



Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

Forename(s)

Candidate signature

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	
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10	
TOTAL	



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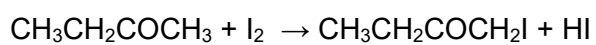
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Answer **all** questions in the spaces provided.

0	1
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An acidified solution of butanone reacts with iodine as shown.



0	1	.	1
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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

	$\text{CH}_3\text{CH}_2\text{COCH}_3$	I_2	H^+
Initial concentration / 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.

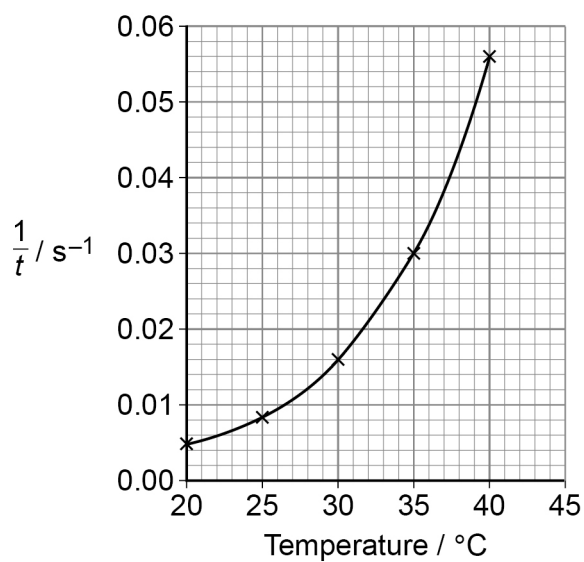
Suggest an observation used to judge when all the iodine had reacted.

[1 mark]

The experiment was repeated at different temperatures.

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

Figure 1



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0 1 . 5

Describe and explain the shape of the graph in **Figure 1**.

[3 marks]

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 ⁻¹
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⁻¹, 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⁻¹



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

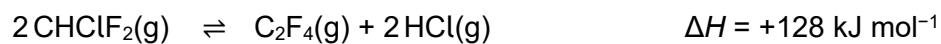
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0	2
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Tetrafluoroethene is made from chlorodifluoromethane in this reversible reaction.



A 2.00 mol sample of CHClF_2 is placed in a container of volume 23.2 dm^3 and heated. When equilibrium is reached, the mixture contains 0.270 mol of CHClF_2

0	2	.	1
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Calculate the amount, in moles, of C_2F_4 and of HCl in the equilibrium mixture.

[2 marks]

Amount of C_2F_4 _____ mol

Amount of 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 _____

Question 2 continues on the next page

Turn over ►



0	2	5
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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

11

0	4
---	---

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

–Cys–Ser–Asp–Phe–

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

0	4	.	1
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Identify the type of protein structure shown.

[1 mark]

Tick (✓) **one** box.

Primary

☐

Secondary

☐

Tertiary

☐

0	4	.	2
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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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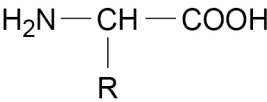


0 4 . 3

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

[1 mark]

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]

0 4 . 5

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

[1 mark]

9



0	5
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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 cm³ of hex-1-ene into a boiling tube in an ice bath.
- b Carefully add 5 cm³ of concentrated phosphoric acid to the hex-1-ene.
- c After 5 minutes add 10 cm³ 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 cm³ 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
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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]

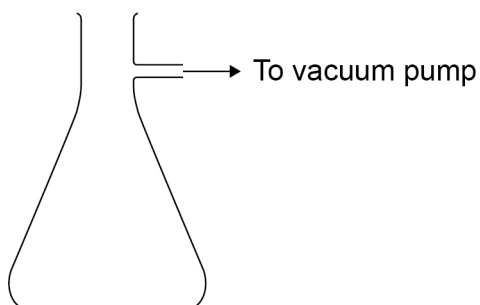
Question 5 continues on the next page

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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 cm³ 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⁻³

[4 marks]

Mass _____ g

12

Turn over ►



0 6

This question is about compound **X** with the empirical formula $\text{C}_2\text{H}_4\text{O}$

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

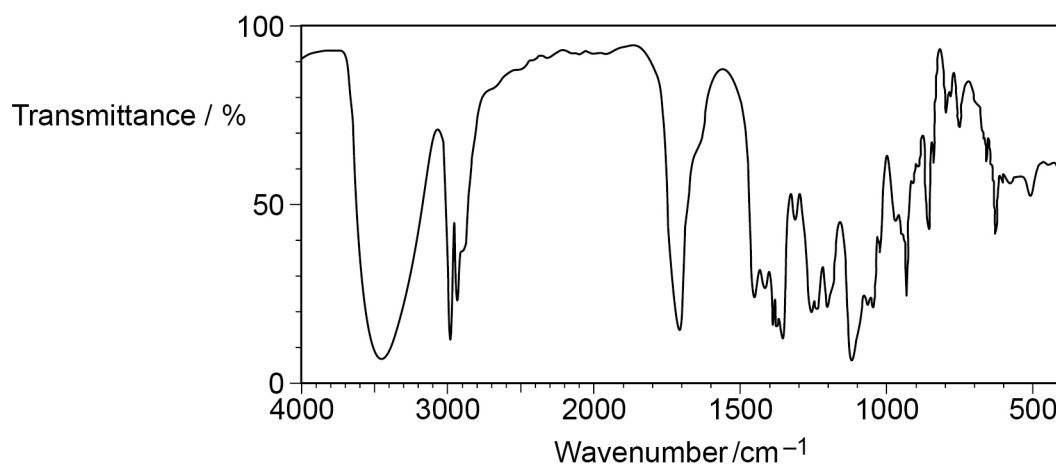


Figure 3

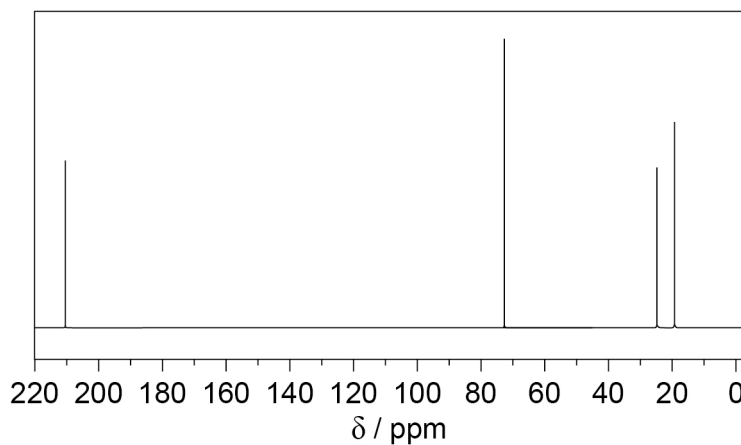


Table 3

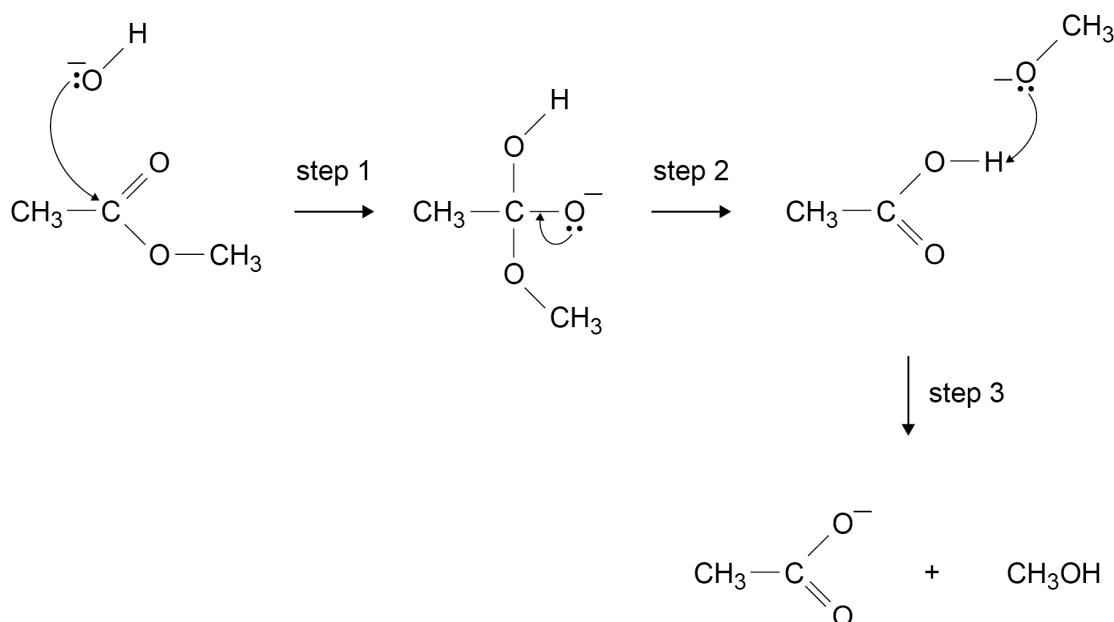
Chemical shift δ / ppm	3.9	3.7	2.1	1.2
Splitting pattern	quartet	singlet	singlet	doublet
Integration value	1	1	3	3



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 CH_3O^- 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
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Benzene reacts with methanoyl chloride (HCOCl) in the presence of a catalyst.

0	8	.	1
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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
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Outline the mechanism for the reaction of benzene with the electrophile, $[\text{HCO}]^+$

[3 marks]

7



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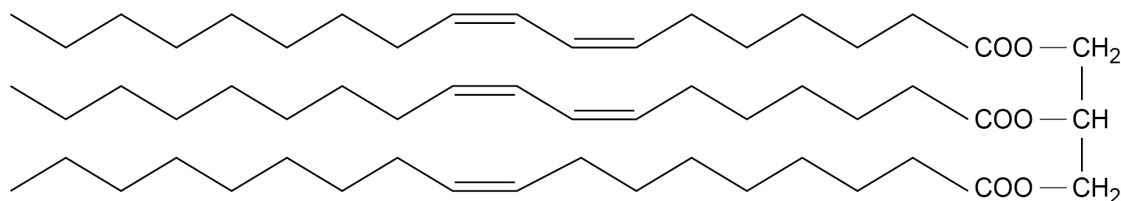
0 9

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 cm³ volumetric flask and make up to the mark with an inert organic solvent.
- Titrate 25.0 cm³ samples of the olive oil solution with 0.025 mol dm⁻³ Br₂(aq).

0 9

1

A suitable target titre for the titration is 30.0 cm³ of 0.025 mol dm⁻³ Br₂(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



0	9	.	2
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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 6.25×10^{-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 cm³ 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
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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 (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

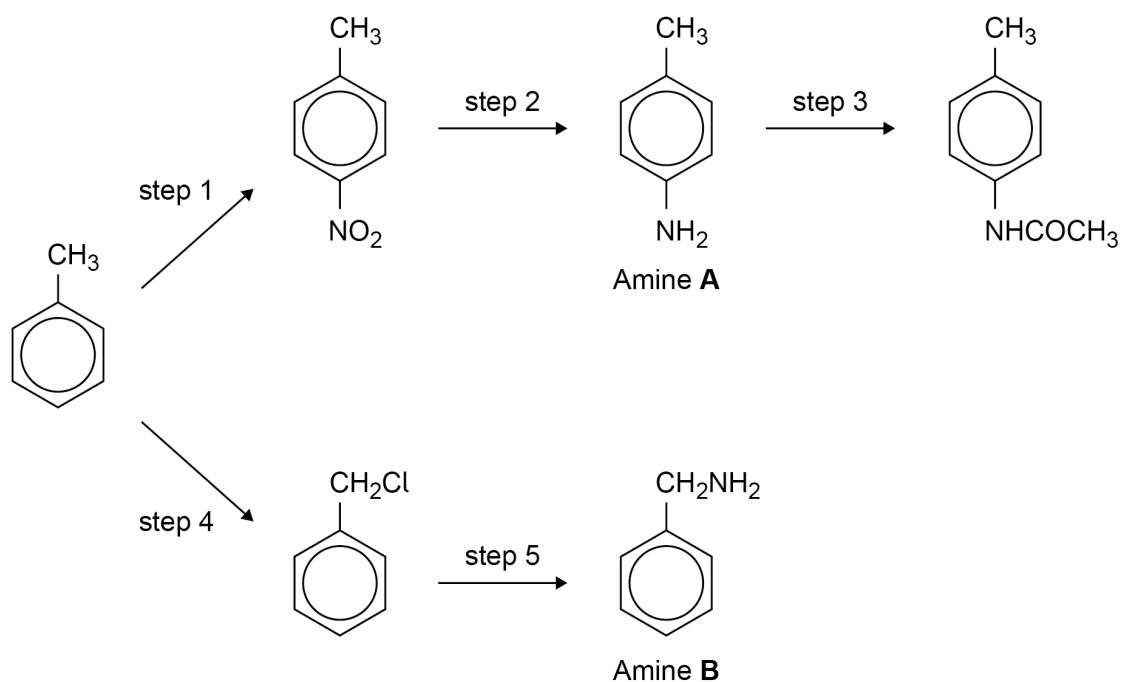
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1	0
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This question is about the reaction scheme shown.



1	0	.	1
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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
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.

5

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

[2 marks]

10

END OF QUESTIONS



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Question
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