



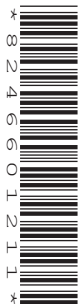
Oxford Cambridge and RSA

Monday 19 October 2020 – Morning

A Level Chemistry B (Salters)

H433/03 Practical skills in chemistry

Time allowed: 1 hour 30 minutes



You must have:

- the Practical Insert (inside this document)
- the Data Sheet for Chemistry B

You can use:

- a scientific or graphical calculator
- an HB pencil



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

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Last name

StemUp Model Solution

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION

- The total mark for this paper is **60**.
- The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **16** pages.

ADVICE

- Read each question carefully before you start your answer.

Answer **all** the questions.

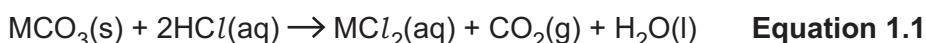
1 A student is investigating the properties of some s-block metals and their compounds.

(a) Complete the electronic configuration, using sub-shells, of an **atom** of sodium and the magnesium **ion** in magnesium carbonate.

sodium **atom** $1s^2$ $2s^2$ $2p^6$ $3s^1$

magnesium **ion** $1s^2$ $2s^2$ $2p^6$ [2]

(b)* Group 2 carbonates react with hydrochloric acid as shown in **equation 1.1**.



A student investigates whether there is a trend in Group 2 of the rate of this reaction. The student uses a method involving collection of the carbon dioxide given off.

Describe a suitable procedure that the student should follow and how the results can be interpreted. [6]

*Set up a conical flask with a bung and delivery tube leading to a gas syringe
(or to an inverted measuring cylinder full of water, collecting over water).
Weigh out the same mass (e.g. 0.50 g) of a Group 2 carbonate, all with the
same particle size (powder), into the flask. Add the same volume (e.g. 50
cm³) of hydrochloric acid of the same concentration (e.g. 1.0 mol dm⁻³, in
excess) and stopper the flask immediately. Keep the temperature the same.
Measure the time taken to collect a fixed volume of CO₂, e.g. 40 cm³, using
a stopwatch. Repeat with at least three named carbonates: MgCO₃, CaCO₃,
SrCO₃ and BaCO₃.
Interpretation: a shorter time means a faster rate; rate is proportional to
1/time. Compare the values of 1/time for each carbonate in order down the
group to see whether the rate increases or decreases down Group 2.
Alternatively record the volume of gas every 10 s and plot a graph of volume
against time for each carbonate; the gradient (tangent) at the origin gives
the initial rate, and the initial rates are then related to the position of the*

Additional answer space if required

metal down the group.

- (c) The student is given a sample of an unknown Group 2 carbonate MCO_3 .

The student is told to heat the sample to constant mass and use the results to identify the Group 2 carbonate.

- (i) Explain the term 'heat to constant mass'.

Heat, cool and weigh, then repeat until there is no further change in mass (the mass remains constant). [1]

- (ii) 4.00 g of a metal carbonate MCO_3 gives 1.91 g of MO on heating to constant mass.

Identify metal M in MCO_3 showing a suitable calculation.

$$\text{mass of CO}_2 \text{ lost} = 4.00 - 1.91 = 2.09 \text{ g}$$

$$\text{moles of CO}_2 = 2.09 / 44.0 = 0.0475 \text{ mol}$$

$$\text{moles of MCO}_3 = \text{moles of CO}_2 = 0.0475 \text{ mol}$$

$$M_r(\text{MCO}_3) = 4.00 / 0.0475 = 84.2$$

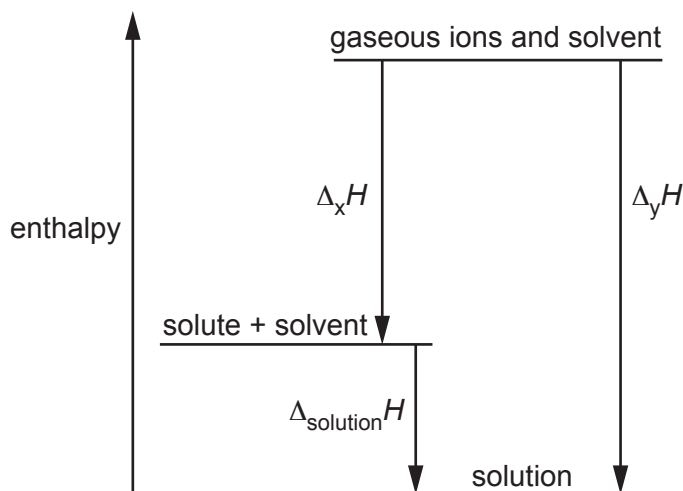
$$A_r(\text{M}) = 84.2 - 60.0 = 24.2$$

so M has $A_r \approx 24.3$, which is magnesium

metal M is *magnesium, Mg* [3]

- (d) Some Group 2 salts are soluble in water.

The enthalpy cycle below shows the key enthalpy changes involved in dissolving ionic solids in water.



Name the enthalpy change(s) represented by $\Delta_x H$ and $\Delta_y H$.

$\Delta_x H$... *Lattice enthalpy (of the ionic solid)*

$\Delta_y H$... *Enthalpy change of hydration of both ions (cation + anion)*

[2]

- (e) The enthalpy change of hydration is less negative for barium ions than for calcium ions.

Student A says this is because barium is more reactive than calcium.

Student B says it is due to the differences between Ca^{2+} and Ba^{2+} ions.

Comment on the students' statements giving the correct chemistry.

Student A is right that barium is more reactive than calcium, but this is not the reason; reactivity has nothing to do with the enthalpy change of hydration.

Student B is correct. A Ba^{2+} ion is larger than a Ca^{2+} ion (same 2+ charge), so Ba^{2+} has a lower charge density.

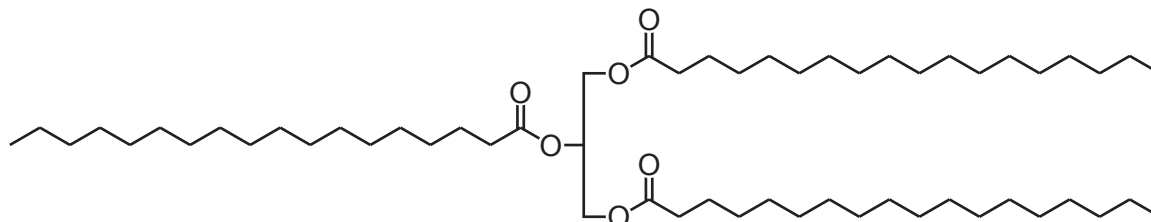
So Ba^{2+} attracts the (δ^- oxygen of) water molecules less strongly than Ca^{2+} does, and less energy is released when Ba^{2+} is hydrated.

[4]

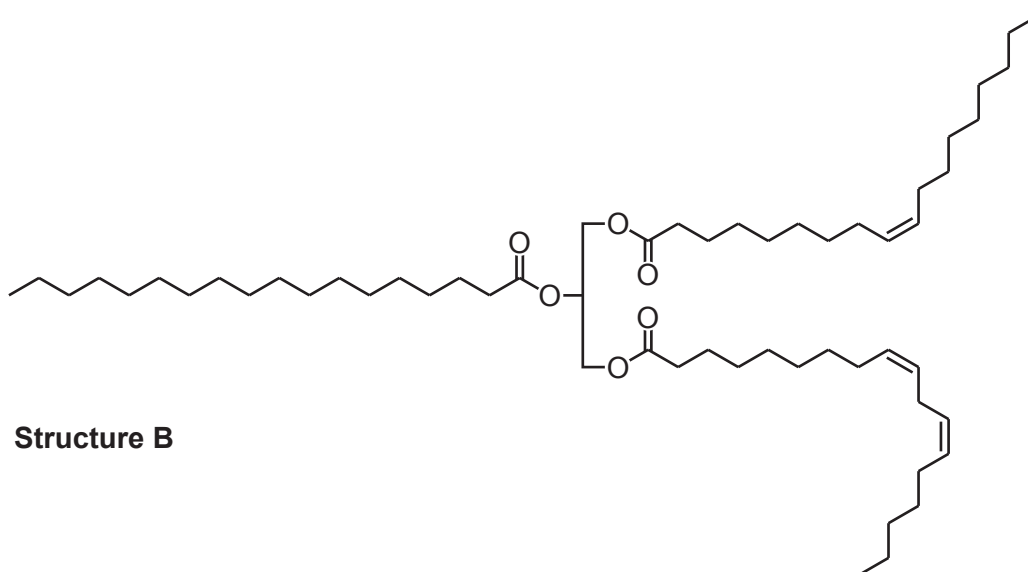
2 Fats and oils are essential to living systems.

Most fats and oils are triesters formed from the reaction of propane-1,2,3-triol (glycerol) with long chain carboxylic acids (fatty acids).

(a) Two triesters **A** and **B** are shown below.



Structure A



Structure B

(i) Structure **B** is described as a 'cis' unsaturated oil.

Explain the meanings of 'cis' and 'unsaturated'.

Unsaturated: the hydrocarbon chains contain C=C double bonds (between carbon atoms).

Cis: the parts of the chain (the H atoms) are on the same side of the C=C double bond, so adjacent parts of the chain are next to each other.

[2]

- (ii) State the types of intermolecular bonds between molecules of both structures **and** describe where in the molecules they occur.

Instantaneous dipole-induced dipole bonds between the non-polar hydrocarbon chains.

Permanent dipole-permanent dipole bonds between the polar C=O and C-O bonds of the ester groups.

[2]

- (iii) Suggest why Structure **A** is more likely to be a solid at room temperature than Structure **B**.

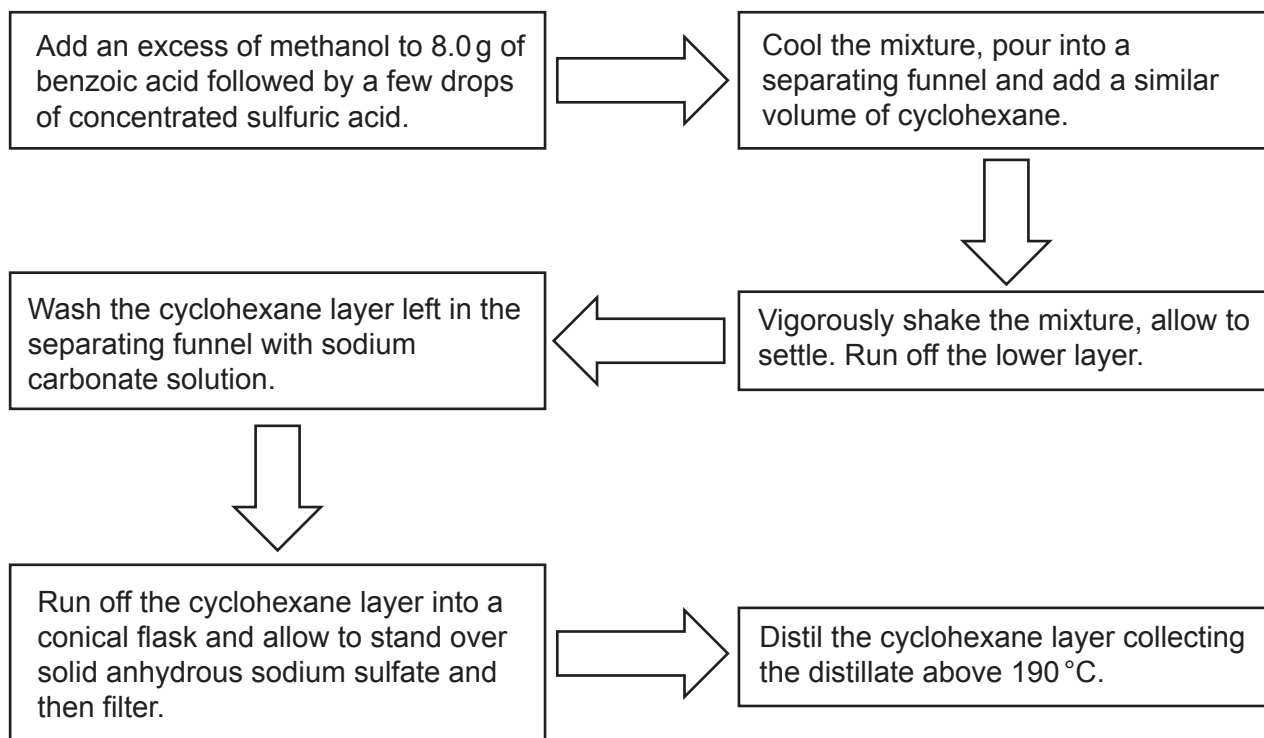
Structure A has straight (saturated) chains, so the chains pack better and closer together, with more points of contact between molecules. So the instantaneous dipole-induced dipole bonds between molecules of A are stronger.

More energy (a higher temperature) is needed to break these bonds, so A has a higher melting point and is solid.

[3]

(b) Methyl benzoate is a liquid at room temperature and has a boiling point of 200 °C.

The steps in a procedure for preparing and purifying the simple ester, methyl benzoate, are shown in the flow chart.



Give the reasons for the following experimental procedures in the flow chart:

(i) adding cyclohexane

Cyclohexane is a solvent for the ester (organic product), which dissolves in it and separates from the aqueous layer. [1]

(ii) adding sodium carbonate solution

It reacts with and neutralises the acid impurities (sulfuric acid and unreacted benzoic acid). [1]

(iii) standing the cyclohexane layer over solid anhydrous sodium sulfate

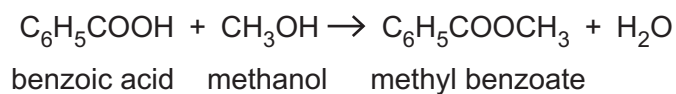
Anhydrous sodium sulfate removes water, so it dries the cyclohexane layer. [1]

(iv) collecting the distillate above 190 °C

This is about the boiling point of the ester; cyclohexane boils off before this, so only pure methyl benzoate is collected. [1]

- (c) A student followed the procedure in the flow chart and obtained 5.46 g of methyl benzoate.

The equation for the preparation is:



Calculate the percentage yield of methyl benzoate.

Give your answer to an **appropriate** number of significant figures.

$$M_r(\text{C}_6\text{H}_5\text{COOH}) = 122.0; \quad M_r(\text{C}_6\text{H}_5\text{COOCH}_3) = 136.0$$

$$\text{moles of benzoic acid} = 8.0 / 122.0 = 0.0656 \text{ mol}$$

$$\text{theoretical mass of ester (100\%)} = 0.0656 \times 136.0 = 8.92 \text{ g}$$

$$\% \text{ yield} = 5.46 / 8.92 \times 100 = 61.2\%$$

$$= 61\% \text{ (2 s.f., as 8.0 g is given to 2 s.f.)}$$

percentage yield = ...61..... % [4]

3 The two isomers of propanol, C_3H_7OH can be used as fuels.

- (a) A student measures the enthalpy change of combustion of propan-1-ol, C_3H_7OH . The apparatus used is shown in **Fig. 3.1**.

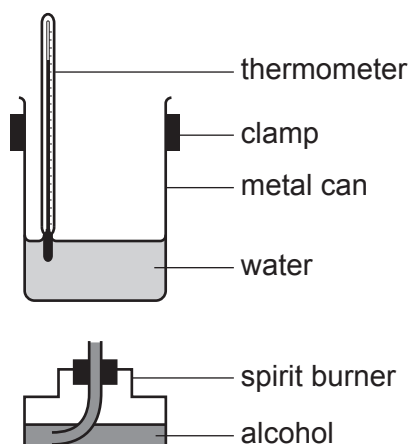


Fig. 3.1

The student's results are shown in **Table 3.1**.

Mass of spirit burner + propan-1-ol	43.11 g
Mass of spirit burner + propan-1-ol after burning	42.92 g
Initial temperature of water	19.7 °C
Final temperature of water	31.2 °C
Mass of water in metal can	100 g

Table 3.1

Use the results in **Table 3.1** to calculate a value for the enthalpy change of combustion of propan-1-ol, $\Delta_c H$, in kJ mol^{-1} .

$$q = mc\Delta T = 100 \times 4.18 \times (31.2 - 19.7) = 100 \times 4.18 \times 11.5 = 4807 \text{ J}$$

$$\text{mass of propan-1-ol burnt} = 43.11 - 42.92 = 0.19 \text{ g}$$

$$\text{moles burnt} = 0.19 / 60.0 = 0.00317 \text{ mol}$$

$$\Delta_c H = -4.807 \text{ kJ} / 0.00317 \text{ mol} = -1518 \text{ kJ mol}^{-1}$$

Enthalpy change of combustion of propan-1-ol, $\Delta_c H = \dots\dots\dots -1520 \dots\dots\dots \text{ kJ mol}^{-1}$ [3]

(b) The data book value for the enthalpy change of combustion of propan-1-ol is $-2021 \text{ kJ mol}^{-1}$.

(i) One reason for the difference is heat loss to the surroundings.

Suggest **two** other reasons for the difference between the experimental value and the data book value.

1 ...incomplete combustion of the propan-1-ol (not enough oxygen),
...so less energy is released than in complete combustion

2 ...evaporation of the fuel from the wick, so not all of the mass
...lost was burnt (also evaporation of water; non-standard conditions)

[2]

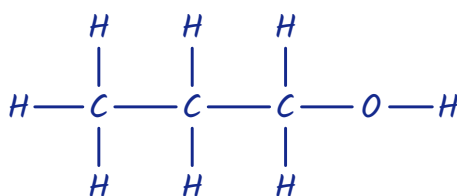
(ii) Describe **one** addition to the apparatus in **Fig. 3.1** that would improve the accuracy of the experimental value for the enthalpy change of combustion.

Use draught shields around the burner and can (and put a lid on the
metal can).

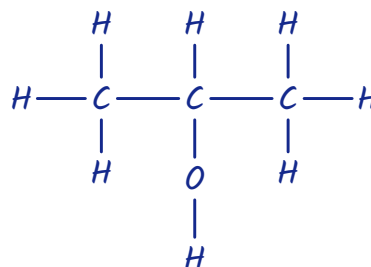
[1]

(c) The data book value for the enthalpy change of combustion of propan-2-ol is very similar to that of propan-1-ol.

(i) Write out the **full** structural formulae of the **two** compounds.



propan-1-ol



propan-2-ol

[1]

(ii) Explain why the enthalpy change of combustion values are exothermic and very similar. Use your answer to (c)(i) and the idea of average bond enthalpies in your answer.

Average bond enthalpies give the energy needed to break (or given out
when forming) a particular bond. Both isomers have the same number
and type of bonds (7 C-H, 2 C-C, 1 C-O, 1 O-H), so the same bonds
are broken and formed, giving very similar values.

Exothermic: more energy is given out forming new bonds (C=O, O-H)
than is taken in breaking old bonds.

[3]

4 This question refers to the Practical Insert that is found inside this document.

- (a)* **Method 1** uses a series of titrations to determine the concentration of hydroxide ions at specific time intervals. The reaction is complete in about 30 minutes.

Suggest the procedure needed for the titrations using **Method 1**, starting from when the reagents are mixed. Include how to calculate the data shown in **Table 4.1**. [6]

Pipette (e.g. 25 cm³ each) the reagents into a flask, mix and start a stopwatch. Immediately, and then every 5 minutes, use a volumetric pipette to withdraw a fixed volume (10.0 cm³) of the reaction mixture. Quench the sample by running it into a fixed volume of excess hydrochloric acid of known concentration (or into a large volume of ice-cold water to cool it rapidly and stop the reaction). Titrate: if quenched in ice-water, titrate the sample with a standard solution of hydrochloric acid from a burette using a suitable indicator, e.g. phenolphthalein (pink to colourless); if quenched in excess acid, back titrate the unreacted acid with a standard solution of NaOH. Add the titrant drop by drop near the end point and record the titre at the colour change. Calculation: $c_1V_1 = c_2V_2$, where c_1 is the concentration of the acid, V_1 is the titre, V_2 is the pipette volume and c_2 is the unknown $[\text{OH}^-]$. So $[\text{OH}^-] = c_1V_1/V_2$ (for a back titration, moles OH^- = moles acid added – moles NaOH used). Repeat for each time to get Table 4.1.

Additional answer space if required

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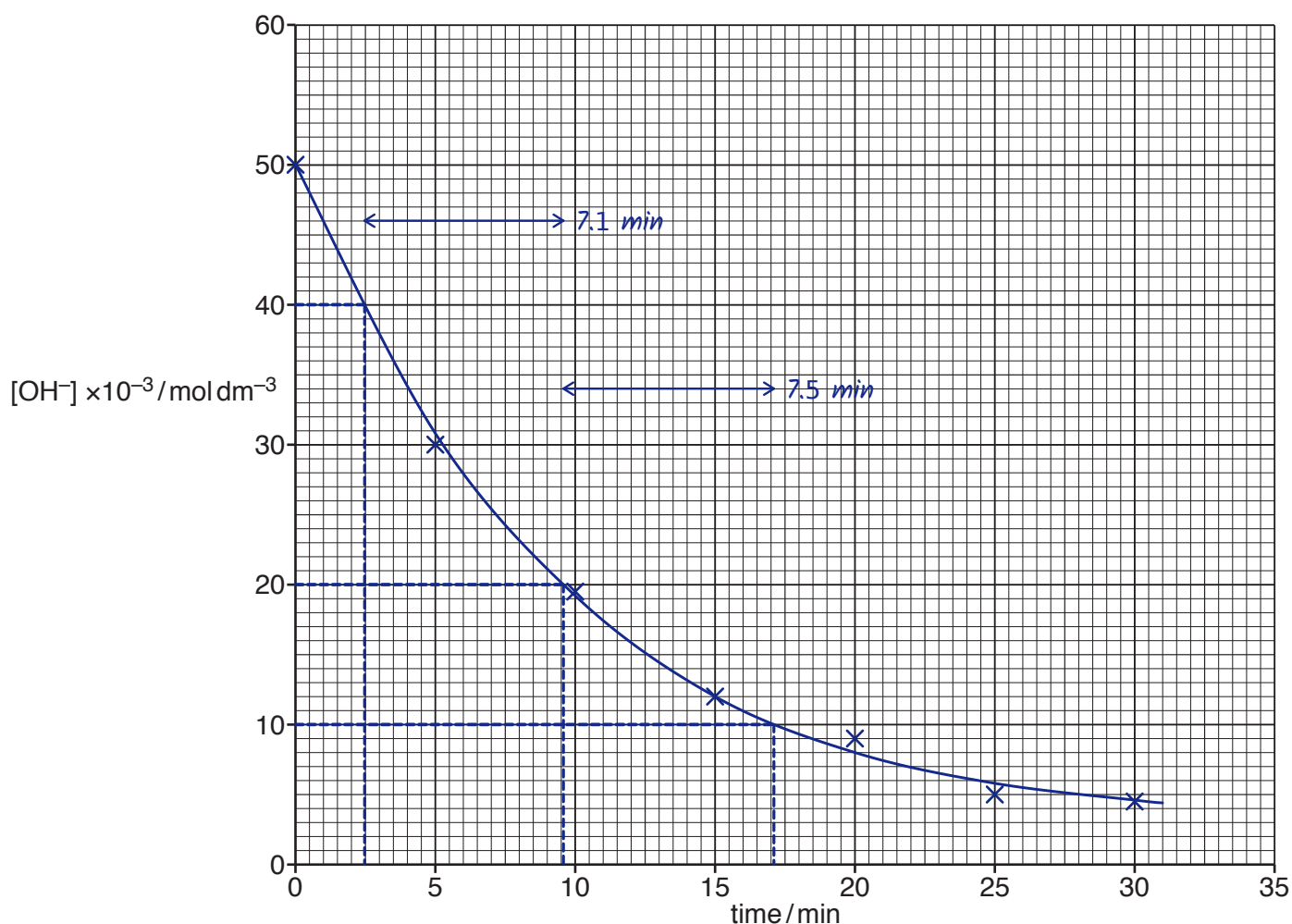
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- (b) (i) Using the data from **Table 4.1** in the Practical Insert, plot a graph on the grid below.

Include a curve of best fit.



[2]

- (ii) Use your graph to calculate the time taken for the concentration of hydroxide ions to fall from 40×10^{-3} to 20×10^{-3} and from 20×10^{-3} to $10 \times 10^{-3} \text{ mol dm}^{-3}$.

Show your working on the graph.

Time taken to fall from 40×10^{-3} to $20 \times 10^{-3} \text{ mol dm}^{-3}$ = ...7.1..... min

Time taken to fall from 20×10^{-3} to $10 \times 10^{-3} \text{ mol dm}^{-3}$ = ...7.5..... min

[2]

- (iii) Explain how the graph shows that the **overall** order of the reaction is first order.

Both reactant concentrations decrease with time at the same rate (equal moles were mixed), so the graph shows the overall order.
The half-lives are the same (constant, about 7 to 7.5 min) for each halving of $[\text{OH}^-]$, so the reaction is first order overall.

[2]

- (iv) A student is told that the reaction followed using **Method 1** goes by **mechanism B**.

The student says that the first reaction in **mechanism B** must be the rate-determining step. This accounts for the overall first order of the reaction.

Comment on the student's statement.

The rate-determining step is the slowest step in the mechanism, and only species in or before it appear in the rate equation.
The student is right: the first step of mechanism B involves only one species (C_4H_9Br), so it gives first order. If the second step were rate-determining, the kinetics would be second order. [2]

- (c) (i) Use the data in **Table 4.2** to determine the order of reaction with respect to 1-bromobutane and hydroxide ions in **Method 2**.

Give your reasoning.

First order with respect to 1-bromobutane: mixtures 1 and 2, $[C_4H_9Br]$ doubles with $[OH^-]$ constant and the rate doubles (3.2 to 6.5×10^{-6}).
First order with respect to OH^- : mixtures 2 and 3, $[OH^-]$ increases five times with $[C_4H_9Br]$ constant and the rate increases five times.
 [2]

- (ii) Complete the rate equation for the reaction in part (c)(i).

Rate = $k[1\text{-bromobutane}][OH^-]$ [1]

END OF QUESTION PAPER

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