

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

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Forename(s)

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Candidate signature

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I declare this is my own work.

# A-level CHEMISTRY

## Paper 2 Organic and Physical Chemistry

Time allowed: 2 hours

### Materials

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.
- 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 105.

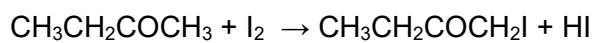
For Examiner's Use	
Question	Mark
1	
2	
3	
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6	
7	
8	
9	
10	
<b>TOTAL</b>	



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

0 1

An acidified solution of butanone reacts with iodine as shown.



0 1 . 1

Draw the displayed formula for  $\text{CH}_3\text{CH}_2\text{COCH}_2\text{I}$

Give the name of  $\text{CH}_3\text{CH}_2\text{COCH}_2\text{I}$

[2 marks]

Displayed formula

Name \_\_\_\_\_



0 1 . 2 The rate equation for the reaction is



**Table 1** shows the initial concentrations used in an experiment.

**Table 1**

	$\text{CH}_3\text{CH}_2\text{COCH}_3$	$\text{I}_2$	$\text{H}^+$
Initial concentration / $\text{mol dm}^{-3}$	4.35	0.00500	0.825

The initial rate of reaction in this experiment is  $1.45 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$

Calculate the value of the rate constant,  $k$ , for the reaction and give its units.

**[3 marks]**

$k$  \_\_\_\_\_

Units \_\_\_\_\_

0 1 . 3 Calculate the initial rate of reaction when all of the initial concentrations are halved.

**[1 mark]**

Initial rate of reaction \_\_\_\_\_  $\text{mol dm}^{-3} \text{ s}^{-1}$

**Question 1 continues on the next page**

Turn over ►



0 1 . 4

An experiment was done to measure the time,  $t$ , taken for a solution of iodine to react completely when added to an excess of an acidified solution of butanone.

Suggest an observation used to judge when all the iodine had reacted.

[1 mark]

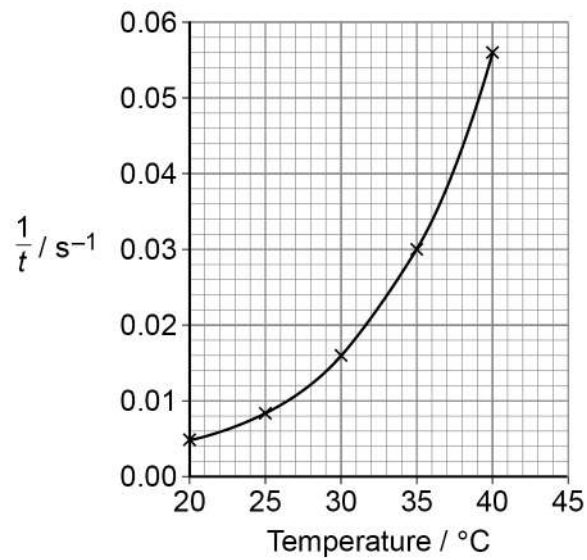
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The experiment was repeated at different temperatures.

**Figure 1** shows how  $\frac{1}{t}$  varied with temperature for these experiments.

**Figure 1**



0 1 . 5

Describe and explain the shape of the graph in **Figure 1**.**[3 marks]**

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0 1 . 6

Deduce the time taken for the reaction at 35 °C

**[1 mark]**

Time \_\_\_\_\_ s

**Question 1 continues on the next page****Turn over ►**

**0 1** . **7** For a different reaction, **Table 2** shows the value of the rate constant at different temperatures.

**Table 2**

Experiment	Temperature / K	Rate constant / s <sup>-1</sup>
1	$T_1 = 303$	$k_1 = 1.55 \times 10^{-5}$
2	$T_2 = 333$	$k_2 = 1.70 \times 10^{-4}$

This equation can be used to calculate the activation energy,  $E_a$

$$\ln \left( \frac{k_1}{k_2} \right) = \frac{E_a}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

Calculate the value, in kJ mol<sup>-1</sup>, of the activation energy,  $E_a$

The gas constant,  $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

**[5 marks]**

$E_a$  \_\_\_\_\_ kJ mol<sup>-1</sup>



0 1 . 8

Name and outline the mechanism for the reaction of butanone with KCN followed by dilute acid.

**[5 marks]**

Name of mechanism \_\_\_\_\_

Outline of mechanism

21

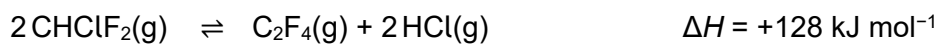
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**0 2**

Tetrafluoroethene is made from chlorodifluoromethane in this reversible reaction.



A 2.00 mol sample of  $\text{CHClF}_2$  is placed in a container of volume  $23.2 \text{ dm}^3$  and heated. When equilibrium is reached, the mixture contains 0.270 mol of  $\text{CHClF}_2$

**0 2 . 1**

Calculate the amount, in moles, of  $\text{C}_2\text{F}_4$  and of  $\text{HCl}$  in the equilibrium mixture.

**[2 marks]**

Amount of  $\text{C}_2\text{F}_4$  \_\_\_\_\_ mol

Amount of  $\text{HCl}$  \_\_\_\_\_ mol

**0 2 . 2**

Give an expression for  $K_c$  for this equilibrium.

**[1 mark]** $K_c$ 



0 2 . 3 Calculate a value for  $K_c$

Give its units.

[3 marks]

$K_c$  \_\_\_\_\_ Units \_\_\_\_\_

0 2 . 4 State and explain the effect of using a higher temperature on the equilibrium yield of tetrafluoroethene.

[3 marks]

Effect on yield \_\_\_\_\_

Explanation \_\_\_\_\_

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Question 2 continues on the next page

Turn over ►



0 2 . 5

Chemists provided evidence that was used to support a ban on the use of chlorodifluoromethane as a refrigerant.

Many refrigerators now use pentane as a refrigerant.

State the environmental problem that chlorodifluoromethane can cause.

Give **one** reason why pentane does not cause this problem.

**[2 marks]**

Environmental problem \_\_\_\_\_

\_\_\_\_\_

Reason why pentane does not cause this problem \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

11



**0 3**

This question is about 2-methylbut-1-ene.

**0 3 . 1**

Name the mechanism for the reaction of 2-methylbut-1-ene with concentrated sulfuric acid.

Outline the mechanism for this reaction to form the major product.

**[5 marks]**

Name of mechanism \_\_\_\_\_

Outline of mechanism to form major product

**0 3 . 2**Draw the structure of the minor product formed in the reaction in Question **03.1**

Explain why this is the minor product.

**[3 marks]**

Structure of minor product

Explanation \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Turn over ►



0 3 . 3 Draw the skeletal formula of a functional group isomer of 2-methylbut-1-ene.

[1 mark]

0 3 . 4 2-methylbut-1-ene can form a polymer.

State the type of polymerisation.

Draw the repeating unit for the polymer formed.

[2 marks]

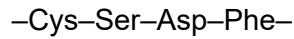
Type of polymerisation \_\_\_\_\_

Repeating unit



**0 4**

Proteins are polymers made from amino acids.  
Part of the structure of a protein is shown.



Each amino acid in the protein is shown using the first three letters of its name.

**0 4 . 1**

Identify the type of protein structure shown.

**[1 mark]**

Tick (✓) **one** box.

Primary

Secondary

Tertiary

**0 4 . 2**

Draw a structure for the –Cys–Ser– section of the protein.  
Use the Data Booklet to help you answer this question.

**[2 marks]**

Question 4 continues on the next page

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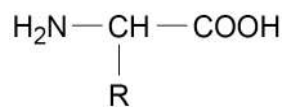
0 4 . 3

Name the other substance formed when two amino acids react together to form part of a protein chain.

**[1 mark]**

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The general structure of an amino acid is shown.



R represents a group that varies between different amino acids.  
R groups can interact and contribute to protein structure.

0 4 . 4

Explain why the strength of the interaction between two cysteine R groups differs from the strength of the interaction between a serine R group and an aspartic acid R group.

Use the Data Booklet to help you answer this question.

**[4 marks]**

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0 4 . 5

Deduce the type of interaction that occurs between a lysine R group and an aspartic acid R group.

**[1 mark]**

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9



**0 5**

This question is about the preparation of hexan-2-ol.  
Hexan-2-ol does not mix with water and has a boiling point of 140 °C

Hexan-2-ol can be prepared from hex-1-ene using this method.

- a Measure out 11.0 cm<sup>3</sup> of hex-1-ene into a boiling tube in an ice bath.
- b Carefully add 5 cm<sup>3</sup> of concentrated phosphoric acid to the hex-1-ene.
- c After 5 minutes add 10 cm<sup>3</sup> of distilled water to the mixture and transfer the boiling tube contents to a separating funnel.
- d Shake the mixture and allow it to settle.
- e Discard the lower (aqueous) layer.
- f Add a fresh 10 cm<sup>3</sup> sample of distilled water and repeat steps **d** and **e**.
- g Transfer the remaining liquid to a beaker.
- h Add 2 g of anhydrous magnesium sulfate and allow to stand for 5 minutes.
- i Filter the mixture under reduced pressure.
- j Distil the filtrate and collect the distillate that boils in the range 130–160 °C

**0 5 . 1**

It is important to wear eye protection and a lab coat when completing this experiment.

Suggest, with a reason, **one** other appropriate safety precaution for this experiment.

**[2 marks]**

Precaution \_\_\_\_\_

Reason \_\_\_\_\_

\_\_\_\_\_

**0 5 . 2**

Give a reason for adding the distilled water in steps **c** and **f**.

**[1 mark]**

\_\_\_\_\_

\_\_\_\_\_

**0 5 . 3**

Give a reason for adding anhydrous magnesium sulfate in step **h**.

**[1 mark]**

\_\_\_\_\_

\_\_\_\_\_

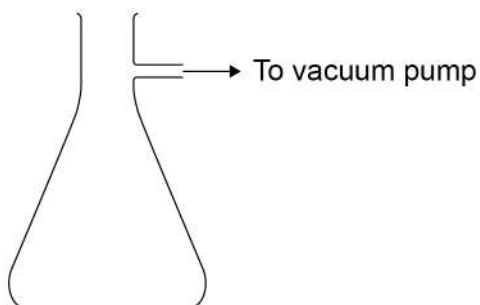
Question 5 continues on the next page

Turn over ►



0 5 . 4

Complete and label the diagram of the apparatus used to filter the mixture under reduced pressure in step i.

**[2 marks]**

0 5 . 5

Identify the most likely organic impurity, other than hex-1-ene, in the distillate collected in step j.

Suggest **one** reason why it could be difficult to remove this impurity.

**[2 marks]**

Impurity \_\_\_\_\_

Reason \_\_\_\_\_

\_\_\_\_\_





0 5 . 6

Calculate the mass, in g, of hexan-2-ol formed from 11.0 cm<sup>3</sup> of hex-1-ene if the yield is 31.0%

Give your answer to 1 decimal place.

Density of hex-1-ene = 0.678 g cm<sup>-3</sup>

[4 marks]

Mass \_\_\_\_\_ g

12

Turn over ►



0 6

This question is about compound **X** with the empirical formula  $C_2H_4O$

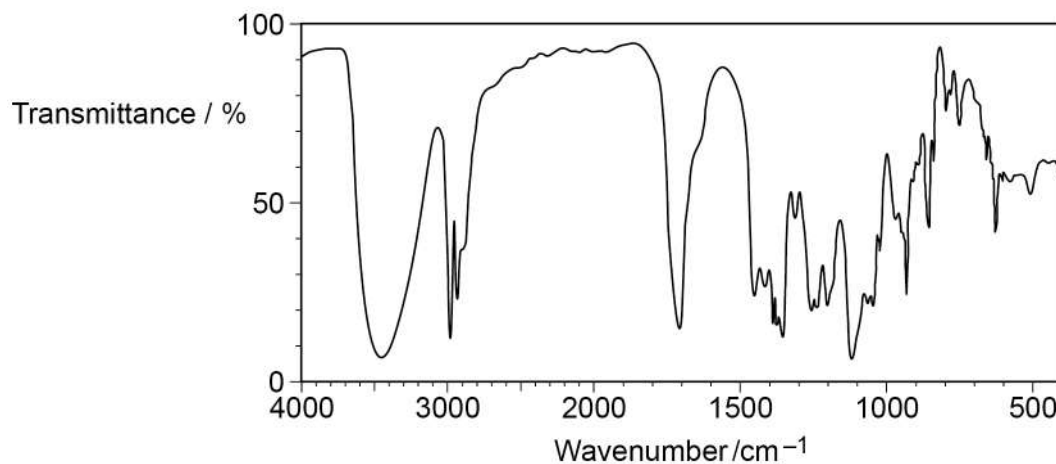
**Figure 2** shows the infrared spectrum of **X**.

**Figure 3** shows the  $^{13}C$  NMR spectrum of **X**.

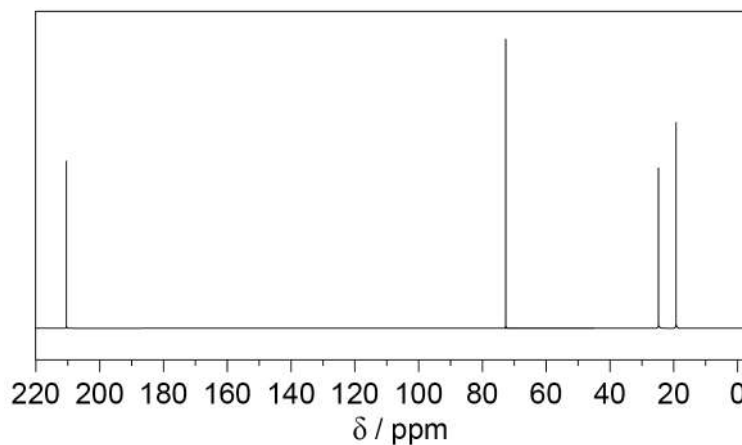
The  $^1H$  NMR spectrum of **X** shows four peaks with different chemical shift values.

**Table 3** gives data for these peaks.

**Figure 2**



**Figure 3**



**Table 3**

<b>Chemical shift <math>\delta</math> / ppm</b>	3.9	3.7	2.1	1.2
<b>Splitting pattern</b>	quartet	singlet	singlet	doublet
<b>Integration value</b>	1	1	3	3





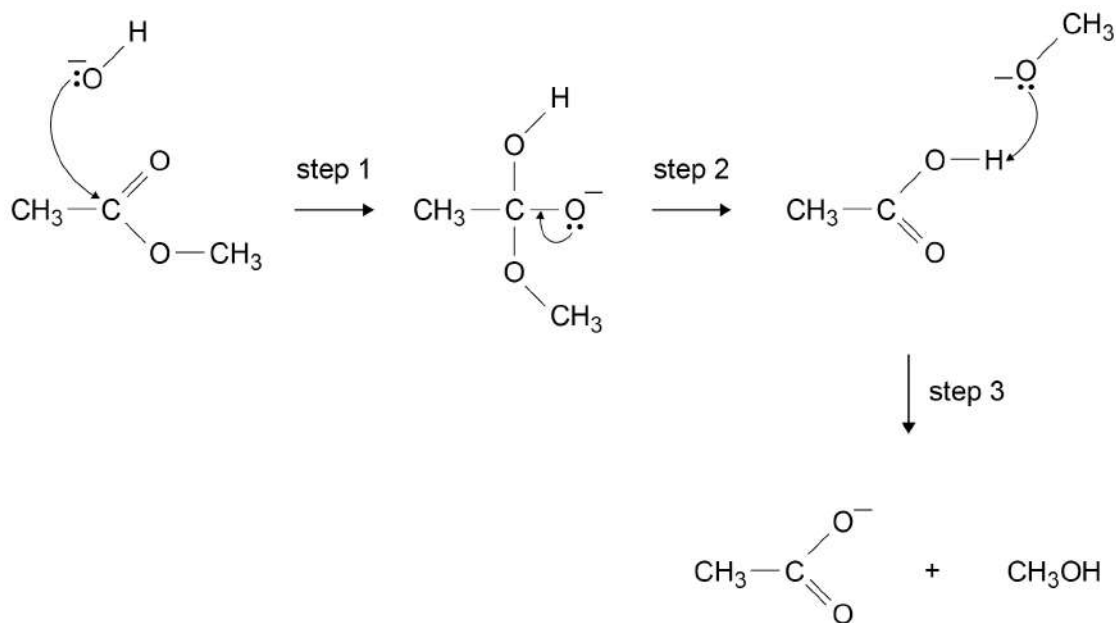


0 7

This question is about esters.

**Figure 4** shows an incomplete mechanism for the reaction of an ester with aqueous sodium hydroxide.

**Figure 4**



0 7 . 1

Add **three** curly arrows to complete the mechanism in **Figure 4**.

[3 marks]

0 7 . 2

Name the type of reaction shown in **Figure 4**.

[1 mark]

0 7 . 3

Deduce the role of the  $\text{CH}_3\text{O}^-$  ion in step 3 shown in **Figure 4**.

[1 mark]

0 7 . 4

A triester in vegetable oil reacts with sodium hydroxide in a similar way.

Give a use for a product of this reaction.

[1 mark]

6

Turn over ►



**0 8**

Benzene reacts with methanoyl chloride (HCOCl) in the presence of a catalyst.

**0 8 . 1**

Give an equation for the overall reaction when benzene reacts with methanoyl chloride.

Name the organic product.

**[2 marks]**

Equation \_\_\_\_\_

Name \_\_\_\_\_

**0 8 . 2**

Identify the catalyst needed in this reaction.

Give an equation to show how the catalyst is used to form the electrophile,  $[\text{HCO}]^+$ **[2 marks]**

Catalyst \_\_\_\_\_

Equation \_\_\_\_\_

**0 8 . 3**Outline the mechanism for the reaction of benzene with the electrophile,  $[\text{HCO}]^+$ **[3 marks]**

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**7**

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box*

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ANSWER IN THE SPACES PROVIDED**

**Turn over ►**



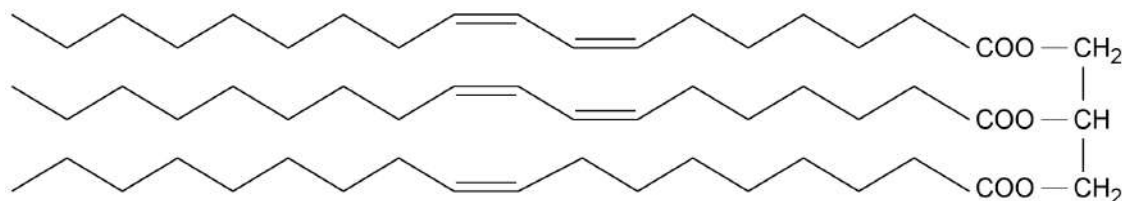
0 9

This question is about olive oil.

A sample of olive oil is mainly the unsaturated fat **Y** mixed with a small amount of inert impurity.

The structure of **Y** in the olive oil is shown.

**Y** has the molecular formula  $C_{57}H_{100}O_6$  ( $M_r = 880$ ).



The amount of **Y** is found by measuring how much bromine water is decolourised by a sample of oil, using this method.

- Transfer a weighed sample of oil to a 250 cm<sup>3</sup> volumetric flask and make up to the mark with an inert organic solvent.
- Titrate 25.0 cm<sup>3</sup> samples of the olive oil solution with 0.025 mol dm<sup>-3</sup> Br<sub>2</sub>(aq).

0 9 . 1

A suitable target titre for the titration is 30.0 cm<sup>3</sup> of 0.025 mol dm<sup>-3</sup> Br<sub>2</sub>(aq).

Justify why a much smaller target titre would **not** be appropriate.

Calculate the amount, in moles, of bromine in the target titre.

[2 marks]

Justification \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Amount of bromine \_\_\_\_\_ mol





09.2

Calculate a suitable mass of olive oil to transfer to the volumetric flask using your answer to Question 09.1 and the structure of **Y**.

Assume that the olive oil contains 85% of **Y** by mass.

(If you were unable to calculate the amount of bromine in the target titre, you should assume it is  $6.25 \times 10^{-4}$  mol. This is **not** the correct amount.)

[5 marks]

Mass of olive oil \_\_\_\_\_ g

Question 9 continues on the next page

Turn over ►



The olive oil solution can be prepared using this method.

- Place a weighing bottle on a balance and record the mass, in g, to 2 decimal places.
- Add olive oil to the weighing bottle until a suitable mass has been added.
- Record the mass of the weighing bottle and olive oil.
- Pour the olive oil into a 250 cm<sup>3</sup> volumetric flask.
- Add organic solvent to the volumetric flask until it is made up to the mark.
- Place a stopper in the flask and invert the flask several times.

**0 9 . 3** Suggest an extra step to ensure that the mass of olive oil in the solution is recorded accurately.

Justify your suggestion.

**[2 marks]**

Extra step \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Justification \_\_\_\_\_

\_\_\_\_\_

**0 9 . 4** State the reason for inverting the flask several times.

**[1 mark]**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



0 9 . 5

A sample of the olive oil was dissolved in methanol and placed in a mass spectrometer. The sample was ionised using electrospray ionisation. Each molecule gained a hydrogen ion ( $\text{H}^+$ ) during ionisation. The spectrum showed a peak for an ion with  $\frac{m}{z} = 345$  formed from an impurity in the olive oil.

The ion with  $\frac{m}{z} = 345$  was formed from a compound with the empirical formula  $\text{C}_5\text{H}_{10}\text{O}$

Deduce the molecular formula of this compound.

[2 marks]

Show your working.

Molecular formula \_\_\_\_\_

12

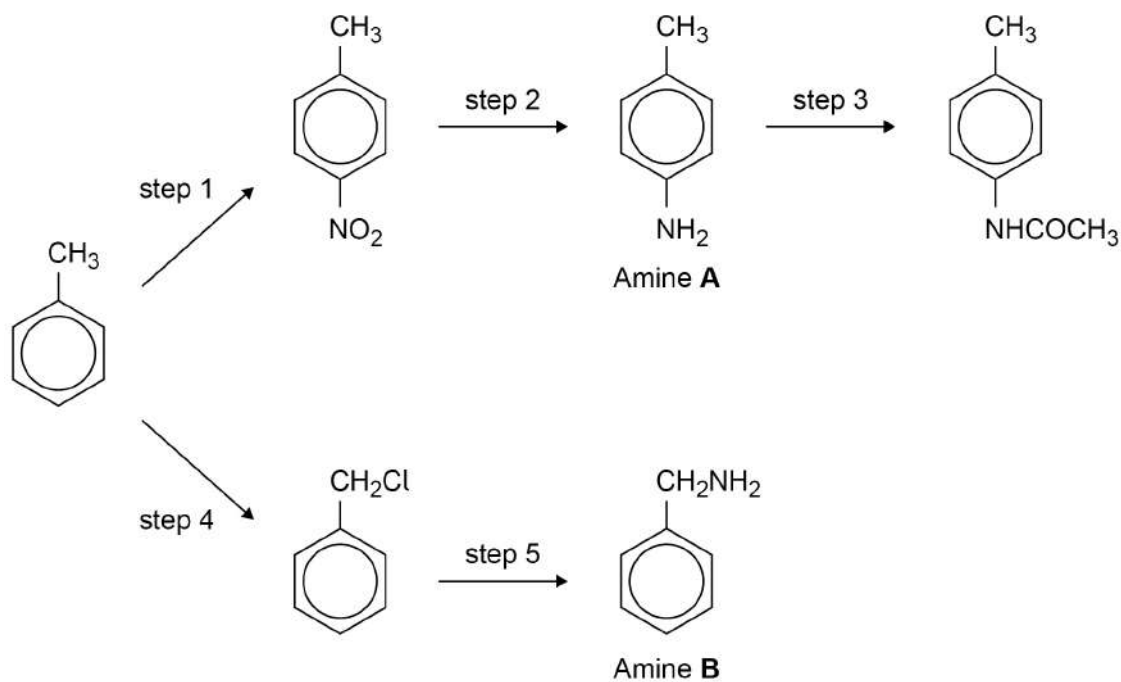
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1 0

This question is about the reaction scheme shown.



1 0 . 1

State the reagents needed for step 1 and the reagents needed for step 2.

[3 marks]

step 1 \_\_\_\_\_

\_\_\_\_\_

step 2 \_\_\_\_\_

\_\_\_\_\_

1 0 . 2

Give the name of the mechanism for the reaction in step 3.

[1 mark]

\_\_\_\_\_



1 0 . 3 Name the reagent for step 4.

State a necessary condition for step 4.

[2 marks]

Reagent \_\_\_\_\_

Condition \_\_\_\_\_

1 0 . 4 Amine **A** is formed in step 2 and amine **B** is formed in step 5.

Explain why the yield of **B** in step 5 is less than the yield of **A** in step 2.

[2 marks]

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

1 0 . 5 Explain why amine **B** is a stronger base than amine **A**.

[2 marks]

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

10

END OF QUESTIONS

