OXFORD AQA

INTERNATIONAL QUALIFICATIONS

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____
I declare this is my own work.

INTERNATIONAL A-LEVEL
CHEMISTRY (9620)

Unit 4: Organic 2 and Physical 2

Wednesday 17 January 2024 07:00 GMT Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert
- 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 80.

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

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

0 1 When hydrogen iodide is heated in a sealed container, it breaks down to form an equilibrium mixture containing hydrogen and iodine.

$$2\,HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad \Delta H = +10.4\ kJ\ mol^{-1}$$

0 1 . 1 At 500 K the partial pressure of hydrogen iodide in the equilibrium mixture is 520 kPa

The equilibrium constant, $K_p = 6.25 \times 10^{-3}$ at 500 K

Give the expression for the equilibrium constant, K_p

Calculate the partial pressure of hydrogen in the equilibrium mixture.

[4 marks]

K_p

Partial pressure of H_2 _____ kPa

0 1 . 2 Explain why K_p has no units for this equilibrium.

[1 mark]

_____

_____

_____

0 1 . 3 Explain why the value of K_p decreases when the temperature is decreased.

[2 marks]

_____

_____

_____

_____

7

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0 2 This question is about polyamides and their monomers.

Polyamides are also called nylons.
Nylon-6,6 is the most common nylon and is used to make clothes.

0 2 . 1 One of the monomers used to produce nylon-6,6 is hexane-1,6-diamine.

Give the **empirical** formula of hexane-1,6-diamine.

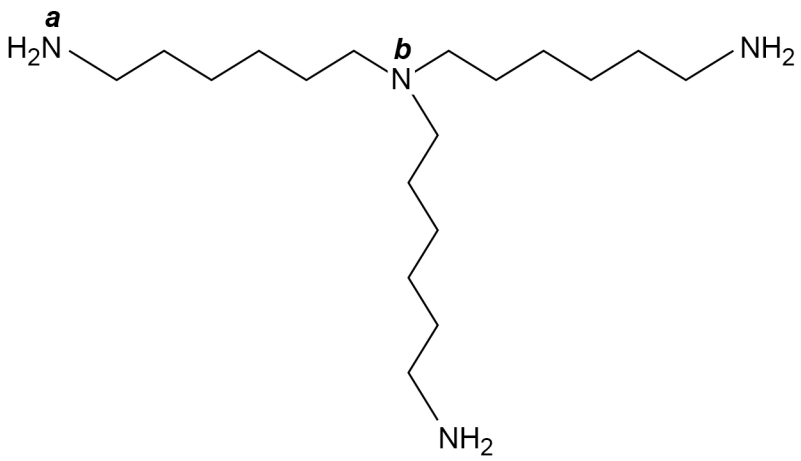
[1 mark]

_____

0 2 . 2 Hexane-1,6-diamine can be made from 1,6-dichlorohexane and ammonia.
Several organic impurities are formed in this synthesis.

One of these impurities, compound **E**, is shown. Two of the nitrogen atoms are labelled.

Compound E



Amines can be classified as primary, secondary or tertiary and can form quaternary salts.

State the classification of the functional group containing the atom labelled ***a***.

State the classification of the functional group containing the atom labelled ***b***.

Deduce how many peaks would be present in the ^{13}C NMR spectrum of compound **E**.

[2 marks]

a _____

b _____

Number of ^{13}C NMR peaks _____

Turn over ►

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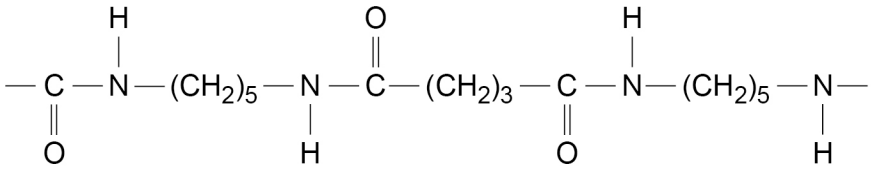
Other nylons can be produced from different monomers. These nylons have different properties from nylon-6,6

0 2 . 3 **Figure 1** shows a section of a nylon chain formed from two monomers.

Figure 1



Use **Figure 1** to identify the structure of each monomer.

Give the name of the monomer that contains a carbonyl group.

[3 marks]

Monomer 1 _____

Monomer 2 _____

Name _____

Do not write outside the box

0 2 . 4 Nylons have a high melting point compared with other polymers with chains of similar length.

Which feature is responsible for the high melting point of nylons?

Tick (✓) **one** box.

[1 mark]

Polar C–N bonds in the chains ☐

Van der Waals forces in the chains ☐

Hydrogen bonds between chains ☐

Strong C–C bonds between chains ☐

0 2 . 5 Nylons are melted and shaped at high temperatures into useful products.

The nylons need to be dry when they are melted to ensure that there is no water present.

Explain why the presence of water can cause hydrolysis of nylons at high temperatures.

[2 marks]

_____

_____

_____

_____

_____

_____

9

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0 3 This question is about two isomers, propanal and propanone.

One of these isomers reacts with warm acidified potassium dichromate(VI) solution.

0 3 . 1 Draw the skeletal formula of the organic product formed in this reaction.

State the colour change observed.

[2 marks]

Skeletal formula

Colour change _____

Propanal and propanone both react with HCN

0 3 . 2 Name the mechanism for these reactions.

[1 mark]

_____

0 3 . 3 Write an equation for the reaction of propanal with HCN

Use IUPAC rules to name the product of this reaction.

[2 marks]

Equation

_____

Name _____

0 3 . 4 State why the product of the reaction between propanone and HCN does **not** rotate the plane of plane polarised light.

[1 mark]

_____

_____

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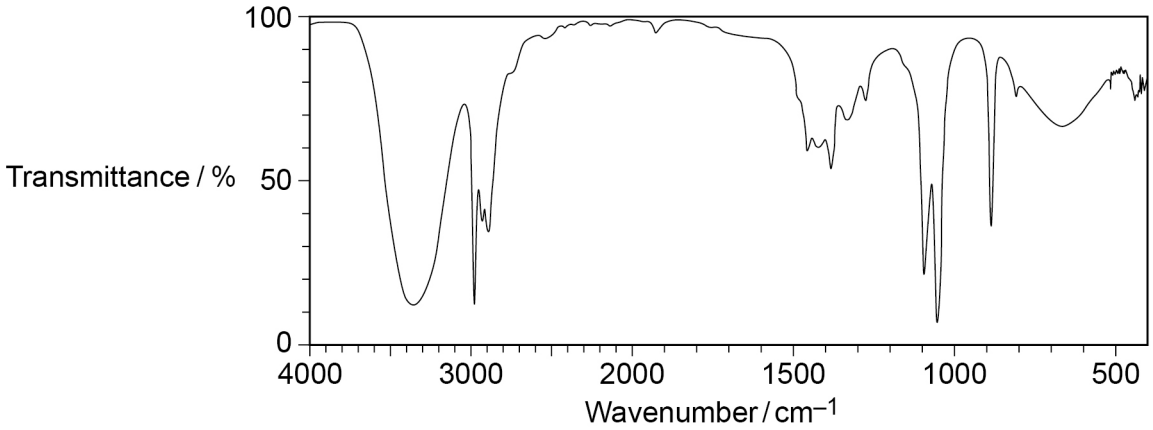
Propanone is reacted with $NaBH_4$ in aqueous solution. The product is dried.

Figure 2 shows the infrared spectrum of the product.

Figure 2



0 3 . 5 Explain how **Figure 2** shows that no unreacted propanone remains.

Use **Table A** on the Chemistry Data Sheet.

[1 mark]

_____

_____

Question 3 continues on the next page

Do not write outside the box

Propanone reacts with iodine in acidic conditions.

$$CH_3COCH_3(aq) + I_2(aq) \longrightarrow CH_2ICOCH_3(aq) + HI(aq)$$

The rate equation for the reaction is

$$\text{Rate} = k\,[CH_3COCH_3(aq)]\,[H^+(aq)]$$

0 3 . 6 Suggest why $[I_2(aq)]$ does not appear in the rate equation but does appear in the overall equation for the reaction.

[1 mark]

_____

_____

0 3 . 7 State the role of $H^+(aq)$ in this reaction.

Explain your answer.

[2 marks]

Role of $H^+(aq)$ _____

Explanation _____

_____

10

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Turn over for the next question

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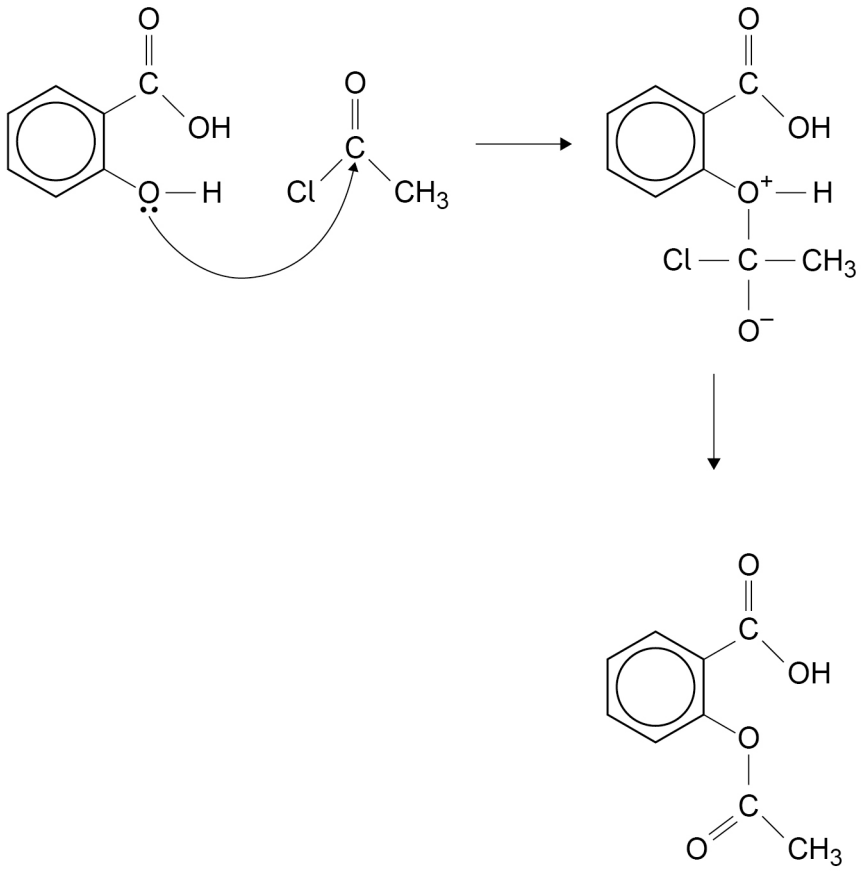
0 4 Salicylic acid ($C_7H_6O_3$) can be used to produce aspirin.

0 4 . 1 Salicylic acid reacts with ethanoyl chloride in a nucleophilic addition–elimination reaction to produce aspirin.

An incomplete reaction mechanism is shown.

Complete the mechanism by adding lone pairs and curly arrows.

[2 marks]



aspirin

Do not write outside the box

0 4 . 2 1.15 g of salicylic acid (M_r = 138.0) are used in this reaction to make aspirin.
The percentage yield is 80.0 %

Calculate the mass, in g, of aspirin that is produced.

[3 marks]

Mass _____ g

0 4 . 3 Aspirin does **not** dissolve easily in water but is soluble in ethanol.

Describe how an impure sample of aspirin can be made pure by recrystallisation with ethanol.

[4 marks]

_____

_____

_____

_____

_____

_____

_____

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_____

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_____

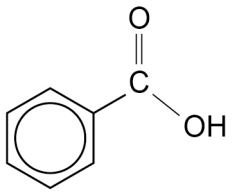
Question 4 continues on the next page

Do not write outside the box

0 4 . 4 In industry, salicylic acid is reacted with ethanoic anhydride to produce aspirin.

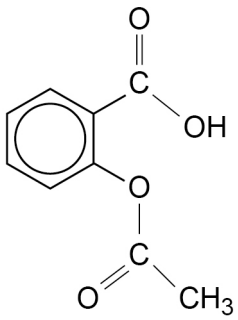
Draw structures to complete the equation for the reaction of salicylic acid with ethanoic anhydride to produce aspirin and one other product.

Give **one** reason why ethanoic anhydride is used instead of ethanoyl chloride in industry.



Salicylic acid

+



Aspirin

+

[3 marks]

Reason _____

_____

12

Do not write outside the box

0 5 This question is about the hydrolysis of the ester, ethyl methanoate.

Ethyl methanoate can be hydrolysed with sulfuric acid as a catalyst.

$$HCOOCH_2CH_3 + H_2O \rightarrow HCOOH + CH_3CH_2OH$$

A student follows this method.

Step 1 Add 5.0 cm^3 of ethyl methanoate and 100 cm^3 of 0.25 mol dm^{-3} sulfuric acid to a flask and start a timer.

Step 2 Put a stopper in the flask and shake the flask.

Step 3 Immediately take a 5.0 cm^3 sample of the reaction mixture and add this to a conical flask containing ice-cold water.

Step 4 Titrate the sample using dilute NaOH(aq)

Step 5 At 10 minutes, take another 5.0 cm^3 sample of the reaction mixture and add this to another conical flask containing ice-cold water.

Step 6 Titrate this sample using dilute NaOH(aq)

Step 7 Repeat **Step 5** and **Step 6** every 10 minutes.

0 5 . 1 State why the mixture is shaken at the start of the experiment in **Step 2**.

[1 mark]

0 5 . 2 State why each 5.0 cm^3 sample is added to ice-cold water.

[1 mark]

0 5 . 3 Suggest why the sample is taken in **Step 3** and immediately titrated in **Step 4**.

[1 mark]

Question 5 continues on the next page

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The results of the experiment are used to calculate the concentration of ethyl methanoate each time a sample is taken. The calculated concentrations are shown in **Table 1**.

Table 1

Time of sample / minute	$[HCOOCH_2CH_3]$ / mol dm^{-3}
10	0.34
20	0.16
30	0.073
40	0.023
50	0.016
60	0.0070

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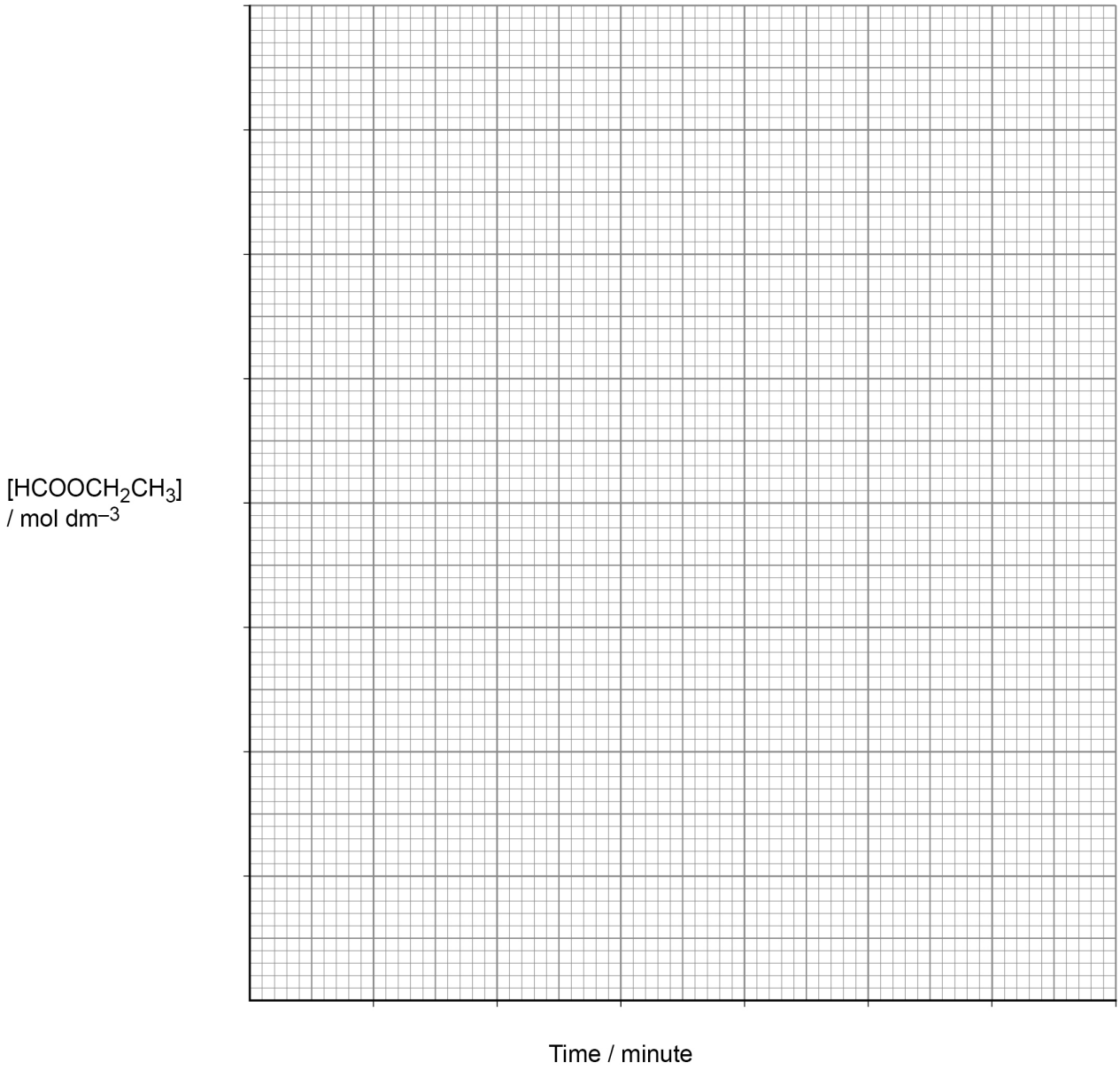
0 5 . 4 On **Figure 3**, plot a graph of [$HCOOCH_2CH_3$] against time.

Draw a curve through the points.

[3 marks]

Figure 3



0 5 . 5 Calculate the rate of reaction at 30 minutes.

Give the units.

Show your working on **Figure 3**.

[3 marks]

Rate _____

Units _____

Turn over ►

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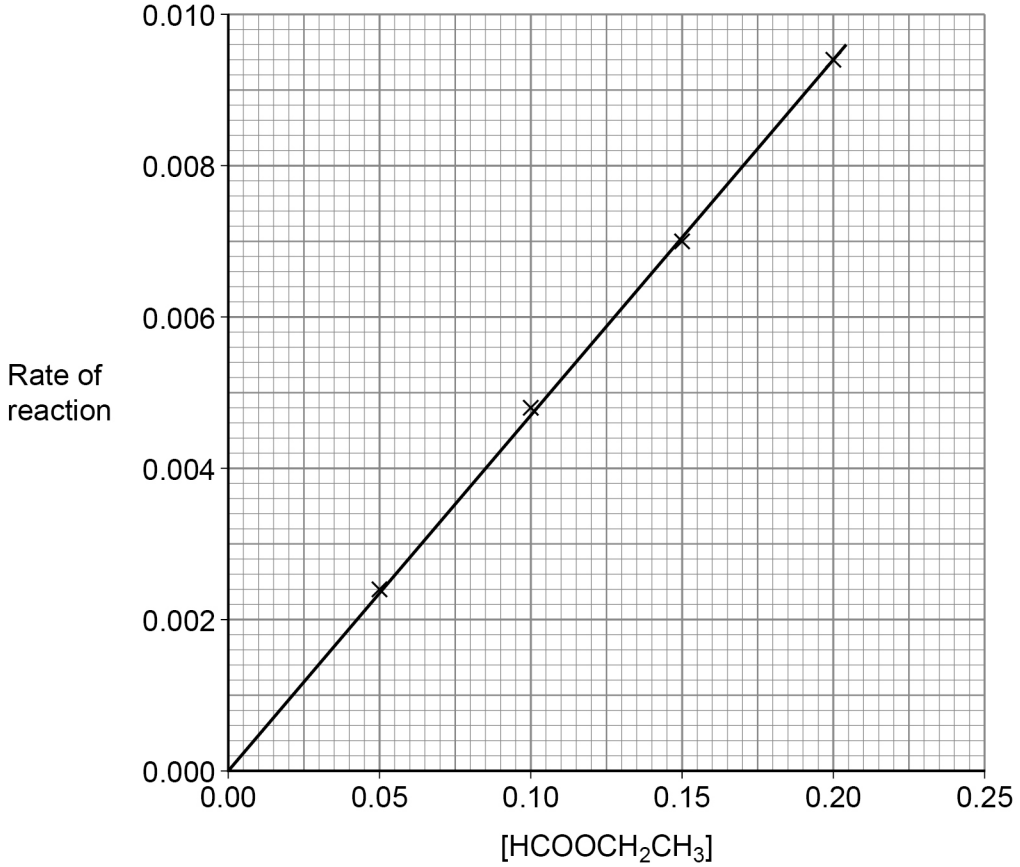
Another student did the same experiment at a different temperature and determined the rate of reaction at different concentrations of ethyl methanoate.

Figure 4 shows this student's graph of rate against concentration.

Figure 4



0 5 . 6 Deduce the order of reaction with respect to $[HCOOCH_2CH_3]$

Give a reason for your answer.

[2 marks]

Order _____

Reason _____

_____

11

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0 6 Benzene reacts with chloromethane in the presence of aluminium chloride to form methylbenzene.

0 6 . 1 Write an equation to show how the electrophile CH_3^+ is produced from chloromethane and aluminium chloride.

Outline a mechanism for the reaction of this electrophile with benzene.

[4 marks]

Equation

Mechanism

0 6 . 2 State why benzene undergoes electrophilic substitution rather than electrophilic addition.

[1 mark]

Question 6 continues on the next page

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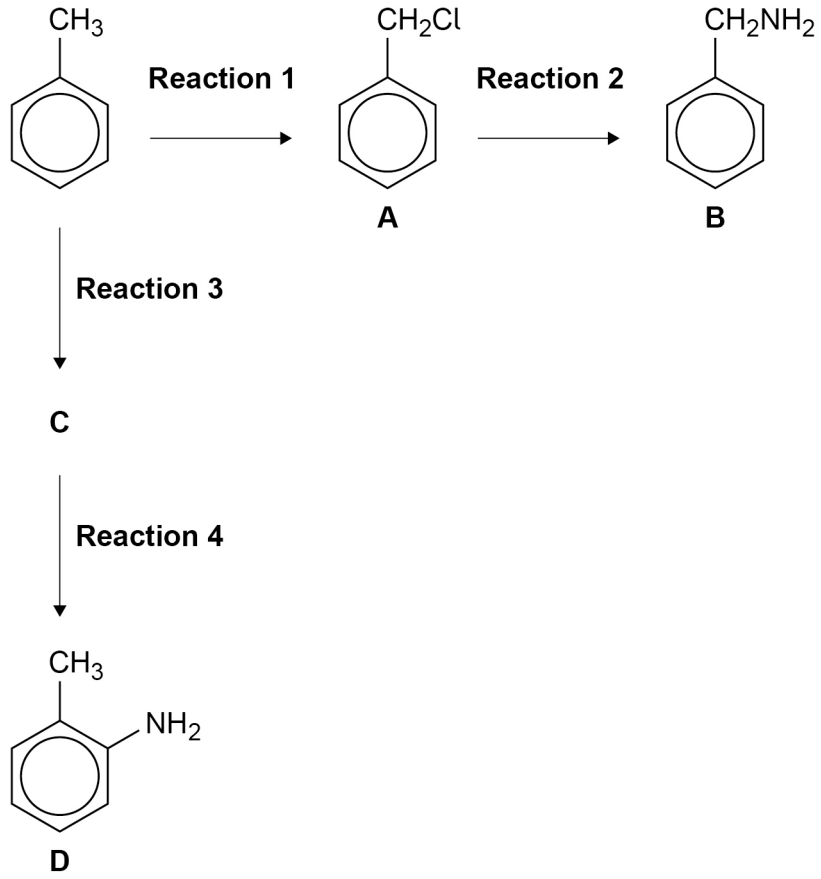
Figure 5 shows some reactions of methylbenzene.

Figure 5



0 6 . 3 Name the mechanism for **Reaction 1**.

[1 mark]

---

0 6 . 4 **Reaction 2** involves the reaction of compound **A** with ammonia.

What is the role of ammonia in this reaction?

Tick (✓) **one** box.

[1 mark]

Nucleophile only ☐

Base only ☐

Nucleophile and base ☐

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0 6 . 5 **Reaction 4** is a reduction reaction.

Give the structure of compound **C** formed in **Reaction 3**.

Identify the reagent(s) used for **Reaction 3**.

[2 marks]

Structure

Reagent(s) _____

0 6 . 6 State why compounds **B** and **D** are difficult to distinguish from each other using mass spectrometry.

[1 mark]

_____

_____

10

Turn over for the next question

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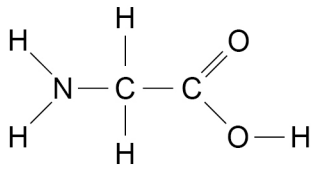
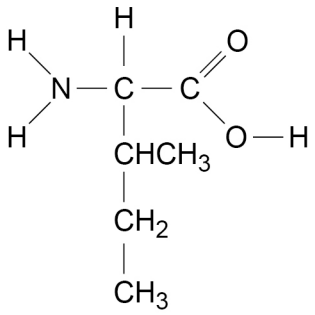
0 7 The structures of three amino acids are shown.

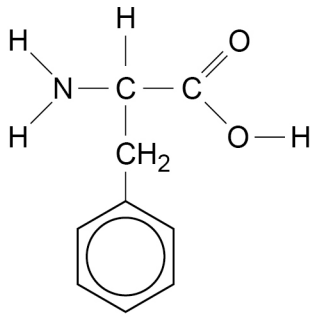
Glycine



Isoleucine



Phenylalanine



0 7 . 1 Write an equation for the reaction of aqueous sodium hydrogencarbonate with glycine.

[1 mark]

_____

0 7 . 2 Use IUPAC rules to name isoleucine.

[1 mark]

_____

0 7 . 3 Draw the structure of the species present in a crystal of phenylalanine.

Explain why crystals of phenylalanine are soluble in water.

[2 marks]

Structure

Explanation _____

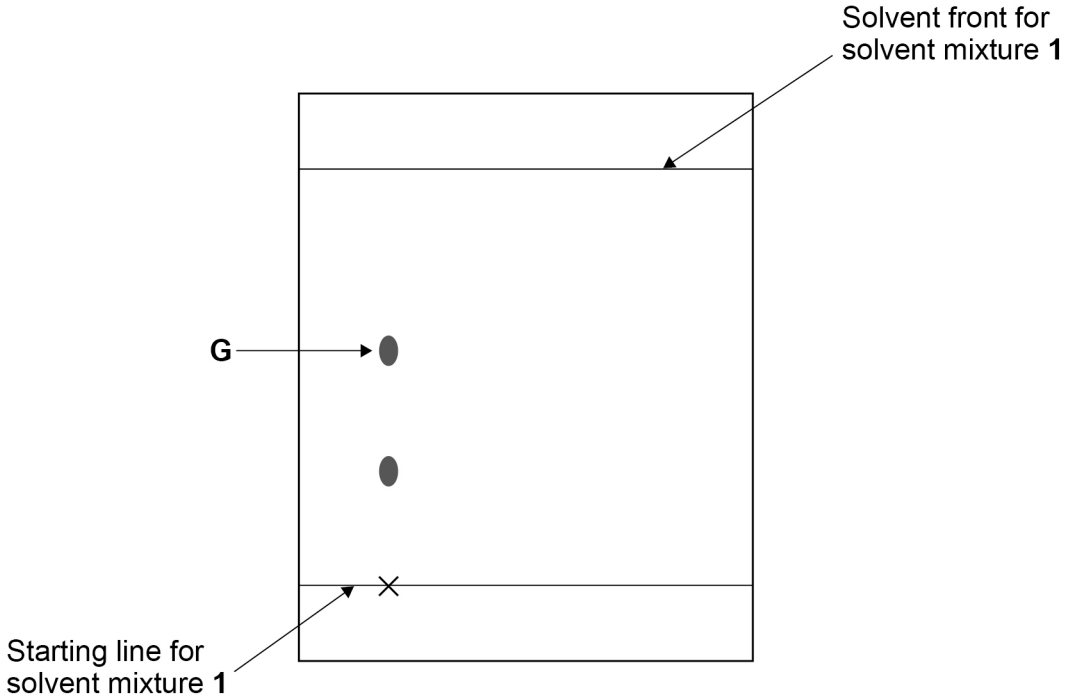
_____

Do not write outside the box

A peptide, formed from one glycine, one isoleucine and one phenylalanine, is hydrolysed. The resulting mixture is analysed by thin-layer chromatography (TLC) with solvent mixture **1**.

After the final position of the solvent front is marked, the TLC plate is viewed under ultraviolet light and spots are marked as shown in **Figure 6**.

Figure 6



0 7 . 4 Use **Figure 6** to calculate the R_f value of **G**.

Show your working.

[1 mark]

Question 7 continues on the next page

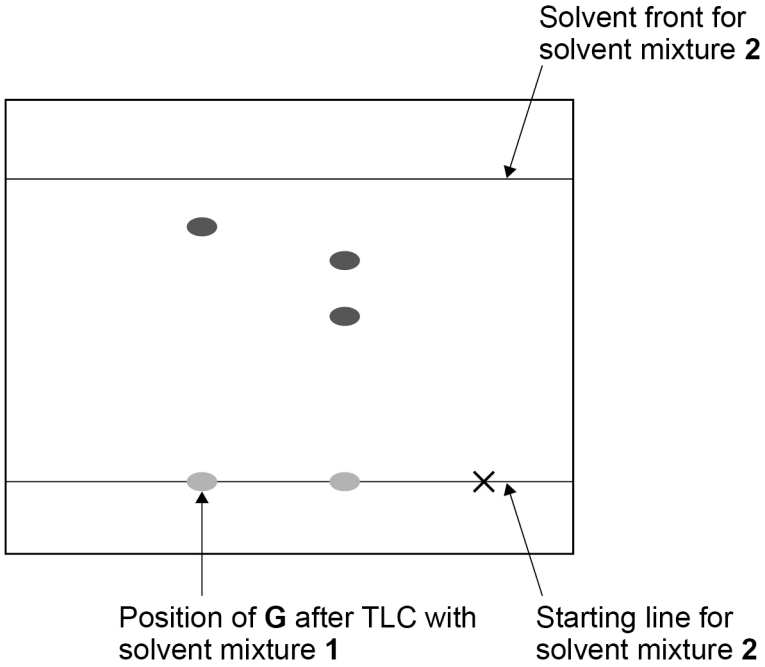
Do not write outside the box

The TLC plate is then rotated through 90° and a new starting line is drawn.

The TLC plate is placed in a different solvent, solvent mixture **2**, for a second chromatography experiment.

Again, after the final position of the solvent front is marked, the plate is viewed under ultraviolet light and the position of the spots marked on it. This is shown in **Figure 7**.

Figure 7



0 7 . 5 Explain why a second chromatography experiment is needed.

[1 mark]

0 7 . 6 Explain how **Figures 6** and **7** show that the amino acids are more soluble in solvent mixture **2** than in solvent mixture **1**.

[1 mark]

Do not write outside the box

Amino acids join together to form protein chains.

0 7 . 7 A protein chain can form a folded sheet, called a β-pleated sheet.

State the classification of protein structure of a β-pleated sheet.

[1 mark]

Cisplatin is a drug that can be used to treat cancer.

0 7 . 8 Explain how cisplatin stops the multiplication of cancer cells.

[2 marks]

0 7 . 9 State a risk associated with the use of cisplatin to treat cancer.

[1 mark]

11

Turn over for the next question

Do not write outside the box

0 8 Nuclear magnetic resonance (NMR) spectroscopy can be used to distinguish between isomers and determine structures.

Tetramethylsilane (TMS) is used as a standard in ^{13}C and ^{1}H NMR spectroscopy.

0 8 . 1 Draw the structure of tetramethylsilane (TMS).

[1 mark]

0 8 . 2 TMS is non-toxic.

Give two other reasons why TMS is a suitable standard.

[2 marks]

Reason 1 _____

_____

Reason 2 _____

_____

Do not write outside the box

Compound **W** with molecular formula C_6H_{12} decolourises bromine water.

W has two peaks in its ^{13}C spectrum and one singlet peak in its ^{1}H NMR spectrum.

0 8 . 3 Draw the structure of **W**.

[1 mark]

0 8 . 4 Draw the structural isomer of **W** that has only one peak in its ^{13}C NMR spectrum and one peak in its ^{1}H NMR spectrum.

[1 mark]

CCl_4 is the solvent used to take the ^{1}H NMR spectrum of **W**.

0 8 . 5 Explain why CCl_4 is non-polar despite the difference in electronegativity between C and Cl

[1 mark]

Question 8 continues on the next page

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The structure of **X** is shown

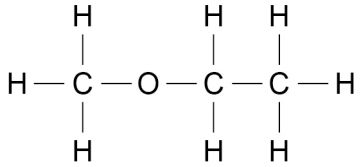

Table 2 shows data for ^{1}H NMR spectrum of **X**.

Table 2

Chemical shift / ppm	1.2	3.3	3.5
Spin-spin splitting pattern			
Integration value	3	3	2

0 8 . 6 Complete **Table 2** to show the spin-spin splitting patterns for the three peaks in the ^{1}H NMR spectrum of **X**.

Use **Table B** on the Chemistry Data Sheet.

[2 marks]

Do not write outside the box

Two isomers of $C_2H_4O_2$ are investigated using NMR spectroscopy.

For each isomer of $C_2H_4O_2$

- the ^1H NMR spectrum has only two peaks
- the integration ratio of the peaks is 3:1

0 8 . 7 Give the structures of the two isomers.

[2 marks]

Isomer 1

Isomer 2

10

END OF QUESTIONS

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