Oxford Cambridge and RSA

Tuesday 20 May 2025 – Morning

AS Level Chemistry A

H032/02 Depth in chemistry

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry A

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 | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

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 **70**.
- 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 **24** pages.

ADVICE
- Read each question carefully before you start your answer.

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1 A student is investigating the enthalpy change of neutralisation for a strong acid and a strong alkali.

(a) Explain what is meant by an **alkali**.

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..... **[1]**

(b) Write the ionic equation for the neutralisation reaction between an acid and an alkali.

..... **[1]**

(c) The student mixes 40.0 cm^3 of 1.40 mol dm^{-3} HCl and 40.0 cm^3 of 1.40 mol dm^{-3} NaOH.

The temperature rises by 9.40 °C

(i) Calculate the enthalpy change of neutralisation, in kJ mol^{-1}.

Give your answer to **3** significant figures.

Assume that the density of all solutions and the specific heat capacity, *c*, of the reaction mixture is the same as for water.

Enthalpy change of neutralisation = ... kJ mol^{-1} **[4]**

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(ii) The student repeats the experiment using the same volume and concentration of NaOH but using 20.0 cm^3 of 2.80 mol dm^{-3} HCl instead of 40.0 cm^3 of 1.40 mol dm^{-3} HCl.

The temperature rise is greater than 9.4 °C.

Explain why.

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..... **[2]**

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2 This question is about reactions of some Group 2 elements and their compounds.

(a) The table below shows the first and second ionisation energies of magnesium and calcium.

Group 2 element	**1st Ionisation energy / kJ mol^{-1}**	**2nd Ionisation energy / kJ mol^{-1}**
Mg	738	1451
Ca	590	1145

(i) Write an equation to represent the **second** ionisation energy of calcium.

Include state symbols.

..... **[1]**

(ii)* Magnesium and calcium differ in their reactivity.

Give a balanced equation for the reaction of **calcium** with water and describe what would be observed. Explain why this is a redox reaction.

Explain the difference in reactivity of magnesium and calcium.

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Extra answer space if required.

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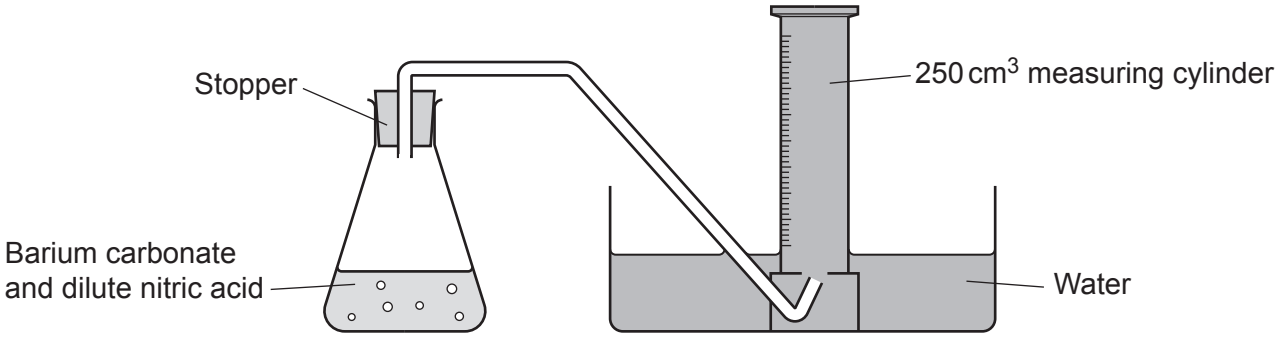
(b) A student adds 1.51 g of barium carbonate, $BaCO_3$ (molar mass 197.3 g mol^{-1}), to an excess of dilute nitric acid. The equation is shown below.

$$BaCO_3(s) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

The student uses the following apparatus.



(i) Calculate the volume, in cm^3, of gas the student expects to be produced at room temperature and pressure (RTP).

Give your answer to **3** significant figures.

Volume of gas ..... cm^3 **[2]**

(ii) The volume of gas collected is less than the calculated volume.

Suggest **two** reasons for this difference.

1 .....

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2 .....

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[2]

(iii) Suggest **one** way in which the student could modify the apparatus to produce a volume closer to the calculated volume.

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..... **[1]**

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3 Malic acid tablets are sold as a health supplement.

A student carries out a titration to determine the mass of malic acid, $C_4H_6O_5$, in **one** tablet.

The student follows the method below:

Step 1 Crush **three** tablets, transfer the powder into a beaker and dissolve in distilled water.

Step 2 Transfer the solution into a 250.0 cm^3 volumetric flask and make up to the mark with distilled water.

Step 3 Pipette 25.0 cm^3 of the solution from **Step 2** into a conical flask and add a few drops of indicator.

Step 4 Titrate this solution with 0.0800 mol dm^{-3} sodium hydroxide, NaOH, in the burette.

The equation for the neutralisation reaction is:

$C_4H_6O_5 + 2NaOH \rightarrow C_4H_4O_5Na_2 + 2H_2O$

(a) The student takes burette readings to the nearest 0.05 cm^3.

The student's readings are shown in the table.

The rough titre has been omitted.

(i) Complete the table below.

Titration	1	2	3
Final reading / cm^3	23.60	46.70	25.65
Initial reading / cm^3	0.30	23.65	2.50
Titre / cm^3	.....	.....	.....

[1]

(ii) Calculate the mean titre of NaOH that the student should use to analyse the results.

Mean titre = ... cm^3 **[1]**

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(iii) Calculate the mass, in mg, of malic acid in **one** tablet.

Assume that malic acid (molar mass 134.0 g mol^{-1}) is the only acid in the tablets.

Give your answer to **3** significant figures.

Mass of malic acid ..... mg **[5]**

(b) Another student carries out the same experiment.

Instead of rinsing the burette used in **Step 4** with 0.0800 mol dm^{-3} NaOH, the student rinses with water before filling it up with 0.0800 mol dm^{-3} NaOH.

State and explain how this error would affect the titre.

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..... **[2]**

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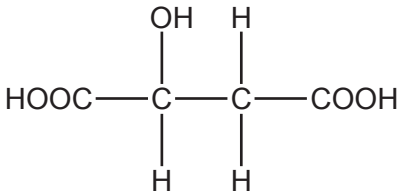
(c) The structure of malic acid is shown below.



When malic acid is heated with an acid catalyst, a mixture of *cis* and *trans* stereoisomers is produced.

Draw the structures of the *cis* and *trans* isomers.

cis	*trans*

[2]

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4 The alkanes belong to a homologous series of hydrocarbons.

Table 4.1 shows information about some straight chain alkanes.

Table 4.1

Alkane	**Molecular formula**	**Boiling point / °C**	**Enthalpy change of combustion / kJ mol^{-1}**
Propane	C_3H_8	–42	–2219
Butane	C_4H_{10}	0	To estimate in part **(b)(iv)**
Pentane	C_5H_{12}	36	–3509
Hexane	C_6H_{14}	69	–4163

(a) State and explain the trend in boiling points of the straight chain alkanes in **Table 4.1.**

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..... **[4]**

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(b) When alkanes undergo complete combustion carbon dioxide and water are produced.

(i) Write the balanced equation for the complete combustion of **one** mole of pentane.

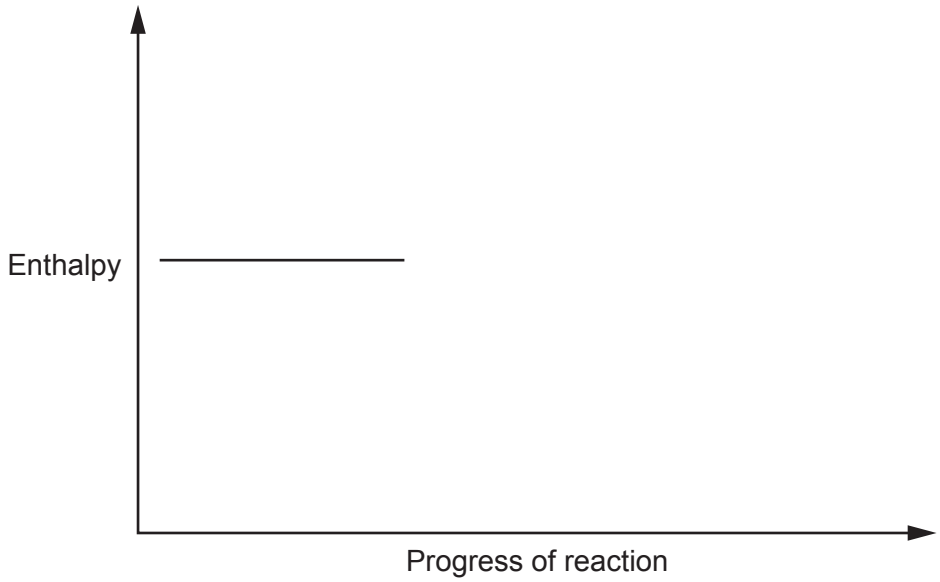
..... **[1]**

(ii) Use the information in **Table 4.1** to calculate the mass of carbon dioxide formed when 1.00 kJ of energy is released during the complete combustion of pentane.

Mass of carbon dioxide .....g **[2]**

(iii) Complete the enthalpy profile diagram for the complete combustion of pentane.

On your diagram:
- Label the enthalpy change as ΔH.
- Include the formulae of the reactants and products.
- Label the activation energy as Ea.



[2]

(iv) Use the data in **Table 4.1** to estimate a value for the enthalpy change of combustion of butane.

Give your answer to **2** significant figures.

Estimated enthalpy change of combustion of butane .....kJ mol^{-1} **[1]**

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(c) Besides pentane, there are two other structural isomers of C_5H_{12}.

Draw the **skeletal** formulae of these two other structural isomers and state the systematic name of each.

	Isomer 1	**Isomer 2**
Skeletal formula		
Systematic name		

[2]

(d) In the presence of ultraviolet radiation, propane reacts with bromine to form a mixture of products.

Two of these products are structural isomers of C_3H_7Br.

(i) Write an equation, using molecular formulae, for the formation of C_3H_7Br from propane.

..... **[1]**

(ii) The first step in the mechanism of the reaction is the homolytic fission of a Br–Br bond.

Explain what is meant by **homolytic fission**.

.....

..... **[1]**

(iii) Complete the equations for the propagation steps in the mechanism.

Use molecular formulae for organic species and dots (•) for unpaired electrons on radicals.

C_3H_8 + Br• → ..... + ...

..... + ... → C_3H_7Br + ...

[2]

(iv) Explain why two structural isomers of C_3H_7Br are formed.

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..... **[1]**

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5 This question is about haloalkanes.

(a) Chloromethane, CH_3Cl is a covalent molecule.

(i) Draw a 'dot-and-cross' diagram for CH_3Cl.

Show outer electrons only.

Use a different symbol for the electrons of each element.

[1]

(ii) Name the shape of the chloromethane molecule and predict the value of the H–C–C*l* bond angle.

Name of shape .....

Bond angle .....

[2]

(b) Chloroethene, $H_2C{=}CHCl$, is a covalent molecule with a double bond.

The bond angles in $H_2C{=}CHCl$ are different from those in CH_3Cl.

Predict the H–C–C*l* bond angle in $H_2C{=}CHCl$ and explain why it is different from the H–C–C*l* bond angle in CH_3Cl.

Bond angle .....

Explanation .....

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[3]

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(c)* 2-Chlorobutane, $CH_3CH_2CHClCH_3$, is an organic liquid with a boiling point of 70 °C.

A student prepares 2-chlorobutane from butan-2-ol, $CH_3CH_2CHOHCH_3$, as shown in the equation below.

$$CH_3CH_2CHOHCH_3 + NaCl + H_2SO_4 \rightarrow CH_3CH_2CHClCH_3 + NaHSO_4 + H_2O$$

The student's method is outlined below.

- Add 9.25 g $CH_3CH_2CHOHCH_3$ to an excess of NaC*l*(aq) in a pear-shaped flask.
- Add an excess of concentrated sulfuric acid.
- Heat the flask under reflux for about 45 minutes.

The student obtains a reaction mixture containing an organic layer (density = 0.87 g cm^{-3}) and an aqueous layer (density = 1.00 g cm^{-3}).

After purification, the percentage yield of $CH_3CH_2CHClCH_3$ is 65.0 %.

Describe how the student could obtain a pure, dry sample of $CH_3CH_2CHClCH_3$ from the reaction mixture and explain the reason for carrying out each purification step.

Calculate the mass of pure $CH_3CH_2CHClCH_3$ that would be expected from this preparation.

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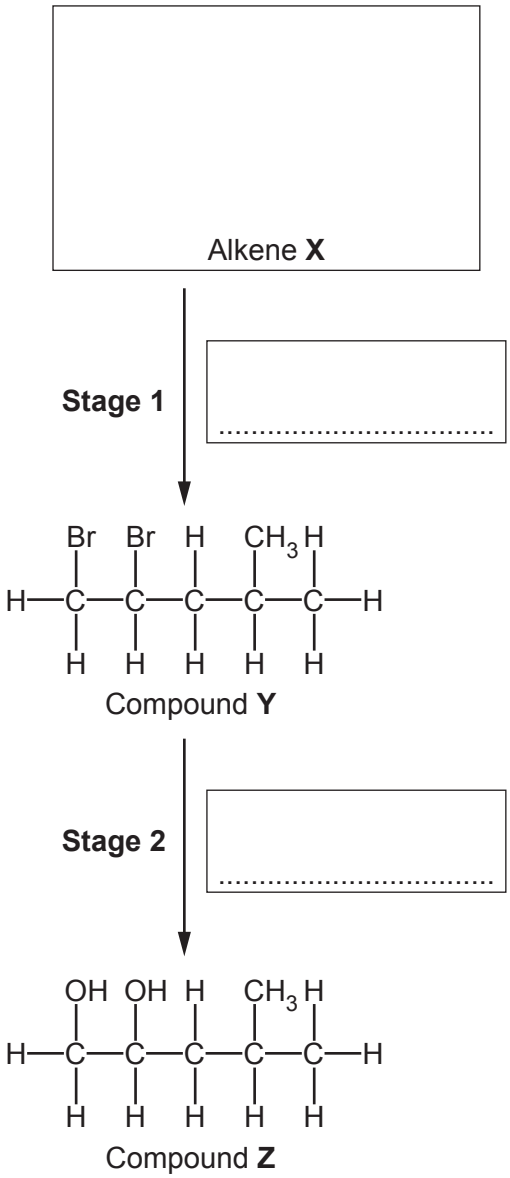
(d) Haloalkanes are important intermediates in organic synthesis.

A student plans a two-stage synthesis to prepare compound **Z** from a hydrocarbon alkene **X**.

(i) Draw the structure of the hydrocarbon alkene **X** in the box and write down the reagents for each stage on the dotted lines.



[3]

(ii) State the name of the mechanism of the reaction in **Stage 2**.

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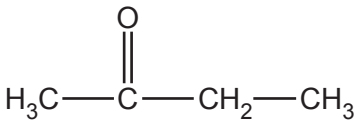
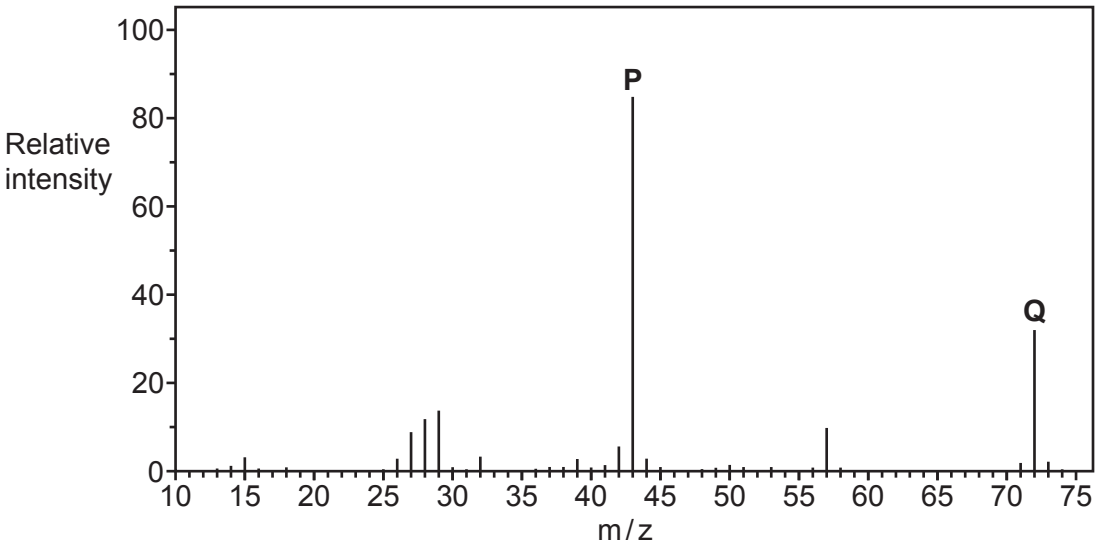
6 Compound **A** is a ketone. It has the following structure.



(a) The mass spectrum of compound **A** is shown below.



(i) Draw structures for the ions responsible for peak **P** and peak **Q**.

ion responsible for peak **P**	ion responsible for peak **Q**

[2]

(ii) Explain why there is a small peak at m/z = 73

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..... **[1]**

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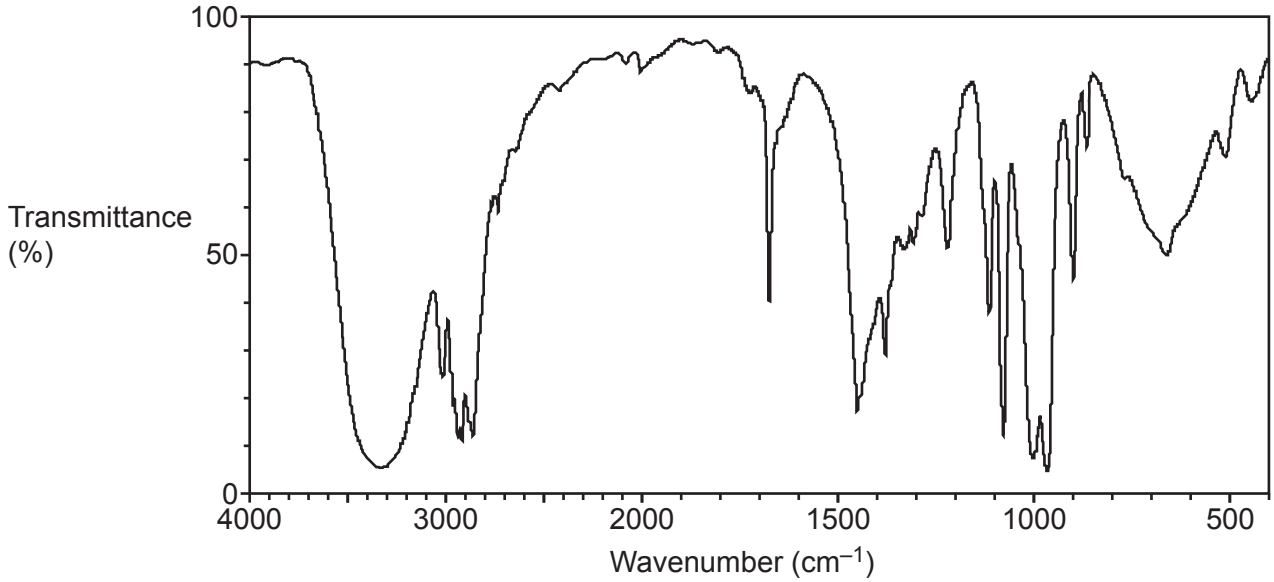
(b) Compound **B** is a non-cyclic structural isomer of Compound **A**.

The infrared spectrum of Compound **B** is shown below.



(i) State the effect infrared radiation has on covalent bonds.

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..... **[1]**

(ii) Identify **two** functional groups which are likely to be present in Compound **B** but are not present in Compound **A**.

Explain your answers.

Functional group .....

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Explanation .....

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[2]

END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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