

Centre Number					Candidate Number				
Surname	ANSWERS								
Other Names									
Candidate Signature									

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	



General Certificate of Education
Advanced Subsidiary Examination
June 2014

Chemistry

CHEM2

Unit 2 Chemistry in Action

Tuesday 3 June 2014 1.30 pm to 3.15 pm

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

Time allowed

- 1 hour 45 minutes

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.
- 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 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
 - use good English
 - organise information clearly
 - use scientific terminology accurately.

Advice

- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.



JUN14CHEM201

WMP/Jun14/CHEM2/F9w

CHEM2

Section A

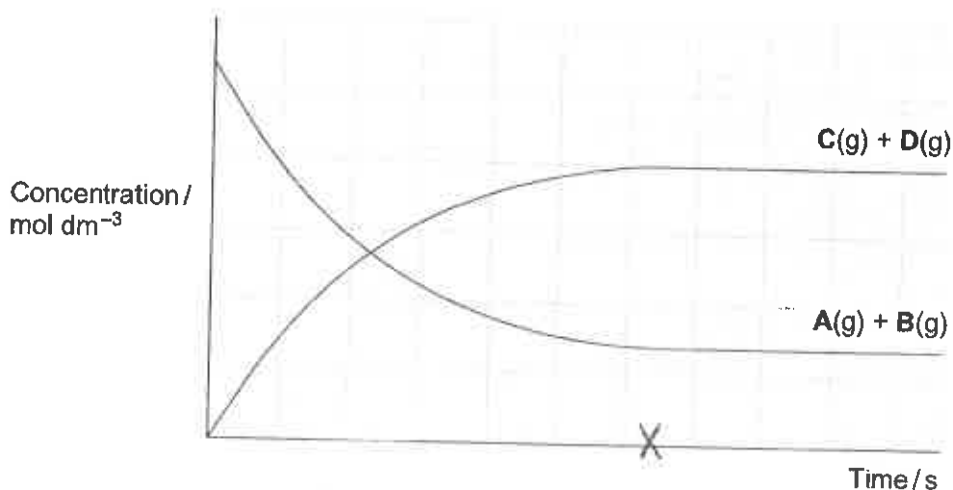
Answer **all** questions in the spaces provided.

- 1 A dynamic equilibrium is established when gas A is mixed with gas B at a given temperature.



Figure 1 shows how the concentrations of reactants and products change with time.

Figure 1



- 1 (a) (i) On the appropriate axis of Figure 1, place an X to show the time when equilibrium is first established.

[1 mark]

- 1 (a) (ii) State how the rate of the forward reaction and the rate of the reverse reaction are related to each other at equilibrium.

[1 mark]

forward rate = backwards rate

This could have been asked as "define a dynamic equilibrium". The answer is the same but add "in a closed system" if 2 marks.



- 1 (b) Give the meaning of the term **dynamic** in the context of a dynamic equilibrium. [1 mark]

Both forward and backwards reactions happening at the same time.

- 1 (c) The total pressure on the system is increased at constant temperature.

- 1 (c) (i) State and explain the effect, if any, of this change on the position of this equilibrium. [2 marks]

Effect ... No change

Explanation ... Same number of gaseous moles on both sides of the equation.

- 1 (c) (ii) State and explain the effect, if any, of this change on the time taken to reach this equilibrium.

Effect ... Time decreases

Be careful here!
Time decreases -
rate increases!

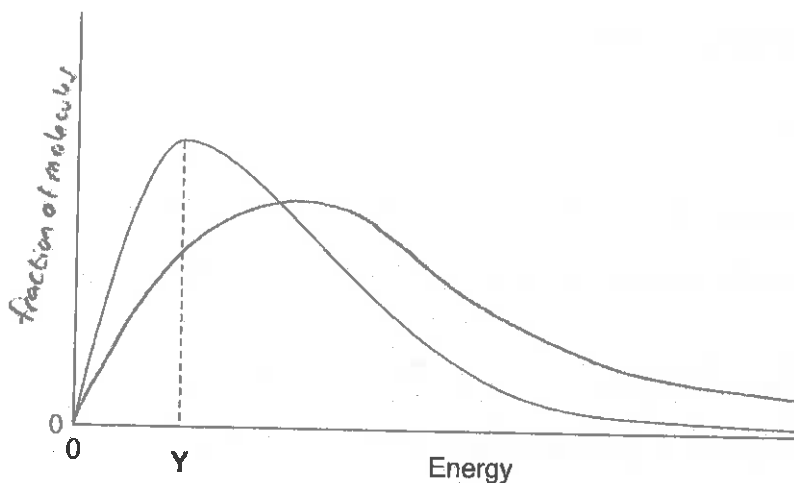
[3 marks]

Explanation ... Increasing pressure will increase both the rate of the forward and backwards reactions, this is because more particles in a given volume and hence more successful collisions.



- 2 **Figure 2** shows the Maxwell–Boltzmann distribution of molecular energies in a sample of gas at temperature T .

Figure 2



- 2 (a) One of the axes is labelled.
Label the other axis.

[1 mark]

- 2 (b) State why the curve starts at the origin.

[1 mark]

There are no molecules with zero energy.

- 2 (c) Which of the following, **A**, **B** or **C**, describes what the value of **Y** represents in **Figure 2**?
Write the correct letter, **A**, **B** or **C**, in the box.

[1 mark]

- A The energy needed for a successful collision
- B The minimum energy needed for a reaction to occur
- C The most probable energy

C



2 (d) On Figure 2, draw a distribution of molecular energies in this sample of gas at a higher temperature.

[2 marks]

2 (e) The pressure of the original sample of gas is doubled at temperature T .

State the effect, if any, of this change on the value of Y .

[1 mark]

No effect.

Pressure would not cause an increase in energy - even though it would affect rate.

6

Turn over for the next question

Turn over ►



3 Antimony is a solid element that is used in industry. The method used for the extraction of antimony depends on the grade of the ore.

3 (a) Antimony can be extracted by reacting scrap iron with low-grade ores that contain antimony sulfide (Sb_2S_3).

3 (a) (i) Write an equation for the reaction of iron with antimony sulfide to form antimony and iron(II) sulfide.

iron(II)sulfide = FeS [1 mark]



3 (a) (ii) Write a half-equation to show what happens to the iron atoms in this reaction.

[1 mark]



3 (b) In the first stage of the extraction of antimony from a high-grade ore, antimony sulfide is roasted in air to convert it into antimony(III) oxide (Sb_2O_3) and sulfur dioxide.

3 (b) (i) Write an equation for this reaction.

[1 mark]

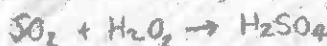


3 (b) (ii) Identify one substance that is manufactured directly from the sulfur dioxide formed in this reaction.

[1 mark]



A few answers available but
this seems the most logical.



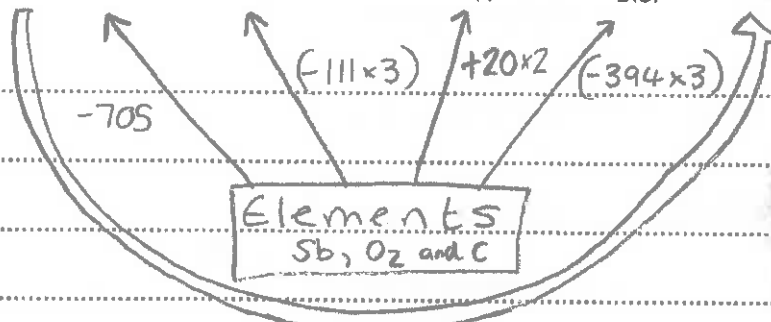
- 3 (c) In the second stage of the extraction of antimony from a high-grade ore, antimony(III) oxide is reacted with carbon monoxide at high temperature.
- 3 (c) (i) Use the standard enthalpies of formation in **Table 1** and the equation given below **Table 1** to calculate a value for the standard enthalpy change for this reaction.

Table 1

	Sb ₂ O ₃ (s)	CO(g)	Sb(l)	CO ₂ (g)
$\Delta H_f^\circ / \text{kJ mol}^{-1}$	-705	-111	+20	-394

POINT TOWARD
YOU FORM!

[3 marks]

Reverse to multiply
by the moles!Also don't forget the
Sb which has changed
state (s to l).

$$+1038 + (-1142) = -104 \text{ kJ mol}^{-1}$$

- 3 (c) (ii) Suggest why the value for the standard enthalpy of formation of liquid antimony, given in **Table 1**, is not zero.

[1 mark]

Sb has changed state, solid \rightarrow Liquid. (NOT IN
STANDARD STATE)

- 3 (c) (iii) State the type of reaction that antimony(III) oxide has undergone in this reaction.



[1 mark]

Reduction.

- 3 (d) Deduce **one** reason why the method of extraction of antimony from a low-grade ore, described in part 3(a), is a low-cost process. Do not include the cost of the ore.

[1 mark]

uses scrap iron!



4 There are many uses for Group 2 metals and their compounds.

4 (a) State a medical use of barium sulfate.
State why this use of barium sulfate is safe, given that solutions containing barium ions are poisonous.

Use Barium Meal

A barium meal is when you swallow a small amount of $BaSO_4$ which absorbs x-rays.

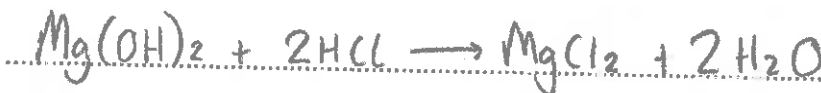
[2 marks]

Why this use is safe $BaSO_4$ is insoluble.

4 (b) Magnesium hydroxide is used in antacid preparations to neutralise excess stomach acid.

Write an equation for the reaction of magnesium hydroxide with hydrochloric acid.

[1 mark]



4 (c) Solutions of barium hydroxide are used in the titration of weak acids.

State why magnesium hydroxide solution could **not** be used for this purpose.

[1 mark]

$Mg(OH)_2$ is not very soluble.

4 (d) Magnesium metal is used to make titanium from titanium(IV) chloride.

Write an equation for this reaction of magnesium with titanium(IV) chloride.

[1 mark]



4 (e) Magnesium burns with a bright white light and is used in flares and fireworks.

Use your knowledge of the reactions of Group 2 metals with water to explain why water should **not** be used to put out a fire in which magnesium metal is burning.

[2 marks]

Hydrogen gas would be released which is highly explosive.



[Extra space]

7

Turn over for the next question

Turn over ►



5 Trifluoromethane (CHF_3) can be used to make the refrigerant chlorotrifluoromethane (CClF_3).

5 (a) Chlorotrifluoromethane is formed when trifluoromethane reacts with chlorine.



The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

5 (a) (i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Cl_2

[4 marks]

Initiation step



First propagation step



Second propagation step



There are
other 2nd
propagation
steps as long
as they can be
used.

Termination step to form hexafluoroethane



5 (a) (ii) Give **one** essential condition for this reaction.

[1 mark]

UV light.



5 (b) In some refrigeration systems, CHF_3 has replaced CClF_3 because of concerns about ozone depletion.

5 (b) (i) Identify the species formed from CClF_3 that is responsible for the catalytic decomposition of ozone in the upper atmosphere.

[1 mark]

$\cdot\text{Cl}$

5 (b) (ii) Write an overall equation to represent the decomposition of ozone into oxygen.

[1 mark]



7

Turn over for the next question

Turn over ►



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ANSWER IN THE SPACES PROVIDED**



6 This question is about Group 7 chemistry.

6 (a) Sea water is a major source of iodine.
The iodine extracted from sea water is impure. It is purified in a two-stage process.



6 (a) (i) State the initial oxidation state and the final oxidation state of sulfur in Stage 1. [2 marks]

Oxidation state of S in SO_2 +4

Oxidation state of S in H_2SO_4 +6

6 (a) (ii) State, in terms of electrons, what has happened to chlorine in Stage 2. [1 mark]

It has been reduced. $Cl_2 + 2e^- \longrightarrow 2Cl^-$

6 (b) When concentrated sulfuric acid is added to potassium iodide, iodine is formed in the following redox equations.

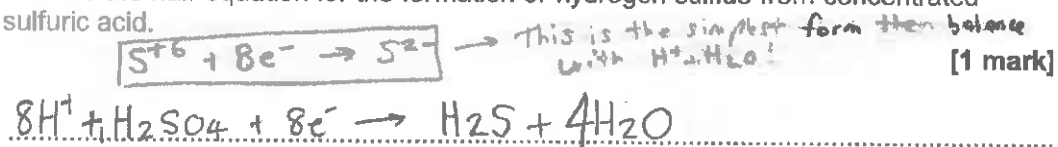


6 (b) (i) Balance the equation for the reaction that forms sulfur. [1 mark]

6 (b) (ii) Deduce the half-equation for the formation of iodine from iodide ions. [1 mark]



6 (b) (iii) Deduce the half-equation for the formation of hydrogen sulfide from concentrated sulfuric acid. [1 mark]



Question 6 continues on the next page

Turn over ►



6 (c) A yellow precipitate is formed when silver nitrate solution, acidified with dilute nitric acid, is added to an aqueous solution containing iodide ions.

6 (c) (i) Write the **simplest ionic equation** for the formation of the yellow precipitate. [1 mark]



make sure you
write the ionic equation
All the others are just
spectators

6 (c) (ii) State what is observed when concentrated ammonia solution is added to this yellow precipitate. [1 mark]

The ppt would NOT dissolve!

Both AgCl and
AgBr would dissolve!

6 (c) (iii) State why the silver nitrate solution is acidified when testing for iodide ions. [1 mark]

To remove any ions that could interfere with the test.

Certain other
ions could form
ppt's which would
cause errors.

6 (c) (iv) Explain why dilute hydrochloric acid is not used to acidify the silver nitrate solution in this test for iodide ions. [1 mark]

HCl contains Cl^- ions which would form a white precipitate!



6 (d) Chlorine is toxic to humans. This toxicity does not prevent the large-scale use of chlorine in water treatment.

6 (d) (i) Give **one** reason why water is treated with chlorine.

[1 mark]

To kill microorganisms.

6 (d) (ii) Explain why the toxicity of chlorine does **not** prevent this use.

[1 mark]

It is used in very low amounts - also the health benefits outweigh the risks.

6 (d) (iii) Write an equation for the reaction of chlorine with cold water.

You need to know this!

[1 mark]



6 (e) Give the formulas of the **two** different chlorine-containing compounds that are formed when chlorine reacts with cold, dilute, aqueous sodium hydroxide.

[1 mark]

Formula 1 NaClO

Formula 2 NaCl

14


Turn over for the next question

Turn over ►



- 7 Table 2 gives the names and structures of some structural isomers with the molecular formula C_5H_{10}

Table 2

	Name of isomer	Structure
Isomer 1	pent-2-ene	$CH_3CH=CHCH_2CH_3$
Isomer 2	cyclopentane	
Isomer 3	3-methylbut-1-ene	$(CH_3)_2CHCH=CH_2$
Isomer 4	2-methylbut-2-ene	$(CH_3)_2C=CHCH_3$
Isomer 5	2-methylbut-1-ene	$H_2C=C(CH_3)CH_2CH_3$

- 7 (a) Isomer 1 exists as E and Z stereoisomers.

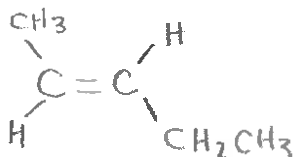
- 7 (a) (i) State the meaning of the term **stereoisomers**.

[2 marks]

Same structural formula but atoms are
arranged differently in space.

- 7 (a) (ii) Draw the structure of the E stereoisomer of Isomer 1.

[1 mark]



- 7 (b) A chemical test can be used to distinguish between separate samples of Isomer 1 and Isomer 2.

Identify a suitable reagent for the test.
State what you would observe with Isomer 1 and with Isomer 2.

[3 marks]

Reagent... Bromine water

Observation with Isomer 1... Bromine decolourises (orange → colourless)

Observation with Isomer 2... No change (stays orange)

- 7 (c) Use Table A on the Data Sheet when answering this question.
Isomer 3 and Isomer 4 have similar structures.

- 7 (c) (i) State the infrared absorption range that shows that Isomer 3 and Isomer 4 contain the same functional group.

[1 mark]

1620 - 1680 → C=C bond.

*C=C is
the functional
group.*

- 7 (c) (ii) State one way that the infrared spectrum of Isomer 3 is different from the infrared spectrum of Isomer 4.

[1 mark]

The fingerprint region would be different → unique
for each compound.

Question 7 continues on the next page

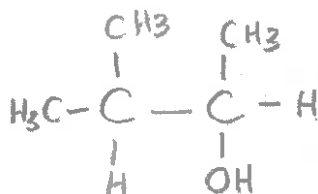
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- 7 (d) Two alcohols are formed by the hydration of Isomer 4.

Draw the **displayed formula** for the alcohol formed that is oxidised readily by acidified potassium dichromate(VI).

[1 mark]

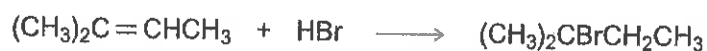


Need to ensure the alcohol formed is a 2° alcohol!
if another isomer it would be a 3° alcohol and could not be oxidised.

- 7 (e) Isomer 4 reacts with hydrogen bromide to give two structurally isomeric bromoalkanes.

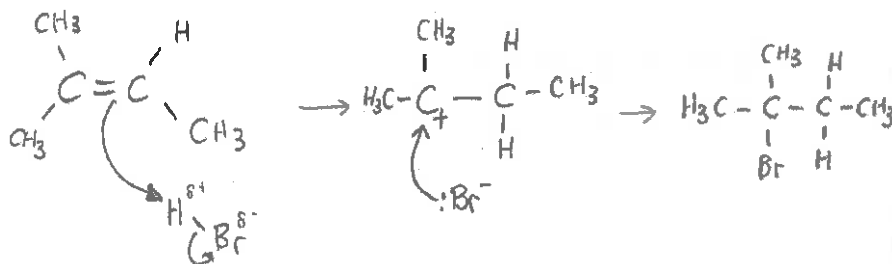
- 7 (e) (i) Name and outline a mechanism for the reaction of Isomer 4 with hydrogen bromide to give 2-bromo-2-methylbutane as the major product.

[5 marks]



Name of mechanism... electrophilic addition

Mechanism



7 (e) (ii) The minor product in this reaction mixture is 2-bromo-3-methylbutane.

Explain why this bromoalkane is formed as a minor product.

[2 marks]

Because the tertiary carbocation is more stable than the secondary carbocation formed if 2-bromo-3-methylbutane is formed!

for more info
read up on
Markovnikov's
rule.

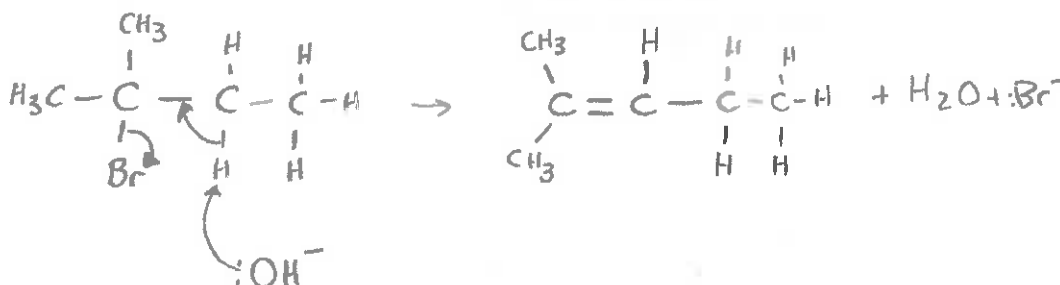
7 (f) Name and outline a mechanism for the following reaction to form Isomer 5.
State the role of the hydroxide ion in this reaction.

[5 marks]



Name of mechanism

Mechanism



Role of hydroxide ion $:\text{OH}^-$ acting as a base.

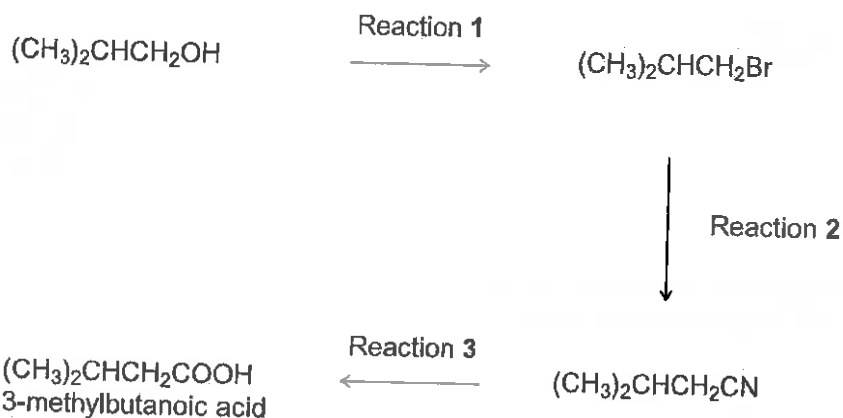
You need to know
when it is a
base and
when it is a
nucleophile



Section B

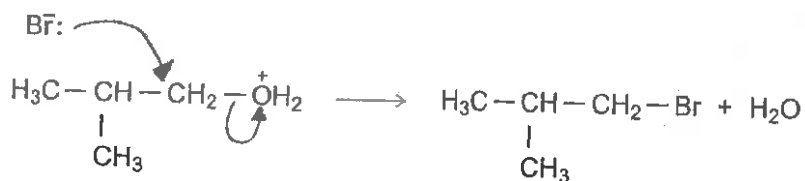
Answer **all** questions in the spaces provided.

- 8 The carboxylic acid 3-methylbutanoic acid is used to make esters for perfumes. The following scheme shows some of the reactions in the manufacture of this carboxylic acid.



- 8 (a) One of the steps in the mechanism for Reaction 1 involves the replacement of the functional group by bromine.
- 8 (a) (i) Use your knowledge of organic reaction mechanisms to complete the mechanism for this step by drawing **two** curly arrows on the following equation.

[2 marks]



8 (a) (ii) Deduce the name of the mechanism in Question 8 (a) (i).

Give the IUPAC name of $(\text{CH}_3)_2\text{CHCH}_2\text{Br}$

[2 marks]

Nucleophilic Substitution

1-bromo methyl propane.

8 (b) Reaction 3 is an acid-catalysed reaction in which water is used to break chemical bonds when the CN functional group is converted into the COOH functional group. Infrared spectroscopy can be used to distinguish between the compounds in this reaction.

Deduce the name of the type of reaction that occurs in Reaction 3.

Identify **one** bond in $(\text{CH}_3)_2\text{CHCH}_2\text{CN}$ and a **different** bond in $(\text{CH}_3)_2\text{CHCH}_2\text{COOH}$ that can be used with infrared spectroscopy to distinguish between each compound. For each of these bonds, give the range of wavenumbers at which the bond absorbs. Use **Table A** on the Data Sheet when answering this question.

[3 marks]

Hydrolysis

← it says in the question that water is used to break bonds!

$\text{C}\equiv\text{N}$ - 2220-2260 absorption.

$\text{O}-\text{H}(\text{acid})$ - 2500 - 3000.

• Could also have chosen $\text{C}=\text{O}$ or $\text{C}-\text{O}$!

Question 8 continues on the next page

Turn over ►



- 8 (c) When 3-methylbutanoic acid reacts with ethanol in the presence of an acid catalyst, an equilibrium is established. The organic product is a pleasant-smelling ester.



The carboxylic acid is very expensive and ethanol is inexpensive. In the manufacture of this ester, the mole ratio of carboxylic acid to ethanol used is 1 to 10 rather than 1 to 1.

- 8 (c) (i) Use Le Chatelier's principle to explain why a 1 to 10 mole ratio is used. In your explanation, you should **not** refer to cost.

[3 marks]

The increased ethanol concentration will cause the equilibrium position to shift to the right, creating a greater yield of ester.

[Extra space]

- 8 (c) (ii) Explain how a catalyst increases the rate of a reaction.

[2 marks]

It provides an alternate pathway that lowers activation energy.

[Extra space]



9 Ethanol is an important fuel.

9 (a) A dilute aqueous solution of ethanol can be produced by the fermentation of an aqueous solution of glucose.
It is claimed that the ethanol obtained from this solution is a carbon-neutral biofuel.

Write an equation for this fermentation reaction.

Give **two** other essential conditions for this reaction to produce a good yield of ethanol.

Name a process used to produce a much more concentrated solution of ethanol from a dilute aqueous solution.

State the meaning of the term **carbon-neutral** in the context of this biofuel.

[5 marks]



Conditions:

• Anaerobic (No oxygen).

• 35°C temperature (25 → 41 accepted)

(Could also have yeast/enzymes).

→ fractional distillation is the process to improve concentration.

Carbon Neutral is when there is no net CO₂ emission to the atmosphere.

[Extra space]

Question 9 continues on the next page

Turn over ►



- 9 (b) A student carried out a laboratory experiment to determine the enthalpy change when a sample of ethanol was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 75.0 g of water increased by 5.50 °C when 2.40×10^{-3} mol of pure ethanol was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1} , for the enthalpy change when one mole of ethanol is burned.

(The specific heat capacity of water is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$)

Deduce **two** reasons why the student's value for the standard enthalpy of combustion of ethanol is different from a Data Book value of $-1279 \text{ kJ mol}^{-1}$.

[5 marks]

$$q = mc \Delta T$$

$$q = 75 \times 4.18 \times 5.50 \quad q = 1724 \text{ J}$$

$$\frac{1724}{2.4 \times 10^{-3}} = \frac{718333}{1000} = -718 \text{ kJ mol}^{-1}$$

Turn it into
kJ

Remember the
answer is
negative because
heat was given
out (exothermic)

Two reasons for the difference is heat loss from calorimeter and incomplete combustion when burning.

[Extra space]



9 (c) Mean bond enthalpies can be used to calculate enthalpies of reaction.

9 (c) (i) Give the meaning of the term **mean bond enthalpy**.

[2 marks]

Enthalpy change needed to break covalent bonds
averaged out over a range of compounds

9 (c) (ii) Consider the mean bond enthalpy data in **Table 3**.

Table 3

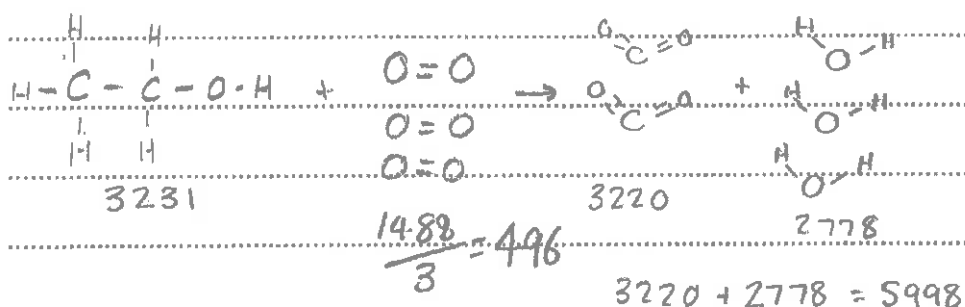
	C-H	C-C	C-O	O=O	C=O	O-H
Mean bond enthalpy/ kJ mol ⁻¹	412	348	360	to be calculated	805	463

Use the data in **Table 3** and the equation shown to calculate a value for the bond enthalpy for the O=O double bond in an oxygen molecule.

[3 marks]



$$\text{Reactants} - \text{products} = \Delta H$$



$$5998 - 3231 = 2767$$

$$2767 - 1279 = 1488$$

$$\text{O}=\text{O} = 496 \text{ kJ mol}^{-1}$$

END OF QUESTIONS



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ANSWER IN THE SPACES PROVIDED**

