A

Surname ____________________

Other Names ____________________

Centre Number ____________________

Candidate Number ____________________

Candidate Signature ____________________

I declare this is my own work.

# A-level
# CHEMISTRY

## Paper 2 Organic and Physical Chemistry

## 7405/2

**Monday 8 June 2020 Afternoon**

**Time allowed: 2 hours**

**At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.**

**[Turn over]**

J U N 2 0 7 4 0 5 2 0 1

**For this paper you must have:**
- **the Periodic Table/Data Booklet, 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.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do NOT write 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 105.

DO NOT TURN OVER UNTIL TOLD TO DO SO

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

**0 1**

**This question is about rates of reaction.**

**Phosphinate ions ($H_2PO_2^-$) react with hydroxide ions to produce hydrogen gas as shown.**

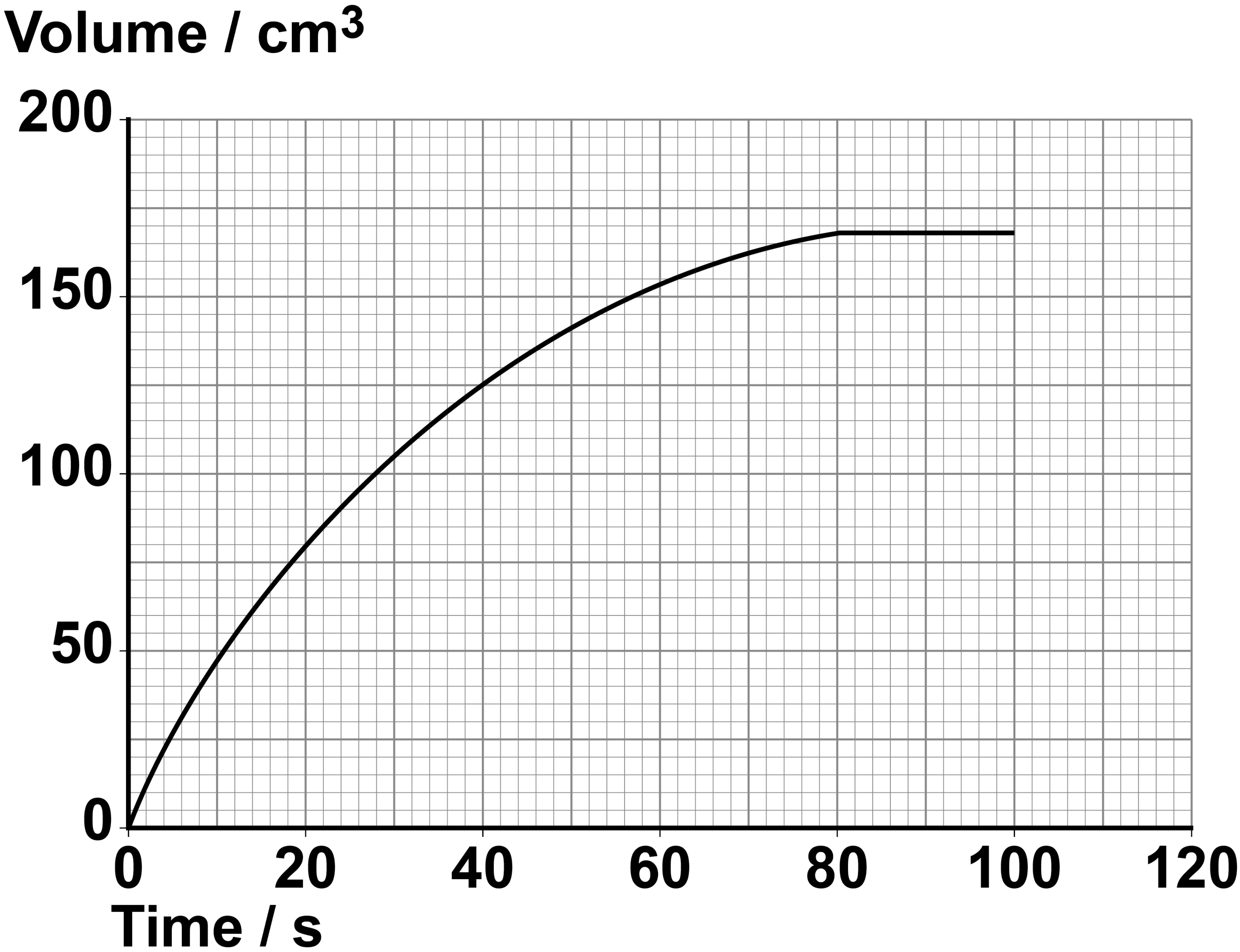
$$H_2PO_2^- + OH^- \longrightarrow HPO_3^{2-} + H_2$$

**A student completed an experiment to determine the initial rate of this reaction.**

**The student used a solution containing phosphinate ions and measured the volume of hydrogen gas collected every 20 seconds at a constant temperature.**

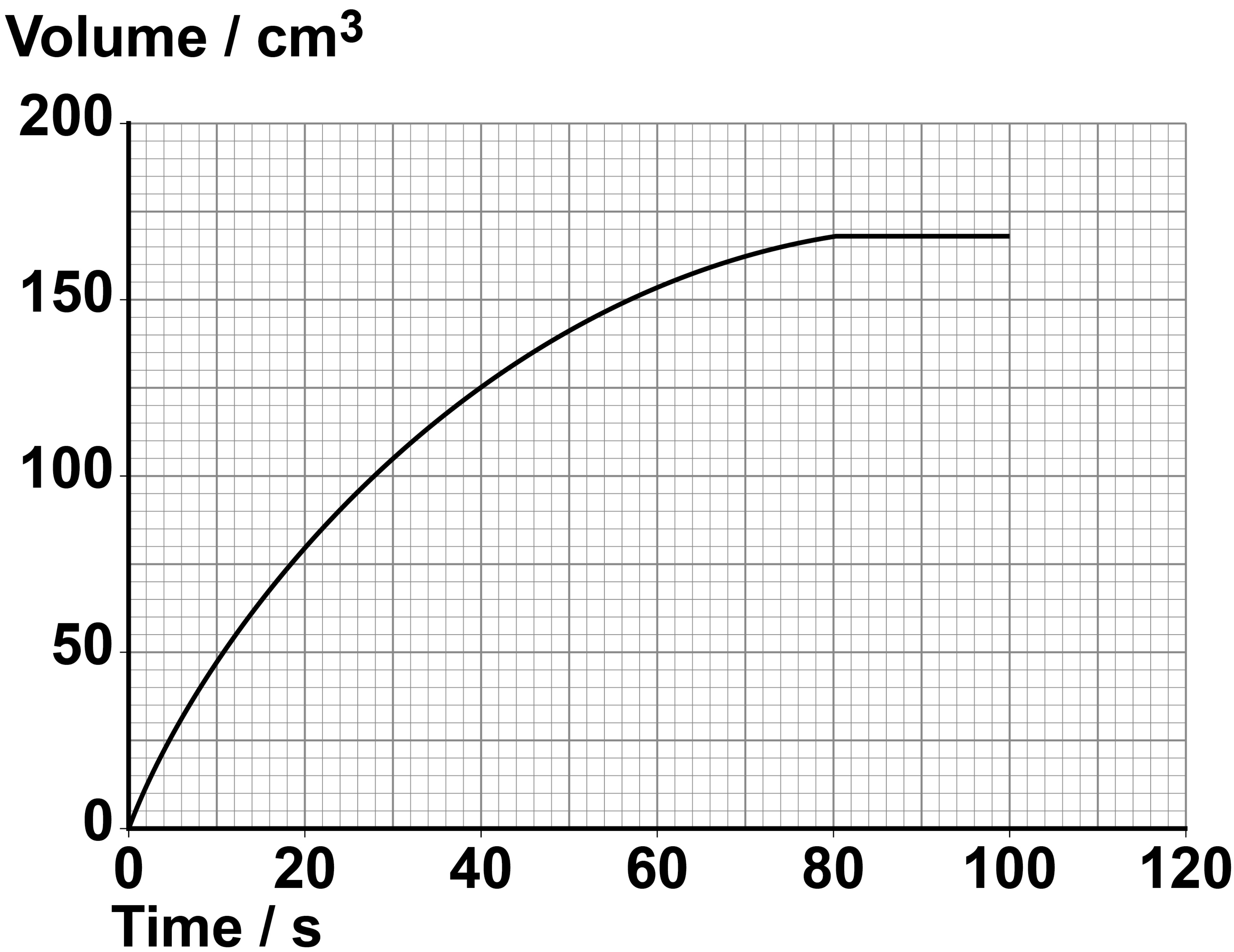
**FIGURE 1, on the opposite page, shows a graph of the student's results.**

# FIGURE 1




[Turn over]

# REPEAT OF FIGURE 1



**0 1 . 1**

**Use the graph in FIGURE 1 to determine the initial rate of reaction for this experiment. State its units. Show your working on the graph. [3 marks]**

**Rate** ______________________

**Units** ______________________

**0 1 . 2**

**Another student reacted different initial concentrations of phosphinate ions with an excess of hydroxide ions. The student measured the time (*t*) taken to collect 15 $cm^3$ of hydrogen gas. Each experiment was carried out at the same temperature.**

**TABLE 1 shows the results.**

**TABLE 1**

| Initial $[H_2PO_2^-]$ / mol $dm^{-3}$ | *t* / s |
|---|---|
| 0.25 | 64 |
| 0.35 | 32 |
| 0.50 | 16 |
| 1.00 | 4 |

**State the relationship between the initial concentration of phosphinate and time (*t*).**

**Deduce the order of the reaction with respect to phosphinate. [2 marks]**

**Relationship** ______________________________

______________________________________________

**Order** ______________________________________

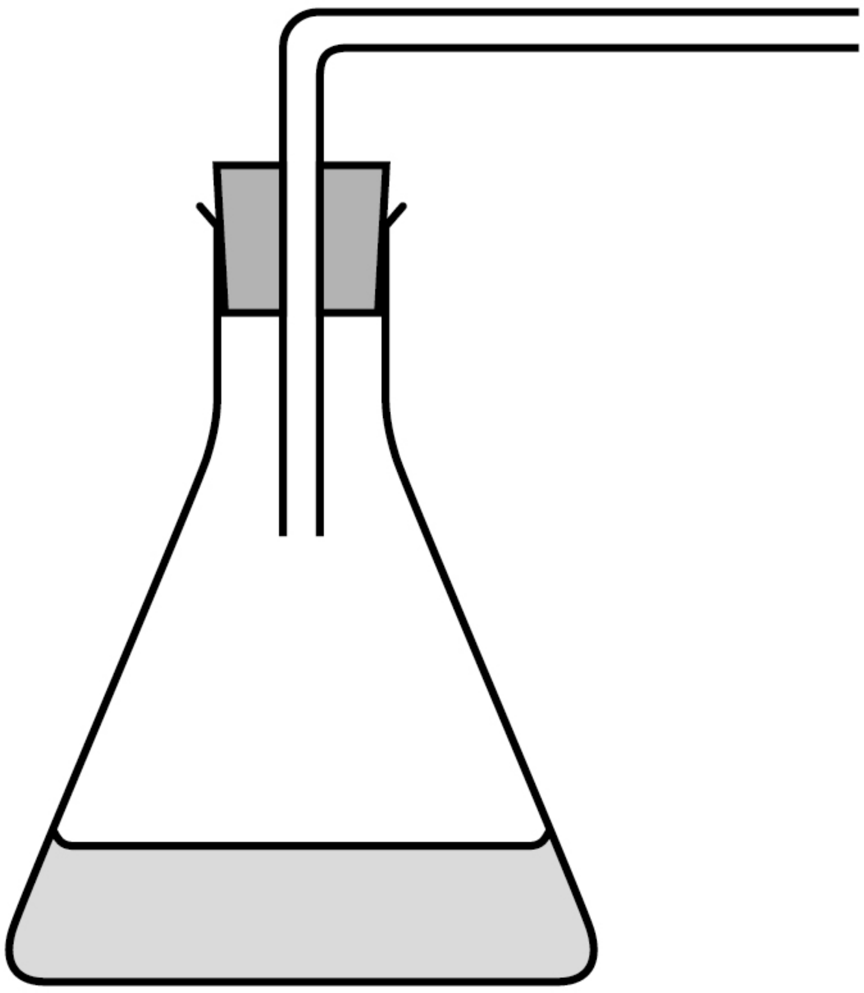
______________________________________________

**[Turn over]**

**0 1 . 3**

**Complete the diagram in FIGURE 2 to show how the hydrogen gas could be collected and measured in the experiments in Questions 01.1 and 01.2. [1 mark]**

**FIGURE 2**



**The rate equation for a different reaction is *rate* = *k* [L] [M]$^2$**

**0 1 . 4**

**Deduce the overall effect on the rate of reaction when the concentrations of both L and M are halved. [1 mark]**

**[Turn over]**

**0 1 . 5**

**The rate of reaction is $0.0250\ mol\ dm^{-3}\ s^{-1}$ when the concentration of L is $0.0155\ mol\ dm^{-3}$**

**Calculate the concentration of M if the rate constant is $21.3\ mol^{-2}\ dm^{6}\ s^{-1}$**
**[3 marks]**

**Concentration of M ____________ $mol\ dm^{-3}$**

**01.6**

**Define the term overall order of reaction.**
**[1 mark]**

**[Turn over]**

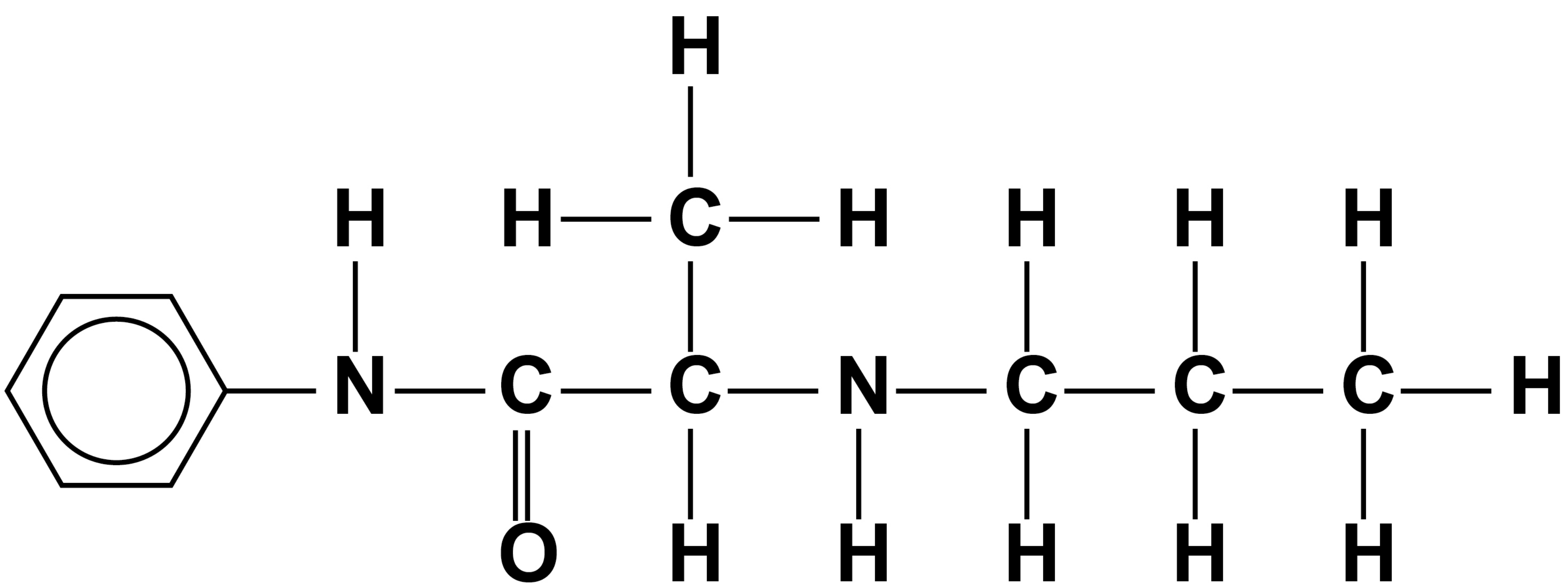
**11**

## 0 2

Prilocaine is used as an anaesthetic in dentistry.

FIGURE 3 shows the structure of prilocaine.

FIGURE 3



## 0 2 . 1

Draw a circle around any chiral centre(s) in FIGURE 3. [1 mark]

0 2 . 2

**Identify the functional group(s) in the prilocaine molecule. [1 mark]**

**Tick (✓) the box(es) corresponding to the functional group(s).**

☐ **AMIDE**

☐ **AMINE**

☐ **ESTER**

☐ **KETONE**

**[Turn over]**

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## 0 2 . 3

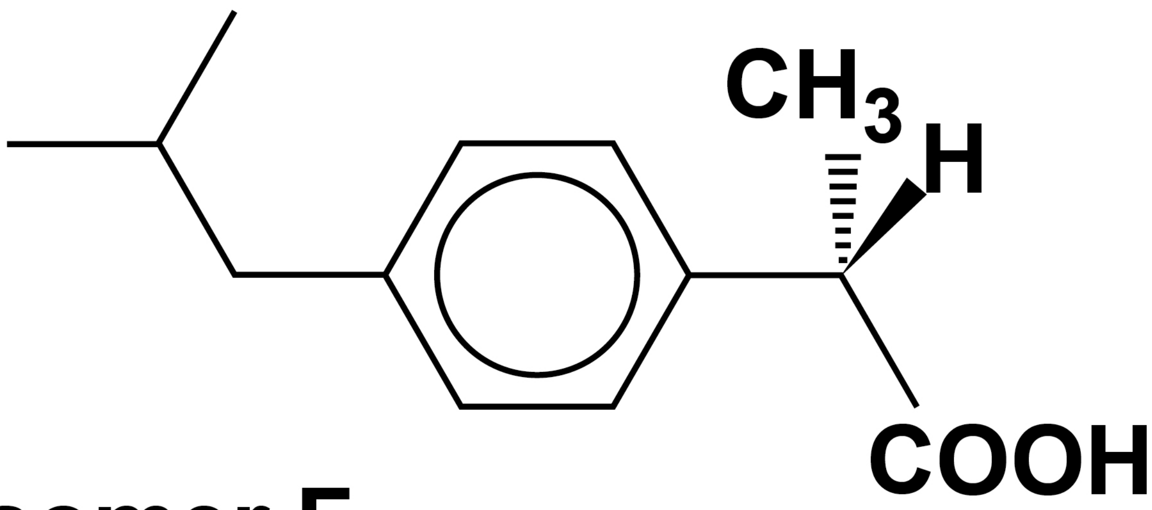
**Prilocaine is completely hydrolysed in the human body to give a mixture of products.**

**Draw the structures of the two organic products formed in the complete hydrolysis of prilocaine in acidic conditions. [3 marks]**

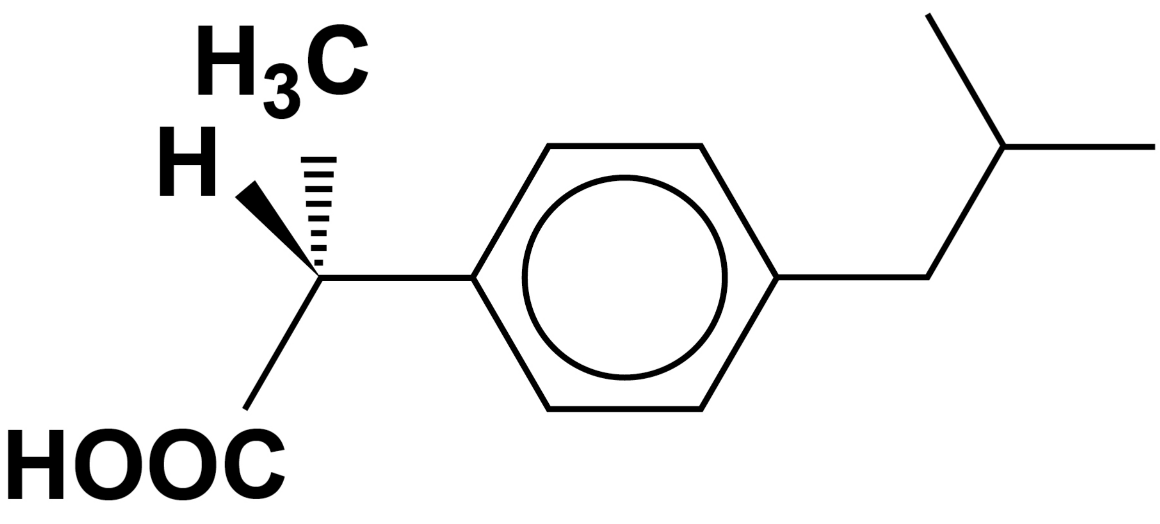
**0 2 . 4**

**FIGURE 4 shows optical isomers F and G.**

**FIGURE 4**




**Isomer F**




**Isomer G**

**Isomer F is the active compound in the medicine ibuprofen.**

In the manufacture of ibuprofen both isomers F and G are formed. An enzyme is then used to bind to isomer G and catalyse its hydrolysis.

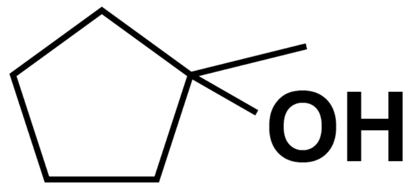
After the products of hydrolysis of G are removed, a pure sample of isomer F is collected.

Explain how a structural feature of this enzyme enables it to catalyse the hydrolysis of isomer G but not the hydrolysis of isomer F. [2 marks]

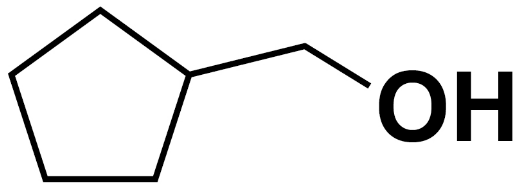
**0 3**

**This question is about the structural isomers shown.**

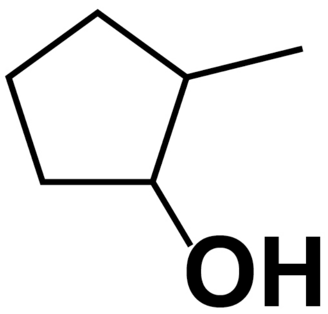
**P**



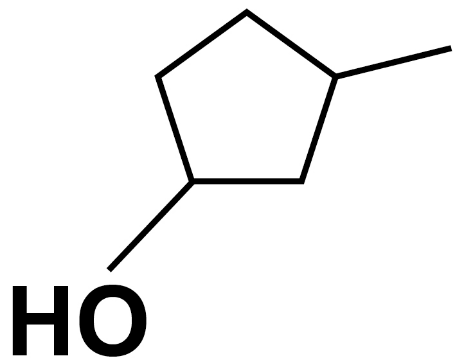

**Q**



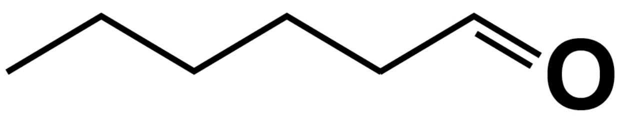

**R**



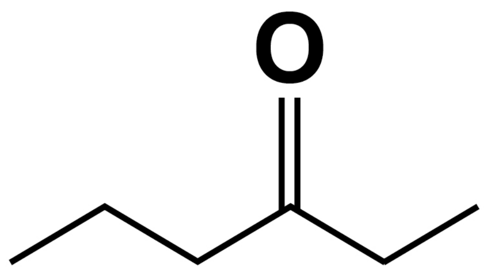

**S**




**T**




**U**



**0 3 . 1**

**Identify the isomer(s) that would react when warmed with acidified potassium dichromate(VI).**

**State the expected observation when acidified potassium dichromate(VI) reacts. [2 marks]**

**Isomer(s)** ______________________________

______________________________

**Expected observation** ______________________________

______________________________

______________________________

**[Turn over]**

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**0 3 . 2**

**Identify the isomer(s) that would react with Tollens' reagent.**

**State the expected observation when Tollens' reagent reacts. [2 marks]**

**Isomer(s)** ______________________________

______________________________

**Expected observation** ______________________________

______________________________

______________________________

**[Turn over]**

**0 3 . 3**

**Separate samples of each isomer are warmed with ethanoic acid and a few drops of concentrated sulfuric acid. In each case the mixture is then poured into a solution of sodium hydrogencarbonate.**

**Identify the isomer(s) that would react with ethanoic acid.**

**Suggest a simple way to detect if the ethanoic acid reacts with each isomer.**

**Give a reason why the mixture is poured into sodium hydrogencarbonate solution.**
**[3 marks]**

**Isomer(s)** ______________________________

**Suggestion** ______________________________

___________________________________________

___________________________________________

___________________________________________

Reason ______________________________

______________________________

______________________________

0 3 . 4

**State the type of structural isomerism shown by isomers P, Q, R and S. [1 mark]**

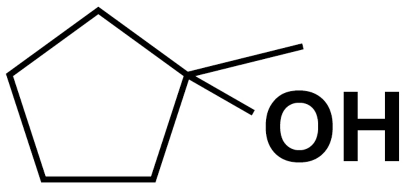
______________________________

______________________________

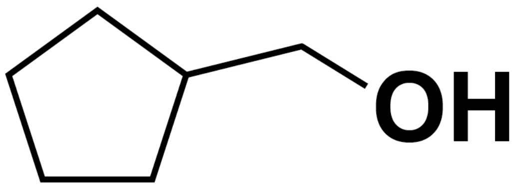
**[Turn over]**

# REPEAT OF ISOMERS

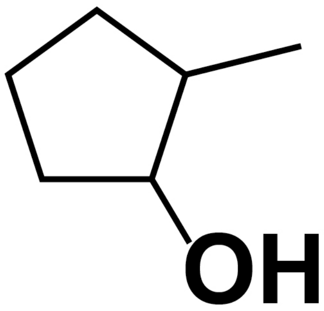
**P**



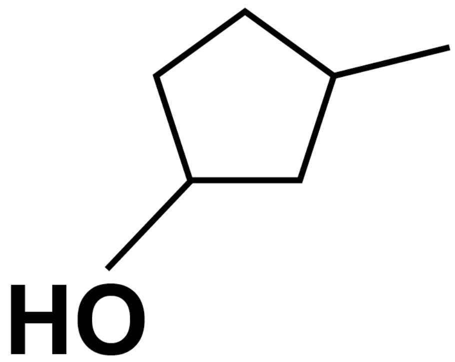

**Q**



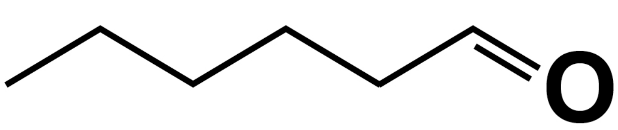

**R**



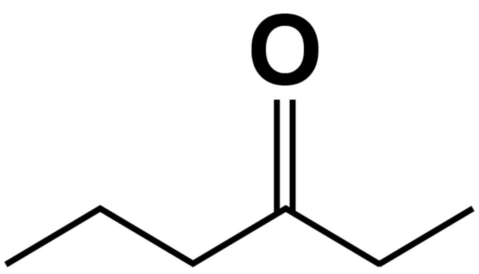

**S**




**T**




**U**



**03.5**

**Describe fully how infrared spectra can be used to distinguish between isomers R, S and T.**

**Use data from TABLE A in the Data Booklet in your answer. [4 marks]**

**[Turn over]**

**03.6**

**State why mass spectrometry using electrospray ionisation is NOT a suitable method to distinguish between the isomers. [1 mark]**

______________________________________________

______________________________________________

**13**

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**[Turn over]**

**0 4**

**Aspirin can be produced by reacting salicylic acid with ethanoic anhydride.**

**An incomplete method to determine the yield of aspirin is shown.**

1. **Add about 6 g of salicylic acid to a weighing boat.**
2. **Place the weighing boat on a 2 decimal place balance and record the mass.**
3. **Tip the salicylic acid into a 100 $cm^3$ conical flask.**
4. **________________________________**
5. **Add 10 $cm^3$ of ethanoic anhydride to the conical flask and swirl.**
6. **Add 5 drops of concentrated phosphoric acid.**
7. **Warm the flask for 20 minutes.**

8. **Add ice-cold water to the reaction mixture and place the flask in an ice bath.**
9. **Filter off the crude aspirin from the mixture and leave it to dry.**
10. **Weigh the crude aspirin and calculate the yield.**

**[Turn over]**

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**04.1**

**Describe the instruction that is missing from step 4 of the method.**

**Justify why this step is necessary.**
**[2 marks]**

**Instruction** ______________________________

______________________________

**Justification** ______________________________

______________________________

______________________________

______________________________

______________________________

**[Turn over]**

**0 4 . 2**

**Suggest a suitable piece of apparatus to measure out the ethanoic anhydride in step 5. [1 mark]**

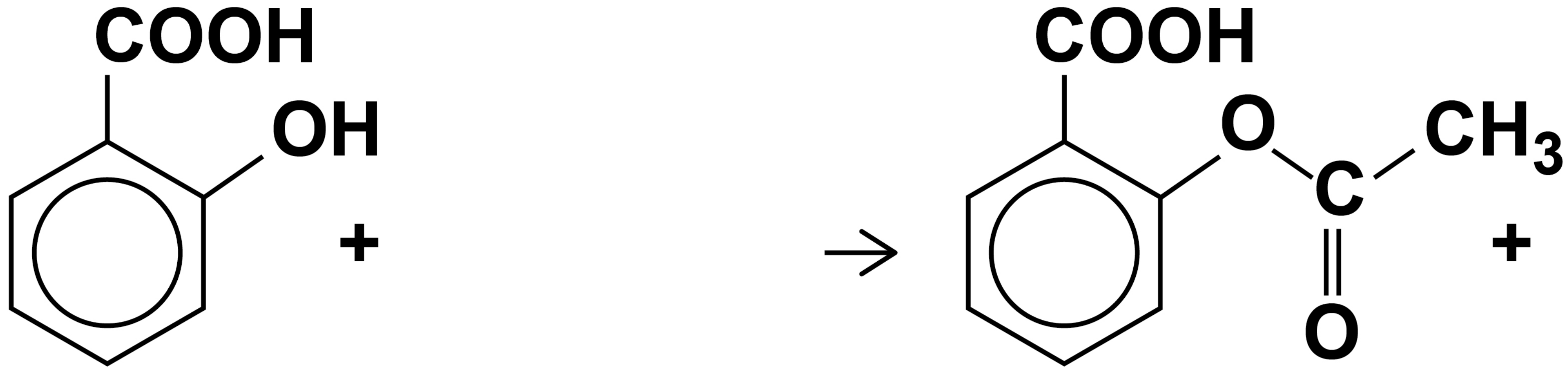
**0 4 . 3**

**Identify a hazard of using concentrated phosphoric acid in step 6. [1 mark]**

**[Turn over]**

**0 4 . 4**

**Complete the equation for the reaction of salicylic acid with ethanoic anhydride to produce aspirin. [1 mark]**




**Salicylic acid** **Aspirin**

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[Turn over]

**0 4 . 5**

**A 6.01 g sample of salicylic acid ($M_r$ = 138.0) is reacted with 10.5 $cm^3$ of ethanoic anhydride ($M_r$ = 102.0).**

**In the reaction the yield of aspirin is 84.1%**

**The density of ethanoic anhydride is 1.08 g $cm^{-3}$**

**Show by calculation which reagent is in excess.**

**Calculate the mass, in g, of aspirin ($M_r$ = 180.0) produced. [5 marks]**

Reagent in excess ______________________

Mass of ____________________ g

[Turn over]

## REPEAT OF METHOD

**Aspirin can be produced by reacting salicylic acid with ethanoic anhydride.**

**An incomplete method to determine the yield of aspirin is shown.**

1. **Add about 6 g of salicylic acid to a weighing boat.**
2. **Place the weighing boat on a 2 decimal place balance and record the mass.**
3. **Tip the salicylic acid into a 100 $cm^3$ conical flask.**
4. **________________________________**
5. **Add 10 $cm^3$ of ethanoic anhydride to the conical flask and swirl.**
6. **Add 5 drops of concentrated phosphoric acid.**
7. **Warm the flask for 20 minutes.**
8. **Add ice-cold water to the reaction mixture and place the flask in an ice**

bath.

9. Filter off the crude aspirin from the mixture and leave it to dry.

10. Weigh the crude aspirin and calculate the yield.

**0 4 . 6**

**Suggest TWO ways in which the melting point of the crude aspirin collected in step 9 would differ from the melting point of pure aspirin. [2 marks]**

**Difference 1** ______________________________

________________________________________

________________________________________

**Difference 2** ______________________________

________________________________________

________________________________________

**04.7**

**The crude aspirin can be purified by recrystallisation using hot ethanol (boiling point = 78 °C) as the solvent.**

**Describe TWO important precautions when heating the mixture of ethanol and crude aspirin. [2 marks]**

**Precaution 1** ______________________________

______________________________________________

______________________________________________

**Precaution 2** ______________________________

______________________________________________

______________________________________________

**0 4 . 8**

**The pure aspirin is filtered under reduced pressure. A small amount of cold ethanol is then poured through the Buchner funnel.**

**Explain the purpose of adding a small amount of cold ethanol. [1 mark]**

**[Turn over]**

0 4 . 9

**A sample of the crude aspirin is kept to compare with the purified aspirin.**

**Describe one difference in appearance you would expect to see between these two solid samples. [1 mark]**

**16**

**0 5**

**This question is about 2-bromopropane.**

**0 5 . 1**

**Define the term electronegativity.**

**Explain the polarity of the C–Br bond in 2-bromopropane. [3 marks]**

**Electronegativity** ____________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________

**Explanation** ____________________________

____________________________________________

____________________________________________

____________________________________________

____________________________________________

**0 5 . 2**

**Outline the mechanism for the reaction of 2-bromopropane with an excess of ammonia. [4 marks]**

**0 5 . 3**

**Draw the skeletal formula of the main organic species formed in the reaction between a LARGE EXCESS of 2-bromopropane and ammonia.**

**Give a use for the organic product.**
**[2 marks]**

**Skeletal formula**

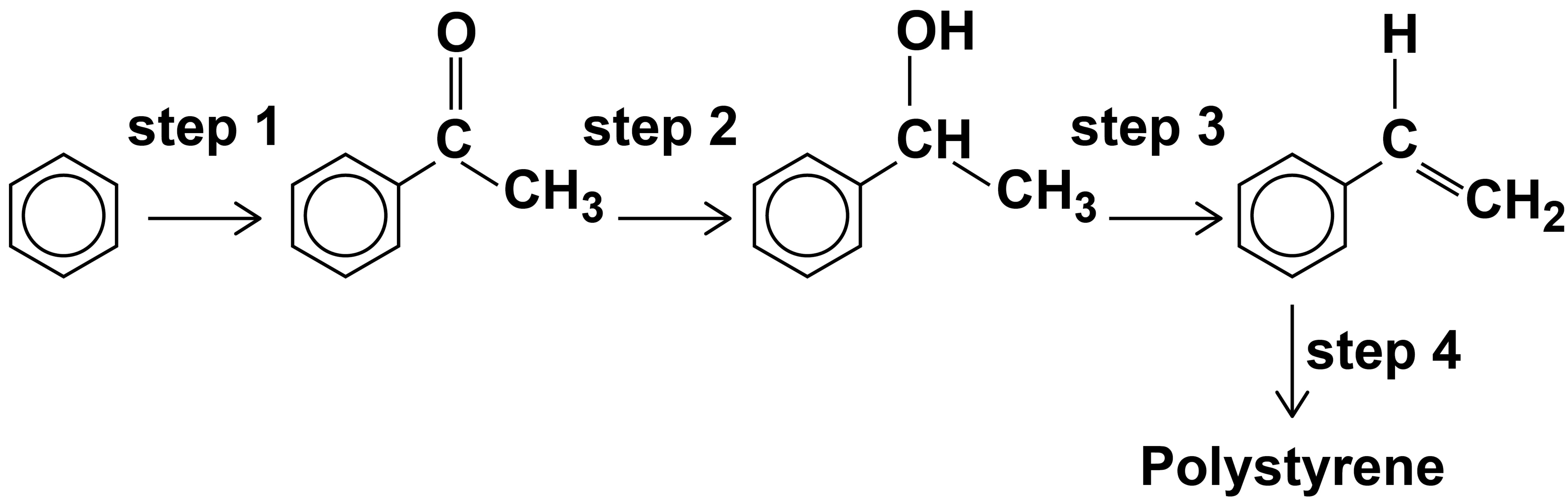
**Use** ____________________________________



9

**0 6**

**Polystyrene can be made from benzene in the series of steps shown.**



**0 6 . 1**

**State the type of reaction in step 1.**

**Identify the reagent(s) and conditions needed for step 1.**
**[3 marks]**

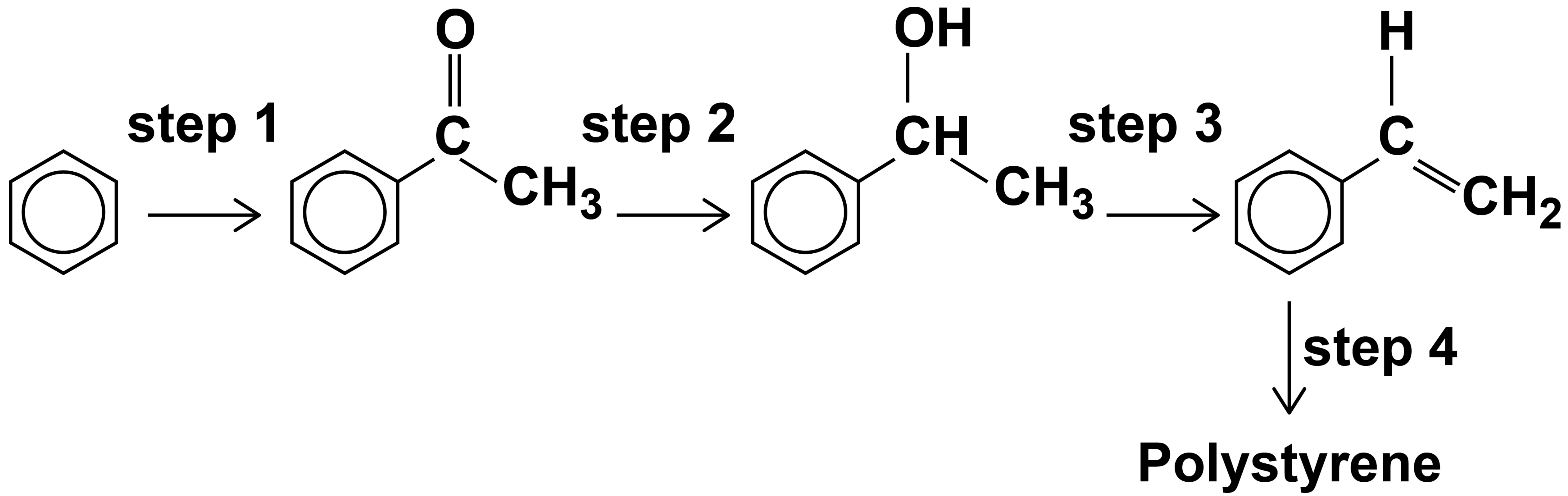
**Type of reaction** ____________________

**Reagent(s)** ____________________

**Conditions** ____________________

**[Turn over]**

# REPEAT OF FORMULA



**0 6 . 2**

**State the name of the mechanism for the reaction in step 2.**

**Identify the inorganic reagent needed for step 2.**

**Name the organic product of step 2. [3 marks]**

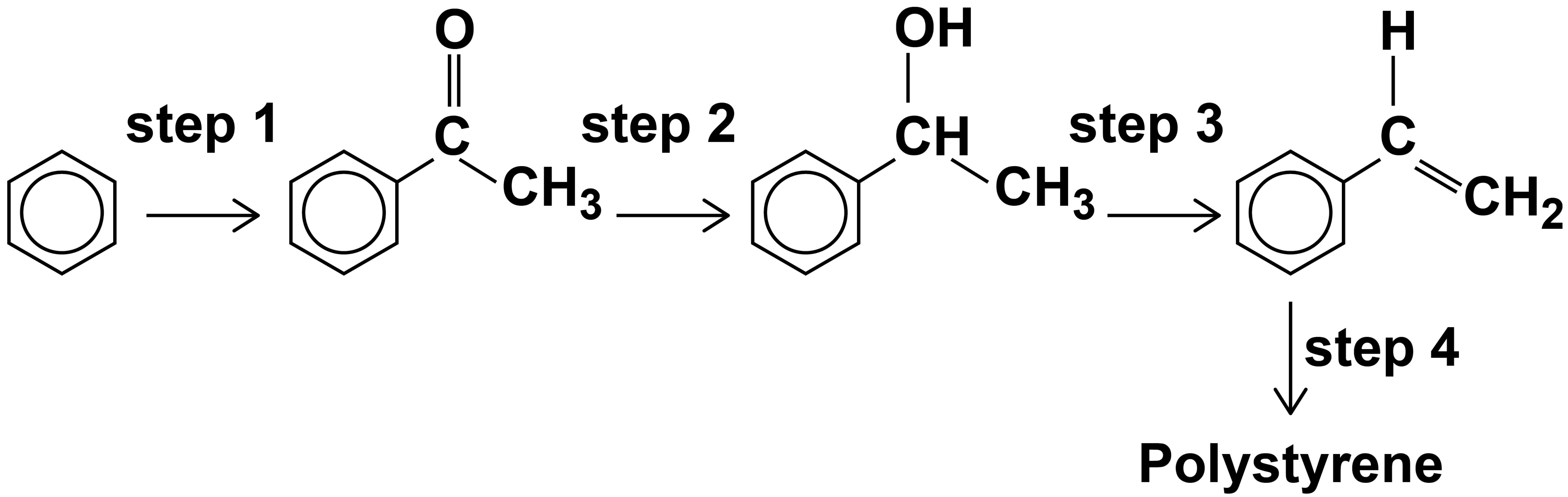
**Name of mechanism** ______________________________

**Inorganic reagent** ______________________________

**Name of organic product** ______________________________

**[Turn over]**

# REPEAT OF FORMULA



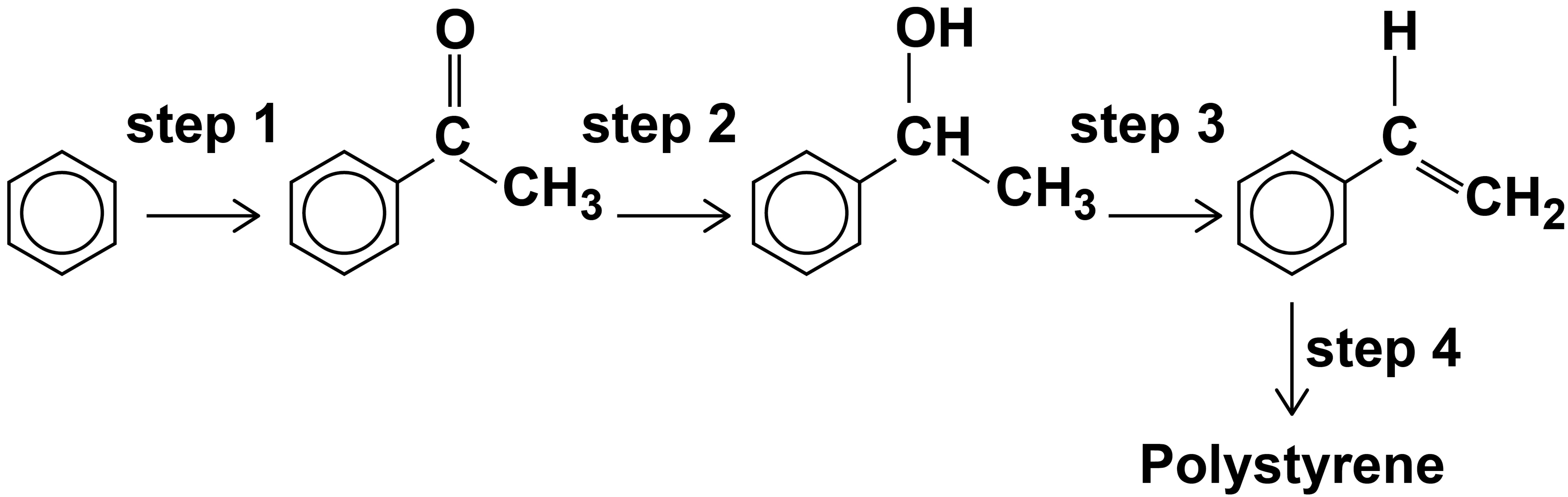
**0 6 . 3**

**The organic product of step 2 is reacted with concentrated sulfuric acid in step 3.**

**Outline the mechanism for step 3. [3 marks]**

**[Turn over]**

# REPEAT OF FORMULA



**0 6 . 4**

**Draw the repeating unit of polystyrene. [1 mark]**

**10**

**[Turn over]**

0 7

This question is about NMR spectroscopy.

0 7 . 1

A compound is usually mixed with $Si(CH_3)_4$ and either $CCl_4$ or $CDCl_3$ before recording the compound's $^1H$ NMR spectrum.

State why $Si(CH_3)_4$, $CCl_4$ and $CDCl_3$ are used in $^1H$ NMR spectroscopy.

Explain how their properties make them suitable for use in $^1H$ NMR spectroscopy.
[6 marks]

[Turn over]

**0 7 . 2**

**Deduce the splitting pattern for each of the peaks given by the H atoms labelled *x*, *y* and *z* in the $^{1}$H NMR spectrum of the compound shown.**

$$\overset{x}{CH_3}\overset{y}{CH}ClCO\overset{z}{CH}(CH_3)_2$$

**[3 marks]**

***x*** ____________________________

***y*** ____________________________

***z*** ____________________________

**[Turn over]**

**0 7 . 3**

**Suggest why it is difficult to use TABLE B in the Data Booklet to predict the chemical shift ($\delta$ value) for the peak given by the H atom labelled *y*. [1 mark]**

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**[Turn over]**

**07.4**

**Two isomers of $CH_3CHClCOCH(CH_3)_2$ each have two singlet peaks only in their $^1H$ NMR spectra.**

**In both spectra the integration ratio for the two peaks is 2:9**

**Deduce the structures of these two isomers [2 marks]**

**Isomer 1**

**Isomer 2**

**[Turn over]**

| |
|---|
| |
| **12** |

**0 8**

**This question is about citric acid, a hydrated tricarboxylic acid. Its formula can be represented as $H_3Y.xH_2O$**

**0 8 . 1**

**A 1.50 g sample of $H_3Y.xH_2O$ contains 0.913 g of oxygen by mass.**

**The sample burns completely in air to form 1.89 g of $CO_2$ and 0.643 g of $H_2O$**

**On the opposite page, show that the empirical formula of citric acid is $C_3H_5O_4$**
**[5 marks]**

**08.2**

**A 3.00 g sample of $H_3Y.xH_2O$ ($M_r$ = 210.0) is heated to constant mass.**

**The anhydrous $H_3Y$ that remains has a mass of 2.74 g**

**Show, using these data, that the value of $x$ = 1**

**[2 marks]**

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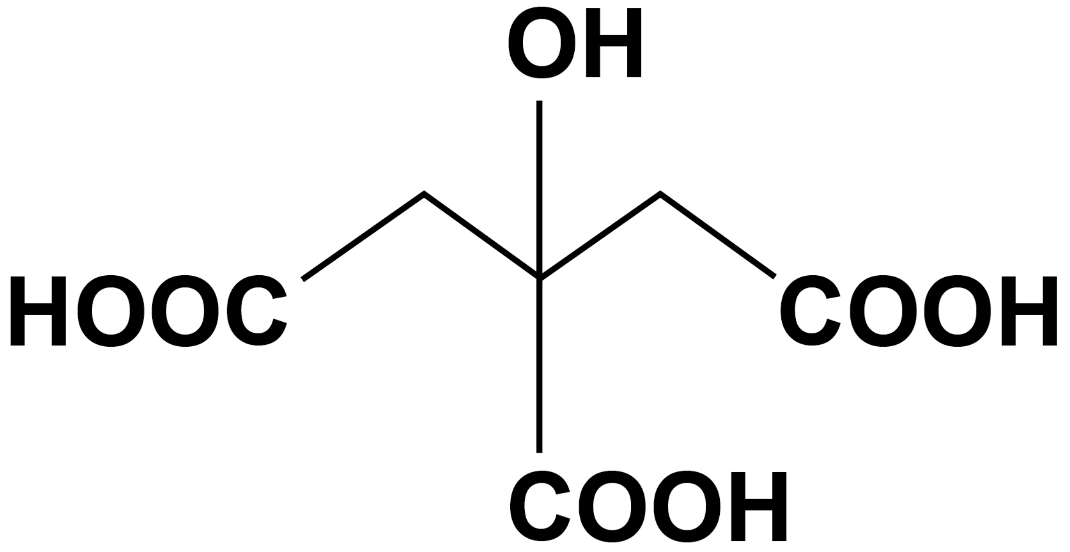
[Turn over]

FIGURE 5 shows the structure of $H_3Y$

FIGURE 5



0 8 . 3

Complete this IUPAC name for $H_3Y$
[1 mark]

______________________________

propane-1, 2, 3-tricarboxylic acid

**0 8 . 4**

**State the number of peaks you would expect in the $^{13}C$ NMR spectrum for $H_3Y$**
**[1 mark]**

---

[Turn over]

9

**0 9**

**A and B react together to form an equilibrium mixture.**

$$A(aq) + 2\ B(aq) \rightleftharpoons C(aq)$$

**An aqueous solution containing 0.25 mol of A is added to an aqueous solution containing 0.25 mol of B.**

**When equilibrium is reached, the mixture contains 0.015 mol of C.**

**0 9 . 1**

**Calculate the amount of A and the amount of B, in moles, in the equilibrium mixture.**
**[2 marks]**

**Amount of A** ________________ **mol**

**Amount of B** ________________ **mol**

**0 9 . 2**

**At a different temperature, another equilibrium mixture contains 0.30 mol of A, 0.25 mol of B and 0.020 mol of C in 350 $cm^3$ of solution.**

**Calculate the value of the equilibrium constant $K_c$**

**Deduce the units of $K_c$ [4 marks]**

$K_c$ ______________________

Units ______________________

[Turn over]

**When an excess of water is added to chloroethanal, an equilibrium mixture is formed.**

**$ClCH_2CHO(aq) + H_2O(l) \rightleftharpoons ClCH_2CH(OH)_2(aq)$**

**An expression for an equilibrium constant (*K*) for the reaction under these conditions is**

$$K = \frac{[ClCH_2CH(OH)_2]}{[ClCH_2CHO]}$$

**0 9 . 3**

**Suggest why an expression for *K* can be written without the concentration of water. [1 mark]**

**[Turn over]**

**0 9 . 4**

**Distilled water is added to 4.71 g of chloroethanal ($M_r$ = 78.5) to make 50.0 $cm^3$ of solution. The mixture is allowed to reach equilibrium.**

**The value of the equilibrium constant ($K$) is 37.0**

**Calculate the equilibrium concentration, in mol $dm^{-3}$, of $ClCH_2CH(OH)_2$ [5 marks]**

Concentration ________________ mol $dm^{-3}$

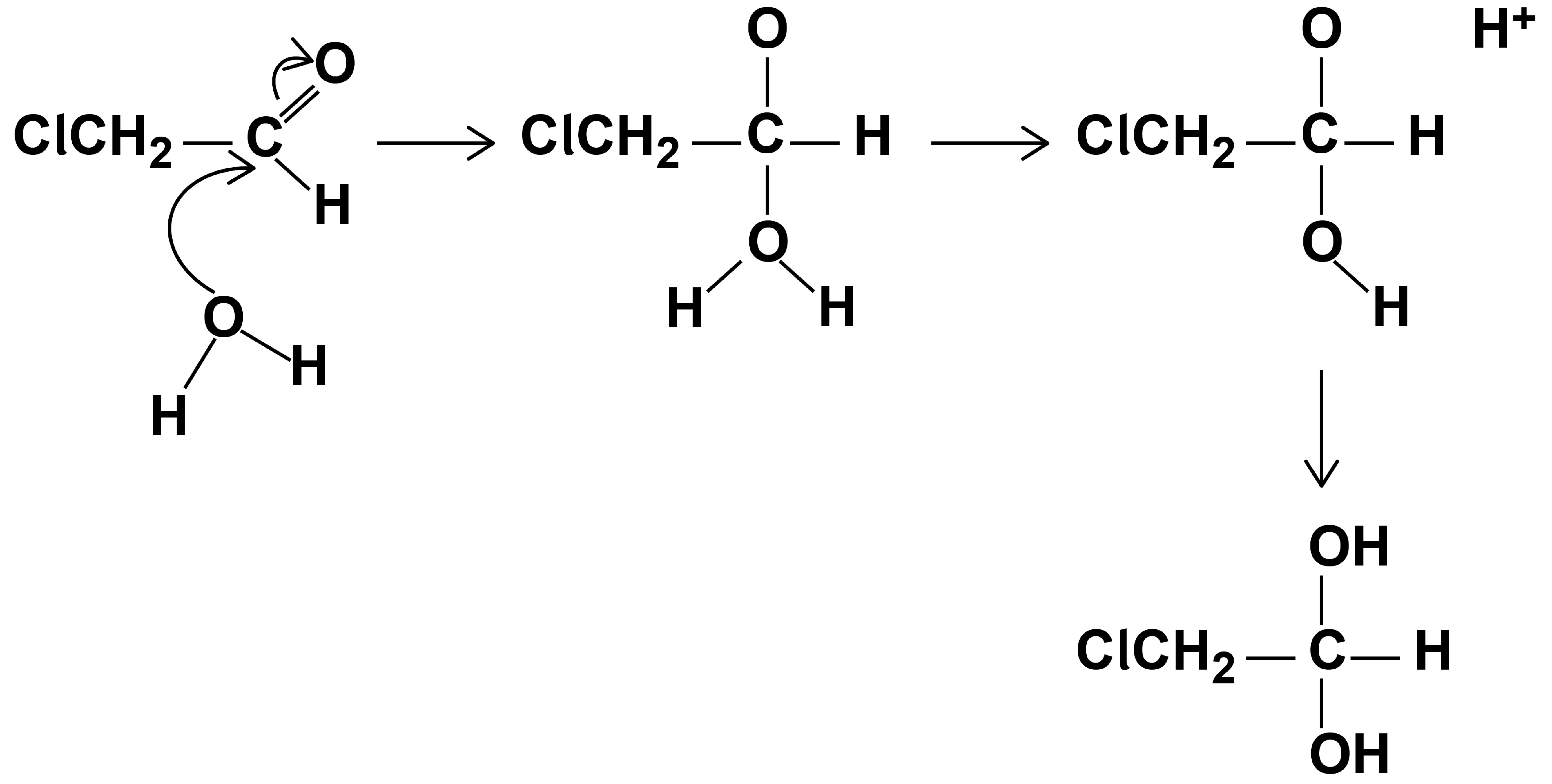
[Turn over]

**0 9 . 5**

**FIGURE 6, on the opposite page, shows an incomplete nucleophilic addition mechanism for the reaction of water with chloroethanal.**

**Complete the mechanism in FIGURE 6, on the opposite page, by adding TWO curly arrows, all relevant charges and any lone pairs of electrons involved. [3 marks]**

FIGURE 6



[Turn over]

**0 9 . 6**

**When an excess of water is added to ethanal a similar nucleophilic addition reaction occurs.**

$$CH_3CHO(aq) + H_2O(l) \rightleftharpoons CH_3CH(OH)_2(aq)$$

**Suggest why this reaction is slower than the reaction in Question 09.5. [3 marks]**

**END OF QUESTIONS**

18

**Additional page, if required.**

**Write the question numbers in the left-hand margin.**

**Additional page, if required.**

**Write the question numbers in the left-hand margin.**

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| For Examiner's Use | |
|---|---|
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| **TOTAL** | |