Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

AS CHEMISTRY

Paper 2 Organic and Physical Chemistry

Tuesday 23 May 2023 Morning Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- 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.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
Section B	
TOTAL	

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Advice

You are advised to spend about 65 minutes on **Section A** and 25 minutes on **Section B**.

Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 This question is about the analysis of organic compounds.

For each pair of compounds in Questions **01.1** and **01.2**, give a reagent (or combination of reagents) that could be added separately to each compound in a single reaction to distinguish between them.

State what is observed in each case.

0 1 . 1 $CH_3CH_2CH_2CHO$ and $CH_3CH_2CH(OH)CH_3$

[3 marks]

Reagent(s) _____

Observation with $CH_3CH_2CH_2CHO$ _____

_____

Observation with $CH_3CH_2CH(OH)CH_3$ _____

_____

0 1 . 2 Cyclohexane and cyclohexene

[3 marks]

Reagent(s) _____

Observation with cyclohexane _____

_____

Observation with cyclohexene _____

_____

Do not write outside the box

0 1 . 3 **Table 1** gives the precise relative molecular masses (M_r) of some organic compounds measured using high resolution mass spectrometry.

Table 1

Molecular formula	C_5H_{12}	C_5H_{10}	C_6H_6
M_r	72.1416	70.1260	to be calculated

Use these data to find the relative atomic masses (A_r) of hydrogen and carbon.
Give your answers to 4 decimal places.

Use these calculated A_r values to find the relative molecular mass (M_r) of C_6H_6
Give your answer to 4 decimal places.

[3 marks]

A_r of hydrogen _____

A_r of carbon _____

M_r of C_6H_6 _____

9

Turn over ►

Do not write outside the box

0 2 This question is about fuels.

0 2 . 1 Crude oil is separated into fractions by fractional distillation.

State the meaning of the term 'fraction' in this context.

[1 mark]

0 2 . 2 Petrol for cars contains branched and cyclic alkanes produced by catalytic cracking.

Identify the catalyst used in this process.

[1 mark]

0 2 . 3 3-Ethyl-4-methylhexane is a branched alkane in petrol.

Draw the skeletal formula of this alkane.

[1 mark]

0 2 . 4 Give the equation for the complete combustion of 3-ethyl-4-methylhexane.
Use the molecular formula for 3-ethyl-4-methylhexane in your equation.

[2 marks]

Do not write outside the box

0 2 . 5 Carbon dioxide is a product from the combustion of petrol in cars. Carbon dioxide acts as a greenhouse gas when it absorbs infrared radiation.

Give **one** reason why carbon dioxide absorbs infrared radiation.

[1 mark]

0 2 . 6 Nitrogen monoxide (NO) is formed when petrol is burned in cars.

State **one** environmental problem that NO causes.

State what is used to remove NO from the exhaust gases formed in petrol-fuelled cars.

[2 marks]

Environmental problem _____

Removal of NO _____

0 2 . 7 Petrol sold in the UK contains 10% bioethanol. Bioethanol is ethanol made from crops by fermentation and is considered to be carbon-neutral.

State what is meant by the term 'carbon-neutral'.

[1 mark]

9

Turn over for the next question

Do not write outside the box

0 3 This question is about reactions of halogenoalkanes with hydroxide ions.

0 3 . 1 Outline the mechanism for the nucleophilic substitution reaction of 1-bromobutane with sodium hydroxide.

[2 marks]

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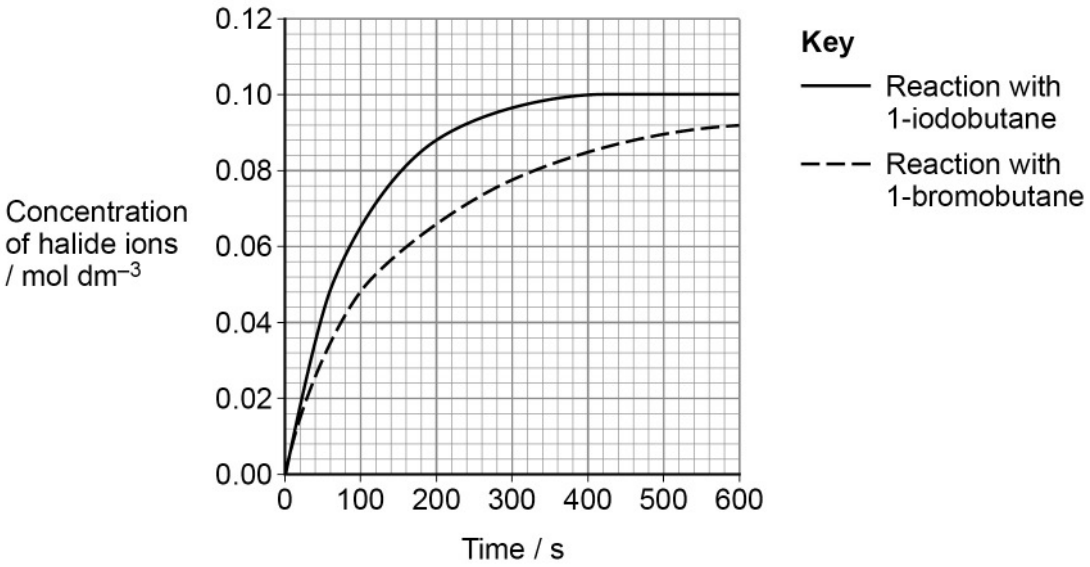
A student investigated the rate of nucleophilic substitution of halogenoalkanes with hydroxide ions.

Identical concentrations of 1-bromobutane and 1-iodobutane were reacted separately with sodium hydroxide solution under the same conditions.

The concentration of halide ions was monitored during each experiment.

Figure 1 shows the student's results.

Figure 1



0 3 . 2 State how **Figure 1** shows that the rate of reaction of 1-iodobutane is faster than the rate of reaction of 1-bromobutane.

State why the rates are different.

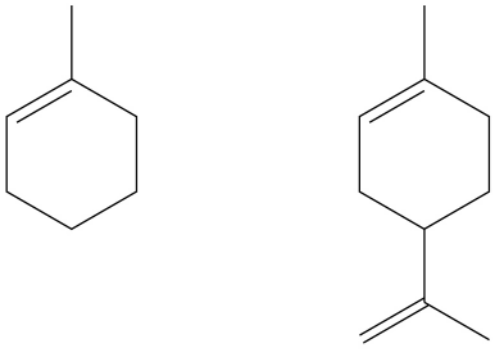
[2 marks]

4

Turn over for the next question

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0 4 1-Methylcyclohexene and limonene are cyclic alkenes with a citrus smell.
1-Methylcyclohexene is manufactured and used in the chemical industry.
Limonene is found naturally in orange peel.



1-methylcyclohexene **limonene**

0 4 . 1 1-Methylcyclohexene reacts with HBr to form two structural isomers.
The major product is 1-bromo-1-methylcyclohexane.

Name and outline the mechanism for the formation of this major product.

[5 marks]

Name of mechanism _____

Outline of mechanism

Do not write outside the box

0 4 . 2 Draw the skeletal formula of the minor product formed in the reaction in Question **04.1**.

Explain why the products are formed in different amounts.

[4 marks]

Skeletal formula

Explanation _____

0 4 . 3 Draw the structure of the major product when an excess of HBr reacts with limonene.

[1 mark]

10

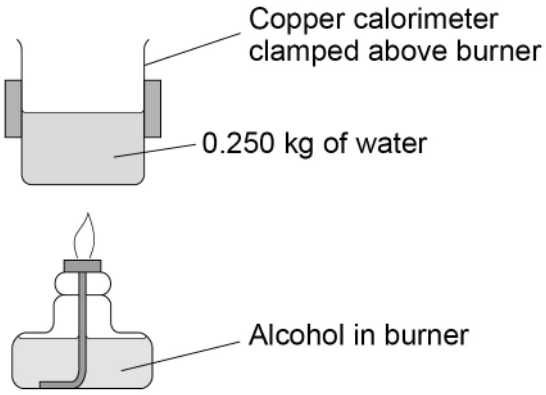
Turn over for the next question

Do not write outside the box

0 5 A student is provided with a 0.0300 mol sample of an alcohol.
The student decides to identify the alcohol using an experiment to determine its enthalpy of combustion.

Figure 2 shows the apparatus used.

Figure 2



0 5 . 1 The student finds that when all the alcohol is burned, the temperature of the water increases from 18.9 °C to 78.1 °C

Calculate the enthalpy of combustion, in kJ mol^{-1}, for the alcohol.
The specific heat capacity of water, c = 4.18 J g^{-1} K^{-1}

[3 marks]

Enthalpy of combustion _____ kJ mol^{-1}

Do not write outside the box

0 5 . 2 **Table 2** shows the enthalpies of combustion of some alcohols.

Table 2

Alcohol	**Enthalpy of combustion / kJ mol^{-1}**
Ethanol	–1367
Propan-1-ol	–2021
Butan-1-ol	–2676

Explain how your answer to Question **05.1** suggests that the alcohol is butan-1-ol.

(If you have been unable to obtain an answer for Question **05.1**, assume that the answer is –2120 kJ mol^{-1})

[2 marks]

Question 5 continues on the next page

Do not write outside the box

0 5 . 3 The equation for the complete combustion of gaseous pentan-1-ol is shown.

$$CH_3(CH_2)_3CH_2OH(g) + 7\tfrac{1}{2}O_2(g) \rightarrow 5\,CO_2(g) + 6\,H_2O(g) \qquad \Delta H = -3388 \text{ kJ mol}^{-1}$$

Table 3 shows some bond enthalpy data.

Table 3

	C–H	C–O	O–H	C=O	O=O
Bond enthalpy / kJ mol^{-1}	412	360	463	805	496

Use data from **Table 3** to calculate a value for the mean C–C bond enthalpy in pentan-1-ol.

[3 marks]

C–C bond enthalpy _____ kJ mol^{-1}

Do not write outside the box

0 5 . 4 The energy stored in fuels can be compared using energy density values measured in kJ dm^{-3}

Calculate the energy density of butan-1-ol.

enthalpy of combustion of butan-1-ol = –2676 kJ mol^{-1}
density of butan-1-ol = 0.810 kg dm^{-3}
relative molecular mass (M_r) of butan-1-ol = 74.0

[2 marks]

Energy density _____ kJ dm^{-3}

10

Turn over for the next question

Do not write outside the box

0 6 This question is about intermolecular forces in some organic compounds.

Table 4 gives some information about three organic compounds.

Table 4

Compound	dichloromethane	tetrachloromethane	propan-1-ol
Boiling point / °C	40	77	97
Polarity of molecules	polar	non-polar	polar

0 6 . 1 State why the C–Cl bonds in dichloromethane and tetrachloromethane are polar.

[1 mark]

0 6 . 2 Suggest why tetrachloromethane molecules are non-polar.

[1 mark]

0 6 . 3 Explain why tetrachloromethane has a higher boiling point than dichloromethane.

[2 marks]

Do not write outside the box

0 6 . 4 Propan-1-ol has a higher boiling point than the other two compounds because of hydrogen bonding.

Describe the hydrogen bonding in propan-1-ol.

[2 marks]

6

Turn over for the next question

Do not write outside the box

0 7 This question is about the preparation of 2,3,3-trimethylbut-1-ene.

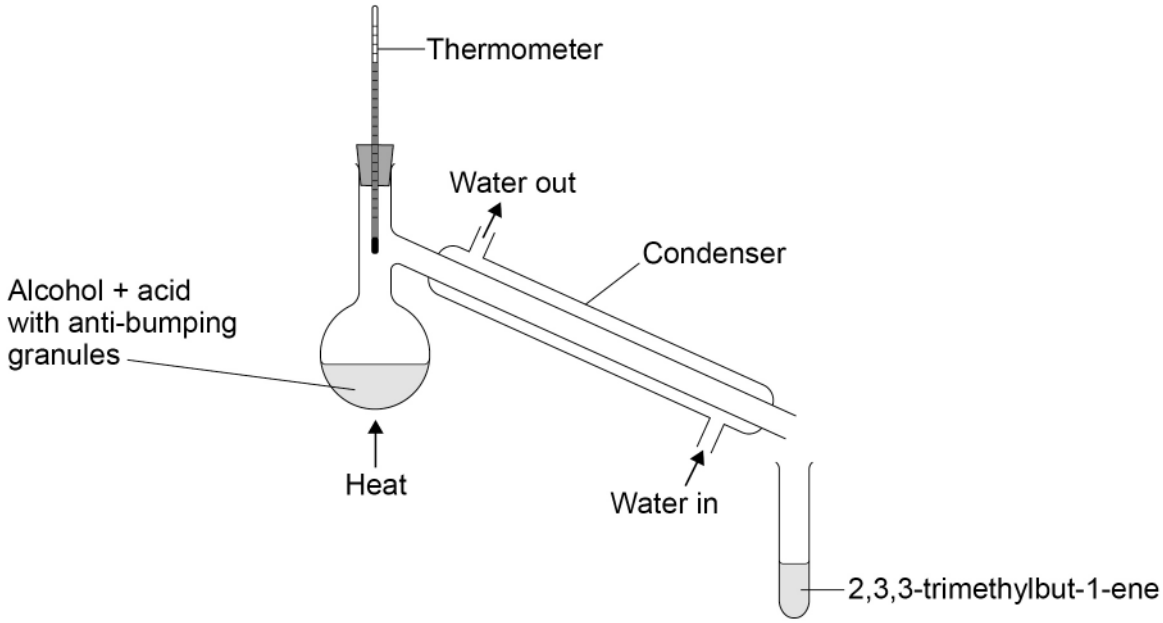


2,3,3-trimethylbutan-1-ol 2,3,3-trimethylbut-1-ene

The preparation is done by heating the alcohol with concentrated phosphoric acid, that acts as a catalyst.

Figure 3 shows the apparatus used.

Figure 3



The distillate is collected in the range 77–82 °C

0 7 . 1 Explain why the water should enter the condenser at the bottom and not at the top.

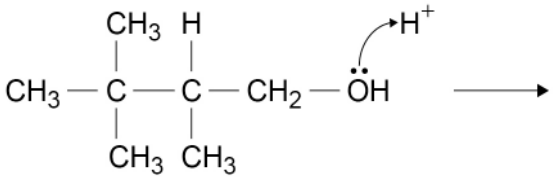
[2 marks]

Do not write outside the box

0 7 . 2 Name and complete the mechanism for this reaction.

[4 marks]

Name of mechanism _____



0 7 . 3 In a similar experiment, 12.0 cm^3 of 2,3,3-trimethylbutan-1-ol (M_r = 116.0) produces 6.12 g of 2,3,3-trimethylbut-1-ene.

Calculate the percentage yield.

density of 2,3,3-trimethylbutan-1-ol = 0.818 g cm^{-3}

[5 marks]

Percentage yield _____

11

Turn over ►

Do not write outside the box

0 8 Draw the Maxwell–Boltzmann distribution curves for a fixed mass of a gas at two different temperatures.
This gas decomposes when heated.

By reference to these distribution curves, explain why the rate of decomposition of this gas increases at higher temperatures.

[6 marks]

Do not write outside the box

6

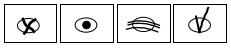
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Section B

Answer **all** questions in this section.

Only **one** answer per question is allowed.
For each question completely fill in the circle alongside the appropriate answer.

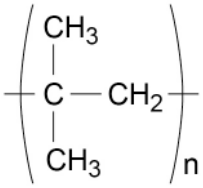
CORRECT METHOD  WRONG METHODS 

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked. Do **not** use additional sheets for this working.

0 9 Which monomer forms this polymer?



[1 mark]

A but-1-ene 

B *E*-but-2-ene 

C *Z*-but-2-ene 

D methylpropene 



Do not write outside the box

1 0 Which equation represents a propagation step in the chlorination of methane?

[1 mark]

A $\bullet H + Cl_2 \rightarrow HCl + \bullet Cl$ ⬭

B $\bullet Cl + CH_4 \rightarrow CH_3Cl + \bullet H$ ⬭

C $\bullet CH_3 + Cl_2 \rightarrow CH_3Cl + \bullet Cl$ ⬭

D $\bullet CH_3 + \bullet Cl \rightarrow CH_3Cl$ ⬭

1 1 Which is the overall equation for the reaction of $CCl_3CH_2CCl_3$ with an excess of chlorine in ultraviolet radiation?

[1 mark]

A $CCl_3CH_2CCl_3 + \frac{1}{2}Cl_2 \rightarrow CCl_3CHClCCl_3 + \frac{1}{2}H_2$ ⬭

B $CCl_3CH_2CCl_3 + Cl_2 \rightarrow CCl_3CHClCCl_3 + HCl$ ⬭

C $CCl_3CH_2CCl_3 + 2\,Cl_2 \rightarrow CCl_3CCl_2CCl_3 + 2\,HCl$ ⬭

D $CCl_3CH_2CCl_3 + Cl_2 \rightarrow CCl_3CCl_2CCl_3 + H_2$ ⬭

1 2 Most scientists believe that ozone in the upper atmosphere should not be allowed to become depleted.

Which is a valid reason for this belief?

[1 mark]

A Ozone absorbs ultraviolet radiation. ⬭

B Ozone helps to prevent global warming. ⬭

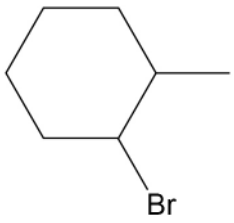
C Ozone helps to remove pollutants such as chloroalkanes. ⬭

D Ozone is an efficient disinfectant. ⬭

Turn over for the next question

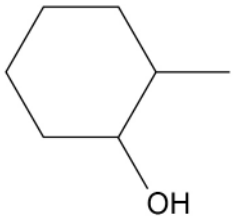
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1 3 Which is **not** a possible product of the reaction of this compound with potassium hydroxide?

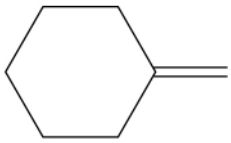


[1 mark]

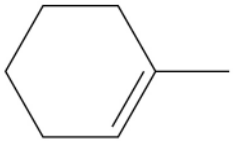
A



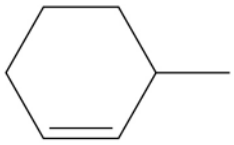
B



C

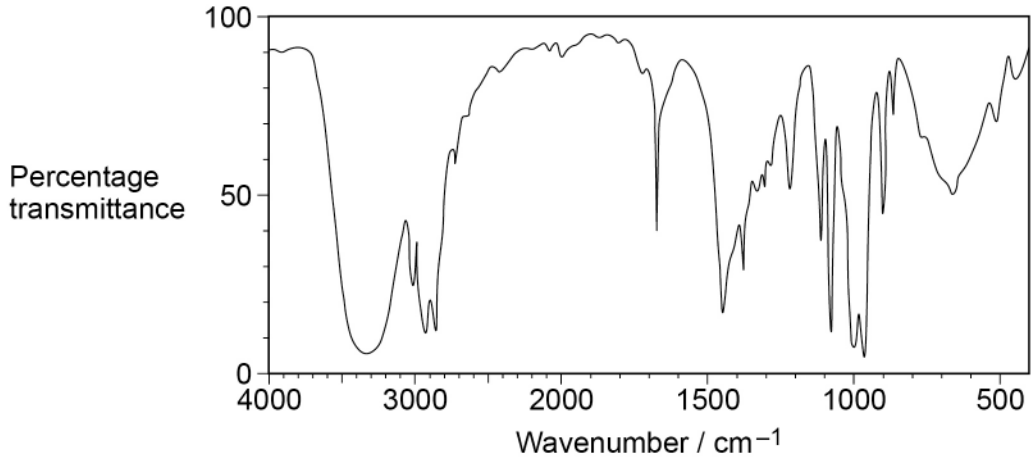


D



Do not write outside the box

1 4 The infrared spectrum of an organic compound is shown.



Which compound could produce this spectrum?

[1 mark]

A but-1-ene ⬭

B but-2-en-1-ol ⬭

C butanoic acid ⬭

D butan-2-ol ⬭

1 5 Which reaction results in an overall change in shape around a carbon atom?

[1 mark]

A oxidation of propanal with acidified potassium dichromate(VI) ⬭

B polymerisation of tetrafluoroethene ⬭

C reaction of bromoethane with an excess of concentrated ammonia ⬭

D reaction of methane with an excess of chlorine in ultraviolet radiation ⬭

Turn over for the next question

Do not write outside the box

1 6 Which statement about the industrial production of ethanol from ethene at 300 °C is correct?

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -46 \text{ kJ mol}^{-1}$$

[1 mark]

A An increase in pressure decreases the equilibrium yield of ethanol. ⬭

B An increase in pressure increases the value of K_c ⬭

C An increase in temperature increases the equilibrium yield of ethanol. ⬭

D An increase in temperature decreases the value of K_c ⬭

1 7 What is the minimum volume, in dm^3, of air needed for the complete combustion of 1 dm^3 of methane?

Assume that air contains 20% of oxygen by volume.

Assume that all volumes are measured at the same temperature and pressure.

[1 mark]

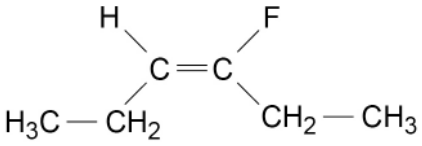
A 1 ⬭

B 2 ⬭

C 5 ⬭

D 10 ⬭

1 8 Which is the IUPAC name for this compound?



[1 mark]

A *E*-3-fluorohex-3-ene ⬭

B *E*-4-fluorohex-3-ene ⬭

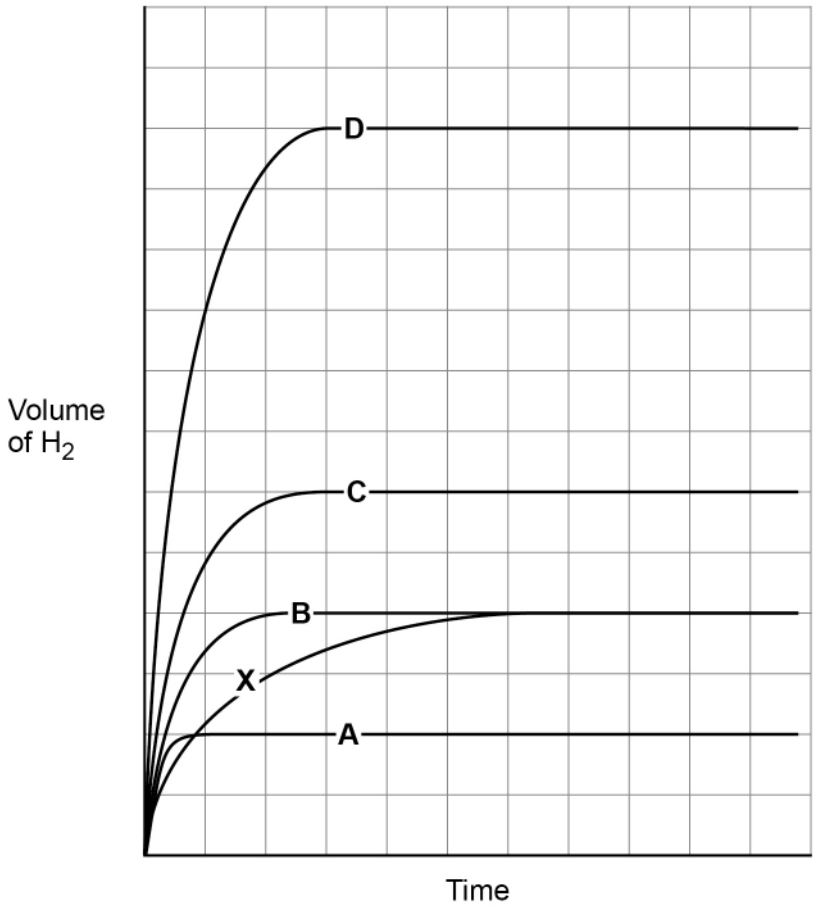
C *Z*-3-fluorohex-3-ene ⬭

D *Z*-4-fluorohex-3-ene ⬭

Do not write outside the box

1 9 Magnesium reacts with an acid to form hydrogen gas.

Line **X** on the graph shows how the volume of hydrogen gas varies with time when 50 cm^3 of 0.50 mol dm^{-3} acid reacts with an excess of magnesium.



The reaction is repeated under the same conditions but using 25 cm^3 of 1.50 mol dm^{-3} acid. The magnesium is in excess.

Which line represents this second reaction?

[1 mark]

A line **A** ⬭

B line **B** ⬭

C line **C** ⬭

D line **D** ⬭

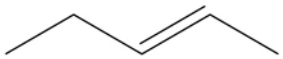
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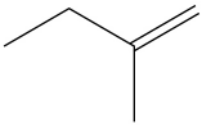
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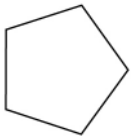
2 0 Which compound has the greatest M_r?

[1 mark]

A  ⬭

B  ⬭

C  ⬭

D  ⬭

2 1 Which compound has the empirical formula C_2H_4O?

[1 mark]

A butanal ⬭

B ethanoic acid ⬭

C ethanol ⬭

D methylpropanoic acid ⬭

2 2 The alcohol $CH_3CH_2CH_2OH$ can be oxidised.

Which compound **cannot** be produced by oxidation of this alcohol?

[1 mark]

A CO_2 ⬭

B CH_3COCH_3 ⬭

C CH_3CH_2CHO ⬭

D CH_3CH_2COOH ⬭

Do not write outside the box

2 3 What is the atom economy for the formation of ethylamine in this reaction?

$$CH_3CH_2Br + 2\,NH_3 \rightarrow CH_3CH_2NH_2 + NH_4Br$$

[1 mark]

A 31.5% ⬭

B 35.7% ⬭

C 36.1% ⬭

D 41.3% ⬭

15

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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