Please write clearly in block capitals.

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

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	
3	
4	
5	
6	
7	
8	
9	
10	
TOTAL	

Do not write outside the box

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

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

$$CH_3CH_2COCH_3 + I_2 \rightarrow CH_3CH_2COCH_2I + HI$$

0 1 . 1 Draw the displayed formula for $CH_3CH_2COCH_2I$

Give the name of $CH_3CH_2COCH_2I$

[2 marks]

Displayed formula

Name ______________________________

0 1 . 2 The rate equation for the reaction is

$$rate = k[CH_3CH_2COCH_3][H^+]$$

Table 1 shows the initial concentrations used in an experiment.

Table 1

	$CH_3CH_2COCH_3$	I_2	H^+
Initial concentration / mol dm^{-3}	4.35	0.00500	0.825

The initial rate of reaction in this experiment is 1.45×10^{-4} mol dm^{-3} 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 ______________________ mol dm^{-3} s^{-1}

Question 1 continues on the next page

Turn over ►

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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.

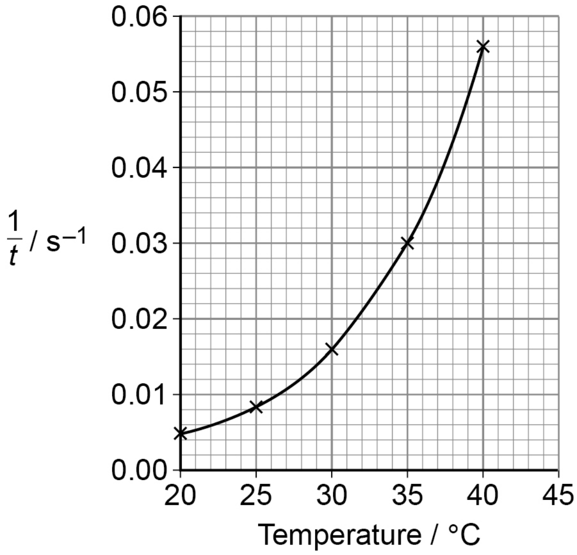
Suggest an observation used to judge when all the iodine had reacted.

[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

Do not write outside the box

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 J K^{-1} 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

Turn over for the next question

Do not write outside the box

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

$$2\,CHClF_2(g) \rightleftharpoons C_2F_4(g) + 2\,HCl(g) \qquad \Delta H = +128\ kJ\ mol^{-1}$$

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 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

Do not write outside the box

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

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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 ______________________________

____

____

____

Do not write outside the box

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 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]

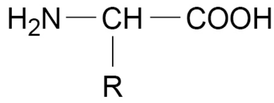
Question 4 continues on the next page

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]

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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]

____

9

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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^3 of hex-1-ene into a boiling tube in an ice bath.

b Carefully add 5 cm^3 of concentrated phosphoric acid to the hex-1-ene.

c After 5 minutes add 10 cm^3 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^3 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

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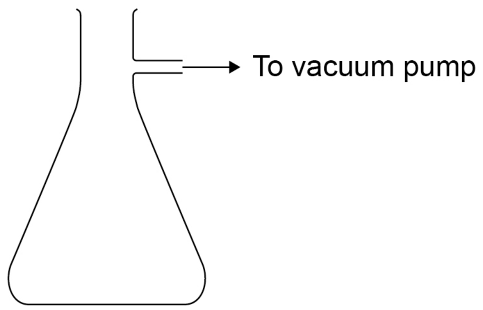
0 5 . 4 Complete and label the diagram of the apparatus used to filter the mixture under reduced pressure in step **i**.

[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 ______________________________

____

Do not write outside the box

0 5 . 6 Calculate the mass, in g, of hexan-2-ol formed from 11.0 cm^3 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

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 ^{1}H NMR spectrum of **X** shows four peaks with different chemical shift values. **Table 3** gives data for these peaks.

Figure 2

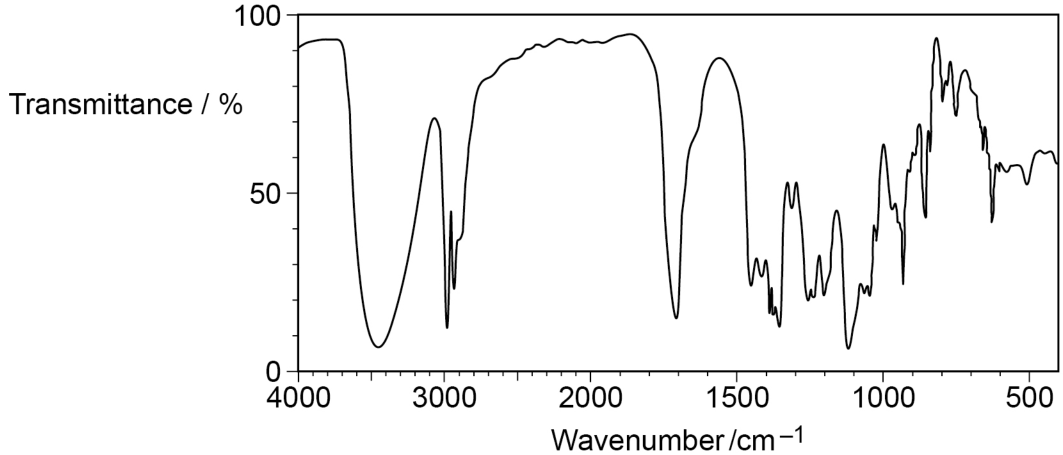


Figure 3

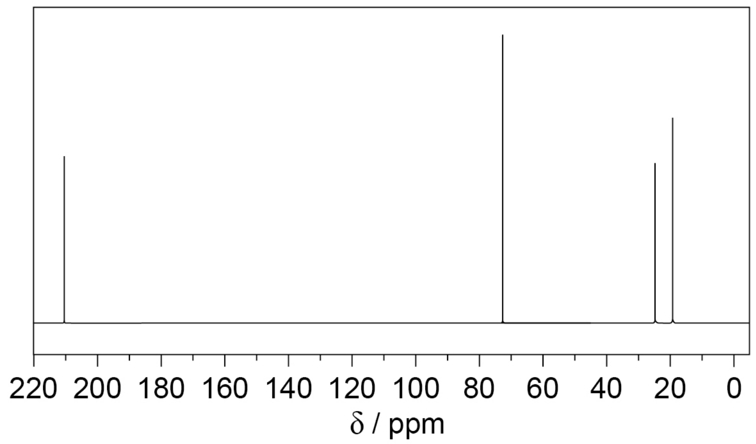


Table 3

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

Do not write outside the box

Show how information from **Figure 2**, **Figure 3** and **Table 3** can be used to deduce the structure of compound **X**.

[6 marks]

The answer space for this question continues on the next page

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6

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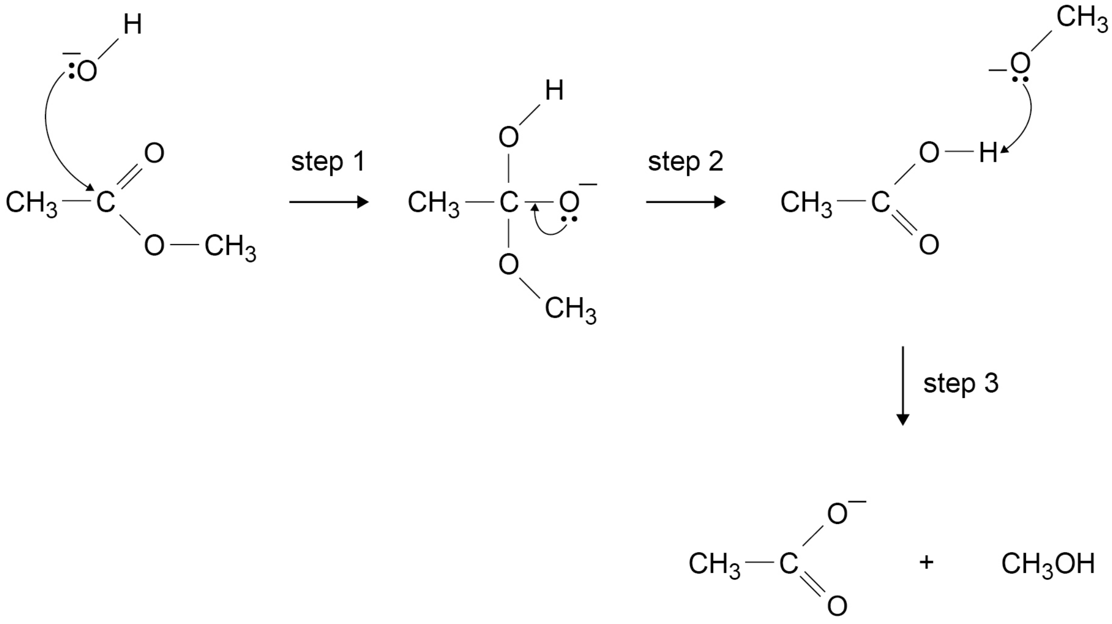
0 7 This question is about esters.

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 ►

Do not write outside the box

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, $[HCO]^+$

[2 marks]

Catalyst ______________________________

Equation ______________________________

0 8 . 3 Outline the mechanism for the reaction of benzene with the electrophile, $[HCO]^+$

[3 marks]

7

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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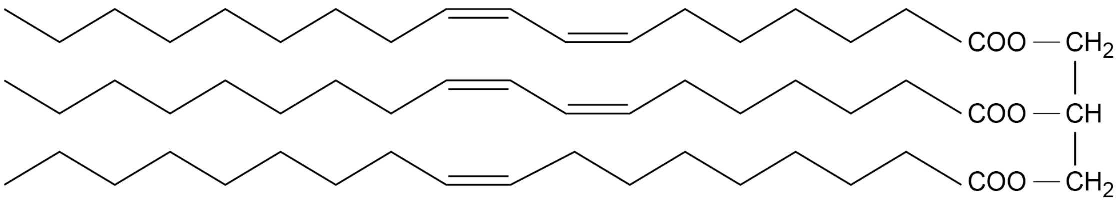
0 9 This question is about olive oil.

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 cm^3 volumetric flask and make up to the mark with an inert organic solvent.
- Titrate 25.0 cm^3 samples of the olive oil solution with 0.025 mol dm^{-3} $Br_2(aq)$.

0 9 . 1 A suitable target titre for the titration is 30.0 cm^3 of 0.025 mol dm^{-3} $Br_2(aq)$.

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

Do not write outside the box

0 9 . 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 6.25×10^{-4} mol. This is **not** the correct amount.)

[5 marks]

Mass of olive oil ____________________ g

Question 9 continues on the next page

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^3 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 (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 $C_5H_{10}O$

Deduce the molecular formula of this compound.

[2 marks]

Show your working.

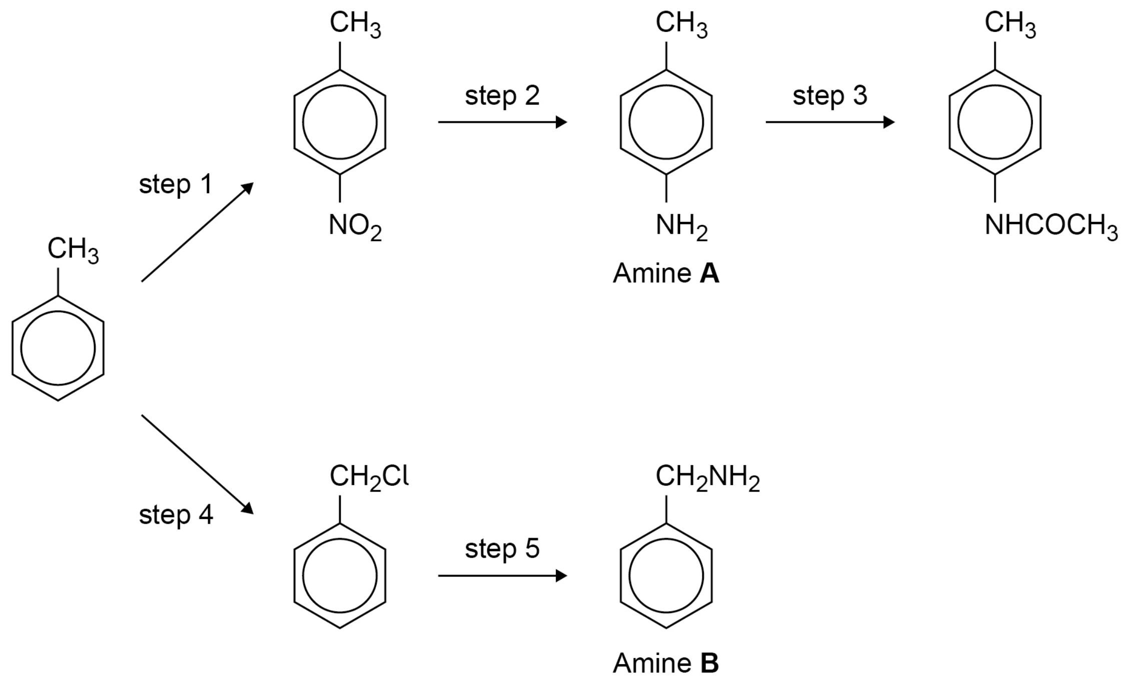
Molecular formula ____________________

12

Turn over for the next question

Do not write outside the box

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]

____

Do not write outside the box

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