  
*Accept NaOH in the equation.*
- (ii) decreases; [1]
- (c) (i)  *$\text{C}_4\text{H}_9\text{Br}$ :*  
 $[\text{C}_4\text{H}_9\text{Br}]$  doubles **and** time halves/rate doubles / rate proportional to  $[\text{C}_4\text{H}_9\text{Br}]$ ;  
*Do not accept rate increases when  $[\text{C}_4\text{H}_9\text{Br}]$  increases.*
- NaOH:*  
 $[\text{NaOH}]$  doubles **and** time/rate does not change / rate independent of  $[\text{NaOH}]$ ; [2]
- (ii) increases rate; [1]  
*Accept increases number of collisions.*
- (iii) rate depends on  $[\text{C}_4\text{H}_9\text{Br}]$  only / rate does not depend on  $[\text{OH}^-]$  /  $\text{S}_{\text{N}}1$  reaction / first order reaction / if it was primary, reaction would be  $\text{S}_{\text{N}}2$ ;  
tertiary; [2]  
*Accept ECF.*

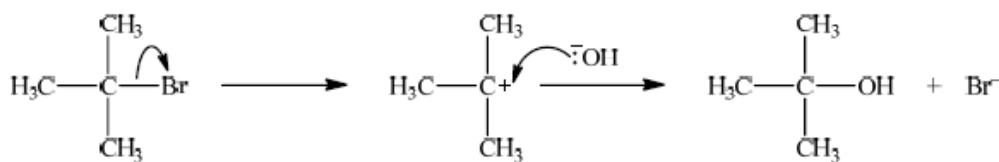
- (iv)  $(CH_3)_3CBr$ ;  
*Allow both condensed and full structural formula.*  
*Accept ECF.*

[1]

- (v)  $C_4H_9Br + Br_2 \rightarrow C_4H_8Br_2 + HBr$  ;

[1]

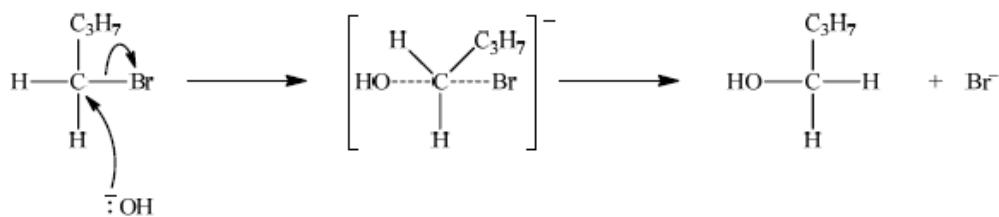
(d)



curly arrow showing  $Br^-$  leaving;  
representation of tertiary carbocation;  
curly arrow going from lone pair/negative charge on O in  $OH^-$  to  $C^+$ ;  
*Do not allow arrow originating on H in  $OH^-$ .*

formation of  $(CH_3)_3COH$  and  $Br^-$ ;  
*Accept  $Br^-$  anywhere on product side in the reaction scheme.*

If primary halogenoalkane has been answered in (c)(iii) apply ECF for the mechanism:



curly arrow going from lone pair/negative charge on O in  $OH^-$  to C;  
*Do not allow curly arrow originating on H in  $OH^-$ .*

curly arrow showing  $Br^-$  leaving;  
*Accept curly arrow either going from bond between C and Br to Br in bromobutane or in the transition state.*

representation of transition state showing negative charge, square brackets and partial bond;

*Do not penalize if HO and Br are not at  $180^\circ$  to each other.*  
*Do not award M3 if OH—C bond is represented.*

formation of organic product  $C_4H_9OH$  and  $Br^-$ ;  
*Accept  $Br^-$  anywhere on product side in the reaction scheme.*

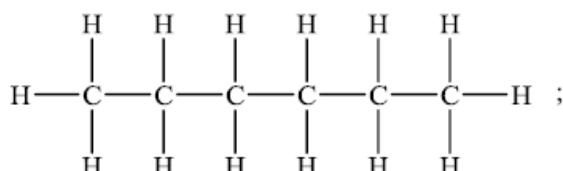
7. (a) (i) molar mass =  $102.20 \text{ (g mol}^{-1}\text{)}$ ;  
amount ( $= \frac{5.00}{102.20}$ ) = 0.0489 (mol); [2]

- (ii) theoretical yield =  $(84.18 \times 0.0489 =) 4.12 \text{ (g)}$ ;  
percentage yield =  $\left( \frac{2.62}{4.12} \times 100 = \right) 63.6 \%$ ;  
*Accept alternative calculation method.* [2]

- (iii) yield above 100% not possible / experimental yield > theoretical yield / OWTTE;  
*Must have reference to a final yield.*

sample contaminated with hexan-1-ol/water / inadequate drying / OWTTE;  
*Do not accept error in reading balance/weighing scale.* [2]

- (b) (i) hydrogen and Ni/Pd/Pt catalyst;



[2]

*Allow condensed structural formula  $CH_3(CH_2)_4CH_3$ .*

- (ii) 2-methylpentane;  
3-methylpentane;  
2,2-dimethylbutane;  
2,3-dimethylbutane; [3 max]

- (iii) hexane;  
*Accept the molecular structure, full structural formula or condensed structural formula.*

straight chain/no branches, hence increased surface area/more closely packed;  
stronger/larger/greater London/dispersion/van der Waals'; [3]

*Accept the opposite arguments.*  
*Do not accept stronger/larger/greater intermolecular forces.*

- (iv) margarine; [1]

(c) (i) *Initiation:*  
 $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$ ;

*Essential condition:*  
UV/sunlight/hf/hv / heat;

*Propagation:*  
 $\text{Cl}\cdot + \text{R}-\text{H} \rightarrow \text{HCl} + \text{R}\cdot$  /  $\text{R}\cdot + \text{Cl}_2 \rightarrow \text{RCl} + \text{Cl}\cdot$ ;

*Termination:*  
 $\text{Cl}\cdot + \text{Cl}\cdot \rightarrow \text{Cl}_2$  /  $\text{Cl}\cdot + \text{R}\cdot \rightarrow \text{RCl}$  /  $\text{R}\cdot + \text{R}\cdot \rightarrow \text{R}_2$ ; [4]

*Allow more specific detail of R based on hexane (e.g.  $\text{CH}_3(\text{CH}_2)_4\text{CH}_2-\text{H}$ ) in mechanistic steps.*

(ii) three/3; [1]  
*If all three isomers are represented correctly award mark.*

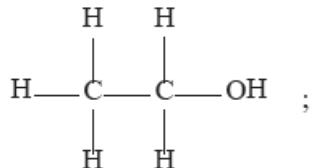
6. (a) boiling points increase (from the first member to the fifth member);  
increasing size of molecule/area of contact/number of electrons (from the first to the fifth member);  
strength of intermolecular/van der Waals'/London/dispersion forces increase / more energy required to break the intermolecular bonds (from first member to fifth member);

[3]

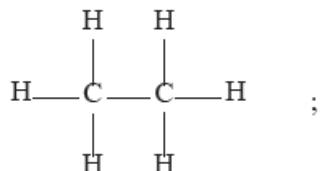
- (b) same general formula;  
successive members differ by CH<sub>2</sub>;  
same functional group / similar/same chemical properties;  
gradual change in physical properties; [2 max]  
*Accept specific physical property such as melting point, boiling point only once.*

(c)

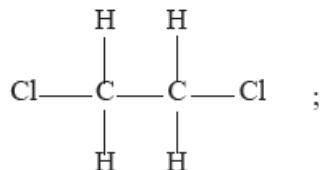
A:



B:

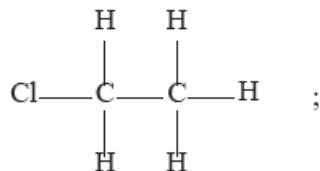


C:



1,2-dichloroethane;

D:



*Accept condensed formulas.*

[5]

*Penalize missing hydrogens only once.*

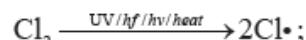
- (d) add bromine water/bromine;  
pentane no change/stays brown **and** pent-1-ene decolourizes bromine water/bromine;

**OR**

add acidified KMnO<sub>4</sub>;  
pentane no change/stays purple **and** pent-1-ene decolourizes acidified KMnO<sub>4</sub>; **[2 max]**  
*Accept any correct colour change.*  
*Do not accept 'clear' instead of 'colourless'.*

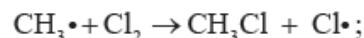
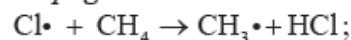
- (e) E: primary **and** F: secondary;  
G: primary;  
G / E: only one alkyl group/2 H atoms attached to the carbon atom attached to the Cl / only one carbon atom attached to the carbon atom attached to the Cl;  
F: two alkyl groups/1 H atom attached to the carbon atom attached to the Cl / two carbon atoms attached to the carbon atom attached to the Cl; **[4]**

- (f) *Initiation:*

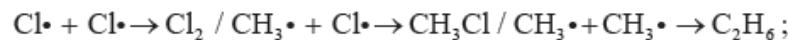


*Reference to UV/hf/hv/heat must be included.*

*Propagation:*



*Termination:*



**[4]**

*Allow representation of radical without • (e.g. Cl, CH<sub>3</sub>) if consistent throughout mechanism.*

*If representation of radical (i.e. •) is inconsistent, penalize once only.*

SL B 10s

- (b) same general formula;  
same functional group;  
successive members differ by CH<sub>2</sub>;  
*Allow methylene for CH<sub>2</sub>.*

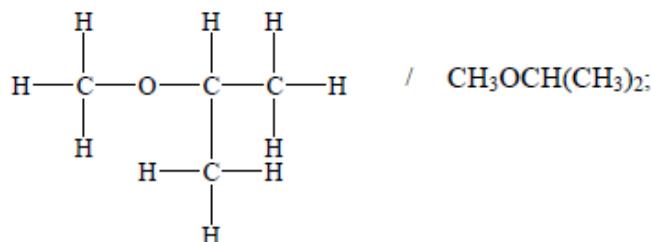
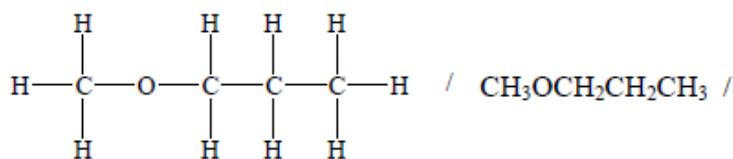
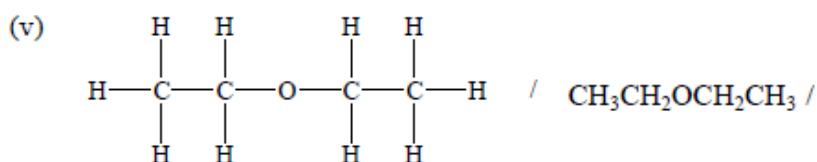
similar chemical properties;  
gradually changing physical properties; **[2 max]**

- (c) (i) A: butan-1-ol;  
B: butan-2-ol;  
C: (2-)methylpropan-2-ol;  
D: (2-)methylpropan-1-ol; **[4]**  
*Accept answers in the form of 1-butanol and 2-methyl-2-propanol etc.*  
*Penalize incorrect punctuation, e.g. commas for hyphens, only once.*

(ii) C/(2-)methylpropan-2-ol; **[1]**

(iii) A/butan-1-ol; **[1]**

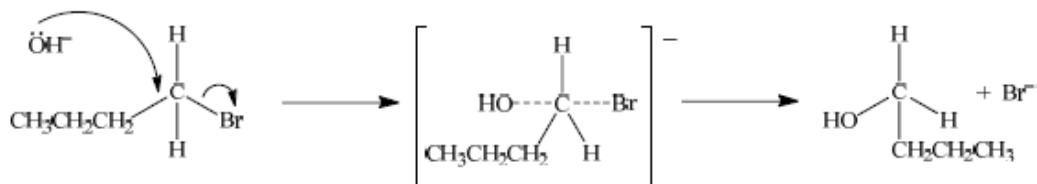
(iv) B/butan-2-ol; **[1]**



[1]

(d) (i)  $\text{S}_{\text{N}}2$ ; [1]

(ii)



curly arrow going from lone pair/negative charge on O in  $\text{OH}^-$  to C;  
Do not allow curly arrow originating on H in  $\text{OH}^-$ .

curly arrow showing Br leaving;

Accept curly arrow either going from bond between C and Br to Br in 1-bromobutane or in the transition state.

representation of transition state showing negative charge, square brackets and partial bonds;

[3]

Do not penalize if HO and Br are not at  $180^\circ$  to each other.

Do not award third mark if  $\text{OH}---\text{C}$  bond is represented.

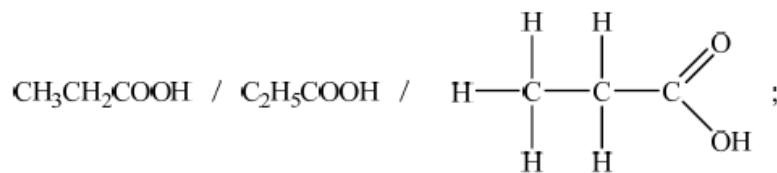
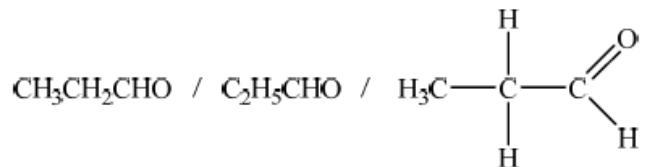
7. (a) (i) butane < propanal < propan-1-ol;  
 butane has van der Waals/London/dispersion forces;  
 propanal has dipole-dipole attractive forces;  
 propan-1-ol has hydrogen bonding;  
*imf marks are independent of the order.*  
*Treat references to bond breaking as contradictions if the imfs are correct.*

[4]

- (ii) butane is least soluble;  
 it cannot form hydrogen bonds/attractive forces with water molecules;

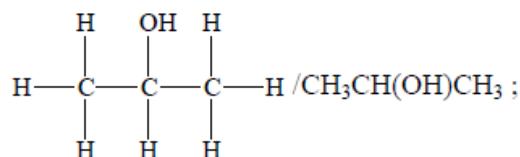
[2]

- (iii) propanal and propanoic acid;



[3]

- (iv)



[1]

- (v) secondary (alcohol);  
 propanone / acetone;

[2]

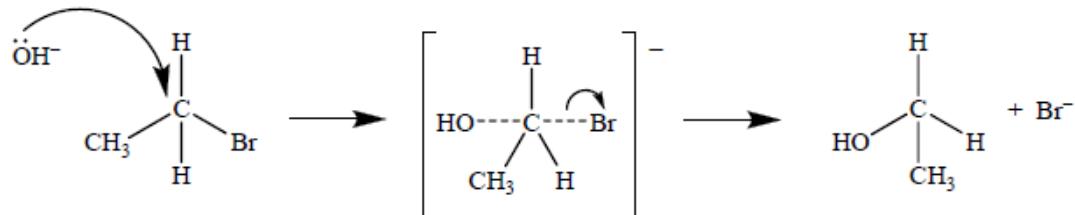
- (b) (i) hydrogen bromide / hydrobromic acid;  
*Do not accept HBr, as name is asked for.*

[1]

- (ii) sodium hydroxide / hydroxide ions (name required);  
 dilute and aqueous / dilute and warm / aqueous and warm;

[2]

(iii)



curly arrow from  $\text{OH}^-$  to C atom;

*Accept from lone pair or minus sign or O. Do not award marking point if arrow originates from the H of  $\text{OH}^-$ .*

curly arrow from bond between C and Br to bromine atom on bromoethane or the transition state;

transition state including negative charge and partial bonds;

[3]

(iv) hydration of ethene / steam + ethene;

*Allow equation*

(ethanol used as) solvent/fuel/antiseptic/intermediate to form other compounds;

[2]

SL B 08s

(c) (i) orange to green; [1]

(ii) A is propan-1-ol/1-propanol;  
*Do not accept propanol*

B is propanal;

C is propanoic acid;

[3]

(iii) esterification / condensation;  
propyl ethanoate;

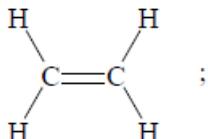
[2]

(iv) A has (stronger) hydrogen bonding;  
B has (weaker) dipole-dipole attractions;  
*At least one of stronger or weaker needed to score both marks.*

[2]

SL B 07s

5. (a)



Allow  $CH_2=CH_2$ .

a hydrocarbon that contains at least one C=C (or C≡C)/carbon-carbon double bond (or triple bond)/carbon to carbon multiple bond;  
*Do not accept just "double bond".*

[2]

- (b)  $C_2H_4 + H_2O \rightarrow C_2H_5OH$  ;  
addition/hydration reaction;

[2]

- (c) heat under reflux;

EITHER

potassium dichromate(VI) /  $K_2Cr_2O_7$  /  $Cr_2O_7^{2-}$  and acidified /  $H^+$ ;  
orange to green;

OR

potassium permanganate / manganate(VII) /  $KMnO_4$  /  $MnO_4^-$  and acidified /  $H^+$ ;  
purple to colourless;

*Penalise wrong oxidation state, but not missing oxidation state.*

ethanoic acid;

[4 max]

- (d)  $CH_3COOH + C_2H_5OH \rightarrow CH_3COOCH_2CH_3 + H_2O$  ;

*Accept  $CH_3COOC_2H_5$ .*

sulfuric acid/  $H_2SO_4$ /(ortho)phosphoric acid/  $H_3PO_4$  ;

ethyl ethanoate;

solvent / flavouring / perfumes / plasticizers;

[4]

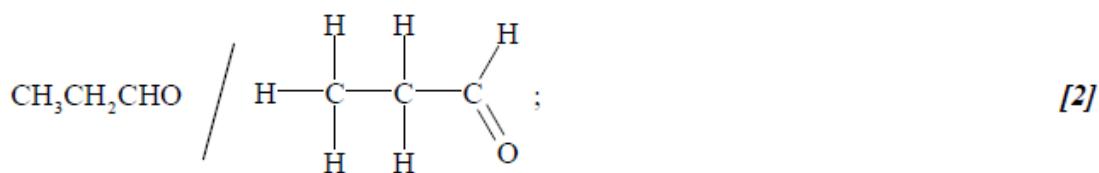
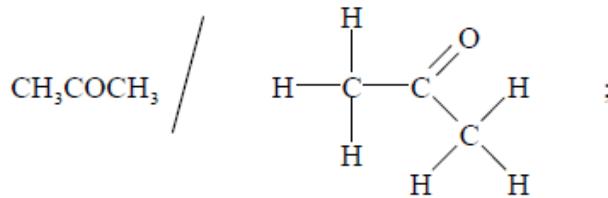
- (e) presence of double bond / multiple bond;

absence of two functional groups / no other functional groups;

[2]

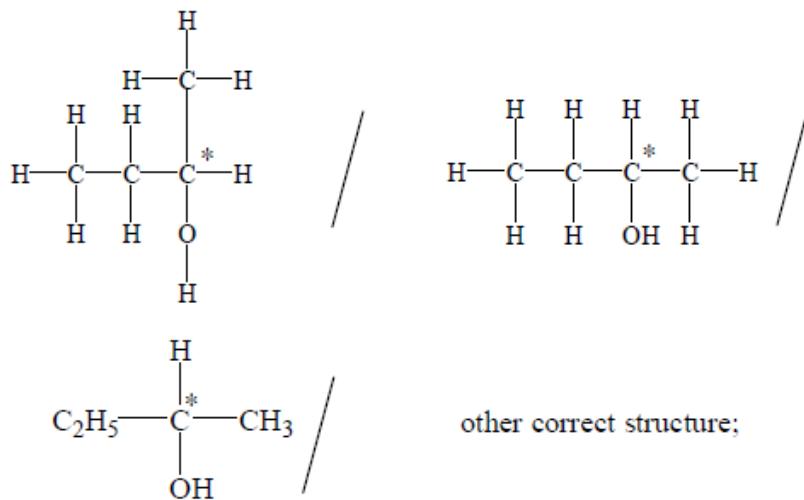
- (f) (i) same molecular formula but different structural formula / arrangement of atom within a molecule / OWTTE; [1]

(ii)



*Accept unsaturated alcohol and cyclic alcohol as alternative answers.  
If more than two correct isomers given – no penalty – but a third incorrect structure cancels a correct one. i.e. two correct, one incorrect equals [1].*

- (iii) isomers that can rotate plane polarized light in opposite directions;  
*Do not accept bend, reflect plane-polarized light.*



*Penalise missing bonds / hydrogens.*

correct identification of chiral carbon (\*);

[3]

(e) (i)  $\text{CH}_2\text{CH}_2$ ; [1]



*Allow appropriate acyl chloride.*

(iii)  $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$ ;  
 $\text{HOOC}(\text{CH}_2)_4\text{COOH}$ ; [2]

*Allow correct alternative.*

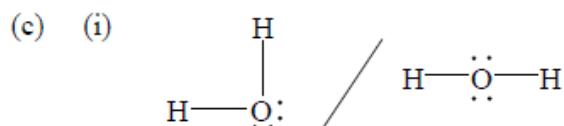
*Accept correct names as alternatives.*

*If correct structure and incorrect name given, award the mark.*  
*Penalise COOH – C once only.*

(f) (addition polymers) contain  $\text{C}=\text{C}$  /  $\text{C}\equiv\text{C}$ ;  
(condensation polymers) contain two reactive/functional groups; [2]

(g) methyl methanoate;  
 $\text{HCOOCH}_3$ ; [2]  
*Accept other correct alternative.*

SL B 06s



*Allow a combination of dots, crosses or lines.*

bent / V shaped / angular

$104.5^\circ$ ;

*Accept answers in range  $104^\circ$  to  $106^\circ$ .*

repulsion of the two non-bonding pairs of electrons forces bond angle to be  
smaller / non-bonding pairs repel more than bonding pairs; [4]

(ii) ethanol is polar and ethane is non-polar;  
ethanol forms hydrogen bonds / dipole–dipole attractions with water and ethane  
does not; [2]

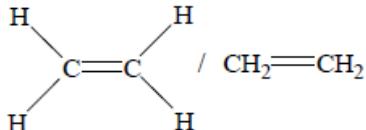
(d) butane < propanone < propanol;  
butane has van der Waals' forces;  
*Accept vdW, dispersion or London forces or attractions between temporary dipoles.*  
propanone has dipole-dipole attractions;  
propanol has (the stronger) H-bonding; [4]

SL B 05s

8. (a) A  $\text{CH}_3\text{CH}_2\text{COOH}$  /  $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$ ;  
*Accept  $\text{C}_2\text{H}_5$  for  $\text{CH}_3\text{CH}_2$ .*  
propanoic acid;
- B or C  $\text{CH}_3\text{COOCH}_3$ ;  
methyl ethanoate;
- C or B  $\text{HCOOCH}_2\text{CH}_3$ ;  
*Accept  $\text{HCOOC}_2\text{H}_5$ .*  
ethyl methanoate; [6]
- (b) (i) A forms hydrogen bonds with water;  
A ionizes / dissociates to give  $\text{H}^+$  ions;  
*Accept correct equation.* [2]
- (ii)  $\text{C}_2\text{H}_5\text{COOH} + \text{NaOH} \rightarrow \text{C}_2\text{H}_5\text{COONa} + \text{H}_2\text{O}$ ;  
*Allow ECF from A.* [1]
- (iii) no  $\text{C}=\text{C}$  bond;  
*Do not accept "no double bonds".* [1]
- (c) highest boiling point is A;  
molecules of A can form hydrogen bonds (with other molecules of A); [2]
- (d) (i) esters;  
flavourings / plasticizers / solvents / perfumes; [2]
- (ii) carboxylic acid / alkanoic acid;  
alcohol / alkanol;  
water; [3]
- (e) any feasible formula containing  $\text{C}=\text{C}$  (e.g.  $\text{CH}_3\text{CHC(OH)}_2$  or  $\text{HOCH}=\text{C(OH)}\text{CH}_3$ );  
*Accept more detailed formula.*  
addition;  
mixture is decolorised / colour change is from yellow/orange to colourless;  
*Do not accept discoloured instead of decolorised.* [3]

SL B 04s

7. (a) ethene;



[2]

(b) A addition / hydration;

H<sub>2</sub>O / water / steam;

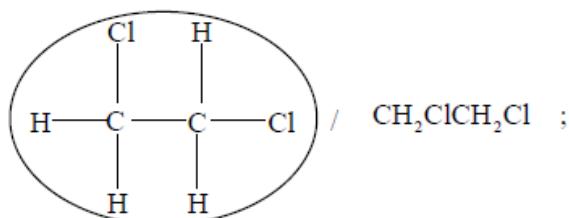
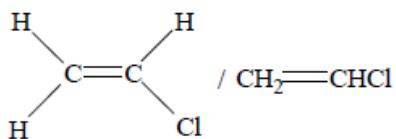
B oxidation;

acidified K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>,

Accept acidified KMnO<sub>4</sub>.

[4]

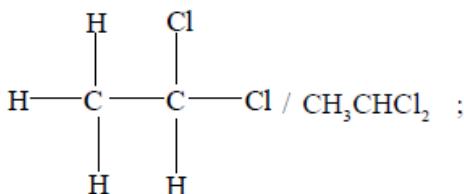
(c)



[3]

The compound formed directly may be circled or indicated by some other means.  
Accept any other structure showing a Cl atom on each C atom.

(d)

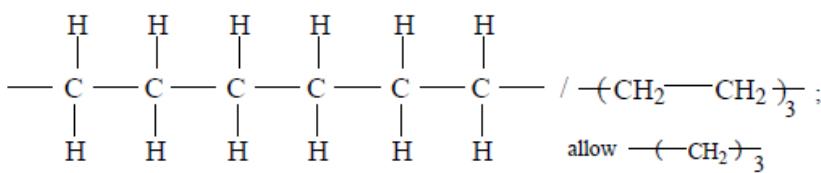


[2]

addition across a double bond occurs at both C atoms / OWTTE;

If 1, 1-dichloroethane is given in (c) accept 1, 2-dichloroethane as the isomer as ECF but  
Award [1] max;

(e) addition polymer;



[2]

8. (a) (i) butane;  
 $\text{C}_4\text{H}_{10}(\text{g}) + \frac{13}{2}\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 5\text{H}_2\text{O}(\text{l});$   
*(ignore state symbols, accept balancing using  $13\text{O}_2$ )*  
*[1] for all formulas and [1] for balancing equation.*
- CO produced;  
CO is poisonous / combines with hemoglobin / OWTTE;  
or  
C;  
which causes respiratory problems; [5]
- (ii) add  $\text{Br}_2$  (water);  
*valid test needed to score further marks*
- A – no effect;  
B – would decolorise  $\text{Br}_2$  (*do not accept discolour*); [3]
- (iii)  $\text{CH}_3\text{CH}=\text{CHCH}_3 + \text{HBr} \rightarrow \text{CH}_3\text{CHBrCH}_2\text{CH}_3;$   
*[1] for HBr in balanced equation, [1] for structure of product.*
- addition; [3]
- (b) (i)  $\text{CH}_3\text{OH} + \text{HCOOH} \rightarrow \text{HCOOCH}_3 + \text{H}_2\text{O};$   
*[1] for both reactants and [1] for both products (accept  $\text{C}_2\text{H}_4\text{O}_2$ )*  
methyl methanoate; [3]
- (ii) ethanoic acid; [1]

SL B 02sQ4

- (e)  $\text{HCOOCH}_3$  *[1];*  
methyl methanoate *[1]*. [2]

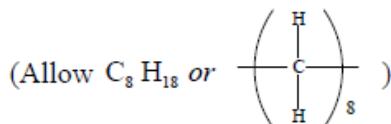
*If full structural formulas are given in (b) (ii) and (e), but the H atoms attached to the C– bonds are omitted, penalize first time only.*

- (f) asymmetric carbon atom / chiral centre / carbon attached to four different atoms/groups / asymmetric molecule. [1]

SL B 01s

- (b) Reference to H– bonding in ethanol/water [1]  
 Ethane not polar [1]  
 No H– bonds / only van der Waals [1]  
 Cholesterol mostly a non-polar chain / hydrocarbon [1] [4 max]
- (c)  $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$  [1]  
 Carbon monoxide/carbon (allow soot)/water OR CO/C/H<sub>2</sub>O  
*(Award [1] for any two.)*
- (Award [1] for any one of the following:)*  
 CO: toxic / reduces oxygen carrying capacity of red blood cells / reduces oxygen carrying capacity of haemoglobin
- C (particulates): influence climate / increase atmospheric turbidity / attenuate solar radiation / cause respiratory problems [3 max]

- (d) Product must show **all** C (8) saturated with H and **no** double bonds [1]



Addition/reduction/hydrogenation/hardening [1] [2 max]

### SL A 13s

5. (a) butan-2-ol/2-butanol; [1]
- (b) CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>OH;  
 (CH<sub>3</sub>)<sub>2</sub>CHCH<sub>2</sub>OH;  
 (CH<sub>3</sub>)<sub>3</sub>COH; [2 max]  
*Accept condensed or full structural formulas.*  
*Penalise missing H atoms or incorrect bonds (such as C–HO, C–H<sub>2</sub>C) only once in the whole paper.*
- (c) C<sub>2</sub>H<sub>5</sub>CHOHCH<sub>3</sub> + [O] → C<sub>2</sub>H<sub>5</sub>COCH<sub>3</sub> + H<sub>2</sub>O ; [1]  
*Accept condensed or full structural formulas.*  
*Accept [O] on top of the arrow.*  
*Do not accept equation without H<sub>2</sub>O.*  
*Do not accept equation with H<sup>+</sup>/Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>.*

### SL A 12sQ2

- (b) *Local pollutant:*  
 carbon monoxide/CO / volatile organics/VOCs / nitrogen oxide/NO / (unburnt) hydrocarbons;  
*Do not accept methane/CH<sub>4</sub>, ethane/C<sub>2</sub>H<sub>6</sub>, propane/C<sub>3</sub>H<sub>8</sub> or butane/C<sub>4</sub>H<sub>10</sub>.*

*Global pollutant:*  
 nitrogen oxide/NO / carbon dioxide/CO<sub>2</sub>; [2]  
*Accept nitrogen dioxide/NO<sub>2</sub> / NO<sub>x</sub> for both local or global pollutant.*  
*Accept other widely used names for NO such as nitric oxide/nitrogen monoxide/nitrogen(II) oxide or nitrogen(IV) oxide for NO<sub>2</sub>.*

### SL A 12s

3. (a) (carbon to carbon) double bond / alkene;  
*Accept if identified on diagram.*

orange/brown/red/yellow to colourless / bromine is decolourized;  
*M2 can be only scored if M1 correct.*

[2]

- (b) (i) COOH/CO<sub>2</sub>H / carboxylic acid / alkanoic acid;  
*Do not allow carboxylic/alkanoic, carbonyl or carboxylate.*

[1]

- (ii) redox / oxidation (of alcohol);

[1]

- (c) (i) aldehyde / alkanal / CHO;  
*Accept C=O / carbonyl.*

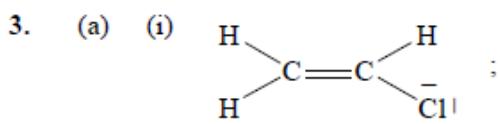
[1]

- (ii) Z < X < Y;  
*Accept Z,X,Y or ZXY.*

no hydrogen bonding in Z / hydrogen bonding in X and Y;  
*Accept statements such as Z has only van der Waals/London/dispersion forces and dipole-dipole forces.*

Y most polar / more electrons / forms dimers / forms two hydrogen bonds / greater molecular/molar mass;  
*Do not accept Y has a larger mass.*

[3]



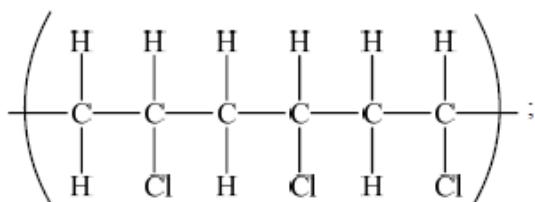
*Accept lines, dots or crosses for electron pairs.  
Lone pairs required on chlorine.*

(approximately)  $120^\circ$ ;

*Accept any bond angle in the range  $113 - 120^\circ$ .*

[2]

(ii)



[1]

*Brackets not required for mark.*

*Allow correct condensed structural formula.*

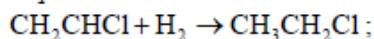
*Continuation bonds from each carbon are required.*

*Cl atoms can be above or below carbon spine or alternating above and below.*

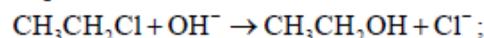
- (iii) plastics are cheap/versatile/a large industry / plastics have many uses / OWTTE;  
 plastics are not biodegradeable / plastics take up large amounts of space in  
 landfill / pollution caused by burning of plastics / OWTTE;  
*Do not accept plastics cause litter.*  
*Allow plastics don't decompose quickly / OWTTE.*

[2]

(b) (i) *Step 1:*



*Step 2:*



[2]

*Allow NaOH or NaCl etc. instead of OH<sup>-</sup> and Cl<sup>-</sup>.*

*Allow abbreviated formulas C<sub>2</sub>H<sub>5</sub>Cl, C<sub>2</sub>H<sub>5</sub>Cl, C<sub>2</sub>H<sub>5</sub>OH.*

- (ii) H<sub>2</sub>SO<sub>4</sub>/H<sup>+</sup>/acidified and Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>/(potassium/sodium) dichromate;  
*Accept suitable oxidizing agents (e.g. KMnO<sub>4</sub> etc.) but only with acid.*  
*Ignore missing or incorrect oxidation states in reagents.*

*(heat under) reflux;*

*Second mark can be scored even if reagent is incorrect.*

[2]

SL A 09s

1. (a) ester;

[1]

(b) amount of oil =  $\frac{1013.0}{885.6} = 1.144 \text{ mol};$

amount of methanol =  $\frac{200.0}{32.05} = 6.240 \text{ mol};$

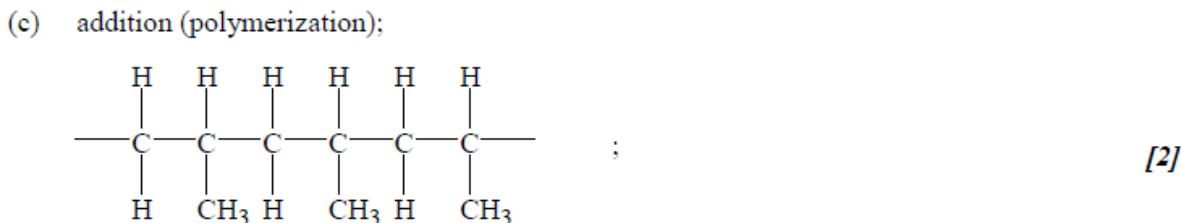
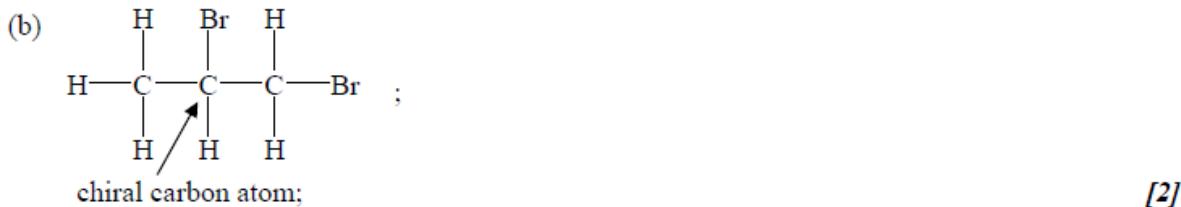
since three mol of methanol react with one mol of vegetable oil the amount of excess  
 methanol =  $6.204 - (3 \times 1.144) = 2.808 \text{ mol};$

[3]

- (d) vegetable oil is mainly non-polar **and** methanol is polar / OWTTE;  
 stirring brings them into more contact with each other / increase the frequency of collisions / OWTTE;  
*Do not allow simply mixing.* [2]
- (e) (relative molecular mass of biodiesel,  $C_{19}H_{36}O_2 = 296.55$ )  
 maximum yield of biodiesel = 3.432 mol / 1018 g ;  
 percentage yield =  $\frac{811.0}{1018} \times 100 = 79.67\%$ ; [2]  
*Allow 80 % for percentage yield.*
- (f) the carbon dioxide was absorbed by plants initially so there is no net increase /  
 vegetable oil is not a fossil fuel / vegetable oil is formed from (atmospheric) carbon dioxide / OWTTE; [1]

SL A 08s

5. (a)  $C_3H_6 + Br_2 \rightarrow C_3H_6Br_2/CH_3CHBrCH_2Br$  ;  
 (orange/brown/red) colour (of bromine) disappears/is decolourized; [2]  
*Do not accept "goes clear".*



SL A 06s

5. (a) same general formula;  
 successive members differ by CH<sub>2</sub>;  
*Do not allow elements or just "they".*  
 similar chemical properties;  
*Allow same/constant.*  
 gradual change in physical properties;  
*Do not allow change periodically.*  
 same functional group;  
*Award [1] each for any two.* [2 max]

- (b) add bromine (water);  
 alkanes – no change / stays or turns brown;  
*Allow red-brown or any combination of brown, orange or yellow.*  
 alkenes – bromine (water) decolorizes;  
*Do not allow clear or discoloured.*

*or*

- add (acidified) KMnO<sub>4</sub>;  
 alkanes – no change;  
 alkenes – KMnO<sub>4</sub> decolorizes / brown / black; [3]

#### SL A 05sQ2

- (c) carbon monoxide / carbon is produced;  
 CO is toxic / poisonous / forms carboxyhemoglobin / interferes with oxygen transport  
 in the body;  
 carbon (soot) is harmful to the respiratory system; [2 max]  
*Award [1] each for any two.*

#### SL A 05s

5.	structural formula	name
	CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> ;	butane / n-butane;
	CH <sub>3</sub> CH(CH <sub>3</sub> )CH <sub>3</sub> ;	(2)-methylpropane; <span style="float: right;">[4]</span>

*Accept more detailed formulas, penalizing missing H atoms once only.*  
*If more than these two formulas given, subtract [1] for each extra formula.*  
*Mark names separately. Accept these two names only.*

## Topic 2 Questions

#### SL B 13s

6. The element boron has two naturally occurring isotopes,  $^{10}\text{B}$  and  $^{11}\text{B}$ .

- (a) (i) Define the term *isotopes of an element*.

[1]

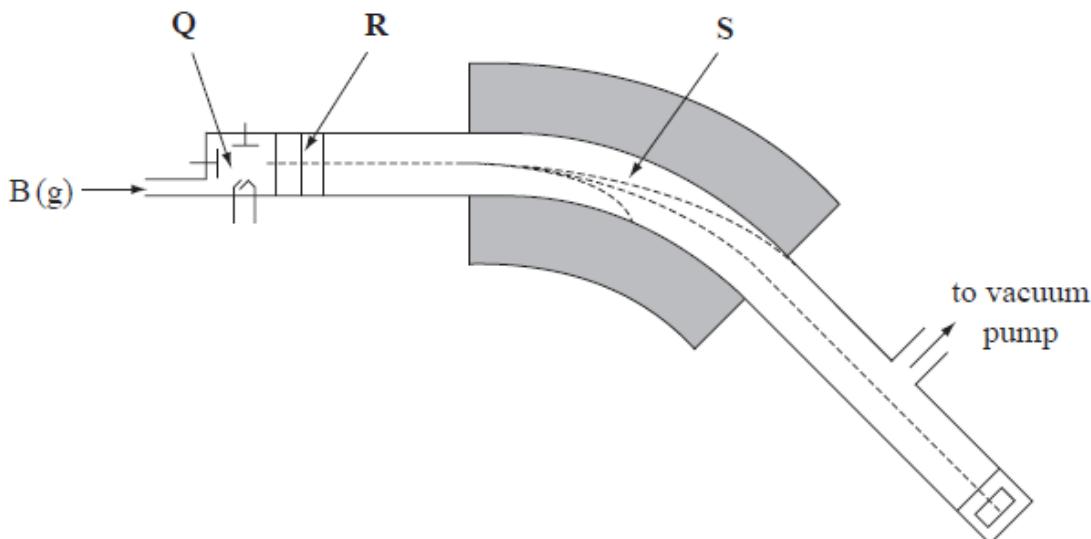
.....  
.....

- (ii) Calculate the percentage abundance of **each** isotope, given that the relative atomic mass of B is 10.81.

[2]

.....  
.....  
.....  
.....  
.....

- (b) The percentage abundance of the isotopes of boron can be determined with a mass spectrometer. The diagram shows the operation of a mass spectrometer.



- (i) State the names of stages **R** and **S**.

[1]

**R:** .....

**S:** .....

- (ii) Deduce the number of protons, neutrons and the electron arrangement of the main ion of  $^{11}B$  formed in stage **Q**.

[2]

Protons:

.....

Neutrons:

.....

Electron arrangement:

.....

(iii) Identify the species that is used as the scale for the mass of the isotopes.

[1]

.....

SL B 11S Q7

(f) Silicon has three stable isotopes,  $^{28}\text{Si}$ ,  $^{29}\text{Si}$  and  $^{30}\text{Si}$ . The heaviest isotope,  $^{30}\text{Si}$ , has a percentage abundance of 3.1%. Calculate the percentage abundance of the lightest isotope to one decimal place.

[2]

.....  
.....  
.....  
.....

(g) Identify a radioactive isotope of carbon and state **one** of its uses.

[1]

.....  
.....

SL B 10s

4. (a) Define the term *relative atomic mass* ( $A_r$ ).

[1]

(b) Relative atomic masses are obtained using a mass spectrometer. Draw a simple annotated diagram of the mass spectrometer.

[5]

(c) The relative atomic mass of naturally occurring copper is 63.55. Calculate the abundances of  $^{63}\text{Cu}$  and  $^{65}\text{Cu}$  in naturally occurring copper.

[2]

(d) The isotopes of some elements are radioactive. State a radioisotope used in medicine.

[1]

SL B 09s

5. (a) (i) Describe and explain the operation of a mass spectrometer. [5]
- (ii) State **three** factors that affect the degree of deflection of ions in a mass spectrometer. [3]
- (iii) Strontium exists as four naturally-occurring isotopes. Calculate the relative atomic mass of strontium to two decimal places from the following data. [2]

Isotope	Percentage abundance
Sr-84	0.56
Sr-86	9.90
Sr-87	7.00
Sr-88	82.54

SL B 07sQ6

- (f) The relative atomic mass of chlorine is 35.45. Calculate the percentage abundance of the two isotopes of chlorine,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$  in a sample of chlorine gas. [2]

SL B 01s

5. (a) Describe the appearance of the emission spectrum of hydrogen. Explain how this spectrum is related to the electron energy levels of hydrogen. [5]

SL A 11s

2. (a) Explain why the relative atomic mass of argon is greater than the relative atomic mass of potassium, even though the atomic number of potassium is greater than the atomic number of argon.

[1]

.....  
.....  
.....

- (b) Deduce the numbers of protons and electrons in the  $\text{K}^+$  ion.

[1]

.....  
.....  
.....

- (c) Deduce the electron arrangement for the  $\text{K}^+$  ion.

[1]

.....  
.....  
.....

2. (a) In a sample of gallium, the percentage abundance of  $^{69}\text{Ga}$  is 60.4 and  $^{71}\text{Ga}$  is 39.6. Determine the relative atomic mass of gallium. [2]

.....  
.....  
.....  
.....

- (b) State the electron arrangement of the following species. [2]

(i) A potassium ion

.....  
.....

(ii) A sulfide ion

.....  
.....

- (c) Describe the difference between a continuous spectrum and a line spectrum. [2]

.....  
.....  
.....  
.....

2. (a) Define the following terms.

(i) *atomic number*

[1]

.....  
.....

(ii) *mass number*

[1]

.....  
.....

- (b) Use the data below to calculate the relative molecular mass of thallium bromide, TlBr<sub>3</sub>, to two decimal places.

[3]

Isotope	Percentage Abundance
<sup>203</sup> Tl	29.52
<sup>205</sup> Tl	70.48
<sup>79</sup> Br	50.69
<sup>81</sup> Br	49.31

.....  
.....  
.....  
.....

- (c) Write the symbol for the ion with a 2+ charge which has the electron arrangement of 2, 8. [1]

.....

- (d) Write the symbols for three other species, which also have the electron arrangement of 2, 8. [2]

.....  
.....  
.....

2. (a) Define the term *isotope*.

[2]

.....  
.....  
.....

- (b) A sample of argon exists as a mixture of three isotopes.

mass number 36, relative abundance 0.337 %

mass number 38, relative abundance 0.0630 %

mass number 40, relative abundance 99.6 %

Calculate the relative atomic mass of argon.

[2]

.....  
.....  
.....  
.....

- (c) State the number of electrons, protons and neutrons in the ion  $^{56}\text{Fe}^{3+}$ .

[2]

electrons: ..... protons: ..... neutrons: .....

SL A 01s

3. (a) Define the terms *atomic number* and *mass number*.

[2]

Atomic number: .....

Mass number: .....

- (b) For each of the species shown in the table, state the number of each sub-atomic particle present.

[3]

Species	Protons	Neutrons	Electrons
$^{14}_6\text{C}$			
$^{19}_9\text{F}^-$			
$^{40}_{20}\text{Ca}^{2+}$			

## Topic 2 Mark Scheme

SL B 13s

6. (a) (i) atoms of the same element/with the same number of protons/with same atomic number but different number of neutrons/mass number/mass; [1]
- (ii)  $10x + 11(1-x) = 10.81$ ,  $x = 0.19$ ;  
*Accept similar method.*
- $^{10}B$ : 19% and  $^{11}B$ : 81%; [2]
- (b) (i) R: acceleration and S: deflection; [1]
- (ii) Protons: 5 and Neutrons: 6;  
 Electron arrangement:  $2,2 / 1s^2 2s^2$ ;  
*Allow suitable diagram.* [2]
- (iii)  $^{12}C$ /carbon-12; [1]

SL B 11Sq7

- (f)  $2809 = 3.10 \times 30 + 28x + 29(96.9 - x)$ ;  
 $\% ^{28}\text{Si} = (93 + 2810.1 - 2809) = 94.1\%$ ; [2]  
*Award [2] for correct final answer.*
- (g)  $^{14}\text{C}$  and radiocarbon dating/(tracer in) medical/scientific tests;  
 $^{11}\text{C}$  and (tracer in) medical/scientific tests; [1 max]

SL B 10s

4. (a) average mass of isotopes of an element compared to  $(1/12 \text{ g of}) ^{12}\text{C} / \text{average mass of an atom relative to C-12}$  having a mass of exactly 12 / OWTTE; [1]  
*Allow element instead of atom.*  
*Must refer to average mass and C-12.*
- (b) Diagram of mass spectrometer containing in the correct sequence:  
 vaporization/vaporized sample;  
 ionization/electron gun;  
 acceleration/oppositely charged plates;  
 deflection/magnetic field;  
 detection; [5]  
*Award [3] for 5 correct labels, [2] for 3–4 correct labels, [1] for 2 correct labels.*  
*Award [1] for correct order for at least 4 correct labels.*  
*Award [1] for diagram, which must at least show ionization (e.g. electron beam), acceleration (e.g. charged plates) and deflection (e.g. magnetic field) even if these are incorrectly labelled.*
- (c)  $63x + 65(1-x) = 63.55$ ;  
*(or some other mathematical expression).*
- $^{63}\text{Cu} = 72.5\%$  and  $^{65}\text{Cu} = 27.5\%$ ;  
*Allow  $^{63}\text{Cu} = 0.725$  and  $^{65}\text{Cu} = 0.275$ .* [2]  
*Award [2] for correct final answer.*
- (d)  $^{60}\text{Co} / ^{131}\text{I} / ^{125}\text{I}$ ;  
*Must contain correct mass numbers.*  
*Allow other formats such as cobalt-60, Co-60 etc.*  
*Award no marks if a correct radioisotope is given with an incorrect radioisotope.*  
*Allow any other radioisotope if you can verify its use.* [1]

SL B 09s

5. (a) (i) a vaporized sample must be used;  
 bombarded with (high energy) electrons to form positive ions;  
 accelerated by passing through an electric field;  
 deflected by passing through a magnetic field;  
 detected by producing a current;  
*Award [2 max] if just the words vaporization, ionization, acceleration, deflection and detection are used with no explanation.*  
 [5]

(ii) (size of the positive) charge (on the ion);  
 mass (of the ion);  
 strength of the magnetic field;  
 velocity/speed (of the ions) / strength of electric field;  
*m/z scores the first two marking points.*  
 [3 max]

(iii) 
$$A_r = \frac{[(0.56 \times 84) + (9.90 \times 86) + (7.00 \times 87) + (82.54 \times 88)]}{100} ;$$
  

$$= 87.71 ;$$
  
*Award [1 max] if answer not given to two decimal places.*  
*Award [2] for correct final answer.*  
*Apply -1(U) if answer quoted in g or g mol<sup>-1</sup>.*  
 [2]

SL B 07s

$$(f) \quad A_t(\text{Cl}) = 35.45 = \frac{35x + 37(100-x)}{100};$$

$^{35}\text{Cl} = 77.5\%$  and  $^{37}\text{Cl} = 22.5\%;$  [2]

SL B 01s

5. (a) (First [3] marks could be scored from a labelled diagram)  
 Line spectrum [1]  
 (Lines) converge [1]  
 At high energy / high frequency / shorter wave length / blue end of spectrum [1]  
 Electron transition between energy levels [1] (either direction)  
 Each transition/line is related to energy difference /  $\Delta E = \frac{hc}{\lambda}$  /  $E = h\nu$  [1] [5 max]

SL A 11s

2. (a) argon has a greater proportion of heavier isotopes / OWTTE / argon has a greater number of neutrons; [1]

(b) 19 protons **and** 18 electrons; [1]

(c) 2, 8, 8;  
Accept  $1s^2 2s^2 2p^6 3s^2 3p^6$ . [1]

SL A 08s

2. (a)  $\frac{69 \times 00.4}{100} + \frac{1 \times 59.0}{100};$   
69.8; [2]
- (b) (i) Potassium ion 2,8,8;  
(ii) Sulfide ion 2,8,8;  
*Allow electron configuration in terms of spdf.* [2]
- (c) (continuous spectrum) has all colours/wavelengths/frequencies;  
(line spectrum) has only lines of specific colours/wavelengths/frequencies/has some colours missing; [2]

#### SL A 06s

2. (a) (i) number of protons in the nucleus/atom;  
*Do not accept protons and electrons.* [1]
- (ii) number of protons and neutrons in the nucleus/atom; [1]
- (b)  $A_r(\text{Tl}) = 203 \times 0.2952 + 205 \times 0.7048 / 204.41;$   
 $A_r(\text{Br}) = 79 \times 0.5069 + 81 \times 0.4931 / 79.99;$   
 $M_r(\text{TlBr}_3) = 204.41 + 3 \times 79.99 = 444.38 / 444.37;$  [3]  
*Correct answer scores [3].*  
*Ignore units of g or g mol<sup>-1</sup>.*  
*Apply ECF to  $M_r$  from  $A_r$  values.*
- (c) Mg<sup>2+</sup>; [1]
- (d) Al<sup>3+</sup>, O<sup>2-</sup>, Ne, Na<sup>+</sup>, F<sup>-</sup>, N<sup>3-</sup>; [2]  
*Do not accept Fl<sup>-</sup>.*  
*Award [2] for any three, [1] any two.*

#### SL A 04s

2. (a) atoms of the same element / same number of protons / same atomic number;  
having different numbers of neutrons / different (mass number);  
*Award only [1] max if reference made to elements but not atoms.*
- (b) relative atomic mass =  $\frac{36 \times 0.337 + 38 \times 0.0630 + 40 \times 99.6}{100};$   
= 39.98 / 39.99 / 40.0; [2]
- (c) 23 electrons;  
26 protons;  
30 neutrons; [2]  
*Award [2] for three correct, [1] for two correct.*

#### SL A 01s

3. (a) (Atomic number)

Number of protons in an atom / nucleus [1]

(Mass number)

Number of protons and neutrons in an atom / nucleus [1]

[2 max]

(b)

Species	Protons	Neutrons	Electrons
$^{14}_6\text{C}$	6	8	6
$^{19}_9\text{F}^-$	9	10	10
$^{40}_{20}\text{Ca}^{2+}$	20	20	18

[1]

[1]

[1]

[3 max]

## Topic 3 Questions

SL B 12sQ6f

- (iii) The reactions between the halogens and water show that fluorine is more reactive than bromine. Explain why, on an atomic level, fluorine is the more reactive element.

[3]

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SL B 11s

5. (a) (i) Define the term *first ionization energy*.

[2]

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.....  
.....  
.....

(ii) Explain why the first ionization energy of magnesium is higher than that of sodium. [2]

.....  
.....  
.....  
.....

(b) Explain why:

(i) calcium has a higher melting point than potassium.

[2]

.....  
.....  
.....  
.....

(ii) sodium oxide has a higher melting point than sulfur trioxide.

[3]

.....  
.....  
.....  
.....  
.....  
.....

7. Carbon and silicon belong to the same group of the periodic table.

- (a) Distinguish between the terms *group* and *period* in terms of electron arrangement. [2]

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.....  
.....  
.....

- (b) State the period numbers of both carbon and silicon. [1]

.....  
.....

SL B 10sQ4

- (e) State a balanced equation for the reaction of sodium with water. Include state symbols. [2]

- (f) With reference to electronic arrangements, suggest why the reaction between rubidium and water is more vigorous than that between sodium and water. [2]

- (g) Describe and explain what you will see if chlorine gas is bubbled through a solution of

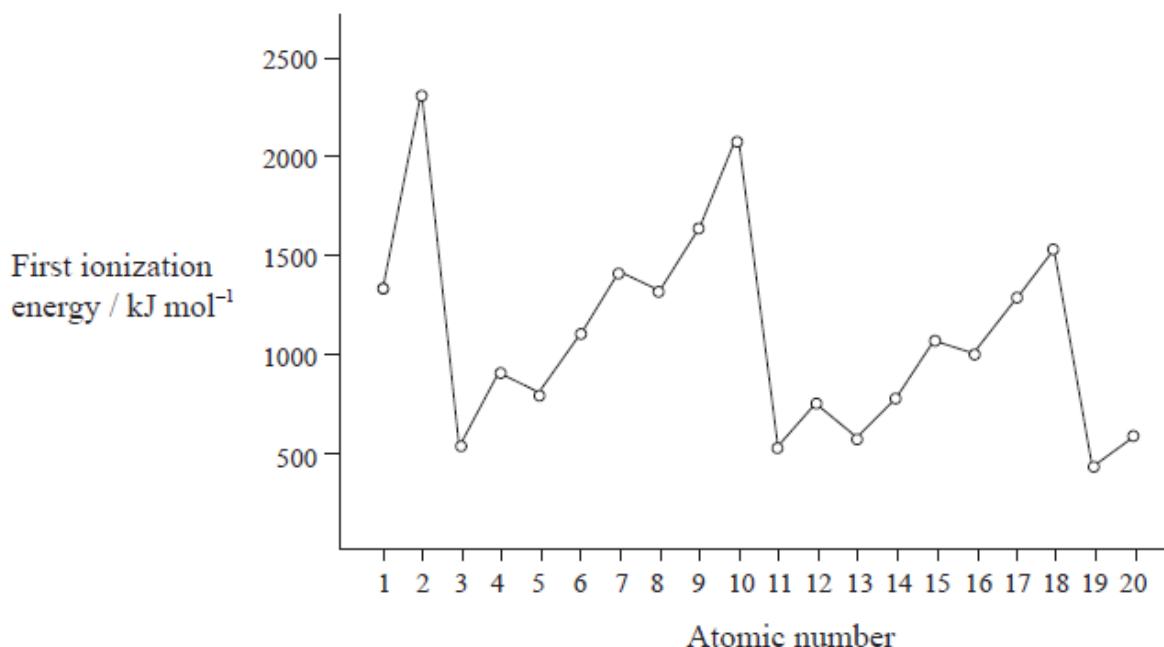
- (i) potassium iodide. [2]

- (ii) potassium fluoride. [1]

- (h) Explain why the melting points of the elements decrease down group 1 and increase down group 7. [4]

SL B 09sQ5

- (b) The graph of the first ionization energy plotted against atomic number for the first twenty elements shows periodicity.



(i) Define the term *first ionization energy* and state what is meant by the term *periodicity*. [2]

(ii) State the electron arrangement of argon and explain why the noble gases, helium, neon and argon show the highest first ionization energies for their respective periods. [3]

(iii) A graph of atomic radius plotted against atomic number shows that the atomic radius decreases across a period. Explain why chlorine has a smaller atomic radius than sodium. [1]

(iv) Explain why a sulfide ion,  $S^{2-}$ , is larger than a chloride ion,  $Cl^-$ . [1]

(v) Explain why the melting points of the Group 1 metals ( $Li \rightarrow Cs$ ) decrease down the group whereas the melting points of the Group 7 elements ( $F \rightarrow I$ ) increase down the group. [3]

SL B 08sQ6

(c) The oxides of magnesium, aluminium and phosphorus illustrate the change in nature of elements from metallic to non-metallic. Each of the three oxides is mixed with separate samples of pure water. For each of the oxides, state whether the **resulting solution** is acidic, basic or neutral. Write an equation for each reaction that occurs. [4]

SL B 06s

7. (a) Explain why
- (i) the first ionization energy of magnesium is lower than that of fluorine. [2]
  - (ii) magnesium has a higher melting point than sodium. [3]
- (b) Discuss the acid-base nature of the period 3 oxides. Write an equation to illustrate the reaction of one of these oxides to produce an acid, and another equation of another of these oxides to produce a hydroxide. [5]

SL B 05s

6. (a) The letters **W**, **X**, **Y** and **Z** represent four consecutive elements in the periodic table. The number of electrons in the highest occupied energy levels are:

$$\mathbf{W}: 3, \mathbf{X}: 4, \mathbf{Y}: 5, \mathbf{Z}: 6$$

Write the formula for

- (i) an ionic compound formed from **W** and **Y**, showing the charges. [2]
  - (ii) a covalent compound containing **X** and **Z**. [1]
- (b) State the number of protons, electrons and neutrons in the ion  $^{15}_7\text{N}^{3-}$ . [2]

SL B 05s

7. (a) State and explain the trends in the atomic radius and the ionization energy

- (i) for the alkali metals Li to Cs. [4]
- (ii) for the period 3 elements Na to Cl. [4]

- (b) (i) Describe **three** similarities and **one** difference in the reactions of lithium and potassium with water. [4]
- (ii) Give an equation for **one** of these reactions. Suggest a pH value for the resulting solution, and give a reason for your answer. [3]

- (c) Classify each of the following oxides as acidic, basic or amphoteric.

- (i) aluminium oxide [1]
- (ii) sodium oxide [1]
- (iii) sulfur dioxide [1]

- (d) Write an equation for each reaction between water and

- (i) sodium oxide. [1]
- (ii) sulfur dioxide. [1]

SL B 01sQ5

- (b) (i) Explain each of the terms *ionisation energy* and *electronegativity*. [5]

(ii) Give the equation for the reaction of potassium with water and explain why potassium is more reactive than lithium. [4]

(c) Describe and explain the trends in atomic radii and electronegativity on descending the halogen group and across Period 3. [6]

SL A 13s

TABLE 8

2. Table 8 of the Data Booklet shows the atomic and ionic radii of the elements.

- (a) Describe and explain the trend in atomic radius across period 3. [3]

.....

.....

.....

.....

.....

.....

- (b) A student formulates the following hypothesis: "If phosphorus were to form a positive ion,  $P^{3+}$ , its ionic radius would probably be between  $110 \times 10^{-12} \text{ m}$  and  $212 \times 10^{-12} \text{ m}$ ." Evaluate this hypothesis. [2]

.....

.....

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SLA 07s

2. (a) State the meaning of the term *electronegativity*. [1]

.....  
.....

- (b) State and explain the trend in electronegativity across period 3 from Na to Cl. [2]

.....  
.....  
.....  
.....

- (c) Explain why  $\text{Cl}_2$  rather than  $\text{Br}_2$  would react more vigorously with a solution of  $\text{I}^-$ . [2]

.....  
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.....  
.....

SL A 03s

4. Explain the following statements.

- (a) The first ionization energy of sodium is

- (i) less than that of magnesium. [2]

.....  
.....  
.....  
.....

- (ii) greater than that of potassium. [1]

.....  
.....

- (b) The electronegativity of chlorine is higher than that of sulfur. [2]

.....  
.....  
.....

SL A 03s

5. The element vanadium has two isotopes,  $^{50}_{23}\text{V}$  and  $^{51}_{23}\text{V}$ , and a relative atomic mass of 50.94.

- (a) Define the term *isotope*.

[1]

.....  
.....

- (b) State the number of protons, electrons and neutrons in  $^{50}_{23}\text{V}$ .

[2]

.....  
.....

- (c) State and explain which is the more abundant isotope.

[1]

.....  
.....

- (d) State the name and the mass number of the isotope relative to which all atomic masses are measured.

[1]

.....

1. The values of atomic radius and ionic radius for the period 3 elements are given below.

Symbol of element	Na	Mg	Al	Si	P	S	Cl
Atomic radius / $10^{-12}$ m	186	160	143	117	110	104	99
Ionic radius / $10^{-12}$ m	98	65	45	42	212	190	181

- (a) Complete the following table to show the number of protons and electrons in each of the following species:

[3]

	Number of protons	Number of electrons
Na	.....	.....
Al <sup>3+</sup>	.....	.....
P <sup>3-</sup>	.....	.....

- (b) Explain why the atomic radius decreases from sodium to chlorine.

[2]

.....  
.....  
.....  
.....

- (c) The ionic radius of aluminium is smaller than its atomic radius. The ionic radius of phosphorus is greater than its atomic radius. Explain the large difference in ionic radius between aluminium and phosphorus.

[2]

.....  
.....  
.....  
.....

(d) Sodium and chlorine both react with water.

- (i) Write an equation for the reaction between sodium and water and state whether the resulting solution is acidic, neutral or alkaline. [2]

.....  
.....  
.....

- (ii) Write an equation for the reaction between chlorine and water and state whether the resulting solution is acidic, neutral or alkaline. [2]

.....  
.....  
.....

### Topic 3 Mark Scheme

SL B 12sQ6f

- (iii) fluorine accepts/attracts electrons more readily/strongly / is a better oxidizing agent;  
fluorine has smaller atomic radius/fewer energy levels/shells;  
*Do not allow fluorine atom smaller.*

so nucleus attracts electrons more strongly; [3]  
*Allow opposite argument for bromine.*

SL B 11s

5. (a) (i) the amount of energy required to remove one (mole of) electron(s); from (one mole of) an atom(s) in the gaseous state; [2]
- (ii) greater positive charge on nucleus / greater number of protons / greater core charge;  
greater attraction by Mg nucleus for electrons (in the same shell) / smaller atomic radius; [2]
- (b) (i) calcium ionic charge is twice/greater than the potassium ionic charge / calcium has more delocalized electrons than potassium;  
greater attraction of delocalized electrons and  $\text{Ca}^{2+}$  / less attraction between the delocalized electrons and  $\text{K}^+$ ;  
*Do not accept calcium ion has a  $2^+$  without comparison to  $\text{K}^+$ .* [2]
- (ii)  $\text{Na}_2\text{O}$  ionic/(stronger electrostatic) attractions between  $\text{Na}^+$  and  $\text{O}^{2-}$ ;  
 $\text{SO}_3$  has (weak) intermolecular/van der Waals'/London/dispersion/dipole-dipole attractions;  
intermolecular/van der Waals'/London/dispersion/dipole-dipole forces are weaker/more easily broken than (strong) ionic bonds / ionic bonds are stronger/harder to break than intermolecular bond/van der Waals'/London/dispersion/dipole-dipole forces; [3]

#### SL B 11s

7. (a) *Group:* number of outershell/valence electrons;  
*Period:* number of occupied (electron) shells; [2]
- (b) C: 2 and Si: 3; [1]

#### SL B 10sQ4

- (e)  $2\text{Na}(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{NaOH}(\text{aq}) + \text{H}_2(\text{g})$  /  $\text{Na}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{NaOH}(\text{aq}) + \frac{1}{2}\text{H}_2(\text{g})$  [2]  
*Award [1] for correct balanced equation.*  
*Award [1] for correct state symbols for sodium, water, sodium hydroxide and hydrogen.*  
*Second mark is not dependent on equation being correctly balanced.*
- (f) (Rb more reactive because) electron lost further from nucleus so less tightly held;  
Rb electron is in 5th energy level and (Na less reactive) as electron lost in 3rd energy level / OWTTE; [2]  
*Allow [1 max] for electron arrangements of Na (e.g. 2,8,1) and Rb if second mark is not scored.*
- (g) (i) solution becomes yellow/orange/brown/darker;  
chlorine is more reactive than iodine (and displaces it from solution) / OWTTE; [2]  
*Allow correct equation ( $2\text{KI} + \text{Cl}_2 \rightarrow 2\text{KCl} + \text{I}_2$ ) for second mark or stating that iodine/ $\text{I}_2$  is formed.*
- (ii) no colour change/nothing happens as fluorine is more reactive than chlorine / OWTTE; [1]

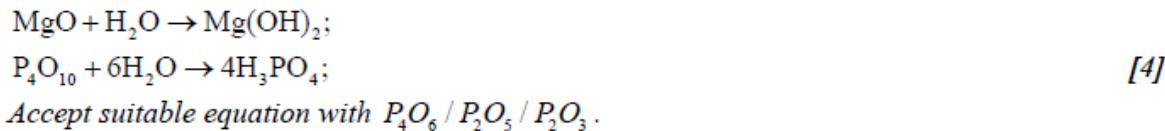
- (h) *Down group 1:*  
 metallic bonding gets weaker;  
 radii/atoms get bigger / delocalized electrons shielded/screened from nucleus by filled shells;
- Down group 7:*  
 increased  $M_r$  of halogen molecules / OWTTE;  
 intermolecular/van der Waals/London/dispersion forces increase; [4]

SL B 09sQ5

- (b) (i) first ionization energy:  $M(g) \rightarrow M^+(g) + e^-/e^-$  / the (minimum) energy (in  $\text{kJ mol}^{-1}$ ) to remove one electron from a gaseous atom / the energy required to remove one mole of electrons from one mole of gaseous atoms;  
 periodicity: repeating pattern of (physical and chemical) properties; [2]
- (ii) 2.8.8/sp version;
- Accept any two of the following:*  
 the outer energy level/shell is full;  
 the increased charge on the nucleus;  
 great(est) attraction for electrons; [3 max]
- (iii) 17 p in Cl nucleus attract the outer level more than 11 p in Na nucleus / greater nuclear charge attracts outer level more; [1]  
*Allow converse for Na.*  
*Do not accept larger nucleus.*
- (iv)  $S^{2-}$  has one proton less/ smaller nuclear charge so outer level held less strongly / OWTTE; [1]  
*Allow converse for chloride.*  
*Do not accept larger nucleus.*
- (v) the radii of the metal atoms increase (from  $\text{Li} \rightarrow \text{Cs}$ ) (so the forces of attraction are less between them) / OWTTE;  
 the forces of attraction between halogen molecules are van der Waals;  
 forces increase with increasing mass/number of electrons; [3]

SL B 08sQ6

- (c) ( $\text{MgO}$ ) basic **and** ( $\text{P}_4\text{O}_6$  /  $\text{P}_4\text{O}_{10}$ ) acidic;  
 $(\text{Al}_2\text{O}_3)$  neutral;  
*Formulas not required but it must be clear which oxide is being referred to*



SL B 06s

7. (a) (i) electron removed from higher energy level / further from nucleus / greater atomic radius;  
increased repulsion by extra inner shell electrons / increased shielding effect; [2]

(ii) Mg has twice as many / more delocalized electrons (compared to Na);  
the ionic charge is twice as big / greater in Mg (than Na);  
(electrostatic) attraction between ions and electrons is much greater; [3]

(b) oxides of Na, Mg are basic  
Al is amphoteric  
Si, P, S and Cl are acidic

*Award 7 correct [3], 6/5 correct [2] and 4/3 correct [1].*

$$\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3 / \text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 /$$

$$\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4 / \text{P}_4\text{O}_6 + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_3;$$

$$\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH} / \text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2;$$

*Accept equation using  $\text{P}_2\text{O}_3$  or  $\text{P}_2\text{O}_5$ .*

SL B 05s

6. (a) (i)  $\text{W}^{3+}\text{Y}^{3-}$ ;  
Award [1] for formula ( $\text{WY}$ ) and [1] for charges ( $\text{W}:3+ \text{Y}:3-$ )  
Accept  $\text{WY}$ , charges  $\text{W}: 3+$   $\text{Y}: 3-$  for [2].  
*Answers must be in terms of W and Y.*

(ii)  $\text{XZ}_2$ ;  
Accept  $\text{XZ}$ .  
*Answers must be in terms of X and Z.*

(b) 7 protons, 8 neutrons, 10 electrons;  
Award [2] for three correct and [1] for two correct.

SL B 05s

7. (a) (i) *Li to Cs*  
 atomic radius increases;  
 because more full energy levels are used or occupied / outer electrons further from nucleus / outer electrons in a higher shell;  
 ionization energy decreases;  
 because the electron removed is further from the nucleus / increased repulsion by inner-shell electrons; [4]  
*Accept increased shielding effect.*
- (ii) *Na to Cl*  
 atomic radius decreases;  
 because nuclear charge increases **and** electrons are added to same main (outer) energy level;  
 ionization energy increases;  
 because nuclear charge increases **and** the electron removed is closer to the nucleus/is in the same energy level; [4]  
*Accept "core charge" for "nuclear charge".*  
*In (i) and (ii) explanation mark dependent on correct trend.*
- (b) (i) *similarities [3 max]*  
 the metal floats / moves on the surface;  
 fizzing / effervescence / bubbles; (*accept sound is produced*)  
 solution gets hot;  
 solution becomes alkaline / basic;  
 they react to form the metal hydroxide;  
 hydrogen is evolved;  
*differences [1 max]*  
 flame / hydrogen burns with potassium (and not with lithium) / reaction faster / more vigorous with potassium / slower or less vigorous with lithium; [4 max]
- (ii)  $2\text{Li} + 2\text{H}_2\text{O} \rightarrow 2\text{Li}^+ + 2\text{OH}^- + \text{H}_2$  /  $2\text{K} + 2\text{H}_2\text{O} \rightarrow 2\text{K}^+ + 2\text{OH}^- + \text{H}_2$ ;  
*Accept LiOH / KOH.*  
 $\text{pH} \geq 11$ ;  
 LiOH/KOH is a strong base/strong alkali / high concentration of  $\text{OH}^-$ ; [3]
- (c) (i) *aluminium oxide*  
 amphoteric;
- (ii) *sodium oxide*  
 basic;
- (iii) *sulfur dioxide*  
 acidic; [3]
- (d) (i)  $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Na}^+ + 2\text{OH}^-$  ;  
 (ii)  $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$  ;  
*Accept NaOH and  $\text{H}^+ + \text{HSO}_3^- / 2\text{H}^+ + \text{SO}_3^{2-}$ .* [2]

SL B 01s

- (b) (i) Ionisation energy: (energy) required to remove one electron [1]  
                  from outermost shell [1]  
                  from gaseous atom [1]  
                  (Allow monatomic element but not gaseous element)

*(Correct equation, with (g) indicated, could score [2])*

Electronegativity: tendency / ability / power to attract (not gain) electrons [1]  
                  of a shared pair / covalent bond [1] [5 max]

- (ii)  $2\text{K} + 2\text{H}_2\text{O} \rightarrow 2\text{KOH} + \text{H}_2$  products correct [1]  
                  balanced [1]

K bigger /  $e^-$  farther from the nucleus / K has more electron shells / increased shielding [1]

$e^-$  less strongly attracted / more easily lost [1] [4 max]

- (c) Halogens: electronegativity decreases down group [1]  
                  radius increases down group [1]  
                  shielding effect too [1]  
                  more shells [1]

- Period 3: electronegativity increases [1]  
                  radius falls [1]  
                  nuclear charge increases [1]  
                  electrons in same shell [1]

[6 max]

#### SL A 13s

2. (a) decreases (from left to right/across period 3);  
        same number of shells/energy levels / shielding effect remains the same;  
        number of protons/nuclear charge increases so attraction of nucleus on outer electrons increases / OWTTE; [3]
- (b) hypothesis is wrong since ionic radius should be smaller than atomic radius/ $110 \times 10^{-12}$  m;  
        greater attraction of the nucleus on outer electrons / effective charge of nucleus greater / repulsive forces between electrons smaller; [2]

#### SL A 07s

2. (a) the ability of an element/atom/nucleus to attract a bonding pair of electrons; [1]
- (b) electronegativity increases (along period 3 from Na to Cl);  
        number of protons increases / nuclear charge increases / core charge increases / size of atoms decreases; [2]  
*Do not accept greater nuclear attraction.*
- (c)  $\text{Cl}_2$  is a stronger oxidizing agent / Chlorine's outer shell closer to nucleus;  
         $\text{Cl}_2$  has greater attraction for electrons / has a higher electron affinity; [2]  
*Accept converse argument for  $\text{Br}_2$ .*

#### SL A 03s

4. (a) (i) Na has lower nuclear charge / number of protons;  
 electrons being removed are from same energy level / shell;  
 or Na has larger radius / electron further from nucleus; [2 max]  
*Award this mark if both electron arrangements are given.*
- (ii) Na electron closer to nucleus / in lower energy level / Na has less shielding effect; [1]  
*Allow counter arguments for Mg in (i) and K in (ii).*
- (b) chlorine has a higher nuclear charge;  
 attracts the electron pair / electrons in bond more strongly; [2]

#### SL A 03s

5. (a) atom of same element / same number of protons but with different mass number / number of neutrons; [1]
- (b) protons 23  
 electrons 23  
 neutrons 27 [2]  
*Three correct [2], two correct [1].*
- (c)  $^{51}_{23}\text{V}$  / 51 nearer to  $A_r$  value of 50.94; [1]
- (d) carbon, 12 /  $^{12}\text{C}$ ; [1]

#### SL A 02s

1. (a) Na 11 protons and 11 electrons [1];  
 $\text{Al}^{3+}$  13 protons and 10 electrons [1];  
 $\text{P}^{3-}$  15 protons and 18 electrons [1]. [3]
- (b) (*Award [1] for any two from the following:*)  
 increasing proton number / nuclear charge [1];  
 electrons attracted more strongly to nucleus [1];  
 electrons in same shell / energy level / no change in shielding [1]. [2]
- (c) Al loses electrons, P gains electrons (*allow equations*) [1];  
 phosphide/phosphorus has one more shell / energy level than aluminium [1]. [2]  
*Allow 2.8 and 2.8.8 for second mark.*
- (d) (i)  $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$  [1];  
 alkaline [1]; [2]
- (i)  $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{HClO}$  [1];  
 acidic [1]. [2]

## Topic 4 Questions

#### SL B 13sQ6

(c) (i) Deduce the Lewis structures of  $\text{NH}_3$  and  $\text{BF}_3$ .

[2]



(ii) Describe how covalent bonds are formed.

[1]

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(iii) Compare the shapes of the two molecules and explain the difference using valence shell electron pair repulsion theory (VSEPR).

[4]

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(iv) Predict and explain whether the molecules  $\text{NH}_3$  and  $\text{BF}_3$  are polar molecules. [2]

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SL B 12s

5. Ethane,  $C_2H_6$ , and disilane,  $Si_2H_6$ , are both hydrides of group 4 elements with similar structures but with different chemical properties.

(a) (i) Deduce the Lewis (electron dot) structure for  $Si_2H_6$  showing all valence electrons. [1]

(ii) State and explain the H–Si–H bond angle in  $Si_2H_6$ . [2]

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(iii) State which of the bonds, Si–H or C–H, is more polar. Explain your choice. [2]

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(iv) Predict, with an explanation, the polarity of the two molecules.

[2]

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(v) Explain why disilane has a higher boiling point than ethane.

[2]

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b

(ii) Compare the structure and bonding in carbon dioxide and silicon dioxide.

[3]

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.....

- (c) Describe and compare **three** features of the structure and bonding in the **three** allotropes of carbon: diamond, graphite and C<sub>60</sub> fullerene. [6]

(d) Both silicon and carbon form oxides.

(i) Draw the Lewis structure of  $\text{CO}_2$  and predict its shape and bond angle.

[2]

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(ii) Describe the structure and bonding in  $\text{SiO}_2$ .

[2]

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(iii) Explain why silicon dioxide is a solid and carbon dioxide is a gas at room temperature. [2]

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(e) Describe the bonding within the carbon monoxide molecule.

[2]

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SL B 09s

6. (a) (i) Draw the Lewis structures for carbon monoxide, CO, carbon dioxide, CO<sub>2</sub> and methanol, CH<sub>3</sub>OH.

[3]

(ii) List, with an explanation, the three compounds in order of increasing carbon to oxygen bond length (shortest first).

[2]

(b) Predict the shape and bond angles for the following species:

(i) CO<sub>2</sub> [2]

(ii) CO<sub>3</sub><sup>2-</sup> [2]

(iii) BF<sub>4</sub><sup>-</sup> [2]

SL B 08s

6. (a) Draw the Lewis structures of the following molecules. Use the VSEPR theory to predict the shape of each molecule and deduce whether it is polar or non polar.

(i) BF<sub>3</sub> and PCl<sub>3</sub> [5]

(ii) SO<sub>2</sub> and CO<sub>2</sub> [5]

(b) State and explain the difference in the following.

(i) The reactivity of Na and K with Cl<sub>2</sub>. [2]

(ii) The ease of oxidation of Br<sup>-</sup>(aq) and I<sup>-</sup>(aq) with Cl<sub>2</sub>. [2]

(iii) The conductivity of magnesium as compared to sulfur. [2]

SL B 07s

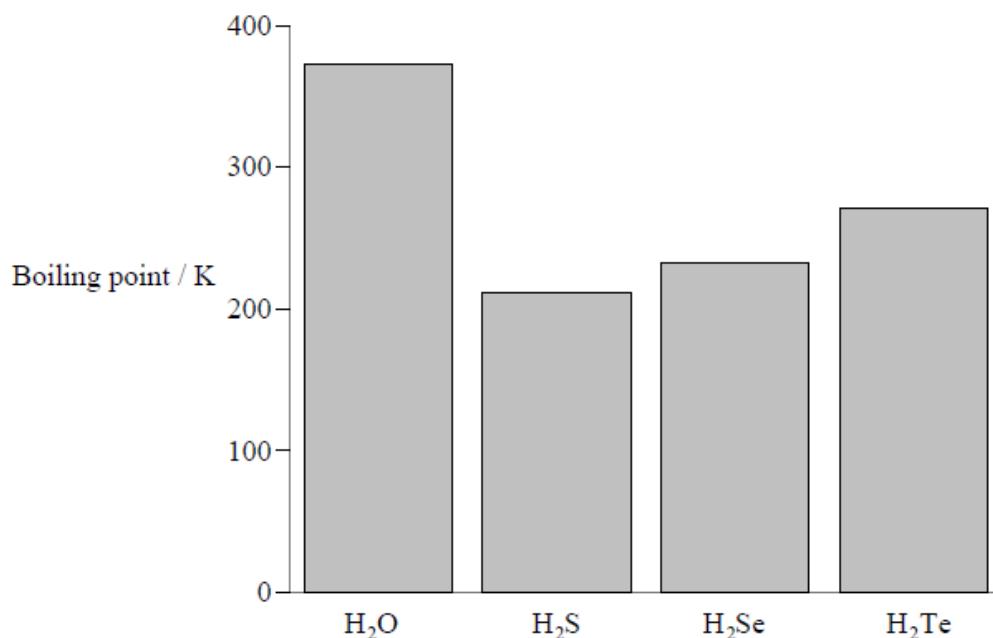
6. (a) State the electron arrangement for atoms of aluminium, nitrogen and fluorine. [2]
- (b) Describe the bonding present in samples of solid aluminium and nitrogen gas. [4]
- (c) Aluminium fluoride,  $\text{AlF}_3$ , is a solid up to a temperature of  $1250^\circ\text{C}$  whereas nitrogen trifluoride,  $\text{NF}_3$ , is a gas above  $-129^\circ\text{C}$ . Describe the bonding and structure in samples of each of these substances. [5]
- (d) Explain why
- (i) aluminium conducts electricity in both the solid and liquid state. [1]
- (ii) aluminium fluoride conducts electricity in the liquid state but not in the solid state. [2]
- (iii) nitrogen trifluoride does not conduct in either the liquid or solid states. [1]
- (e) Draw the Lewis structure of  $\text{NCl}_3$ . Predict, giving a reason, the  $\text{Cl} - \text{N} - \text{Cl}$  bond angle in  $\text{NCl}_3$ . [3]

SL B 05sQ6

- (c) State the type of bonding in the compound  $\text{SiCl}_4$ . Draw the Lewis structure for this compound. [3]
- (d) Outline the principles of the valence shell electron pair repulsion (VSEPR) theory. [3]
- (e) (i) Use the VSEPR theory to predict and explain the shape and the bond angle of each of the molecules  $\text{SCl}_2$  and  $\text{C}_2\text{Cl}_2$ . [6]
- (ii) Deduce whether or not each molecule is polar, giving a reason for your answer. [3]

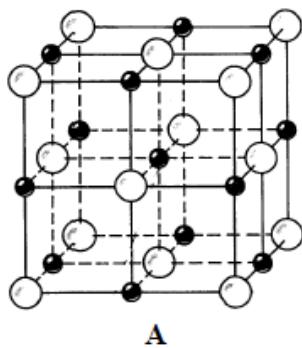
SL B 03s

6. (a) The boiling points of the hydrides of the group 6 elements are shown below.

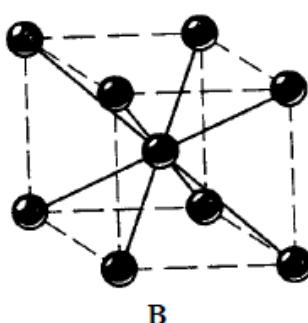


- (i) Explain the trend in boiling points from H<sub>2</sub>S to H<sub>2</sub>Te. [2]
- (ii) Explain why the boiling point of water is higher than would be expected from the group trend. [2]
- (b) (i) State the shape of the electron distribution around the oxygen atom in the water molecule and state the shape of the molecule. [2]
- (ii) State and explain the value of the HOH bond angle. [2]
- (c) Explain why the bonds in silicon tetrachloride, SiCl<sub>4</sub>, are polar, but the molecule is not. [2]

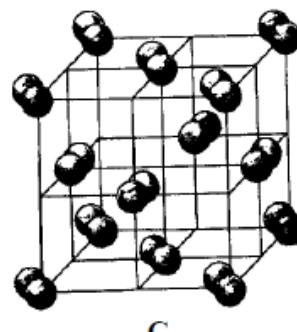
The diagrams below represent the structures of iodine, sodium and sodium iodide.



A



B



C

- (d) (i) Identify which of the structures (A, B and C) correspond to iodine, sodium and sodium iodide. [1]
- (ii) State the type of bonding in each structure. [3]
- (e) (i) Sodium and sodium iodide can both conduct electricity when molten, but only sodium can conduct electricity when solid. Explain this difference in conductivity in terms of the structures of sodium and sodium iodide. [4]
- (ii) Explain the high volatility of iodine compared to sodium and sodium iodide. [2]

SL B 02s

6. (a) The elements sodium and fluorine and the compound sodium fluoride can be used to show the connection between bonding, structure and physical properties.
- (i) Describe the type of bonding in sodium metal and explain why sodium is a good conductor of electricity. [4]
- (ii) Draw a Lewis structure for fluorine. Name and describe the bonding within and between the molecules in liquid fluorine. [5]
- (iii) Write the electronic structures of both sodium and fluorine and describe how the atoms combine to form sodium fluoride. [4]
- (iv) Explain why sodium fluoride does not conduct electricity until it is heated above its melting point. [1]
- (b) Sketch and name the shape of each of the following molecules:
- (i)  $\text{SiH}_4$  [2]
- (ii)  $\text{PH}_3$  [2]
- (c) State the bond angle in  $\text{SiH}_4$  and explain why the bond angle in  $\text{PH}_3$  is less than in  $\text{SiH}_4$ . [2]

SL B 01s

6. (a) The electronegativity value of carbon is 2.5 and that of oxygen is 3.5.
- (i) Draw a Lewis (electron dot) structure for the carbon dioxide molecule, state its shape and give the bond angle. [3]
- (ii) Using the concepts of molecular shape and bond polarity, predict, with an explanation, whether or not the carbon dioxide **molecule** is polar. [3]

SL A 09s

3. Sodium oxide,  $\text{Na}_2\text{O}$ , is a white solid with a high melting point.

- (a) Explain why solid sodium oxide is a non-conductor of electricity. [1]

.....  
.....

SL A 04s

3. (a) (i) Draw Lewis (electron dot) structures for CO<sub>2</sub> and H<sub>2</sub>S showing all valence electrons. [2]

(ii) State the shape of each molecule and explain your answer in terms of VSEPR theory. [4]

CO<sub>2</sub> .....  
.....  
.....

H<sub>2</sub>S .....  
.....

(iii) State and explain whether each molecule is polar or non-polar. [2]

.....  
.....  
.....  
.....

(b) Identify the strongest type of intermolecular force in each of the following compounds. [3]

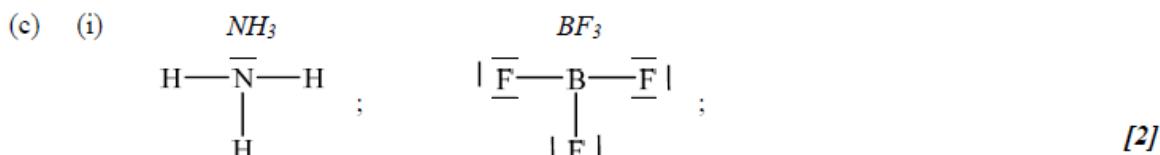
CH<sub>3</sub>Cl .....

CH<sub>4</sub> .....

CH<sub>3</sub>OH .....

## Topic 4 Mark Scheme

SL B 13sQ6



*Accept any combination of lines, dots or crosses to represent electron pairs.*

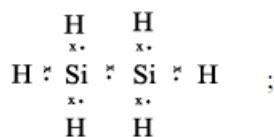
- (ii) sharing of electrons between atoms; [1]

- (iii)  $NH_3$ : (trigonal/triangular) pyramidal;  
 $BF_3$ : trigonal/triangular planar;  
 $NH_3$  has 4 negative centres of charge/three bonding pairs and one lone pair **and**  
 $BF_3$  has 3 negative centres of charge/three bonding pairs / OWTTE;  
(bond angles)  $107^\circ$  in  $NH_3$  **and**  $120^\circ$  in  $BF_3$ ;  
*Accept  $107.5^\circ$  for  $NH_3$ .* [4]

- (iv)  $BF_3$  not polar as no net dipole moment / BF bond polarities cancel each other out / symmetrical distribution of charge;  
 $NH_3$  polar as net dipole moment present / NH bond polarities do not cancel each other out / unsymmetrical distribution of charge; [2]  
*Accept suitable diagram showing dipole moments.*  
*Do not accept electronegativities cancel out.*

SL B 12s

5. (a) (i)



[1]

*Accept any combination of lines, dots or crosses to represent electron pairs.*

- (ii)  $109^\circ$  /  $109.5^\circ$  /  $109^\circ 28'$ ;  
four/tetrahedrally arranged negative charge centres/electron domains/electron pairs (around central/silicon atom) / equal repulsion between bonding pairs (around central/silicon atom) / OWTTE;  
*M2 is an independent marking point.*  
*Reference must be made to negative or electron.*  
*Do not accept tetrahedral molecule.* [2]

- (iii) C–H;  
larger difference in electronegativity (for C–H bond) / smaller difference in electronegativity (for Si–H bond) /  $\Delta EN (CH) = 0.4$  **and**  $\Delta EN (SiH) = 0.3$ ; [2]

- (iv) both (molecules) non-polar;  
both (molecules) symmetrical / polar bond effects cancel out / OWTTE; [2]

- (v) stronger/larger/greater van der Waals'/London/dispersion forces;  
*Do not accept stronger/larger/greater intermolecular forces.*

more electrons / stronger instantaneous dipole; [2]  
*Do not accept larger mass.*

(b) (i)  $(-1560 \times 2 =) -3120$  (kJ);

[1]

(ii) *Structure:*

CO<sub>2</sub> molecular **and** SiO<sub>2</sub> three-dimensional/network/giant lattice/giant covalent/macromolecular/repeating tetrahedral units;  
CO<sub>2</sub> linear **and** SiO<sub>2</sub> tetrahedral;

*Intramolecular Bonding:*

covalent bonds in CO<sub>2</sub> **and** SiO<sub>2</sub>;  
double bonds in CO<sub>2</sub> **and** single bonds in SiO<sub>2</sub>;  
*Accept diagrams showing bonding types (double and single) within the structures.*

[3 max]

SL B 11sq7

- (c) Award [2 max] for three of the following features:

*Bonding*

*Graphite and C<sub>60</sub> fullerene:* covalent bonds **and** van der Waals'/London/dispersion forces;

*Diamond:* covalent bonds (and van der Waals'/London/dispersion forces);

*Delocalized electrons*

*Graphite and C<sub>60</sub> fullerene:* delocalized electrons;

*Diamond:* no delocalized electrons;

*Structure*

*Diamond:* network/giant structure / macromolecular / three-dimensional structure  
**and** *Graphite:* layered structure / two-dimensional structure / planar;

*C<sub>60</sub> fullerene:* consists of molecules / spheres made of atoms arranged in hexagons/pentagons;

*Bond angles*

*Graphite:* 120° **and** *Diamond:* 109°;

*C<sub>60</sub> fullerene:* bond angles between 109–120°;

*Allow Graphite:* sp<sup>2</sup> **and** *Diamond:* sp<sup>3</sup>.

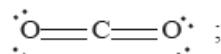
*Allow C<sub>60</sub> fullerene:* sp<sup>2</sup> **and** sp<sup>3</sup>.

*Number of atoms each carbon is bonded to*

*Graphite and C<sub>60</sub> fullerene:* each C atom attached to 3 others;

*Diamond:* each C atom attached to 4 atoms / tetrahedral arrangement of C (atoms); [6 max]

- (d) (i)



linear **and** 180°;

*Accept crosses, lines or dots as electron pairs.*

[2]

- (ii) network/giant structure / macromolecular;

each Si atom bonded covalently to 4 oxygen atoms **and** each O atom bonded covalently to 2 Si atoms / single covalent bonds;

*Award [1 max] for answers such as network-covalent, giant-covalent or macromolecular-covalent.*

*Both M1 and M2 can be scored by a suitable diagram.*

[2]

- (iii) *Silicon dioxide:* strong/covalent bonds in network/giant structure/macromolecule;

*Carbon dioxide:* weak/van der Waals'/dispersion/London forces between molecules;

[2]

- (e) triple (covalent) bond;

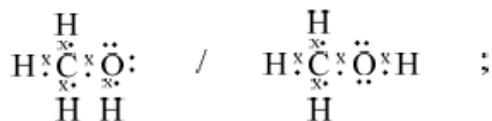
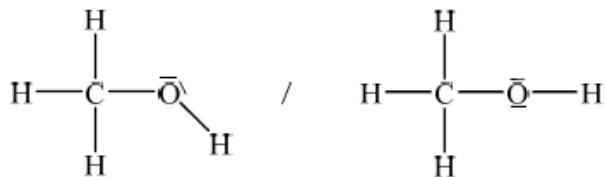
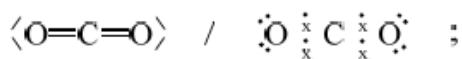
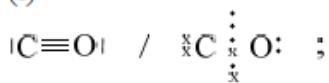
one electron pair donated by oxygen to carbon atom / dative (covalent)/coordinate (covalent) bond;

*Award [1 max] for representation of C≡O.*

*Award [2] if CO shown with dative covalent bond.*

[2]

6. (a) (i)



[3]

All outer electron pairs must be shown for mark in each case.

Accept electrons shown as all x rather than • and x.

(ii)  $\text{CO} < \text{CO}_2 < \text{CH}_3\text{OH};$ 

triple bonds are shorter than double bonds which are shorter than single bonds / the more pairs of electrons that are shared the stronger the attracting so the shorter the bond / OWTTE;

[2]

The order must be correct to gain the second marking point unless ECF from (a).

(b) (i)  $(\text{CO}_2)$  linear;  
180°;

[2]

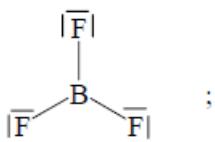
(ii)  $(\text{CO}_3^{2-})$  trigonal planar/triangular planar;  
120°;

[2]

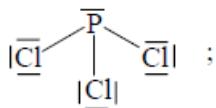
(iii)  $(\text{BF}_4^-)$  tetrahedral;  
109.5° / 109° / 109° 28' ;

[2]

6. (a) (i)



trigonal planar;

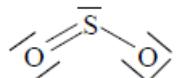


(trigonal) pyramidal;

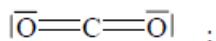
$\text{BF}_3$  non-polar and  $\text{PCl}_3$  polar;

[5]

(ii)



angular/bent/v-shaped;



linear;

$\text{SO}_2$  polar and  $\text{CO}_2$  non polar;

[5]

*Do not allow ECF from wrong Lewis structures.*

*Penalize missing lone pairs on fluorine, oxygen and chlorine once only.*

*Penalize missing or extra lone pairs on central atom every time.*

(b) (i) K more reactive / Na less reactive;

easier to remove electron from K / lower IE;

[2]

(ii)  $\text{I}^-$  more easily oxidised /  $\text{Br}^-$  less easily oxidized;

easier to remove electron from  $\text{I}^-$ ;

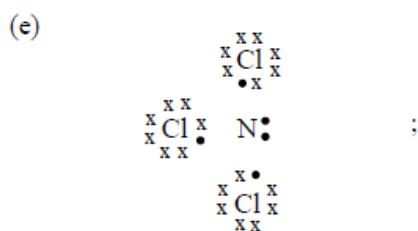
[2]

(iii) Mg conductor/S non-conductor;

Mg's sea of/delocalised electrons free to move, whereas S's electrons are covalently bonded/not free to move;

[2]

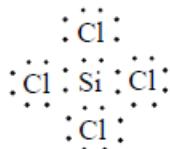
6. (a) Al – 2,8,3;  
 N – 2,5;  
 F – 2,7; [2 max]  
*Award [2] for three correct, [1] for two or one correct.*  
*Accept correct configuration using s,p,d notation.*
- (b) aluminium  
 metallic bonding;  
 positive ions/  $\text{Al}^{3+}$  ions in a sea of / delocalized (valence) electrons;  
 nitrogen,  $\text{N}_2$   
 covalent/triple bond between nitrogen atoms;  
 van der Waals' forces between the molecules; [4]
- (c)  $\text{AlF}_3$   
 giant / 3-dimensional ionic lattice;  
strong ionic bonds / attraction between  $\text{Al}^{3+}$  and  $\text{F}^-$  ions;  
 $\text{NF}_3$   
 simple molecular structure / strong covalent bonds within molecules;  
weak(er) forces between molecules;  
 dipole-dipole / van der Waals' / London forces; [5]
- (d) (i) electrons delocalized/move through structure in both the solid and liquid state; [1]  
 (ii) free moving ions in liquid state;  
ions fixed in position in solid state; [2]  
 (iii) no free moving charged particles / no ions and no electrons to carry charge; [1]



bond angle:  $107^\circ - 109^\circ$ ;

greater repulsion between lone pair and bonding pairs / OWTTE; [3]  
*NOT between electron pairs and atoms.*  
*Award [1 max] if lone pair missed on nitrogen, ECF for bond angle of  $120^\circ$ .*

- (c) Si—Cl bonds are covalent;



[3]

*Accept lines for electron pairs.*

*Award [1] for covalent bonds and [1] for lone pairs.*

- (d) find number of electron pairs/charge centres in (valence shell of) central atom;  
electron pairs/charge centres (in valence shell) of central atom repel each other;  
to positions of minimum energy/repulsion / maximum stability;  
pairs forming a double or triple bond act as a single bond;  
non-bonding pairs repel more than bonding pairs / OWTTE; [3 max]  
*Do not accept repulsion between bonds or atoms.*  
*Award [1] each for any three points.*

- (e) (i)  $\text{SCl}_2$  two bonding pairs, two non-bonding pairs;

angular / bent / non-linear / V-shaped;

*Both these marks can be scored from a diagram.*

$90^\circ < \text{angle} < 107^\circ$ ;

$\text{C}_2\text{Cl}_2$  two charge centres around each C;

linear;

*Both these marks can be scored from a diagram*

$\text{angle} = 180^\circ$ ; [6]

- (ii)  $\text{SCl}_2$  is polar;

$\text{C}_2\text{Cl}_2$  is non-polar;

No net dipole movement for  $\text{C}_2\text{Cl}_2$  but angular  $\text{SCl}_2$  has a resultant dipole OWTTE; [3]

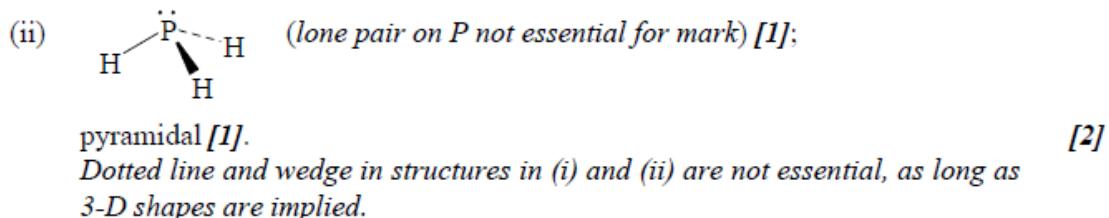
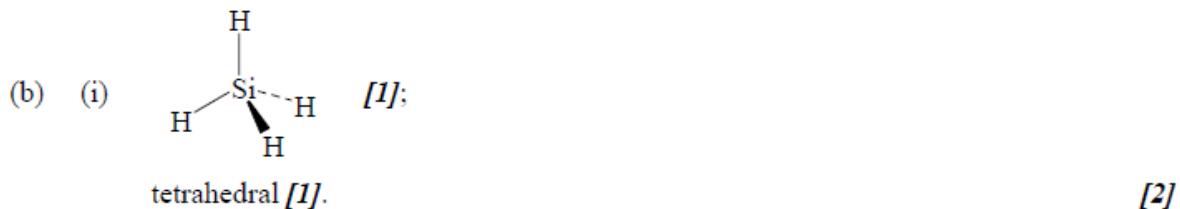
*Mark can be scored from a diagram.*

*Allow ECF based on the answers given to (i).*

6. (a) (i) as molecules become larger / heavier / have higher  $M_r$  values / number of electrons increases;  
van der Waals' / London / dispersion forces increase; [2]
- (ii) hydrogen bonding **between molecules** in H<sub>2</sub>O;  
this bonding is stronger (than van der Waals' forces); [2]  
*Must be an implied comparison with 6 (a) (i)*
- (b) (i) tetrahedral (*accept correct 3-D diagram*);  
bent / V-shape / angular (*accept suitable diagram*); [2]
- (ii) 105° (*accept 103 – 106°*);  
lone pairs **repel** each other more than bonding pairs;  
*Do not accept repulsion of atoms.* [2]
- (c) bonds are polar as Cl more electronegative than Si;  
*Allow “electronegativities are different”*  
molecule is symmetrical, hence polar effects cancel out / OWTTE; [2]
- (d) (i) A – sodium iodide, B – sodium, C – iodine (*three correct [1]*);  
*Accept correct formulas.* [1]
- (ii) A – ionic bonding;  
B – metallic bonding;  
C – van der Waals' forces (and covalent bonding); [3]
- (e) (i) (for Na) (lattice of) positive ions / atoms;  
delocalized / free electrons / sea of electrons;
- (for NaI) oppositely charged ions / positive and negative ions;  
free to move (only) in molten state; [4]
- (ii) forces between I<sub>2</sub> molecules are weak;  
ionic / metallic bonding strong(er); [2]

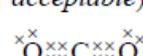
SL B 02s

6. (a) (i) positive ions (*not nuclei*) [1];  
 delocalised/sea of electrons [1];  
 electrostatic attraction between the two [1];  
 electrons free to move [1].  
*Any mention of negative ions, first three marks lost.* [4]
- (ii) :F:F: (*allow × or •, accept F—F*) [1];  
 covalent [1];  
 shared pairs of electrons [1];  
 van der Waals' / dispersion / London forces [1];  
 attraction between temporary / fluctuating / oscillating / induced dipoles [1]. [5]
- (iii) sodium 2,8,1 (*or diagram or spdf*) [1];  
 fluorine 2,7 (*or diagram or spdf*) [1];  
 sodium's outer electron transfers to fluorine [1];  
 oppositely charged ions / ions formed with complete octets of electrons [1]. [4]
- (iv) Ions not free to move in solid / can move in molten state [1]



- (c)  $109^\circ - 109.5^\circ$  [1];  
 non-bonding pairs repel more than bonding pairs [1].  
*Do not allow non-bonding pairs repel atoms.* [2]

SL B 01s

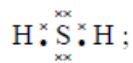
6. (a) (i) Correct Lewis diagram **all** valency  $e^-$  must be shown (*lines for lone pairs are acceptable*) [1]  
  
 Linear [1]  
 $180^\circ$  [1] [3 max]
- (ii) Diagram or statement showing O more electronegative than C [1]  
*(Accept C-O bond is polar)*  
 Cancelling out effect [1]  
 Molecule not polar [1] [3 max]
- ( $O=\overset{\delta-}{C}=\overset{\delta+}{O}$  scores [2])

SL A 09s

3. (a) in the solid state ions are in fixed positions/there are no moveable ions / OWTTE; [1]  
*Do not accept answer that refers to atoms or molecules.*

SL A 04s

3. (a) (i)  $\begin{array}{c} \text{O} & : & \text{C} & : & \text{O} \\ \text{xx} & & & & \text{xx} \end{array} ;$  [2]



*Accept dots, crosses, a combination of dots and crosses or a line to represent a pair of electrons.*

- (ii)  $\text{CO}_2$  is linear;  
two charge centres or bonds and no lone pairs (around C);  
 $\text{H}_2\text{S}$  is bent / v-shaped / angular;  
two bond pairs, two lone pairs (around S); [4]

- (iii)  $\text{CO}_2$  is non-polar,  $\text{H}_2\text{S}$  is polar;  
bond polarities cancel  $\text{CO}_2$  but not in  $\text{H}_2\text{S}$ ; [2]

- (b)  $\text{CH}_3\text{Cl}$  – dipole-dipole attractions;  
 $\text{CH}_4$  – van der Waals' / dispersion / London forces;  
 $\text{CH}_3\text{OH}$  – hydrogen bond; [3]

## Topic 5 Questions

SL B 13s

7. To determine the enthalpy change of combustion of methanol,  $\text{CH}_3\text{OH}$ , 0.230 g of methanol was combusted in a spirit burner. The heat released increased the temperature of  $50.0 \text{ cm}^3$  of water from  $24.5^\circ\text{C}$  to  $45.8^\circ\text{C}$ .

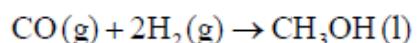
- (a) (i) Calculate the enthalpy change of combustion of methanol.

[4]

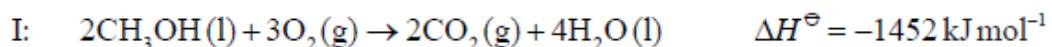
- (ii) Using the theoretical value in Table 12 of the Data Booklet, discuss the experimental results, including one improvement that could be made.

[3]

- (b) Methanol can be produced according to the following equation.



Calculate the standard enthalpy change of this reaction using the following data:

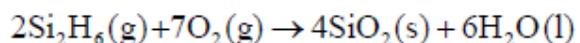


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SL B 12sQ5

**TABLE 10 and 12**

- (b) Disilane undergoes complete oxidation to form silicon dioxide and water.



The standard enthalpy change for this reaction,  $\Delta H^\ominus = -5520 \text{ kJ}$ .

- (i) Calculate the standard enthalpy change, in kJ, for the corresponding combustion reaction of 2 moles of ethane, using Table 12 of the Data Booklet. [1]

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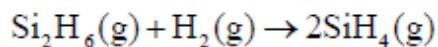
- (c) The different properties of the hydrides can be accounted for by the different bond enthalpies of the covalent bonds formed by silicon and carbon.

(i) Define the term *average bond enthalpy*.

[2]

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(ii) Disilane reacts with hydrogen to produce silane,  $\text{SiH}_4$ .



Use values from Table 10 of the Data Booklet to calculate the enthalpy change,  $\Delta H^\ominus$ , for this reaction.

[3]

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SL B 10s

Methanol has the formula  $\text{CH}_3\text{OH}$

6. (a) In an experiment to measure the enthalpy change of combustion of ethanol, a student heated a copper calorimeter containing 100 cm<sup>3</sup> of water with a spirit lamp and collected the following data.

Initial temperature of water: 20.0 °C  
Final temperature of water: 55.0 °C  
Mass of ethanol burned: 1.78 g  
Density of water: 1.00 g cm<sup>-3</sup>

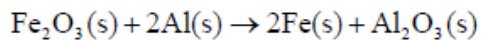
- (i) Use the data to calculate the heat evolved when the ethanol was combusted. [2]  
(ii) Calculate the enthalpy change of combustion per mole of ethanol. [2]  
(iii) Suggest two reasons why the result is not the same as the value in the Data Booklet. [2]

SL B 04s

**TABLE 10**

5. (a) The standard enthalpy change of formation of Al<sub>2</sub>O<sub>3</sub>(s) is -1669 kJ mol<sup>-1</sup> and the standard enthalpy change of formation of Fe<sub>2</sub>O<sub>3</sub>(s) is -822 kJ mol<sup>-1</sup>.

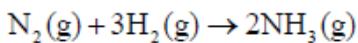
- (i) Use these values to calculate  $\Delta H^\ominus$  for the following reaction.



State whether the reaction is exothermic or endothermic. [3]

- (ii) Draw an enthalpy level diagram to represent this reaction. State the conditions under which standard enthalpy changes are measured. [2]

- (c) Consider the following reaction.

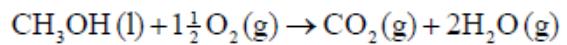


- (i) Use values from Table 10 in the Data Booklet to calculate the enthalpy change,  $\Delta H^\ominus$ , for this reaction. [3]

SL A 11s

**TABLE 10**

1. Methanol is made in large quantities as it is used in the production of polymers and in fuels. The enthalpy of combustion of methanol can be determined theoretically or experimentally.



- (a) Using the information from Table 10 of the Data Booklet, determine the theoretical enthalpy of combustion of methanol. [3]

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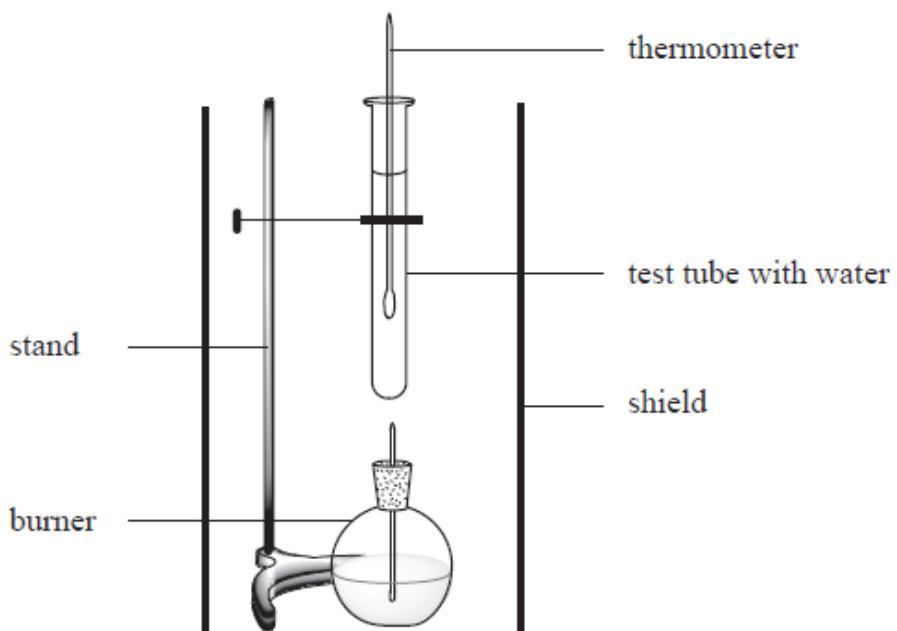
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- (b) The enthalpy of combustion of methanol can also be determined experimentally in a school laboratory. A burner containing methanol was weighed and used to heat water in a test tube as illustrated below.



The following data were collected.

Initial mass of burner and methanol / g	80.557
Final mass of burner and methanol / g	80.034
Mass of water in test tube / g	20.000
Initial temperature of water / °C	21.5
Final temperature of water / °C	26.4

- (i) Calculate the amount, in mol, of methanol burned.

[2]

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(ii) Calculate the heat absorbed, in kJ, by the water.

[3]

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(iii) Determine the enthalpy change, in  $\text{kJ mol}^{-1}$ , for the combustion of 1 mole of methanol.

[2]

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- (c) The Data Booklet value for the enthalpy of combustion of methanol is  $-726 \text{ kJ mol}^{-1}$ . Suggest why this value differs from the values calculated in parts (a) and (b).

(i) Part (a)

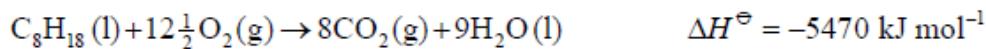
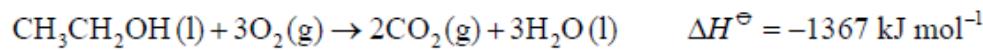
[1]

(ii) Part (b)

[1]

4. Ethanol is used as a component in fuel for some vehicles. One fuel mixture contains 10 % by mass of ethanol in unleaded petrol (gasoline). This mixture is often referred to as Gasohol E10.

- (a) Assume that the other 90 % by mass of Gasohol E10 is octane. 1.00 kg of this fuel mixture was burned.



- (i) Calculate the mass, in g, of ethanol and octane in 1.00 kg of the fuel mixture. [1]

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- (ii) Calculate the amount, in mol, of ethanol and octane in 1.00 kg of the fuel mixture. [1]

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- (iii) Calculate the total amount of energy, in kJ, released when 1.00 kg of the fuel mixture is completely burned. [3]

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- (b) If the fuel blend was vaporized before combustion, predict whether the amount of energy released would be greater, less or the same. Explain your answer.

[2]

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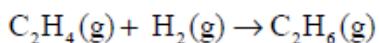
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SL A 09s

TABLE 10 and 12

2. Two students were asked to use information from the Data Booklet to calculate a value for the enthalpy of hydrogenation of ethene to form ethane.

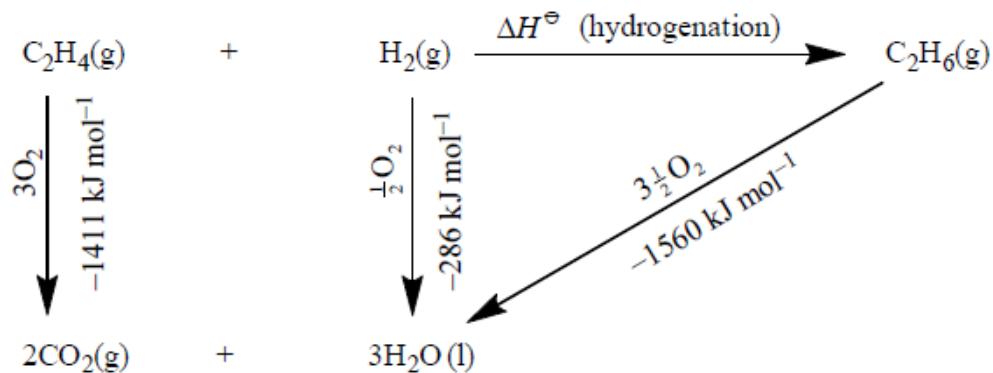


John used the average bond enthalpies from Table 10. Marit used the values of enthalpies of combustion from Table 12.

- (a) Calculate the value for the enthalpy of hydrogenation of ethene obtained using the average bond enthalpies given in Table 10. [2]

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- (b) Marit arranged the values she found in Table 12 into an energy cycle.



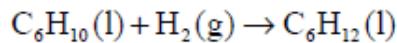
Calculate the value for the enthalpy of hydrogenation of ethene from the energy cycle. [1]

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- (c) Suggest **one** reason why John's answer is slightly less accurate than Marit's answer. [1]

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- (d) John then decided to determine the enthalpy of hydrogenation of cyclohexene to produce cyclohexane.



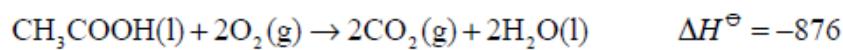
- (i) Use the average bond enthalpies to deduce a value for the enthalpy of hydrogenation of cyclohexene. [1]

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- (ii) The percentage difference between these two methods (average bond enthalpies and enthalpies of combustion) is greater for cyclohexene than it was for ethene. John's hypothesis was that it would be the same. Determine why the use of average bond enthalpies is less accurate for the cyclohexene equation shown above, than it was for ethene. Deduce what extra information is needed to provide a more accurate answer. [2]

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3. (a) The standard enthalpy changes of three combustion reactions at 298 K are given below in  $\text{kJ mol}^{-1}$ .



Use the data above to calculate the standard enthalpy change for the following reaction.



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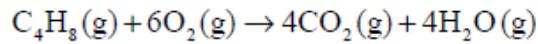
3. (a) Define the term *average bond enthalpy*.

[2]

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- (b) Use the information from Table 10 in the Data Booklet to calculate the enthalpy change for the complete combustion of but-1-ene according to the following equation.

[3]



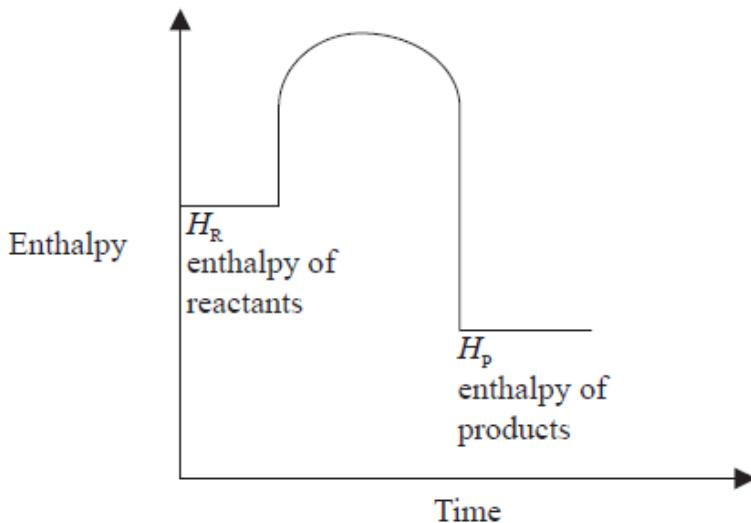
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- (c) Predict, giving a reason, how the enthalpy change for the complete combustion of but-2-ene would compare with that of but-1-ene based on average bond enthalpies.

[1]

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- (e) The enthalpy level diagram for a certain reaction is shown below.



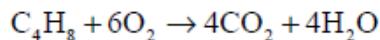
State and explain the relative stabilities of the reactants and products.

[2]

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SL A 06s

1. But-1-ene gas, burns in oxygen to produce carbon dioxide and water vapour according to the following equation.



- (a) Use the data below to calculate the value of  $\Delta H^\ominus$  for the combustion of but-1-ene.

[3]

Bond	C–C	C=C	C–H	O=O	C=O	O–H
average bond enthalpy / $\text{kJ mol}^{-1}$	348	612	412	496	743	463

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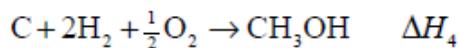
- (b) State and explain whether the reaction above is endothermic or exothermic.

[1]

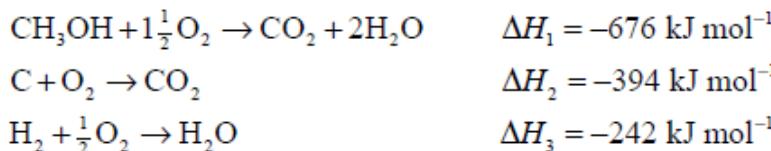
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- (c) Calculate the enthalpy change,  $\Delta H_4$  for the reaction

[4]



using Hess's Law and the following information.



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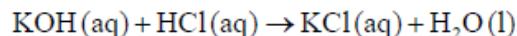
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1. In aqueous solution, potassium hydroxide and hydrochloric acid react as follows.



The data below is from an experiment to determine the enthalpy change of this reaction.

50.0 cm<sup>3</sup> of a 0.500 mol dm<sup>-3</sup> solution of KOH was mixed rapidly in a glass beaker with 50.0 cm<sup>3</sup> of a 0.500 mol dm<sup>-3</sup> solution of HCl.

Initial temperature of each solution = 19.6 °C

Final temperature of the mixture = 23.1 °C

- (a) State, with a reason, whether the reaction is exothermic or endothermic. [1]

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- (b) Explain why the solutions were mixed rapidly. [1]

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- (c) Calculate the enthalpy change of this reaction in kJ mol<sup>-1</sup>. Assume that the specific heat capacity of the solution is the same as that of water. [4]

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- (d) Identify the **major** source of error in the experimental procedure described above. Explain how it could be minimized. [2]

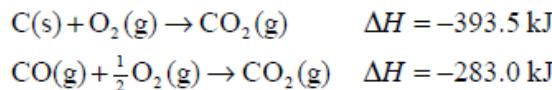
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- (e) The experiment was repeated but with an HCl concentration of  $0.510 \text{ mol dm}^{-3}$  instead of  $0.500 \text{ mol dm}^{-3}$ . State and explain what the temperature change would be. [2]

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SL A 01s

1. (a) Hess's law states that, whether a reaction occurs in one or several steps, the total enthalpy change is the same. Illustrate your understanding of this law by using the data below to calculate the enthalpy change ( $\Delta H$ ) when one mole of solid carbon is converted into carbon monoxide.



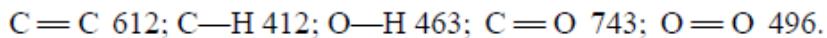
[3]

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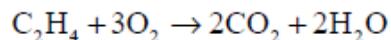
- (b) State what is meant by the term *endothermic reaction*. [1]

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- (c) Enthalpy changes may also be calculated by using bond enthalpies, some values of which ( $\text{kJ mol}^{-1}$ ) are provided below:



The balanced equation for the complete combustion of one mole of ethene,  $\text{C}_2\text{H}_4$ , in oxygen is shown below:



- (i) Use the equation and the bond enthalpy data above to calculate the enthalpy change for the complete combustion of one mole of ethene. [4]

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- (ii) State, with a brief explanation, whether the reaction is endothermic or exothermic. [1]

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## Topic 5 Mark Scheme

SL B 13s

7. (a) (i) ( $q = mc\Delta T =$ )  $0.0500 \times 4.18 \times 21.3 = 4.45$  (kJ);  
*Do not accept m = 0.05023 kg.*

$$(n \text{ methanol} =) \frac{0.230}{32.05} = 7.18 \times 10^{-3} \text{ (mol)};$$

$$\Delta H = \frac{4.45}{7.18 \times 10^{-3}};$$

$$\Delta H = -6.20 \times 10^2 \text{ kJ mol}^{-1};$$

*Accept integer values of molar mass.*

*Final answer must have negative sign and correct units.*

*Award [4] for correct final answer with correct units.*

[4]

- (ii) less heat is liberated than theoretically  $-726 \text{ kJ mol}^{-1}$ ;  
 probably due to heat loss/incomplete combustion;  
 determine heat capacity of calorimeter and take heat absorbed by calorimeter  
 into account / any suitable insulation method / measure temperature with time  
 and extrapolation of graph to compensate heat loss / OWTTE;  
*If the value calculated in (a) (i) is more exothermic than theoretically, allow ECF for M1 and for improvement if consistent.*

[3]

- (b)  $\Delta H^\ominus = \frac{1}{2}\Pi + \text{III} - \frac{1}{2}\text{I}$  / correct diagram/energy cycle;  
 $-283 - 572 - (-726);$   
 $-129 \text{ (kJ mol}^{-1}\text{)};$   
*Award [3] for correct final answer.*

[3]

### SL B 12sQ5

- (b) (i)  $(-1560 \times 2) = -3120$  (kJ); [1]

- (c) (i) energy needed to break (one mol of) a bond in a gaseous molecule;  
 averaged over similar compounds; [2]  
*Do not allow averaged over several compounds.*

- (ii) *Bonds broken:*  
 $6\text{Si-H, Si-Si, H-H} / (+)2570$  (kJ);  
*Bonds formed:*  
 $8\text{Si-H} / (-)2544$  (kJ);  
 $+26$  (kJ);

**OR**

- Bonds broken:*  
 $\text{Si-Si, H-H} / (+)662$  (kJ);  
*Bonds formed:*  
 $2\text{Si-H} / (-)636$  (kJ);  
 $+26$  (kJ);

[3]

### SL B 10s

6. (a) (i)  $100 \times 4.18 \times 35.0 ;$   
 $14630 \text{ J} / 14600 \text{ J} / 14.6 \text{ kJ};$  [2]  
*Award [2] for correct final answer.*  
*No ECF here if incorrect mass used.*

(ii)  $\frac{1.78}{46.08} = 0.0386 \text{ mol} ;$

$\frac{14.6}{0.0386} = (-)378 \text{ kJ mol}^{-1} ;$  [2]

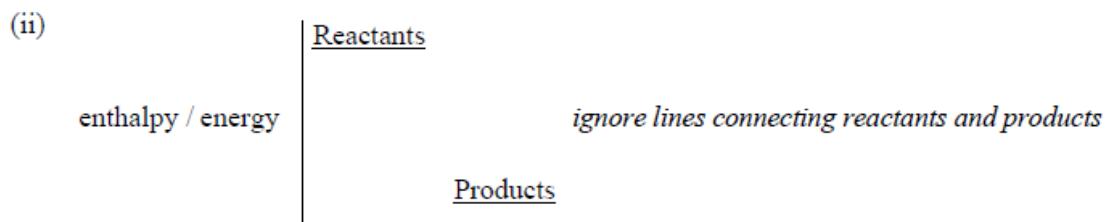
*Accept (-)377 and (-)379 kJ mol<sup>-1</sup>.*  
*Award [2] for correct final answer.*

- (iii) heat loss;  
incomplete combustion;  
heat absorbed by calorimeter not included; [2 max]  
*Accept other sensible suggestions.*

SL B 04s

5. (a) (i)  $\Delta H = \Delta H_f \text{ (products)} - \Delta H_f \text{ (reactants) } / = (-1669) - (-822)$   
 $= -847 \text{ kJ}$

*Ignore units;*  
exothermic (ECF from sign of  $\Delta H$ ) ; [3]



[1] for the diagram  
ECF from sign of  $\Delta H$  in (a) (i)  
298 K / 25 °C AND 1 atm / 101(.3) kPa; [2]  
Both needed for the mark.

SL A 11s

1. (a) amount of energy required to break bonds of reactants  
 $3 \times 413 + 358 + 464 + 1.5 \times 498 \text{ (kJ mol}^{-1}\text{)} / 2808 \text{ (kJ mol}^{-1}\text{)};$

amount of energy released during bond formation of products  
 $4 \times 464 + 2 \times 746 \text{ (kJ mol}^{-1}\text{)} / 3348 \text{ (kJ mol}^{-1}\text{)};$

$$\Delta H = -540 \text{ (kJ mol}^{-1}\text{)};$$

Award [3] for correct final answer.

Award [2] for (+)540.

If old Data Booklet is used accept answer:  $-535 \text{ (kJ mol}^{-1}\text{)}$  or award [2] for (+)535.

- (b) (i)  $m(\text{methanol}) = (80.557 - 80.034) = 0.523 \text{ (g)};$

$$n(\text{methanol}) = \left( \frac{0.523 \text{ g}}{32.05 \text{ g mol}^{-1}} \right) = 0.0163 \text{ (mol)};$$

Award [2] for correct final answer.

- (ii)  $\Delta T = (26.4 - 21.5) = 4.9 \text{ (K)};$

$$q = (mc\Delta T) = 20.000 \times 4.18 \times 4.9 \text{ (J)} / 20.000 \times 4.18 \times 4.9 \times 10^{-3} \text{ (kJ)};$$

$$0.41 \text{ (kJ)};$$

Award [3] for correct final answer.

$$(iii) \Delta H_c^\ominus = -\frac{0.41 \text{ (kJ)}}{0.0163 \text{ (mol)}} / -25153 \text{ (J mol}^{-1}\text{)};$$

$$= -25 \text{ (kJ mol}^{-1}\text{)};$$

Award [2] for correct final answer.

Award [1] for (+)25 (kJ mol<sup>-1</sup>).

- (c) (i) bond enthalpies are average values/differ (slightly) from one compound to another (depending on the neighbouring atoms) / methanol is liquid not gas in the reaction;

[1]

- (ii) not all heat produced transferred to water / heat lost to surroundings/environment / OWTTE / incomplete combustion (of methanol) / water forms as H<sub>2</sub>O(l) instead of H<sub>2</sub>O(g);

[1]

*Do not allow just "heat lost".*

### SL A 11s

4. (a) (i) (10% 1000 g =) 100 g ethanol **and** (90% 1000 g =) 900 g octane;

[1]

- (ii)  $n(\text{ethanol}) = 2.17 \text{ mol}$  **and**  $n(\text{octane}) = 7.88 \text{ mol};$

[1]

$$E_{\text{released from ethanol}} = (2.17 \times 1367) = 2966 \text{ (kJ)};$$

$$E_{\text{released from octane}} = (7.88 \times 5470) = 43104 \text{ (kJ)};$$

$$\text{total energy released} = (2966 + 43104) = 4.61 \times 10^4 \text{ (kJ)};$$

[3]

Award [3] for correct final answer.

Accept answers using whole numbers for molar masses and rounding.

- (b) greater;

fewer intermolecular bonds/forces to break / vaporization is endothermic / gaseous fuel has greater enthalpy than liquid fuel / OWTTE;

[2]

*M2 cannot be scored if MI is incorrect.*

### SL A 09s

2. (a) energy required = C=C + H-H/612 + 436 and  
 energy released = C-C + 2(C-H)/347 + 2(413) /  
 energy required = C=C + H-H + 4(C-H)/612 + 436 + 4(413) and  
 energy released = C-C + 6(C-H)/347 + 6(413);

$$\Delta H = (1048 - 1173)/(2700 - 2825) = -125 \text{ kJ mol}^{-1}; \quad [2]$$

(b)  $\Delta H = -1411 + (-286) - (-1560) = -137 \text{ kJ mol}^{-1}; \quad [1]$

(c) the actual values for the specific bonds may be different to the average values / the combustion values referred to the specific compounds / OWTTE; [1]

(d) (i)  $-125 \text{ kJ mol}^{-1}; \quad [1]$

(ii) average bond enthalpies do not apply to the liquid state / OWTTE;  
 the enthalpy of vaporization/condensation of cyclohexene and cyclohexane / OWTTE; [2]

#### SL A 08s

3. (a)  $(2\text{C(s)} + 2\text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)}) \Delta H^\ominus = -788 \text{ kJ};$   
 $(2\text{H}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow 2\text{H}_2\text{O(l)}) \Delta H^\ominus = -572 \text{ kJ};$   
 $(2\text{CO}_2\text{(g)} + 2\text{H}_2\text{O(l)} \rightarrow \text{CH}_3\text{COOH(l)} + 2\text{O}_2\text{(g)}) \Delta H^\ominus = +876 \text{ kJ};$

$$2\text{C(s)} + 2\text{H}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow \text{CH}_3\text{COOH(l)} \quad \Delta H^\ominus = -484 \text{ (kJ)}; \quad [4]$$

*Award [4] for correct final answer.*

#### SL A 07s

3. (a) amount of energy needed to break one mole of (covalent) bonds;  
 in the gaseous state;  
 average calculated from a range of compounds; [2 max]  
*Award [1] each for any two points above.*

- (b) bonds broken:  $612 + 2 \times 348 + 8 \times 412 + 6 \times 496 / 7580 \text{ kJ mol}^{-1};$   
 bonds made:  $8 \times 743 + 8 \times 463 / 9648 \text{ kJ mol}^{-1};$   
 $(\text{bonds broken} - \text{bonds made}) = \Delta H = -2068 \text{ (kJ mol}^{-1}\text{)}; \quad [3]$   
*Award [3] for the correct answer.*  
*Allow full ECF – 1 mistake equals 1 penalty.*  
*Allow kJ but not other wrong units.*

- (c) same/equal, because the same bonds are being broken and formed; [1]

- (e) products more stable than reactants;  
 bonds are stronger in products than reactants /  $H_p < H_R$  / enthalpy / stored energy  
 of products less than reactants; [2]

#### SL A 06s

1. (a) (Amount of energy required to break bonds of reactants)

$$8 \times 412 + 2 \times 348 + 612 + 6 \times 496 / 7580 \text{ (kJ mol}^{-1}\text{)};$$

(Amount of energy released during bond formation)

$$4 \times 2 \times 743 + 4 \times 2 \times 463 / 9648 \text{ (kJ mol}^{-1}\text{)};$$

$$\Delta H = -2068 \text{ (kJ or kJ mol}^{-1}\text{)};$$

[3]

*ECF from above answers.*

*Correct answer scores [3].*

*Award [2] for (+)2068.*

*If any other units apply –1(U), but only once per paper.*

- (b) exothermic and  $\Delta H^\ominus$  is negative / energy is released;

[1]

*Apply ECF to sign of answer in part (a).*

*Do not mark if no answer to (a).*

- (c)  $-1 \times \Delta H_1 / 676$ ;

$$1 \times \Delta H_2 / -394;$$

$$2 \times \Delta H_3 / -484;$$

$$\Delta H_4 = -202 \text{ (kJ mol}^{-1}\text{)};$$

[4]

*Accept alternative methods.*

*Correct answers score [4].*

*Award [3] for (+)202 or (+)40 (kJ/kJ mol<sup>-1</sup>).*

*–1(U) if units incorrect (ignore if absent).*

## SL A 05s

1. (a) exothermic because temperature rises / heat is released;

[1]

- (b) to make any heat loss as small as possible / so that all the heat will be given out very quickly;

[1]

*Do not accept “to produce a faster reaction”.*

- (c) heat released = mass  $\times$  specific heat capacity  $\times$  temp increase /  $q = mc\Delta T / 100 \times 4.18 \times 3.5$ ;

$$= 1463 \text{ J} / 1.463 \text{ kJ; (allow 1.47 kJ if specific heat = 4.2)}$$

$$\text{amount of KOH / HCl used} = 0.500 \times 0.050 = 0.025 \text{ mol};$$

$$\Delta H = (1.463 \div 0.025) = -58.5 \text{ (kJ mol}^{-1}\text{)}; (\text{minus sign needed for mark})$$

[4]

*Use ECF for values of q and amount used.*

*Award [4] for correct final answer.*

*Final answer of 58.5 or +58.5 scores [3].*

*Accept 2, 3 or 4 significant figures.*

- (d) heat loss (to the surroundings);

insulate the reaction vessel / use a lid / draw a temperature versus time graph;

[2]

- (e) 3.5 °C / temperature change would be the same;

amount of base reacted would be the same / excess acid would not react / KOH is the

limiting reagent;

[2]

## SL A 01s

1. (a)  $C + \frac{1}{2}O_2 \rightarrow CO$  (*ignore state symbols*) [1]  
 some evidence of working e.g. cycle or changing sign of  $\Delta H$  [1]  
 $-110.5$  (*units not required*) [1]  
 $(-110.5$  on its own scores [3]) [3 max]
- (b) absorbs heat /  $\Delta H$  is positive / absorbs energy / products have more energy than reactants. [1]
- (c) (i) Breaking bonds  $C = C$ ;  $4(C-H)$ ;  $3(O=O)$  [1]  
 Making bonds  $2(O=C=O)$ ;  $2(H-O-H)$  [1]  
 Breaking +3748                    Making -4824 [1]  
 Enthalpy of combustion =  $-1076$  (+1076 scores [3 max]) [1] [4 max]  
*(In the absence of any credit, award [1] for breaking (+) and making (-) or  $\Delta H_c = H_{products} - H_{reactants}$ .)*
- (ii) Exothermic since  $\Delta H_c$  is negative (*NB consequential on sign in (c) (ii)*). [1]  
*(If (c) (i) is not attempted, allow exothermic because hydrocarbon combustion gives out heat / OWTTE).*

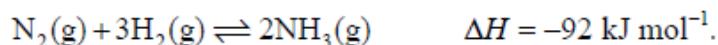
## Topic 6 Questions

SL B 08sQ7

- (d) When 2.0 g of calcium carbonate pieces,  $\text{CaCO}_3$ , react with  $50 \text{ cm}^3$  of  $2.0 \text{ mol dm}^{-3}$  hydrochloric acid,  $\text{HCl}$  (aq), at  $25^\circ\text{C}$ , carbon dioxide gas is evolved. Describe the effect of the following changes on the rate of reaction between  $\text{CaCO}_3$  and  $\text{HCl}$  and explain your answer in terms of the collision theory.
- (i) The same mass of  $\text{CaCO}_3$  pieces react with  $50 \text{ cm}^3$  of  $1.0 \text{ mol dm}^{-3}$   $\text{HCl}$  (aq) at  $25^\circ\text{C}$ . [2]
- (ii) The same mass of  $\text{CaCO}_3$  pieces react with  $100 \text{ cm}^3$  of  $2.0 \text{ mol dm}^{-3}$   $\text{HCl}$  (aq) at  $25^\circ\text{C}$ . [2]
- (iii) The same mass of  $\text{CaCO}_3$  powder reacts with  $50 \text{ cm}^3$  of  $2.0 \text{ mol dm}^{-3}$   $\text{HCl}$  (aq) at  $25^\circ\text{C}$ . [2]
- (iv) The same mass of  $\text{CaCO}_3$  pieces reacts with  $50 \text{ cm}^3$  of  $2.0 \text{ mol dm}^{-3}$   $\text{HCl}$  (aq) at  $35^\circ\text{C}$ . [3]
- (e) State why the addition of a catalyst increases the rate of a reaction. [1]

SL B 02s

5. Ammonia is made on a large scale by the Haber process. The main reaction occurring is



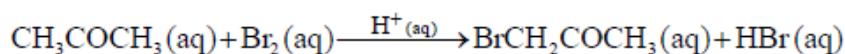
- (f) Use the collision theory to explain the effect of increasing the temperature on the rate of reaction between nitrogen and hydrogen. [3]

SL B 01sQ4b

- (iii) Outline the main features of the Collision Theory. [4]

SL A 12s

1. Propanone reacts with bromine in acidic solution according to the following equation.



A student investigated the kinetics of this reaction using data logging equipment. Her data are shown below.

	A	B	C	D	E	F
1		Initial concentration / mol dm <sup>-3</sup>				
2	Experiment	[CH <sub>3</sub> COCH <sub>3</sub> ] ± 0.001	[Br <sub>2</sub> ] ± 0.0001	[H <sup>+</sup> ] ± 0.0001	Time for colour to fade / s ± 1	Rate of reaction / mol dm <sup>-3</sup> s <sup>-1</sup>
3	1	0.200	0.0100	0.0500	250	4.00 × 10 <sup>-5</sup>
4	2	0.400	0.0100	0.0500	125	8.00 × 10 <sup>-5</sup>
5	3	0.200	0.0200	0.0500	500	4.00 × 10 <sup>-5</sup>
6	4	0.200	0.0100	0.1000	125	8.00 × 10 <sup>-5</sup>
7	5	0.400	0.0050	0.0500	63	X
8						

- (a) (i) Identify the reagent the student used to monitor the rate of reaction.

[1]

.....

- (ii) Calculate the rate of reaction for Experiment 5 and comment on the precision of your result.

[2]

.....

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.....

.....

(iii) Determine the percentage uncertainty in the calculated rate for Experiment 4.

[2]

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(b) (i) Describe how the rate of reaction changes when the concentration of  $\text{CH}_3\text{COCH}_3$  is doubled and explain this change on a molecular level.

[2]

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(ii) The student suggested that  $\text{H}^+$  acts as a catalyst in the reaction. Describe the effect of a catalyst on a chemical reaction.

[1]

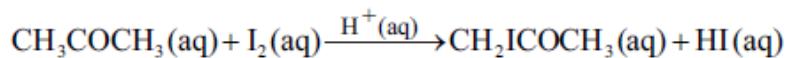
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(iii) Comment on whether or not this hypothesis is supported, with reference to the chemical equation and the experimental data.

[2]

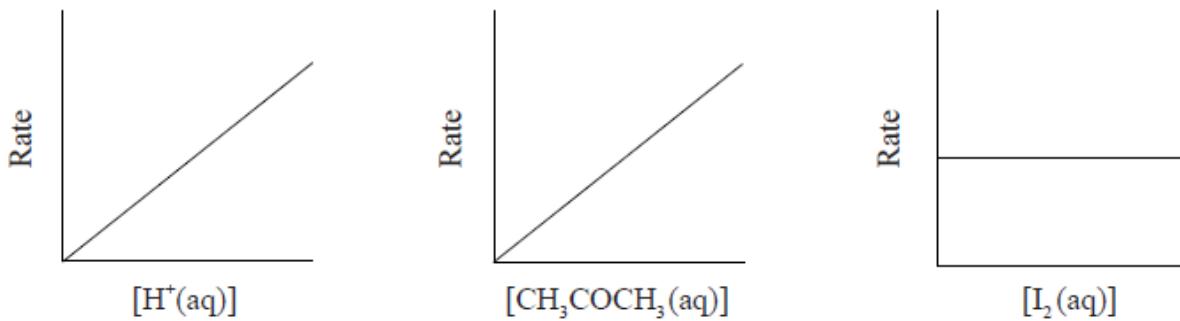
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2. Alex and Hannah were asked to investigate the kinetics involved in the iodination of propanone. They were given the following equation by their teacher.



Alex's hypothesis was that the rate will be affected by changing the concentrations of the propanone and the iodine, as the reaction can happen without a catalyst. Hannah's hypothesis was that as the catalyst is involved in the reaction, the concentrations of the propanone, iodine and the hydrogen ions will all affect the rate.

They carried out several experiments varying the concentration of one of the reactants or the catalyst whilst keeping other concentrations and conditions the same. Their results are shown graphically below.



- (a) Discuss whether either Alex's or Hannah's hypothesis is correct. [2]

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- (b) Explain why the reaction rate will increase with increasing temperature. [2]

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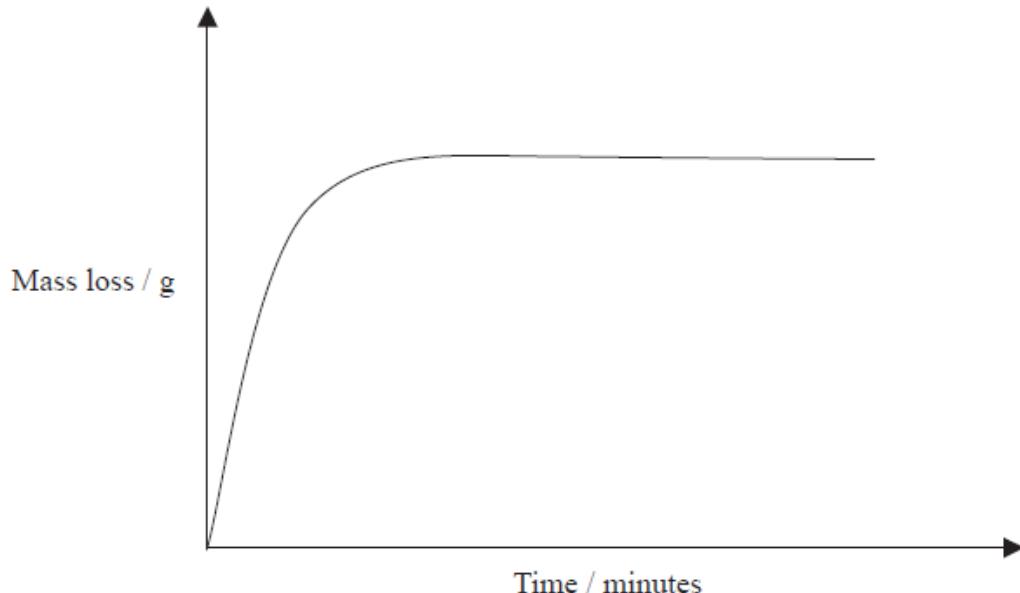
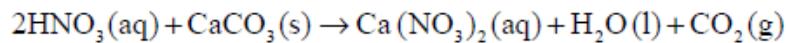
- (c) (i) This reaction uses a catalyst. Sketch and annotate the Maxwell-Boltzmann energy distribution curve for a reaction with and without a catalyst on labelled axes below. [3]

- (ii) Describe how a catalyst works. [1]

.....  
.....

SL A 07s

1. Excess  $0.100 \text{ mol dm}^{-3}$  nitric acid is added to a certain mass of powdered calcium carbonate at  $20^\circ\text{C}$ . The rate of reaction is monitored by measuring the change in mass over time due to the loss of carbon dioxide.



- (a) Define the term *rate of reaction*.

[1]

.....  
.....

- (b) Explain why the mass loss remains constant after a certain time.

[1]

.....  
.....

- (c) Draw a line on the graph above, to show what the graph would look like if the same mass of calcium carbonate in larger pieces were reacted with excess  $0.100 \text{ mol dm}^{-3}$  nitric acid.

[1]

- (d) Explain in terms of the collision theory what would happen to the rate if the reaction was conducted at 50 °C.

[3]

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- (e) Determine the rate of formation of carbon dioxide when the nitric acid reacts at a rate of  $2.00 \times 10^{-3}$  mol cm<sup>-3</sup> s<sup>-1</sup>.

[1]

.....  
.....

- (f) Calculate the volume of carbon dioxide produced at  $1.01 \times 10^5$  Pa and 20.0 °C when 0.350 g of calcium carbonate reacts with excess 0.100 mol dm<sup>-3</sup> nitric acid.

[3]

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SL A 05s

3. When a small quantity of a strongly smelling gas such as ammonia is released into the air, it can be detected several metres away in a short time.

- (a) Use the kinetic molecular theory to explain why this happens. [2]

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- (b) State and explain how the time taken to detect the gas changes when the temperature is increased. [2]

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SL A 05s

4. (a) Identify **two** features of colliding molecules that react together in the gas phase. [2]

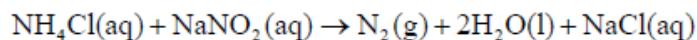
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- (b) For many reactions, the rate approximately doubles for a 10 °C rise in temperature. State **two** reasons for this increase and identify which of the two is the more important. [3]

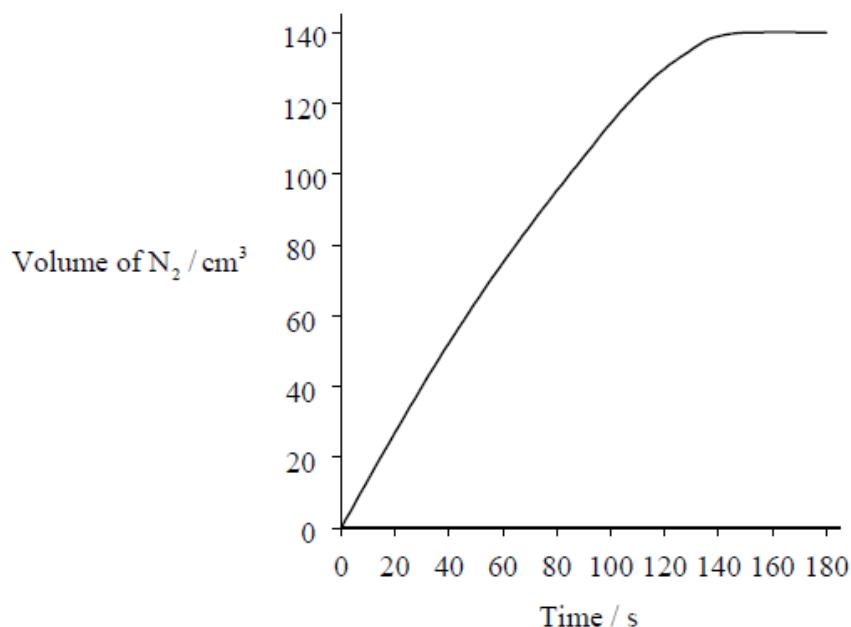
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SL A 04s

1. The reaction between ammonium chloride and sodium nitrite in aqueous solution can be represented by the following equation.



The graph below shows the volume of nitrogen gas produced at 30 second intervals from a mixture of ammonium chloride and sodium nitrite in aqueous solution at 20 °C.



- (a) (i) State how the rate of formation of nitrogen changes with time. Explain your answer in terms of collision theory. [2]

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- (ii) Explain why the volume eventually remains constant. [1]

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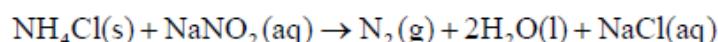
- (b) (i) State how the rate of formation of nitrogen would change if the temperature were increased from 20 °C to 40 °C. [1]

.....  
.....

- (ii) State **two** reasons for the change described in (b)(i) and explain which of the two is more important in causing the change. [3]

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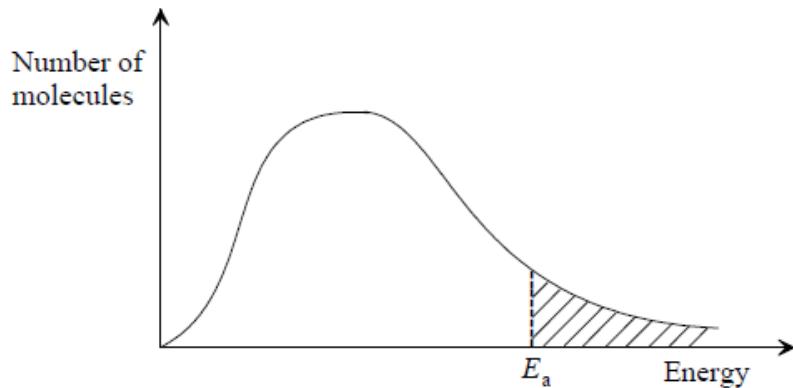
- (iii) The reaction between **solid** ammonium chloride and aqueous sodium nitrite can be represented by the following equation.



State and explain how the rate of formation of nitrogen would change if the same amount of ammonium chloride were used as large lumps instead of as a fine powder. [2]

.....  
.....  
.....  
.....

2.



The diagram shows the distribution of energy for the molecules in a sample of gas at a given temperature,  $T_1$ .

- (a) In the diagram  $E_a$  represents the *activation energy* for a reaction. Define this term. [1]

.....  
.....

- (b) On the diagram above draw another curve to show the energy distribution for the same gas at a higher temperature. Label the curve  $T_2$ . [2]

- (c) With reference to your diagram, state and explain what happens to the rate of a reaction when the temperature is increased. [2]

.....  
.....  
.....  
.....

## Topic 6 Mark Scheme

SL B 08s

- (d) (i) rate of reaction decreases;  
less frequent collisions between reactants; [2]
- (ii) no effect;  
no change in concentration of HCl; [2]
- (iii) rate of reaction increases;  
increase in surface area increases frequency of collisions; [2]
- (iv) rate of reaction increases;  
kinetic energy of reacting particles increases, more frequent collisions;  
greater proportion of particles have energy  $\geq E_a$ ;  
*(i) – (iv) second mark dependent on correct first mark* [3]
- (e) activation energy is lowered; [1]

SL B 02s

- (f) (*Award [1] for any three of the following:*)
- successful collisions need minimum/activation energy / correct geometry [1];  
increasing temperature causes increase in energy of particles [1];  
so increased proportion of successful collisions [1];  
so increased frequency of collisions / more collisions per unit time [1].  
*Do not accept just "more collisions".* [3]

SL B 01s

- (iii) Molecules must collide in order to react [1]  
Not all collisions lead to a reaction [1]  
Minimum energy needed/activation energy [1]  
Appropriate collision geometry required [1] [4 max]

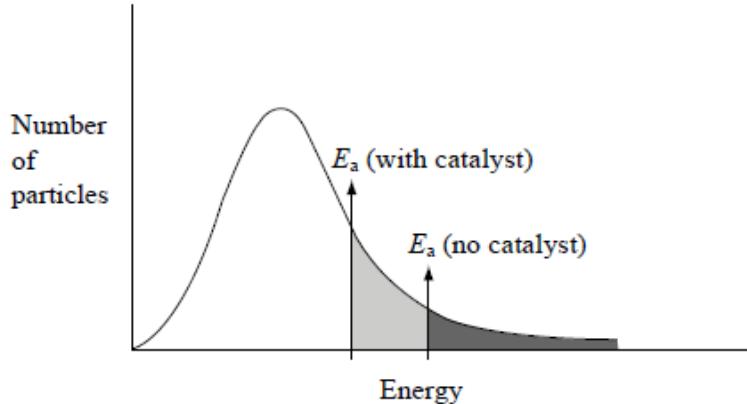
SL A 12s

1. (a) (i) bromine/ $\text{Br}_2$ :  
*Do not allow Br or bromide/ $\text{Br}^-$ .* [1]
- (ii)  $7.9 \times 10^{-5}$  (mol dm $^{-3}$  s $^{-1}$ );  
*The number of significant figures must be correct.*  
*Allow  $8.0 \times 10^{-5}$  (mol dm $^{-3}$  s $^{-1}$ ).*
- (only 2 significant figures) because of precision of time/[Br<sub>2</sub>] measurements; [2]  
*Allow answers based on rate laws or orders of reaction.*  
*M2 can only be scored if M1 correct.*
- (iii) [Br<sub>2</sub>]: 1% and Time: 0.8%;  
*Percentage Uncertainty: 1.8%;* [2]  
*Accept Percentage Uncertainty: 2%.*  
*Do not allow answers based on rate laws or orders of reaction.*
- (b) (i) rate doubles;  
*Do not allow rate increases.*
- increased frequency of collisions / more collisions per unit time; [2]  
*Do not accept "more collisions".*
- (ii) catalyst increases rate of reaction without chemically changing/being consumed / OWTTE;  
*Do not award mark for stating catalyst increases rate of forward and reverse reactions (equally).*
- catalyst lowers activation energy / offers an alternative reaction pathway; [1 max]
- (iii) (valid hypothesis) as rate increases as [H<sup>+</sup>] increases/comparing data in Experiments 1 and 4;  
H<sup>+</sup> is not in equation/does not chemically change / OWTTE; [2]  
*No marks awarded if invalid hypothesis stated.*

SL A 10s

2. (a)  $[I_2]$  does not affect rate / OWTTE;  
neither correct/both partially correct with explanation as to how; [2]
- (b) more particles/molecules have sufficient energy to overcome activation energy / OWTTE;  
more frequent collisions; [2]

(c) (i)



axes correctly labelled  $x =$  energy/velocity/speed,  $y =$  number/% of molecules/particles/probability;

graph showing correct curve for Maxwell-Boltzmann distribution;

*If two curves are drawn, first and second mark can still be scored, but not third.*

*Curve(s) must begin at origin and not go up at high energy.*

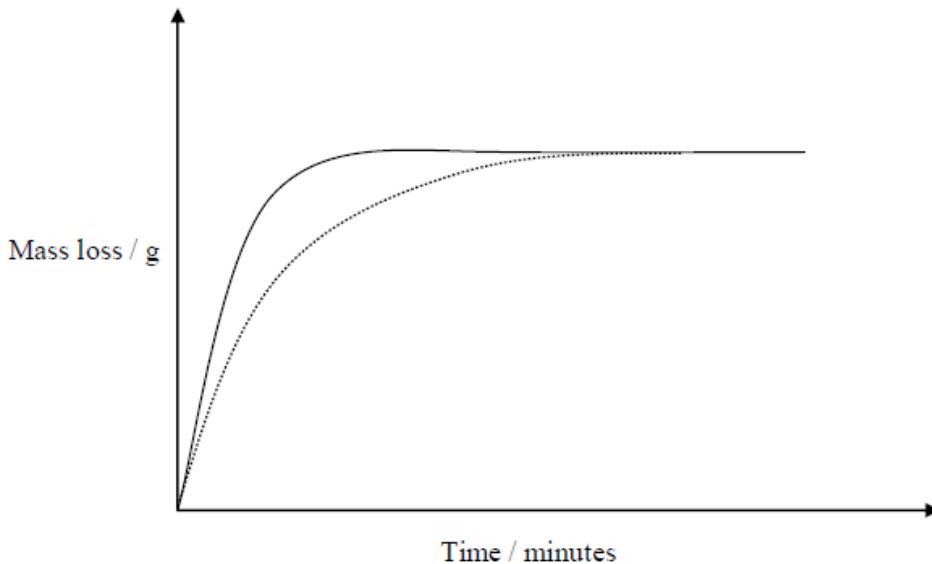
two activation energies shown with  $E_{\text{cat}}$  shown lower;

*Award the mark for the final point if shown on an enthalpy level diagram.*

[3]

- (ii) catalyst provides an alternative pathway of lower energy / OWTTE; [1]  
*Accept catalyst lowers activation energy (of reaction).*

1. (a) change of concentration/mass/amount/volume / of a reactant/product with time; [1]  
*Do not accept "substance".*
- (b) all the  $\text{CaCO}_3(s)$  has been consumed / no further  $\text{CO}_2(g)$  is produced / reaction is complete ; [1]  
*Do not accept reaction has stopped or all reactants used up.*
- (c) line on graph should be initially less steep / a smaller gradient **and** should plateau at the same mass loss; [1]



- (d) there are more particles with KE greater than or equal to  $E_a$ ;  
 collisions more frequent / more collisions per unit time / more successful/forceful collisions per unit time;  
 the rate increases; [3]
- (e)  $1.00 \times 10^{-3}$  ( $\text{mol cm}^{-3} \text{s}^{-1}$ ); [1]  
*Ignore units even if wrong.*  
*Apply -1(sf).*

$$(f) n(\text{CO}_2) = n(\text{CaCO}_3) = \frac{0.350}{100.09 \text{ g mol}^{-1}};$$

$$V = \frac{nRT}{P} / V(\text{CO}_2) = \frac{n(\text{CO}_2) \times 293 \times 8.31}{1.01 \times 10^5};$$

$$= 8.43 \times 10^{-5} \text{ m}^3 / 84.3 \text{ cm}^3 / 0.0843 \text{ dm}^3;$$

[3]

*Units required for mark.*

*Apply -1(SF).*

*Award [3] for correct final answer.*

*Allow for ECF from  $n(\text{CaCO}_3)$  up to [2 max].*

3. (a) the particles/molecules of ammonia gas are in rapid/random/constant motion; and will diffuse/spread out / OWTTE; [2]
- (b) less time;  
 (the particles/molecules of ammonia gas will have) greater velocity/greater kinetic energy/greater rate of diffusion/move faster; [2]  
*Do not accept "greater energy".*

SL A 05s

4. (a) molecules must have sufficient/minimum energy / energy  $\geq$  activation energy; appropriate collision geometry / correct orientation; [2]
- (b) increased frequency of collisions / collisions more likely;  
*Not just "more collisions", there must be a reference to time.*  
 increased proportion of molecules with sufficient energy to react /  $E \geq E_a$ ;  
*Not "activation energy is reduced".*  
 Proportion of molecules with  $E \geq E_a$  is more important; (*dependent on correct second marking point*); [3]

SL A 04s

1. (a) (i) it is decreasing;  
 less frequent collisions / fewer collisions per second or (unit) time; [2]
- (ii) reactant(s) used up / reaction is complete; [1]  
*Do not accept reaction reaches equilibrium.*
- (b) (i) it would increase;  
*Accept a quantitative answer such as "doubles".* [1]
- (ii) more frequent collisions;  
 collisions or molecules have more energy (OWTTE);  
 more molecules with energy  $\geq E_a$ ; [3]
- (iii) rate would be lower;  
 smaller surface area; [2]

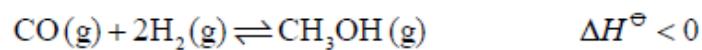
SL A 03s

- 2 (a) activation energy = **minimum** energy required for a reaction to occur; [1]
- (b) curve moved to the right;  
 peak lower; [2]  
*Deduct [1] if shaded area smaller at  $T_2$  or if  $T_2$  line touches the x-axis*
- (c) rate increased;  
 as more molecules with energy  $\geq E_a$ ; [2]

## Topic 7 Questions

SL B 13sQ7

- (c) The manufacture of gaseous methanol from CO and H<sub>2</sub> involves an equilibrium reaction.



- (i) Outline the characteristics of a chemical equilibrium.

[2]

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- (ii) Deduce the equilibrium constant expression,  $K_c$ , for this reaction.

[1]

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- (iii) Identify **one** other important industrial synthesis that is an equilibrium reaction.

[1]

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(d) State and explain the effect of the following changes on the equilibrium position of the reaction in part (c).

(i) Increase in temperature.

[2]

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(ii) Increase in pressure.

[2]

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(iii) Addition of a catalyst.

[2]

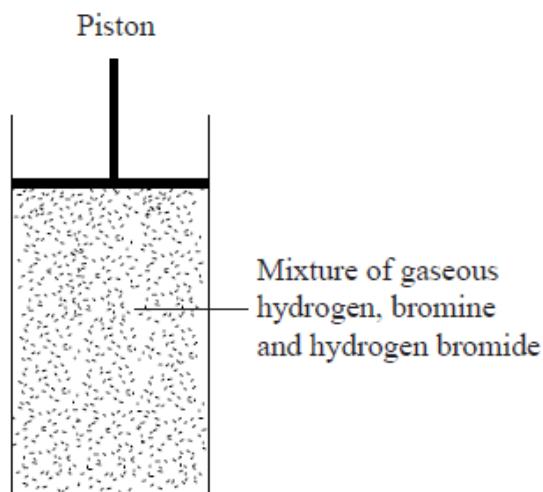
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6. Consider the equilibrium system involving bromine and its hydride.



- (a) State an equation to represent the equilibrium with  $\text{H}_2(\text{g})$  and  $\text{Br}_2(\text{g})$  as reactants. [1]

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- (b) (i) Predict what happens to the position of equilibrium if a small amount of hydrogen is introduced. [1]

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- (ii) State and explain the effect of increasing the pressure on the position of equilibrium. [2]

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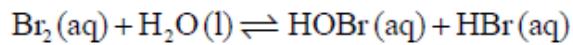
- (c) (i) Deduce the equilibrium constant expression,  $K_c$ , for the equilibrium in (a). [1]

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.....  
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- (ii) State the effect of increasing  $[H_2]$  on the value of  $K_c$ . [1]

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.....

- (e) When bromine dissolves in water, 1 % of the original bromine molecules react according to the following equation.



- (iii) Estimate the magnitude of  $K_c$  for this reaction. Choose your value from the following options: [1]

$$K_c = 0$$

$$K_c < 1$$

$$K_c = 1$$

$$K_c > 1$$

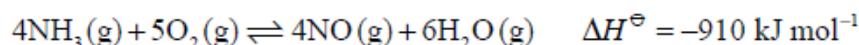
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- (iv) State and explain what happens to the equilibrium, in (e), when aqueous sodium hydroxide is added to the reaction solution at equilibrium. [2]

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- (d) (i) A state of equilibrium can exist when a piece of copper metal is placed in a solution of copper(II) sulfate. Outline the characteristics of a chemical system in dynamic equilibrium. [2]
- (ii) For an exothermic reaction state how an increase in temperature would affect both  $K_c$  and the position of equilibrium. [2]

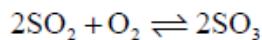
7. (a) The following equilibrium is involved in the industrial production of nitric acid from ammonia.



Describe the effect, if any, of each of the following changes on the equilibrium concentration of nitrogen monoxide in a particular equilibrium mixture, giving a reason in each case.

- (i) Increasing the pressure, at constant temperature [2]
  - (ii) Increasing the temperature, at constant pressure [2]
  - (iii) Addition of a heterogeneous catalyst, at constant pressure and temperature [2]
- (b) Deduce the equilibrium constant expression,  $K_c$ , including units for the forward reaction in part (a). [2]
- (c) Identify which of the changes in part (a) will affect the value of  $K_c$  and predict whether the value of  $K_c$  will increase or decrease. [2]

6. Consider the following reaction in the Contact process for the production of sulfuric acid for parts (a) to (f) in this question.

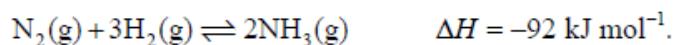


- (a) Write the equilibrium constant expression for the reaction. [1]
- (b) (i) State the catalyst used in this reaction of the Contact process. [1]
- (ii) State and explain the effect of the catalyst on the value of the equilibrium constant and on the rate of the reaction. [4]
- (c) Use the collision theory to explain why increasing the temperature increases the rate of the reaction between sulfur dioxide and oxygen. [2]
- (d) Using Le Chatelier's principle state and explain the effect on the position of equilibrium of  
(i) increasing the pressure at constant temperature. [2]  
(ii) removing of sulfur trioxide. [2]  
(iii) using a catalyst. [2]
- (e) Using the following data, explain whether the above reaction is exothermic or endothermic. [2]

Temperature / K	Equilibrium constant $K_c / \text{dm}^3 \text{ mol}^{-1}$
298	$9.77 \times 10^{25}$
500	$8.61 \times 10^{11}$
700	$1.75 \times 10^6$

SL B 02s

5. Ammonia is made on a large scale by the Haber process. The main reaction occurring is



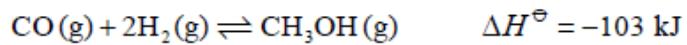
- (a) State **two** characteristics of a reversible reaction at equilibrium. [2]
- (b) This reaction is described as *homogeneous*. State what is meant by the term *homogeneous*. [1]
- (c) Write the equilibrium constant expression for the reaction. [2]
- (d) When nitrogen and hydrogen are mixed together at room temperature and atmospheric pressure the reaction is very slow. In industry, typical values of pressure and temperature used are 250 atmospheres and 450 °C.
- (i) State the effects on both the rate of reaction and the value of the equilibrium constant of increasing the temperature. [2]
- (ii) State the effects on both the rate of reaction and the value of the equilibrium constant of increasing the pressure. [2]
- (iii) Suggest why a pressure of 1000 atmospheres is not used. [1]
- (e) Name the catalyst used in the Haber process. State and explain its effect on the value of the equilibrium constant. [3]
- (g) A mixture of nitrogen and hydrogen is left at 450 °C and 250 atmospheres until equilibrium is reached. Use Le Chatelier's principle to state and explain what will happen to the position of equilibrium when
- (i) some of the ammonia is removed; [2]
- (ii) the pressure is increased. [2]

SL B 01s

4. (a) Define the term *rate of reaction*. For a reaction of your choice, state the reactants and outline an experimental procedure by which you could obtain a value for the rate of reaction. [5]
- (b) (i) State Le Chatelier's Principle. [1]
- (ii) State the factors which affect the **position** of equilibrium in a reaction. Explain the influence of **one** of these factors using Le Chatelier's Principle. [3]
- (iv) State the factors which affect the **time** taken to reach equilibrium and explain briefly the influence of **one** of these factors. [3]
- (c) Write an equation, including state symbols, for the synthesis of ammonia by the Haber process. Explain the use of high pressure and moderately-high temperatures in the production of ammonia. [4]

SL A 11s

3. Methanol may be produced by the exothermic reaction of carbon monoxide gas and hydrogen gas.



- (a) State the equilibrium constant expression,  $K_c$ , for the production of methanol.

[1]

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- (b) State and explain the effect of changing the following conditions on the amount of methanol present at equilibrium:

- (i) increasing the temperature of the reaction at constant pressure.

[2]

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- (ii) increasing the pressure of the reaction at constant temperature.

[2]

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- (c) The conditions used in industry during the production of methanol are a temperature of 450 °C and pressure of up to 220 atm. Explain why these conditions are used rather than those that could give an even greater amount of methanol. [2]

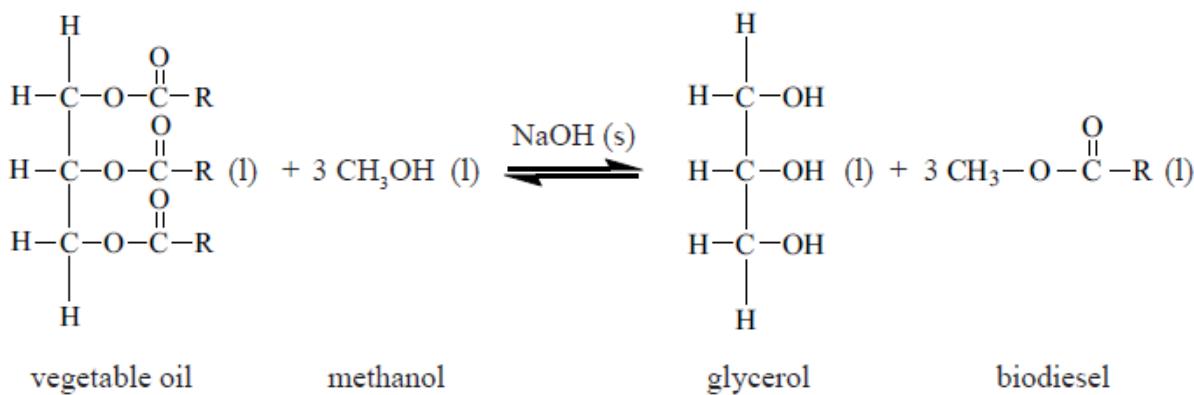
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- (d) A catalyst of copper mixed with zinc oxide and alumina is used in industry for this production of methanol. Explain the function of the catalyst. [1]

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SL A 09sQ1

1. Biodiesel makes use of plants' ability to fix atmospheric carbon by photosynthesis. Many companies and individuals are now using biodiesel as a fuel in order to reduce their carbon footprint. Biodiesel can be synthesized from vegetable oil according to the following reaction.



- (c) The reversible arrows in the equation indicate that the production of biodiesel is an equilibrium process.

- (i) State what is meant by the term *dynamic equilibrium*.

[1]

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.....

- (ii) Using the abbreviations [vegetable oil], [methanol], [glycerol] and [biodiesel] deduce the equilibrium constant expression ( $K_c$ ) for this reaction.

[1]

- (iii) Suggest a reason why excess methanol is used in this process.

[1]

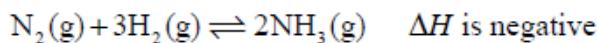
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- (iv) State and explain the effect that the addition of the sodium hydroxide catalyst will have on the position of equilibrium.

[2]

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4. Ammonia is produced by the Haber process according to the following reaction.



- (a) State the equilibrium constant expression for the above reaction.

[1]

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- (b) Predict, giving a reason, the effect on the position of equilibrium when the pressure in the reaction vessel is increased.

[2]

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- (c) State and explain the effect on the value of  $K_c$  when the temperature is increased.

[2]

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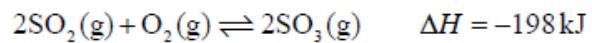
- (d) Explain why a catalyst has no effect on the position of equilibrium.

[1]

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SL A 04s

4. Consider the following equilibrium reaction.



Using Le Chatelier's Principle, state and explain what will happen to the position of equilibrium if

- (a) the temperature increases.

[2]

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- (b) the pressure increases.

[2]

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SL A 03s

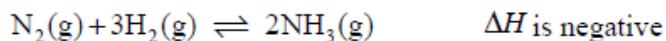
1. The table below gives information about the percentage yield of ammonia obtained in the Haber process under different conditions.

Pressure/ atmosphere	Temperature/°C			
	200	300	400	500
10	50.7	14.7	3.9	1.2
100	81.7	52.5	25.2	10.6
200	89.1	66.7	38.8	18.3
300	89.9	71.1	47.1	24.4
400	94.6	79.7	55.4	31.9
600	95.4	84.2	65.2	42.3

- (a) From the table, identify which combination of temperature and pressure gives the highest yield of ammonia. [1]

.....

- (b) The equation for the main reaction in the Haber process is



Use this information to state and explain the effect on the yield of ammonia of increasing the

- (i) pressure: ..... [2]

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.....

- (ii) temperature: ..... [2]

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- (c) In practice, typical conditions used in the Haber process are a temperature of 500 °C and a pressure of 200 atmospheres. Explain why these conditions are used rather than those that give the highest yield. [2]

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- (d) Write the equilibrium constant expression,  $K_c$ , for the production of ammonia. [1]

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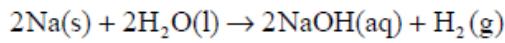
SL A 03s

3. (a) The relative molecular mass of aluminium chloride is 267 and its composition by mass is 20.3 % Al and 79.7 % chlorine. Determine the empirical and molecular formulas of aluminium chloride.

[4]

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- (b) Sodium reacts with water as follows.



1.15 g of sodium is allowed to react completely with water. The resulting solution is diluted to 250 cm<sup>3</sup>. Calculate the concentration, in mol dm<sup>-3</sup>, of the resulting sodium hydroxide solution.

[3]

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## Topic 7 Mark Scheme

SL B 13sQ7

- (c) (i) rate of forward reaction equals rate of backward reaction; concentrations of reactants and products do not change / constant macroscopic properties; [2]
- (ii)  $K_c = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$ ; [1]  
*Do not award mark if incorrect brackets are used or brackets omitted.*
- (iii) Haber process/production of NH<sub>3</sub> / contact process/production of H<sub>2</sub>SO<sub>4</sub>; [1]  
*Accept suitable equation.*
- (d) (i) shifts to left/reactants;  
 to endothermic side / (forward) reaction is exothermic; [2]
- (ii) shifts to the right/products;  
 to the side with fewer gas molecules/moles of gas; [2]
- (iii) no effect on equilibrium;  
 rate of forward and backward reaction increase equally / activation energy of forward and backward reaction lowered equally; [2]

SL B 12s

6. (a)  $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \rightleftharpoons 2\text{HBr}(\text{g})$ ; [1]
- (b) (i) shifts to right/toward products/forward reaction favoured; [1]  
*Accept reverse statement if process written the other way around.*  
*Answer must match stated equation.*
- (ii) no effect;  
 same amounts/number of (gaseous) moles/molecules on both sides; [2]
- (c) (i)  $(K_c) = \frac{[\text{HBr}]^2}{[\text{H}_2][\text{Br}_2]}$ ; [1]
- (ii) no effect (only depends on the temperature); [1]
- (e) (i) Br<sub>2</sub>: 0  
 HBr: -1  
 HOBr: +1 [2]  
*Award [2] for three correct.*  
*Award [1] for any two correct.*
- (ii) bromine is oxidized **and** reduced / disproportionation; [1]
- (iii)  $K_c < 1$ ; [1]
- (iv) shifts to right/toward products/forward reaction favoured;  
 to replace H<sup>+</sup>/HBr/HOBr / to remove H<sub>2</sub>O formed from neutralization; [2]

SL B 10s

- (d) (i) macroscopic properties remain constant / concentrations remain constant / no change to copper solution seen;  
rate of reverse/backwards reaction = rate of forward reaction; [2]
- (ii)  $K_c$  decreases;  
position of equilibrium shifts to left; [2]

SL B 08s

7. (a) (i) (equilibrium shifted to the left) equilibrium concentration of NO is reduced;  
more gas molecules on the right hand side than on the left; [2]
- (ii) (equilibrium shifted to the left) equilibrium concentration of NO is reduced;  
(forward) reaction is exothermic; [2]
- (iii) no effect on the equilibrium concentration of NO;  
catalyst increases the rate of forward and reverse reaction equally; [2]
- (b)  $K_c = \frac{[\text{NO}]^4 [\text{H}_2\text{O}]^6}{[\text{NH}_3]^4 [\text{O}_2]^5}$ ;  
mol dm<sup>-3</sup>; [2]
- (c) increase in temperature;  
 $K_c$  decreases; [2]

SL B 06s

6. (a)  $K / K_c = [\text{SO}_3]^2 + [\text{SO}_2]^2 [\text{O}_2]$ ;  
*Accept correct  $K_p$  expression.* [1]
- (b) (i) vanadium(V) oxide / (di)vanadium ptaaoxide /  $\text{V}_2\text{O}_5$ ;  
*Allow just vanadium oxide but not correct formula.* [1]
- (ii) catalyst does not affect the value of  $K_c$ ;  
forward and reverse rates increase equally/by the same factor;  
catalyst increases the rate of the reaction;  
(by providing an alternative path for the reaction with) lower activation energy; [4]
- (c) more energetic collisions / more molecules have energy greater than activation energy;  
more frequent collisions;  
*Do not accept more collisions without reference to time.* [2]
- (d) (i) shifts equilibrium position to the products/right;  
to the side with fewer gas molecules or moles / lower volume of gas; [2]
- (ii) shifts equilibrium position to the products/right;  
to compensate for loss of  $\text{SO}_3$  / produce more  $\text{SO}_3$ ; [2]
- (iii) no effect;  
forward and backward rates increased equally / by the same factor; [2]
- (e) exothermic;  
 $K_c$  decreases with increasing temperature / back reaction favoured / heat used up / OWTTE; [2]

5. (a) forward and reverse reactions still occurring / forward and reverse rates equal [1];  
concentrations of reactants and products unchanged [1]. [2]
- (b) Reactants and products in the same phase/state. [1]
- (c)  $K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$   
*Accept correct expression for  $K_p$*   
 Use of [] and formulas in correct position [1];  
 powers correct [1]. [2]
- (d) (i) rate increased [1];  
 equilibrium constant decreased [1]. [2]
- (ii) rate increased [1];  
 equilibrium constant unchanged [1]. [2]
- (iii) too expensive / greater cost of energy or pipes / more safety precautions / thicker pipes [1]
- (e) iron / Fe [1];  
 equilibrium constant unchanged [1];  
 only temperature affects  $K_c$  / catalyst speeds up forward and reverse reactions equally / activation energy reduced by same amount for both forward and reverse reactions [1]. [3]
- (f) (*Award [1] for any three of the following:*)  
 successful collisions need minimum/activation energy / correct geometry [1];  
 increasing temperature causes increase in energy of particles [1];  
 so increased proportion of successful collisions [1];  
 so increased frequency of collisions / more collisions per unit time [1].  
*Do not accept just "more collisions".* [3]
- (g) (i) shifted to right [1];  
 to replace the ammonia removed [1]; [2]
- (ii) shifted to right [1];  
 fewer gas moles on the right / OWTTE [1]. [2]

4. (a) Change of concentration of reactant/product with time [1]  
 Identify feasible reaction [1]  
 State what is to be measured [1]  
 Record time for specific event [1]  
 Plot graph of reciprocal time  $\left(\frac{1}{t}\right)$  [1] [5 max]
- (N.B. we are timing [1] a specific process e.g. gas/precipitate appearing, etc. [1])
- (b) (i) If a system at **equilibrium** is disturbed, the **equilibrium** moves in the direction which tends to reduce the disturbance (OWTTE). [1]
- (ii) Temperature and pressure / concentration [1] (*ignore others*)  
 For the factor chosen, [1] for effect/influence and [1] for explanation [3 max]
- Temperature: effect depends on whether endothermic or exothermic [1], explanation [1]  
 Pressure: effect depends on number of moles of gaseous reactants and products [1], explanation [1]  
 Concentration: effect depends on whether change is to reactants or products [1], explanation [1]
- (iii) Molecules must collide in order to react [1]  
 Not all collisions lead to a reaction [1]  
 Minimum energy needed/activation energy [1]  
 Appropriate collision geometry required [1] [4 max]
- (iv) Temperature, concentration/pressure, catalyst, surface area [2]  
*(Award [2] for 3 or 4 factors and [1] for 2 factors)*  
*(Award [1] for explanation, for example)*
- Temperature increase: increases frequency / number of collisions / more molecules have sufficient energy to react [1]
- Conc./pressure increase: increase in the number / frequency of collisions [1]
- Catalyst: reduces minimum energy needed to react / reduces  $E_a$  / provides alternative reaction pathway with lower energy [1]
- Surface area: increases number of collisions [1] [3 max]
- (c)  $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$  (*state symbols and  $\rightleftharpoons$  required*) [1]
- Low temperature, high yield [1]  
 Low temperature, low rate [1]  
 High pressure, high yield [1]  
 High pressure, high rate [1] } [3 max] [4 max]

SL A 11s

3. (a)  $(K_c =) \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2};$  [1]

*Do not award mark if incorrect brackets are used or brackets are missing.*

- (b) (i) amount (of methanol)/product decreases / less methanol;  
 (forward reaction) exothermic / reverse reaction endothermic / OWTTE; [2]

- (ii) amount (of methanol)/product increases / more methanol;  
 3 gas molecules/mol → 1 / decrease in volume / fewer gas molecules on right hand side/products / more gas molecules on left hand side/reactants; [2]

- (c) high pressure expensive / greater cost of operating at high pressure;  
 lower temperature – lower (reaction) rate; [2]

- (d) increases rate of forward and reverse reactions (equally) / lowers activation energy/ $E_a$  (of both the forward and reverse reaction equally) / provides alternative path with lower activation energy/ $E_a$ ;  
*Accept reactants adsorb onto the catalyst surface and bonds weaken resulting in a decrease in the activation energy.* [1]

SL A 09s

- (c) (i) rate of the forward reaction is equal to the rate of the reverse reaction / forward and reverse reactions occur **and** the concentrations of the reactants and products do not change / OWTTE; [1]

(ii)  $K_c = \frac{[\text{glycerol}] \times [\text{biodiesel}]^3}{[\text{vegetable oil}] \times [\text{methanol}]^3};$  [1]

- (iii) to move the position of equilibrium to the right/product side / increase the yield of biodiesel; [1]

- (iv) no effect (on position of equilibrium);  
 increases the rate of the forward and the reverse reactions equally (so equilibrium reached quicker) / it lowers  $E_a$  for both the forward and reverse reactions by the same amount / OWTTE;  
*No ECF for explanation.* [2]

SL A 07s

4. (a) 
$$(K_c) = \frac{[\text{NH}_3]^2}{[\text{H}_2]^3[\text{N}_2]};$$
 [1]

*Do not allow round brackets unless  $K_p$  is used.*

- (b) equilibrium shifts to the right / products;  
 $4 \text{ mol} \rightarrow 2 \text{ mol of gas}$  / fewer moles of gas on the right/products; [2]

- (c)  $K_c$  decreases;  
equilibrium position shifts to the left/reactants / forward reaction is exothermic / reverse reaction is endothermic; [2]

- (d) catalyst increases the rate of the forward and backward reactions equally / lowers the activation energy of both forward and backward reaction equally / lowers  $E_a$  so rate of forward and backward reactions increase; [1]

#### SL A 04s

4. (a) (position of) equilibrium shifts to the left / towards reactants;  
(forward) reaction is exothermic /  $\Delta H$  is negative / the reverse reaction is endothermic / OWTTE;  
*Do not accept "Le Chatelier's Principle" without some additional explanation.* [2]

- (b) (position of) equilibrium shifts to the right / towards products;  
fewer gas molecules on the right hand side / volume decreases in forward reaction / OWTTE;  
*Do not accept "Le Chatelier's Principle" without some additional explanation.* [2]

#### SL A 03s

1. (a)  $200^\circ\text{C}$     $600 \text{ atm}$ . (*both for [1], units not needed*); [1]  
*allow the "highest pressure and the lowest temperature"*

- (b) (i) yield increases / equilibrium moves to the right / more ammonia;  
 $4 (\text{gas}) \text{ molecules} \rightarrow 2$  / decrease in volume / fewer molecules on right hand side; [2]
- (ii) yield decreases / equilibrium moves to the left / less ammonia;  
exothermic reaction / OWTTE; [2]

- (c) high pressure expensive / greater cost of operating at high pressure / reinforced pipes etc. needed;  
lower temperature – greater yield, but **lowers** rate; [2]  
*Do not award a mark just for the word "compromise".*

- (d)  $K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$  (*ignore units*); [1]

#### SL A 03s

3. (a) Al  $\frac{20.3}{26.98}$  Cl  $\frac{79.70}{35.45}$  or similar working (*no penalty for use of 27 or 35.5*);  
empirical formula AlCl<sub>3</sub>;  
molecular formula:  $n = \frac{267}{133.5} = 2$ ;  
Al<sub>2</sub>Cl<sub>6</sub>; [4]

*Full credit can be obtained if the calculations are carried out by another valid method. Two correct formulas but no valid method scores [2 max].*

- (b) moles of Na =  $\frac{1.15}{23} = 0.05$ ;  
moles of NaOH = 0.05;  
*Accept "same as moles of Na"*  
concentration =  $\left( \frac{0.05}{0.25} \right) = 0.20 \text{ (mol dm}^{-3}\text{)}$ ; [3]  
*Allow ECF from moles of NaOH*

## Topic 8 Questions

SL B 13sQ6

- (d) (i) Define an *acid* according to the Lewis theory. [1]

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- (ii) State and explain the acid-base character of NH<sub>3</sub> and BF<sub>3</sub> according to the Lewis theory. [3]

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- (d) Hydrogen bromide forms a strong acid when dissolved in water whereas hydrogen fluoride forms a weak acid. Distinguish between the terms ***strong acid*** and ***weak acid***. State equations to describe the dissociation of each acid in aqueous solution. [3]

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- (iii) Carbon dioxide and silicon dioxide can both be described as acidic oxides. Describe the pH changes that occur when each is added to separate samples of water. [2]

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- (c) (i) Define the terms *acid* and *base* according to the Brønsted-Lowry theory and state one example of a weak acid and one example of a strong base. [2]

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- (ii) Describe **two** different methods, one chemical and one physical, other than measuring the pH, that could be used to distinguish between ethanoic acid and hydrochloric acid solutions of the same concentration.

[4]

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- (iii) Black coffee has a pH of 5 and toothpaste has a pH of 8. Identify which is more acidic and deduce how many times the  $[H^+]$  is greater in the more acidic product.

[2]

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- (d) Samples of sodium oxide and sulfur trioxide are added to separate beakers of water. Deduce the equation for each reaction **and** identify each oxide as acidic, basic or neutral.

[3]

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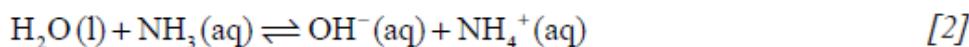
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(c) (i) Define a Brønsted-Lowry acid. [1]

(ii) Deduce the two acids and their conjugate bases in the following reaction:



(iii) Explain why the following reaction can also be described as an acid-base reaction.

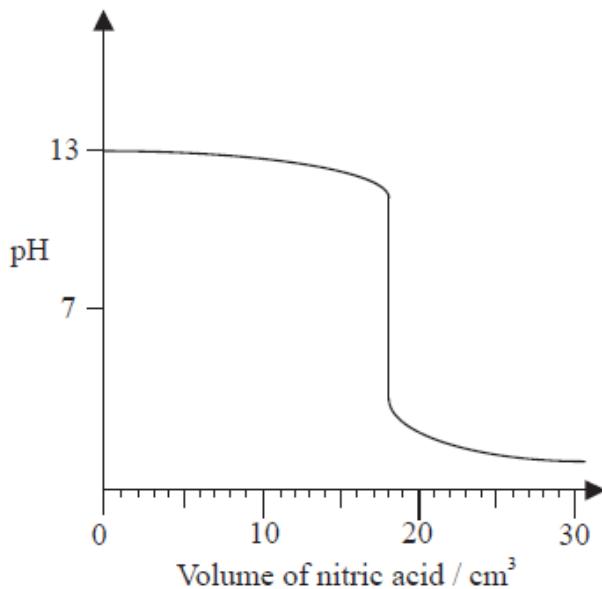


(d) Ethanoic acid,  $\text{CH}_3\text{COOH}$ , is a weak acid.

(i) Define the term *weak acid* and state the equation for the reaction of ethanoic acid with water. [2]

(ii) Vinegar, which contains ethanoic acid, can be used to clean deposits of calcium carbonate from the elements of electric kettles. State the equation for the reaction of ethanoic acid with calcium carbonate. [2]

7. (a) Explain why a  $1.0 \text{ mol dm}^{-3}$  solution of sodium hydroxide has a pH of 14 whereas  $1.0 \text{ mol dm}^{-3}$  ammonia solution has a pH of about 12. Use equations in your answer. [5]
- (b)  $20.0 \text{ cm}^3$  of a known concentration of sodium hydroxide is titrated with a solution of nitric acid. The graph for this titration is given below.



- (i) State an equation for the reaction between sodium hydroxide and nitric acid. [1]
- (ii) Calculate the concentration of the sodium hydroxide solution before the titration. [2]
- (iii) From the graph determine the volume of nitric acid required to neutralize the sodium hydroxide and calculate the concentration of the nitric acid. [2]
- (iv) Predict the volume of ethanoic acid of the same concentration as the nitric acid in (b) (iii), required to neutralize  $20.0 \text{ cm}^3$  of this sodium hydroxide solution. [1]
- (c) State and explain two methods, other than measuring pH, which could be used to distinguish between  $1.0 \text{ mol dm}^{-3}$  solutions of nitric acid and ethanoic acid. [4]

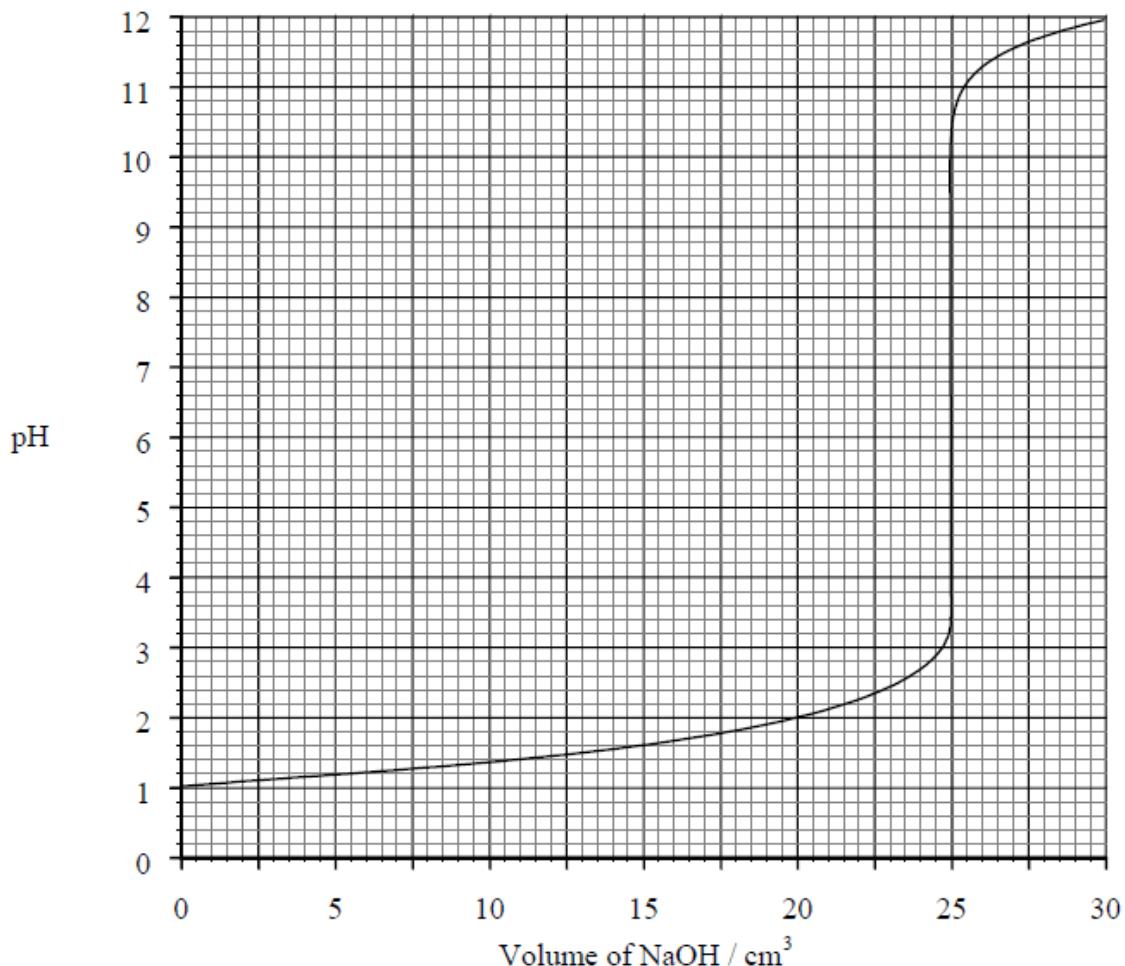
#### SL B 06s

8. (a) Identify one example of a strong acid and one example of a weak acid. Outline three different methods to distinguish between equimolar solutions of these acids in the laboratory. State how the results would differ for each acid. [5]
- (b) State the name used to describe substances that can act as an acid and a base. Use equations to illustrate how  $\text{HCO}_3^-$  can behave both as an acid and base. [3]
- (c) Vinegar has a pH of approximately 3 and some detergents have a pH of approximately 8. State and explain which of these has the higher concentration of  $\text{H}^+$  and by what factor. [1]

#### SL B 03s

7. (a) Define the terms *strong acid* and *weak acid*. Using hydrochloric and ethanoic acid as examples, write equations to show the dissociation of each acid in aqueous solution. [4]
- (b) (i) Calcium carbonate is added to separate solutions of hydrochloric acid and ethanoic acid of the same concentration. State **one** similarity and **one** difference in the observations you could make. [2]
- (ii) Write an equation for the reaction between hydrochloric acid and calcium carbonate. [2]
- (iii) Determine the volume of  $1.50 \text{ mol dm}^{-3}$  hydrochloric acid that would react with exactly 1.25 g of calcium carbonate. [3]
- (iv) Calculate the volume of carbon dioxide, measured at 273 K and  $1.01 \times 10^5 \text{ Pa}$ , which would be produced when 1.25 g of calcium carbonate reacts completely with the hydrochloric acid. [2]

- (c) The graph below shows the change in pH when aqueous sodium hydroxide is added to 20 cm<sup>3</sup> of aqueous hydrochloric acid.



By reference to the graph

- (i) state the [H<sup>+</sup>] before any alkali is added. [1]
- (ii) state by how much the [H<sup>+</sup>] changes after the addition of 20 cm<sup>3</sup> of aqueous sodium hydroxide. [1]
- (iii) determine the volume of the same sodium hydroxide solution needed to neutralize 20 cm<sup>3</sup> of aqueous ethanoic acid of the same concentration as the hydrochloric acid. [1]

- (d) A solution of HA is a weak acid. Distinguish between a *weak acid* and a *strong acid*. [1]

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- (e) Describe an experiment, other than measuring the pH, to distinguish HA from a strong acid of the same concentration and describe what would be observed. [2]

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SL A 10sQ3b

Ethanoic acid has the formula CH<sub>3</sub>COOH

- (iii) State an equation, including state symbols, for the reaction of ethanoic acid with water. Identify a Brønsted-Lowry acid in the equation and its conjugate base. [3]

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SL A 09sQ3

(c) (i) State the acid-base nature of sodium oxide.

[1]

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(ii) State the equation for the reaction of sodium oxide with water.

[1]

.....

SL A 02s

2. In aqueous solution, sodium hydroxide is a strong base and ammonia is a weak base.

(a) Use the Brønsted–Lowry theory to state why both substances are classified as bases.

[1]

.....

(b) Solutions of  $0.1 \text{ mol dm}^{-3}$  sodium hydroxide and  $0.1 \text{ mol dm}^{-3}$  ammonia have different electrical conductivities.

(i) State and explain which solution has the greater conductivity.

[1]

.....

(ii) The pH value of  $0.1 \text{ mol dm}^{-3}$  ammonia solution is approximately 11. State and explain how the pH value of the  $0.1 \text{ mol dm}^{-3}$  sodium hydroxide solution would compare.

[2]

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.....

(c) Write an equation to show the reaction of ammonia with water and classify **each** product as a Brønsted–Lowry acid or base.

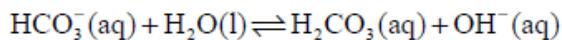
[2]

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SL A 01s

2. Sodium hydrogencarbonate dissolves in water forming an alkaline solution according to the following ionic equilibrium:



- (a) Why is the solution alkaline? [1]

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.....

- (b) Using the Brønsted–Lowry theory, state, with a brief explanation, whether the  $\text{HCO}_3^-$  ion is behaving as an acid or as a base. [2]

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.....  
.....

- (c) Identify the conjugate base of carbonic acid,  $\text{H}_2\text{CO}_3$ . [1]

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## Topic 8 Mark Scheme

### SL B 13sQ6

- (d) (i) electron pair acceptor; [1]

(ii)  $\text{NH}_3$ : Lewis base;

$\text{BF}_3$ : Lewis acid;

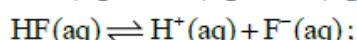
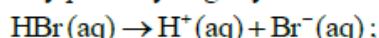
$\text{NH}_3$  has non-bonding/lone pair of electrons and  $\text{BF}_3$  has only 3 pairs of electrons around B/incomplete octet;

*Reference to outer electrons of N and B is needed for the mark.*

[3]

### SL B 12sQ6

- (d) *Strong acid:* acid/electrolyte (assumed to be almost) 100%/completely dissociated/ionized (in solution/water) / OWTTE and *Weak acid:* acid/electrolyte only partially/slightly dissociated/ionized (in solution/water) / OWTTE;



[3]

### SL B 12sQ5b

(iii)  $\text{CO}_2$ :

pH (of resultant solution) weakly acidic / pH in range 5.5–6.5 (accept any value in this range);

$\text{SiO}_2$ :

pH remains as 7;

[2]

SL B 11Sq5

(c) (i) acid is a proton/ $\text{H}^+$  donor **and** base is a proton/ $\text{H}^+$  acceptor;  
 $\text{H}_2\text{CO}_3/\text{CH}_3\text{COOH}$  **and**  $\text{NaOH}/\text{KOH}/\text{Ba}(\text{OH})_2$ ;  
*Accept any suitable examples.*

[2]

(ii) *Chemical [2 max]*

reaction with reactive metal/Mg/Zn/carbonate/hydrogen carbonate;  
hydrochloric acid would react faster/more vigorously / ethanoic acid would react slower/less vigorously;

**OR**

react with alkali;

temperature change will be more for hydrochloric acid / temperature change will be less for ethanoic acid;

*Physical [2 max]*

conductivity;

hydrochloric acid will conduct more/higher / ethanoic acid will conduct less/lower;

[4 max]

*Accept other suitable examples.*

(iii) black coffee;

$10^3/1000$  times;

[2]

(d)  $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{NaOH}(\text{aq})$  ;

$\text{SO}_3(\text{l}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_4(\text{aq})$  ;

*Ignore state symbols.*

$\text{Na}_2\text{O}$ : basic **and**  $\text{SO}_3$ : acidic;

[3]

SL B 09sQ6

(c) (i) donates a proton /  $\text{H}^+$  ion;

[1]

(ii) (acid)                          (conjugate base)

$\text{H}_2\text{O}$                                $\text{OH}^-$  ;

$\text{NH}_4^+$                                $\text{NH}_3$  ;

[2]

*[1 max] if all four acids and bases given but not clearly paired.*

(iii) Lewis acid accepts an electron pair / Lewis base donates an electron pair;

$\text{F}^-$  is the base /  $\text{BF}_3$  is the acid;

[2]

- (d) (i) partially dissociated or ionized;  
 $\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_3\text{O}^+$  /  $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$  ; [2]  
 $\rightleftharpoons$  required for mark.
- (ii)  $2\text{CH}_3\text{COOH} + \text{CaCO}_3 \rightarrow \text{Ca}(\text{CH}_3\text{COO})_2 + \text{CO}_2 + \text{H}_2\text{O}$  [2]  
*Award [1] for correct reactants and products and [1] for balancing.*

SL B 07s

7. (a) NaOH is a strong base /  $\text{NH}_3$  is a weak base;  
 NaOH completely dissociates/ionizes;  
 $\text{NH}_3$  partially dissociates/ionizes;
- pH 14 has high  $[\text{OH}^-]$  / low  $[\text{H}^+]$  / pH 12 has lower  $[\text{OH}^-]$  / higher  $[\text{H}^+]$ ;  
 $\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^-$ ;  
 $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$ ; ( $\rightleftharpoons$  required) [5 max]
- (b) (i)  $\text{NaOH} + \text{HNO}_3 \rightarrow \text{NaNO}_3 + \text{H}_2\text{O}$  ; [1]
- (ii) 1 pH / pOH unit represents a 10 fold change in concentration;  
 So if a  $1.0\text{ mol dm}^{-3}$  NaOH solution has a pH of 14  
 then a  $0.10\text{ mol dm}^{-3}$  solution will have a pH of 13; [2]  
*Units needed for the mark.*  
*Award [2] for correct final answer.*
- (iii)  $18.0\text{ cm}^3$ ;  

$$\left( \frac{0.10 \times 20.0}{18.0} \right) = 0.11\text{ mol dm}^{-3}$$
; [2]  
*Allow ECF from an incorrect value of concentration in part (ii).*
- (iv)  $18.0\text{ cm}^3$ ; [1]
- (c) conductivity;  
 nitric acid will contain more ions and have a higher conductivity / ethanoic acid will have fewer ions and have a lower conductivity;  
 rate of reaction with metal / carbonate / hydrogencarbonate;  
 nitric acid will react more rapidly / produce bubbles faster / ethanoic acid will react less rapidly / produce bubbles more slowly;  
 reaction with alkali;  
 temperature change will be less for ethanoic acid; [4 max]  
*Accept any two methods and explanations from above.*

SL B 06s

8. (a) HCl/H<sub>2</sub>SO<sub>4</sub>/HNO<sub>3</sub> / any strong acid;  
 CH<sub>3</sub>COOH / H<sub>2</sub>CO<sub>3</sub> / any weak acid;  
 Measure pH – the strong acid has the lower pH;  
*Accept universal indicator and two correct colours.*  
 Measure (electrical) conductivity – this is greater for the stronger acid;  
 Add magnesium/carbonate – more gas bubbles with the stronger acid / Mg or carbonate would disappear faster with stronger acid; [5]
- (b) amphoteric/amphiprotic;  
 as an acid: HCO<sub>3</sub><sup>-</sup> + H<sub>2</sub>O → H<sub>3</sub>O<sup>+</sup> + CO<sub>3</sub><sup>2-</sup> / HCO<sub>3</sub><sup>-</sup> → H<sup>+</sup> + CO<sub>3</sub><sup>2-</sup>;  
 as a base: HCO<sub>3</sub><sup>-</sup> + H<sub>2</sub>O → OH<sup>-</sup> + H<sub>2</sub>CO<sub>3</sub> / HCO<sub>3</sub><sup>-</sup> + H<sup>+</sup> → H<sub>2</sub>CO<sub>3</sub>; *accept H<sub>2</sub>O + CO<sub>2</sub>.* [3]
- (c) vinegar and factor of 10<sup>5</sup>; [1]

SL B 03s

7. (a) strong acid completely dissociated / ionized;  
 weak acid only partially dissociated / ionized;  
 HCl(aq) → H<sup>+</sup>(aq) + Cl<sup>-</sup>(aq);  
 CH<sub>3</sub>COOH(aq) ⇌ CH<sub>3</sub>COO<sup>-</sup>(aq) + H<sup>+</sup>(aq); [4]  
*Insist on both arrows as shown, state symbols not needed.*  
*Also accept H<sub>2</sub>O(l) and H<sub>3</sub>O<sup>+</sup>(aq) in equations.*
- (b) (i) bubbling / effervescence / dissolving of CaCO<sub>3</sub> / gas given off (*do not accept CO<sub>2</sub> produced*);  
 more vigorous reaction with HCl / OWTTE; [2]
- (ii) 2HCl(aq) + CaCO<sub>3</sub>(s) → CaCl<sub>2</sub>(aq) + CO<sub>2</sub>(g) + H<sub>2</sub>O(l);  
*[1] for correct formulas, [1] for balanced, state symbols not essential.* [2]
- (iii) amount of CaCO<sub>3</sub> =  $\frac{1.25}{100.09}$  = 0.0125 mol (*no penalty for use of 100*);  
 amount of HCl =  $2 \times 0.0125 = 0.0250$  mol (*allow ECF*);  
 volume of HCl = 0.0167 dm<sup>3</sup> / 16.7 cm<sup>3</sup> (*allow ECF*); [3]
- (iv) 1:1 ratio of CaCO<sub>3</sub> to CO<sub>2</sub> / use 0.0125 moles CO<sub>2</sub> (*allow ECF*);  
 $(0.0125 \times 22.4) = 0.28$  dm<sup>3</sup> / 280 cm<sup>3</sup> /  $2.8 \times 10^{-4}$  m<sup>3</sup> (*allow ECF*);  
*Accept calculation using pV=nRT.* [2]
- (c) (i) 0.1 (mol dm<sup>-3</sup>) (*units not needed but penalize if incorrect*); [1]
- (ii) to 0.01 / decreases by factor of 10 / goes down by 0.09; [1]
- (iii) 25 cm<sup>3</sup>; [1]

SL A 13sQ1

(d) weak acids partially dissociated/ionized **and** strong acids completely dissociated/  
ionized (in solution/water) / OWTTE; [1]

(e) measuring electrical conductivity;  
strong acids have greater electrical conductivity / weak acids have lower electrical  
conductivity;

OR

adding a reactive metal / carbonate / hydrogen carbonate;  
*Accept correct example.*

stronger effervescence with strong acids / weaker with weak acids / OWTTE;

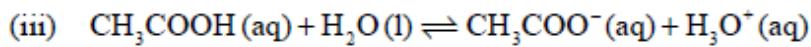
OR

adding a strong base;  
*Accept correct example.*

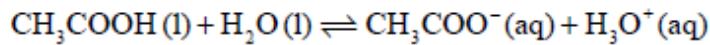
strong acid would increase more in temperature / weak acids increase less in  
temperature;

[2]

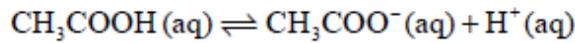
SL A 10s



OR



OR



correct equation;

state symbols **and**  $\rightleftharpoons$ ;

BL acid is  $\text{CH}_3\text{COOH}$  and cb is  $\text{CH}_3\text{COO}^-$  / BL acid is  $\text{H}_3\text{O}^+$  and cb is  $\text{H}_2\text{O}$ ;

[3]

SL A 09sQ3

(c) (i) basic; [1]  
*Allow alkaline*

(ii)  $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$  /  $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Na}^+ + 2\text{OH}^-$ ; [1]  
*Do not accept  $\rightleftharpoons$*

SL A 02s

2. (a) Both are proton acceptors. [1]
- (b) (i) sodium hydroxide, more ions / more dissociated [1]
- (ii) greater / 12–14 [1];  
more  $\text{OH}^-$  / less  $\text{H}^+$  [1].  
*Second mark can only be awarded if the first mark has been achieved.* [2]
- (c)  $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$  [1];  
acid base [1]; [2]

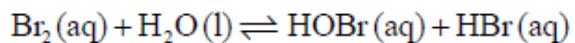
SL A 01s

2. (a)  $[\text{OH}^-] > [\text{H}^+]$  / pH > 7 / more  $\text{OH}^-$   
(Accept  $\text{OH}^-$  ions formed) [1]
- (b) Base [1]  
Accepting a proton / ( $\text{H}^+$ ) / hydrogen ion [1] [2 max]
- (c)  $\text{HCO}_3^-$  / hydrogencarbonate / bicarbonate [1]

## Topic 9 Questions

SL B 12sQ6

- (e) When bromine dissolves in water, 1 % of the original bromine molecules react according to the following equation.



- (i) Deduce the oxidation numbers of bromine in the reactant **and** products.

[2]

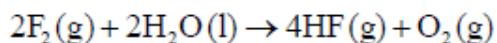
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- (ii) Explain the changes in the oxidation numbers of bromine.

[1]

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- (f) Fluorine reacts with water to produce oxygen.



- (i) Identify the oxidizing agent in the reaction.

[1]

.....

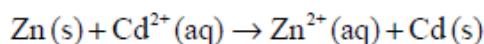
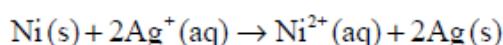
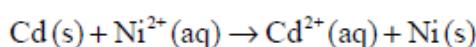
- (ii) 100 cm<sup>3</sup> of fluorine gas is added to water. Calculate the volume of oxygen produced at the same temperature and pressure.

[1]

.....

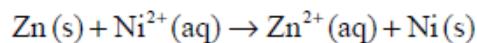
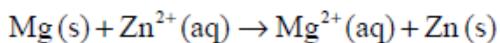
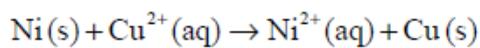
5. (a) (i) Draw an annotated diagram of a voltaic cell composed of a magnesium electrode in  $1.0 \text{ mol dm}^{-3}$  magnesium nitrate solution and a silver electrode in  $1.0 \text{ mol dm}^{-3}$  silver nitrate solution. State the direction of electron flow on your diagram. [4]
- (ii) Deduce half-equations for the oxidation and reduction reactions. [2]

(b) Consider the following three redox reactions.



- (i) Deduce the order of reactivity of the four metals, cadmium, nickel, silver and zinc and list in order of **decreasing** reactivity. [2]
- (ii) Identify the best oxidizing agent and the best reducing agent. [2]
- (c) (i) Solid sodium chloride does not conduct electricity but molten sodium chloride does. Explain this difference. [2]
- (ii) Outline what happens in an electrolytic cell during the electrolysis of molten sodium chloride using inert electrodes. Deduce equations for the reactions occurring at each electrode. [4]

8. (a) Consider the following reactions.



- (i) List the four metals in order of decreasing reactivity. [2]
- (ii) State and explain which is the strongest reducing agent in these reactions. [2]
- (iii) State and explain which is the strongest oxidizing agent in these reactions. [2]
- (b) Electrolysis of molten lead(II) bromide can be carried out using platinum electrodes.
- (i) Explain why lead(II) bromide does not conduct electricity in the solid state but does in the molten state. [2]
- (ii) State a half-equation for the reaction occurring at the positive electrode (anode) and identify whether the change is oxidation or reduction. [2]
- (iii) State a half-equation for the reaction occurring at the negative electrode (cathode) and identify whether the change is oxidation or reduction. [2]

SL B 07sQ8

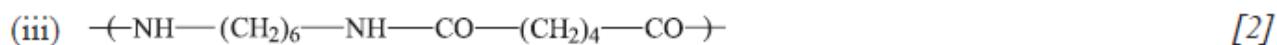
- (d) Nitric acid and ammonia may be used to make a buffer solution.
- (i) Describe the behaviour of a buffer solution. [2]
- (ii) Describe how you could prepare a buffer solution using  $0.100 \text{ mol dm}^{-3}$  solutions of nitric acid and ammonia. [3]

SL B 07sQ5f

- (iii) State the meaning of the term *optical isomers*. Draw the alcohol with the molecular formula  $\text{C}_4\text{H}_{10}\text{O}$  which exhibits optical isomerism and identify the chiral carbon atom. [3]

SL B 06sQ8

(e) Given the structures of the repeating units of the polymers below, identify the monomers from which they are formed.



(f) Describe the essential differences between the structures of monomers that form addition polymers and the structures of monomers that form condensation polymers. [2]

SL B 06sQ8

(d) Describe the composition and behaviour of a buffer solution. [3]

SL B 06sQ6

(f) The value of  $\Delta G^\ominus$  for the reaction is  $-140 \text{ kJ}$  at  $298 \text{ K}$ .

(i) State the name of the term represented by  $\Delta G^\ominus$ . [1]

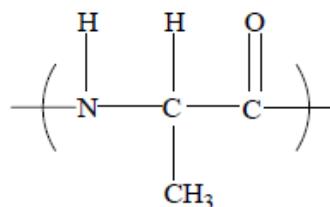
(ii) State what can be deduced from the sign of  $\Delta G^\ominus$ . [1]

(iii) The values of  $\Delta H^\ominus$  and  $\Delta S^\ominus$  for this reaction at  $298 \text{ K}$  are  $\Delta H^\ominus = -196 \text{ kJ}$  and  $\Delta S^\ominus = -188 \text{ J K}^{-1}$ . State and explain what will happen to the spontaneity of the reaction if the temperature of the reaction is increased. [2]

SL B 04sQ7

- (f) Polymers can also be formed in a different type of reaction. Identify this type of reaction and name two different types of such polymers. [3]

- (g) The polymer with the repeating unit



exists as optical isomers.

- (i) State a test for optical isomers.  
(ii) Identify the chiral centre in the repeating unit.  
(iii) Draw the two enantiomeric forms of the repeating unit. [4]

SL B 04sQ5a

- (iii) Estimate, without doing a calculation, the magnitude of the entropy change for this reaction. Explain your answer. [3]

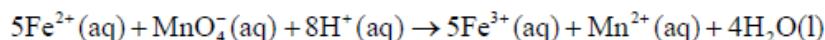
- (b) Explain in terms of  $\Delta G^\circ$ , why a reaction for which both  $\Delta H^\circ$  and  $\Delta S^\circ$  values are positive can sometimes be spontaneous and sometimes not. [4]

C

- (ii) The magnitude of the entropy change,  $\Delta S$ , at 27 °C for the reaction is  $62.7 \text{ J K}^{-1} \text{ mol}^{-1}$ . State, with a reason, the sign of  $\Delta S$ . [2]
- (iii) Calculate  $\Delta G$  for the reaction at 27 °C and determine whether this reaction is spontaneous at this temperature. [3]

SL B 04s

6. Consider the following redox equation.



- (a) (i) Determine the oxidation numbers for Fe and Mn in the reactants and in the products. [2]
- (ii) Based on your answer to (i), deduce which substance is oxidized. [1]
- (iii) The compounds CH<sub>3</sub>OH and CH<sub>2</sub>O contain carbon atoms in different oxidation states. Deduce the oxidation states and state the kind of chemical change needed to make CH<sub>2</sub>O from CH<sub>3</sub>OH. [3]
- (b) A part of the reactivity series of metals, in order of decreasing reactivity, is shown below.

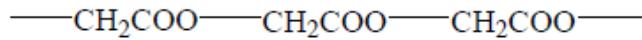
magnesium  
zinc  
iron  
lead  
copper  
silver

If a piece of copper metal were placed in separate solutions of silver nitrate and zinc nitrate

- (i) determine which solution would undergo reaction. [1]
- (ii) identify the type of chemical change taking place in the copper and write the half-equation for this change. [2]
- (iii) state, giving a reason, what visible change would take place in the solutions. [2]
- (c) (i) Solid sodium chloride does not conduct electricity but molten sodium chloride does. Explain this difference, and outline what happens in an electrolytic cell during the electrolysis of molten sodium chloride using carbon electrodes. [4]
- (ii) State the products formed and give equations showing the reactions at each electrode. [4]
- (iii) State what practical use is made of this process. [1]

SL B 03sQ8

- (c) The first synthetic thread was made from a polyester. A section of the polyester is drawn below:



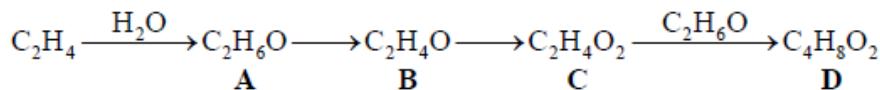
- (i) Give the structural formula of the monomer (containing two functional groups) that could be used to make this polyester and state the names of the two functional groups. [3]
- (ii) State, giving a reason, whether this polyester is made by a condensation reaction or an addition reaction. [2]

SL B 03sQ7

- (d) (i) Define the term *buffer solution*. [2]
- (ii) State a suitable mixture that can act as a buffer solution. [2]

SL B 02s

4. This question is about four compounds **A**, **B**, **C** and **D**, which can be made from ethene by the following reactions. All four compounds are liquid at room temperature, and each compound's molecular formula is shown. Two of the reagents needed for the reactions are shown on the arrows.



Magnesium was added to each compound and the only compound that produced a gas was **C**.

- (a) Use the information above to identify **each** of the compounds **A**, **B**, **C** and **D**, giving the name of each one. [4]
- (b) (i) State the type of reaction occurring when **C** is converted to **D**, and state a catalyst that is used. What other product is formed? [3]
- (ii) Write the structural formulas of **A** and **C**. [2]
- (iii) State a use of compounds of the same type as **D** in the food industry. [1]
- (d) Arrange the compounds **A**, **B** and **C** in order of **increasing** boiling point (lowest boiling point first). Explain your choice by referring to the intermolecular forces in **each** case. [4]
- (f) None of the compounds **A**, **B**, **C** and **D** exist as optical isomers. State the structural feature which is present in a compound that exists as optical isomers. [1]

SL B 01sQ6

- (e) The molecule HOOC—X—COOH (where X represents a hydrocarbon group) can be used to form both a polyamide and a polyester. Give the names or formulas of **two** monomers needed to produce the polyamide and the polyester. Draw the structures of **both** the polyamide and polyester linkages and draw the repeating unit in **either** the polyamide or the polyester. [5]

SL A 13s

3. Both sodium and sodium chloride can conduct electricity.

- (a) Compare how electric current passes through sodium and sodium chloride by completing the table below.

[3]

	Sodium	Sodium chloride
<b>State of matter</b>	..... .....	..... .....
<b>Particles that conduct the current</b>	..... .....	..... .....
<b>Reaction occurring</b>	..... .....	..... .....

- (b) Sodium can be obtained by electrolysis from molten sodium chloride. Describe, using a diagram, the essential components of this electrolytic cell.

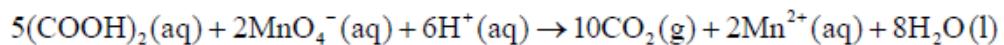
[3]

- (c) State **one** example that shows the economic importance of electrolysis.

[1]

.....  
.....

4. Ethanedioic acid (oxalic acid),  $(\text{COOH})_2$ , reacts with acidified potassium permanganate solution,  $\text{KMnO}_4$ , according to the following equation.



The reaction is a redox reaction.

- (a) Define *oxidation* in terms of electron transfer.

[1]

.....  
.....

- (b) Calculate the change in oxidation numbers of carbon and manganese.

[2]

Carbon:  
.....  
.....

Manganese:  
.....  
.....

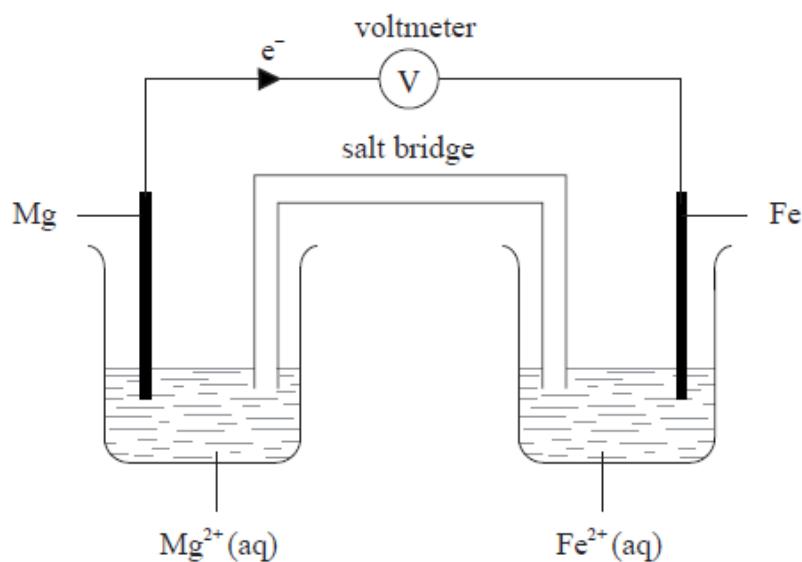
- (c) Identify the oxidizing and reducing agents.

[1]

Oxidizing agent:  
.....

Reducing agent:  
.....

4. Chemical energy can be converted to electrical energy in the voltaic cell below.



- (a) (i) State the electron arrangement of a magnesium atom. [1]

.....  
.....  
.....  
.....

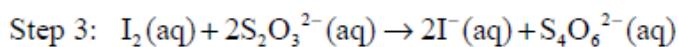
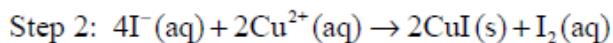
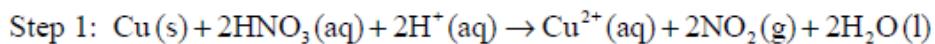
- (ii) State the half-equation which describes the change at the Mg electrode and deduce which metal is the positive electrode (cathode) of the cell. [2]

.....  
.....  
.....  
.....

- (b) Deduce the equation for the overall reaction occurring in the cell. [1]

.....  
.....  
.....

1. Brass is a copper containing alloy with many uses. An analysis is carried out to determine the percentage of copper present in three identical samples of brass. The reactions involved in this analysis are shown below.



- (a) (i) Deduce the change in the oxidation numbers of copper and nitrogen in step 1. [2]

Copper:

.....

Nitrogen:

.....

- (ii) Identify the oxidizing agent in step 1. [1]
- .....

- (b) A student carried out this experiment three times, with three identical small brass nails, and obtained the following results.

$$\text{Mass of brass} = 0.456 \text{ g} \pm 0.001 \text{ g}$$

Titre	1	2	3
Initial volume of $0.100 \text{ mol dm}^{-3} \text{ S}_2\text{O}_3^{2-}$ ( $\pm 0.05 \text{ cm}^3$ )	0.00	0.00	0.00
Final volume of $0.100 \text{ mol dm}^{-3} \text{ S}_2\text{O}_3^{2-}$ ( $\pm 0.05 \text{ cm}^3$ )	28.50	28.60	28.40
Volume added of $0.100 \text{ mol dm}^{-3} \text{ S}_2\text{O}_3^{2-}$ ( $\pm 0.10 \text{ cm}^3$ )	28.50	28.60	28.40
Average volume added of $0.100 \text{ mol dm}^{-3} \text{ S}_2\text{O}_3^{2-}$ ( $\pm 0.10 \text{ cm}^3$ )	28.50		

- (i) Calculate the average amount, in mol, of  $S_2O_3^{2-}$  added in step 3. [2]

.....  
.....  
.....  
.....

- (ii) Calculate the amount, in mol, of copper present in the brass. [1]

.....  
.....

- (iii) Calculate the mass of copper in the brass. [1]

.....  
.....

- (iv) Calculate the percentage by mass of copper in the brass. [1]

.....  
.....

- (v) The manufacturers claim that the sample of brass contains 44.2 % copper by mass. Determine the percentage error in the result. [1]

.....  
.....

- (c) With reference to its metallic structure, describe how brass conducts electricity. [1]

.....  
.....

SL A 09sQ3

- (b) Molten sodium oxide is a good conductor of electricity. State the half-equation for the reaction occurring at the positive electrode during the electrolysis of molten sodium oxide. [1]

.....

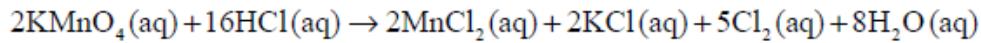
SL A 09s

4. (a) Define oxidation in terms of electron transfer.

[1]

.....  
.....

- (b) Chlorine can be made by reacting concentrated hydrochloric acid with potassium manganate(VII),  $\text{KMnO}_4$ .



- (i) State the oxidation number of manganese in  $\text{KMnO}_4$  and in  $\text{MnCl}_2$ .

[2]

$\text{KMnO}_4$  .....

$\text{MnCl}_2$  .....

- (ii) Deduce which species has been oxidized in this reaction and state the change in oxidation number that it has undergone.

[2]

.....  
.....

SL A 08s

5. (a) The compound  $\text{C}_3\text{H}_6$  reacts with bromine. Write an equation and state an observation for this reaction.

[2]

.....  
.....  
.....  
.....

- (b) The product formed in part (a) exists as optical isomers. Draw the structural formula of the product and identify the chiral carbon atom.

[2]

SL A 08s

- (b) Predict, giving a reason, whether the entropy change ( $\Delta S^\ominus$ ) for the formation of  $\text{CH}_3\text{COOH}(\text{l})$  would be positive or negative.

[1]

.....  
.....

SL A 08s

4. (a) Explain the term *buffer solution*.

[2]

.....  
.....  
.....  
.....

- (b) State whether each of the following will act as a buffer solution and give a reason for your choice.

- (i) A 1.0 dm<sup>3</sup> solution prepared from 0.50 mol of NH<sub>3</sub>(aq) and 0.25 mol of HCl(aq). [2]

.....  
.....  
.....  
.....

- (ii) A 1.0 dm<sup>3</sup> solution prepared from 0.50 mol of NH<sub>3</sub>(aq) and 0.25 mol of H<sub>2</sub>SO<sub>4</sub>(aq). [1]

.....  
.....  
.....  
.....

SL A 07sQ3

- (d) Predict, giving a reason, whether the entropy change,  $\Delta S$ , for the reaction in (b) would be positive or negative.

[1]

.....  
.....

SL A 06s

4. (a) In terms of electron transfer define:

(i) *oxidation*

[1]

.....  
.....

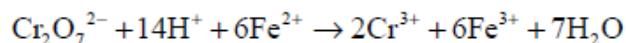
(ii) *oxidizing agent*

[1]

.....  
.....

- (b) Deduce the **change** in oxidation number of chromium in the below reaction. State with a reason whether the chromium has been oxidized or reduced.

[2]

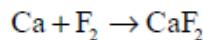


.....  
.....  
.....  
.....  
.....

#### SL A 01sQ3

- (c) State, giving a reason, which reactant in the following equation is acting as an oxidising agent:

[2]



.....  
.....  
.....

#### Topic 9 Mark Scheme

#### SL B 12sQ6

- (e) (i) *Br<sub>2</sub>: 0*

*HBr: -1*

*HOBr: +1*

[2]

*Award [2] for three correct.*

*Award [1] for any two correct.*

- (ii) bromine is oxidized **and** reduced / disproportionation;

[1]

(f) (i) F<sub>2</sub>/fluorine;  
Do not allow F.

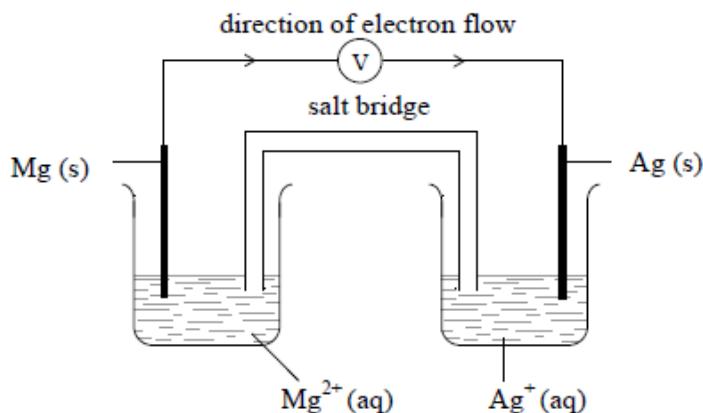
[1]

(ii) 50 (cm<sup>3</sup>) / 0.050 dm<sup>3</sup>;

[1]

SL B 10s

5. (a) (i)

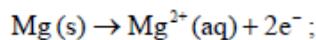


correctly labelled electrodes and solutions;  
labelled salt bridge;  
voltmeter;  
Allow bulb or ammeter.

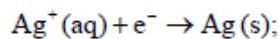
direction of electron flow;

[4]

(ii) Oxidation:



Reduction:



[2]

Ignore state symbols.

Award [1 max] if equations not labelled reduction or oxidation or labelled the wrong way round.

Allow e instead of e<sup>-</sup>.

Penalize equilibrium sign or reversible arrows once only in parts (a) (ii) and (c) (ii).

(b) (i) Zn > Cd > Ni > Ag

Zn most reactive;

rest of order correct;

[2]

(ii) Best oxidizing agent:



Do not accept Ag.

Best reducing agent:



Do not accept Zn<sup>2+</sup>.

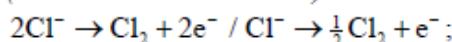
[2]

- (c) (i) sodium chloride crystals consist of ions in a (rigid) lattice / ions cannot move (to electrodes) / *OWTTE*; when melted ions free to move / ions move when potential difference/voltage applied; [2]

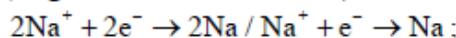
- (ii) positive sodium ions/ $\text{Na}^+$  move to negative electrode/cathode and negative chloride ions/ $\text{Cl}^-$  move to positive electrode/anode;

electrons released to positive electrode/anode by negative ions and accepted from negative electrode/cathode by positive ions / reduction occurs at the negative electrode/cathode and oxidation occurs at the positive electrode/anode /  $\text{Na}^+$  ions are reduced and  $\text{Cl}^-$  ions are oxidized;

*(Positive electrode/anode):*



*(Negative electrode/cathode):*



[4]

*Award [1 max] if equations not labelled or labelled wrong way round.*

*Allow e instead of  $e^-$ .*

*Penalize equilibrium sign or reversible arrows once only in parts (a) (ii) and (c) (ii).*

#### SL B 08s

8. (a) (i)  $\text{Mg} > \text{Zn} > \text{Ni} > \text{Cu}$  [2]

*Four metals in correct order, award [2], first and last metal order correct award [1].*

- (ii) Mg;  
Mg can reduce all other species/has a greater tendency to donate electrons; [2]

- (iii)  $\text{Cu}^{2+}$ ;  
 $\text{Cu}^{2+}$  can oxidise other species/has a greater tendency to accept electrons; [2]  
*Do not accept Cu*

- (b) (i) (solid state) ions in fixed position;  
(molten state) ions are free to move; [2]

- (ii)  $2\text{Br}^- \rightarrow \text{Br}_2 + 2\text{e}^- / \text{Br}^- \rightarrow \frac{1}{2}\text{Br}_2 + \text{e}^- ;$   
*Accept e instead of  $e^-$*   
oxidation; [2]

- (iii)  $\text{Pb}^{2+} + 2\text{e}^- \rightarrow \text{Pb};$   
*Accept e instead of  $e^-$*   
reduction; [2]

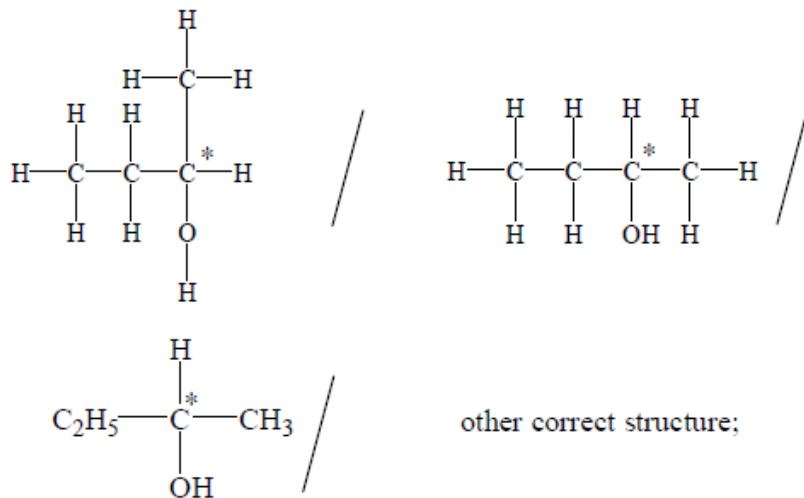
*Award [1] for two correct equations with wrong electrodes.*

#### SL B 07sQ8

- (d) (i) a solution which resists change in pH;  
when a small amount of strong acid or base is added to it; [2]
- (ii) react excess ammonia with nitric acid;  
stated volumes with about 50 % more ammonia solution;  
gives a solution containing the weak base and its salt with the acid /  
 $\text{NH}_4^+$  and  $\text{NH}_3$ ; [3]  
*Accept suitable volumes from about 20 cm<sup>3</sup> to about 500 cm<sup>3</sup> for 2<sup>nd</sup> mark.*

SL B 07sQ5f

- (iii) isomers that can rotate plane polarized light in opposite directions;  
*Do not accept bend, reflect plane-polarized light.*



*Penalise missing bonds / hydrogens.*

correct identification of chiral carbon (\*); [3]

SL B 06sQ8

(e) (i)  $\text{CH}_2\text{CH}_2$ ; [1]



*Allow appropriate acyl chloride.*

(iii)  $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$ ; [2]  
 $\text{HOOC}(\text{CH}_2)_4\text{COOH}$ ;

*Allow correct alternative.*

*Accept correct names as alternatives.*

*If correct structure and incorrect name given, award the mark.*  
*Penalise COOH – C once only.*

(f) (addition polymers) contain  $\text{C}=\text{C}$  /  $\text{C}\equiv\text{C}$ ;  
(condensation polymers) contain two reactive/functional groups; [2]

(g) methyl methanoate;  
 $\text{HCOOCH}_3$ ; [2]  
*Accept other correct alternative.*

SL B 06s

(d) weak acid + salt of weak acid / weak acid + conjugate base.  
*Accept equivalent descriptions of a basic buffer.*  
the solution resists pH change;  
*Do not accept pH does not change.*  
when small amounts of acid or base are added; [3]  
*Only award if previous answer correct.*

SL B 06s

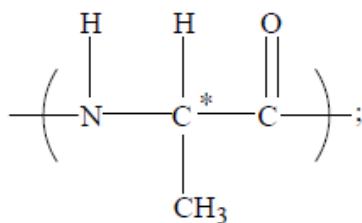
(f) (i) standard free energy change (of a reaction); [1]  
(ii) (reaction is) spontaneous / spontaneity of the reaction; [1]  
(iii) spontaneity would decrease;  
 $-\text{T}\Delta S^\ominus$  becomes more positive and  $\Delta G^\ominus$  becomes less negative/more positive /  
OWTTE; [2]

SL B 04sQ7

(f) condensation polymer;  
polyesters;  
polyamides; [3]

- (g) (i) optical isomers rotate the plane of polarized light (in opposite directions); [1]

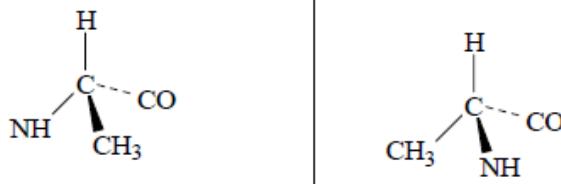
(ii)



[1]

*The chiral centre may be indicated by an asterisk, circle, highlight, etc.*

(iii)



[2]

*Award [1] for one 3-D structure and [1] for showing that the second structure is a mirror image of the first one.*

### SL B 04sQ5a

- (iii) entropy change will be zero / very small;  
 (structure of / bonding in) reactants and products similar / only solids involved;  
 the disorder / randomness will not change; [3]

- (b) a reaction is spontaneous when  $\Delta G^\ominus$  is negative / non-spontaneous when  $\Delta G^\ominus$  is positive;  
 at high T,  $\Delta G^\ominus$  is negative;  
 (because)  $T\Delta S^\ominus$  is greater than  $\Delta H^\ominus$ ;  
 at low T,  $\Delta G^\ominus$  is positive because  $T\Delta S^\ominus$  is smaller than  $\Delta H^\ominus$  / OWTTE; [4]

- (ii) negative;  
 decrease in the number of gas molecules / OWTTE; [2]

- (iii)  $\Delta G = \Delta H - T\Delta S$ ;  
 $\Delta G = -76.0 - 300 (-0.0627)$ ;

*Award [1] for 300 K.*

*Award [1] for conversion of units J to kJ or vice versa.*

*Allow ECF from c(i) from  $\Delta H$ .*

*Allow ECF from c(ii) for sign of  $\Delta S$ .*

$= -57.2 \text{ (kJ mol}^{-1}\text{)}$  is spontaneous / or non-spontaneous if positive value obtained;

[3 max]

### SL B 04s

6. (a) (i) Fe reactant +2 AND Fe product +3 AND Mn product +2;  
 Mn reactant +7; [2]  
*Do not accept Roman numerals.*
- (ii)  $\text{Fe}^{2+}$  / iron(II) ions / ferrous ions; [1]  
*Do not accept "iron".*
- (iii)  $\text{CH}_3\text{OH}$  oxidation state -2;  
 $\text{CH}_2\text{O}$  oxidation state 0;  
 (change is) oxidation / dehydrogenation; [3]
- (b) (i) silver nitrate; [1]
- (ii) oxidation;  
 $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$ ; [2]
- (iii) (silver nitrate) solution turns blue / grey or black or silver solid forms;  
 copper ions form /  $\text{Cu}^{2+}$  ions form / silver deposited; [2]
- (c) (i) sodium chloride crystals consist of ions in a rigid lattice / ions can not move about;  
 when melted the ions are free to move or ions move when a voltage is applied;  
 in electrolysis positive sodium ions or  $\text{Na}^+$  ions move to the negative electrode or  
 cathode;  
 and negative chloride ions or  $\text{Cl}^-$  move to the positive electrode or anode; [4]
- (ii) sodium formed at cathode or negative electrode;  
 $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$ ;  
 chlorine formed at anode or positive electrode;  
 $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$ ; [4]  
*1st and 3rd marks can be scored in (c) (i).*
- (iii) manufacture of sodium and chlorine / one stated use of chlorine or sodium; [1]

SL B 03sQ8

- (c) (i)  $\text{CH}_2\text{OH COOH}$ ;  
 alcohol (*accept hydroxy(l)*);  
 carboxylic acid; [3]  
*Last two marks dependent on correct monomer or reasonable attempt at identifying the monomer.*
- (ii) condensation;  
 eliminates  $\text{H}_2\text{O}$  / a small molecule is eliminated; [2]

SL B 03sQ7

- (d) (i) a solution that resists pH change / maintains a (nearly) constant pH;  
when small amounts of acid or alkali are added; [2]
- (ii) Any suitable example, [1] for each correct component.  
e.g. ammonia solution and ammonium chloride;  
ethanoic acid and sodium ethanoate; [2]  
weak acid + salt of weak acid / weak base + salt of weak base [1 max]  
blood [1 max]

SL B 02s

4. (a) A is ethanol [1];  
B is ethanal [1];  
C is ethanoic acid [1];  
D is ethyl ethanoate [1]. [4]
- (b) (i) esterification / condensation [1];  
(concentrated) sulfuric acid /  $\text{H}_2\text{SO}_4$  (not dilute) [1];  
water /  $\text{H}_2\text{O}$  [1]. [3]
- (ii)  $\text{CH}_3\text{CH}_2\text{OH}$  [1];  
 $\text{CH}_3\text{COOH}$  [1]. [2]
- (iii) flavourings / other valid uses [1]
- (c) hydrogen /  $\text{H}_2$  [1];  
 $2\text{CH}_3\text{COOH} + \text{Mg} \rightarrow (\text{CH}_3\text{COO})_2\text{Mg} + \text{H}_2$  [1];  
magnesium ethanoate [1]. [3]
- (d) B, A, C [1];  
B has dipole–dipole attractions [1];  
A has hydrogen bonding [1];  
C has more/stronger hydrogen bonding / forms dimers [1]. [4]
- (e)  $\text{HCOOCH}_3$  [1];  
methyl methanoate [1]. [2]
- If full structural formulas are given in (b) (ii) and (e), but the H atoms attached to the C– bonds are omitted, penalize first time only.
- (f) asymmetric carbon atom / chiral centre / carbon attached to four different atoms/groups / asymmetric molecule. [1]

SL B 01s

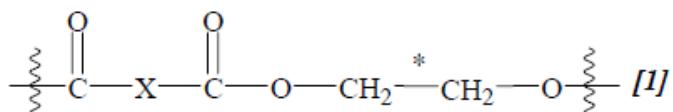
(e)  $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$  /  $\text{H}_2\text{N} \sim \text{NH}_2$  / correct name [1]

HOCH2CH2OH / HO — OH / correct name [1]

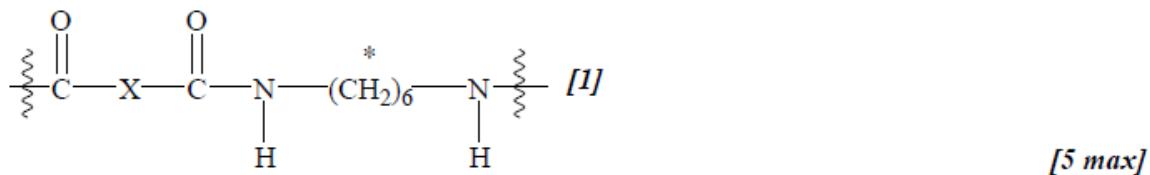
(Award [1] each for the following two structures)



**EITHER** the polyester repeating unit



OR the polyamide repeating unit



\* This part of the statement should be related to their formulation of the respective monomers and may well be represented in the repeating unit as ~~~ at the location shown (\*).

SL A 13s

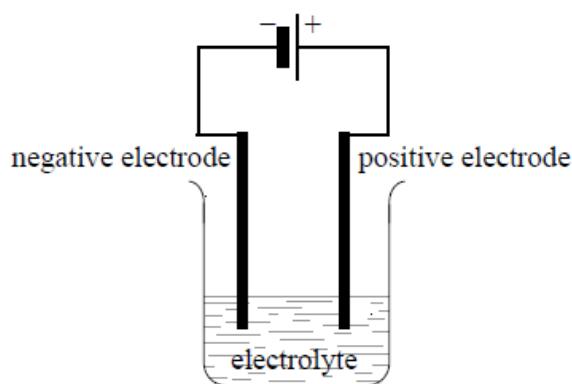
3. (a)

	Sodium	Sodium chloride
State of matter	solid (and liquid)	liquid / aqueous/solution
Particles that conduct the current	electrons	Ions / $\text{Na}^+$ and $\text{Cl}^-$
Reaction occurring	no reaction occurs	(redox) reaction occurs / electrolysis

[3]

*Award [1] for each feature that is correct for both sodium and sodium chloride.  
Accept equation or half-equations for the reaction of sodium chloride in “reaction occurring”.*

(b)



clear diagram containing all elements (power supply, connecting wires, electrodes, container and electrolyte);

labelled positive electrode/anode and negative electrode/cathode;

*Accept positive and negative by correct symbols near power supply.*

*Accept power supply if shown as conventional long/short lines (as in diagram above)  
or clearly labelled DC power supply.*

labelled electrolyte/ $\text{NaCl(l)}$ ;  
*State of  $\text{NaCl}$  not needed.*

[3]

(c)

production of aluminium/chlorine/lithium/magnesium/hydrogen/sodium hydroxide/sodium chlorate / electroplating / purification of metals;

[1]

*Do not allow production of sodium.*

SL A 13s

4. (a) loss of electrons; [1]

(b) Carbon:  
III to IV / +3 to +4 / (+)1; [2]

Manganese:  
VII to II / +7 to +2 / -5;  
Penalize incorrect notation such as 3+ once only.

(c) Oxidizing agent:  $\text{MnO}_4^-$  and Reducing agent:  $(\text{COOH})_2$ ;  
Accept correct names instead of formulas.  
Do not accept Mn and C. [1]

SL A 12s

4. (a) (i) 2,8,2; [1]

(ii)  $\text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^-$  ;  
Fe/iron; [2]  
Do not accept  $\text{Fe}/\text{Fe}^{2+}$  half-equation or  $\text{Fe}^{2+}$ .

(b)  $\text{Mg(s)} + \text{Fe}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Fe(s)}$ ; [1]

SL A 10s

1. (a) (i) *Copper:*  
0 to +2 / increases by 2 / +2 / 2+;  
*Allow zero/nought for 0.*
- Nitrogen:*  
+5 to +4 / decreases by 1 / -1 / 1-; [2]  
*Penalize missing + sign or incorrect notation such as 2+, 2<sup>+</sup> or II, once only.*
- (ii) nitric acid/HNO<sub>3</sub> / NO<sub>3</sub><sup>-</sup>/nitrate; [1]  
*Allow nitrogen from nitric acid/nitrate but not just nitrogen.*
- (b) (i)  $0.100 \times 0.0285$  ;  
 $2.85 \times 10^{-3}$  (mol); [2]  
*Award [2] for correct final answer.*
- (ii)  $2.85 \times 10^{-3}$  (mol); [1]
- (iii)  $(63.55 \times 2.85 \times 10^{-3}) = 0.181$  g ; [1]  
*Allow 63.5.*
- (iv)  $\left( \frac{0.181}{0.456} \times 100 \right) 39.7\%$ ; [1]
- (v)  $\left( \frac{44.2 - 39.7}{44.2} \times 100 \right) 10/10.2\%$ ; [1]  
*Allow 11.3 % i.e. percentage obtained in (iv) is used to divide instead of 44.2 %.*
- (c) *Brass has:*  
delocalized electrons / sea of mobile electrons / sea of electrons free to move; [1]  
*No mark for just "mobile electrons".*

#### SL A 09sQ3

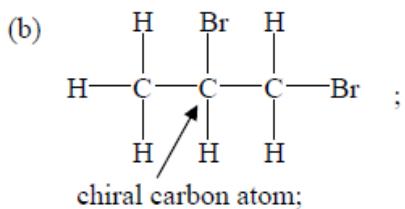
- (b)  $2O^{2-} \rightarrow O_2 + 4e^-$  /  $O^{2-} \rightarrow \frac{1}{2}O_2 + 2e^-$  ; [1]  
*Accept e instead of e<sup>-</sup>.*

#### SL A 09s

4. (a) Loss of (one or more) electrons; [1]
- (b) (i) (KMnO<sub>4</sub>) + 7;  
(MnCl<sub>2</sub>) + 2; [2]  
*Must have + sign for mark.*  
*[1 max] if roman numerals or 7+ or 2+ used or if + signs are missing.*
- (ii) Cl<sup>-</sup> / chloride / chlorine / Cl (has been oxidized) / HCl ;  
oxidation number from -1 to 0 / has increased by one ; [2]  
*If HCl is given for first mark, it must be clear that it is the Cl that has the change of oxidation number.*

#### SL A 08s

5. (a)  $\text{C}_3\text{H}_6 + \text{Br}_2 \rightarrow \text{C}_3\text{H}_6\text{Br}_2/\text{CH}_3\text{CHBrCH}_2\text{Br}$ ;  
 (orange/brown/red) colour (of bromine) disappears/is decolourized;  
*Do not accept "goes clear".* [2]



[2]

SL A 08s

- (b) negative because decrease in number of moles of gas; [1]

SL A 08s

4. (a) (buffer solution) resists changes in pH;  
 on addition of small amounts of acid or alkali; [2]
- (b) (i) will act as buffer;  
 it consists of weak base and its salt/ contains both  $\text{NH}_3$  and  $\text{NH}_4\text{Cl}$ /a weak base and its conjugate acid / OWTTE; [2]
- (ii) will not act as buffer because it only produces the salt  $(\text{NH}_4)_2\text{SO}_4$  / absence of weak base / OWTTE; [1]

SL A 07sQ3

- (d)  $\Delta S$  would be positive as  $7 \text{ mol} \rightarrow 8 \text{ mol}$  of gas / more moles of gas on RHS; [1]

SL A 06s

4. (a) (i) loss of electrons; [1]
- (ii) (a species that) gains electrons (from another species) / causes electron loss; [1]
- (b) changes by 3;  
 reduced because its oxidation number decreased  $+6 \rightarrow +3$  /  $6+ \rightarrow 3+$  / it has gained electrons; [2]

SL A 01sQ3

- (c) Fluorine/ $\text{F}_2$  [1]  
 $\text{F}_2$  gains electrons /  $\text{F}_2$  is reduced / oxidation number decreases [1]  
 or  
 Ca loses electrons / Ca oxidation number increases [1] [2 max]