



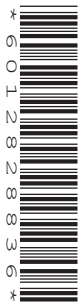
Oxford Cambridge and RSA

AS Level Chemistry A

H032/02 Depth in chemistry

Friday 10 June 2016 – Afternoon

Time allowed: 1 hour 30 minutes



You must have:

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

You may use:

- a scientific 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 Group 2 elements are metals that react with oxygen and water.

(a) Magnesium is oxidised when it burns in oxygen to form an ionic compound.

(i) Write the electron configuration, in terms of sub-shells, of a magnesium atom.

$1s^2 2s^2 2p^6 3s^2$ [1]

(ii) Explain what happens when magnesium is oxidised in terms of electron transfer.

$Each\ Mg\ atom\ loses\ (transfers)\ two\ electrons,\ its\ 3s\ electrons,\ to$
 $oxygen:\ Mg \rightarrow Mg^{2+} + 2e^{-}$ [1]

(b) The trend in the first and second ionisation energies of Group 2 elements can be linked to the increase in chemical reactivity down the group.

The first and second ionisation energies of calcium and strontium are given in the table.

Element	First ionisation energy /kJ mol ⁻¹	Second ionisation energy /kJ mol ⁻¹
Ca	590	1145
Sr	550	1064

(i) Write an equation, including state symbols, to represent the **second** ionisation energy of strontium.

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

(ii) Explain why the first ionisation energy of strontium is less than the first ionisation energy of calcium.

$Sr\ has\ a\ larger\ atomic\ radius\ than\ Ca\ (one\ more\ shell),\ so\ its\ outer$
 $electron\ is\ further\ from\ the\ nucleus,\ and\ there\ is\ more\ shielding\ from$
 $inner\ shells.\ The\ greater\ nuclear\ charge\ of\ Sr\ is\ outweighed\ by\ the$
 $increased\ distance\ and\ shielding,\ so\ there\ is\ less\ nuclear\ attraction\ on\ the$
 $outer\ electron\ and\ less\ energy\ is\ needed\ to\ remove\ it.$ [3]

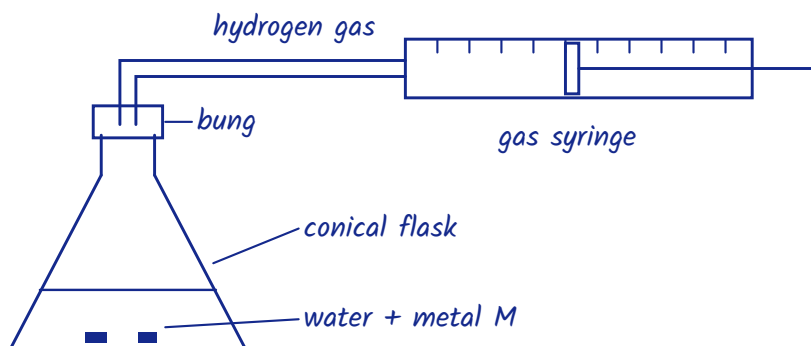
- (c) A student reacts a Group 2 metal, M, with water.



The student measures the volume of hydrogen gas produced.

0.162 g of the metal produces 97.0 cm³ of gas measured at room temperature and pressure.

- (i) Draw a labelled diagram of the apparatus that can be used to carry out this experiment.



[2]

- (ii) Identify the Group 2 metal, M.

Show your working.

$$n(\text{H}_2) = 97.0 \div 24\,000 = 4.04 \times 10^{-3} \text{ mol}$$

$$1 : 1 \text{ ratio, so } n(\text{M}) = 4.04 \times 10^{-3} \text{ mol}$$

$$\text{molar mass of M} = 0.162 \div 0.00404 = 40.1 \text{ g mol}^{-1}$$

$$A_r = 40.1, \text{ so M is calcium}$$

Group 2 metal = ...calcium, Ca..... [3]

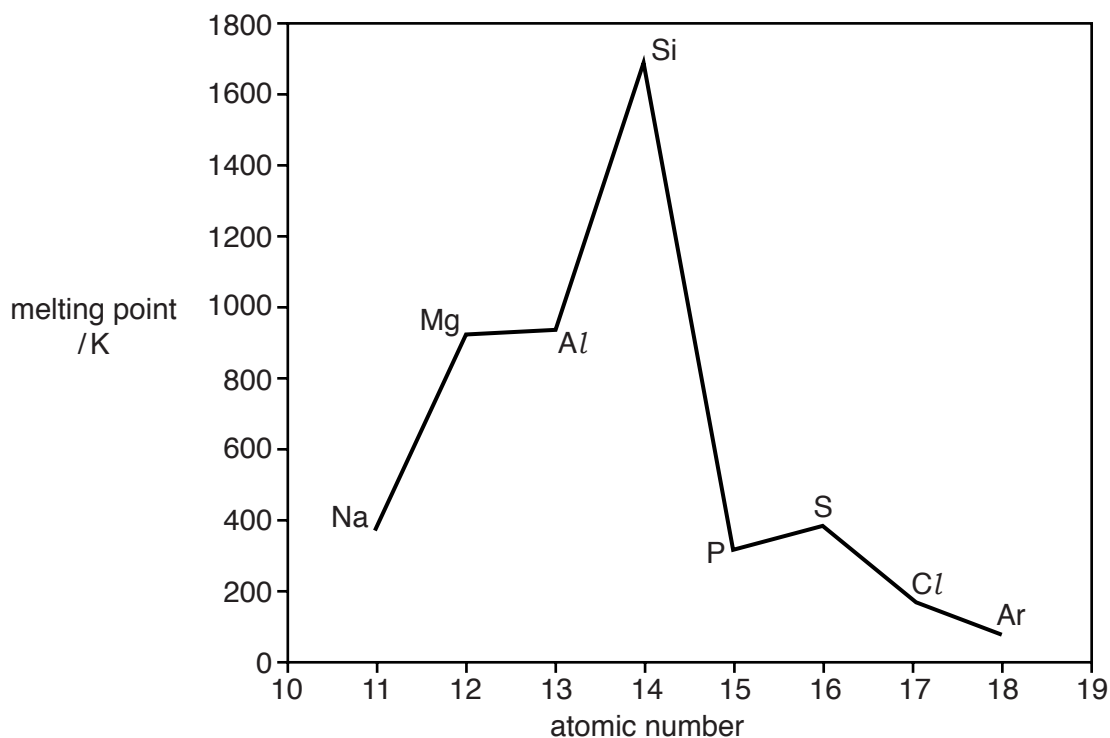
- (d) The student plans to repeat the experiment using the same mass of a Group 2 metal from further down the group.

Predict whether the volume of hydrogen produced would be greater than, less than or the same as the volume in the first experiment.

Explain your answer.

Less volume of hydrogen: the metal has a larger A_r , so the same mass contains fewer moles (atoms) of metal, so fewer moles of H_2 form (e.g. Sr: $0.162 \div 87.6 \times 24\,000 = 44.4 \text{ cm}^3$). [1]

- 2 The graph shows the melting points of the elements in Period 3 of the periodic table.



- (a) Phosphorus and chlorine have simple molecular structures.
More information about phosphorus and chlorine is given in the table below.

Element	Molecular formula
phosphorus	P_4
chlorine	Cl_2

Explain the differences in the melting points of phosphorus and chlorine.

Phosphorus (P_4) molecules have more electrons than chlorine (Cl_2) molecules.
So there are stronger London forces (induced dipole-dipole interactions)
between P_4 molecules than between Cl_2 molecules.
More energy is required to break the intermolecular forces (London forces)
between P_4 molecules, so phosphorus has a higher melting point than chlorine.

[3]

- (b) Magnesium and silicon have different types of giant structures.

Describe the bonding in magnesium and in silicon.

Include the names of the particles and describe the forces between the particles in the structures.

Magnesium has metallic bonding: a giant metallic lattice of positive ions

(cations, Mg^{2+}) and delocalised electrons.

The forces are strong electrostatic attractions between the Mg^{2+} cations and the delocalised electrons.

Silicon has covalent bonding: a giant covalent lattice of Si atoms.

The forces are strong covalent bonds between atoms: the attraction between a shared pair of electrons and the nuclei of the bonded atoms.

[4]

- (c) Aluminium forms a sulfide, Al_2S_3 .

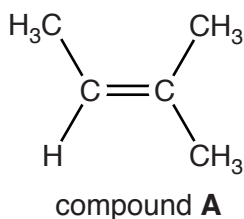
Al_2S_3 reacts with water to form aluminium hydroxide and hydrogen sulfide, H_2S .

Write an equation for the reaction of Al_2S_3 with water.



[1]

3 Compound **A** is an alkene.



(a) The C=C bond in a molecule of compound **A** has restricted rotation because it comprises a σ bond and a π bond.

(i) Describe **one** difference between the σ bond and the π bond.

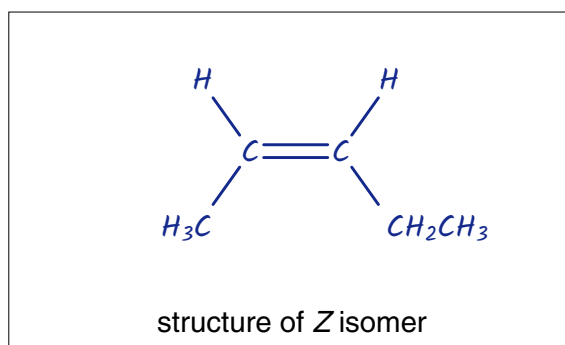
A σ bond is formed by direct (head-on) overlap of orbitals, with electron density between the bonding nuclei, whereas a π bond is formed by sideways overlap of p-orbitals, with electron density above and below the bonding nuclei. [1]

(ii) Explain why compound **A** does **not** have *E/Z* isomers.

The right-hand carbon atom of the C=C bond is attached to two identical groups (two CH₃ groups), so swapping groups gives the same molecule. [1]

(iii) A structural isomer of compound **A** has *E/Z* isomers.

Draw the structure of the *Z* isomer and then name this isomer.

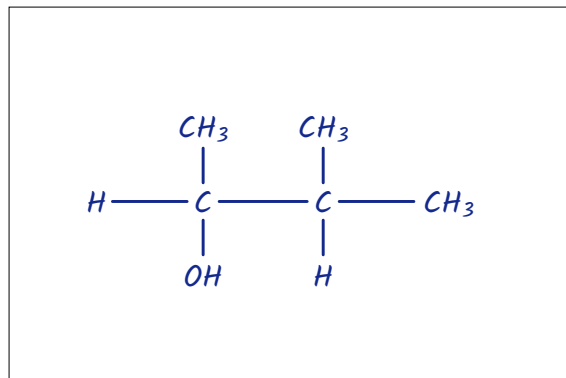
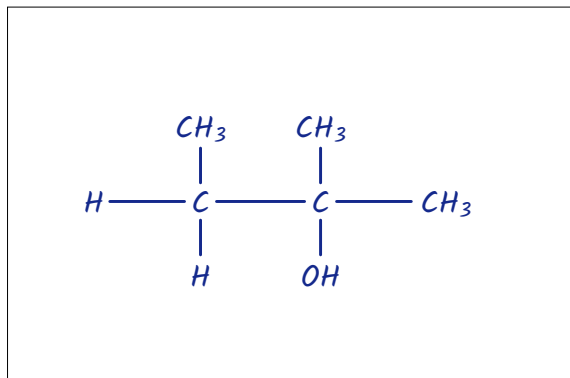


name *(Z)-pent-2-ene*

[2]

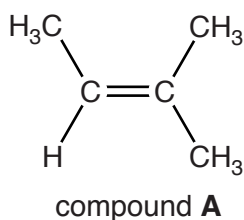
(b) Compound **A** can be made from alcohol **B** by heating with an acid catalyst.

Suggest **two** possible structures for alcohol **B**.



[2]

(c)* Compound **A** reacts with hydrogen bromide to form a mixture of two different organic products.



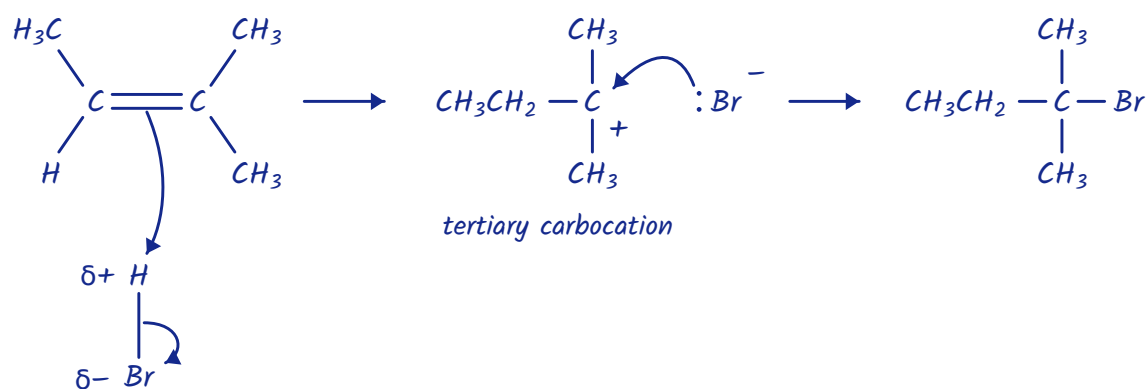
Give the structures of the **two** possible organic products of the reaction.

Outline the mechanism, using the 'curly arrow' model, for the formation of one of the organic products from compound **A**.

Explain which of the two organic products is more likely to be formed.

Products: $(\text{CH}_3)_2\text{CBrCH}_2\text{CH}_3$, 2-bromo-2-methylbutane, and $\text{CH}_3\text{CHBrCH}(\text{CH}_3)\text{CH}_3$, 2-bromo-3-methylbutane.

Mechanism (electrophilic addition) for 2-bromo-2-methylbutane:



The major product is 2-bromo-2-methylbutane. It forms from the tertiary carbocation, which is more stable than the secondary carbocation that gives 2-bromo-3-methylbutane, because the C^+ has more electron-donating alkyl (CH_3) groups attached. Br bonds to the C atom with the fewest H atoms.

[6]

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Turn over for the next question

4 Nitrogen forms several different oxides.

N_2O is a useful anaesthetic and NO has been linked to the depletion of ozone in the stratosphere.

(a) The standard enthalpy changes of formation of N_2O and NO are given in the table.

Compound	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{N}_2\text{O (g)}$	+ 82.0
NO (g)	+ 90.2

- (i) Explain, in terms of bond breaking and bond making, why the enthalpy change of formation of NO is endothermic.

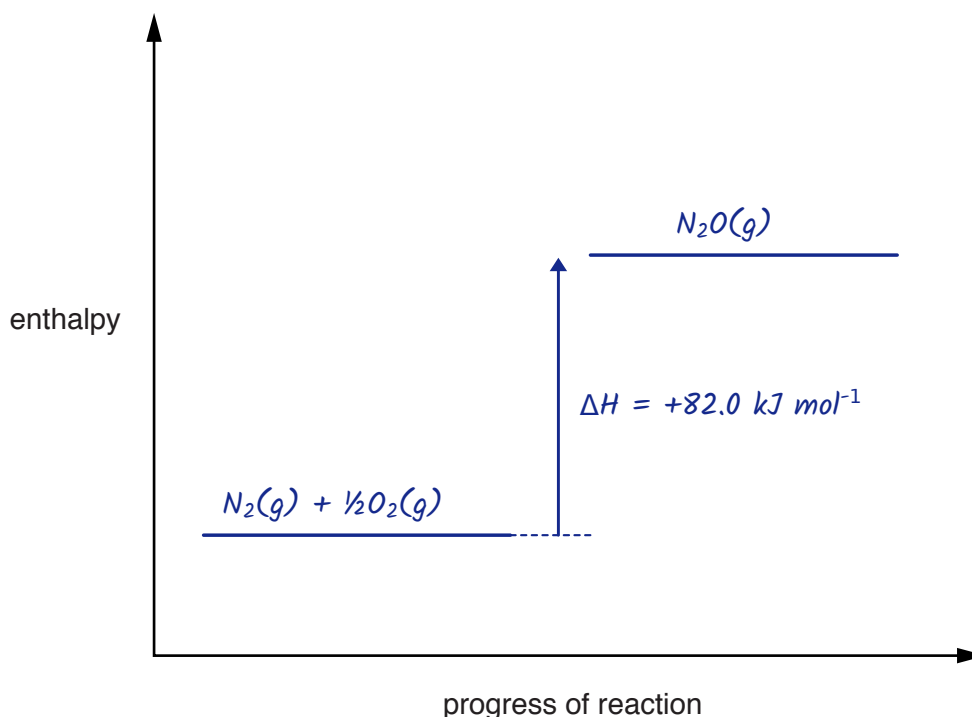
More energy is required to break the bonds in N_2 (strong $\text{N}\equiv\text{N}$) and O_2 than is released by making the bonds in NO.

[1]

- (ii) Draw a fully labelled enthalpy profile diagram to represent the enthalpy change of formation of N_2O .

The formulae, with state symbols, of the reactants and products should be included as part of the diagram.

You are **not** expected to show the activation energy for the reaction.



[2]

- (b) N_2O is supplied as a compressed gas in steel cylinders for use as an anaesthetic. The cylinders are stored at 20.0°C .

Calculate the gas pressure, in Pa, in a 2.32 dm^3 steel cylinder containing 187 g of N_2O gas.

Give your answer in standard form to **three** significant figures.

$$M(\text{N}_2\text{O}) = 44.0 \text{ g mol}^{-1}, \text{ so } n(\text{N}_2\text{O}) = 187 \div 44.0 = 4.25 \text{ mol}$$

$$V = 2.32 \text{ dm}^3 = 2.32 \times 10^{-3} \text{ m}^3; \quad T = 20.0 + 273 = 293 \text{ K}$$

$$p = nRT \div V = (4.25 \times 8.314 \times 293) \div (2.32 \times 10^{-3})$$

$$p = 4.46 \times 10^6 \text{ Pa}$$

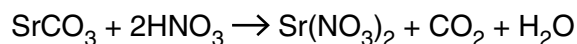
pressure = ... 4.46×10^6 Pa [4]

- (c) NO radicals catalyse the breakdown of ozone in the stratosphere.

Write **two** equations to show how NO radicals catalyse this breakdown.



- 5 A student investigates the reaction between strontium carbonate and dilute nitric acid.



The rate of reaction is determined from the loss in mass over a period of time.

- (a) (i) Explain why there is a loss in mass during the reaction.

Carbon dioxide gas is produced and given off (escapes) from the container. [1]

- (ii) An excess of strontium carbonate, SrCO_3 , is mixed with 20.0 cm^3 of 1.25 mol dm^{-3} nitric acid, HNO_3 .

Calculate the mass of SrCO_3 that reacts with the HNO_3 .

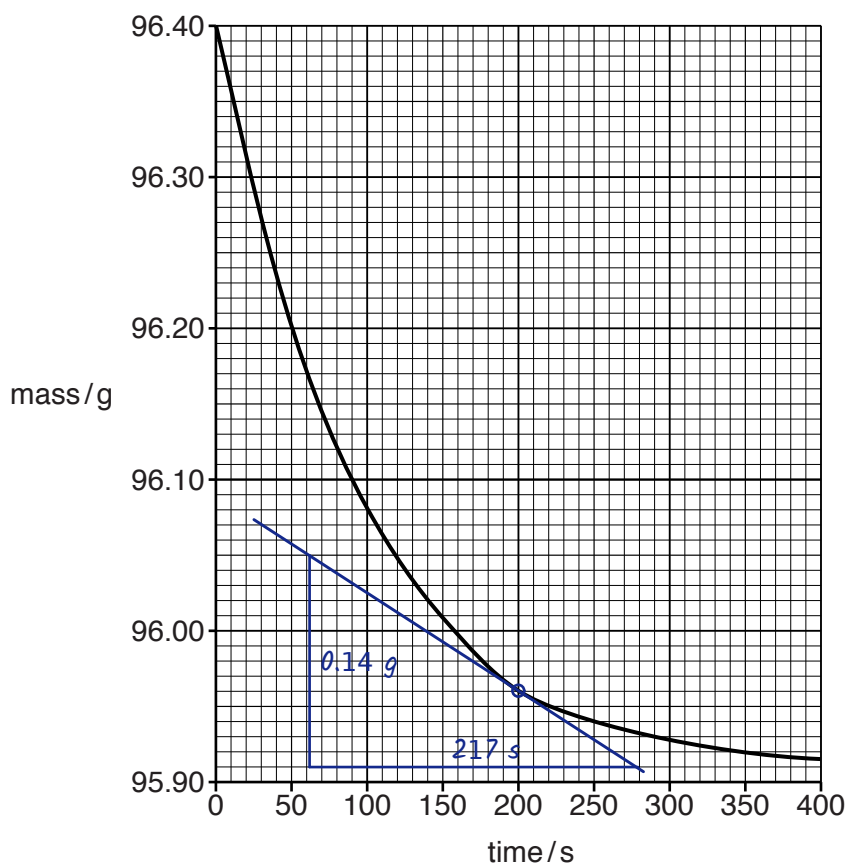
$$n(\text{HNO}_3) = 1.25 \times 20.0 \div 1000 = 0.0250\text{ mol}$$

$$n(\text{SrCO}_3) = 0.0250 \div 2 = 0.0125\text{ mol}$$

$$\text{mass} = 0.0125 \times 147.6 = 1.845\text{ g}$$

mass = ...1.85..... g [3]

- (b) The student plots a graph of total mass (reagents + container) against time.



- (i) Describe and explain the change in the rate of the reaction during the first 200 seconds of the experiment.

The rate decreases (the reaction slows down) because the concentration of nitric acid decreases as reactants are used up, so there are less frequent collisions (fewer collisions per second). [2]

- (ii) Using the graph, calculate the rate of reaction, in g s^{-1} , at 200 seconds.

Show your working on the graph.

Tangent drawn to the curve at 200 s (see graph).

gradient = change in mass $\div$ change in time

$$= (96.05 - 95.91) \div (279 - 62)$$

$$= 0.14 \div 217 = 6.45 \times 10^{-4} \text{ g s}^{-1}$$

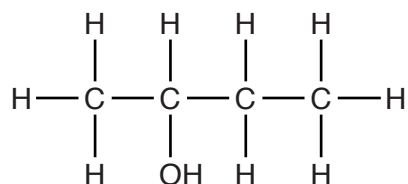
rate of reaction = $6.45 \times 10^{-4} \text{ g s}^{-1}$ [2]

- (c) Outline a method that could be used to obtain the results that are plotted on the graph.

Your answer should include the apparatus required and the procedure for the experiment.

Apparatus: conical flask, (top-pan) balance and stopwatch.
Put the nitric acid in the conical flask on the balance, add the strontium carbonate and start the stopwatch immediately.
Record the total mass every 30 s (at regular time intervals of 30 s) until 400 s. [3]

- 6 This question is about the properties and reactions of butan-2-ol.



Some properties of butan-2-ol are listed in the table.

Melting point	-115 °C
Boiling point	99.5 °C

- (a) Why is butan-2-ol classified as a secondary alcohol?

The -OH group is attached to a carbon atom that is attached to two other carbon atoms (alkyl groups) and one hydrogen atom. [1]

- (b) The shape around the oxygen atom in butan-2-ol is non-linear.

Predict the C–O–H bond angle and explain this shape.

bond angle*104.5°*.....

explanation *The O atom has two bonding pairs and two lone pairs of electrons around it.*

The electron pairs repel each other as far apart as possible, and lone pairs repel more than bonding pairs, so the angle is less than 109.5°.

..... [4]

- (c) Butan-2-ol can be oxidised by heating with an oxidising agent.

- (i) Write an equation for the reaction.

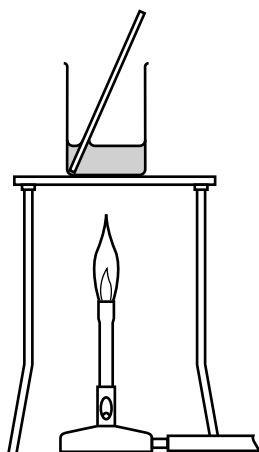
Use [O] to represent the oxidising agent and show the structure of the organic product.



(product: butanone, $\text{CH}_3\text{COCH}_2\text{CH}_3$)

[2]

- (ii) A student plans to carry out this oxidation using the apparatus shown in the diagram.



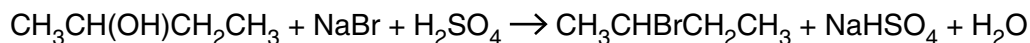
Give **one** reason why the apparatus is **not** suitable and describe a more suitable way of carrying out this oxidation.

Butan-2-ol is volatile and flammable, so it would evaporate (boil away)

from the open beaker.

Instead heat under reflux: round-bottomed flask, vertical condenser. [2]

- (d) 20.2 g of butan-2-ol is reacted with excess sodium bromide and sulfuric acid.



25.2 g of $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$ is formed.

Calculate the percentage yield of $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$.

$$n(\text{butan-2-ol}) = 20.2 \div 74.0 = 0.273 \text{ mol}$$

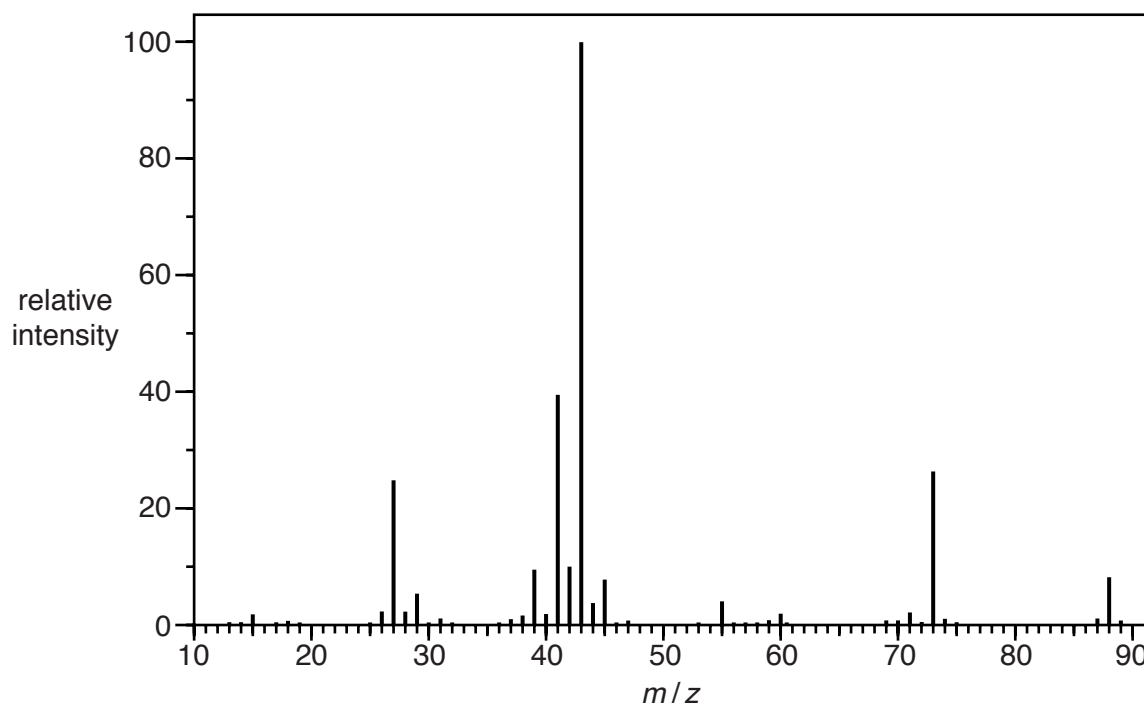
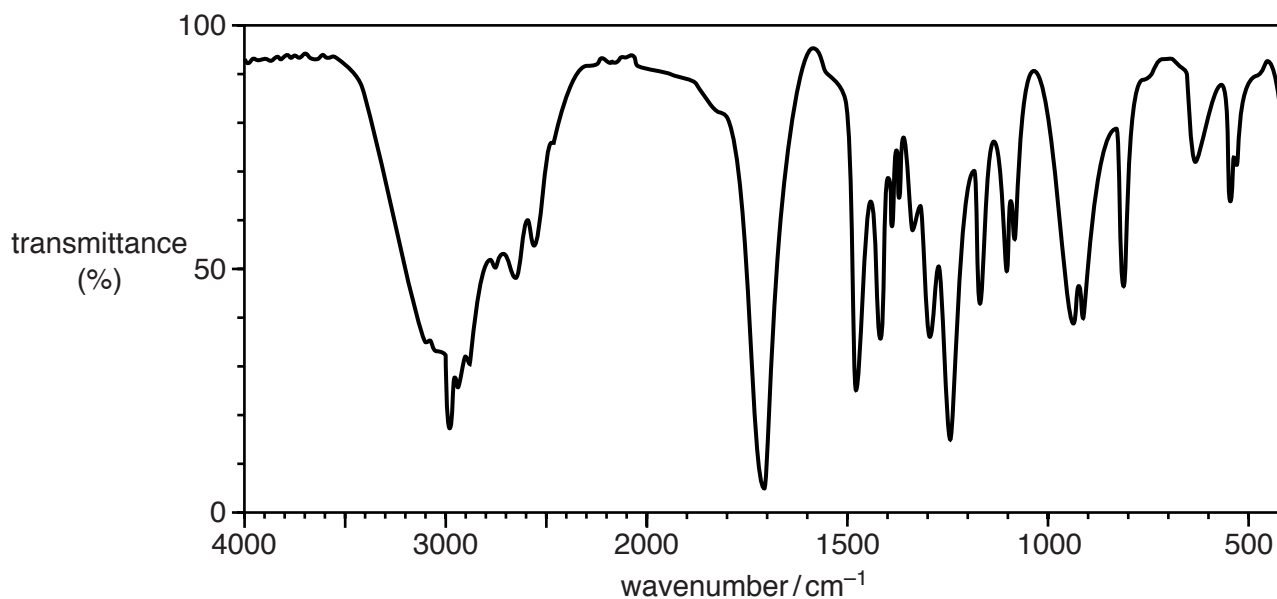
$$n(\text{CH}_3\text{CHBrCH}_2\text{CH}_3) = 25.2 \div 136.9 = 0.184 \text{ mol}$$

$$\text{percentage yield} = 0.184 \div 0.273 \times 100 = 67.4\%$$

percentage yield = ...67.4..... % [3]

- 7* Organic compound **C** has the following percentage composition by mass:
C, 54.5%; H, 9.1%; O, 36.4%.

The infrared spectrum and mass spectrum of compound **C** are shown below.



In the mass spectrum, a secondary carbocation is responsible for the peak with the greatest relative intensity.

Identify compound **C**.

In your answer you should make clear how your conclusion is linked to all the evidence.

Molecular formula:

$$C : H : O = 54.5/12.0 : 9.1/1.0 : 36.4/16.0 = 4.54 : 9.1 : 2.28$$

$\div 2.28$ gives $2 : 4 : 1$, so the empirical formula is C_2H_4O ($M_r = 44.0$).

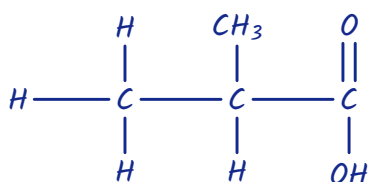
Mass spectrum: the molecular ion peak M^+ is at $m/z = 88$, and $88 \div 44.0 = 2$, so the molecular formula is $C_4H_8O_2$.

IR spectrum: the broad absorption at about 2500 to 3300 cm^{-1} is $O-H$ (carboxylic acid) and the strong absorption at about 1710 cm^{-1} is $C=O$.

So **C** is a carboxylic acid, C_3H_7COOH : either butanoic acid, $CH_3CH_2CH_2COOH$, or 2-methylpropanoic acid, $(CH_3)_2CHCOOH$.

Mass spectrum: the peak with the greatest relative intensity is at $m/z = 43$, which is $C_3H_7^+$. This is a secondary carbocation, so it must be $(CH_3)_2CH^+$, i.e. $CH_3C^+HCH_3$. Butanoic acid would give the primary $CH_3CH_2CH_2^+$ instead.

So compound **C** is 2-methylpropanoic acid, $(CH_3)_2CHCOOH$:



This fits all the evidence: $C_4H_8O_2$ ($M^+ = 88$), $O-H$ and $C=O$ in the IR, and the secondary carbocation $(CH_3)_2CH^+$ at $m/z = 43$; the peak at $m/z = 45$ is $COOH^+$.

[6]

END OF QUESTION PAPER

[illegible]

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