OXFORD

INTERNATIONAL
AQA EXAMINATIONS

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

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.

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

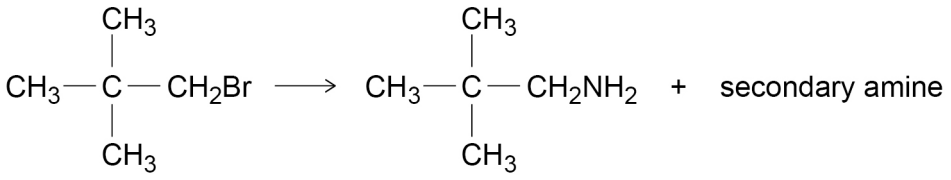
For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	

Do not write outside the box

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**.



A **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]

Do not write outside the box

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

[3 marks]

_____

_____

_____

_____

_____

_____

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}C NMR spectrum.
Another isomer is a tertiary amine that also has three peaks in its ^{13}C NMR spectrum.

Deduce the structure of each isomer.

[2 marks]

Secondary amine

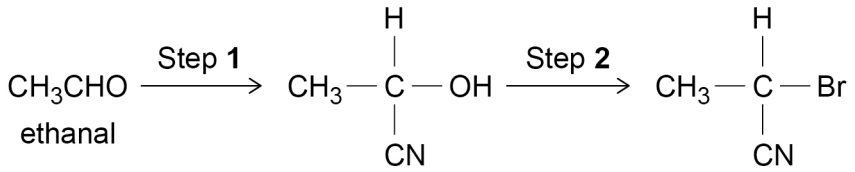
Tertiary amine

8

Do not write outside the box

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.

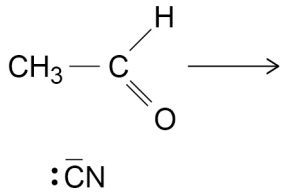


0 2 . 1 Name and complete the mechanism for Step **1**.

[4 marks]

Name of mechanism _____

Mechanism



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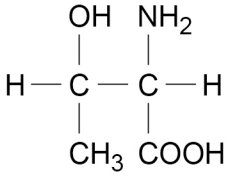
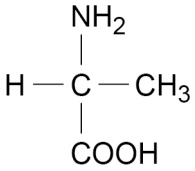
0 2 . 2 The amino acids threonine and alanine are shown.



threonine



alanine

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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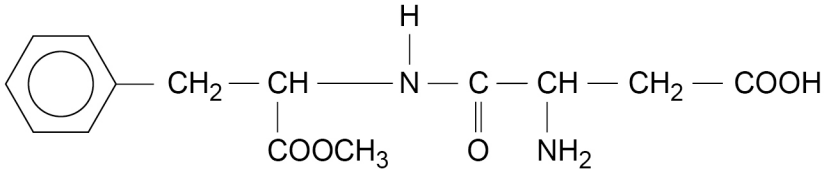
0 2 . 4 Aspartame is the methyl ester of a dipeptide and is used as a sweetener.

The structure of aspartame is shown.



When aspartame is heated in acidic conditions, the peptide bond and the ester group are both hydrolysed.

Draw the structure of each of the two protonated amino acids formed.

[2 marks]

Protonated amino acid 1

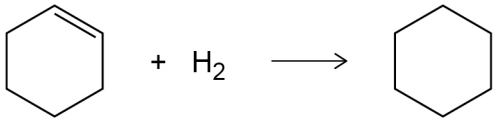
Protonated amino acid 2

9

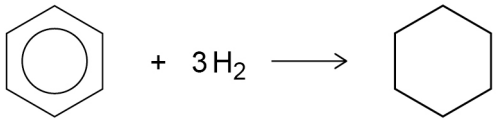
Do not write outside the box

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.



$\Delta H^{\ominus} = -120\ \text{kJ mol}^{-1}$



$\Delta H^{\ominus} = -208\ \text{kJ mol}^{-1}$

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^{-1}

Reason for extra stability _____

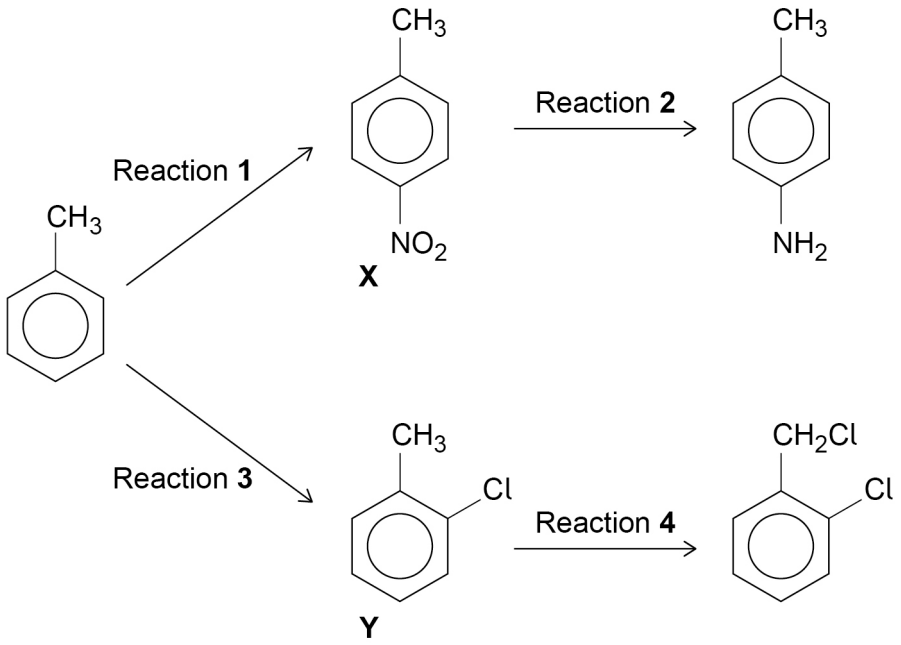
_____

_____

Question 3 continues on the next page

Do not write outside the box

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



0 3 . 2 Reaction **1** involves attack by the electrophile $^{+}NO_2$ on methylbenzene.

Write an equation to show the formation of $^{+}NO_2$

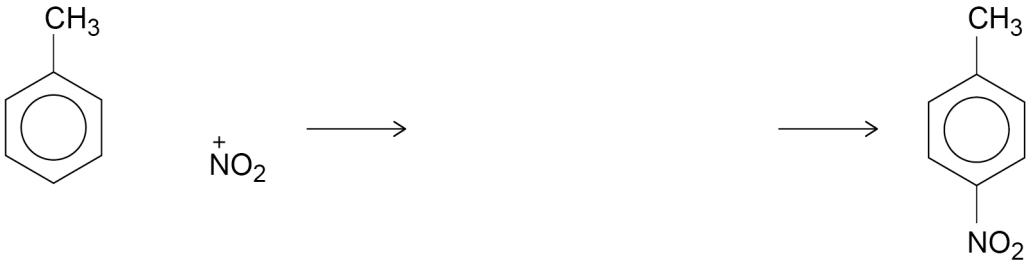
Complete the mechanism of the reaction between methylbenzene and $^{+}NO_2$

[4 marks]

Equation to form $^{+}NO_2$

_____

Mechanism



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

Deduce the name of **Y**.

[1 mark]

_____

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

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

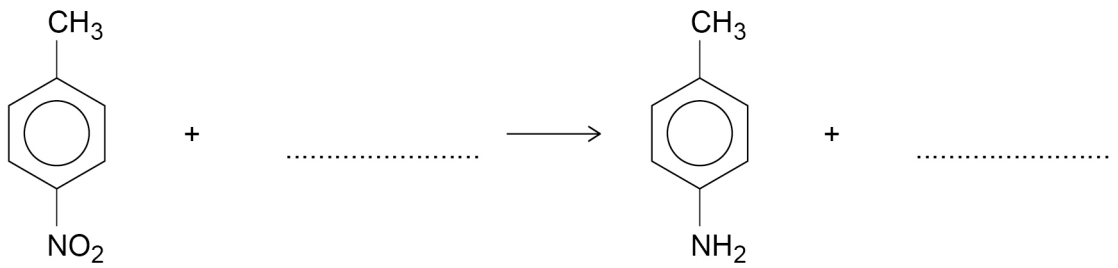
Complete the equation for Reaction **2**, using [H] to represent the reducing agent.

[2 marks]

Substances used to form reducing agent _____

_____

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

_____

Condition

_____

11

Turn over ►

Do not write outside the box

0 4 This question is about carbonyl compounds and their reactions.

0 4 . 1 The aldehyde $(CH_3)_2CHCHO$ 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 $CH_3CH_2COCH_3$ 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** _____

_____

_____

Do not write outside the box

0 4 . 4 Describe how a polarimeter can be used to distinguish between separate samples of two enantiomers.

[2 marks]

_____

_____

_____

_____

0 4 . 5 Two organic compounds are shown.

$HO — (CH_2)_6 — OH$ $HOOC — (CH_2)_4 — COOH$

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

Do not write outside the box

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 9.50×10^{-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 cm^3
After removing the carbon dioxide, the remaining oxygen has a volume of 86 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, $R = 8.31\ J\,K^{-1}\,mol^{-1}$

[5 marks]

Empirical formula _____

13

Do not write outside the box

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]

$CH_3COOH + CH_3CH_2CH_2OH \rightarrow$

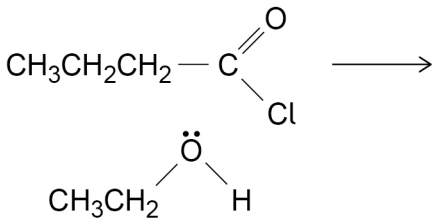
0 5 . 2 Ethyl butanoate can be prepared by reacting ethanol with butanoyl chloride.

Name and complete the mechanism of this reaction.

[4 marks]

Name of mechanism _____

Mechanism



Question 5 continues on the next page

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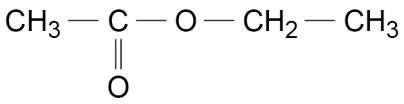
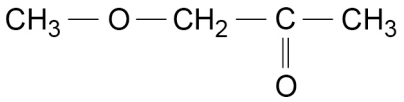
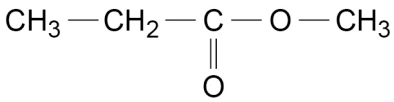
0 5 . 3 There are several structural isomers with the molecular formula $C_4H_8O_2$

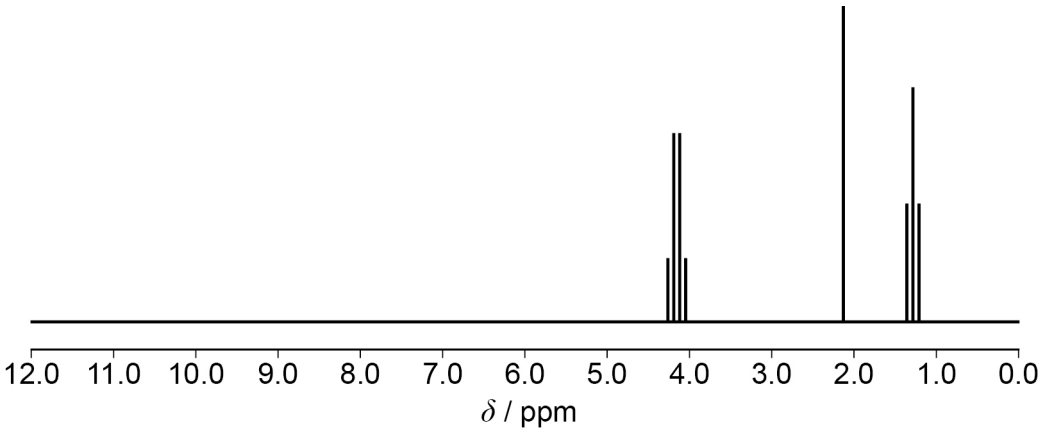
The structures of three of these isomers are shown.

T 

U 

V 

The ^{1}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]

Do not write outside the box

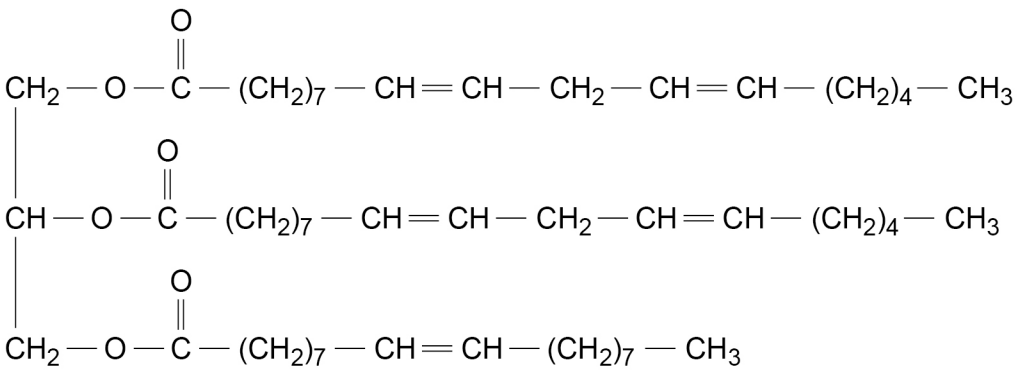
0 5 . 4 Predict the splitting pattern and the integration ratio in the ^{1}H NMR spectrum of **U**.

[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 _____

_____

13

Turn over ►

Do not write outside the box

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

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

Table 1 shows some rate data.

Table 1

Experiment	Initial [P] / mol dm^{-3}	Initial [Q] / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	2.40×10^{-2}	3.30×10^{-2}	2.10×10^{-3}
2	2.40×10^{-2}	1.65×10^{-2}	
3		1.10×10^{-2}	7.00×10^{-4}
4	1.20×10^{-2}		4.20×10^{-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 _____

Do not write outside the box

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

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

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

[2 marks]

_____

_____

_____

_____

_____

_____

9

Turn over for the next question

Do not write outside the box

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

$$2\,N_2O_5(g) \rightarrow 4\,NO_2(g) + O_2(g)$$

Table 2

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

Complete **Table 2**.

[2 marks]

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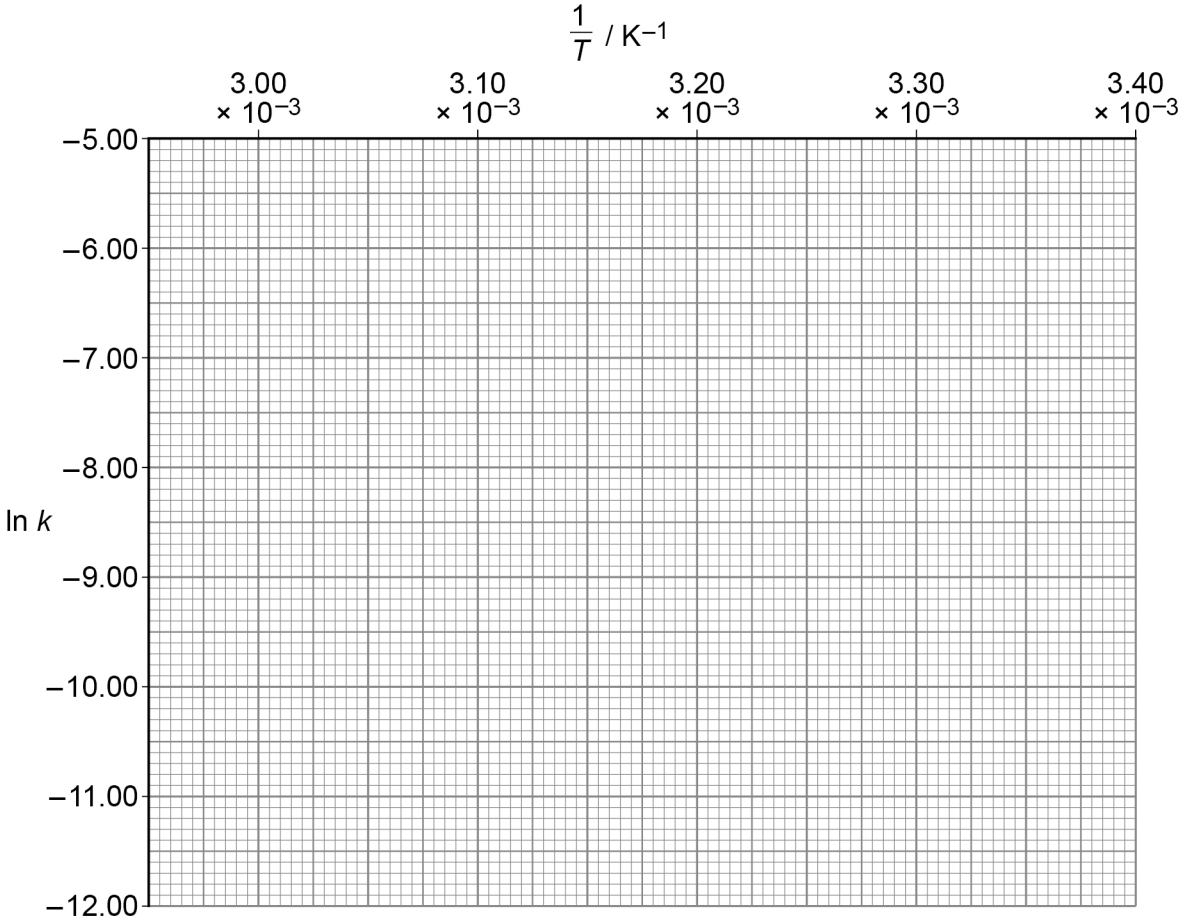
0 7 . 2 Plot a graph of ln k against $\frac{1}{T}$

[2 marks]



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

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

Show your working.

[3 marks]

E_a _____ kJ mol^{-1}

7

Turn over ►

Do not write outside the box

0 8 This question is about partial pressures.

The equation for the reaction between hydrogen and oxygen is

$$2\,H_2(g) + O_2(g) \rightleftharpoons 2\,H_2O(g)$$

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 $H_2O(g)$ in the equilibrium mixture is 0.97

Calculate the partial pressure of $H_2O(g)$ in the equilibrium mixture.

Use your answer to calculate the partial pressure of $O_2(g)$ and of $H_2(g)$ in the equilibrium mixture.

[3 marks]

Partial pressure of $H_2O(g)$ _____ kPa

Partial pressure of $O_2(g)$ _____ kPa

Partial pressure of $H_2(g)$ _____ kPa

0 8 . 2 Write an expression for K_p for this equilibrium.

[1 mark]

K_p

Do not write outside the box

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_2	1.02×10^3
O_2	0.78×10^3
H_2O	3.56×10^3

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 $H_2O(g)$ is $-242\ kJ\,mol^{-1}$

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 $H_2O(g)$ and on the value of K_p

[2 marks]

Effect on yield of $H_2O(g)$ _____

Effect on value of K_p _____

10

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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