AQA

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 20 May 2025 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 | |
| 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 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 halogenoalkanes.

**0 1 . 1** Halogenoalkanes undergo substitution reactions with nucleophiles such as $CN^-$, $NH_3$ and $OH^-$

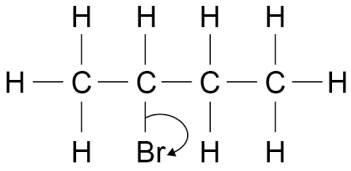
Explain why halogenoalkanes react with nucleophiles.

**[2 marks]**

**0 1 . 2** 2-Bromobutane reacts with ammonia to form $CH_3CH(NH_2)CH_2CH_3$

Complete the mechanism for this reaction.

**[3 marks]**



2-Bromobutane reacts with KOH to give a mixture of products.

**0 1 . 3** Identify the solvent that should be used to ensure that butan-2-ol is the main organic product when 2-brombutane reacts with KOH

**[1 mark]**

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**0 1 . 4** Under different conditions, 2-bromobutane reacts with KOH to form but-1-ene and two other alkenes.

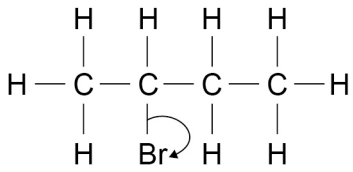
Name and complete the mechanism to form but-1-ene from 2-bromobutane.

Identify the other two alkenes formed.

**[5 marks]**

Name of mechanism _____

Mechanism




Other alkene 1

Other alkene 2

**0 1 . 5** The carbocation $(CH_3)_3C^+$ is formed as an intermediate in the reaction of 2-bromo-2-methylpropane with KCN

Suggest the value of the bond angle around the central C atom in the $(CH_3)_3C^+$ carbocation.

**[1 mark]**

**Question 1 continues on the next page**

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**0 1 . 6** A co-ordinate bond is formed when the $(CH_3)_3C^+$ carbocation reacts with $CN^-$ to form a nitrile.

Explain how this co-ordinate bond is formed during this reaction.

**[2 marks]**

14

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**0 2** Methanol can be made by the reaction of carbon monoxide with hydrogen.

This reaction is done with a catalyst at a high temperature.

**0 2 . 1** Describe how a catalyst increases the rate of a reaction.

**[2 marks]**

**0 2 . 2** Explain why the rate of a reaction increases as the temperature increases.

**[3 marks]**

**0 2 . 3** Hydrogen bonds exist between molecules of liquid methanol.

Draw a diagram to show a hydrogen bond between two molecules of methanol.

Include all the lone pairs of electrons and the partial charges on the atoms involved in this hydrogen bond.

**[3 marks]**

**8**

*Do not write outside the box*

**0 3** Molecules of $CCl_4$ and $CHCl_3$ have similar tetrahedral shapes.

The boiling point of $CCl_4$ is 77 °C

The boiling point of $CHCl_3$ is 61 °C

Explain why $CCl_4$ has a higher boiling point than $CHCl_3$

Your answer should

- explain why these molecules have a tetrahedral shape
- explain why the molecules of each compound are polar or non-polar
- compare the intermolecular forces in these compounds.

**[6 marks]**

*Do not write outside the box*

6

**Turn over ►**

*Do not write outside the box*

**0 4** This question is about some compounds with the molecular formula $C_4H_6O_2$

**0 4 . 1** Compounds **A** and **B**

- each have the molecular formula $C_4H_6O_2$
- are functional group isomers of each other
- each react with sodium carbonate to form a gas.

Compound **A** decolourises bromine water but compound **B** does not.

Draw a possible structure of **A** and a possible structure of **B**.

**[2 marks]**

Compound **A** Compound **B**

*Do not write outside the box*

**0 4 . 2** Compound **C** has the molecular formula $C_4H_6O_2$

In the infrared spectrum of **C**, there is

- absorption in the range 3230–3550 $cm^{-1}$
- absorption in the range 1620–1680 $cm^{-1}$
- **no** absorption in the range 1680–1750 $cm^{-1}$

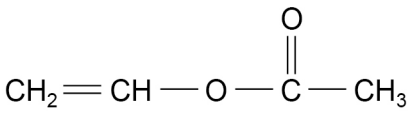
Draw a possible structure of **C**.

Use **Table A** on the Data Sheet to help you answer this question.

**[1 mark]**

**0 4 . 3** Vinyl acetate (VA) has the molecular formula $C_4H_6O_2$

The structure of vinyl acetate is shown.



PVA is an addition polymer of vinyl acetate.

Draw the repeating unit of PVA.

**[1 mark]**

4

**Turn over ►**

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**ANSWER IN THE SPACES PROVIDED**

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**0 5** This question is about determining the relative molecular mass ($M_r$) of different compounds.

**0 5 . 1** The $M_r$ of a compound can be determined by mass spectrometry.

Propanone, prop-2-en-1-ol and butane each have $M_r$ = 58.0

Give the reason why high resolution mass spectrometry can distinguish between propanone and butane, but cannot distinguish between propanone and prop-2-en-1-ol.

**[2 marks]**

**Question 5 continues on the next page**

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**0 5 . 2** A student does an experiment to determine the $M_r$ of a volatile liquid **X**.

In this experiment a conical flask of known volume is filled with vaporised **X** which is then condensed back into a liquid in the flask.

Method

1. Place a piece of aluminium foil over the opening of a conical flask.
2. Record the mass of the conical flask and foil.
3. Remove the foil and add 5 $cm^3$ of liquid **X** to the flask.
4. Replace the foil and use a pin to make a tiny hole in the middle of the foil.
5. Place the conical flask in a large beaker of boiling water (see **Figure 1**) until all of liquid **X** has vaporised. The flask is now full of vaporised **X** (the air and some of **X** escaped through the tiny hole).
6. Allow the conical flask to cool so that the vaporised **X** that was in the flask cools and condenses (air returns to the flask).
7. Record the mass of the conical flask with foil and condensed **X**.

**Figure 1**

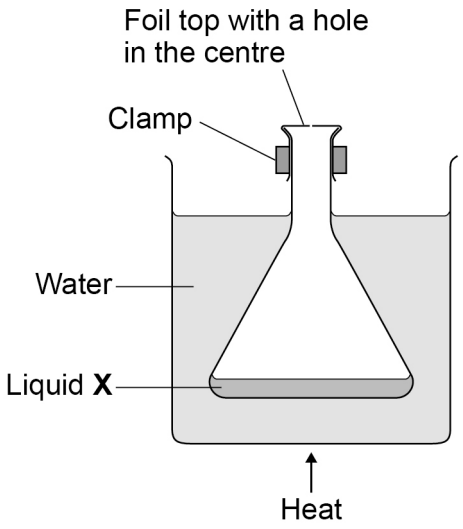



**Table 1** shows the student's results.

**Table 1**

| | |
|---|---|
| Volume of conical flask / $cm^3$ | 272 |
| Temperature of boiling water / °C | 100 |
| Pressure / Pa | 102 000 |
| Mass of flask + foil in step 2 / g | 105.872 |
| Mass of flask + foil + **X** in step 7 / g | 106.633 |

*Do not write outside the box*

Calculate the $M_r$ of **X**.

Assume that the mass of air in the flask is the same in steps 2 and 7.

Gas constant, $R = 8.31$ J K$^{-1}$ mol$^{-1}$

**[5 marks]**

$M_r$ _____

7

**Turn over for the next question**

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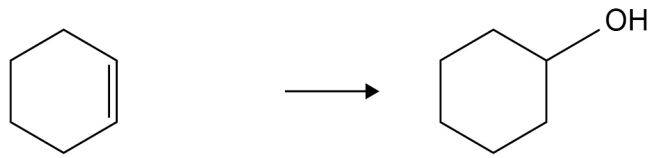
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**ANSWER IN THE SPACES PROVIDED**

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**0 6** Cyclohexanol can be made in the laboratory by the hydration of cyclohexene using concentrated phosphoric acid as a catalyst at low temperature. The cyclohexanol is purified by distillation.

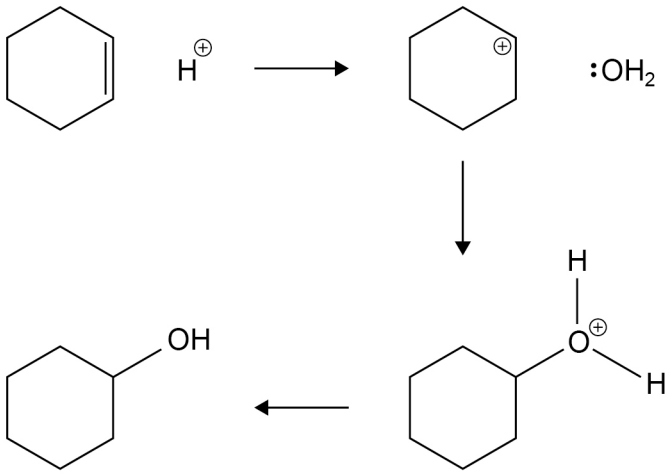
**0 6 . 1** Complete the equation for the conversion of cyclohexene to cyclohexanol in this reaction.

**[1 mark]**




**0 6 . 2** Complete the mechanism for this reaction by adding curly arrows in the relevant places.

**[3 marks]**




**0 6 . 3** Concentrated phosphoric acid ($H_3PO_4$) has a density of 1.69 g $cm^{-3}$

The concentrated acid contains 85% phosphoric acid and 15% water by mass.

Calculate the amount, in mol, of phosphoric acid in 6.0 $cm^3$ of concentrated phosphoric acid.

**[2 marks]**

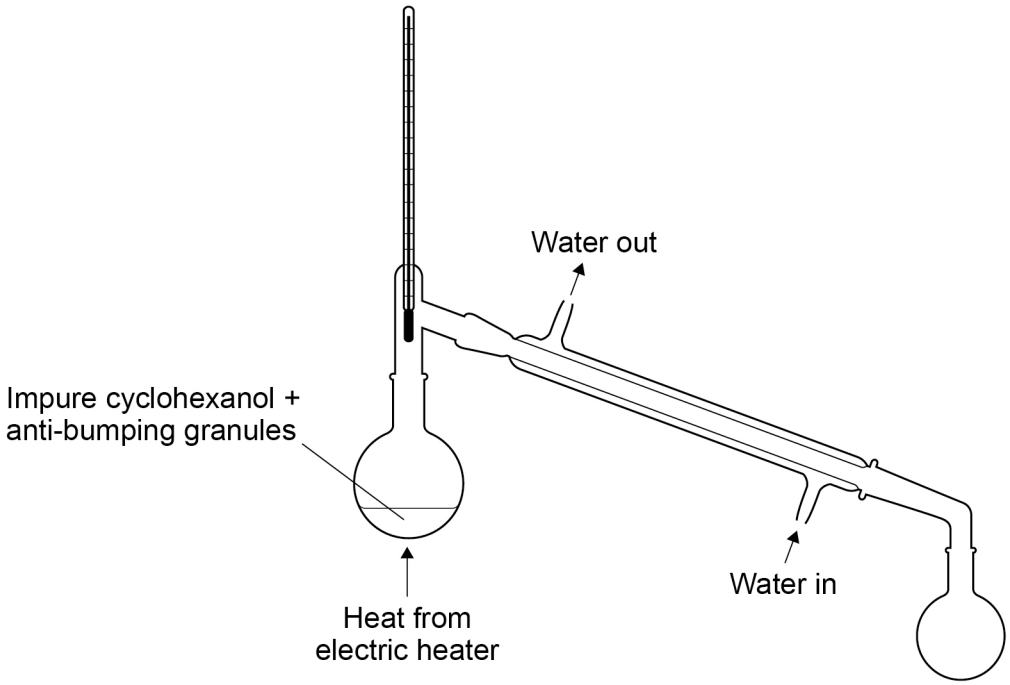
Amount of phosphoric acid _____ mol

**Question 6 continues on the next page**

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A student sets up the apparatus shown in **Figure 2** to purify the cyclohexanol by distillation. Suitable clamps are used to hold the apparatus firmly in place.

**Figure 2**




**0 6 . 4** Explain why the condenser in **Figure 2** is connected so that water enters at the bottom and not at the top.

**[2 marks]**

**0 6 . 5** The flask heated in **Figure 2** contains anti-bumping granules.

State why these are used.

**[1 mark]**

*Do not write outside the box*

**0 6 . 6** Suggest why the flask in **Figure 2** is heated with an electric heater, rather than a Bunsen burner.

**[1 mark]**

**0 6 . 7** State why the apparatus set up in **Figure 2** is dangerous.

State how this problem could be solved.

**[2 marks]**

Why the apparatus is dangerous

How to solve the problem

**0 6 . 8** The cyclohexanol can be dehydrated to re-form cyclohexene by heating with concentrated phosphoric acid.

Name the mechanism for this reaction.

**[1 mark]**

**Question 6 continues on the next page**

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Cyclohexanol biofuel can be made from waste biomass materials such as rice and straw.

Cyclohexanol biofuel can be mixed with diesel and used as fuel in cars.

**0 6 . 9** Give an equation for the complete combustion of cyclohexanol ($C_6H_{11}OH$).

**[1 mark]**

**0 6 . 10** The use of cyclohexanol biofuel mixed with diesel in cars is not carbon-neutral.

State the meaning of the term carbon-neutral.

Give a reason why the use of this mixture as a fuel is **not** carbon-neutral.

**[2 marks]**

Carbon-neutral meaning

Why the fuel is not carbon-neutral

**16**

*Do not write outside the box*

**0 7** This question is about enthalpies of combustion.

**0 7 . 1** Define enthalpy change.

**[1 mark]**

**0 7 . 2** The enthalpy of combustion of ethanol is –1371 kJ $mol^{-1}$

A sample of ethanol is burned completely in air to raise the temperature of 55.0 g of water by 46.2 °C

Calculate the mass of ethanol in the sample.
Assume there is no heat loss.

Specific heat capacity of water, $c$ = 4.18 J $K^{-1}$ $g^{-1}$

**[5 marks]**

Mass of ethanol _____ g

**Question 7 continues on the next page**

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An alkane burns completely in oxygen. The equation for this reaction is shown.

$$C_nH_{2n+2} + \frac{3n+1}{2}O_2 \rightarrow n\,CO_2 + (n+1)\,H_2O$$

**Table 2** gives some mean bond enthalpies.

**Table 2**

| Bond | C=O | O–H |
|---|---|---|
| Bond enthalpy / kJ mol$^{-1}$ | 805 | 463 |

**0 7 . 3** Use **Table 2** to show that an expression for the sum of the bond enthalpies for all the bonds in the **products** is $2536n + 926$

**[1 mark]**

**0 7 . 4** An expression for the sum of the bond enthalpies for all the bonds in the **reactants** is $1916n + 724$

A calculated value for the enthalpy of combustion of an alkane is –3302 kJ mol$^{-1}$

Use this enthalpy change and the expressions to calculate a value of $n$ for this alkane.

Use your value of $n$ to deduce the molecular formula of the alkane.

**[3 marks]**

Value of $n$ _____

Molecular formula _____

**10**

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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 

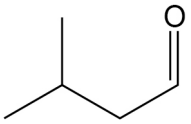
WRONG METHODS 

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 8** What is the name of this compound according to IUPAC rules?



**[1 mark]**

**A** 2-methylbutanal

**B** 3-methylbutanal

**C** 2-methylbutan-1-one

**D** 3-methylbutan-1-one

**Turn over for the next question**

*Do not write outside the box*

**0 9** Which statement about the combustion of petrol in vehicles is correct?

**[1 mark]**

**A** Exhaust gases can contain a mixture of unburned hydrocarbon molecules. ⬭

**B** In the catalytic converter, carbon dioxide is converted into carbon monoxide. ⬭

**C** More nitrogen gas is emitted from the catalytic converter than enters the internal combustion engine. ⬭

**D** Combustion in a plentiful supply of oxygen often causes an increased amount of black solid to be emitted from the exhaust. ⬭

**1 0** Which statement about catalytic cracking is correct?

**[1 mark]**

**A** A high percentage of alkenes is formed. ⬭

**B** A pressure of about 70 MPa is used. ⬭

**C** C–C bonds are broken. ⬭

**D** A nickel catalyst is used. ⬭

**1 1** Which compound produces $(CH_3)_2CHCOCH_3$ on oxidation?

**[1 mark]**

**A** 2-methylpropan-1-ol ⬭

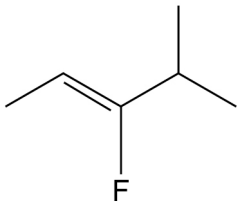
**B** 2,2-dimethylpropan-1-ol ⬭

**C** 2-methylbutan-2-ol ⬭

**D** 3-methylbutan-2-ol ⬭

*Do not write outside the box*

**1 2** What is the name of this compound according to IUPAC rules?




**[1 mark]**

**A** *E*–3-fluoro-2-methylpent-3-ene ⬭

**B** *Z*–3-fluoro-2-methylpent-4-ene ⬭

**C** *E*–3-fluoro-4-methylpent-2-ene ⬭

**D** *Z*–3-fluoro-4-methylpent-2-ene ⬭

**1 3** 2-Methylpentane-1,2,4-triol is refluxed with an excess of acidified potassium dichromate(VI).

What is the molecular formula of the main organic product?

**[1 mark]**

**A** $C_6H_8O_4$ ⬭

**B** $C_6H_{10}O_3$ ⬭

**C** $C_6H_{10}O_4$ ⬭

**D** $C_6H_{12}O_3$ ⬭

**1 4** Sulfur dioxide can be found in the flue gases from the combustion of some fuels.

Which statement about sulfur dioxide is correct?

**[1 mark]**

**A** Sulfur dioxide molecules have a linear shape. ⬭

**B** Sulfur dioxide is a basic oxide. ⬭

**C** Sulfur dioxide reacts with calcium oxide to form $CaSO_4$ as the main product. ⬭

**D** Sulfur dioxide molecules contain polar bonds. ⬭

*Do not write outside the box*

**1 5** Which equation shows a step in the decomposition of ozone by free radicals formed from CFCs in the upper atmosphere?

**[1 mark]**

**A** $Cl\bullet + O_3 \rightarrow O_2 + ClO\bullet$ ⬭

**B** $Cl\bullet + O_3 \rightarrow ClO_2 + O\bullet$ ⬭

**C** $Cl\bullet + O_2 \rightarrow ClO\bullet + O\bullet$ ⬭

**D** $ClO\bullet + O_3 \rightarrow ClO_2 + O_2$ ⬭

**1 6** Crude oil is separated into fractions in a fractionating column at an oil refinery.

Which statement about the fractions collected higher up in the column, compared with those collected lower down, is correct?

**[1 mark]**

**A** They are collected at a higher temperature. ⬭

**B** They have stronger intermolecular forces. ⬭

**C** They are more volatile. ⬭

**D** They are more viscous. ⬭

**1 7** Which of these gases is **not** linked to global warming caused by the absorption of infrared radiation?

**[1 mark]**

**A** $CO_2$ ⬭

**B** $C_3H_8$ ⬭

**C** $H_2O$ ⬭

**D** $N_2$ ⬭

*Do not write outside the box*

**1 8** The standard enthalpies of combustion for carbon, hydrogen and benzene ($C_6H_6$) are –394, –286 and –3273 kJ mol$^{-1}$ respectively.

What is the standard enthalpy of formation of benzene, in kJ mol$^{-1}$?

**[1 mark]**

**A** +51 ⬭

**B** –51 ⬭

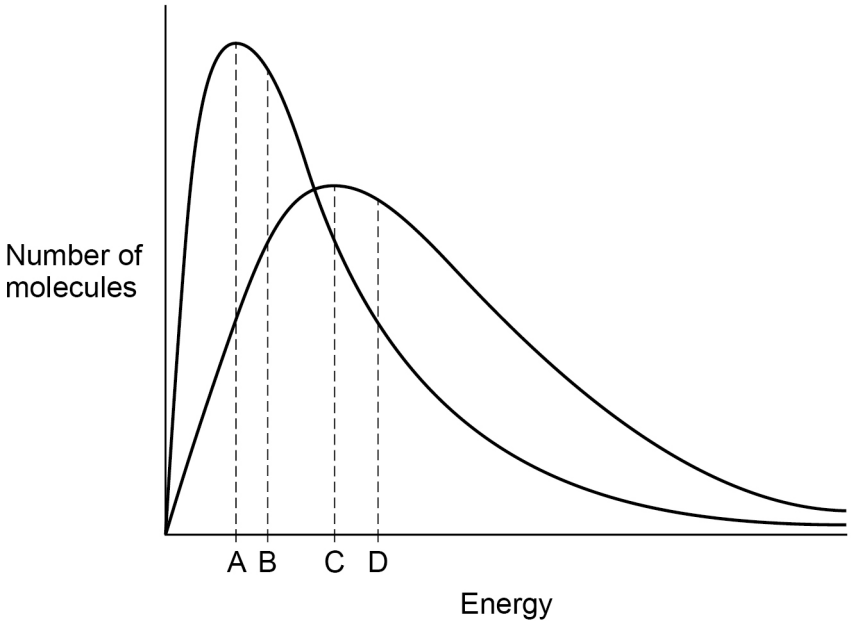
**C** +807 ⬭

**D** –807 ⬭

**1 9** The Maxwell–Boltzmann distribution of molecular energies for a sample of gas at two different temperatures is shown.

Which letter represents the mean energy of the molecules at the lower temperature?

**[1 mark]**




**A** ⬭

**B** ⬭

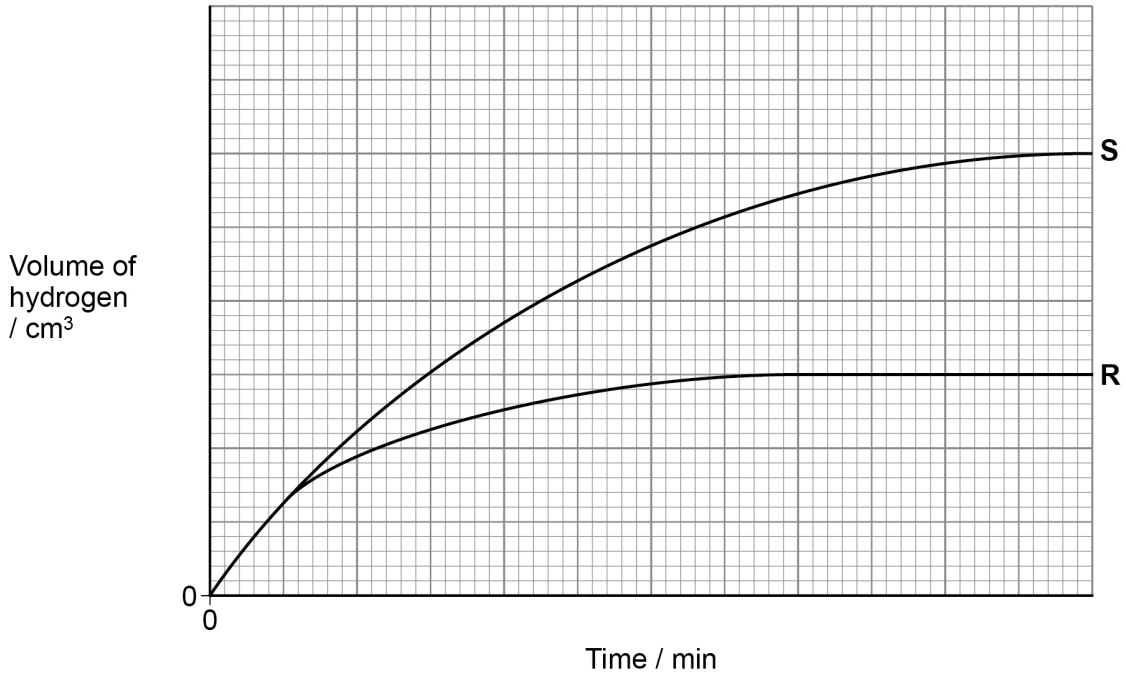
**C** ⬭

**D** ⬭

**Turn over for the next question**

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**2 0** A student adds 0.48 g of magnesium ribbon to 100 $cm^3$ of 1.0 mol $dm^{-3}$ hydrochloric acid.
The student records the volume of hydrogen collected at regular time intervals.
Line **R** on the graph shows the results.




Which of these reactions gives results shown by line **S**?

Assume that the reactions occur at the same temperature.

**[1 mark]**

**A** 0.48 g of magnesium reacting with 200 $cm^3$ of 1.0 mol $dm^{-3}$ hydrochloric acid ⬭

**B** 0.48 g of magnesium reacting with 100 $cm^3$ of 2.0 mol $dm^{-3}$ hydrochloric acid ⬭

**C** 0.96 g of magnesium reacting with 200 $cm^3$ of 1.0 mol $dm^{-3}$ hydrochloric acid ⬭

**D** 0.96 g of magnesium reacting with 200 $cm^3$ of 2.0 mol $dm^{-3}$ hydrochloric acid ⬭

Do not write outside the box

**2 1** Which equation for the reaction of chlorine with excess ethane in the presence of ultraviolet light is correct?

**[1 mark]**

**A** $C_2H_6 + \frac{1}{2}Cl_2 \rightarrow C_2H_5Cl + \frac{1}{2}H_2$ ⬭

**B** $C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$ ⬭

**C** $C_2H_6 + 3Cl_2 \rightarrow C_2Cl_6 + 3H_2$ ⬭

**D** $C_2H_6 + 6Cl_2 \rightarrow C_2Cl_6 + 6HCl$ ⬭

**2 2** Which reaction at 298 K has a standard enthalpy change equal to the standard enthalpy of formation of liquid iodoethane?

**[1 mark]**

**A** $\frac{1}{2}I_2(l) + 2C(s) + \frac{5}{2}H_2(g) \rightarrow C_2H_5I(l)$ ⬭

**B** $\frac{1}{2}I_2(s) + 2C(s) + \frac{5}{2}H_2(g) \rightarrow C_2H_5I(l)$ ⬭

**C** $I_2(l) + 4C(s) + 5H_2(g) \rightarrow 2C_2H_5I(l)$ ⬭

**D** $I_2(s) + 4C(s) + 5H_2(g) \rightarrow 2C_2H_5I(l)$ ⬭

15

**END OF QUESTIONS**

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**ANSWER IN THE SPACES PROVIDED**

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