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

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 2 7 4 0 5 2 0 1

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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

An acidified solution of butanone reacts with iodine as shown.

$$CH_3CH_2COCH_3 + I_2 \longrightarrow CH_3CH_2COCH_2I + HI$$

01.1

Draw the displayed formula for $CH_3CH_2COCH_2I$

Give the name of $CH_3CH_2COCH_2I$

[2 marks]

Displayed formula

Name ____

[Turn over]

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 ______________________________

[Turn over]

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}

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.

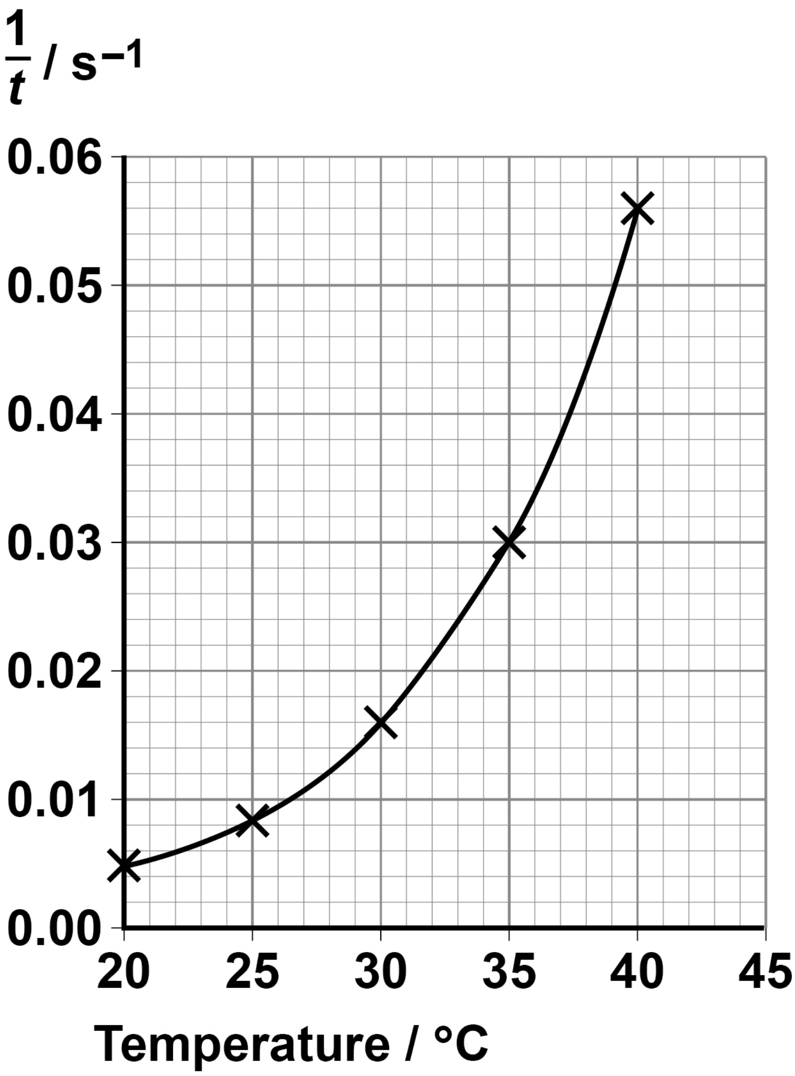
Suggest an observation used to judge when all the iodine had reacted. [1 mark]

[Turn over]

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]

[Turn over]

0 1 . 6

Deduce the time taken for the reaction at 35 °C
[1 mark]

Time ____________________ s

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[Turn over]

01.7

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}

[Turn over]

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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[Turn over]

0 2

Tetrafluoroethene is made from chlorodifluoromethane in this reversible reaction.

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

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

[Turn over]

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 ____________________________________

____

____

____

____

____

____

____

[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

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[Turn over]

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

03.2

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 ______________________________________

____

____

____

____

____

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

[Turn over]

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

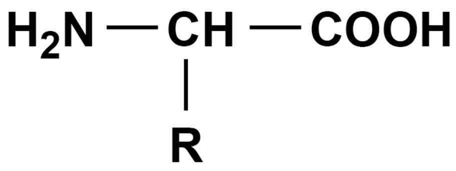
Draw a structure for the –Cys–Ser– section of the protein.
Use the Data Booklet to help you answer this question.
[2 marks]

0 4 . 3

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

[Turn over]

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

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]

____

____

____

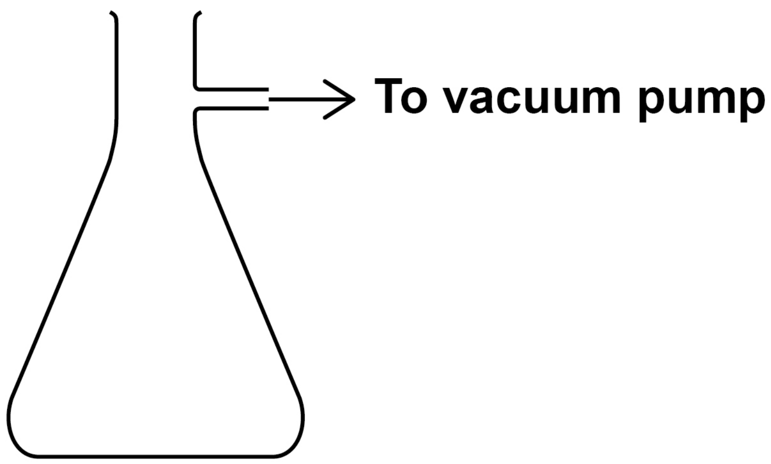
[Turn over]

0 5 . 3

Give a reason for adding anhydrous magnesium sulfate in step H. [1 mark]

0 5 . 4

Complete and label the diagram of the apparatus used to filter the mixture under reduced pressure in step I.
[2 marks]



[Turn over]

05.5

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 ______________________________

____

____

05.6

On the opposite page, 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

[Turn over]

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, on the opposite page, 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, on the opposite page, gives data for these peaks.

FIGURE 2

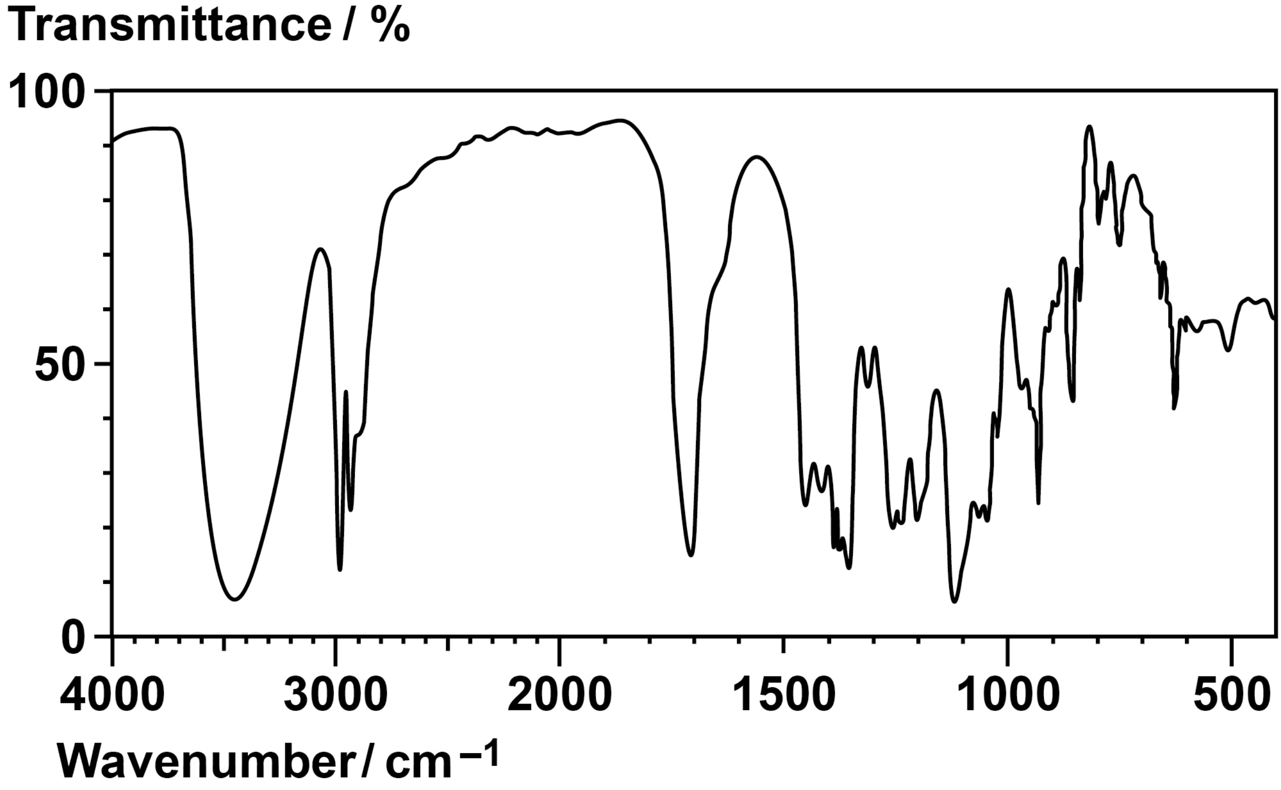


FIGURE 3

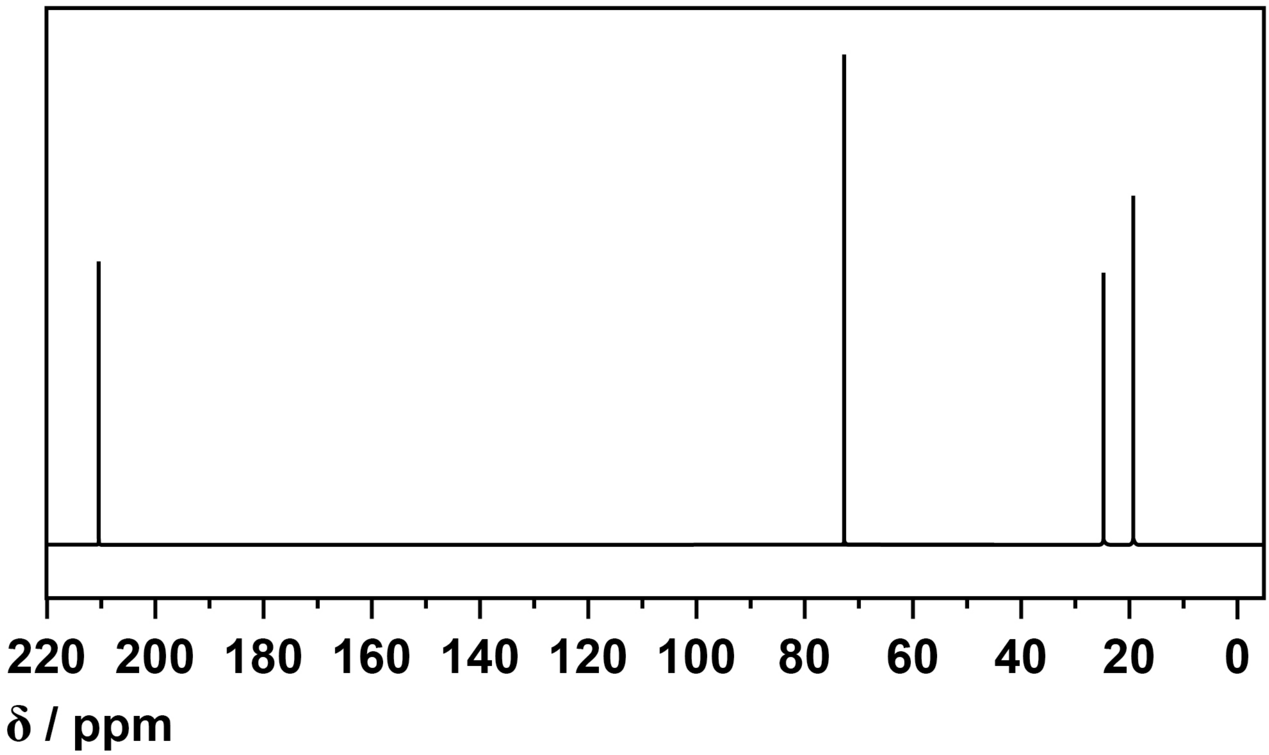


TABLE 3

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

[Turn over]

Show how information from FIGURE 2, FIGURE 3 and TABLE 3, on pages 38 and 39, can be used to deduce the structure of compound X. [6 marks]

[Turn over]

[Turn over]

[Turn over]

6

0 7

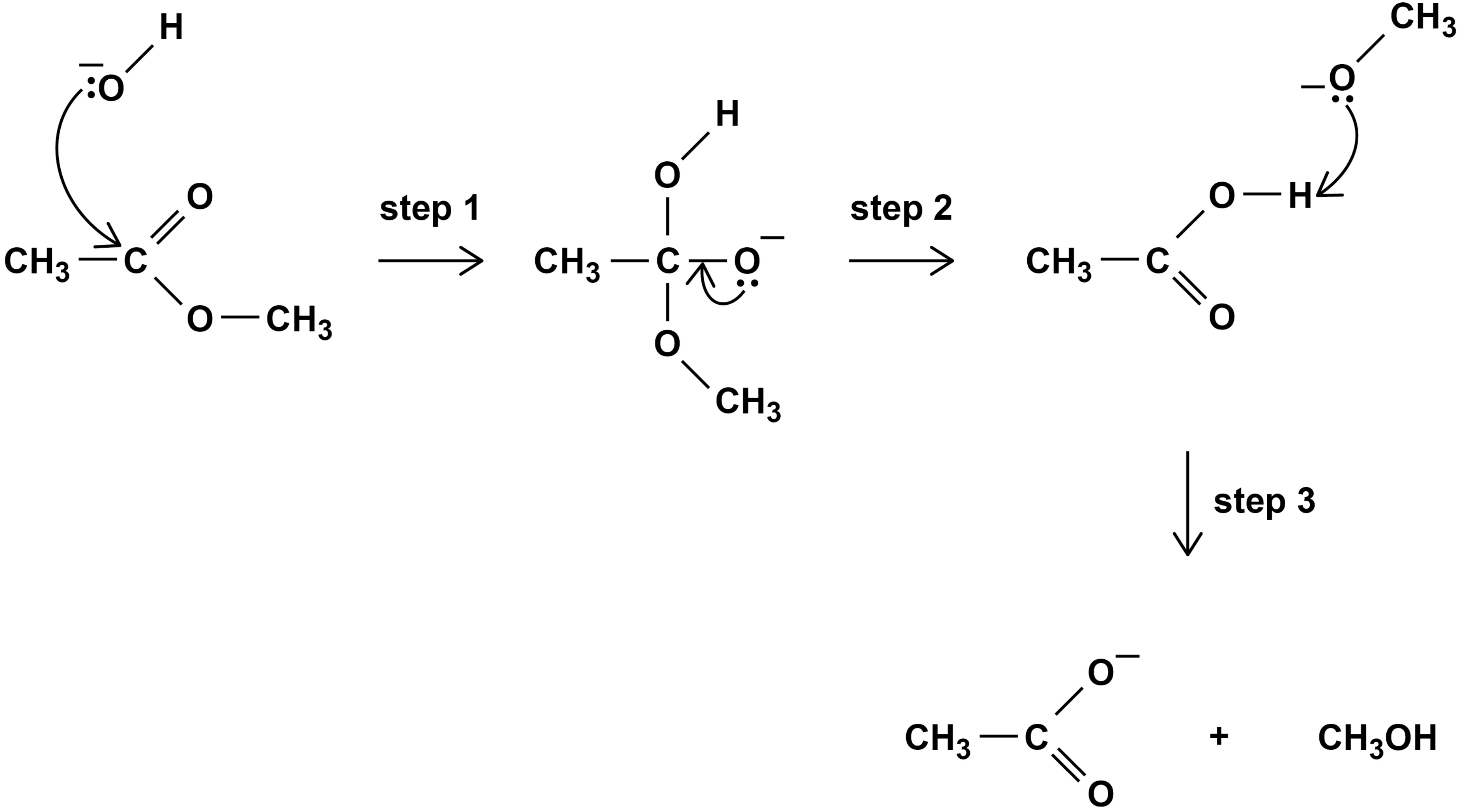
This question is about esters.

FIGURE 4, on the opposite page, shows an incomplete mechanism for the reaction of an ester with aqueous sodium hydroxide.

0 7 . 1

Add THREE curly arrows to complete the mechanism in FIGURE 4. [3 marks]

FIGURE 4



[Turn over]

0 7 . 2

Name the type of reaction shown in FIGURE 4, on page 47. [1 mark]

0 7 . 3

Deduce the role of the CH_3O^- ion in step 3 shown in FIGURE 4, on page 47. [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]

[Turn over]

6

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 ____

08.3

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

[3 marks]

[Turn over]

7

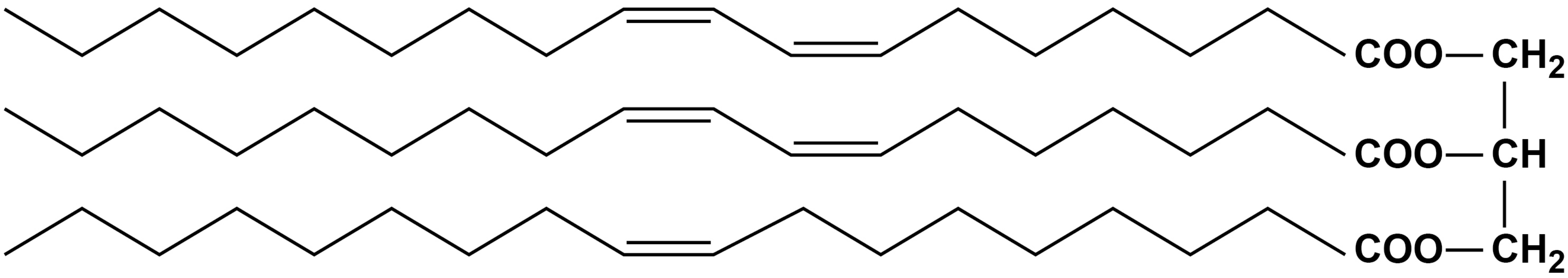
0 9

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} $Br_2(aq)$.**

[Turn over]

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**

[Turn over]

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

[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^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 ______________________________

[Turn over]

12

10

This question is about the reaction scheme shown on the opposite page.

10.1

State the reagents needed for step 1 and the reagents needed for step 2.
[3 marks]

step 1 ____________________

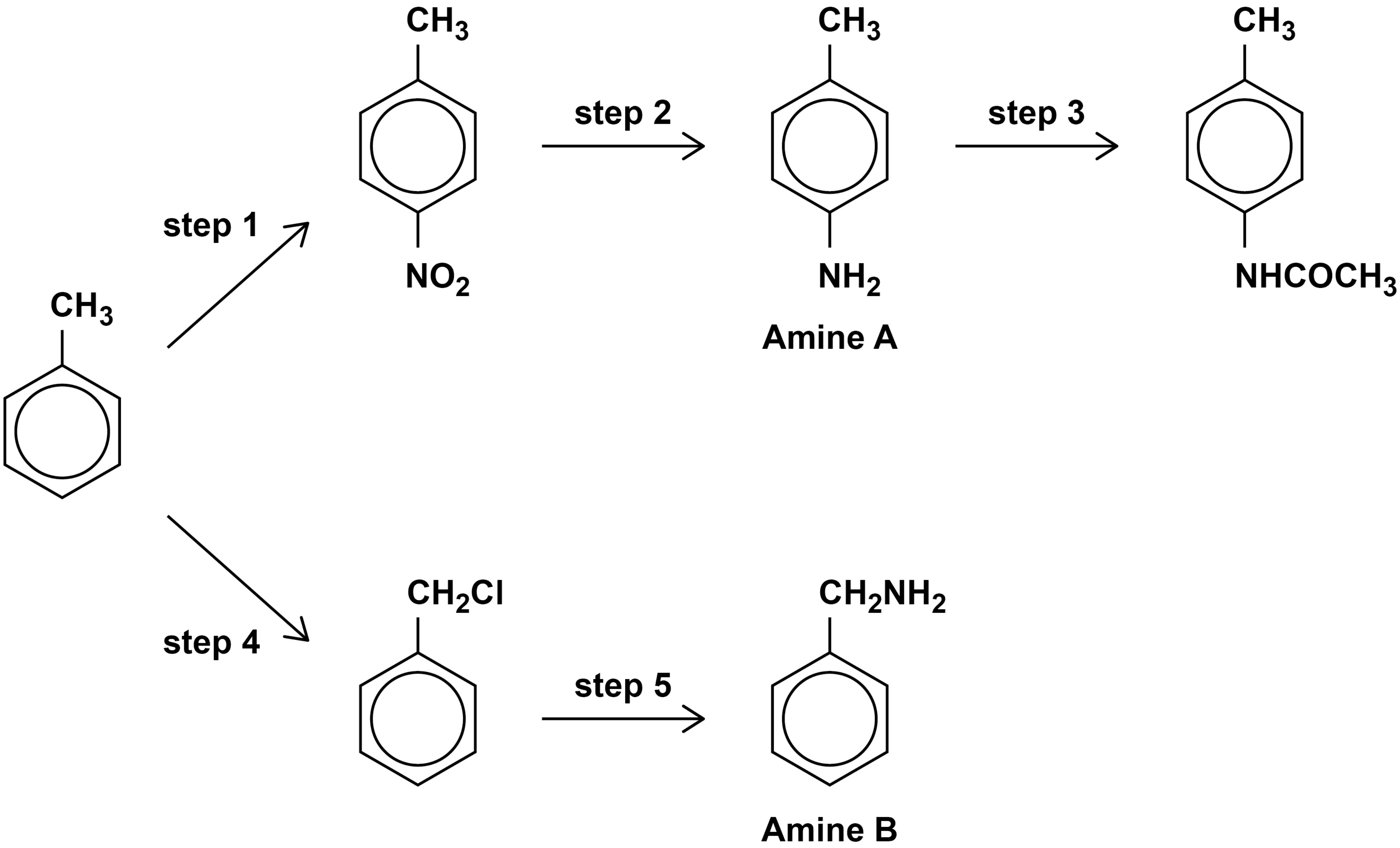
____

____

step 2 ____________________

____

____


CH3
step 1
CH3
NO2
step 2
CH3
NH2
Amine A
step 3
CH3
NHCOCH3
step 4
CH2Cl
step 5
CH2NH2
Amine B

[Turn over]

BLANK PAGE

10.2

Give the name of the mechanism for the reaction in step 3. [1 mark]

____

10.3

Name the reagent for step 4.

State a necessary condition for step 4. [2 marks]

Reagent ______________________________________

Condition _____________________________________

[Turn over]

10.4

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]

10.5

Explain why amine B is a stronger base than amine A. [2 marks]

END OF QUESTIONS

10

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	
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TOTAL	