

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

Thursday 21 January 2021 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	
4	
5	
6	
7	
8	
<b>TOTAL</b>	

## Information

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

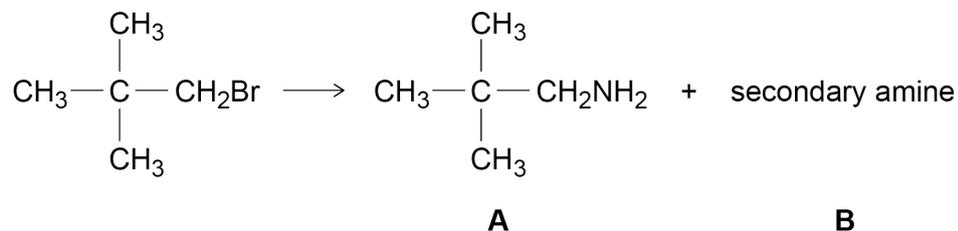


Answer **all** questions in the spaces provided.

0 1

This question is about the formation and properties of amines.

1-Bromo-2,2-dimethylpropane reacts with ammonia to form a mixture of products. Two of these products are the primary amine, **A**, and a secondary amine, **B**.



0 1 . 1

Which of these conditions would form the maximum amount of **A** in the reaction?

Tick (✓) **one** box.

[1 mark]

Use ammonia in excess

Use a catalyst

Use ethanol as the solvent

0 1 . 2

Amine **A** can also be formed by the reduction of a nitrile.

Deduce the structure of this nitrile.

[1 mark]



0 1 . 3 Explain why amine **A** is a stronger base than ammonia.

[3 marks]

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0 1 . 4 Deduce the molecular formula of the secondary amine **B**.

[1 mark]

Molecular formula \_\_\_\_\_

0 1 . 5 Amine **A** has several isomers.

One isomer is a secondary amine with three peaks in its  $^{13}\text{C}$  NMR spectrum.  
Another isomer is a tertiary amine that also has three peaks in its  $^{13}\text{C}$  NMR spectrum.

Deduce the structure of each isomer.

[2 marks]

Secondary amine

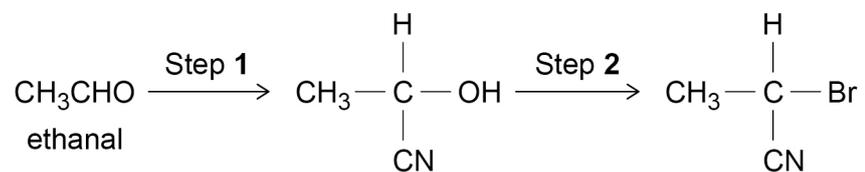
Tertiary amine



0 2

This question is about amino acids.

The amino acid alanine can be synthesised from ethanal in a four-step sequence. The first two steps are shown.



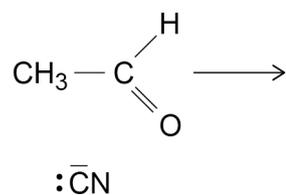
0 2 . 1

Name and complete the mechanism for Step 1.

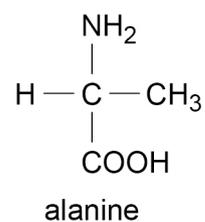
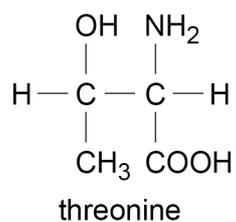
**[4 marks]**

Name of mechanism \_\_\_\_\_

Mechanism



**0 2 . 2** The amino acids threonine and alanine are shown.



Threonine forms two dipeptides when it reacts with alanine.

Draw the structure of each dipeptide.

**[2 marks]**

Dipeptide 1

Dipeptide 2

**0 2 . 3** Alanine can be separated from a mixture with threonine by thin-layer chromatography. Different experiments give different  $R_f$  values for alanine.

Suggest **one** reason for the different values for alanine.

**[1 mark]**

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Turn over ►





0 3

This question is about compounds that contain a ring of six carbon atoms.

0 3 . 1

The equations for the hydrogenation of cyclohexene and of benzene are shown.



Use this information to calculate the extra stability of benzene compared to cyclohexa-1,3,5-triene.

Give a reason for the extra stability of benzene.

[2 marks]

Extra stability \_\_\_\_\_ kJ mol<sup>-1</sup>

Reason for extra stability \_\_\_\_\_

\_\_\_\_\_

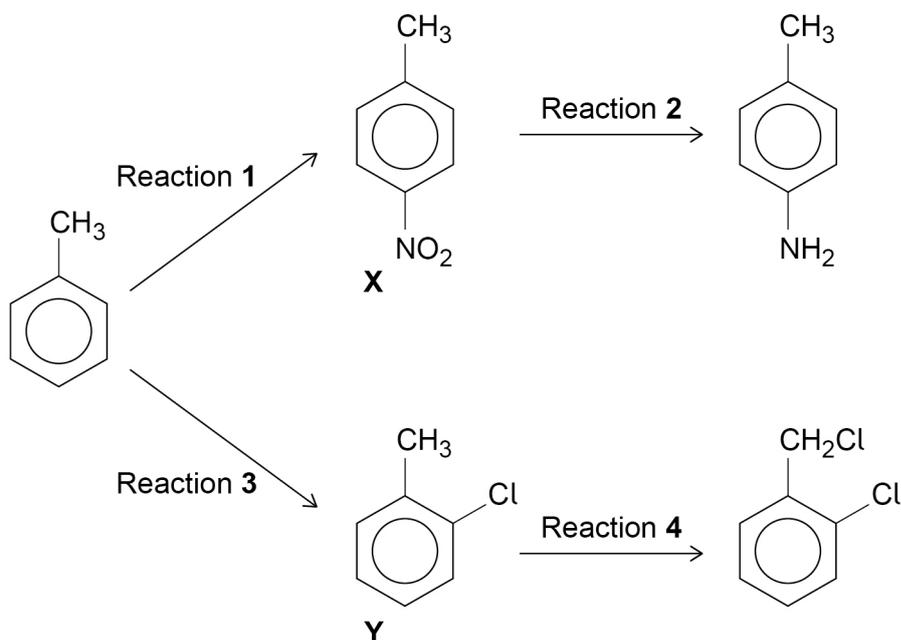
\_\_\_\_\_

Question 3 continues on the next page

Turn over ►



Methylbenzene can be converted into other aromatic compounds as shown in this reaction scheme.



**0 3 . 2** Reaction 1 involves attack by the electrophile  $^+\text{NO}_2$  on methylbenzene.

Write an equation to show the formation of  $^+\text{NO}_2$

Complete the mechanism of the reaction between methylbenzene and  $^+\text{NO}_2$

**[4 marks]**

Equation to form  $^+\text{NO}_2$

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Mechanism



**0 3 . 3** The name of **X** is 1-methyl-4-nitrobenzene.

Deduce the name of **Y**.

[1 mark]

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**0 3 . 4** Reaction **2** involves reduction.

Identify the substances used to form the reducing agent in this reaction.

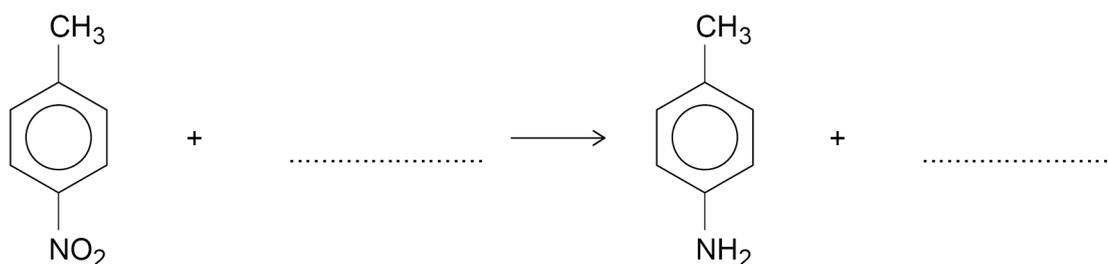
Complete the equation for Reaction **2**, using [H] to represent the reducing agent.

[2 marks]

Substances used to form reducing agent \_\_\_\_\_

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Equation



**0 3 . 5** Write an equation to show the formation of the attacking species in Reaction **4**.

State the condition needed for this reaction.

[2 marks]

Equation

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Condition

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**0 4**

This question is about carbonyl compounds and their reactions.

**0 4 . 1**The aldehyde  $(\text{CH}_3)_2\text{CHCHO}$  can be reduced to a primary alcohol.

Identify a reagent for this reduction.

Give the skeletal formula of the primary alcohol formed.

**[2 marks]**

Reagent \_\_\_\_\_

Skeletal formula of primary alcohol

**0 4 . 2**The ketone  $\text{CH}_3\text{CH}_2\text{COCH}_3$  can be reduced to a secondary alcohol, using the same reagent as in Question **04.1**.

Draw the displayed formula of the secondary alcohol formed.

**[1 mark]****0 4 . 3**Explain why each of the alcohols formed in Question **04.1** and in Question **04.2** does **not** show any optical activity.**[2 marks]**Alcohol formed in **04.1** \_\_\_\_\_\_\_\_\_\_  
\_\_\_\_\_Alcohol formed in **04.2** \_\_\_\_\_\_\_\_\_\_  
\_\_\_\_\_

0 4 . 4

Describe how a polarimeter can be used to distinguish between separate samples of two enantiomers.

**[2 marks]**

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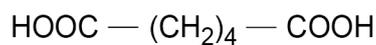
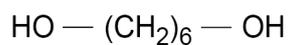
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0 4 . 5

Two organic compounds are shown.



These compounds react together to form a condensation polymer.

Draw the repeating unit of this polymer.

**[1 mark]**

Question 4 continues on the next page

**Turn over ►**

0 4 . 6

The general formula of carbonyl compounds is  $C_nH_{2n}O$

Combustion analysis is used to find the empirical formula of a carbonyl compound, **W**.

A sample containing  $9.50 \times 10^{-4}$  mol of **W** is completely combusted in an excess of oxygen.

After removing the water vapour, the gas mixture has a volume of  $223 \text{ cm}^3$

After removing the carbon dioxide, the remaining oxygen has a volume of  $86 \text{ cm}^3$

All gas volumes are measured at a pressure of 103 kPa and a temperature of 298 K

Use these data to deduce the empirical formula of **W**.

The gas constant,  $R = 8.31 \text{ JK}^{-1} \text{ mol}^{-1}$

[5 marks]

Empirical formula \_\_\_\_\_

13



**0 5**

This question is about compounds containing the carbonyl group.

**0 5 . 1**

Propyl ethanoate can be prepared by reacting ethanoic acid with propan-1-ol.

Complete the equation for this reaction.

**[1 mark]****0 5 . 2**

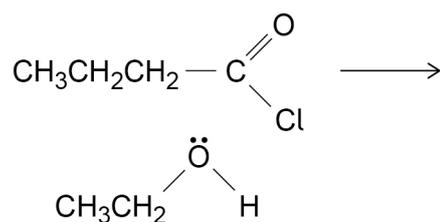
Ethyl butanoate can be prepared by reacting ethanol with butanoyl chloride.

Name and complete the mechanism of this reaction.

**[4 marks]**

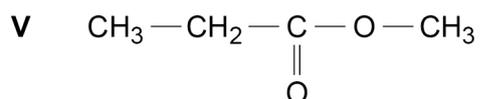
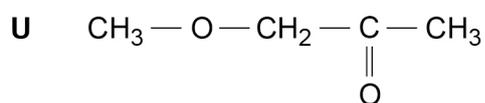
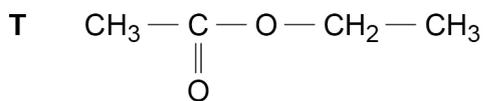
Name of mechanism \_\_\_\_\_

Mechanism

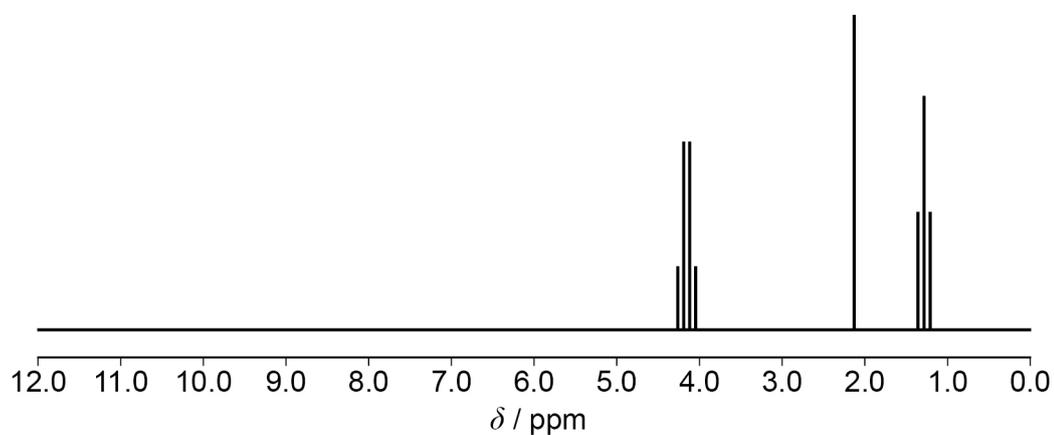
**Question 5 continues on the next page****Turn over ►**

**0 5 . 3** There are several structural isomers with the molecular formula  $C_4H_8O_2$

The structures of three of these isomers are shown.



The  $^1\text{H}$  NMR spectrum of one of these isomers is shown.



The splitting patterns in the spectrum suggest that the spectrum could be that of either **T** or **V**.

Explain, with reference to **Table B** in the Chemistry Data Sheet, how the spectrum confirms that it is the spectrum of **T** and **not** the spectrum of **V**.

**[2 marks]**

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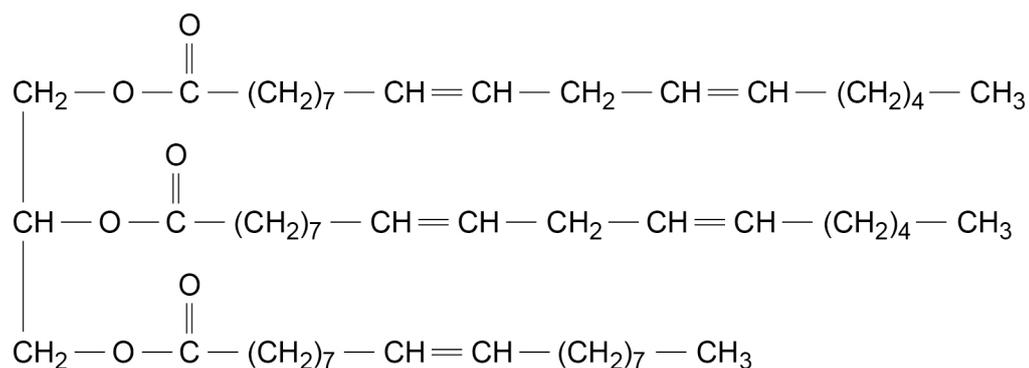


**0 5 . 4** Predict the splitting pattern and the integration ratio in the  $^1\text{H}$  NMR spectrum of **U**.  
[2 marks]

Splitting pattern \_\_\_\_\_

Integration ratio \_\_\_\_\_

**0 5 . 5** One of the esters in sunflower oil has the structure shown.



This ester can be reacted with methanol to form two methyl esters used in biodiesel.

Give the structure of each of these methyl esters.

[2 marks]

1

\_\_\_\_\_

2

\_\_\_\_\_

**0 5 . 6** Aspirin can be made by reacting 2-hydroxybenzoic acid either with ethanoyl chloride or with ethanoic anhydride.

Give **two** advantages of using ethanoic anhydride rather than ethanoyl chloride.

[2 marks]

1 \_\_\_\_\_

\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_



0 6

This question is about rate equations.

0 6 . 1

The initial rate of reaction between compounds **P** and **Q** is measured in a series of experiments at constant temperature. The rate equation deduced is

$$\text{rate} = k[\text{P}][\text{Q}]^2$$

**Table 1** shows some rate data.

**Table 1**

Experiment	Initial [P] / mol dm <sup>-3</sup>	Initial [Q] / mol dm <sup>-3</sup>	Rate / mol dm <sup>-3</sup> s <sup>-1</sup>
1	$2.40 \times 10^{-2}$	$3.30 \times 10^{-2}$	$2.10 \times 10^{-3}$
2	$2.40 \times 10^{-2}$	$1.65 \times 10^{-2}$	
3		$1.10 \times 10^{-2}$	$7.00 \times 10^{-4}$
4	$1.20 \times 10^{-2}$		$4.20 \times 10^{-3}$

Complete **Table 1**.

**[3 marks]**

Space for working

0 6 . 2

Use the data from Experiment **1** to calculate a value for the rate constant,  $k$ .  
State the units of  $k$ .

**[3 marks]**

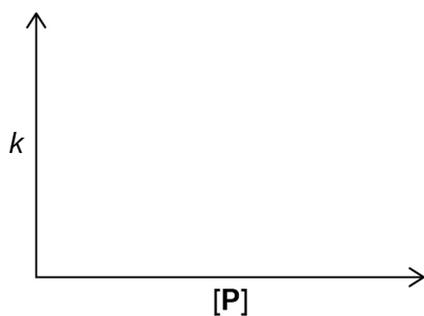
Value of  $k$  \_\_\_\_\_

Units \_\_\_\_\_



0 6 . 3 Sketch a graph to show how  $k$  changes as  $[P]$  is increased.

[1 mark]



0 6 . 4 The rate equation for a different reaction is

$$\text{rate} = k[R]$$

Explain why doubling the temperature has a greater effect on the rate of reaction than doubling the concentration of  $R$ .

[2 marks]

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9

Turn over for the next question

Turn over ►



0 7

The Arrhenius equation can be written as

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

0 7 . 1

Table 2 shows the value of the rate constant at different temperatures for the reaction



Table 2

Rate constant $k$ $/ \text{s}^{-1}$	$\ln k$	Temperature $/ \text{K}$	$\frac{1}{T} / \text{K}^{-1}$
$1.74 \times 10^{-5}$	-10.96	298	$3.36 \times 10^{-3}$
	-9.62	308	$3.25 \times 10^{-3}$
$2.51 \times 10^{-4}$	-8.29	318	$3.14 \times 10^{-3}$
$7.59 \times 10^{-4}$	-7.18		$3.05 \times 10^{-3}$

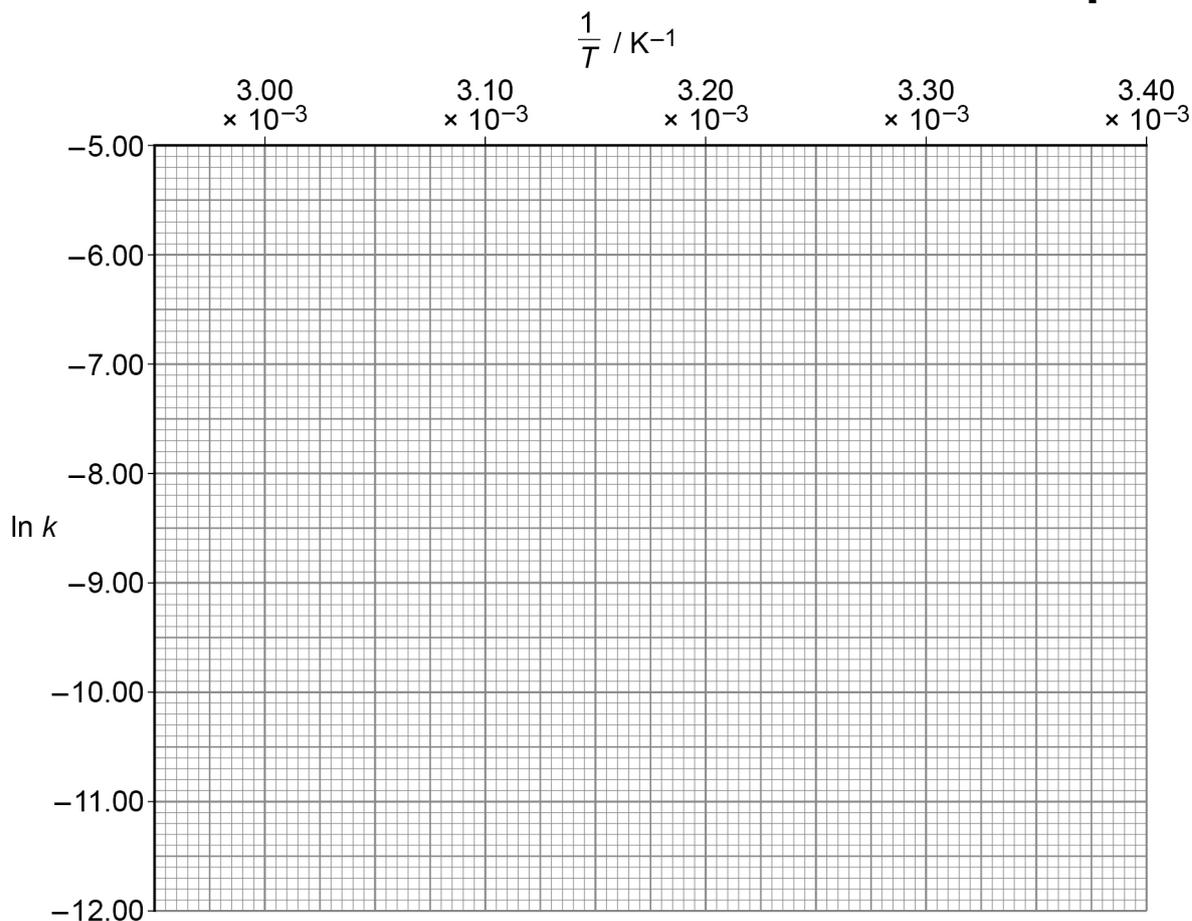
Complete Table 2.

[2 marks]



**0 7 . 2** Plot a graph of  $\ln k$  against  $\frac{1}{T}$

**[2 marks]**



**0 7 . 3** Use your graph to calculate a value for the activation energy ( $E_a$ ), in  $\text{kJ mol}^{-1}$ , for this reaction.

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

Show your working.

**[3 marks]**

$E_a$  \_\_\_\_\_  $\text{kJ mol}^{-1}$

**7**

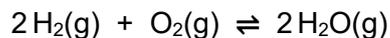
Turn over ►



**0 8**

This question is about partial pressures.

The equation for the reaction between hydrogen and oxygen is

**0 8 . 1**

Hydrogen and oxygen are mixed in a 2:1 mole ratio and allowed to reach equilibrium in a flask.

At equilibrium, the total pressure of the mixture in the flask is 180 kPa

The mole fraction of  $\text{H}_2\text{O}(\text{g})$  in the equilibrium mixture is 0.97

Calculate the partial pressure of  $\text{H}_2\text{O}(\text{g})$  in the equilibrium mixture.

Use your answer to calculate the partial pressure of  $\text{O}_2(\text{g})$  and of  $\text{H}_2(\text{g})$  in the equilibrium mixture.

**[3 marks]**

Partial pressure of  $\text{H}_2\text{O}(\text{g})$  \_\_\_\_\_ kPa

Partial pressure of  $\text{O}_2(\text{g})$  \_\_\_\_\_ kPa

Partial pressure of  $\text{H}_2(\text{g})$  \_\_\_\_\_ kPa

**0 8 . 2**

Write an expression for  $K_p$  for this equilibrium.

**[1 mark]** $K_p$ 

- 0 8 . 3** In another experiment under different conditions, a different equilibrium mixture of the three gases was obtained.

**Table 3** shows the partial pressure of each gas in this equilibrium mixture.

**Table 3**

Gas	Partial pressure / kPa
H <sub>2</sub>	$1.02 \times 10^3$
O <sub>2</sub>	$0.78 \times 10^3$
H <sub>2</sub> O	$3.56 \times 10^3$

Calculate a value for the equilibrium constant ( $K_p$ ) and give its units.

**[3 marks]**

Value of  $K_p$  \_\_\_\_\_

Units \_\_\_\_\_

- 0 8 . 4** The enthalpy of formation of H<sub>2</sub>O(g) is  $-242 \text{ kJ mol}^{-1}$

The temperature of the equilibrium mixture in Question **08.3** is increased.

What is the effect of this change on the value of  $K_p$  for this reaction?

Tick (✓) **one** box.

**[1 mark]**

Increase  No change  Decrease

- 0 8 . 5** The experiment in Question **08.3** was repeated at the same temperature but in a flask of smaller volume.

Deduce the effect, if any, of this change on the yield of H<sub>2</sub>O(g) and on the value of  $K_p$

**[2 marks]**

Effect on yield of H<sub>2</sub>O(g) \_\_\_\_\_

Effect on value of  $K_p$  \_\_\_\_\_

10

**END OF QUESTIONS**



**There are no questions printed on this page**

*Do not write  
outside the  
box*

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ANSWER IN THE SPACES PROVIDED**





