

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname *StemUp Model Solution*

Forename(s)

Candidate signature

I declare this is my own work.

INTERNATIONAL AS CHEMISTRY (9620)

Unit 2: Organic 1 and Physical 1

Tuesday 13 May 2025

07:00 GMT

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
TOTAL	



J U N 2 5 C H O 2 0 1

Answer **all** questions in the spaces provided.

0 1

Crude oil is a mixture of hydrocarbons.

Crude oil is separated into fractions by fractional distillation.

0 1 . 1

Give the meaning of hydrocarbon and of fraction.

[2 marks]

Hydrocarbon A compound containing hydrogen and carbon atoms only.

Fraction A mixture of compounds (hydrocarbons) with similar boiling points.

0 1 . 2

Hydrocarbons are burned to generate electricity.

During the combustion of hydrocarbons, some sulfur-containing compounds are formed.

Identify a reagent used to remove these sulfur-containing compounds.

Explain why these sulfur-containing compounds must be removed.

[2 marks]

Reagent Calcium oxide, CaO (or calcium carbonate, CaCO₃)

Explanation SO₂ is toxic and it dissolves in rain to form acid rain, so it must be removed.



The fractions that contain long chain molecules can be cracked to form short chain molecules.

0 1 . 3

Write an equation to show how one molecule of $C_{12}H_{26}$ can be cracked to form two molecules of C_4H_8 and one molecule of another hydrocarbon.

State **two** conditions used in this reaction.

[2 marks]

Equation $C_{12}H_{26} \rightarrow 2C_4H_8 + C_4H_{10}$

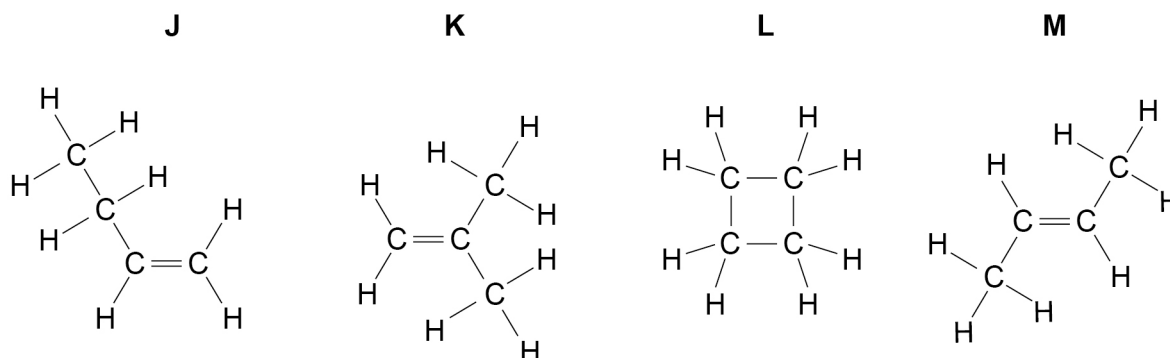
Condition 1 High temperature (about 700 to 900 °C)

Condition 2 High pressure

0 1 . 4

Figure 1 shows four isomers with the molecular formula C_4H_8

Figure 1



Identify the isomer(s) that show(s) *E-Z* isomerism.

Identify the isomer(s) that react with $Br_2(aq)$

[2 marks]

E-Z isomerism M

Reacts with $Br_2(aq)$ J, K and M

Question 1 continues on the next page

Turn over ►



0 1 . 5

Write an equation for the incomplete combustion of C_4H_8 to form carbon monoxide and one other product.

[1 mark]



0 1 . 6

Carbon monoxide and oxides of nitrogen can be removed from the exhaust gases of internal combustion engines in a catalytic converter.

A catalytic converter contains a thin layer of catalyst.

Write an equation to show how these gases are removed in a catalytic converter.

Explain why a thin layer of catalyst is used.

[2 marks]

Equation $2CO + 2NO \rightarrow 2CO_2 + N_2$

Explanation *A thin layer gives a larger surface area of catalyst for the gases to react on, and less of the expensive, rare metal is needed.*



Turn over for the next question

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ANSWER IN THE SPACES PROVIDED**

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0 5

0 2

Propane reacts with Cl_2 to produce 1-chloropropane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$

0 2 . 1

In the first stage of the mechanism, the Cl_2 molecule breaks into two $\text{Cl}^\cdot$ free radicals.

State the condition needed for this to happen.

[1 mark]

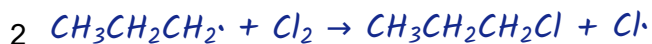
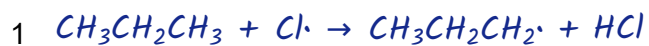
UV light (ultraviolet radiation)

0 2 . 2

Write equations for the **two** propagation steps in the formation of $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$

Use structural formulas in your equations.

[2 marks]



0 2 . 3

Write an equation for the termination step that forms the product $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$

[1 mark]



0 2 . 4

A different alkane reacts with chlorine to produce a chloroalkane with $M_r = 127.0$

The chloroalkane contains 37.8% of carbon and 6.3% of hydrogen by mass.

Calculate the molecular formula of the chloroalkane.

[4 marks]

$$\% \text{ Cl} = 100 - 37.8 - 6.3 = 55.9\%$$

$$\text{C: } 37.8 \div 12.0 = 3.15 \quad \text{H: } 6.3 \div 1.0 = 6.3 \quad \text{Cl: } 55.9 \div 35.5 = 1.57$$

$$\div \text{ smallest (1.57): } \text{C} = 2 \quad \text{H} = 4 \quad \text{Cl} = 1$$

$$\text{empirical formula} = \text{C}_2\text{H}_4\text{Cl}$$

$$M_r \text{ of } \text{C}_2\text{H}_4\text{Cl} = 24.0 + 4.0 + 35.5 = 63.5$$

$$127.0 \div 63.5 = 2$$

$$\text{molecular formula} = 2 \times \text{C}_2\text{H}_4\text{Cl} = \text{C}_4\text{H}_8\text{Cl}_2$$

Molecular formula $\text{C}_4\text{H}_8\text{Cl}_2$

8

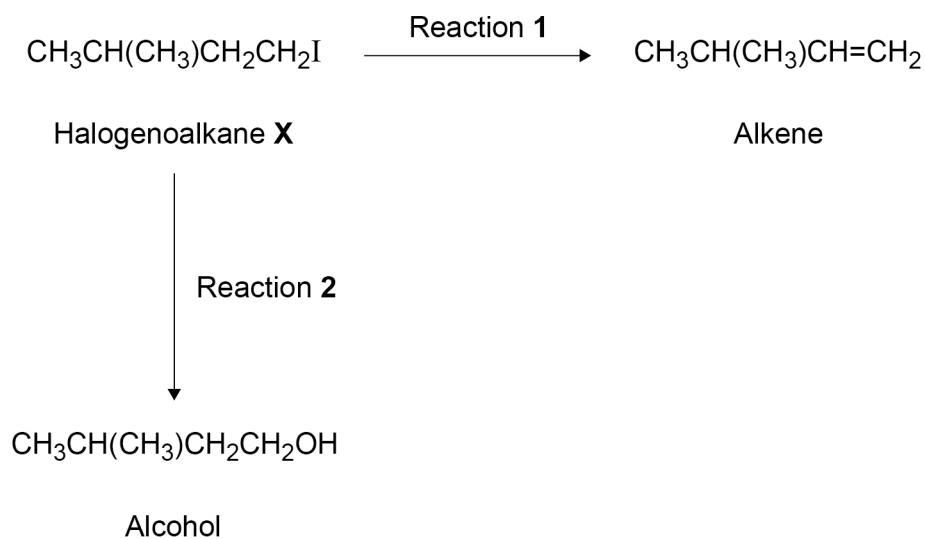
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0 3

Figure 2 shows two reactions of halogenoalkane X.

Figure 2



0 3 . 1

Use IUPAC rules to name X.

[1 mark]

1-iodo-3-methylbutane

0 3 . 2

Name the mechanism for Reaction 1.

Identify the reagent that reacts with X in Reaction 1.

State the condition needed for Reaction 1.

[3 marks]

Name of mechanism EliminationReagent NaOH (or KOH)Condition Dissolved in ethanol (ethanolic), heat under reflux

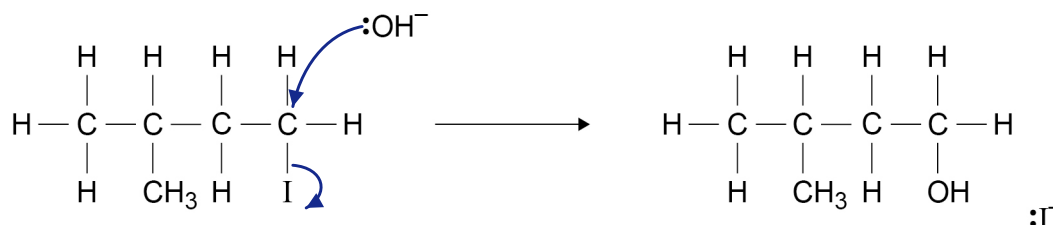
0 3 . 3 Name the mechanism for Reaction 2.

Complete the mechanism by adding curly arrows.

[2 marks]

Name of mechanism Nucleophilic substitution

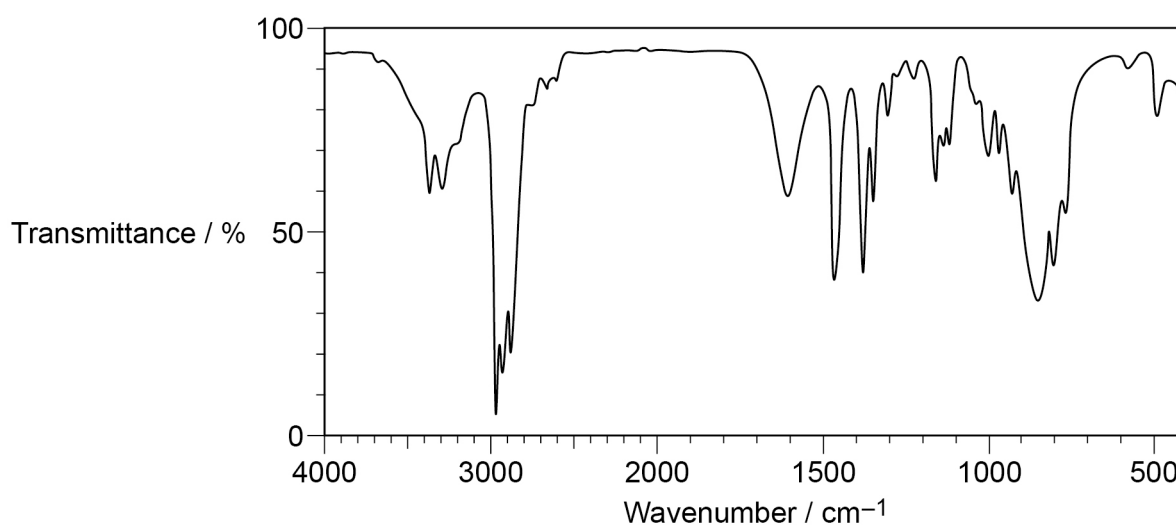
Mechanism



0 3 . 4 In a different reaction, **X** reacts to form another organic compound.

Figure 3 shows the infrared spectrum of this organic compound.

Figure 3



Identify **two** features, between 4000–2000 cm^{-1} in the spectrum, that show that **X** reacted with NH_3 and not KCN

Use data from **Table A** on the Chemistry Data Sheet in your answer.

[2 marks]

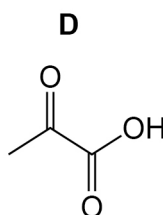
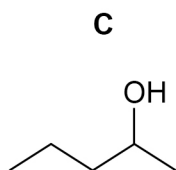
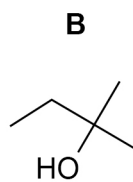
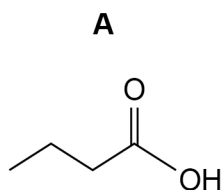
- Broad absorption at 3300 to 3500 cm^{-1} (about 3350 cm^{-1}) due to the N-H bond in an amine.
- No absorption at 2220 to 2260 cm^{-1} , so there is no $\text{C}\equiv\text{N}$ bond (no nitrile).



0 4

Different organic compounds can have the same relative molecular mass.

Compounds **A**, **B**, **C** and **D** have a relative molecular mass of 88.0



These compounds can be distinguished by simple test-tube reactions.

0 4 . 1

Identify a reagent, or combination of reagents, that can be used to distinguish between separate samples of **A** and **B**.

State what is observed.

[3 marks]

Reagent(s) Sodium carbonate solution, $\text{Na}_2\text{CO}_3(\text{aq})$

Observation with **A** Effervescence (bubbles of gas, CO_2) because A is a carboxylic acid.

Observation with **B** No visible change (no reaction).



0 4 . 2

Identify a reagent, or combination of reagents, that can be used to distinguish between separate samples of **B** and **C**.

State what is observed.

[3 marks]

Reagent(s) Acidified potassium dichromate(VI), $K_2Cr_2O_7/H_2SO_4$, warm

Observation with **B** No visible change (stays orange), as B is a tertiary alcohol.

Observation with **C** Orange solution turns green, as C is a secondary alcohol and is oxidised.

0 4 . 3

High resolution mass spectrometry can determine relative molecular masses to four decimal places.

Table 1 shows some precise relative atomic mass values.

Table 1

Atom	Precise relative atomic mass
^1H	1.0079
^{12}C	12.0000
^{16}O	15.9994

Deduce the molecular formulas of **A** and **D**.

Use the data in **Table 1** to show how **A** and **D** can be distinguished from each other.

[3 marks]

Molecular Formula of **A** $C_4H_8O_2$

Molecular Formula of **D** $C_3H_4O_3$

How **A** and **D** can be distinguished from each other Precise M_r

$$A = 48.0000 + 8.0632 + 31.9988 = 88.0620$$

$$D = 36.0000 + 4.0316 + 47.9982 = 88.0298$$

The precise M_r values are different (88.0620 and 88.0298), so A and D give molecular ion peaks at different m/z values.

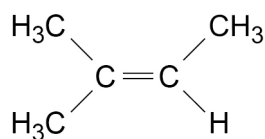
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0 5

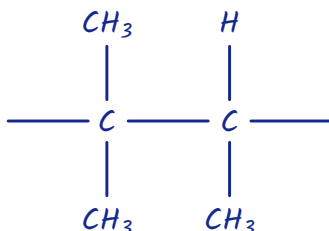
This question is about alkenes.

The structure of 2-methylbut-2-ene is shown.

**0 5 . 1**

2-Methylbut-2-ene can form an addition polymer.

Draw the repeating unit of the polymer.

[1 mark]**0 5 . 2**

Explain why poly(2-methylbut-2-ene) melts at a higher temperature than 2-methylbut-2-ene.

[1 mark]

The polymer molecules are much bigger, so there are stronger (more)

van der Waals' forces between the molecules, which need more energy to

overcome.



0 5 . 3 2-Methylbut-2-ene can react with HBr in an electrophilic addition mechanism.

Explain why HBr is attracted to the double bond in the alkene.

[3 marks]

Br is more electronegative than H, so HBr is polar: $H^{\delta+}-Br^{\delta-}$ (it has a permanent dipole).

The $C=C$ double bond is an area of high electron density (electron rich, due to the π bond).

The electrons in the double bond are attracted to the $H^{\delta+}$ of HBr, so HBr acts as an electrophile.

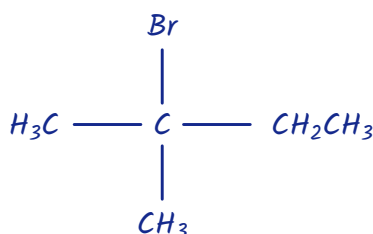
0 5 . 4 When 2-methylbut-2-ene reacts with HBr, a major and minor product are formed.

Draw the structure of the major product.

Explain why there is a higher yield of the major product.

[3 marks]

Structure



Explanation *The major product (2-bromo-2-methylbutane) forms via a tertiary (3°) carbocation, the minor product via a secondary (2°) carbocation.*

The tertiary carbocation is more stable than the secondary carbocation because it has more (three) alkyl groups, which are electron releasing (positive inductive effect), so more of the major product forms.

Turn over ►



0	5	.	5
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The major and minor products are position isomers.

Explain how infrared spectroscopy can be used to distinguish between the major and minor products from this reaction.

[2 marks]

*Both have the same functional groups, so compare the fingerprint region
(below 1500 cm^{-1}) of each spectrum.*

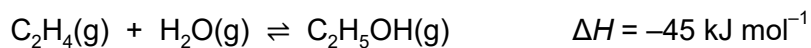
*Compare it with the spectra of known samples (a database) to get an
exact match.*

10



0 6

Ethanol can be produced by the reaction of ethene with steam.



0 6 . 1

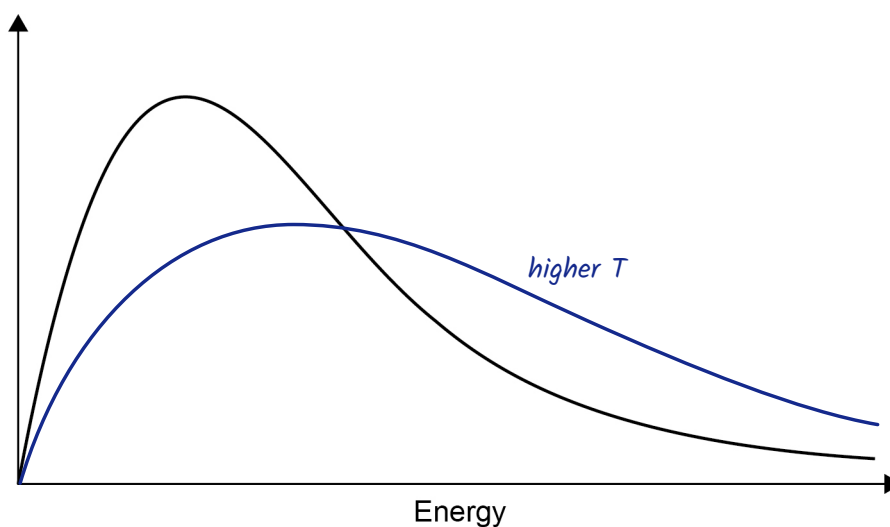
Give an expression for the equilibrium constant, K_c , for this reaction.Deduce the units of K_c

[2 marks]

$$K_c = \frac{[\text{C}_2\text{H}_5\text{OH}]}{[\text{C}_2\text{H}_4][\text{H}_2\text{O}]}$$

Units $\text{mol}^{-1} \text{ dm}^3$

Figure 4 shows the Maxwell–Boltzmann distribution of molecular energies for a sample of ethene at a given temperature.

Figure 4

0 6 . 2

State the label for the y-axis.

[1 mark]

Number (fraction) of molecules with a given energy

0 6 . 3

Draw, on **Figure 4**, a distribution of molecular energies for the same sample of gas at a higher temperature.

[2 marks]

Turn over ►



0 6 . 4

Concentrated phosphoric acid is used as a catalyst in the reaction of ethene with steam.

Explain, in general terms, how a catalyst increases the rate of a reaction.

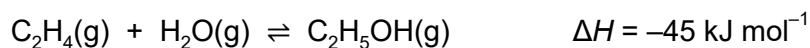
[2 marks]

A catalyst provides an alternative reaction route (mechanism) with a lower activation energy.

So more molecules have energy $\geq E_a$, giving more frequent successful collisions.

0 6 . 5

A pressure of 6.1 MPa is used in the reaction.



Predict the effect of using a higher pressure on the rate of reaction and on the equilibrium yield of ethanol.

[2 marks]

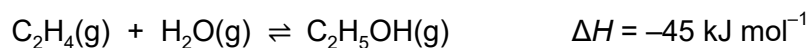
Effect on rate *The rate increases, as the gas molecules are closer together so there are more frequent collisions.*

Effect on yield *The yield of ethanol increases, as there are fewer moles of gas on the right.*



0 6 . 6

A temperature of 300 °C is used in the reaction.



Explain why a higher temperature increases the rate of reaction.

State and explain the effect of a higher temperature on the equilibrium yield of ethanol.

Justify the use of 300 °C in the reaction.

[5 marks]

Why higher temperature increases rate *More molecules have energy greater than or equal to E_a , and they move faster, so there are more frequent successful collisions.*

Effect of higher temperature on yield *The yield decreases.*

Explanation *The forward reaction is exothermic (ΔH is negative), so the reverse reaction is endothermic.*

A higher temperature shifts the equilibrium to the left, in the endothermic direction, to oppose the increase in temperature.

Justification *300 °C is a compromise temperature: a lower temperature would give a higher yield but the rate would be too slow, and a higher temperature would give a faster rate but a lower yield. It gives a reasonable rate with a suitable yield.*

14

Turn over for the next question**Turn over ►**

07

3-Methylbutan-1-ol, $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{OH}$, is oxidised to an aldehyde.

Method

- The mass of an empty test tube is measured.
- Some 3-methylbutan-1-ol, acidified potassium dichromate(VI) and three anti-bumping granules are added to a flask.
- A condenser is connected to the flask and the flask is heated with a water bath.
- The distilled liquid products are collected in the test tube.
- The total mass of the liquid products is measured.
- The total volume of the liquid products is measured.

07.1

The total mass of the liquid products is 11.0 g
The total uncertainty in the mass measurement is ± 0.005 g

Calculate the percentage uncertainty in the mass recorded of liquid products.

[1 mark]

two mass readings, so uncertainty = $2 \times 0.005 = 0.010$ g

% uncertainty = $(0.010 \div 11.0) \times 100 = 0.091\%$

Percentage uncertainty 0.091%

07.2

Why must anti-bumping granules be added to the flask?

Tick (✓) **one** box.

[1 mark]

To act as a catalyst for the reaction

☐

To prevent formation of large bubbles

☒

To prevent the reagents from boiling

☐

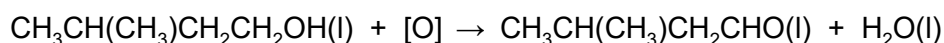

0 7 . 3

State why a Bunsen burner is **not** used to heat the flask.

[1 mark]

3-Methylbutan-1-ol (the alcohol) is flammable, and a naked flame could set it alight.

0 7 . 4

10.0 cm³ of CH₃CH(CH₃)CH₂CH₂OH (*M*_r = 88.0) are used in the reactionDensity of CH₃CH(CH₃)CH₂CH₂OH = 0.809 g cm⁻³Density of CH₃CH(CH₃)CH₂CHO = 0.785 g cm⁻³

Calculate the maximum volume of CH₃CH(CH₃)CH₂CHO that can be collected in this experiment.

Give your answer to 3 significant figures.

[3 marks]

$$\text{mass of alcohol} = 10.0 \times 0.809 = 8.09 \text{ g}$$

$$\text{moles of alcohol} = 8.09 \div 88.0 = 0.0919 \text{ mol}$$

$$1 : 1, \text{ so moles of aldehyde} = 0.0919 \text{ mol}$$

$$M_r \text{ of } \text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CHO} = 86.0$$

$$\text{mass of aldehyde} = 0.0919 \times 86.0 = 7.906 \text{ g}$$

$$\text{volume} = 7.906 \div 0.785 = 10.07 = 10.1 \text{ cm}^3$$

Volume of CH₃CH(CH₃)CH₂CHO 10.1 cm³

Turn over ►



0 7 . 5

3-Methylbutan-1-ol ($\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{OH}$) can also react with hot concentrated sulfuric acid in an elimination reaction to form an alkene.

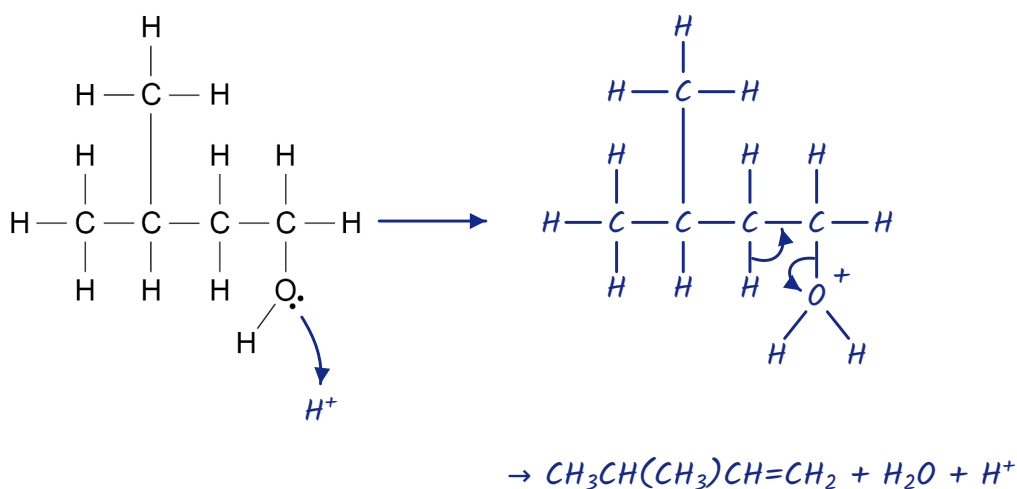
Explain why concentrated sulfuric acid is a catalyst in this reaction.

Outline the mechanism for this reaction.

[4 marks]

Explanation It is used up in the first step but regenerated (H^+ released) at the end, so it is not in the overall equation.

Mechanism



END OF QUESTIONS



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