OXFORD AQA
INTERNATIONAL QUALIFICATIONS

Please write clearly in block capitals.

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

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I declare this is my own work.

INTERNATIONAL A-LEVEL
CHEMISTRY (9620)

Unit 4: Organic 2 and Physical 2

Friday 7 June 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	
9	
10	
TOTAL	

Do not write outside the box

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

0 1 This question is about the equilibrium

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -203 \text{ kJ mol}^{-1}$$

In one experiment, a mixture of 0.850 mol of carbon monoxide and 1.44 mol of hydrogen is allowed to reach equilibrium at a fixed temperature.

At equilibrium, 0.280 mol of methanol is formed.
The total pressure of the equilibrium mixture is 190 kPa

0 1 . 1 Calculate the amount, in mol, of carbon monoxide and of hydrogen in the equilibrium mixture.

[2 marks]

Amount of carbon monoxide _____ mol

Amount of hydrogen _____ mol

0 1 . 2 In a different experiment, the equilibrium amount of methanol is 0.260 mol, of carbon monoxide is 0.350 mol and of hydrogen is 0.550 mol.

The total pressure of the equilibrium mixture is 190 kPa

Calculate the partial pressure of hydrogen, in kPa, in the equilibrium mixture.

[2 marks]

Partial pressure of hydrogen _____ kPa

Do not write outside the box

0 1 . 3 Write an expression for the equilibrium constant (K_p) for this reaction.

[1 mark]

K_p

0 1 . 4 The experiment is done at two different temperatures, T_1 and T_2.
The equilibrium constant (K_p) is determined at each temperature.

The results are shown in **Table 1**.

Table 1

Temperature	K_p / kPa^{-2}
T_1	4.50×10^{-5}
T_2	8.95×10^{-6}

Explain how you can deduce that T_2 is the higher temperature.

[2 marks]

7

Turn over for the next question

Do not write outside the box

0 2 This question is about rates of reaction.

0 2 . 1 Explain what is meant by the order of a reaction with respect to an individual substance.

[1 mark]

Compounds **A** and **B** react together as shown

$$\mathbf{A} + \mathbf{B} \rightarrow \mathbf{C}$$

The initial rates of the reaction are found for different initial concentrations of **A** and **B**. **Table 2** shows data from this reaction.

Table 2

Experiment	[A] / mol dm^{-3}	[B] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.100	0.150	3.68×10^{-5}
2	0.300	0.150	3.31×10^{-4}
3	0.200	0.300	2.94×10^{-4}

0 2 . 2 Deduce the order of the reaction with respect to **A** and the order of the reaction with respect to **B**.

[2 marks]

Order with respect to **A** _____

Order with respect to **B** _____

Do not write outside the box

0 2 . 3 The rate of reaction between compound **D** and compound **E** is investigated.

The reaction is first order with respect to **D** and first order with respect to **E**.

In one experiment, the initial rate is 7.10×10^{-5} mol dm^{-3} s^{-1} when the initial concentration of **D** is 0.160 mol dm^{-3} and the initial concentration of **E** is 0.220 mol dm^{-3}

Calculate the value of the rate constant, *k*, at this temperature.

Give the units of *k*

[3 marks]

k _____

Units _____

6

Turn over for the next question

Do not write outside the box

0 3 This question is about the effect of temperature on the rate of a reaction.

The Arrhenius equation can be written

$$\ln k = \frac{-E_a}{RT} + \ln A$$

A compound decomposes when heated.

Table 3 shows the value of the rate constant at different temperatures for this decomposition.

Table 3

Rate constant *k* / s^{-1}	**ln *k***	**Temperature / K**	**$\frac{1}{T}$ / K^{-1}**
8.68×10^5	13.67	278	3.60×10^{-3}
2.20×10^6	14.60	298	3.36×10^{-3}
	15.42	318	
1.01×10^7	16.13	338	2.96×10^{-3}
1.92×10^7	16.77	358	2.79×10^{-3}

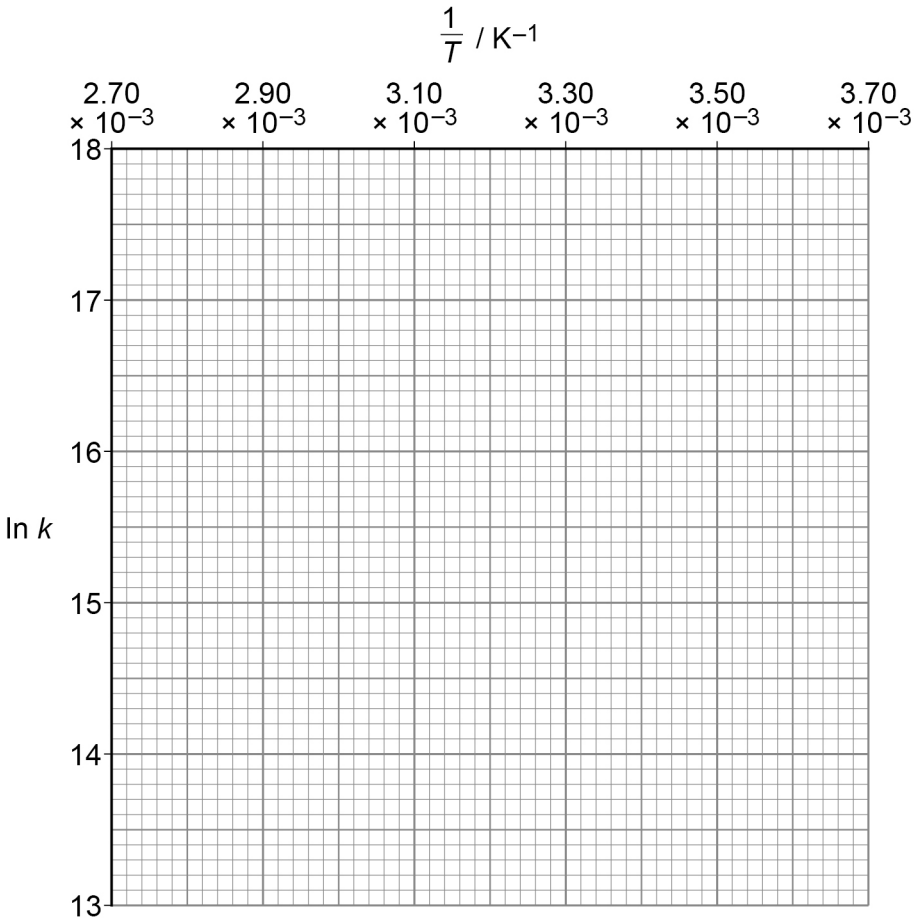
0 3 . 1 Complete **Table 3**.
Give values to 3 significant figures.

[2 marks]

Do not write outside the box

0 3 . 2 Plot a graph of ln k against $\frac{1}{T}$

[2 marks]



0 3 . 3 Use your graph to calculate a value for the activation energy (E_a), in kJ mol^{-1}, for this reaction.

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

[3 marks]

E_a _____ kJ mol^{-1}

7

Do not write outside the box

0 4 This question is about carbonyl compounds.

Compound **F** (C_3H_6O) reacts with Fehling's solution to form a red precipitate.

0 4 . 1 Draw the skeletal formula of **F**.

[1 mark]

0 4 . 2 Identify the organic product formed when **F** reacts with Fehling's solution.

[1 mark]

_____

Butanone reacts with $NaBH_4$ in aqueous solution to form butan-2-ol.

0 4 . 3 Name and outline the mechanism for this reaction.

[4 marks]

Name of mechanism _____

Mechanism

Do not write outside the box

0 4 . 4 The product from the reaction between butanone and $NaBH_4$ is dried.

State how infrared spectroscopy can show that the reaction between butanone and $NaBH_4$ is complete.

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

[1 mark]

_____

_____

_____

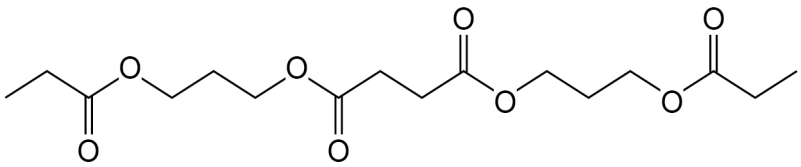
7

Turn over for the next question

Do not write outside the box

0 5 This question is about polymers.

A section of a condensation polymer, **G**, is shown.



Polymer **G**

0 5 . 1 Name this type of condensation polymer.

[1 mark]

_____

0 5 . 2 Draw displayed formulas for each of the **two** monomers used to make polymer **G**.

[2 marks]

Monomer 1

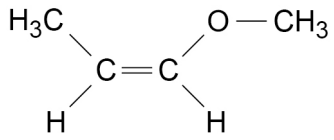
Monomer 2

Do not write outside the box

0 5 . 3 Explain why polymer **G** is biodegradable.

[2 marks]

A different type of polymer can be formed from the monomer **H**.



H

0 5 . 4 Draw the repeating unit of this polymer.

[1 mark]

0 5 . 5 Draw an isomer of **H** that only has two peaks in its ^{13}C NMR spectrum.

[1 mark]

7

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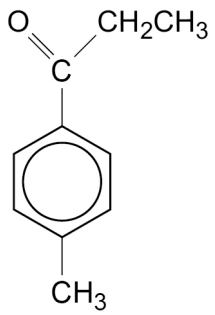
0 6 This question is about the reactions of methylbenzene.

0 6 . 1 Compound **J** can be made from methylbenzene, propanoyl chloride and another reagent.



J

This reagent reacts with propanoyl chloride to make the reactive intermediate that reacts with methylbenzene.

Identify this reagent.

Write an equation for the formation of this reactive intermediate.

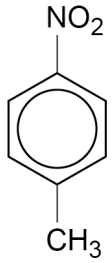
[2 marks]

Reagent _____

Equation _____

Do not write outside the box

Compound **K** is formed when methylbenzene reacts with the reactive intermediate $^{+}NO_2$



K

0 6 . 2 Write an equation to show how $^{+}NO_2$ is formed from concentrated nitric acid and concentrated sulfuric acid.

[1 mark]

_____

0 6 . 3 Name and outline the mechanism for the reaction of $^{+}NO_2$ with methylbenzene to form **K**.

[4 marks]

Name of mechanism _____

Mechanism

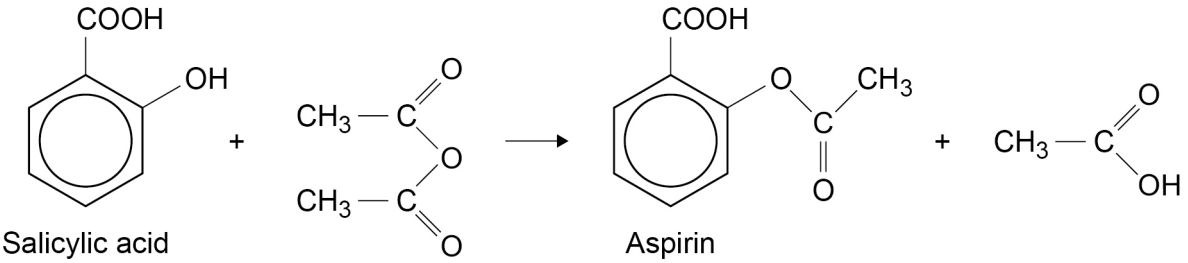
7

Do not write outside the box

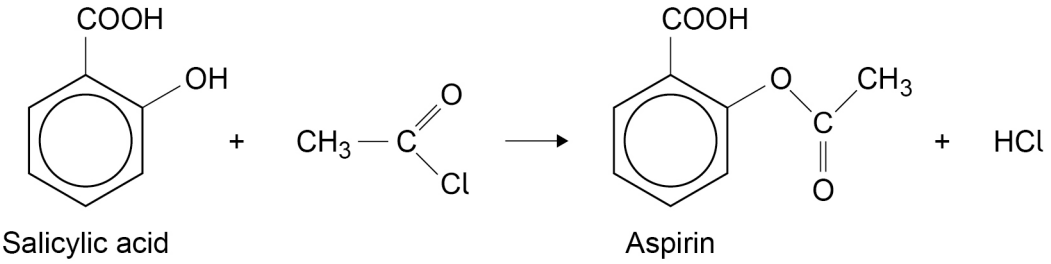
0 7 This question is about the synthesis of aspirin.

Aspirin can be prepared from salicylic acid by Reaction **1** or Reaction **2**.

Reaction **1**



Reaction **2**



0 7 . 1 Explain why Reaction **2** has the higher atom economy.

[1 mark]

_____

_____

_____

0 7 . 2 Companies that manufacture aspirin need to consider factors other than atom economy before deciding which reaction to use.

Give **one** other factor that needs to be considered.

[1 mark]

_____

_____

Do not write outside the box

Aspirin made by either reaction is impure.

0 7 . 3 Give **two** ways that the melting point of impure aspirin would differ from the melting point of pure aspirin.

[2 marks]

Difference 1 _____

_____

Difference 2 _____

_____

Question 7 continues on the next page

Do not write outside the box

Impure aspirin can be purified using the following steps.

Step 1 A small volume of ethanol is heated using a water bath.

Step 2 An impure sample of aspirin is dissolved in a minimum volume of the hot ethanol.

Step 3 The mixture is filtered while hot.

Step 4 The filtrate is cooled in ice.

Step 5 The crystals formed are collected by filtration and washed with a small amount of ice-cold ethanol.

0 7 . 4 State why a water bath is used to heat the ethanol in **Step 1**.

[1 mark]

0 7 . 5 State why the mixture is filtered in **Step 3**.

[1 mark]

0 7 . 6 State why the crystals are washed in **Step 5**.

[1 mark]

0 7 . 7 State why the ethanol used in **Step 5** is ice-cold.

[1 mark]

8

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Turn over for the next question

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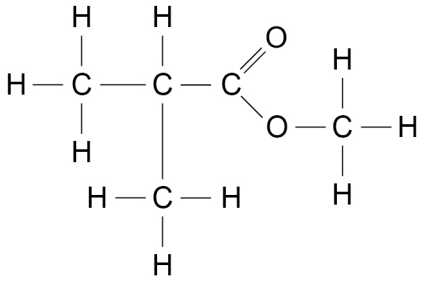
0 8 This question is about esters.

0 8 . 1 Give a use of esters.

[1 mark]

The structure of ester **L** can be confirmed using ^{13}C NMR and ^{1}H NMR spectroscopy.



L

0 8 . 2 State the number of peaks in the ^{13}C NMR spectrum of **L**.

[1 mark]

Table 4 shows data for the ^{1}H NMR spectrum of **L**.

Table 4

Chemical shift / ppm	1.2	2.6	3.7
Integration value			

0 8 . 3 Complete **Table 4** to show the integration values for each peak.

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

[1 mark]

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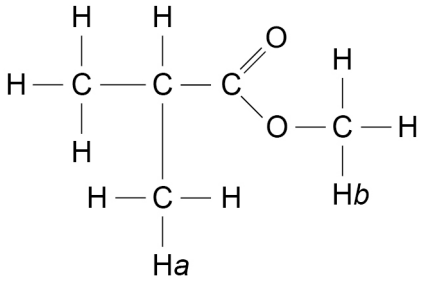
0 8 . 4 In **Figure 1**, two of the H atoms are marked *a* and *b*. These H atoms are in different environments and produce different peaks in the ^{1}H NMR spectrum.

Figure 1



Give the spin-spin splitting pattern that is observed for the peaks that are produced by H*a* and H*b*

[2 marks]

H*a* spin-spin splitting pattern _____

H*b* spin-spin splitting pattern _____

0 8 . 5 Acid hydrolysis of ester **L** produces methanol and compound **M**.

Identify **M**.

Give a reagent that can be used to confirm the functional group in **M**.

State an observation that is made when **M** reacts with this reagent.

[3 marks]

Identity of **M** _____

Reagent _____

Observation _____

_____

8

Turn over ►

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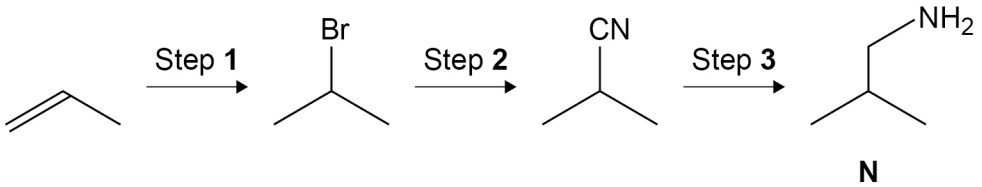
0 9 A synthetic route to form the amine **N** is shown.



0 9 . 1 Identify the reagent for **Step 1**.

Name the mechanism for **Step 1**.

[2 marks]

Reagent _____

Name of mechanism _____

0 9 . 2 Identify a reagent for **Step 2**.

[1 mark]

Reagent _____

0 9 . 3 Identify a reagent for **Step 3**.

State a condition for **Step 3**.

[2 marks]

Reagent _____

Condition _____

0 9 . 4 Amine **N** can be formed in a one-step synthesis from a halogenoalkane.

Identify the halogenoalkane needed for this one-step synthesis.

[1 mark]

Do not write outside the box

0 9 . 5 Amine **N** can be used to form other organic products.

N can act as a nucleophile and a base.

Explain why **N** can act as a nucleophile and as a base.

[2 marks]

0 9 . 6 Ethylamine can react with chloromethane to form a secondary amine.

Name the secondary amine.

[1 mark]

0 9 . 7 Give the structure of the final product in the reaction between ethylamine and an excess of chloromethane.

[1 mark]

10

Turn over for the next question

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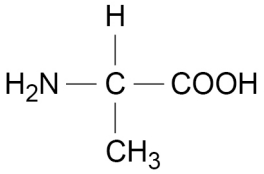
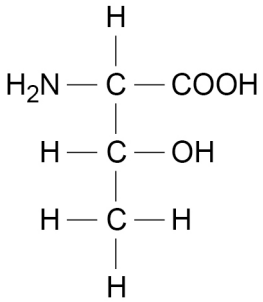
1 0 This question is about amino acids and proteins.

Two amino acids are shown.



alanine



threonine

1 0 . 1 Use IUPAC rules to name threonine.

[1 mark]

_____

Most amino acids can exist as optical isomers (enantiomers).

1 0 . 2 State what is meant by the term optical isomers.

Describe how to distinguish between the **two** optical isomers of alanine.

[3 marks]

Meaning of term _____

Description _____

_____

_____

_____

1 0 . 3 Draw 3D representations of the **two** optical isomers of alanine.

[1 mark]

Do not write outside the box

1 0 . 4 Consider the structure of threonine.

How many optical isomers of threonine are there?

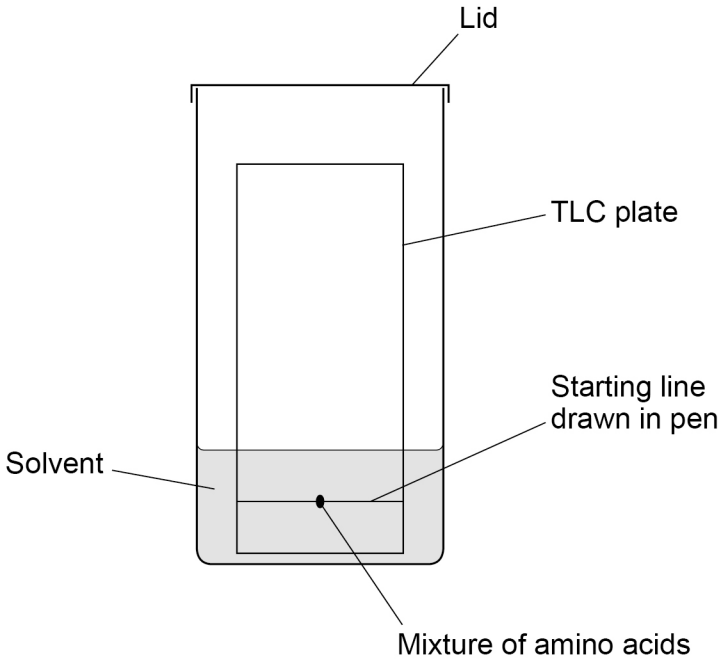
Tick (✓) **one** box.

[1 mark]

2 ☐ 4 ☐ 6 ☐ 8 ☐

Chromatography can be used to identify the compounds in a mixture of amino acids. A student sets up a thin-layer chromatography (TLC) plate as shown in **Figure 2**.

Figure 2



1 0 . 5 Give **two** errors the student made in the experiment shown in **Figure 2**.

[1 mark]

Error 1 _____

_____

Error 2 _____

_____

Do not write outside the box

Another student sets up the experiment correctly but uses a longer TLC plate. The amino acids cannot be seen as they move up the plate.

1 0 . 6 State how the position of amino acids can be seen on a TLC plate at the end of the experiment.

[1 mark]

_____

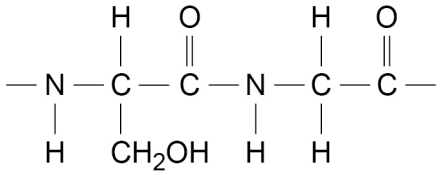
1 0 . 7 State the effect, if any, on the R_f values of using a longer TLC plate.

[1 mark]

_____

Amino acids can react together to form proteins.

A section of a protein chain is shown.



A student hydrolyses this protein with hot sodium hydroxide solution.

1 0 . 8 Draw the products of this hydrolysis.

[2 marks]

Proteins can have primary, secondary and tertiary structures.

1 0 . 9 Give the names of the **two** types of secondary structures of proteins.

[2 marks]

1 _____

2 _____

13

END OF QUESTIONS

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