Please paste the barcoded label here	TOTAL MARKS

NATIONAL SENIOR CERTIFICATE EXAMINATION
MAY 2023

PHYSICAL SCIENCES: PAPER II

EXAMINATION NUMBER													

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 28 pages as well as a DATA SHEET of 3 pages (i–iii). Please make sure that your question paper is complete.
2. Read the questions carefully.
3. **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 blocks above.**
4. Unless instructed otherwise, you do NOT have to give state symbols (phase indicators) when asked to write a balanced chemical equation.
5. Use the data and formulae whenever necessary.
6. Show all the necessary steps in calculations.
7. Where appropriate, take your answers to two decimal places.
8. It is in your own interest to write legibly and to present your work neatly.
9. THREE blank pages (pages 26 to 28) are included at the end of the paper. If you run out of space for an answer, use these pages. Clearly indicate the number of your answer should you use this extra space.

FOR OFFICE USE ONLY: MARKER TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Total
Mark										
Marker Initial										
Moderated Mark										
Moderator Initial										
Question Total	**20**	**22**	**25**	**21**	**32**	**22**	**18**	**27**	**13**	**200**
Re-mark										
Initial										
Code										

QUESTION 1 MULTIPLE CHOICE QUESTIONS

Answer these questions on the multiple-choice answer grid below. Make a clear cross (X) in the box corresponding to the option that you consider to be correct. Every question has only one correct answer.

A	B	C	D

Here the option C has been marked.

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**

1.1 What is the correct formula of magnesium nitride?

A Mg_2N_3
B Mg_3N_2
C $MgNO_2$
D $Mg(NO_2)_2$

1.2 A solution of aluminium sulfate is labelled '1,0 mol·dm^{-3} A$\ell_2(SO_4)_3$'. Which one of the following statements is true?

In 2 dm^3 of solution, there are…

A 6 moles of sulfate ions.
B 1 mole of aluminium ions.
C 2 moles of aluminium ions.
D 1,5 moles of sulfate ions.

1.3 Ethene can be oxidised to form epoxyethane, C_2H_4O.

$$2C_2H_4(g) + O_2(g) \rightleftharpoons 2C_2H_4O(g) \quad \Delta H = -107\ kJ{\cdot}mol^{-1}$$

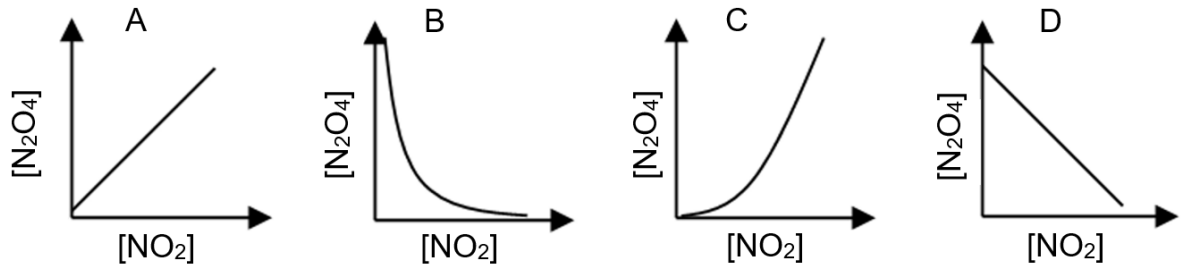
Which set of conditions will give the greatest yield of epoxyethane at equilibrium?

	Pressure	**Temperature (°C)**
A	Low	100
B	High	200
C	High	100
D	Low	200

1.4 $NO_2(g)$ and $N_2O_4(g)$ are in equilibrium in a closed system:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

Which graph represents the mathematical relationship between the concentrations of the gases once a new equilibrium has been established at a constant temperature? Make use of the K_c expression for the reaction.



1.5 The pH values of equal concentrations of the following solutions are compared.

- NaCℓ
- CH_3COONa
- $NH_4Cℓ$

Identify the combination with the highest pH and the lowest pH.

	Highest pH	**Lowest pH**
A	CH_3COONa	NaCℓ
B	NaCℓ	CH_3COONa
C	CH_3COONa	$NH_4Cℓ$
D	$NH_4Cℓ$	CH_3COONa

1.6 Water and ammonia react. One of the products is an ammonium ion. Which statement about this reaction is correct?

A The reaction can be classified as dissociation.
B The resulting solution will be a strong electrolyte.
C The reaction is a redox reaction.
D The water is acting as an acid.

1.7 Which statement regarding the electrorefining of copper is correct?

A Any gold impurity atoms will be oxidised and collect in the sludge below the anode.
B Any nickel impurity atoms will be oxidised to Ni^{2+} ions, which remain in solution.
C The total mass lost at the anode is equal to the total mass gained at the cathode.
D The Cu^{2+} ions are the strongest reducing agents in solution and are preferentially reduced at the cathode.

1.8 Which statement about the chemistry of fluorine, chlorine, bromine and iodine is correct?

A Br^- will reduce $C\ell_2$ but not I_2.
B $C\ell_2$ will oxidise Br^- but not I^-.
C F_2 is the weakest oxidising agent.
D I^- is the weakest reducing agent out of F^-, $C\ell^-$, Br^- and I^-.

1.9 Which is the correct formula of 2,3-dichloro-2-methylpentane?

A $CH_3CH(CH_3)CC\ell_2CH_2CH_3$
B $CH_3CC\ell(CH_3)CHC\ell CH_2CH_3$
C $CH_3CC\ell_2CH(CH_3)CH_2CH_3$
D $CH_3CH_2CH_2CHC\ell CHC\ell CH_3$

1.10 Which two compounds react with each other to form $CH_3CH_2CH_2COOCH_2CH_2CH_3$?

A propanoic acid and propan-2-ol
B propanoic acid and butan-1-ol
C butanoic acid and propan-2-ol
D butanoic acid and propan-1-ol

[20]

QUESTION 2

Aluminium and oxygen react to form aluminium oxide, which has a high melting point.

2.1 Write a balanced equation to represent the reaction that takes place. State symbols are not required. (3)

2.2 Explain, in terms of its bonding and structure, why aluminium oxide …

2.2.1 has a high melting point. (4)

2.2.2 does not conduct electricity when solid. (1)

2.3 Aluminium conducts electricity both when solid and when molten. Describe the bonding and structure of solid aluminium and explain why it conducts electricity. (4)

2.4 The intramolecular bonds found in oxygen molecules are **non-polar covalent bonds**.

2.4.1 Circle the correct word between brackets in the statement below: (1)

This type of bond is found between the oxygen (ATOMS / MOLECULES).

2.4.2 Explain why the bond is called a **covalent** bond. (2)

2.4.3 Explain why the bond is **non-polar**. (2)

2.5 Oxygen molecules are non-polar. Oxygen gas liquefies at −183 °C.

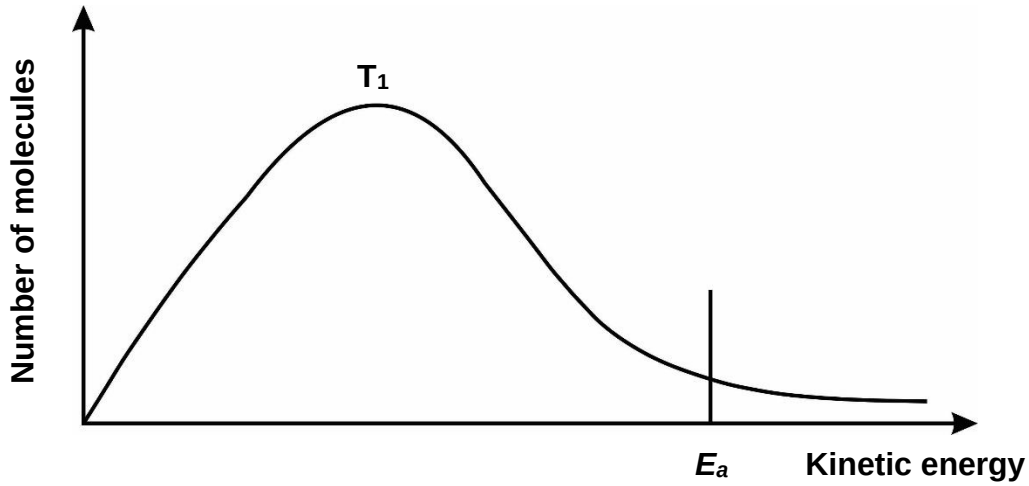
2.5.1 Name the specific type of intermolecular forces in liquid oxygen. (1)

2.5.2 Explain, in terms of the origin of the intermolecular forces, how oxygen gas liquefies. (4)

[22]

QUESTION 3

3.1 The graph below shows the Maxwell–Boltzmann distribution curve for a reaction mixture of two gases at a given temperature, **T_1**. The activation energy for the reaction, E_a, is marked.



3.1.1 On the graph above:

(a) Draw a new distribution curve for the same mixture of gases at a **lower** temperature. Label this curve as **T_2**. (2)

(b) Indicate the position of the activation energy of the reaction at the lower temperature **T_2**. Label this position as **H**. (1)

3.1.2 Define *activation energy*. (2)

3.1.3 Define *catalyst*. (2)

3.1.4 On the graph, indicate the position of the activation energy of the reaction when a catalyst is used. Label this position as **C**.

(1)

3.1.5 Explain how the use of a catalyst results in reactions occurring at a faster rate. Refer to the Maxwell–Boltzmann curve and the collision theory. (4)

3.2 Calcium carbonate reacts with hydrochloric acid as follows:

$$CaCO_3(s) + 2HC\ell(aq) \rightarrow CaC\ell_2(aq) + CO_2(g) + H_2O(\ell)$$

0,04 mol of powdered calcium carbonate is added to 0,10 dm^3 of 0,10 $mol \cdot dm^{-3}$ hydrochloric acid at 25 °C. The total volume of carbon dioxide produced, measured from the start of the experiment, is recorded every 30 seconds. The results are tabulated below:

Time (s)	0	30	60	90	120	150	180	210	240
Volume of CO_2 (cm^3)	0	40	70	88	101	110	116	120	120

3.2.1 How does the rate of the reaction change with time? Choose from INCREASES or DECREASES. Explain the answer by referring to data in the table. (3)

3.2.2 Explain why the rate of reaction changes as identified in Question 3.2.1. (2)

3.2.3 As can be seen in the table, the total volume of CO_2 gas produced is 120 cm^3.

(a) Determine by calculation which is the limiting reagent. (3)

(b) Calculate the molar gas volume, V_m, in **$dm^3 \cdot mol^{-1}$**, at 25°C. Assume 100% yield. (4)

3.2.4 The experiment was repeated using a single lump of $CaCO_3$ of the same mass. How would this affect the reaction rate?

Choose from: INCREASE, DECREASE or NO EFFECT. (1)

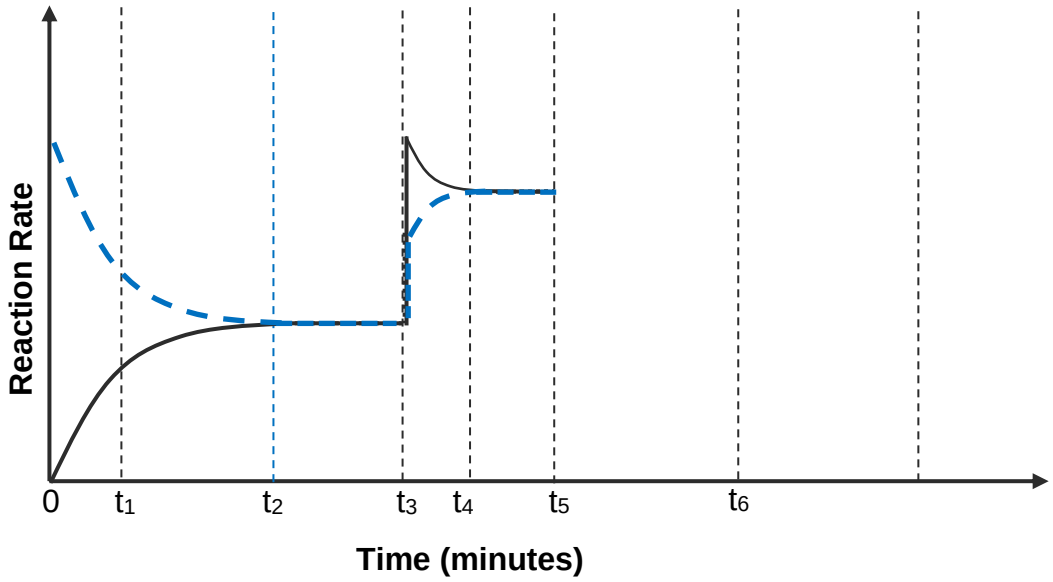
[25]

QUESTION 4

Gas AB decomposes according to the following equation:

$$2AB(g) \rightleftharpoons 2A(g) + B_2(g)$$

A certain amount of AB is sealed in a container and allowed to decompose. The graph of the reaction rate vs time is shown below.



4.1 Is the statement below TRUE or FALSE? (2)

'At $\mathbf{t_1}$ the graph indicates that the concentration of AB is greater than the concentrations of A and B_2.'

4.2 What is represented by the blue dashed line (- - - - -) on the graph? (2)

4.3 Circle the correct word(s) between brackets in the statement below: (1)

Between $\mathbf{t_2}$ and $\mathbf{t_3}$, the concentrations of AB, A and B_2 are:

(EQUAL TO EACH OTHER / CONSTANT / CHANGING).

4.4 The **temperature** of the system was **increased** at time t_3.

Is the forward reaction EXOTHERMIC or ENDOTHERMIC?

Explain by applying Le Châtelier's principle. (3)

4.5 At t_5, the volume of the container was increased at constant temperature, resulting in a **decrease** in the **pressure**.

4.5.1 Explain the effect of this change by applying Le Châtelier's principle. (3)

4.5.2 Complete the rate vs time graph on page 10 from t_5 until after equilibrium is re-established at t_6.

(3)

4.6 Gas AB was pumped into an evacuated container until the concentration was **X** mol·dm^{-3}. The container was sealed. Once equilibrium was established at 25 °C, the concentration of gas B_2 was 0,025 mol·dm^{-3}.

The reaction equation is re-written below:

$$2AB(g) \rightleftharpoons 2A(g) + B_2(g)$$

4.6.1 Write the equilibrium constant expression, K_c, for the reaction. (2)

The value of K_c for the reaction at 25 °C is 1,56 × 10^{-3}.

4.6.2 Show that the equilibrium concentration of gas AB is 0,2 mol·dm^{-3}. (2)

4.6.3 Hence, calculate **X**, the initial concentration of gas AB in the container. (3)

[21]

QUESTION 5

5.1 Consider the equation for the ionisation of the HSO_3^- ion:

$$HSO_3^-(aq) + H_2O \rightleftharpoons SO_3^{2-}(aq) + H_3O^+(aq) \qquad K_a = 6{,}5 \times 10^{-8}$$

5.1.1 Define *ionisation*. (2)

5.1.2 Define *an amphoteric substance*. (2)

5.1.3 Give the formulae of TWO amphoteric substances shown in the above equation. (2)

5.1.4 Define a *base* in terms of the Brønsted–Lowry model. (2)

5.1.5 Give the formulae of TWO substances that act as bases in the above equation. (2)

5.1.6 **Explain** what the size of the K_a value for this reaction indicates about HSO_3^-. (2)

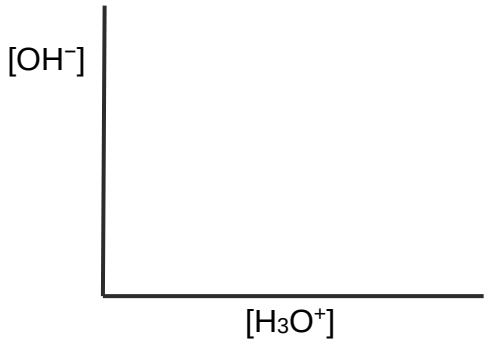
5.1.7 Give the NAME of the conjugate acid of HSO_3^-. (1)

5.1.8 $BaSO_3$ is an insoluble salt. A few crystals of $Ba(NO_3)_2(s)$ are added to the equilibrium mixture. Explain, by applying Le Châtelier's principle, how the pH of the solution will be affected. (5)

$$HSO_3^-(aq) + H_2O \rightleftharpoons SO_3^{2-}(aq) + H_3O^+(aq)$$

5.1.9 Draw the sketch graph below to show the relationship between the hydroxide and hydronium ion concentration in aqueous solutions.

(2)



5.2 5 g of **impure** magnesium carbonate, $MgCO_3$, is added to 50 cm^3 of sulfuric acid of concentration 1,0 $mol \cdot dm^{-3}$.

The balanced equation for the reaction that takes place is:

$$MgCO_3(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + CO_2(g) + H_2O(\ell) \quad \ldots\ldots(i)$$

The reaction is allowed to proceed until all the pure magnesium carbonate reacts.

The excess sulfuric acid is neutralised by adding 28 cm^3 of sodium hydroxide solution of concentration 0,5 $mol \cdot dm^{-3}$.

The balanced equation for the neutralisation reaction is:

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell) \quad \ldots\ldots(ii)$$

Calculate the following, taking answers to three decimal places where appropriate:

5.2.1 The initial (total) number of moles of sulfuric acid to which the impure magnesium carbonate was added. (3)

5.2.2 The number of moles of sulfuric acid in excess. (3)

5.2.3 The number of moles of sulfuric acid that reacted with the pure magnesium carbonate in Reaction (i). (2)

5.2.4 The % purity of the magnesium carbonate. (4)

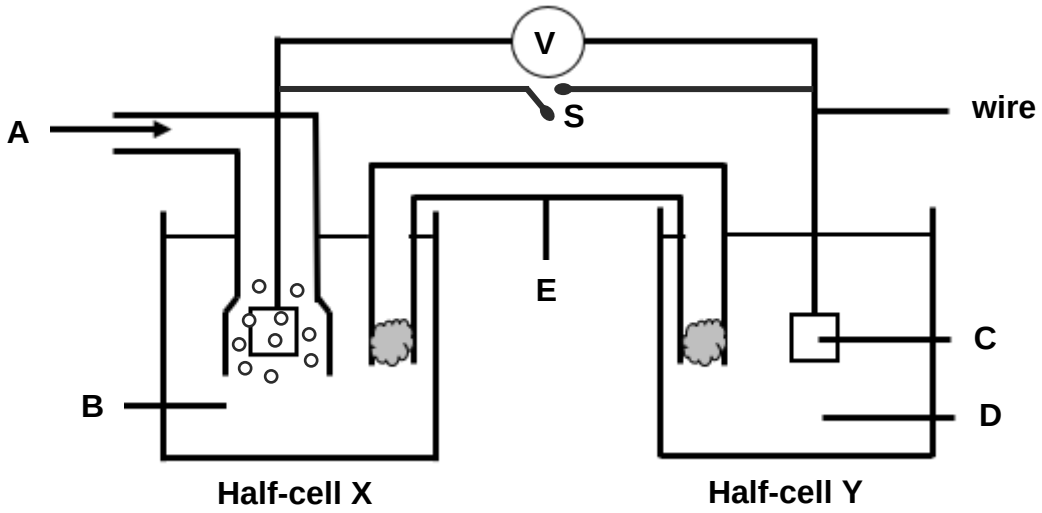
[32]

QUESTION 6

Chlorine gas and iron(II) ions react in aqueous solution as follows:

$$C\ell_2 + 2Fe^{2+} \rightarrow 2C\ell^- + 2Fe^{3+}$$

The diagram below shows a galvanic cell used to determine the cell potential (E^{θ}_{cell}) for the above reaction under standard conditions.



6.1 Give the **chemical formulae** of the substances represented by the letters: (4)

A _____

B _____

C _____

D _____

6.2 Consider the part labelled **E**.

6.2.1 What does **E** represent? (1)

_____

6.2.2 Give the **chemical formula** of a suitable compound that could be dissolved in water to make the solution to fill **E**. (1)

_____

6.2.3 Give two reasons why your choice of compound in Question 6.2.2 is suitable for this purpose. (2)

_____

_____

6.3 Calculate the initial cell potential (E^{θ}_{cell}) for this cell under standard conditions. (4)

6.4 Identify the reducing agent in this cell. (1)

6.5 Circle the correct options between brackets in the statement below. (2)

When switch **S** is closed, electrons will flow from half-cell (**X** to **Y** OR **Y** to **X**) through (THE WIRE OR **E**).

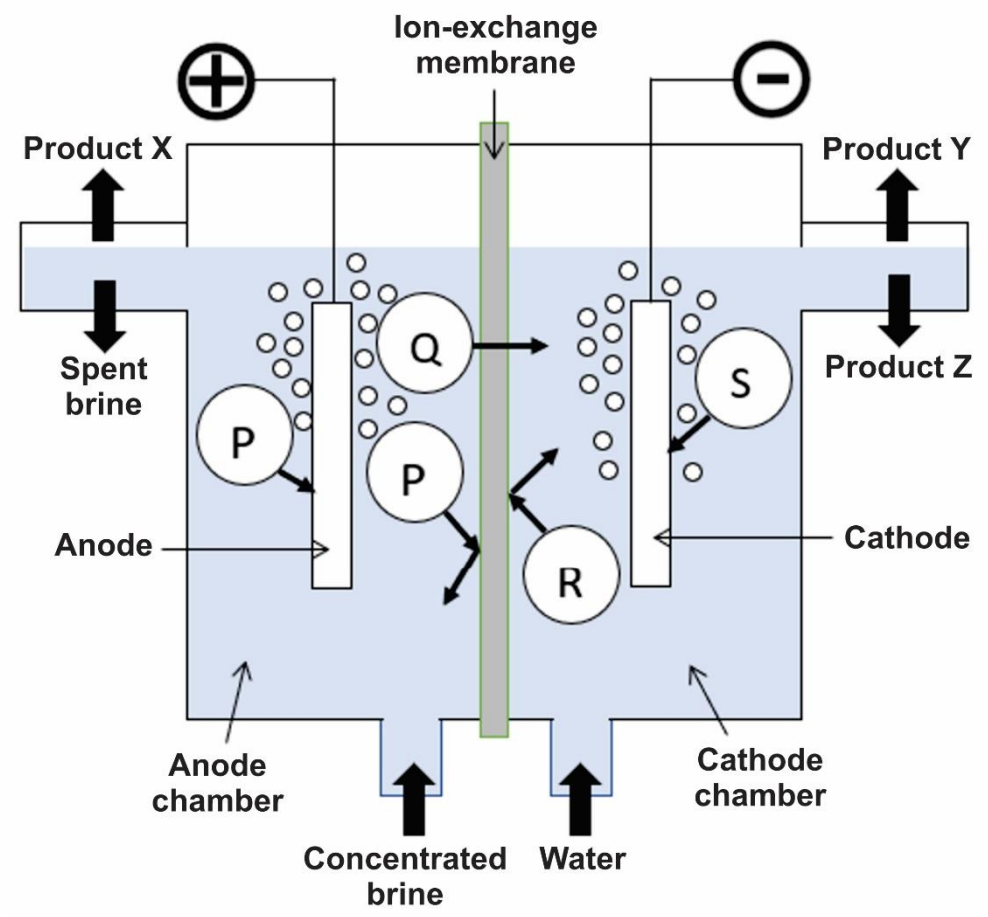
6.6 The standard solution of the Fe^{3+} electrolyte is prepared using $Fe_2(SO_4)_3$. Explain what concentration of $Fe_2(SO_4)_3$ solution should be prepared. (3)

6.7 Iron(III) hydroxide is far less soluble than iron(II) hydroxide. Make use of this fact and Le Châtelier's principle to explain how the emf of the cell will be affected if some NaOH is added to the $Fe^{2+} \mid Fe^{3+}$ half-cell. (4)

[22]

QUESTION 7

The diagram below represents the membrane cell used in the chlor-alkali industry.



7.1 What is brine, the raw material of this process? (2)

7.2 Describe the energy conversion taking place in this cell. (2)

7.3 Identify the products of the process, labelled **X**, **Y** and **Z**. (3)

X

Y

Z

7.4 Identify substances **P** and **S** that react at the electrodes. (2)

P

S

7.5 Identify substance **Q** that can pass through the membrane. (1)

7.6 Explain why hydroxide ions should be prevented from entering the anode compartment. Write down a half-reaction from Table 4 to support your answer. (4)

7.7 Name the two other types of cells used for the chlor-alkali process and state one disadvantage of each of these. (4)

[18]

QUESTION 8

Consider the data tabulated below and answer the questions that follow.

Table A		
Compound	**Melting point (°C)**	**Boiling point (°C)**
methane	–182	–164
ethane	–183	–89
propane	–188	–42
butane	–138	–0,5
pentane	–130	36
hexane	–95	
heptane	–91	98
octane	–57	125
eicosane	37	343

Table B		
Compound	**Melting point (°C)**	**Boiling point (°C)**
methanoic acid	8,4	101
ethanoic acid	16,6	118
propanoic acid	–21	141
butanoic acid	–8	164
pentanoic acid	–34,5	186
hexanoic acid	–4,0	205
heptanoic acid	–7,5	223
octanoic acid	16,7	239

8.1 All the compounds in Table **A** belong to the same homologous series.

8.1.1 Define *homologous series*. (2)

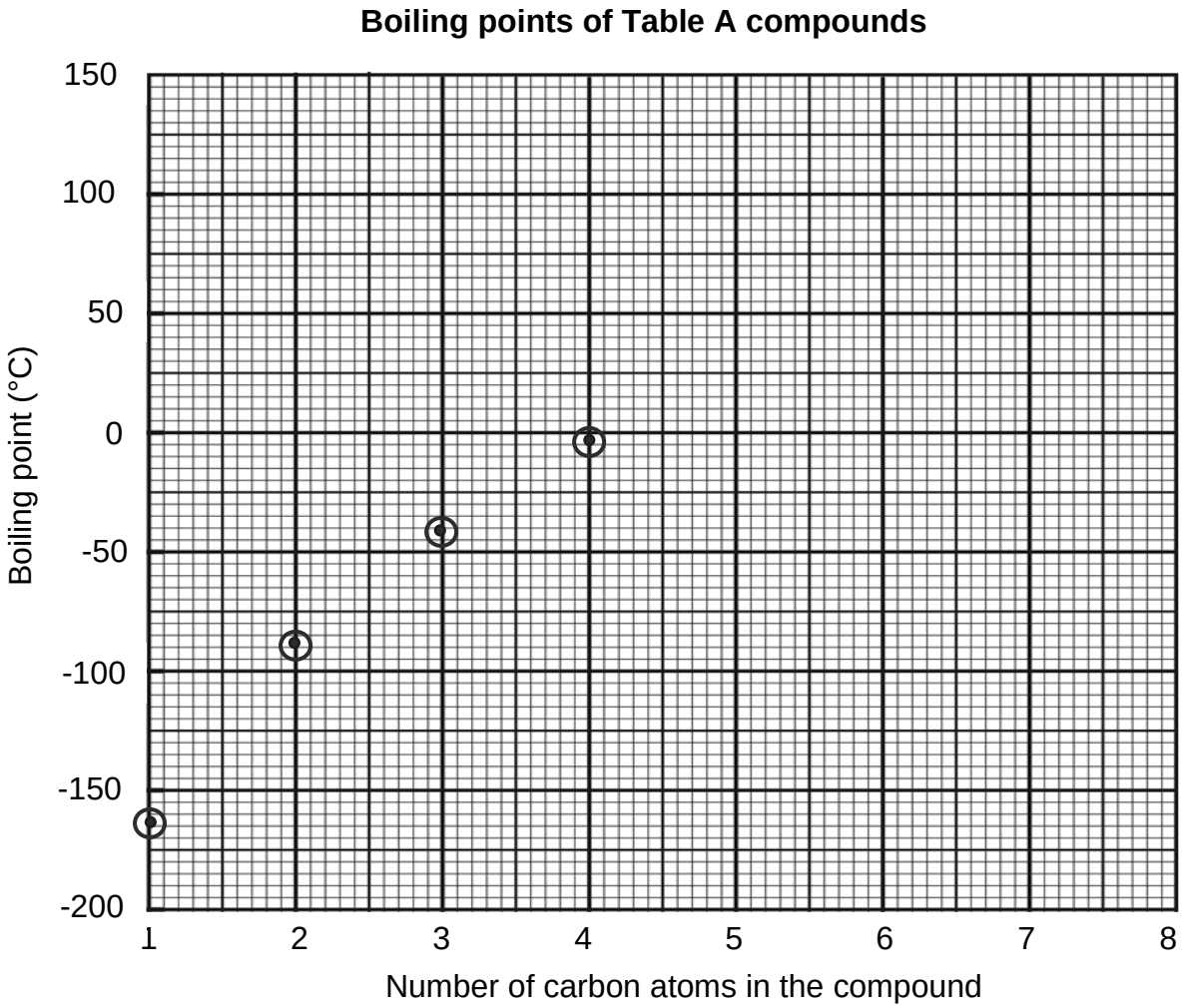
8.1.2 Name the homologous series of the compounds in Table **A**. (1)

8.1.3 State whether the compounds in Table **A** are SATURATED or UNSATURATED. (1)

8.1.4 Eicosane has a chain length of 20 carbon atoms. Write down the molecular formula of eicosane. (1)

8.2 **Name** the functional group of the compounds in Table **B**. (1)

A graph of the **boiling points** of the compounds in Table **A** (excluding eicosane) has been partially drawn below.



8.3 Plot the **boiling points** of pentane, heptane and octane. Draw a **CURVE** of best fit through the points.

(3)

8.4 Read off the **boiling point** of hexane and write down the missing value in Table **A**.

(1)

8.5 Write down all the hydrocarbons listed that will be liquid at room temperature (25 °C).

(2)

8.6 Butane and ethanoic acid have similar molar masses.

8.6.1 Write down the condensed structural formula of ethanoic acid. (1)

8.6.2 When comparing the boiling points of two compounds with different intermolecular forces, why is it important that the compounds have similar molar masses? (2)

8.6.3 Explain why ethanoic acid has a much higher boiling point than butane. (4)

8.7 Consider the compound pentanoic acid.

8.7.1 Draw the structural formula of a **chain** isomer of this compound. (3)

8.7.2 Draw the structural formula of a straight-chain **functional** isomer of this compound. (3)

8.7.3 Give the IUPAC name of the compound drawn in Question 8.7.2. (2)

[27]

QUESTION 9

Jamie and Mufunwa compared the rates of the substitution reactions of different haloalkanes with OH^-. They heated the reactants under reflux in a dilute aqueous alkali solution. They tabulated their data as follows:

Table 1: Rates of substitution reactions of haloalkanes

Reaction	Reactants	Trial	Time taken to react
A	1-chlorobutane and OH^-	1	578 s
		2	590 s
		3	582 s
B	1-bromobutane and OH^-	1	125 s
		2	116 s
		3	134 s
C	1-iodobutane and OH^-	1	20 s
		2	19 s
		3	20 s

9.1 Suggest TWO improvements that can be made to the format in which the gathered data has been presented in the table. (2)

9.2 Why did Jamie and Mufunwa carry out each reaction three times? (2)

9.3 Give the SPECIFIC name for this type of substitution reaction. (1)

9.4 Give the IUPAC name of the organic product of Reaction **B**. (2)

9.5 Analyse the data to predict which bond out of C—Cℓ, C—Br and C—I is the strongest. Justify your answer. (2)

9.6 Kwen reacted 1-chlorobutane with a hot concentrated solution of KOH in an ethanol solvent. A different type of reaction occurred under these conditions.

9.6.1 Give the SPECIFIC name of the type of reaction that occurred. (1)

9.6.2 Write a balanced equation for Kwen's reaction, using condensed structural formulae. (3)

[13]

Total: 200 marks

ADDITIONAL SPACE (ALL QUESTIONS)

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

