OXFORD

INTERNATIONAL
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Please write clearly in block capitals.

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I declare this is my own work.

INTERNATIONAL A-LEVEL

CHEMISTRY (9620)

Unit 4: Organic 2 and Physical 2

Wednesday 14 June 2023 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.
- 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).
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

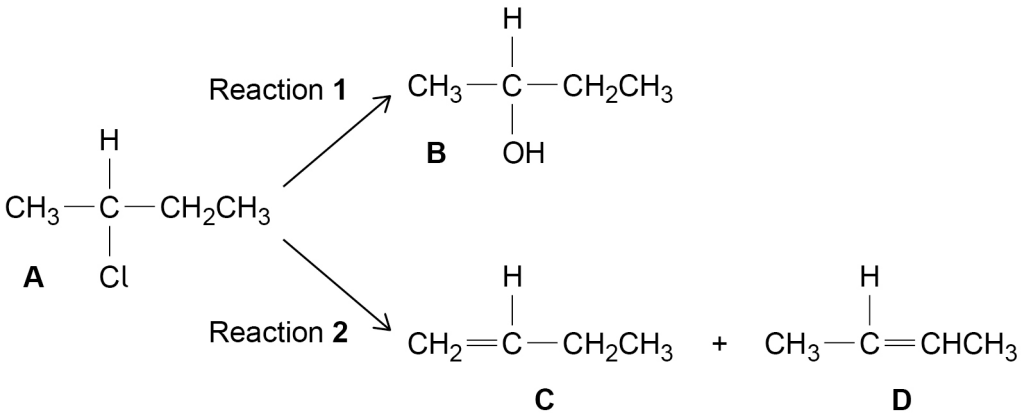
For Examiner's Use	
Question	Mark
1	
2	
3	
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5	
6	
7	
8	
9	
TOTAL	

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

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

0 1 The reaction scheme shows two reactions of compound **A**.



Potassium hydroxide can be used as the reagent in both reactions.

These two reactions can occur concurrently.

0 1 . 1 Name the type of mechanism in Reaction **1** and the type of mechanism in Reaction **2**.

[2 marks]

Reaction **1** mechanism _____

Reaction **2** mechanism _____

0 1 . 2 The yield of **B** can be maximised by using these conditions:

- a solvent containing water and ethanol
- a low concentration of potassium hydroxide
- warming the reaction mixture.

Suggest **two** changes to these conditions that would maximise the yields of **C** and **D**.

[2 marks]

Change 1 _____

_____

Change 2 _____

_____

Do not write outside the box

0 1 . 3 Compound **B** exists as a pair of enantiomers.

Complete the diagrams to show the structure of each enantiomer.

[1 mark]



0 1 . 4 Describe how to distinguish between separate samples of the two enantiomers.

[2 marks]

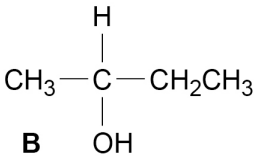
0 1 . 5 Draw the skeletal formula of the *E*-isomer of **D**.

[1 mark]

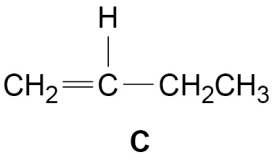
Question 1 continues on the next page

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0 1 . 6 Compound **B** can be converted into compound **E**, $CH_3COCH_2CH_3$
The structures of **B** and **C** are repeated here to help you.



B

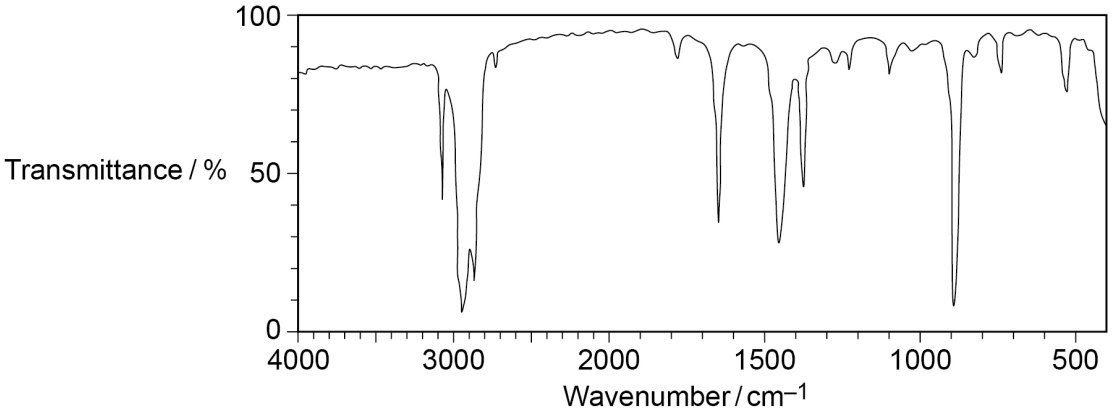


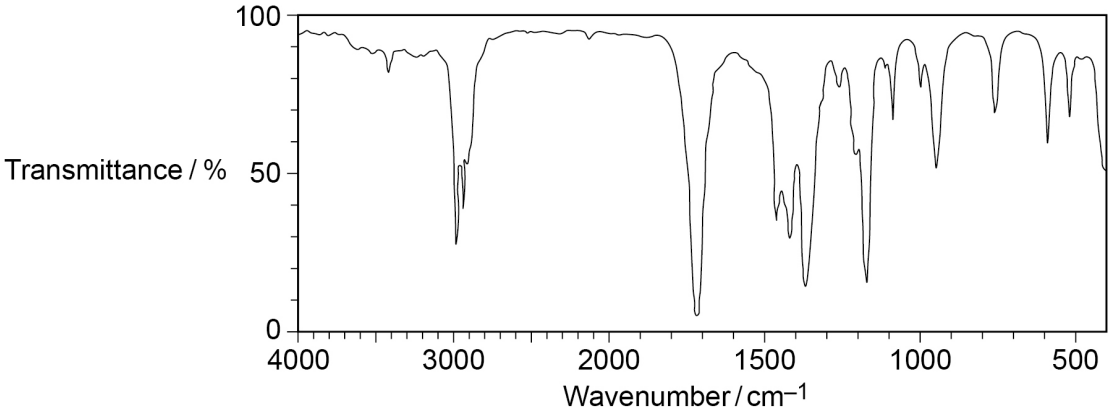
C

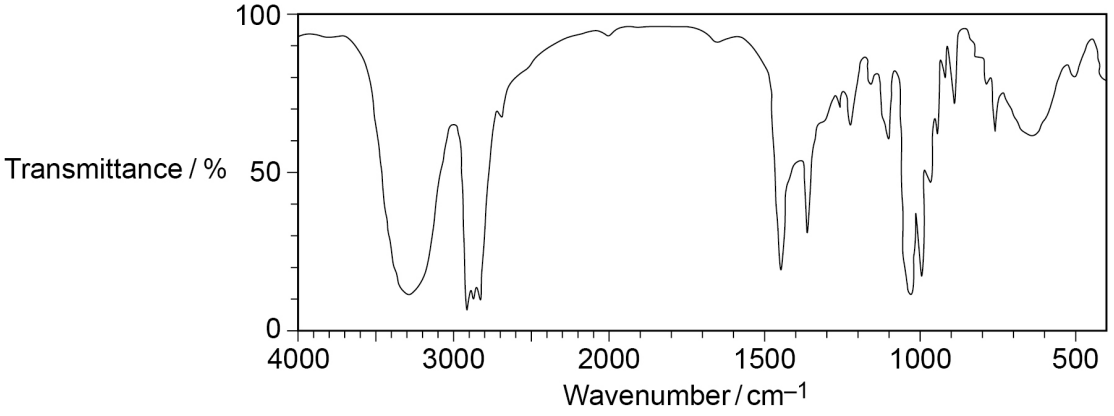
The infrared spectra of **B**, **C** and **E** are shown, but not necessarily in that order.

Use **Table A** in the Chemistry Data Sheet to identify the compound (**B**, **C** or **E**) responsible for each spectrum.
Write the correct letter in the box next to each spectrum.

[2 marks]

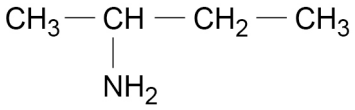






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0 1 . 7 Compound **A** can also be converted into a primary amine with this structure.



This primary amine has secondary amine and tertiary amine isomers.
Both have three peaks in their ^{13}C NMR spectra.

Draw the structure of each isomer.

[2 marks]

Secondary amine

Tertiary amine

0 1 . 8 Ammonia and two amines are shown in decreasing order of base strength.

methylamine CH_3NH_2
ammonia NH_3
phenylamine $C_6H_5NH_2$

Explain why:
- methylamine is a stronger base than ammonia
- phenylamine is a weaker base than ammonia.

[4 marks]

Explanation for methylamine

Explanation for phenylamine

16

Do not write outside the box

0 2 This question is about esters.

0 2 . 1 A word equation for a reaction to form an ester is

alcohol + acid anhydride → ester + carboxylic acid

Give the structure of the alcohol and of the acid anhydride that react to form the ester $CH_3COOCH(CH_3)_2$ and the carboxylic acid CH_3COOH

[2 marks]

Alcohol

Acid anhydride

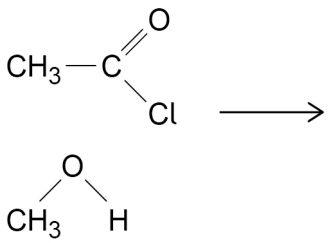
0 2 . 2 Esters can also be made from acyl chlorides.

Name and complete the mechanism for the formation of an ester from ethanoyl chloride and methanol.

[4 marks]

Name of mechanism _____

Mechanism



Do not write outside the box

0 2 . 3 A polyester known as PEA can be made from the diol $HOCH_2CH_2OH$ and the dicarboxylic acid $HOOC(CH_2)_4COOH$

Draw the repeating unit of PEA.

[1 mark]

0 2 . 4 Name the strongest type of attractive force between the polymer chains in PEA.

[1 mark]

_____

_____

8

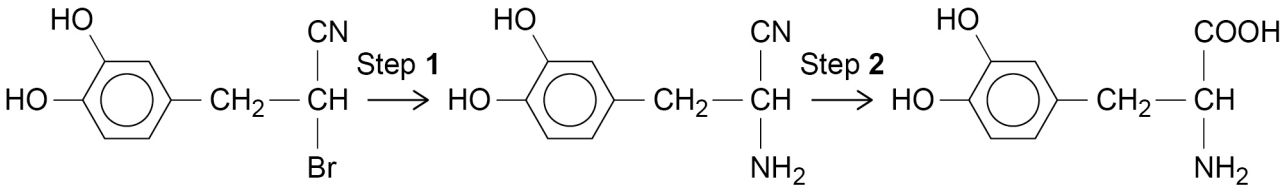
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0 3 This question is about amino acids.

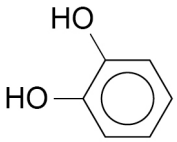
The amino acid known as L-DOPA is used in medicine.

0 3 . 1 Two steps in a possible synthesis of L-DOPA are shown.



L-DOPA

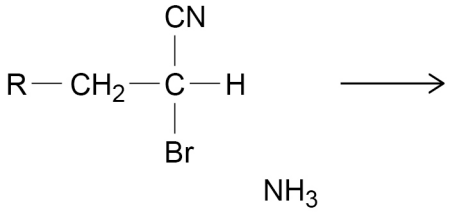
Name and complete the mechanism for Step **1**, in which R represents the structure.



[4 marks]

Name of mechanism _____

Mechanism



0 3 . 2 State the structural feature of L-DOPA that is responsible for its optical activity.

[1 mark]

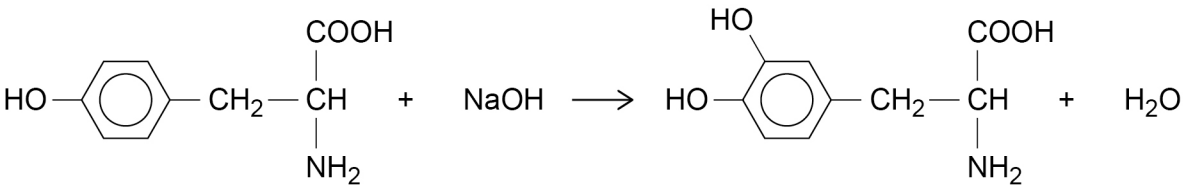
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_____

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0 3 . 3 A student suggested that the amino acid tyrosine could be converted into L-DOPA in one step using sodium hydroxide.

The student wrote this incorrect equation for the one-step reaction.



tyrosine **L-DOPA**

Suggest **two** reasons why this conversion could **not** occur in one step.

[2 marks]

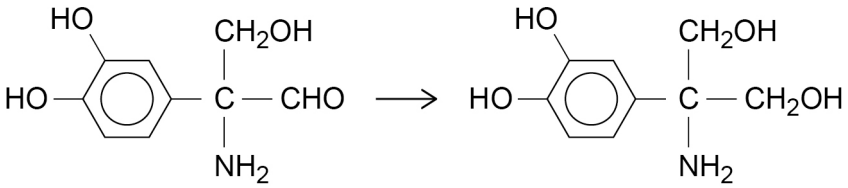
1 _____

_____

2 _____

_____

0 3 . 4 An isomer of L-DOPA can be converted into compound **F**.



F

This reaction involves nucleophilic addition.

Identify the reagent and the nucleophile used to form compound **F**.

[2 marks]

Reagent _____

_____

Nucleophile _____

_____

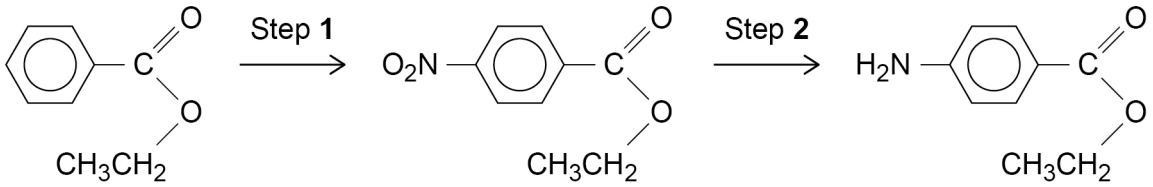
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Turn over ►

Do not write outside the box

0 4 This question is about benzocaine, another compound used in medicine.

A suggested synthesis of benzocaine starting from ethyl benzoate is shown.



ethyl benzoate benzocaine

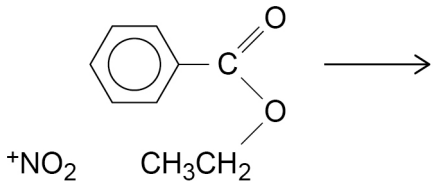
0 4 . 1 Identify the mixture of reagents needed for Step **1**.

[1 mark]

0 4 . 2 The attacking species in Step **1** is the nitronium ion ($^+NO_2$)

Complete the mechanism for Step **1**.

[3 marks]



0 4 . 3 How many peaks are there in the ^{13}C NMR spectrum of benzocaine?

Tick (✓) **one** box.

[1 mark]

4 ☐ 7 ☐ 9 ☐

Do not write outside the box

0 4 . 4 In this synthesis, a chemist obtains a yield of 10.7 g of benzocaine.
The percentage yield is 11.2%

The relative molecular masses of starting material and product are:

- starting material (ethyl benzoate) 150.0
- product (benzocaine) 165.0

Calculate the mass, in g, of ethyl benzoate used.

[3 marks]

Mass _____ g

0 4 . 5 Suggest **one** reason why the percentage yield of benzocaine is very low in this synthesis.

[1 mark]

_____

_____

9

Turn over ►

Do not write outside the box

0 5 This question is about peptides and proteins.

Table 1 gives information about three naturally occurring amino acids.

Table 1

Amino acid	Three-letter abbreviation	Structure	M_r
glycine	gly	H_2NCH_2COOH	75.0
alanine	ala	$CH_3CH(NH_2)COOH$	89.0
serine	ser	$HOCH_2CH(NH_2)COOH$	105.0

0 5 . 1 Draw the structure of the dipeptide formed from two molecules of glycine.

[1 mark]

0 5 . 2 A dipeptide is formed from one molecule of glycine and one molecule of serine.

Deduce the relative molecular mass of this dipeptide.

[1 mark]

M_r _____

0 5 . 3 Peptides can be represented using the three-letter abbreviations for amino acids shown in **Table 1**.

The tripeptide that forms when glycine links to alanine then to serine has the abbreviation gly–ala–ser.
The abbreviation ser-ala-gly represents a different tripeptide.

Deduce the abbreviation for each of the other four tripeptides that can form from one molecule of each amino acid in **Table 1**.

[2 marks]

1 _____

2 _____

3 _____

4 _____

Do not write outside the box

0 5 . 4 Use IUPAC rules to name alanine.

[1 mark]

0 5 . 5 Draw the structure of the organic species formed when serine reacts separately with:

- an excess of hydrochloric acid
- ethanoyl chloride.

[2 marks]

With an excess of hydrochloric acid

With ethanoyl chloride

0 5 . 6 Proteins have primary, secondary and tertiary structures.
These structures are maintained by bonds and attractive forces.
The primary structure of a protein is maintained by covalent bonding.

Name the bond or attractive force responsible for maintaining the secondary structure of a protein.

Name a **different** bond or attractive force responsible for maintaining the tertiary structure of a protein.

[2 marks]

Bond or attractive force in secondary structure _____

Bond or attractive force in tertiary structure _____

0 5 . 7 One method of analysing the structure of polypeptides and proteins is to use thin-layer chromatography (TLC) to identify the constituent amino acids.

State how the constituent amino acids are produced from a polypeptide.

[1 mark]

Do not write outside the box

A mixture of amino acids, obtained from a polypeptide, is analysed using TLC.

Figure 1 shows the TLC plate at the end of the analysis.

Figure 1

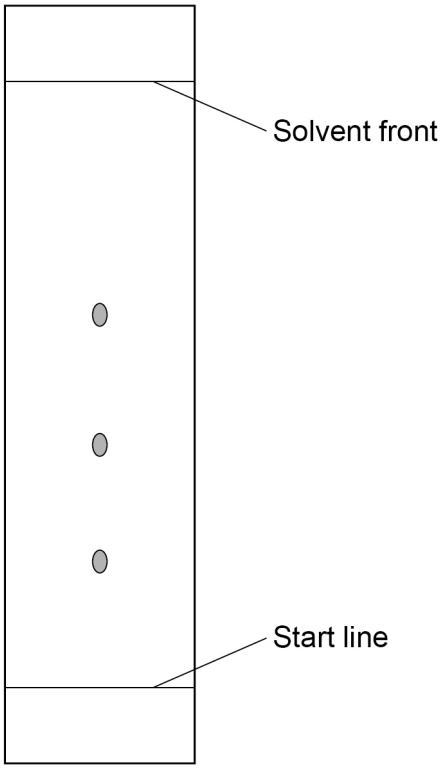


Table 2 shows the R_f values of some amino acids.

Table 2

Amino acid	arginine	aspartic acid	alanine	isoleucine	phenylalanine
R_f value	0.16	0.21	0.30	0.53	0.61

0 5 . 8 Use **Figure 1** and **Table 2** to identify **two** of the amino acids in the mixture.

[1 mark]

0 5 . 9 Give the R_f value of the other amino acid in the mixture that is **not** shown in **Table 2**.

[1 mark]

12

Do not write outside the box

0 6 Substances **G** and **H** react together as shown.

$$2\,\mathbf{G} + \mathbf{H} \rightarrow \text{products}$$

The initial rate of reaction is determined in a series of experiments at constant temperature.

The rate equation for this reaction is

$$rate = k[\mathbf{G}]^2[\mathbf{H}]$$

Table 3 shows some of the data recorded.

Table 3

Experiment	Initial [G] / mol dm^{-3}	Initial [H] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.0150	0.0250	1.50×10^{-5}
2	0.0450	0.0250	
3	0.0300		1.50×10^{-5}
4		0.0750	1.20×10^{-4}

0 6 . 1 Use the data from Experiment **1** to calculate a value for the rate constant, k

Deduce the units of k

[3 marks]

Value of k _____

Units of k _____

0 6 . 2 Complete **Table 3**.

[3 marks]

Space for working

6

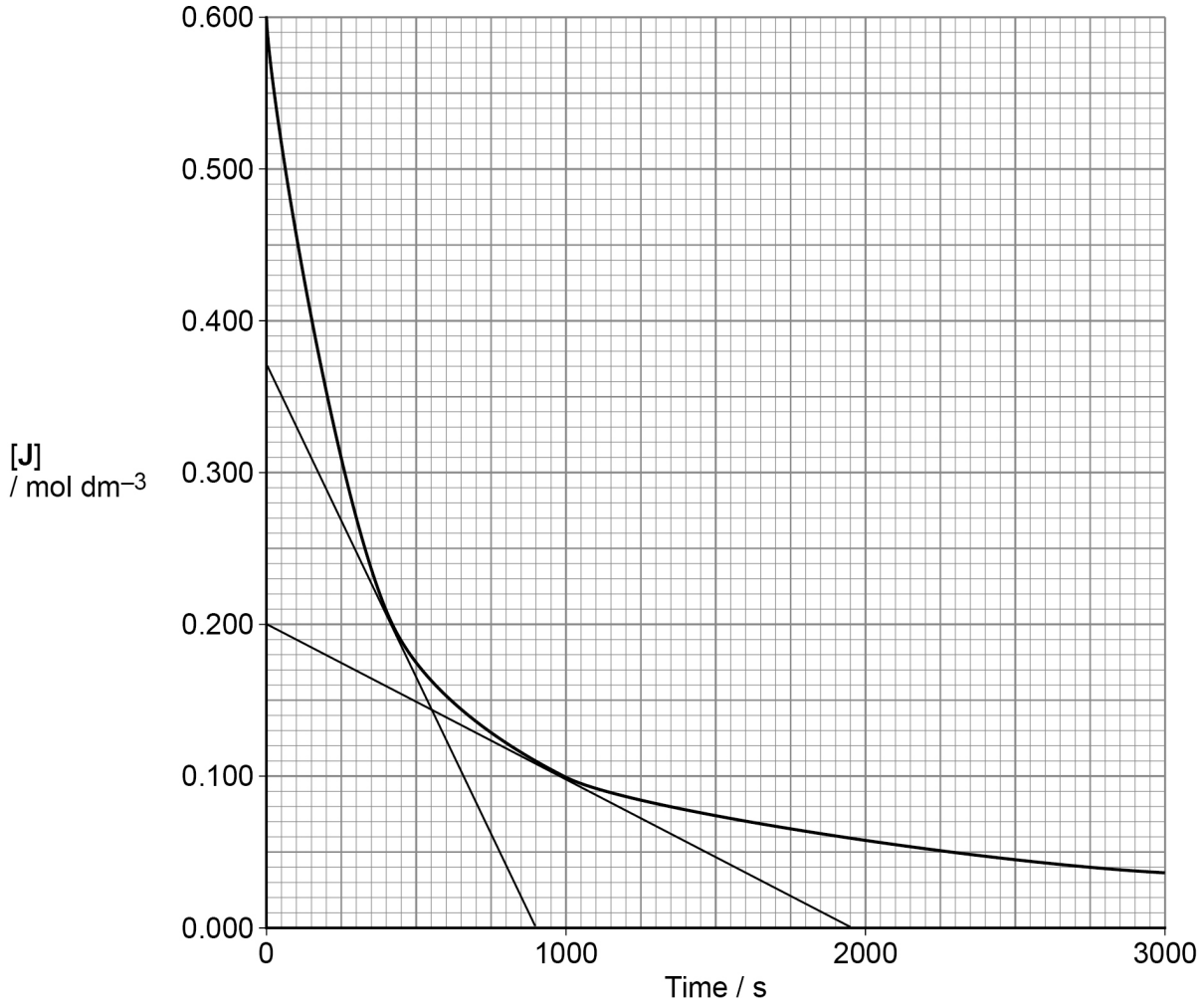
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0 7 In an experiment, compound **J** is decomposed.
The concentration of **J** is measured at different times during the decomposition.

Figure 2 shows a graph of the results.

Figure 2



Do not write outside the box

0 7 . 1 Tangents have been drawn on **Figure 2** at [**J**] = 0.200 mol dm^{-3} and at [**J**] = 0.100 mol dm^{-3}

Use the tangents to calculate the rate of reaction at each of these concentrations.

[4 marks]

Rate at [**J**] = 0.200 mol dm^{-3} _____ mol dm^{-3} s^{-1}

Rate at [**J**] = 0.100 mol dm^{-3} _____ mol dm^{-3} s^{-1}

0 7 . 2 Use your answers from Question **07.1** to deduce the order of reaction with respect to **J**.

Justify your deduction.

[2 marks]

Order of reaction _____

Justification _____

_____

_____

6

Turn over ►

Do not write outside the box

0 8 This question is about the reversible reaction between nitrogen and hydrogen gases.

In an experiment, 1.00 mol of nitrogen and 3.00 mol of hydrogen are mixed in a sealed container and allowed to reach equilibrium.

The equation shows the reaction that occurs.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

0 8 . 1 The amount of nitrogen in the equilibrium mixture is 0.74 mol

Calculate the amounts, in mol, of hydrogen and of ammonia in the equilibrium mixture.

Calculate the total amount, in mol, of gas in the equilibrium mixture.

[3 marks]

Amount of hydrogen _____ mol

Amount of ammonia _____ mol

Total amount of gas _____ mol

0 8 . 2 Write an expression for the equilibrium constant (K_p) for this reaction.

[1 mark]

K_p

Do not write outside the box

0 8 . 3 The temperature of the container is increased.

What happens to the value of K_p?

Tick (✓) **one** box.

[1 mark]

K_p increases. ☐

K_p does not change. ☐

K_p decreases. ☐

0 8 . 4 The original experiment is repeated, using the same conditions of temperature and pressure, but with a small amount of iron catalyst in the sealed container.

State the effect, if any, of this change on the rate of the reverse reaction and on the yield of ammonia.

Give a reason for each of your answers.

[4 marks]

Effect on rate of reverse reaction _____

Reason _____

_____

_____

Effect on yield of ammonia _____

Reason _____

_____

_____

9

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0 9 This question is about the Arrhenius equation.

A reaction is investigated at different temperatures.

Table 4 shows the values of the rate constant (k) for this reaction at two different temperatures.

Table 4

T / K	k / mol dm^{-3} s^{-1}
500	6.21×10^5
1000	7.86×10^7

The Arrhenius equation can be written as

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

In this equation, A is the Arrhenius constant.

Use the data in **Table 4** to calculate the value, in kJ mol^{-1}, of the activation energy (E_a) for this reaction.

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

[5 marks]

E_a _____ kJ mol^{-1}

5

END OF QUESTIONS

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