



eduresourceza.com



St Mary's School
Waverley
Founded 1888

Physical Sciences Preliminary Examination

Paper II – Chemistry

Monday 19 September 2022

Form V

Marks: 200

Examiners: Mrs C Adelaar and Dr C Huysamer

Time: 3 hours

Examination number: _____

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 36 pages and a green data sheet of 3 pages (i-iii). Please make sure that your question paper is complete.
2. Answer ALL the questions on the question paper and hand it in at the end of the examination. Remember to write your examination number in the space provided above.
3. Use the data and formulae whenever necessary.
4. Show your workings in all calculations.
5. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
6. Answers must be expressed in decimal format, not left as proper fractions.
7. Where appropriate, express answers to TWO decimal places.
8. It is in your own interest to write legibly and to present your work neatly.
9. Please make use of point form in explanation questions and be as concise as possible.
10. Extra answer space (pages 34 and 35) is included at the end of the exam paper. If you run out of space for an answer, use this space. If you use this extra space, make sure that you indicate this clearly at the question to ensure that your answer is marked in full.

QUESTION 1

Answer these questions on the multiple-choice answer grid provided below. There is only one correct answer for each of the multiple-choice questions. Make a clear cross (×) in the box corresponding to the letter that you consider to be correct. Every question has only one correct answer.

A	B	C	D
----------	----------	----------	----------

Here, the option C has been marked as an example.

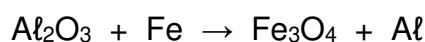
1.1	A	B	C	D
1.2	A	B	C	D
1.3	A	B	C	D
1.4	A	B	C	D
1.5	A	B	C	D
1.6	A	B	C	D
1.7	A	B	C	D
1.8	A	B	C	D
1.9	A	B	C	D
1.10	A	B	C	D

(10 x 2) **[20]**

1.1 What is the correct formula for the substance gold (III) dichromate?

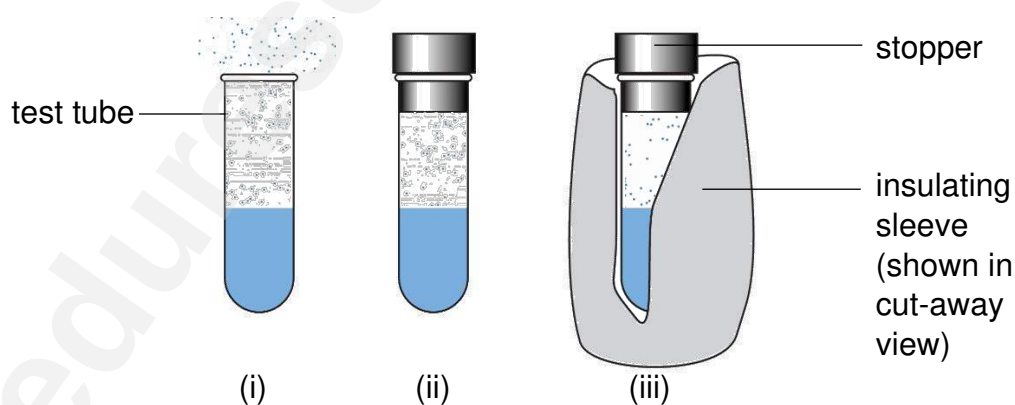
- A $\text{Au}_3(\text{Cr}_2\text{O}_7)_2$
- B $\text{Au}_2(\text{Cr}_2\text{O}_7)_3$
- C $\text{Ag}_2(\text{CrO}_4)_3$
- D $\text{Ag}_3(\text{Cr}_2\text{O}_7)_2$

1.2 Which mole ratio is CORRECT for the substances in the chemical reaction below once balanced?



	First substance in ratio	Second substance in ratio	Mole ratio
A	Fe	Al	3 : 2
B	Fe	Fe_3O_4	1 : 3
C	Al_2O_3	Fe_3O_4	4 : 3
D	Fe_3O_4	Al	3 : 4

1.3 Consider the three images below



Which statement is correct?

- A Only tube (iii) represents a closed system.
- B Tubes (iii) and (ii) both represent closed systems.
- C Only tube (ii) represents a closed system.
- D All three tubes represent closed systems.

- 1.4 Solid sodium carbonate dissolves exothermically in water producing a saturated solution at equilibrium.

Solid K_2CO_3 is now added to the solution.

Which statement is FALSE concerning the addition of solid K_2CO_3 ?

- A It will have no effect on the equilibrium.
- B It will produce a precipitate of sodium carbonate.
- C It will favour the reverse reaction
- D It will favour the endothermic reaction.

- 1.5 Which compound in a 1 mol.dm^{-3} solution is the most acidic?

- A ammonium chloride
- B sodium hydroxide
- C nitric acid
- D sulphuric acid

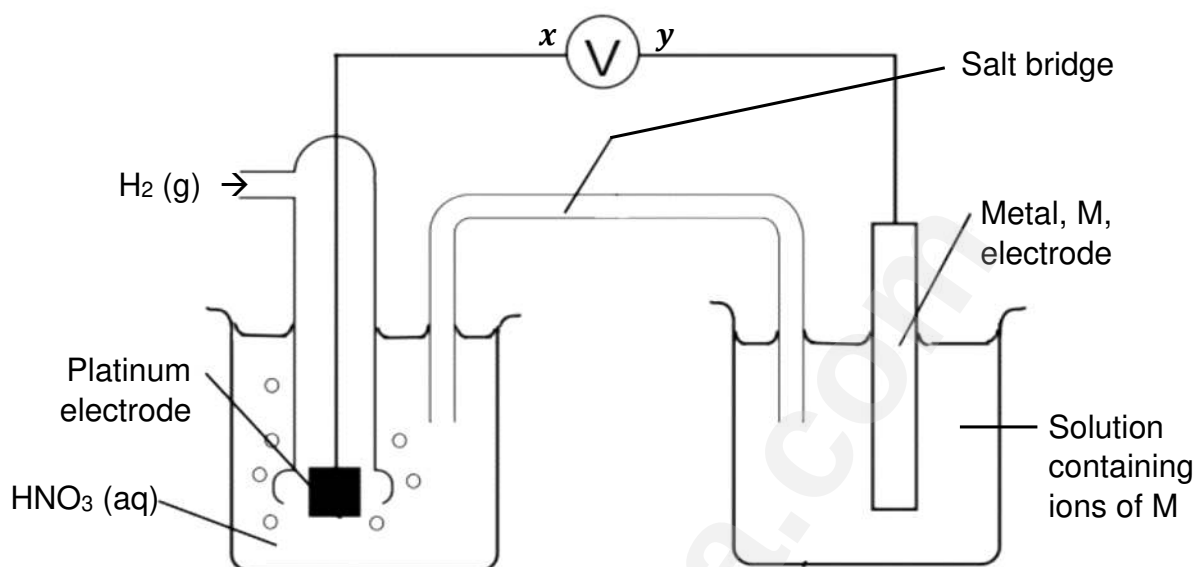
- 1.6 As pure water is heated, its ionisation constant (K_w) changes from 1×10^{-14} to 5×10^{-13} . What conclusion CANNOT be drawn?

- A As water is heated its pH decreases.
- B As water is heated the concentration of hydroxide ions in solution increases.
- C As water is heated the concentration of hydronium ions in solution decreases.
- D The ionisation of water is endothermic.

- 1.7 An acid has a K_a value of k . At equilibrium the concentration of the acid is a . What is the equilibrium concentration of the hydronium ions in solution?

- A $\sqrt{ka}$
- B $ka/2$
- C $\sqrt{k/a}$
- D ka

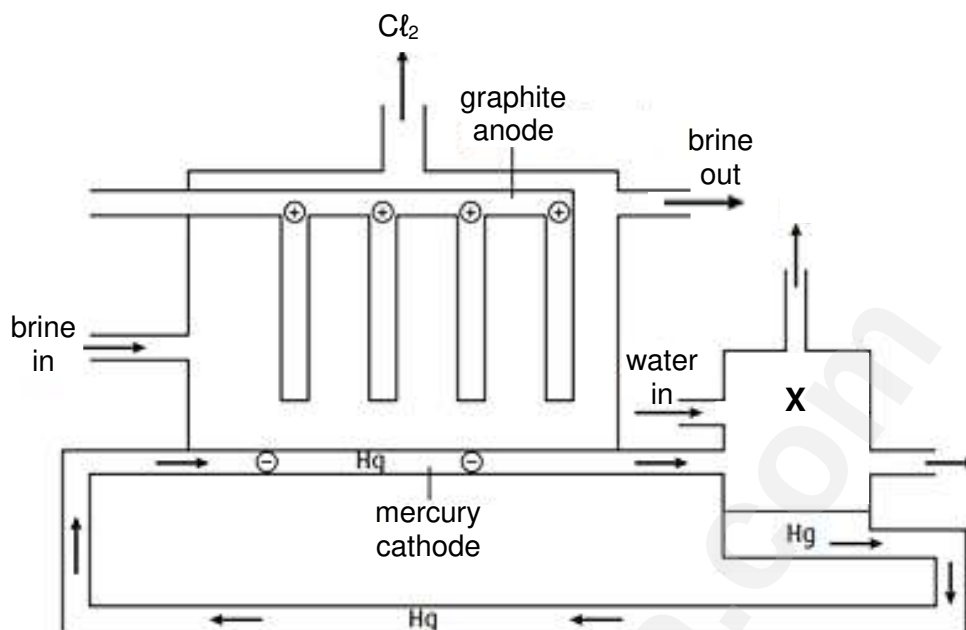
- 1.8 The diagram shows the Standard Hydrogen Electrode connected to an unknown metal M. The reading on the voltmeter is +0,80 V.



Which option correctly identifies the polarity of the voltmeter and the half-reaction taking place at M?

	Polarity at x	Polarity at y	Half reaction at M
A	+	-	$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightarrow \text{NO}_2(\text{g}) + \text{H}_2\text{O}$
B	+	-	$\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$
C	-	+	$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightarrow \text{NO}_2(\text{g}) + \text{H}_2\text{O}$
D	-	+	$\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$

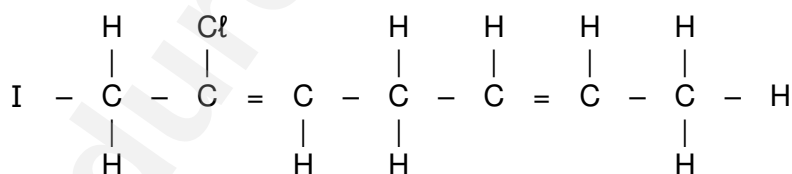
1.9 The cell below is a mercury cathode cell, now seldom used in the chlor-alkali industry.



Which of the reactions below occurs at **X**?

- A $2 \text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$
- B $2 \text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2 \text{OH}^-$
- C $2 \text{NaCl} + 2 \text{H}_2\text{O} \rightarrow 2 \text{NaOH} + \text{H}_2 + \text{Cl}_2$
- D $2 \text{Na} + 2 \text{H}_2\text{O} \rightarrow 2 \text{NaOH} + \text{H}_2$

1.10 What is the IUPAC name for the organic compound shown below?



- A 1-iodo-2-chlorohept-2,5-diene
- B 2-chloro-1-iodohepta-2,5-diene
- C 2-chloro-1-iodohept-2,5-diene
- D 1-iodo-2-chlorohepta-2,5-diene

(10 x 2) [20]

QUESTION 2

2.1 Define *intermolecular forces*.

(2)

2.2 Use only substances from the list below when answering Questions 2.2.1 to 2.2.8. The substances and their phases are given at room temperature.

HF (g)	Fe (s)	F₂ (g)	He (g)
NaF (s)	PH₃ (g)	graphite (s)	CO₂ (g)

In the answer column, write down only the **formula** (except in the case of graphite) of the substance. Substances may be used more than once.

Read each word of the descriptions below carefully!

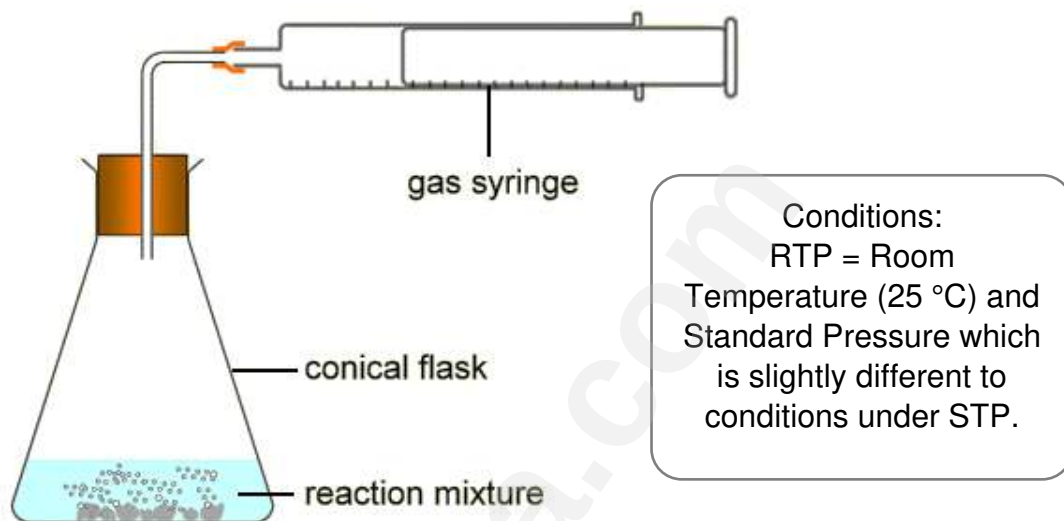
Select **one** substance from the table above that:

	Description	Answer	
2.2.1	is a polar molecule which has polar covalent bonding		(1)
2.2.2	is a compound which has pure covalent bonding		(1)
2.2.3	has hydrogen bonding		(1)
2.2.4	shows bonding between a positive kernel and a sea of delocalised electrons		(1)
2.2.5	forms a giant covalent network structure		(1)
2.2.6	is formed through a transfer of electrons and subsequent electrostatic attraction		(1)
2.2.7	experiences only van der Waals forces between its atoms		(1)
2.2.8	has polar intramolecular bonds and experiences only induced dipole or dispersion forces between its molecules		(1)

[10]

QUESTION 3

The rate of reaction between large calcium carbonate chips and an excess of hydrochloric acid was studied by a student who collected the carbon dioxide generated during the chemical reaction in a graduated syringe under room temperature and pressure (RTP) conditions as shown below.

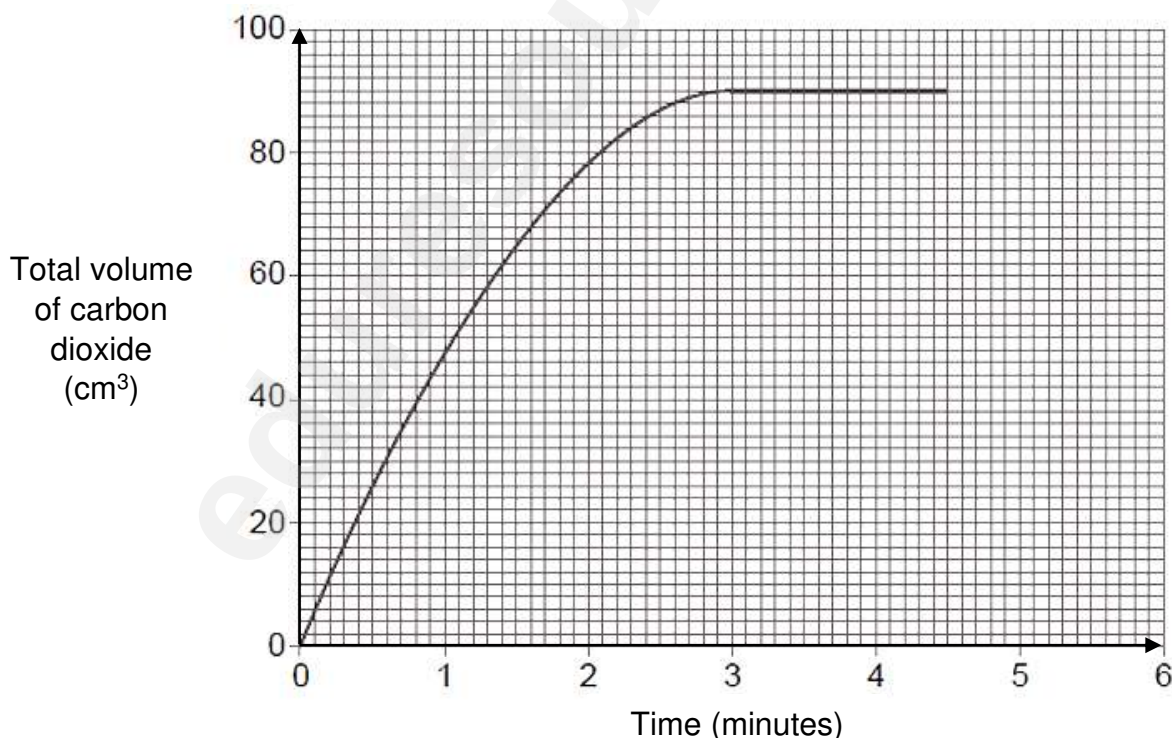


The balanced chemical reaction is shown below:



$$V_m \text{ at RTP} = 24 \text{ dm}^3 \cdot \text{mol}^{-1}$$

The results for **Experiment 1** are shown in the graph below.



Refer to the graph in order to answer the questions below.

3.1 How long did it take for the reaction to reach completion?

_____ (1)

3.2 What volume of carbon dioxide was produced in this reaction?

_____ (1)

3.3 Determine the average rate of the reaction. Give your answer in $\text{cm}^3.\text{s}^{-1}$.

_____ (3)

3.4 Determine the number of moles of hydrochloric acid that reacted in the reaction.

_____ (5)

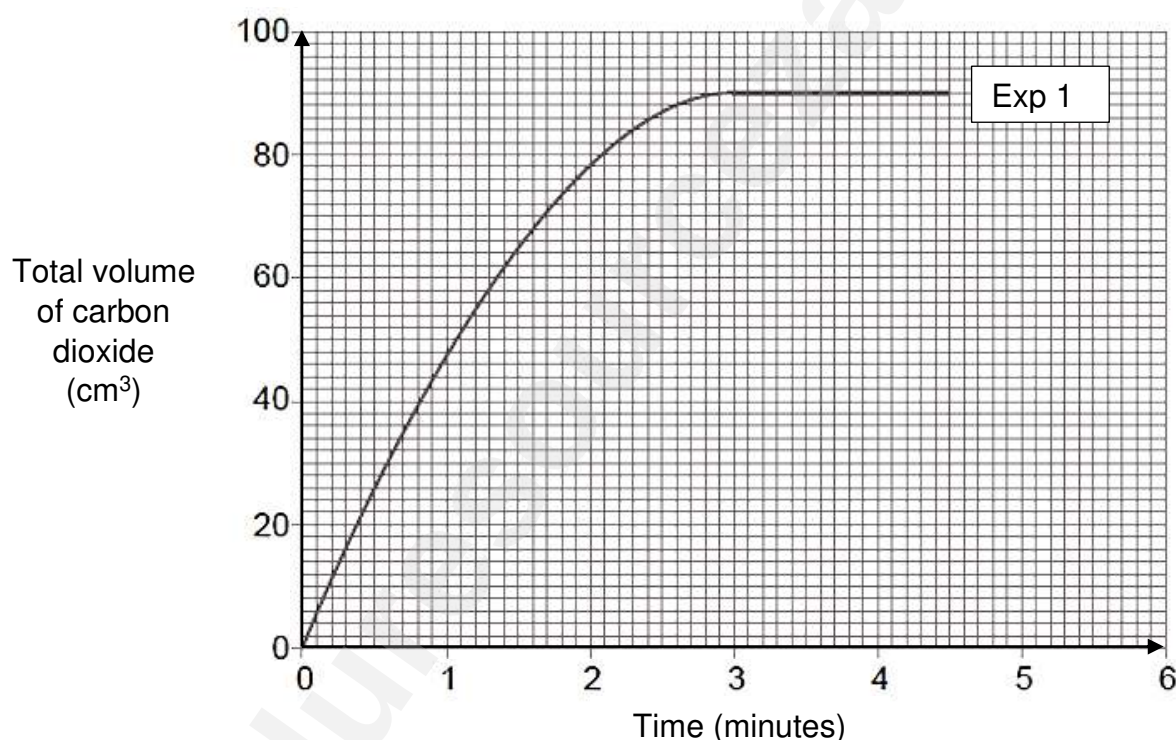
The balanced chemical reaction is repeated below for ease of use



The student repeated the experiment under varying conditions as shown in the table below. Only conditions that were changed have been recorded below.

Experiment	Mass of CaCO_3 (g)	Concentration of HCl (mol.dm^{-3})	Initial temperature of HCl ($^{\circ}\text{C}$)
1 (initial)	x	0,4	25
2	$0,75x$	0,4	25
3	x	0,4	30
4	x	0,2	35

3.5 On the graph below (repeated from the page 8), draw in a line for Experiment 2.



(2)

3.6 The Maxwell-Boltzmann curve on the following page, is provided for Experiment 1.

3.6.1 Define *activation energy*.

(2)

(2)

(2)

eduresource

(5)

The student had access to the following **extra information** from the teacher:

The effect of concentration and temperature changes on rate:

Concentration:

For a theoretical reaction: $aA + bB \rightarrow cC + dD$

Then the rate expression is: $\text{rate} \propto [A]^a.[B]^b$

Temperature:

As you increase the temperature the rate of reaction increases. As a rough approximation, for many reactions happening at around room temperature, the rate of reaction doubles for every 10°C rise in temperature.

Refer to the **extra information** above, the reaction equation, and the data in the table below (repeated here for ease of use) to answer the questions that follow.



Table of results (repeated from page 10)

Experiment	Mass of CaCO_3 (g)	Concentration of HCl (mol.dm^{-3})	Initial temperature of HCl ($^\circ\text{C}$)
1 (initial)	x	0,4	25
2	$0,75x$	0,4	25
3	x	0,4	30
4	x	0,2	35

3.8 Write the rate expression for the reaction above.

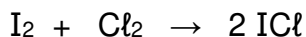
(1)

(4)

[28]

QUESTION 4

4.1 Iodine reacts with chlorine to form iodine monochloride, ICl .



4.1.1 Draw a Lewis diagram to show a molecule of iodine monochloride.

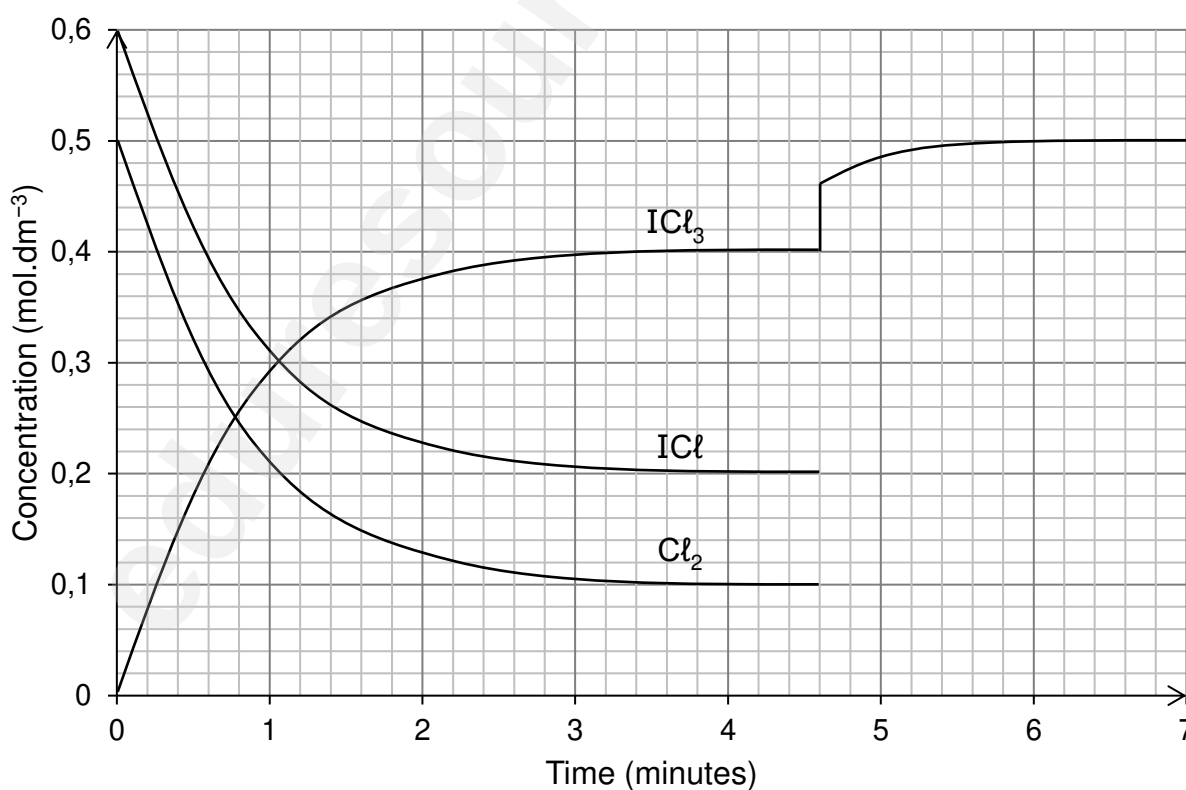
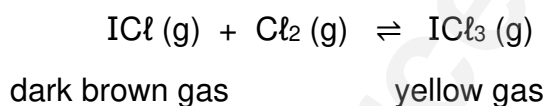


(2)

Iodine monochloride (a dark brown gas) reacts with chlorine to form iodine trichloride (a yellow gas).

This reaction is investigated at a constant temperature in a sealed container.

A dynamic equilibrium mixture is established according to the following equation and the graph below.



4.1.2 Compare the rates of the forward and reverse reactions at $t = 2$ minutes.

(1)

- 4.1.3 How does this graph indicate that dynamic chemical equilibrium has been reached between 3,9 – 4,6 seconds?

(2)

- 4.1.4 Give the equilibrium constant expression and then calculate the value of K_c for this equilibrium at $t = 4,4$ minutes.

(4)

Refer to the graph. At $t = 4,6$ minutes, an adjustment was made to the system while the temperature remained unchanged. Only the change for the iodine trichloride line is shown, but **all three** substances underwent a change.

- 4.1.5 State *Le Châtelier's principle*.

(2)

- 4.1.6 Which reaction rate was increased at $t = 4,6$ minutes?

(1)

- 4.1.7 Describe the colour of the re-established equilibrium mixture at $t = 7$ minutes.

(1)

- 4.1.8 Use all the information provided on the graph to determine the **type** and **nature** (increase or decrease) of the **disturbance** to the equilibrium at $t = 4,6$ minutes.

(2)

Downloaded from eduresourceza.com

$$\text{ICl (g)} + \text{Cl}_2 \text{ (g)} \rightleftharpoons \text{ICl}_3 \text{ (g)}$$
[illegible]
$$\text{CO (g)} + 2 \text{H}_2 \text{(g)} \rightleftharpoons \text{CH}_3\text{OH (g)}$$

A graph showing the rate of a reversible reaction over time. The vertical axis is labeled 'Rate' and the horizontal axis is labeled 'Time'. The horizontal axis has three marked points: t_0 , t_1 , and t_2 . Two curves are plotted: a solid line labeled 'forward' and a dashed line labeled 'reverse'. The 'forward' curve starts at a high rate at t_0 and decreases exponentially towards a horizontal asymptote. The 'reverse' curve starts at zero at t_0 and increases exponentially towards the same horizontal asymptote. The two curves intersect at t_1 . At t_2 , both curves have reached the same constant rate value.

Downloaded from eduresourceza.com

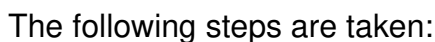
(4)

(2)

(1)

(1)

Once the acid is in solution, the following balanced reaction can take place.



- The titration results are shown in the table below:

5.1.1 Write the formula of the conjugate base of the acid, H_2A , in its ionisation reaction with water.

[illegible]

Before dispensing the solution from the burette during the rough titration, there was an air bubble below the tap as shown in the picture alongside. At the end of the rough titration the air bubble had disappeared.



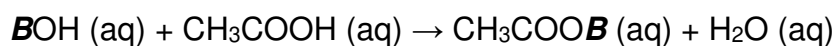
- air bubble

Answer by completing the statement below with THE SAME AS or GREATER THAN or LESS THAN.

The final burette reading will be _____ expected. (1)

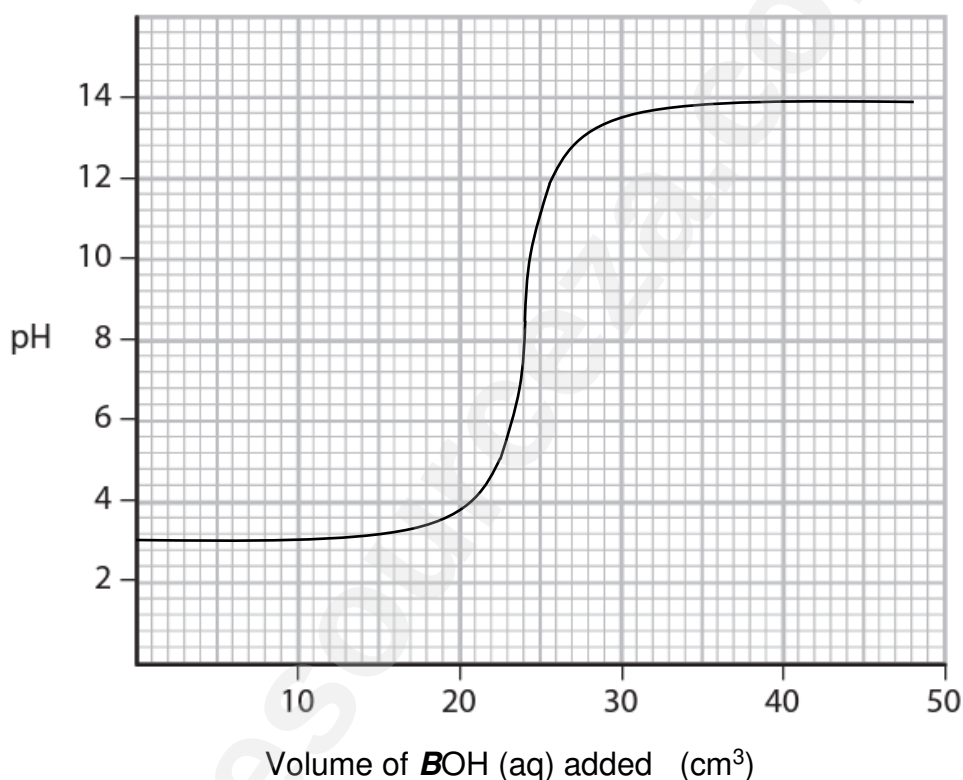
(1)

- 5.2 The following information is provided for answering questions about a titration carried out between solutions of an unknown hydroxide (**BOH**) and ethanoic acid according to the following balanced chemical reaction.



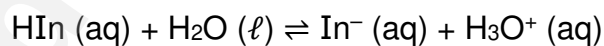
The following steps are taken:

- 15 cm³ of ethanoic acid was placed into a conical flask along with an indicator.
- The **BOH** solution was added to the conical flask as shown in the graph below.



Indicators:

All indicators ionise in water according to the following equilibrium equation:



Indicator	pH range	Colour of indicator molecule	Colour of indicator ion
Methyl orange	3,1 – 4,4	orange	red
Bromothymol blue	6,0 – 7,6	yellow	blue
Cresolphthalein	8,2 – 9,8	colourless	purple
Indigo carmine	11,6 – 13,0	yellow	blue

5.2.1 Is the base, **BOH**, in the titration weak or strong?

_____ (1)

5.2.2 From the graph, determine the volume of **BOH** (aq) that was required to neutralise the ethanoic acid in the titration.

_____ (1)

5.2.3 Which of the solutions, the acid or the base, has the greater initial concentration in this titration? No calculation is required to answer this question.

_____ (1)

5.2.4 Give the name of the most suitable indicator for this titration from the table on the previous page.

_____ (1)

5.2.5 From the previous page, refer to the indicator equilibrium equation, the indicator chosen by you in 5.2.4 above, and the colours of your indicator.

Use Le Châtelier's principle to predict and explain the colour change that will be observed as **BOH** (aq) is added to the conical flask **after the end point** of the titration has been reached.

_____ (4)

5.2.6 Define *hydrolysis* of a salt.

(2)

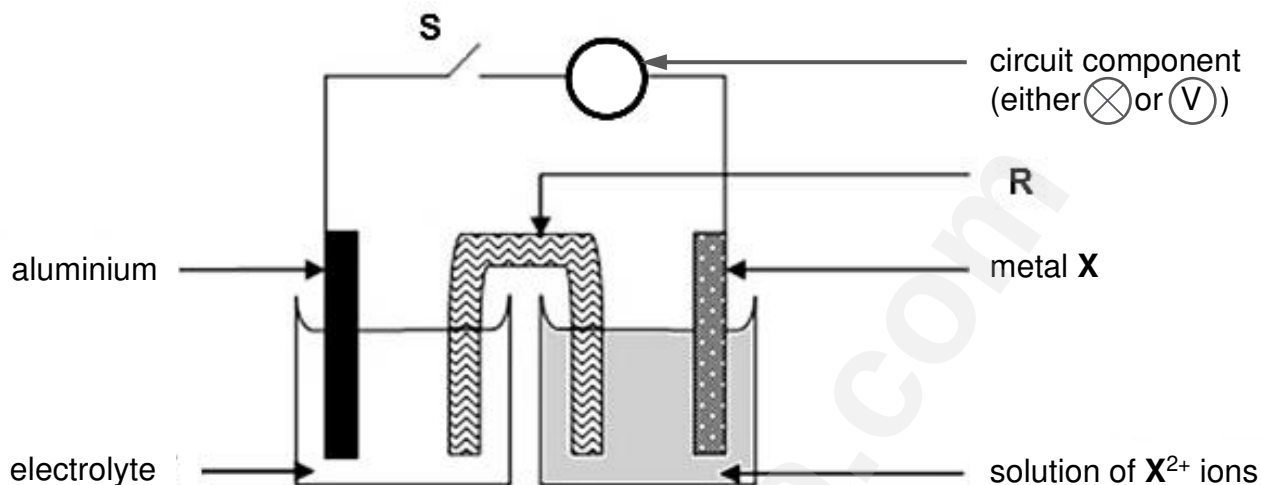
5.2.7 Explain whether the salt of this reaction, CH_3COOB , is acidic or alkaline. You may make use of equations where necessary to support your explanation.

(4)

[29]

QUESTION 6

An electrochemical cell is constructed as shown in the diagram below. It consists of an aluminium electrode placed into a solution containing a suitable electrolyte and an unknown electrode **X** placed into a solution of X^{2+} ions. The solution at electrode **X** is clear but has a deep colour.



6.1 Define *oxidation*.

(1)

6.2 With the switch, **S**, closed and a light bulb connected, the cell is left for a period of time. The aluminium electrode corrodes and, when weighed, has a lower mass.

State whether the aluminium electrode is the anode or the cathode of this cell. Substantiate your answer with reference to the stated observation.

(3)

6.3 State the conditions under which standard electrode potentials can be used to determine the emf of **the cell above**.

(2)

The light bulb is replaced with a voltmeter and the cell operates under standard conditions. The voltmeter shows a reading of 2 V.

6.4 Calculate the standard electrode potential of **X**.

(4)

6.5 Based on your findings in question 6.4, write the cell notation for the electrochemical cell. Standard conditions are not required, but phase labels must be included.

(4)

6.6 Consider the salt bridge labelled, **R**.

6.6.1 Give the chemical formula for a substance which could be an electrolyte for this salt bridge.

(2)

6.6.2 State the **function** of the salt bridge.

(2)

6.7 If the cell has delivered a current for 45 minutes, state what will have happened to the intensity of the coloured solution at electrode **X**. State only INCREASE, DECREASE or REMAINS THE SAME.

(1)

- 6.8 While the cell is set up to deliver its full potential difference, with the voltmeter connected, a few drops of a saturated solution of sodium carbonate are added to the electrolyte in the **X** half-cell. A precipitate forms.

6.8.1 State whether the voltmeter reading will INCREASE, DECREASE or REMAIN THE SAME.

_____ (1)

6.8.2 Explain your answer to 6.8.1 above.

_____ (2)

6.9 The surface area of the electrodes is increased.

6.9.1 Is EMF ALONE or CURRENT ALONE or BOTH or NEITHER, affected by the increased surface area?

_____ (1)

6.9.2 Give a reason for your choice above.

_____ (1)

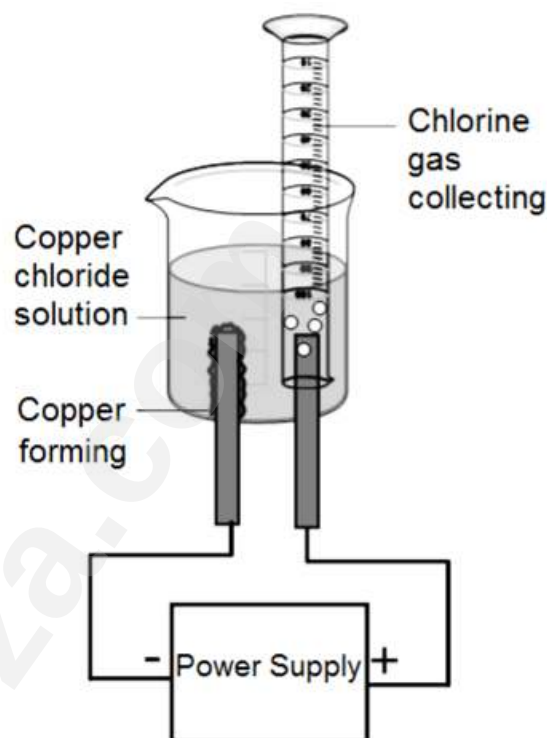
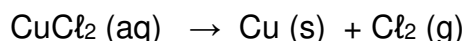
[24]

QUESTION 7

Electrolysis is an important chemical process carried out both at a small scale in laboratories as well as on an industrial scale.

- 7.1 A concentrated copper (II) chloride solution undergoes electrolysis when an electric current is passed through it as shown in the diagram alongside.

The following balanced equation shows the overall predominant reaction that occurs:



- 7.1.1 Describe the energy conversion that occurs in this cell.

(2)

- 7.1.2 At the anode, chloride ions are oxidised to form chlorine gas.

What condition is necessary to ensure the formation of chlorine gas as opposed to the formation of oxygen gas? Explain why this condition is necessary.

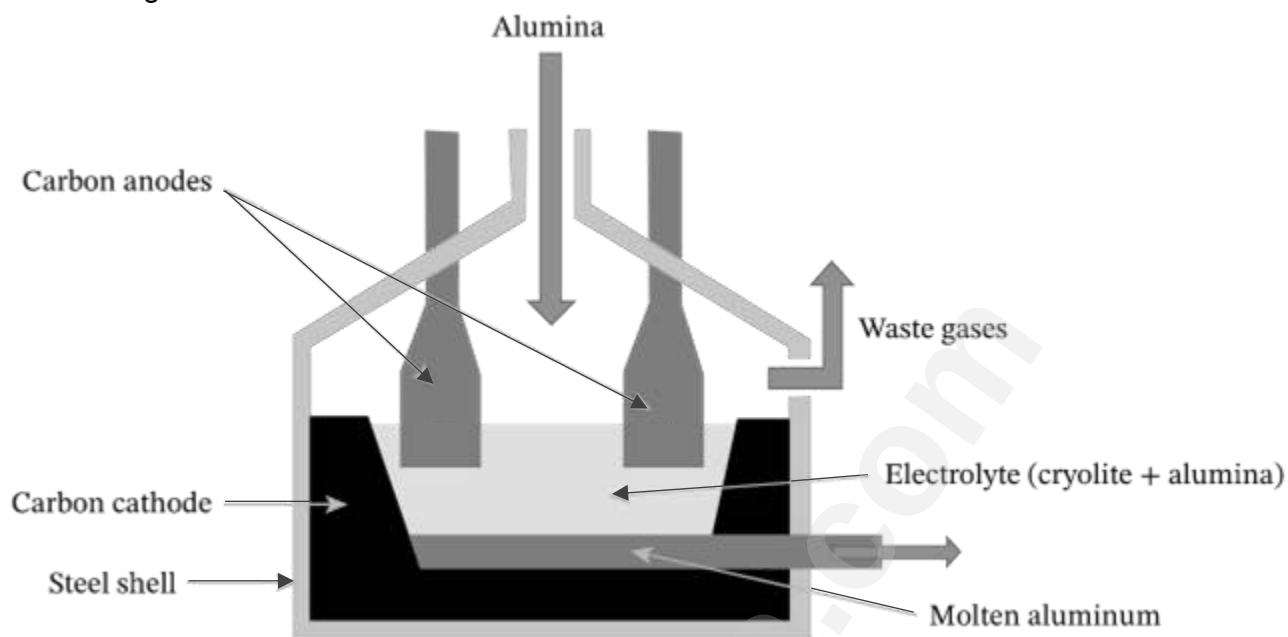
(3)

7.1.3 Over a period of 5 minutes 0.005 mol of copper metal is formed in the cell.

- (a) Write down the half-reaction occurring at the cathode of this cell.

- (b) Determine the current supplied to this cell in order to produce 0,005 mol of copper metal.

- 7.2 An industrial application of electrolysis is the recovery of aluminium from bauxite as shown in the diagram below.



- 7.2.1 The housing of the cell, lined with graphite, is the cathode. Is the sign of the electrical potential supplied to the cathode **positive** or **negative**?

_____ (1)

- 7.2.2 What is the product of the half-reaction at the anodes?

_____ (1)

- 7.2.3 There are waste gases formed and released in this process.

Explain briefly how the waste gas is formed and state the consequence of the formation of this gas for the anodes of the cell.

_____ (2)

- 7.2.4 Explain how the use of cryolite reduces the cost of running this cell.

_____ (2)

[18]

QUESTION 8

8.1 Refer to the following two molecules and the information provided about them:

Name:	heptan-1-ol	methanol
Condensed structural formula:	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ OH	CH ₃ OH
Boiling point (°C):	195	64,7
Solubility in water	Only slightly miscible	Completely miscible

8.1.1 Name the homologous series to which both these molecules belong.

(1)

8.1.2 **Name** the functional group which is characteristic of the homologous series.

(1)

8.1.3 Define *structural isomers*.

(2)

8.1.4 Name one type of structural isomerism that **heptan-1-ol** can exhibit and give the IUPAC name of an isomer which matches your choice of isomer type.

Type of structural isomerism: _____

IUPAC name of isomer: _____

(2)

8.1.5 Name the **predominant** intermolecular force present in each substance:

Heptan-1-ol: _____

Methanol: _____

(2)

8.1.6 Draw **two** molecules of methanol using Couper notation and then use a dashed line to show the position of the **predominant** intermolecular force between them.

(2)

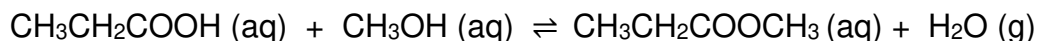
8.1.7 Explain why neptan-1-ol has a higher boiling point than methanol.

(4)

8.1.8 Account for the very poor solubility of heptan-1-ol compared to methanol.

(3)

- 8.2 The ester, $\text{CH}_3\text{CH}_2\text{COOCH}_3$ can be formed from the reaction between propanoic acid and methanol with an acid catalyst according to the reaction below:



8.2.1 Name the ester formed above.

_____ (2)

8.2.2 Identify which bonds are broken and which bonds are made during the esterification process, in each of the substances indicated in the table below. Water has been done for you. Use couple notation to indicate the relevant bond only. Do not include neighbouring atoms.

Bonds broken:	Propanoic acid:	Methanol:
Bonds made:	Ester:	Water: H–O

(3)

8.2.3 Draw a functional isomer of the ester $\text{CH}_3\text{CH}_2\text{COOCH}_3$.

(2)

[24]

QUESTION 9

9.1 Hydrocarbons are involved in many organic chemical reactions, some of which are known as tests for saturation/unsaturation.

9.1.1 Define a *saturated compound*.

 _____ (2)

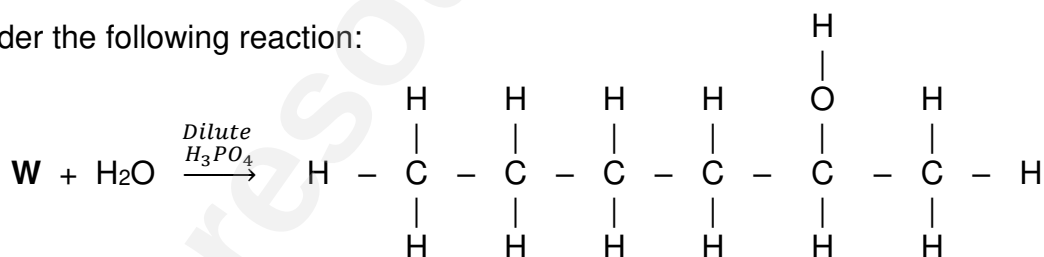
9.1.2 Name the **general type** of reaction where a hydrocarbon reacts spontaneously to discolour a solution of bromine at room temperature.

_____ (1)

9.1.3 What does this chemical reaction (question 9.1.2 above) tell us about the nature of the specific reactant hydrocarbon involved?

 _____ (1)

9.2 Consider the following reaction:



9.2.1 Based on the second reactant, H₂O, and the condition for the reaction shown above, name the **specific type** of reaction that takes place.

_____ (1)

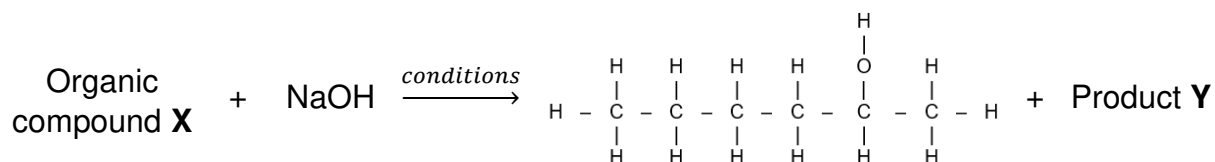
9.2.2 What other condition, not specifically shown above must be met for this reaction to take place?

 _____ (1)

9.2.3 Give the IUPAC name for compound **W**.

_____ (2)

- 9.3 The same product of the reaction shown on the previous page in question 9.2 can also be produced through a hydrolysis reaction with compound **X** as shown below.



9.3.1 Name the **general type** of reaction shown above.

_____ (1)

9.3.2 State the conditions required for this reaction to take place.

_____ (2)

9.3.3 Answer the following questions about substances **X** and **Y**.

(a) Give a possible condensed structural formula for organic reactant **X**.

(2)

(b) What type of bond is found in product **Y**?

_____ (1)

- 9.4 In a combustion reaction, 1 volume of alkane **Z** reacts exactly with 5 volumes of oxygen as it forms carbon dioxide and water vapour only.

9.4.1 Give the molecular formula of alkane **Z**.

_____ (2)

9.4.2 State the energy transfer that happens which makes the combustion of fossil fuels an important reaction.

_____ (2)

[18]

TOTAL: 200 MARKS

Downloaded from eduresourceza.com

**REMEMBER TO CLEARLY INDICATE AT THE QUESTION THAT YOU USED THE
ADDITIONAL SPACE TO ENSURE THAT ALL ANSWERS ARE MARKED.**

[illegible]

eduresourceza.com

MARKING GRID FOR EXAMINER'S USE ONLY

Examination number: _____

Chemistry Preliminary examination 2022

Question	Topic	Possible Marks	Marks obtained	Percentage
1	MCQ	20		
2	Bonding	10		
3	Rates of reactions	28		
4	Equilibrium	28		
5	Acids and bases	29		
6	Electrochemistry	24		
7	Electrolysis	18		
8	Organic	24		
9	Organic reactions	18		
Total		200		

Sources: Acknowledgements and Thanks:

Question 1: Images and questions from:

<https://people.chem.umass.edu/botch/Chem122S08/Chapters/Ch6/ThermoDef.html><https://www.thestudentroom.co.uk/showthread.php?t=5922384><https://level8chem.wordpress.com/the-chlor-alkali-industry/>Question 3: Image from: <https://www.markedbyteachers.com/gcse/science/chemistry-rate-of-reaction-coursework-for-calcium-carbonate-and-hydrochloric-acid.html> ; Graph from: CIE O Level Chemistry: Chemical reactions Accessed from:https://cdn.savemyexams.co.uk/uploads/5/0/8/7/50878855/61-rate_of_reaction_qp_o_level_-_cie_-_chemistry_.pdf<https://www.chemguide.co.uk/physical/basicrates/temperature.html>Question 4: Data from: <https://www.coursehero.com/tutors-problems/Chemistry/28105618-/> and CIE O Level Chemistry 5070/21Paper 2 Theory May/June 2017 Accessed from: https://cdn.savemyexams.co.uk/uploads/2018/07/5070_s17_qp_21.pdfQuestion 5: Adapted from: AQA AS Chemistry 7404/1 Paper 1 June 2019 Accessed from: <https://filestore.aqa.org.uk/sample-papers-and-mark-schemes/2019/june/AQA-74041-QP-JUN19.PDF>Image from: <http://www2.csudh.edu/oliver/demos/buretuse/buretuse.htm>

Questions 6&7: Adapted from: Thomas More College Trial 2019 and St Andrew's College & DSG Prelim 2020 and

<https://www.nagwa.com/en/explainers/213180242428/>

Question 8: Aspects from Edexcel A level Chemistry: Organic chemistry: Alcohols – open response questions Accessed from:

https://cdn.savemyexams.co.uk/uploads/5/0/8/7/50878855/15.2_-_alcohols_-_open-response_qp.pdf