



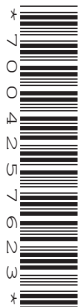
Oxford Cambridge and RSA

AS Level Chemistry A

H032/02 Depth in Chemistry

Friday 25 May 2018 – Morning

Time allowed: 1 hour 30 minutes



You must have:

- the Data Sheet for Chemistry A
(sent with general stationery)

You may use:

- a scientific or graphical calculator



First name										
Last name	StemUp Model Solution									
Centre number						Candidate number				

INSTRUCTIONS

- Use black ink. HB pencil may be used for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional answer space is required, you should use the lined page(s) at the end of the booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION

- The total mark for this paper is **70**.
- The marks for each question are shown in brackets [].
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **20** pages.

Answer **all** the questions.

- 1 A student carries out a titration to determine the molar mass and structure of a weak acid **A**.

The student follows the method below.

- Dissolve a weighed mass of **A** in 100 cm^3 of distilled water and make the solution up to 250 cm^3 in a beaker.
- Add the solution of **A** to a burette.
- Titrate the solution of **A** with a standard solution of sodium hydroxide, NaOH.

- (a) What is meant by the term standard solution?

A solution of known concentration...... [1]

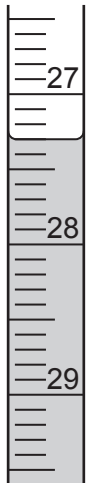
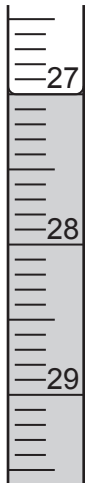
- (b) Sodium hydroxide is an alkali.

What is meant by the term alkali?

A soluble base that releases OH^- ions in aqueous solution...... [1]

- (c) The student carries out a trial, followed by three further titrations.
The diagram shows the initial and final burette readings for the three **further** titrations.

The student measures all burette readings to the nearest 0.05 cm^3 .

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

- (i) Record the student's readings and the titres in the table below.

Calculate the mean titre, to the nearest 0.05 cm^3 , that the student should use for analysing the results.

	Titration 1	Titration 2	Titration 3
Final reading/ cm^3	27.30	27.00	27.75
Initial reading/ cm^3	0.45	0.60	1.25
Titre/ cm^3	26.85	26.40	26.50

mean of concordant titres 2 and 3 = $(26.40 + 26.50) \div 2$

mean titre = ...26.45..... cm^3 [4]

- (ii) The uncertainty in each burette reading is $\pm 0.05\text{ cm}^3$.

Calculate the percentage uncertainty for the titre in **Titration 1**.

$$\% \text{ uncertainty} = (2 \times 0.05) \div 26.85 \times 100$$

$$= 0.372 \%$$

percentage uncertainty = ...0.372..... % [1]

- (iii) The student realised that the solution of **A** had not been prepared correctly.

How should the student have made up the solution?

Dissolve A in distilled water in a beaker, transfer the solution and all the washings to a 250 cm^3 volumetric flask (not a beaker), make up to the mark with distilled water and invert to mix. [1]

(d) A student repeats the titration to determine the molar mass and structure of **A**.

- The student prepares a 250.0 cm³ solution from 1.513 g of **A**.
- The solution of **A** is added to the burette and titrated with 25.0 cm³ volumes of 0.112 mol dm⁻³ NaOH(aq).
- 1 mol of **A** reacts with 2 mol of NaOH.
- The student obtains a mean titre of 27.30 cm³.

(i) Calculate the molar mass of **A** from these results.

Give your answer to the nearest whole number.

Show your working.

$$n(\text{NaOH}) = 0.112 \times 25.0 \div 1000 = 0.00280 \text{ mol}$$

$$n(\text{A}) \text{ in } 27.30 \text{ cm}^3 = 0.00280 \div 2 = 0.00140 \text{ mol}$$

$$n(\text{A}) \text{ in } 250.0 \text{ cm}^3 = 0.00140 \times 250.0 \div 27.30 = 0.0128 \text{ mol}$$

$$M(\text{A}) = 1.513 \div 0.0128 = 118 \text{ g mol}^{-1}$$

molar mass of **A** = ...118..... g mol⁻¹ [4]

(ii) **A** is an organic acid, containing C, H and O only.
One molecule of **A** contains two COOH groups.

Suggest the structure of **A**.

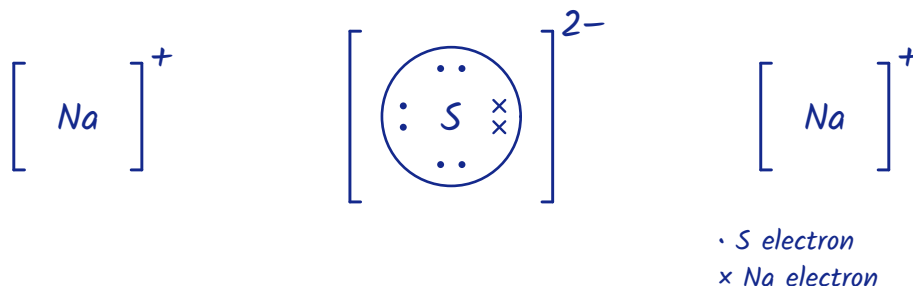


[1]

2 Sodium sulfide, Na_2S , is an ionic compound of sodium, Na, and sulfur, S.

(a) Draw a 'dot-and-cross' diagram to show the bonding in sodium sulfide.

Show outer electrons only.



[2]

(b) The table below compares the properties of sodium sulfide, sodium and sulfur.

Complete the table.

		Sodium sulfide	Sodium	Sulfur
Melting point/°C		1180	98	113
Type of structure (giant or simple)		<i>giant</i>	<i>giant</i>	<i>simple</i>
Electrical conductivity (good or poor)	solid	<i>poor</i>	<i>good</i>	<i>poor</i>
	liquid	<i>good</i>	<i>good</i>	<i>poor</i>

[3]

(c) Selenium is in the same group of the periodic table as sulfur.

(i) Complete the full electron configuration of a selenium atom.

$1s^2$ *2s² 2p⁶ 3s² 3p⁶ 3d¹⁰ 4s² 4p⁴*..... [1]

(ii) Sodium selenide reacts with hydrochloric acid to form a toxic gas, **B**, with a relative molecular mass of 81.0.

Identify gas **B** and write an equation for this reaction.

Gas **B** *H₂Se*.....

Equation *Na₂Se + 2HCl → 2NaCl + H₂Se*..... [2]

3 This question is about halogens.

(a) Bromine is used to extract iodine from a solution containing iodide ions.

(i) Write an ionic equation for the reaction.

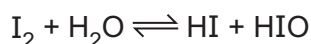


(ii) Explain why iodine is less reactive than bromine.

Iodine atoms have a larger atomic radius than bromine atoms; the electron gained goes into a shell further from the nucleus.
Iodine has more inner shells, so there is more shielding.
So in iodine there is weaker nuclear attraction on the electron to be gained, so iodine gains an electron less readily and is a weaker oxidising agent than bromine.
 [3]

(b) Iodine can be used for the small-scale purification of drinking water.

(i) Iodine reacts with water as shown below.



Using oxidation numbers, explain why this reaction is a disproportionation.

Oxidation number of iodine in I_2 is 0.
Iodine is oxidised from 0 in I_2 to +1 in HIO .
Iodine is reduced from 0 in I_2 to -1 in HI .
The same element, iodine, is both oxidised and reduced, so it is disproportionation.
 [3]

(ii) Chlorine is used to purify water on a large scale.

State **one** disadvantage of using chlorine for the purification of drinking water.

Chlorine is toxic, and it reacts with organic matter in water to form chlorinated hydrocarbons, which may be carcinogenic.
 [1]

- (c) Hydrogen reacts with chlorine to form hydrogen chloride, HCl :

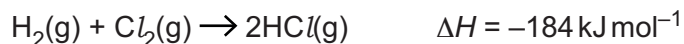


Table 3.1 shows bond enthalpies.

Bond	Bond Enthalpy/ kJ mol^{-1}
H-H	+436
Cl-Cl	+243

Table 3.1

Calculate the bond enthalpy for the H-Cl bond from the information above.

$$\text{Bonds broken: } (\text{H-H}) + (\text{Cl-Cl}) = 436 + 243 = 679 \text{ kJ mol}^{-1}$$

$$\Delta H = \text{bonds broken} - \text{bonds formed}$$

$$-184 = 679 - 2 \times (\text{H-Cl}), \text{ so } 2 \times (\text{H-Cl}) = 679 + 184 = 863$$

$$\text{H-Cl} = 863 \div 2 = +431.5 \text{ kJ mol}^{-1}$$

$$\text{bond enthalpy} = \dots\dots\dots +431.5 \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$

- (d) 'Enthalpy change of vaporisation' is the enthalpy change when one mole of a substance changes from a liquid to a gas at its boiling point.

- (i) Write an equation, including state symbols, to represent the enthalpy change of vaporisation of bromine.



- (ii) Suggest whether the enthalpy change of vaporisation of bromine is exothermic or endothermic.

Explain your answer.

$\dots\dots\dots$ Endothermic: energy is needed to overcome the induced dipole-dipole
 $\dots\dots\dots$ interactions (London forces) between the Br_2 molecules.
 $\dots\dots\dots$

$\dots\dots\dots$ [1]

- 4 The reaction of ammonia, NH_3 , with oxygen to form nitrogen monoxide, NO , is an important industrial process.

The equation for this reaction is shown in **equilibrium 4.1** below.

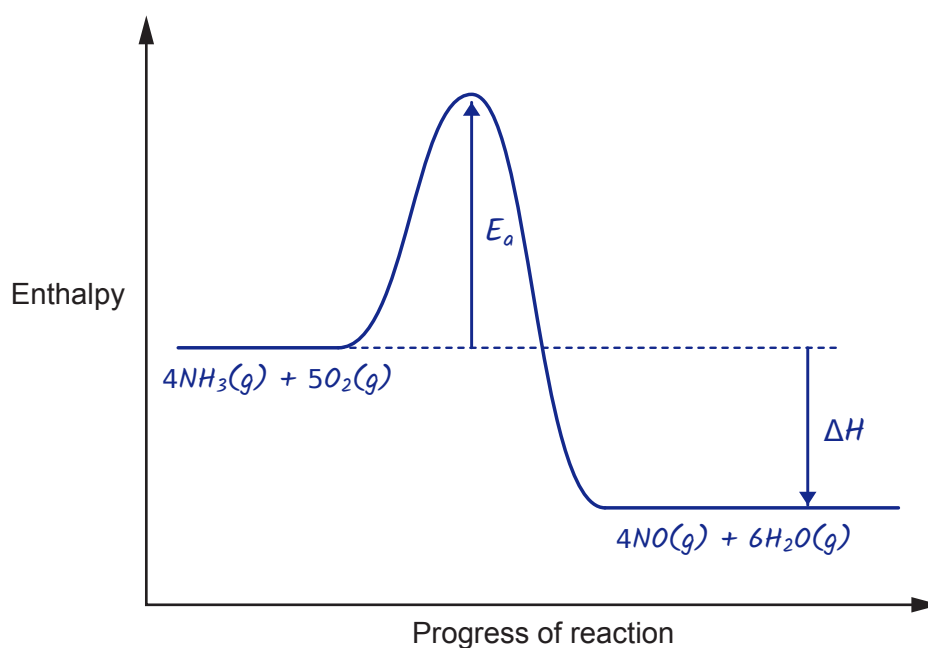


- (a) The forward reaction in **equilibrium 4.1** converts NH_3 into NO .

- (i) Complete the enthalpy profile diagram for this reaction.

On your diagram:

- Label the activation energy, E_a
- Label the enthalpy change of reaction, ΔH
- Include the formulae of the reactants and products.



[2]

- (ii) 5.10 tonnes of NH_3 are converted into NO .

Calculate the energy released, in kJ, for this conversion.

Give your answer in **standard form** and to an **appropriate** number of significant figures.

$$n(\text{NH}_3) = 5.10 \times 10^6 \text{ g} \div 17.0 \text{ g mol}^{-1} = 3.00 \times 10^5 \text{ mol}$$

$$4 \text{ mol } \text{NH}_3 \text{ release } 905 \text{ kJ, so } 1 \text{ mol } \text{NH}_3 \text{ releases } 905 \div 4 = 226.25 \text{ kJ}$$

$$\text{energy released} = 3.00 \times 10^5 \times 226.25 = 67\,875\,000 \text{ kJ}$$

$$= 6.79 \times 10^7 \text{ kJ (3 s.f.)}$$

$$\text{energy released} = \dots\dots\dots 6.79 \times 10^7 \dots\dots\dots \text{ kJ [4]}$$

(b) Write an expression for the equilibrium constant, K_c , in **equilibrium 4.1**.

$$K_c = \frac{[\text{NO}(\text{g})]^4 [\text{H}_2\text{O}(\text{g})]^6}{[\text{NH}_3(\text{g})]^4 [\text{O}_2(\text{g})]^5}$$

[1]

(c) Predict the conditions of temperature and pressure for a maximum equilibrium yield of nitrogen monoxide in **equilibrium 4.1**.

- Explain your prediction in terms of Le Chatelier's principle.
- State and explain how these conditions could be changed to achieve a compromise between equilibrium yield, rate and other operational factors.

Low temperature: the forward reaction is exothermic (ΔH negative), so at

low temperature the equilibrium shifts right, giving more NO .

Low pressure: the left-hand side has fewer gas moles (9 mol of gas form

10 mol), so at low pressure the equilibrium shifts right, to more gas moles.

So maximum yield of NO : low temperature and low pressure.

Compromise: low temperature and pressure give a slow rate, so a higher

temperature (and pressure) is used to increase the rate and frequency of collisions.

But higher temperature reduces the yield and raises energy costs; high

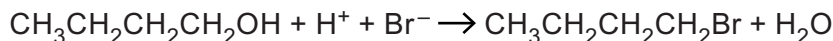
pressure is expensive to generate and a safety risk.

[5]

- 5 (a) 1-Bromobutane is an organic liquid with a boiling point of 102 °C.

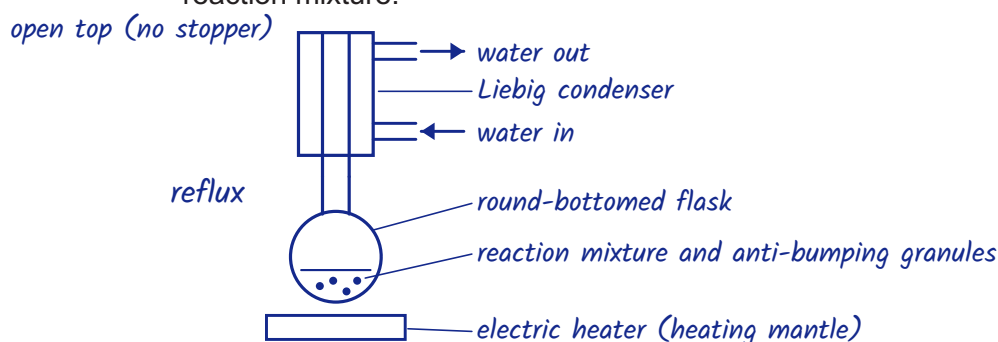
A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour.

The equation is shown below.



The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm⁻³) and an aqueous layer (density = 1.00 g cm⁻³).

- (i)* Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture.



Heat under reflux for one hour with an electric heater (not a flame, as the organic compounds are flammable). Water enters the condenser at the bottom and leaves at the top; the top is open so pressure cannot build up.

Cool, then pour the mixture into a separating funnel. The organic layer is denser (1.27 g cm⁻³) than the aqueous layer, so it is the lower layer; run off and collect the lower organic layer.

Shake the organic layer with aqueous sodium hydrogencarbonate to remove any acid, releasing the pressure, and again keep the lower layer.

Dry the organic layer with an anhydrous salt, e.g. anhydrous MgSO₄ or CaCl₂, then filter or decant.

Redistil the dried liquid and collect the fraction distilling at 102 °C, which is pure 1-bromobutane.

[6]

- (ii) The student used 0.150 mol of butan-1-ol. The student obtained a 61.4% percentage yield of 1-bromobutane.

Calculate the mass of 1-bromobutane obtained.

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

$$n(\text{1-bromobutane}) = 0.150 \times 61.4 \div 100 = 0.0921 \text{ mol}$$

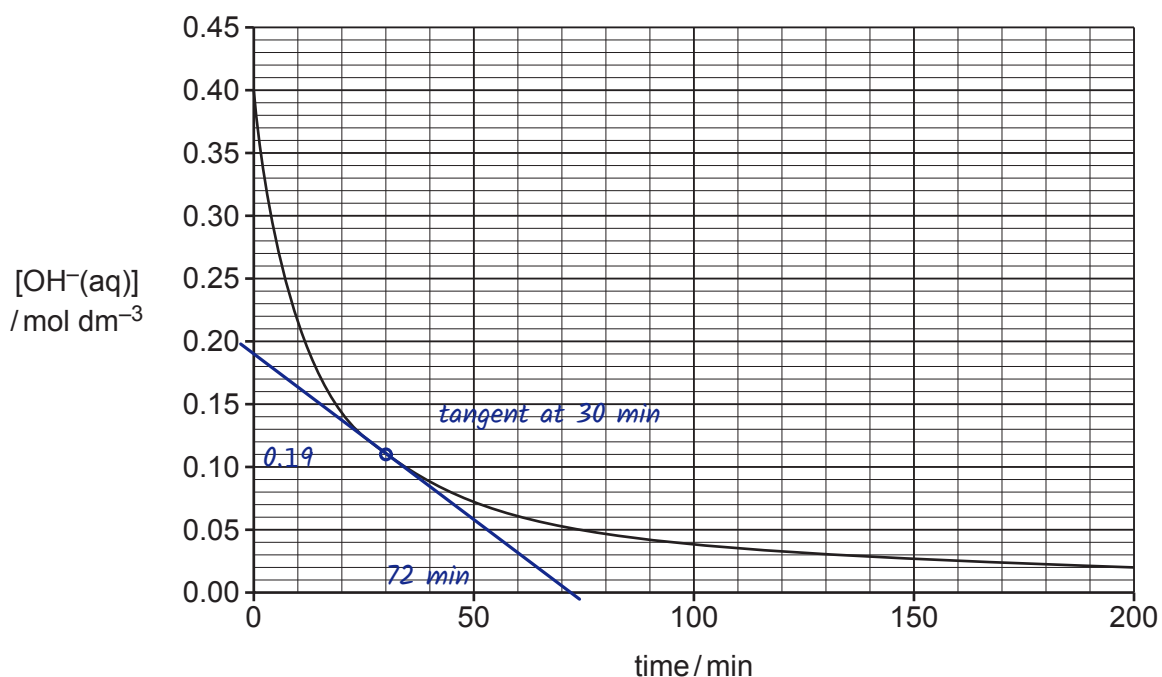
$$M(\text{C}_4\text{H}_9\text{Br}) = 136.9 \text{ g mol}^{-1}$$

$$\text{mass} = 0.0921 \times 136.9 = 12.6 \text{ g}$$

mass = ...12.6..... g [2]

(b) A student investigates the rate of reaction of 1-bromobutane with aqueous hydroxide ions.

The graph shows how the hydroxide ion concentration, $[\text{OH}^-(\text{aq})]$, changes during the reaction.



Using the graph, calculate the rate of reaction, in $\text{mol dm}^{-3} \text{min}^{-1}$, at 30 minutes.

Show your working on the graph and in the space below.

tangent drawn at $t = 30 \text{ min}$, from $(0, 0.19)$ to $(72, 0)$

$$\text{gradient} = -0.19 \div 72 = -2.64 \times 10^{-3}$$

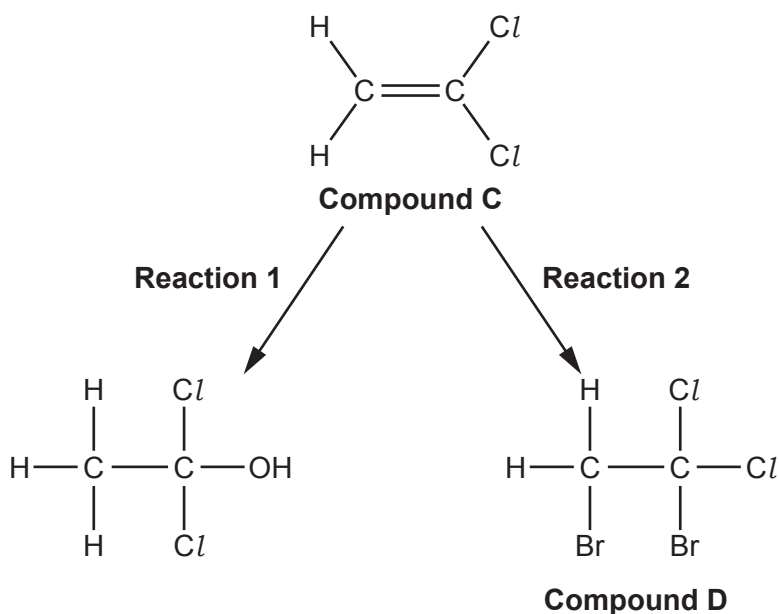
$$\text{rate} = 0.19 \div 72 = 2.64 \times 10^{-3} \text{ mol dm}^{-3} \text{min}^{-1}$$

$$\text{rate of reaction} = 2.64 \times 10^{-3} \text{ mol dm}^{-3} \text{min}^{-1} \quad [2]$$

13
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- 6 Two reactions of compound **C** are shown in the flowchart below.



- (a) State the reagents and conditions for **reaction 1**.

Steam with an acid catalyst (H_3PO_4), at high temperature and pressure.

[1]

- (b) In **reaction 2**, compound **C** reacts with bromine to form compound **D**.

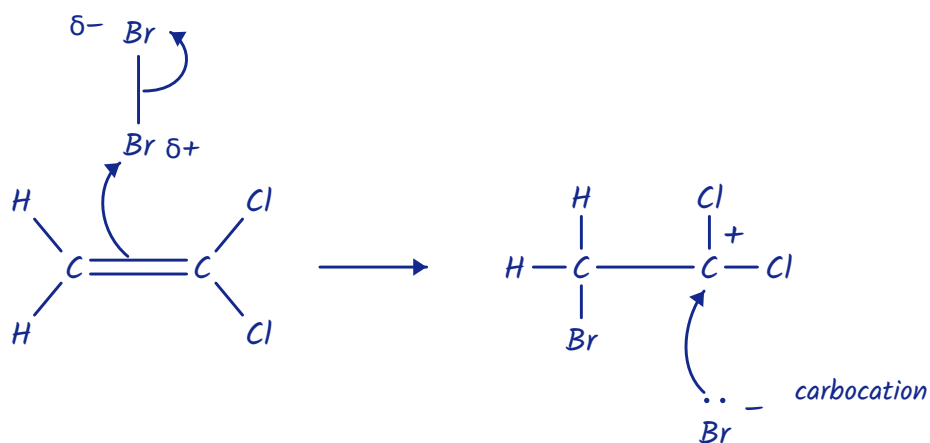
- (i) Give the systematic name of compound **D**.

1,2-dibromo-1,1-dichloroethane

[1]

- (ii) Outline the mechanism for **reaction 2**.

Include curly arrows, charges and relevant dipoles.

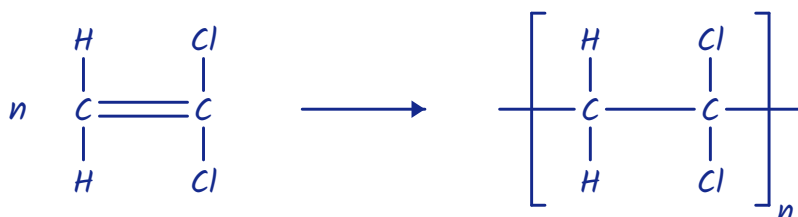


[3]

(c) Compound **C** forms an addition polymer **E**.

(i) Write a balanced equation for this reaction.

Show displayed formulae.



[2]

(ii) State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of waste polymer **E**.

Advantage *The energy released can be used to generate electricity (and less landfill is needed).*

Disadvantage *Combustion forms toxic HCl, which causes acid rain, and CO₂, a greenhouse gas.*

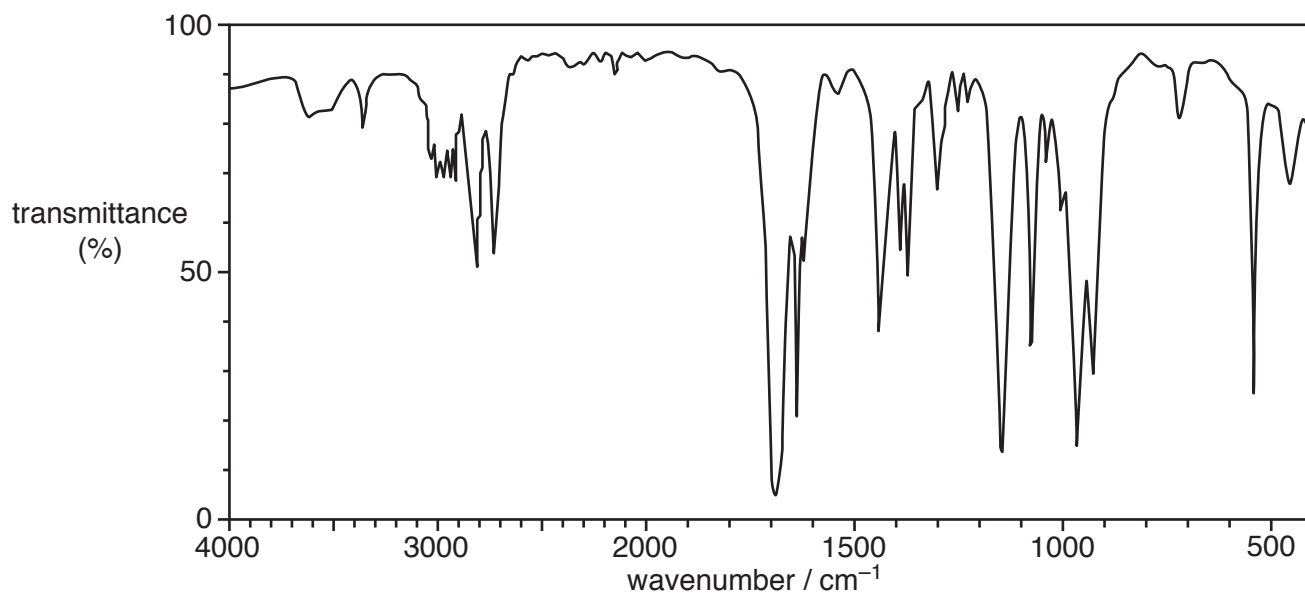
[2]

7* Compound **F** is a *trans* stereoisomer which is a useful intermediate in organic synthesis.

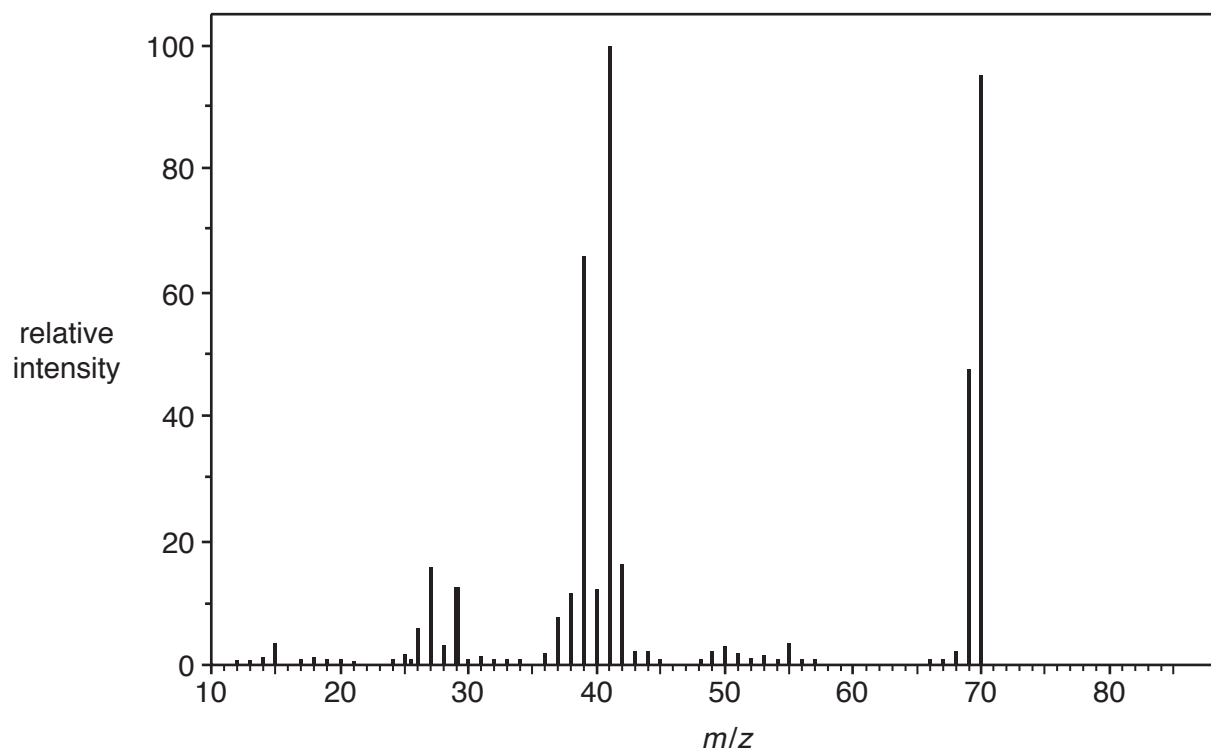
The results of elemental and spectral analysis of compound **F** are shown below.

Percentage composition by mass: C, 68.6 %; H, 8.6 %; O, 22.8 %.

Infrared spectrum



Mass spectrum



In the mass spectrum, the peak with the greatest relative intensity is caused by the loss of a functional group from the molecular ion of compound F.

Determine the structure of compound F.

Explain your reasoning and show your working.

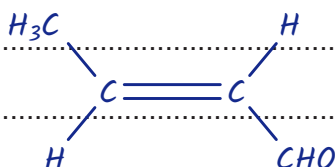
Empirical formula: $C \ 68.6 \div 12.0 = 5.72$; $H \ 8.6 \div 1.0 = 8.6$; $O \ 22.8 \div 16.0 = 1.425$. Ratio $C : H : O = 4.01 : 6.04 : 1 = 4 : 6 : 1$, so the empirical formula is C_4H_6O .

Mass spectrum: molecular ion peak at $m/z = 70$, so $M_r = 70$. C_4H_6O has mass 70, so the molecular formula is C_4H_6O .

IR: strong absorption at about 1700 cm^{-1} (1630 to 1820 cm^{-1}) shows a $C=O$ group (aldehyde or ketone); no broad $O-H$ absorption.

The tallest peak is at $m/z = 41$, $C_3H_5^+$; $70 - 41 = 29$, so a CHO group has been lost from the molecular ion, so F is an aldehyde.

C_4H_6O with $C=O$ needs one more double bond, so F has a $C=C$ bond; this allows E/Z (cis-trans) isomerism. F is trans-but-2-enal, $CH_3CH=CHCHO$:



trans (E) isomer

[6]

END OF QUESTION PAPER

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