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# SUBJECT: SUBJECT NAME

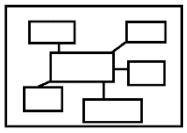
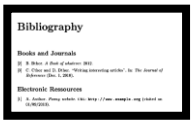
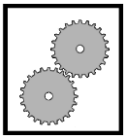
# GRADE 12

# LAST PUSH 2026

# TEACHER AND LEARNER QUESTIONS MANUAL

## PAPER 2: CHEMISTRY

## ICON DESCRIPTION

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|---|---|---|---|
|  MIND MAP |  EXAMINATION GUIDELINE |  CONTENTS |  ACTIVITIES |
|  BIBLIOGRAPHY |  TERMINOLOGY |  WORKED EXAMPLES |  STEPS |

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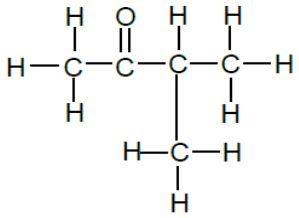
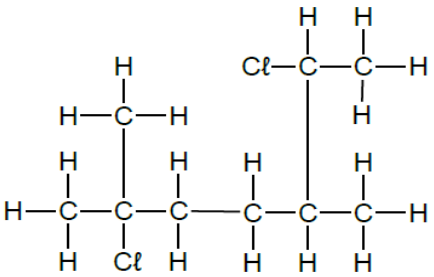
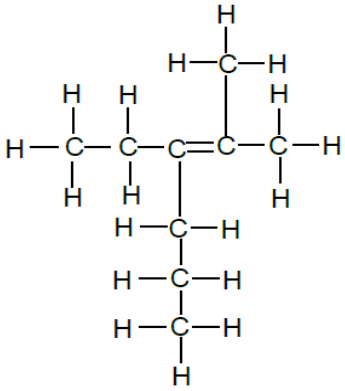



## TOPIC 1: ORGANIC MOLECULES

### A. STRUCTURE AND NOMENCLATURE

### QUESTION 1

The letters **A** to **G** in the table below represent organic compounds.

| | | | |
|---|---|---|---|
| **A** |  | **B** |  |
| **C** | $CH_3CH(CH_3)CH_2CHO$ | **D** | $C_4H_{10}O$ |
| **E** | $C_3H_8$ | **F** | Pentane |
| **G** |  | | |

1.1 Write down the LETTER(S) that represent(s) EACH of the following:

1.1.1 An alcohol. (1)

1.1.2 TWO compounds that are functional isomers of one another. (1)

1.1.3 TWO compounds that belong to the same homologous series. (1)

1.2 Write down the:

1.2.1 IUPAC name of compound **A**. (3)

1.2.2 IUPAC name of compound **B**. (3)

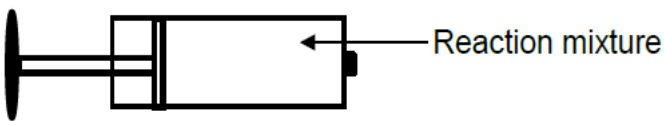
1.2.3 IUPAC name of compound **G**. (3)

1.2.4 STRUCTURAL FORMULAE of two STRAIGHT CHAIN positional isomers of compound **D**. (4)

1.3 Compound **E**, $C_3H_8(g)$, reacts with oxygen, $O_2(g)$, according to the balanced equation:

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

Initially 8 $cm^3$ of compound **E** and 50 $cm^3$ of oxygen were injected into a container of adjustable volume and allowed to react.



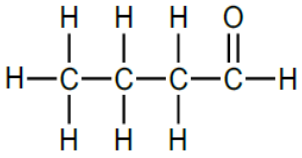
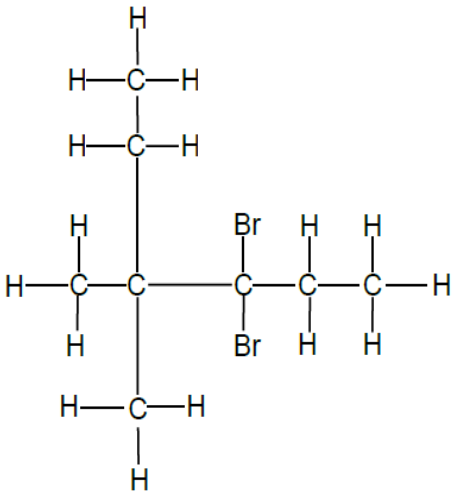

1.3.1 Write down the name for this type of reaction. (1)

1.3.2 Calculate the TOTAL volume of the GASES present in the container at the end of the reaction. (5)

**[22]**

**QUESTION 2**

The letters **A** to **H** in the table below represent organic compounds.

| | | | |
|---|---|---|---|
| **A** |  | **B** |  |
| **C** | Butanone | **D** | $C_4H_{10}O$ |
| **E** | $CH_3C(CH_3)_2CCCH_3$ | **F** | $CH_3COO(CH_2)_2CH_3$ |
| **G** | $C_4H_8O_2$ | **H** | $CH_3C(CH_3)_2CH_2CH_3$ |

2.1 Write down the LETTER that represents EACH of the following:

2.1.1 An alcohol. (1)

2.1.2 A compound with a formyl group. (1)

2.1.3 An unsaturated compound. (1)

2.2 Write down the IUPAC name of compound:

2.2.1 B. (3)

2.2.2 E. (3)

2.3 Two different compounds in the above table are functional isomers.

2.3.1 Define the term functional isomer. (2)

2.3.2 Write down the LETTERS that represent these functional isomers. (1)

2.4 Compound **F** is formed when a carboxylic acid reacts with another organic compound, **X**, in the presence of a catalyst.

Write down the:

2.4.1 NAME or FORMULA of the catalyst. (1)

2.4.2 Type of reaction. (1)

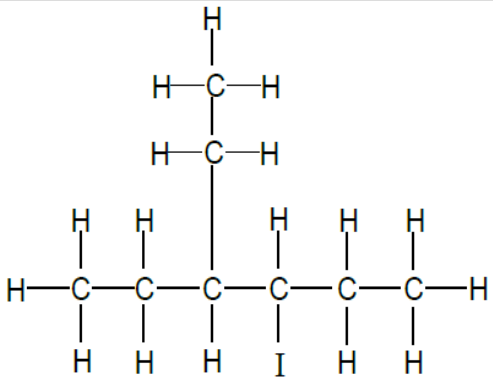
2.4.3 STRUCTURAL FORMULA of compound **F**. (2)

2.4.4 IUPAC name of compound **X**. (2)

**[18]**

**QUESTION 3**

The letters **A** to **F** in the table below represent organic compounds.

| | | | |
|---|---|---|---|
| **A** | $C_5H_{10}O$ | **B** |  |
| **C** | Butanoic acid | **D** | $(CH_3)_3COH$ |
| **E** | $CH_2C(CH_3)_2$ | **F** | $HCOOCH_2CH_2CH_3$ |

3.1 Define the term unsaturated compound. (2)

3.2 Write down the LETTER that represents EACH of the following:

3.2.1 An unsaturated compound. (1)

3.2.2 A functional isomer of compound **C**. (1)

3.3 Name the TWO homologous series to which **A** belongs. (2)

3.4 Is compound **D** a PRIMARY, SECONDARY or TERTIARY alcohol? Give a reason for the answer. (2)

3.5 Write down the IUPAC name of:

3.5.1 Compound **B**. (3)

3.5.2 The POSITIONAL isomer of compound **D**. (2)

3.6 Ethanol reacts with compound **C** to form an organic compound **Z**. Write down the:

3.6.1 Type of reaction. (1)

3.6.2 STRUCTURAL FORMULA of compound **Z**. (2)

3.7 Write down the:

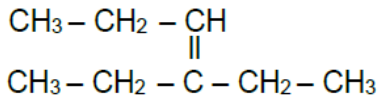
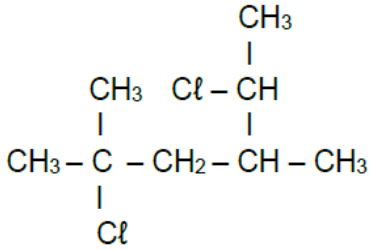
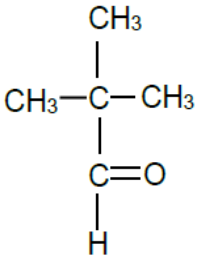
3.7.1 Empirical formula of compound **F**. (1)

3.7.2 STRUCTURAL FORMULA of the CHAIN ISOMER of compound **E**. (2)

**[19]**

**QUESTION 4**

The letters **A** to **H** in the table below represent eight organic compounds.

| | | | |
|---|---|---|---|
| **A** | Butan-2-ol | **B** | $CH_3C(CH_3)_2(CH_2)_2CH_3$ |
| **C** | 3-ethylpent-1-yne | **D** | $CH_3CH_2CH_2CH_2CHO$ |
| **E** |  | **F** | Butan-1-ol |
| **G** |  | **H** |  |

4.1 Define the term hydrocarbon. (2)

4.2 Write down the letter(s) for:

4.2.1 TWO compounds that are UNSATURATED hydrocarbons. (1)

4.2.2 TWO compounds that are CHAIN ISOMERS of each other. (2)

4.2.3 A secondary alcohol. (1)

4.3 Write down the:

4.3.1 STRUCTURAL formula of the FUNCTIONAL ISOMER of compound **D**. (2)

4.3.2 General formula of the homologous series to which compound **B** belongs. (1)

4.3.3 STRUCTURAL formula of compound **C**. (2)

4.4 Write down the IUPAC name of compound:

4.4.1 **E**. (3)

4.4.2 **G**. (3)

4.4.3 **H**. (2)

4.5 Compound **B** undergoes complete combustion. Using MOLECULAR FORMULAE, write down the balanced equation for this reaction. (3)

**[22]**

## B. PHYSICAL PROPERTIES

### QUESTION 1

1.1 The boiling points of straight chain aldehydes and straight chain carboxylic acids are compared. The table below shows the results obtained.

| | INVESTIGATION 1 | INVESTIGATION 2 |
|---|---|---|
| Number of carbon atoms in the compound | Boiling point of aldehydes (°C) | Boiling point of carboxylic acids (°C) |
| 1 | -19 | 101 |
| 2 | 20 | 118 |
| 3 | 49 | 141 |
| 4 | 75 | 164 |

1.1.1 Define the term homologous series. (2)

1.1.2 Write down the:

(a) NAME of the FUNCTIONAL GROUP of the aldehydes. (1)

(b) IUPAC NAME of the compound with the highest vapour pressure in this comparison. (2)

1.1.3 For INVESTIGATION 2:

(a) Write down the controlled variable. (1)

(b) Describe the trend in the boiling points. (1)

(c) Fully explain the answer to QUESTION 1.1.3(b). (2)

1.1.4 Write down the boiling point of butanal. (1)

1.2 The vapour pressures of compounds **A** and **B** are compared.

| | |
|---|---|
| **A** | $CH_3CH_2CH_2CH_2CH_2OH$ |
| **B** | $CH_3CH_2CH_2COOH$ |

How does the vapour pressure of compound A compare to that of compound **B**? Choose from HIGHER THAN, LOWER THAN or EQUAL TO.

Fully explain the answer. (4)

**[14]**

### QUESTION 2

The vapour pressures of different organic compounds are determined at 20 °C. The vapour pressures of compounds **A**, **B** and **C** are NOT shown in the table.

| COMPOUND | IUPAC NAME | MOLAR MASS ($g \cdot mol^{-1}$) | VAPOUR PRESSURE (kPa) AT 20 °C |
|---|---|---|---|
| **A** | Pentane | 72 | |
| **B** | 2-methylbutane | 72 | |
| **C** | 2,2-dimethylpropane | 72 | |
| **D** | Propanoic acid | 74 | 0,32 |
| **E** | Butanal | 72 | 12,2 |

2.1 Define the term vapour pressure. (2)

2.2 The vapour pressures of compounds **A**, **B** and **C** are given in random order below.

| | | |
|---|---|---|
| 79 kPa | 146 kPa | 58 kPa |

2.2.1 Write down the vapour pressure of compound **C**. (1)
2.2.2 Fully explain your answer to QUESTION 2.2.1. (3)
2.3 Compounds **D** and **E** are compared.
2.3.1 Which compound has the lower boiling point? (1)
2.3.2 Fully explain the difference in the vapour pressures between compounds **D** and **E**. (4)
**[11]**

**QUESTION 3**
The boiling points of some organic compounds are shown in the table below. The atmospheric pressure is 101,3 kPa.

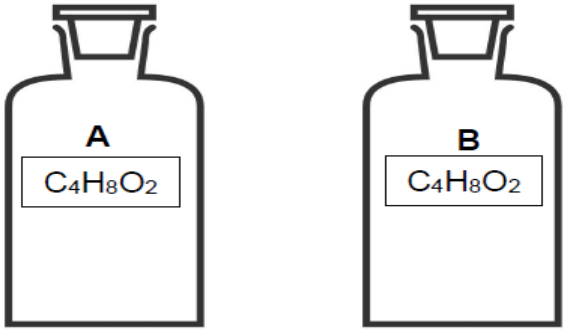
| | ORGANIC COMPOUND | BOILING POINT (°C) |
|---|---|---|
| **A** | $CH_3CH_2CH_2CH_2C\ell$ | 78 |
| **B** | $CH_3CH(CH_3)CH_2C\ell$ | 46 |
| **C** | $CH_3CH_2CH_2CH_2OH$ | 118 |
| **D** | $CH_3CH_2CH_2CHO$ | **X** |

3.1 Define the term boiling point. (2)
3.2 Which ONE of compounds **A**, **B** or **C** is mainly in the liquid phase at 100 °C? (1)
3.3 Explain the difference in the boiling points of compounds **A** and **B**. (3)
3.4 Consider the boiling points below.

| | | |
|---|---|---|
| 75 °C | 120 °C | 126 °C |

3.4.1 Which ONE of these values represents **X**, the boiling point of compound **D**? (1)
3.4.2 Fully explain the answer to QUESTION 3.4.1. (2)
3.5 The atmospheric pressure is now changed to 83 kPa.
How will the boiling points of these organic compounds be affected?
Choose from INCREASE, DECREASE or REMAIN THE SAME. (1)
**[10]**

**QUESTION 4**
Two bottles contain compounds **A** and **B** with the same molecular formula, $C_4H_8O_2$. These compounds are straight chain organic molecules that belong to two different homologous series.



The boiling points are used to distinguish between the two compounds.

4.1 Define the term homologous series. (1)

4.2 Identify the TWO homologous series to which these compounds belong. (2)

The following are the vapour pressures of these compounds at a given temperature:

| | | | |
|---|---|---|---|
| Compound **A** | 0,071 kPa | Compound **B** | 9,7 kPa |

4.3 Write down the:

4.3.1 STRUCTURAL FORMULA of compound **A**. (2)

4.3.2 IUPAC name for a possible compound **B**. (2)

4.4 Write down the strongest type of Van der Waal's forces between the molecules in:

4.4.1 Compound **A**. (1)

4.4.2 Compound **B**. (1)

4.5 Which compound, **A** or **B**, has a higher boiling point? Give a reason for the answer by referring to the strength of the intermolecular forces. (2)

4.6 The boiling point of compound **A** is measured again on another day when the atmospheric pressure is much lower.

How will the boiling point of this compound now be affected?

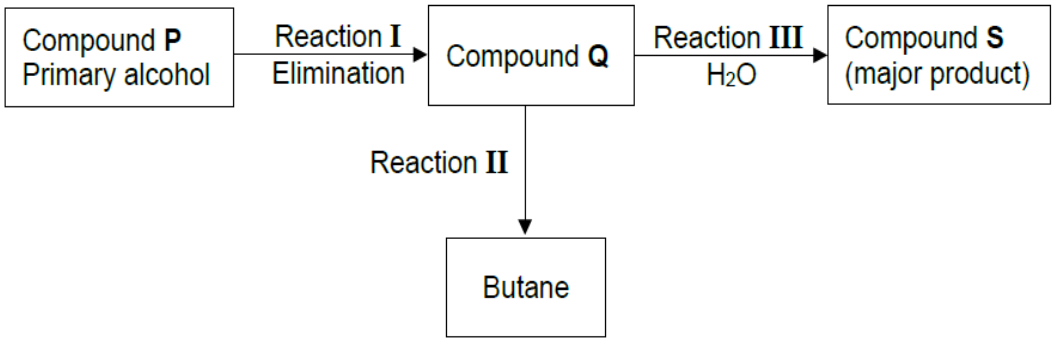
Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

**[12]**

## C. ORGANIC REACTIONS

### QUESTION 1

In the flow diagram below, a primary alcohol P is used as a starting reactant to form different organic compounds under different reaction conditions.




1.1 Write down the TYPE of:

1.1.1 Addition reaction represented by reaction **II**. (1)

1.1.2 Elimination reaction represented by reaction **I**. (1)

1.2 Write down the IUPAC name of compound **P**. (2)

1.3 Consider reaction **III**.

Write down:

1.3.1 The balanced equation using CONDENSED structural formulae. (4)

1.3.2 The NAME or FORMULA of a suitable catalyst. (1)

1.4 Butane can be converted to compound P in a TWO-STEP reaction. Use STRUCTURAL FORMULAE and write down the balanced equations for these TWO reactions. (5)

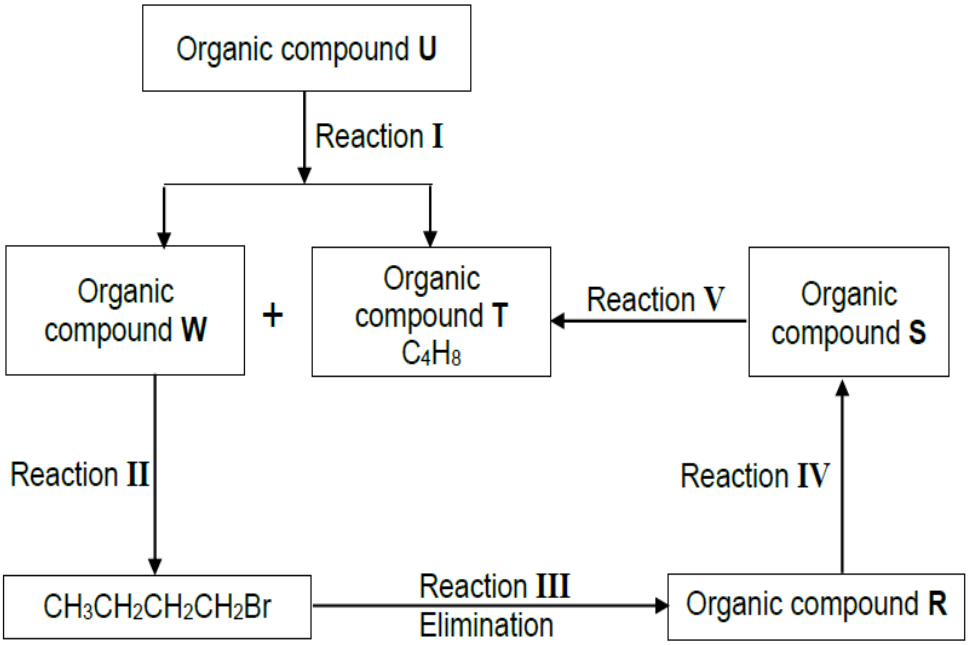
1.5 Write down a balanced equation using MOLECULAR FORMULAE for the complete combustion of butane. (3)

**[17]**

**QUESTION 2**

Study the flow diagram below.

Reaction **I** is a CRACKING REACTION forming two organic compounds, **W** and **T**, as the ONLY products.




2.1 Define the term cracking reaction. (2)

2.2 Is the product in reaction II a PRIMARY, SECONDARY or TERTIARY haloalkane? Give a reason for the answer. (2)

2.3 Write down the:

2.3.1 STRUCTURAL FORMULA of compound **W**. (3)

2.3.2 MOLECULAR formula of compound **U**. (1)

2.4 For reaction **II**, write down:

2.4.1 The NAME or FORMULA of the inorganic reactant. (1)

2.4.2 The type of reaction (Choose from SUBSTITUTION, ADDITION or ELIMINATION.) (1)

2.4.3 ONE reaction condition. (1)

2.5 Write down the TYPE of elimination in reaction **III**. (1)

2.6 Compounds **R** and **T** are positional isomers.

The inorganic reagents shown below are available for reactions **IV** and **V**.

| | | | | |
|---|---|---|---|---|
| $Br_2$ | $H_2SO_4$(conc.) | NaOH(conc.) | HBr | $H_2$ |

Write down:

2.6.1 The balanced equation for reaction IV, using STRUCTURAL FORMULAE and the correct inorganic reagent shown above. (5)

2.6.2 The balanced equation for reaction V, using STRUCTURAL formulae and the correct reagent shown above. (3)

2.6.3 The IUPAC name of compound **T**. (2)

**[22]**

## QUESTION 3

3.1 Consider the cracking reaction below.

$$C_{16}H_{34} \rightarrow C_6H_{14} + C_6H_x + 2C_yH_z$$

3.1.1 Define cracking. (2)

3.1.2 Write down the values represented by x, y and z in the equation above. (3)

Compound $C_6H_{14}$ undergoes complete combustion.

3.1.3 Using MOLECULAR FORMULAE, write down the balanced equation for this reaction. (3)

3.2 Consider the equations for reactions **I** to **III** below.

**A** and **B** represent organic compounds that are POSITIONAL ISOMERS.

**X** is an inorganic product.

| | |
|---|---|
| **I** | $CH_3CH_2CHCHCH_3 + HC\ell \rightarrow \mathbf{A} + \mathbf{B}$ |
| **II** | $\mathbf{A} \xrightarrow[\Delta]{H_2O} CH_3CH_2CH_2CH(OH)CH_3 + \mathbf{X}$ |
| **III** | $CH_3CH_2CH_2CH(OH)CH_3 \longrightarrow CH_3CH_2CHCHCH_3 + H_2O$ |

Write down the:

3.2.1 Definition of positional isomers. (2)

3.2.2 Type of reaction represented by reaction I. (1)

3.2.3 STRUCTURAL formula of compound **B**. (3)

3.2.4 Formula of **X**. (1)

3.2.5 Inorganic reagent for reaction **III**. (1)

Compound **A** can be converted directly to the organic product of reaction **III**.

3.2.6 Besides heat, write down the reaction condition needed for this conversion. (1)

3.2.7 Write down **TWO** terms that describe this type of reaction. (2)

**[19]**

## QUESTION 4

4.1 Study the three organic reactions I, II and III below. Compounds **T** and **W** are organic compounds. **R** and **S** are inorganic substances. Consider only the major products.

| | |
|---|---|
| **I** | $HBr(g) + \mathbf{T} \longrightarrow \mathbf{W}$ |
| **II** | $\mathbf{W} + NaOH(aq) \longrightarrow CH_3CH(OH)CH_2CH_3 + \mathbf{R}$ |
| **III** | $CH_3CH(OH)CH_2CH_3 \xrightarrow{\mathbf{S}} \mathbf{T} + H_2O(\ell)$ |

Write down the:

4.1.1 IUPAC name of compound **W**. (2)

4.1.2 NAME or FORMULA of **R**. (1)

4.1.3 TWO names for the type of reaction in reaction **I**. (2)
4.1.4 NAME or FORMULA of **S**. (1)
4.1.5 STRUCTURAL formula of compound **T**. (2)
Compound **W** can be converted to compound **T** in one step.
4.1.6 State, besides heat, ONE other reaction condition for this conversion. (1)

4.2 A compound with the formula $C_{10}H_{22}$ undergoes a cracking reaction according to the equation:

$$C_{10}H_{22}(\ell) \rightarrow 2X(g) + C_4H_{10}(g)$$

The mixture of the two products is bubbled in bromine water, $Br_2(aq)$, in a darkened room.
4.2.1 Define the term cracking. (2)
4.2.2 State ONE change, besides a change in temperature, that will be observed when the mixture is bubbled in $Br_2(aq)$. (1)
4.2.3 Write down the STRUCTURAL FORMULA of **X**. (2)
4.2.4 Which compound, **X** or $C_4H_{10}$, reacts faster with $Br_2(aq)$? Explain the answer. (3)
**[17]**

## TOPIC 2: RATES AND EXTENT OF REACTIONS

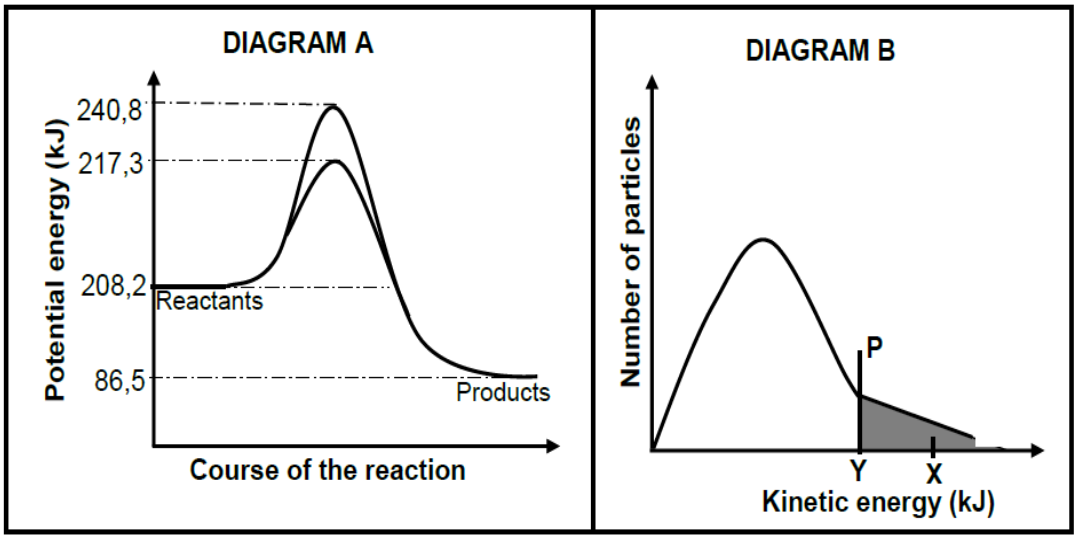
### QUESTION 1

The reaction between aluminium and EXCESS sulphuric acid is used to investigate factors affecting rates of reactions.

$$2A\ell(s) + 3H_2SO_4(aq) \rightarrow A\ell_2(SO_4)_3(aq) + 3H_2(g)$$

1.1 **INVESTIGATION I**

The effect of a catalyst on the rate of reaction is determined.
Aluminium powder of mass 5 g reacts with excess 0,1 mol·dm$^{-3}$ $H_2SO_4$ at 60 °C.
Consider the following energy diagrams (not drawn to scale) for this investigation. **X** and **Y** in diagram **B** represent the activation energies.



1.1.1 Is the reaction between Aℓ(s) and dilute $H_2SO_4$(aq) ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer by referring to the above diagrams. (2)

1.1.2 What does the shaded area to the right of line **P** represent? (1)

1.1.3 Determine the numerical value represented by the letter **X** on diagram **B**. (2)

1.2 **INVESTIGATION II**

The investigation is now repeated at 30 °C using the same reactants (5g Aℓ powder and excess 0,1 mol·dm$^{-3}$ $H_2SO_4$) and catalyst.
How will this affect EACH of the following when compared to **INVESTIGATION I**?
Choose from INCREASES, DECREASES or REMAINS THE SAME.

1.2.1 The size of the shaded area (diagram **B**). (1)

1.2.2 The value of **Y**. (1)

1.2.3 The TOTAL volume of hydrogen gas produced. (1)

1.3 **INVESTIGATION III**

In this investigation, 5 g of the same sample of IMPURE aluminium powder reacts with an EXCESS diluted $H_2SO_4$ at 60 °C in each of three runs. The table below summarises the conditions and the results obtained. (Assume that the impurities do not react.)

$$2A\ell(s) + 3H_2SO_4(aq) \rightarrow A\ell_2(SO_4)_3(aq) + 3H_2(g)$$

| RUN | CONCENTRATION $H_2SO_4$(aq) (mol·dm$^{-3}$) | AVERAGE RATE OF VOLUME $H_2$(g) PRODUCED (cm$^3$·s$^{-1}$) |
|---|---|---|
| 1 | 0,1 | 15 |
| 2 | 0,2 | 19 |
| 3 | 0,4 | 40 |

1.3.1 Write down the independent variable for this investigation. (1)

1.3.2 Use the collision theory to explain how the average rate of the reaction is affected in this investigation. (3)

1.3.3 The time for the reaction to reach completion in RUN **3** is 2,6 minutes.
Calculate the percentage purity of the aluminium. Take the molar gas volume at 60 °C to be 27 000 cm$^3$·mol$^{-1}$. (6)

**[18]**

**QUESTION 2**

2.1 The reaction between pure aluminium, Aℓ(s), and EXCESS hydrochloric acid, HCℓ(aq), is used to investigate the factors that affect the rate of a reaction.
The balanced equation for the reaction is:

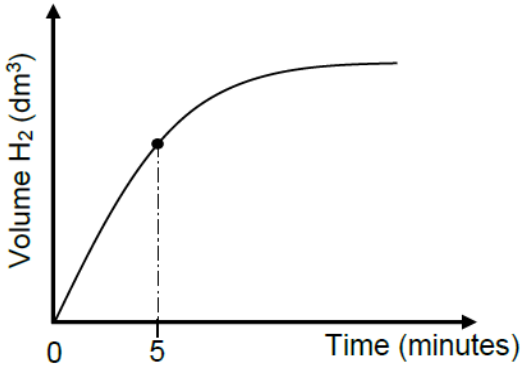
$$2A\ell(s) + 6HC\ell(aq) \rightarrow 2A\ell C\ell_3(aq) + 3H_2(g)$$

2.1.1 Define the term reaction rate. (2)

**EXPERIMENT I**

In this experiment, 1 mol·dm$^{-3}$ HCℓ solution reacts with a 0,5 g Aℓ strip from an aluminium roll at room temperature.

The graph of volume $H_2(g)$ versus time for this experiment, not drawn to scale, is shown below.




2.1.2 For the time interval t = 0 to t = 5 minutes, the average reaction rate for the formation of $H_2(g)$ is 0,033 dm$^3$·min$^{-1}$.
Calculate the mass of Aℓ present in the container at t = 5 minutes.
Take the molar gas volume as 24,5 dm$^3$·mol$^{-1}$. (6)

Assume that the concentration of the HCℓ(aq) stays constant for the duration of the reaction.

2.1.3 Use the collision theory to explain the change in the reaction rate from t = 0 to t = 5 minutes. (4)

**EXPERIMENT II**

Experiment **I** is repeated using a 2 mol·dm$^{-3}$ HCℓ solution.

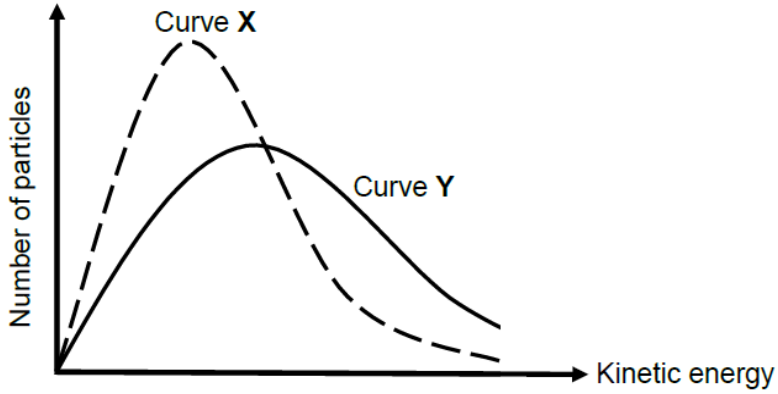
2.1.4 Redraw the above graph (NO numerical values need to be shown) in your ANSWER BOOK and label the curve **A**. On the same set of axes, draw the curve that will be obtained for Experiment **II**. Label this as curve **B**. (2)

**EXPERIMENT III**

Experiment **I** is repeated using 0,5 g pure powdered Aℓ.

2.1.5 How will the volume of $H_2(g)$ produced in Experiment **III** compare to that in Experiment **I**? Choose from GREATER THAN, LESS THAN or EQUAL TO. (1)

2.2 Curve **X** is the Maxwell Boltzmann distribution curve for a reaction under a set of reaction conditions. A change was made to one of the reaction conditions to obtain curve **Y**.



2.2.1 What change was made to obtain curve **Y**? (1)
2.2.2 Give a reason for the answer to QUESTION 2.2.1. (1)
**[17]**

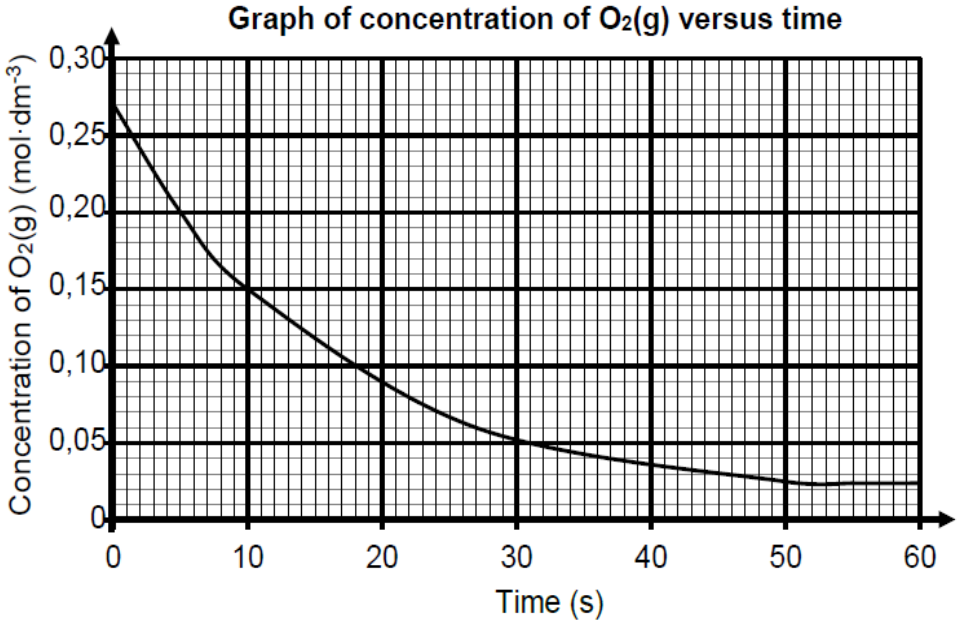
**QUESTION 3**

3.1 Define the term reaction rate. (2)

3.2 Carbon monoxide, CO(g), reacts with oxygen, $O_2(g)$, to form carbon dioxide, $CO_2(g)$, in a sealed container according to the balanced equation:

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

The graph below shows the concentration of $O_2(g)$ versus time.




3.2.1 At which time, 10 s or 30 s, is the reaction rate higher? (1)
3.2.2 The reaction takes place in a 3 dm3 container. Calculate the average rate (in $mol \cdot s^{-1}$) at which $CO_2(g)$ is formed in the first 10 s. (5)
3.2.3 Which reactant is in excess, CO or $O_2$? (1)
3.2.4 This reaction was repeated using a smaller sealed container. How will this affect the magnitude of the gradient of the graph at the beginning of the reaction? Choose from INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)

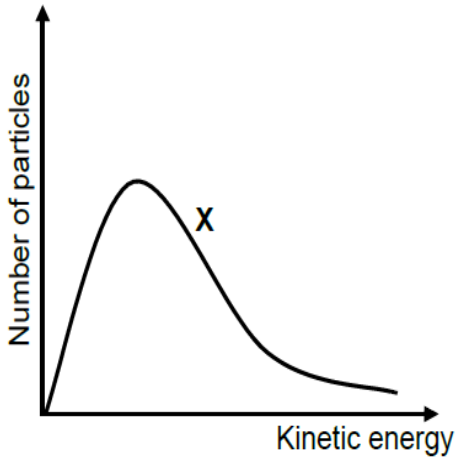
3.3 The reaction between sulphur dioxide, $SO_2(g)$, and oxygen, $O_2(g)$, takes place in a sealed container according to the balanced equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g). \qquad \Delta H = -196\ kJ \cdot mol^{-1}$$

3.3.1 Was there a net release or net absorption of energy during the REVERSE reaction? (1)
3.3.2 Define the term activated complex. (2)

3.3.3 A catalyst, vanadium pentoxide, is added to the reaction. Explain, in terms of the collision theory, why the rate of the reaction will increase. (3)

Curve **X** is the Maxwell Boltzmann distribution curve for the reaction above.




More $SO_2(g)$ is now added to the container at constant temperature.

3.3.4 How will this change affect the heat of the reaction? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

3.3.5 Redraw the above graph in the ANSWER BOOK. On the same set of axes, draw the curve that will now be obtained. Label this as curve **Y**. (2)

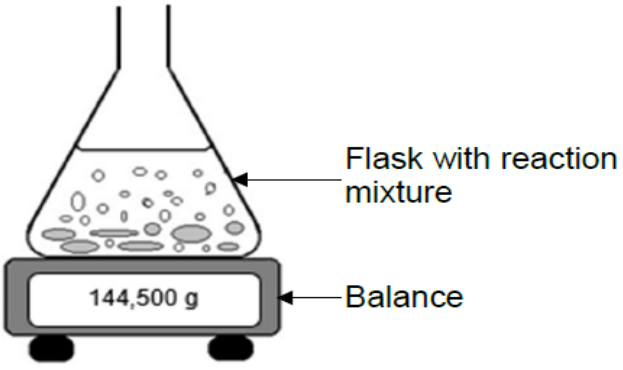
**[20]**

**QUESTION 4**

The reaction between magnesium carbonate pellets, $MgCO_3(s)$, and EXCESS dilute hydrochloric acid, $HC\ell(aq)$, is used to investigate the effect of concentration on the rate of a reaction.

$$MgCO_3(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell) + CO_2(g)$$

The apparatus used for this investigation is shown below.



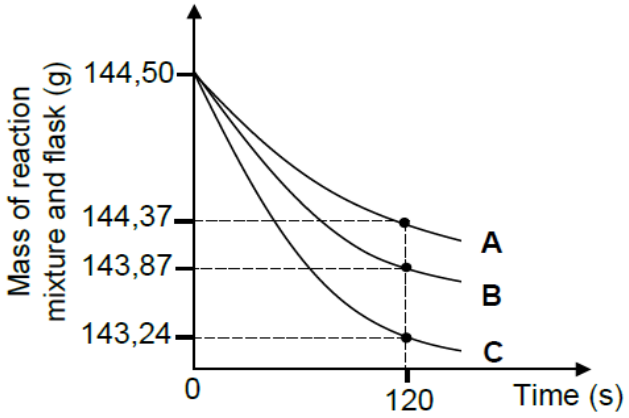

4.1 Define the term rate of reaction. (2)

4.2 Write down ONE controlled variable for this investigation. (1)

Three experiments using different concentrations of $HC\ell(aq)$ are carried out. The concentration of the $HC\ell(aq)$ during each experiment does not change.

| EXPERIMENT | CONCENTRATION OF HCℓ(aq) ($mol \cdot dm^{-3}$) |
|---|---|
| 1 | 0,1 |
| 2 | 0,5 |
| 3 | 1,0 |

The INCOMPLETE graph of the results of the experiments is shown below.




4.3 Give a reason why the mass of the reaction mixture and flask decreases. (1)

4.4 For curve **B**, calculate the average rate at which $CO_2(g)$ is produced for the first 120 s in $dm^3 \cdot s^{-1}$. The molar gas volume is 24,5 $dm^3 \cdot mol^{-1}$. (6)

4.5 Which curve represents EXPERIMENT **1**? Choose from **A**, **B** or **C**.
Use the collision theory to explain the answer. (5)

4.6 How will the final mass of $CO_2(g)$ produced in EXPERIMENT **2** compare to that of EXPERIMENT 3?
Choose from MORE THAN, LESS THAN or THE SAME.
Give a reason for the answer. (2)

**[17]**

## TOPIC 3: CHEMICAL EQUILIBRIUM

### QUESTION 1

1.1 Equilibrium is established at 25 °C in a saturated calcium hydroxide solution according to the reaction:

$$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$$

1.1.1 State Le Chatelier's principle. (2)

1.1.2 A few drops of concentrated hydrochloric acid, HCℓ(conc.), are added to the equilibrium mixture. What effect does this addition have on the mass of $Ca(OH)_2(s)$?
Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

1.1.3 Explain the answer to QUESTION 1.1.2 by using Le Chatelier's principle. (2)

1.2 Initially 70 g of $NH_4HS(s)$ is placed in a 3 $dm^3$ container at 250 °C.
The container is sealed and the reaction is allowed to reach equilibrium according to the balanced equation:

$$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$$

The $K_c$ values for the decomposition of $NH_4HS(s)$ at different temperatures are given in the table below.

| TEMPERATURE (°C) | $K_c$ |
|---|---|
| 200 | $7,5 \times 10^{-2}$ |
| 250 | $18 \times 10^{-2}$ |
| 300 | $40 \times 10^{-2}$ |

1.2.1 Is the decomposition of $NH_4HS(s)$ an EXOTHERMIC or ENDOTHERMIC reaction? (1)

1.2.2 Explain the answer to QUESTION 1.2.1 by using Le Chatelier's principle. (3)

1.2.3 Calculate the mass of $NH_4HS(s)$ that will be present at equilibrium at 250 °C. (8)

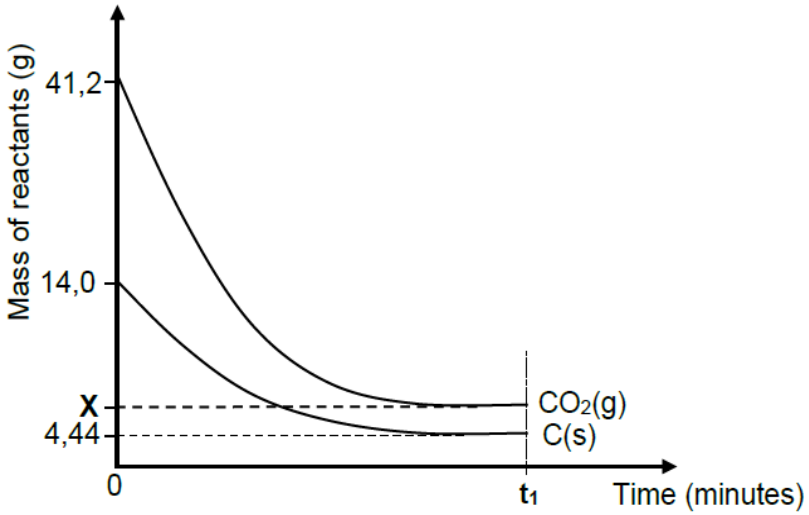
**[17]**

**QUESTION 2**

The reaction between powdered carbon, C(s), and carbon dioxide gas, $CO_2(g)$, takes place in a closed 3 $dm^3$ container according to the balanced equation below.

$$C(s) + CO_2(g) \rightleftharpoons 2CO(g) \qquad \Delta H < 0$$

Equilibrium is reached at temperature T °C.
The graph below, not drawn to scale, shows the curves for the mass of the reactants in the container against time.




2.1 How will EACH of the following changes affect the number of moles of $CO_2(g)$ at equilibrium?
Choose from INCREASES, DECREASES or REMAINS THE SAME.

2.1.1 A catalyst is added. (1)

2.1.2 The volume of the container is increased at a constant temperature. (1)

2.1.3 More powdered carbon is added. (1)

2.2 Explain the answer to QUESTION 2.1.2 by referring to Le Chatelier's principle. (2)

2.3 Calculate the value of **X** shown on the graph. (6)

2.4 Calculate the equilibrium constant, $K_c$, at T °C. (5)

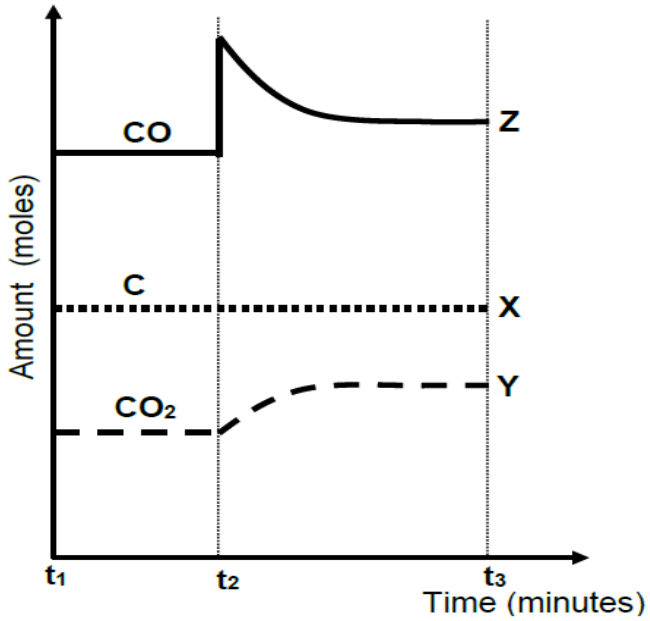
The balanced equation for this reaction is rewritten below for easy reference.

$$C(s) + CO_2(g) \rightleftharpoons 2CO(g). \qquad \Delta H < 0$$

2.5 The graph below shows the equilibrium number of moles of CO(g), C(s) and $CO_2(g)$ in the flask at time $t_1$.

At $t_2$, some CO(g) is added to the flask and the reaction is allowed to reach equilibrium. Curve **Z** correctly shows the change in the amount of CO(g) between $t_2$ and $t_3$.

A learner draws corresponding curves, labelled **X** and **Y**, for C(s) and $CO_2(g)$ respectively.




Which of these curves is the CORRECT representation for these changes?

Choose from: **X** or
**Y** or
**X and Y** (1)

2.6 What effect will the addition of CO(g) have on the equilibrium constant, Kc? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

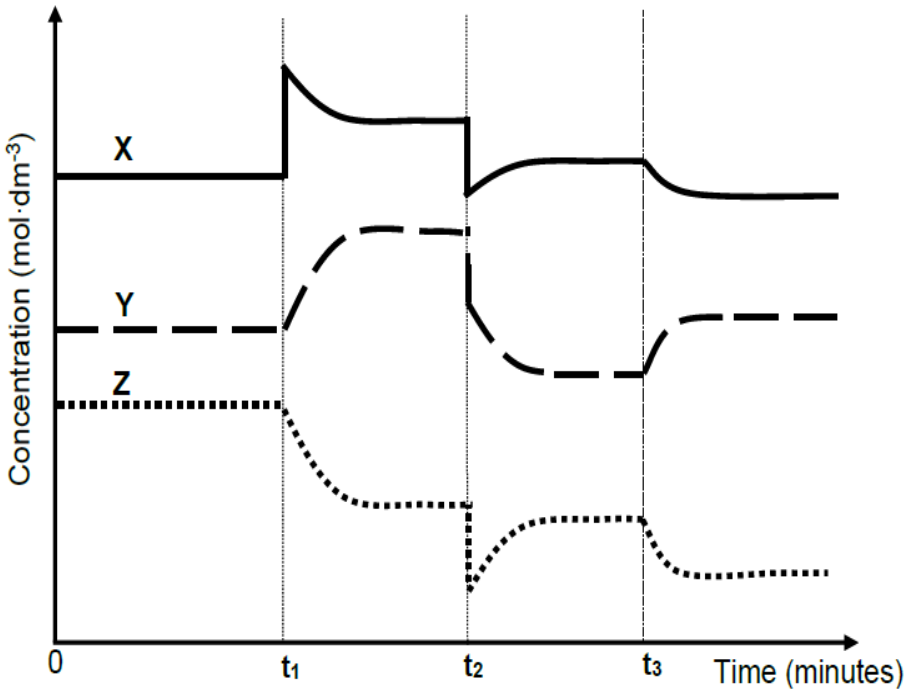
**[19]**

**QUESTION 3**

3.1 The reaction of carbon monoxide gas, CO(g), with oxygen gas, $O_2(g)$, is investigated. The reaction reaches equilibrium in a closed container at constant temperature T °C, according to the balanced equation:

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g). \qquad \Delta H < 0$$

Changes to the conditions of equilibrium are made at different times. The graph shows the results obtained. **X**, **Y** and **Z** represent the gases in the above reaction.




3.1.1 Define the term chemical equilibrium. (2)

Use the graph to answer the questions below.

3.1.2 At $t_1$, oxygen, $O_2(g)$, was added to the container. Write down the letter that represents $O_2(g)$. Choose from **X**, **Y** or **Z**. (1)

3.1.3 At $t_2$, the pressure is adjusted by changing the volume of the container. Was the pressure INCREASED or DECREASED? (1)

3.1.4 Give a reason for the answer to QUESTION 3.1.3. (1)

3.1.5 Write down the NAME or FORMULA of the gas that is represented by the letter **Z**. (1)

3.1.6 Give a reason for the answer to QUESTION 3.1.5. (1)

3.1.7 What change in temperature is made at $t_3$? Choose between INCREASED or DECREASED. (1)

3.1.8 Use Le Chatelier's principle to explain the answer to QUESTION 3.1.7. (3)

3.2 Carbon monoxide gas, CO(g), reacts with water vapour, $H_2O(g)$, at T °C. The reaction reaches chemical equilibrium according to the balanced equation:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

Initially, 0,6 moles of CO(g), 0,6 moles of $H_2O(g)$, 0,1 moles of carbon dioxide gas, $CO_2(g)$, and 0,1 moles of hydrogen gas, $H_2(g)$, were mixed and sealed in a 2 $dm^3$ flask.

If the equilibrium constant, $K_c$, for this reaction at T °C is 4, calculate the mass of CO(g) present in the flask at equilibrium. (9)

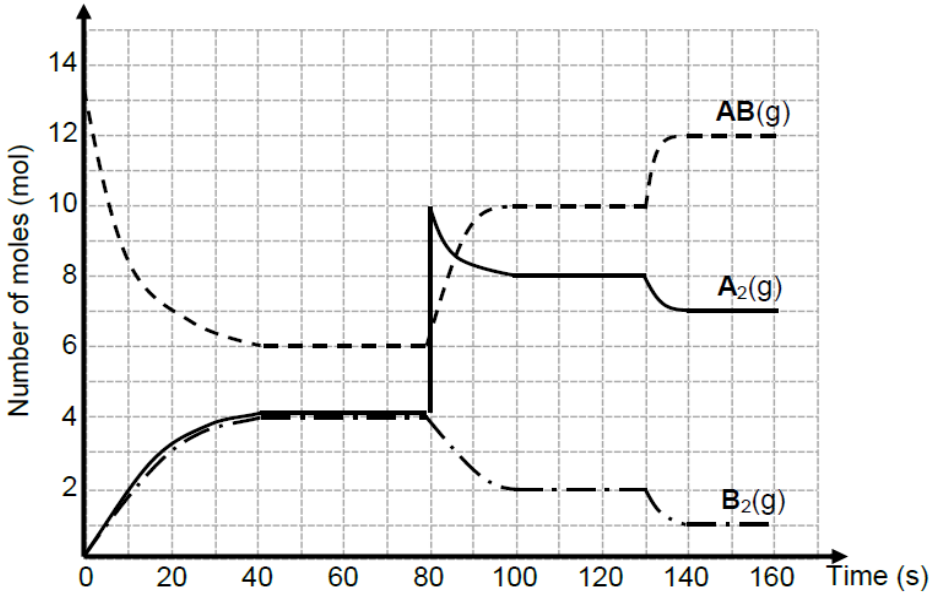
**[20]**

**QUESTION 4**

Consider the following hypothetical reaction reaching equilibrium in a 4 $dm^3$ closed container at 150 °C.

$$2AB(g) \rightleftharpoons A_2(g) + B_2(g)$$

The graph below shows the changes in the amounts of reactants and products over time.




4.1 Write down the meaning of the term reversible reaction. (1)

4.2 State Le Chatelier's principle. (2)

4.3 A change was made to the equilibrium mixture at t = 80 s.

4.3.1 Write down the change made at t = 80 s. (1)

4.3.2 Use Le Chatelier's principle to explain how the system reacts to this change. (2)

4.4 Calculate the equilibrium constant, Kc, at t = 120 s. (4)

4.5 At t = 130 s the temperature of the system is decreased to 100 °C.

4.5.1 Draw a potential energy diagram for this reaction. (3)

4.5.2 Will the equilibrium constant, $K_c$, at 100 °C be GREATER THAN, LESS THAN or EQUAL TO the $K_c$ at 150 °C? Explain the answer. (3)

4.6 The initial reaction now takes place in the presence of a catalyst at 150 °C.

Describe the changes that will be observed on the graph between t = 0 s and t = 60 s. (3)

**[19]**

**QUESTION 5**

Steam, $H_2O(g)$, reacts with hot carbon, C(s), at 1 000 °C according to the following balanced equation:

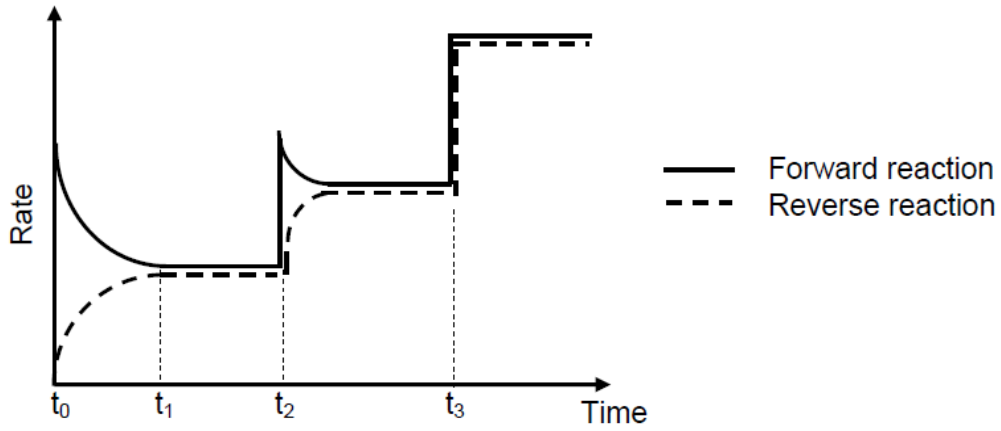
$$2H_2O(g) + C(s) \rightleftharpoons 2H_2(g) + CO_2(g)$$

Initially, 36 g of steam and a certain amount of carbon were placed in a 2 $dm^3$ sealed container and allowed to react. At equilibrium it was found that the amount of carbon changed by 0,225 mol.

5.1 Define the term dynamic equilibrium. (2)

5.2 Calculate the equilibrium constant, $K_c$, for the reaction at 1 000 °C. (8)

5.3 The graph shows how the rates of the forward and reverse reactions change with time.




5.3.1 Give a reason why the rate of the forward reaction decreases between $t_0$ and $t_1$. (1)

5.3.2 What change was made to the equilibrium mixture at $t_3$? (1)

At time $t_2$, the temperature of the system is increased.

5.3.3 Is the forward reaction EXOTHERMIC or ENDOTHERMIC? (1)

5.3.4 Refer to Le Chatelier's principle to explain the answer to QUESTION 5.3.3. (2)

**[15]**

## TOPIC 4: ACIDS AND BASES

**QUESTION 1**

1.1 Sulphuric acid, $H_2SO_4$, ionises into two steps as follows:

**I.** $H_2SO_4(aq) + H_2O(\ell) \rightarrow HSO_4^-(aq) + H_3O^+(aq)$. $Ka = 1 \times 10^3$

**II.** $HSO_4^-(aq) + H_2O(\ell) \rightarrow SO_4^{2-}(aq) + H_3O^+(aq)$. $Ka = 1 \times 10^{-2}$

1.1.1 Define an acid in terms of the Lowry-Brønsted theory. (2)

1.1.2 Write down the NAME or FORMULA of the substance that acts as an ampholyte in the above equations.
Give a reason for the answer. (2)

1.1.3 The conductivity of solutions of $HSO_4^-(aq)$ and $H_2SO_4(aq)$ are compared. Which solution will have a LOWER conductivity?
Explain the answer. (3)

1.2 The pH of a hydrochloric acid solution, HCℓ(aq), is 1,02 at 25 °C.

1.2.1 Calculate the concentration of the HCℓ(aq). (3)

This HCℓ solution reacts with sodium carbonate, $Na_2CO_3$, according to the following balanced equation:

$$2HC\ell(aq) + Na_2CO_3(aq) \rightarrow 2NaC\ell(aq) + CO_2(g) + H_2O(\ell)$$

50 $cm^3$ of the HCℓ solution is added to 25 $cm^3$ of a 0,075 $mol \cdot dm^{-3}$ $Na_2CO_3$ solution.

1.2.2 Calculate the concentration of the EXCESS HCℓ in the new solution. (8)

**[18]**

**QUESTION 2**

2.1 Define an acid according to the Arrhenius theory. (2)

2.2 The table below shows aqueous solutions of different substances, each of concentration 1 $mol \cdot dm^{-3}$ at room temperature.

| | | | | |
|---|---|---|---|---|
| $HNO_3(aq)$ | $H_2SO_4(aq)$ | $NaC\ell(aq)$ | $NaOH(aq)$ | |
| $(COOH)_2(aq)$ | $HCO_3^-(aq)$ | $Mg(OH)_2(aq)$ | $NH_3(aq)$ | $CH_3COOH(aq)$ |

Identify from the table and write down the FORMULA for:

2.2.1 A weak diprotic acid. (1)

2.2.2 A solution with a pH of 7. (1)

2.2.3 An ampholyte. (1)

2.2.4 The solution, which when neutralised with $(COOH)_2(aq)$, will have a pH greater than 7. (2)

2.3 An unknown acid $H_xY$ is investigated.

During a titration, 23,64 $cm^3$ of a 0,11 $mol \cdot dm^{-3}$ HxY solution neutralises 20 $cm^3$ of a 0,26 $mol \cdot dm^{-3}$ NaOH solution.

Calculate the value of **x**. Hence, write down the balanced equation for this reaction. (6)

2.4 In an experiment, 1,5 g of a powdered IMPURE calcium carbonate sample, $CaCO_3(s)$, is reacted with 200 $cm^3$ of a 0,15 $mol \cdot dm^{-3}$ hydrochloric acid solution, HCℓ(aq).

The balanced equation for the reaction is:

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

All the $CO_2(g)$ formed escapes from the solution.

The resulting solution has a pH of 1,61 and a volume of 200 $cm^3$.

Assume that ALL the $CaCO_3(s)$ in the impure sample reacted with the HCℓ(aq) and none of the impurities reacted.

Calculate the mass of the impurities present in the 1,5 g sample of impure $CaCO_3(s)$. (9)

**[22]**

**QUESTION 3**

To identify metal **M** in an unknown metal carbonate, **M**$CO_3$, the following procedure is carried out:

**Step 1:** 0,198 g of IMPURE **M**$CO_3$ is reacted with 25 $cm^3$ of 0,4 $mol \cdot dm^{-3}$ nitric acid, HNO3(aq).

**Step 2:** The EXCESS HNO3(aq) is then neutralised with 20 $cm^3$ of 0,15 $mol \cdot dm^{-3}$ barium hydroxide, $Ba(OH)_2(aq)$.

Assume that the volumes are additive.

The following reactions take place:

$$2HNO_3(aq) + MCO_3(s) \rightarrow M(NO_3)_2(aq) + CO_2(g) + H_2O(\ell)$$

$$2HNO_3(aq) + Ba(OH)_2(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(\ell)$$

3.1 Define the term strong base. (2)

3.2 Calculate the:

3.2.1 Number of moles of $Ba(OH)_2(aq)$ that reacted with the excess $HNO_3(aq)$. (3)

3.2.2 pH of the solution after Step 1. (5)

3.3 The percentage purity of the **M**$CO_3(s)$ in the sample is 85%. Identify metal **M**. (8)

**[18]**

**QUESTION 4**

4.1 A standard solution is prepared by dissolving 10 g of sodium carbonate, $Na_2CO_3(s)$, in 0,7 $dm^3$ of water.

4.1.1 Calculate the concentration of the solution. (3)

4.1.2 Will the pH of the solution be GREATER THAN or LESS THAN 7? (1)

4.1.3 Write an equation that explains the answer to QUESTION 4.1.2. (2)

The sodium carbonate solution is titrated with dilute hydrochloric acid, HCℓ(aq). The following indicators are available for this titration.

| INDICATOR | pH RANGE |
|---|---|
| P | 3,4–4,5 |
| Q | 6,8–7,2 |
| R | 8,3–10 |

4.1.4 Which ONE of the indicators (**P**, **Q** or **R**) is most suitable for this titration? Give a reason for the answer by referring to the data in the table. (2)

4.2 When 0,01 moles of dilute sulphuric acid, $H_2SO_4(aq)$, is mixed with 0,024 moles of potassium hydroxide, KOH(aq), the total volume of the final solution is 0,2 $dm^3$.

$$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell)$$

4.2.1 What is meant by a dilute acid? (2)

4.2.2 Calculate the pH of the final solution. (8)

**[18]**

**QUESTION 5**

5.1 Phosphoric acid, $H_3PO_4(aq)$, is an example of an acid that can ionise in three steps, as shown below.

$H_3PO_4(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + H_2PO_4^-(aq)$. $Ka = 6,9 \times 10^{-3}$

$H_2PO_4^-(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + HPO_4^{2-}(aq)$. $Ka = 6,2 \times 10^{-8}$

$HPO_4^{2-}(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + PO_4^{3-}(aq)$. $Ka = 4,8 \times 10^{-13}$

5.1.1 Which one is the stronger acid, $H_2PO_4^-$ or $HPO_4^{2-}$? Give a reason for the answer by referring to the data above. (2)

5.1.2 Write down the FORMULA for the conjugate base of $H_2PO_4^-(aq)$. (1)

5.1.3 Identify a substance behaving as an ampholyte in the reactions above. (1)

Sodium hydrogen phosphate, $Na_2HPO_4(s)$, is dissolved in water.

5.1.4 Will the resulting solution be ACIDIC or BASIC? (1)

5.1.5 Write a balanced equation to explain the answer to QUESTION 5.1.4. (3)

5.2 Barium hydroxide, $Ba(OH)_2$, dissolves in water according to the balanced equation:

$$Ba(OH)_2(s) \rightarrow Ba^{2+}(aq) + 2OH^-(aq)$$

A 100 $cm^3$ solution is prepared by dissolving an unknown amount of $Ba(OH)_2$ at 25 °C.

25 $cm^3$ of this $Ba(OH)_2$ solution is reacted with 15 $cm^3$ of a 0,2 $mol \cdot dm^{-3}$ $HC\ell$ solution in a flask, according to the balanced equation:

$$Ba(OH)_2(aq) + 2HC\ell(aq) \rightarrow BaC\ell_2(aq) + 2H_2O(\ell)$$

The final pH of the solution is 12,62 at 25 °C.

Calculate the:

5.2.1 Final concentration of the hydroxide ions in the flask. (4)

5.2.2 Number of moles of $Ba(OH)_2$ used to prepare the 100 $cm^3$ solution. (8)

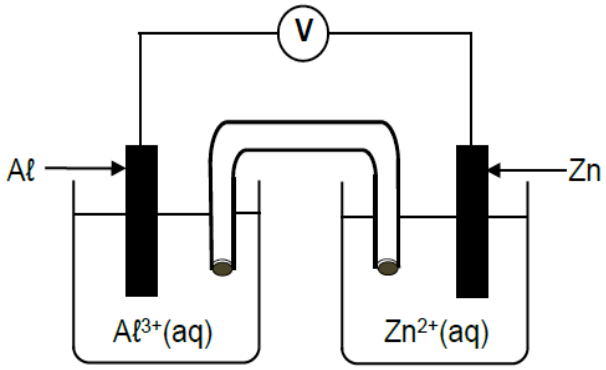
**[20]**

## TOPIC 5: ELECTROCHEMICAL REACTIONS

### A. THE GALVANIC CELLS

**QUESTION 1**

The diagram below represents a cell that operates initially under standard conditions.




1.1 Define the term electrolyte. (2)

1.2 Which ion concentration, $A\ell^{3+}(aq)$ or $Zn^{2+}(aq)$, will increase? Give a reason for the answer. (2)

1.3 Write down the cell notation for this cell. (3)

The electrolyte in the aluminium half-cell is prepared by dissolving some aluminium sulphate, $A\ell_2(SO_4)_3(s)$, in water.

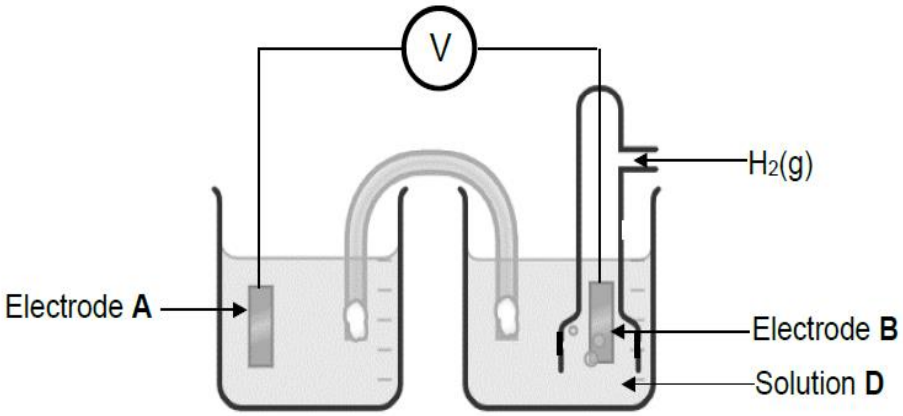
1.4 Calculate the mass of $A\ell_2(SO_4)_3(s)$ needed to prepare 250 $cm^3$ of this solution so that the cell operates initially under STANDARD CONDITIONS. (4)

**[11]**

**QUESTION 2**

The simplified diagram below shows a cell that can be used to measure the standard electrode potential of the half-reaction represented by the equation below.

$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$$




2.1 For solution **D**, write down the NAME or FORMULA of the ions needed. (1)

2.2 Write down the initial reading on the voltmeter. (1)

2.3 Which electrode, **A** or **B**, is the cathode? (1)

2.4 Explain the answer to QUESTION 2.3 in terms of the relative strengths of the reducing agents. (3)

2.5 Write down the:

2.5.1 NAME or FORMULA of the metal used as electrode **A**. (1)

2.5.2 Half-reaction that occurs at electrode **B**. (2)

2.5.3 Cell notation for this cell. (3)

2.6 Give a reason why the voltmeter reading drops to zero after the cell has operated for some time. (1)

**[13]**

**QUESTION 3**

3.1 Dilute hydrochloric acid, HCℓ(aq), reacts with magnesium, Mg(s), at 25 °C according to the following balanced equation:

$$Mg(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2(g)$$

3.1.1 Use oxidation numbers for EACH of the reactants and explain why this reaction is a redox reaction. (2)

3.1.2 Write down the FORMULA of the oxidising agent in this reaction. (1)

It is observed that dilute hydrochloric acid does not react with copper, Cu(s), at 25 °C.

3.1.3 Explain this observation by referring to the relative strengths of the reducing agents. (2)

3.1.4 Will dilute nitric acid, $HNO_3(aq)$, react with copper, Cu(s), at 25 °C? Choose from YES or NO.
Explain the answer in terms of the relative strengths of the oxidising agents. (3)

3.2 A galvanic cell is represented by the following cell notation:

$$Pb(s) \mid Pb^{2+}(aq) \parallel Fe^{3+}(aq), Fe^{2+}(aq) \mid Pt(s)$$

3.2.1 Write down the balanced net ionic equation for this cell. (3)

A stronger reducing agent is now used with the same oxidising agent under the same conditions.

3.2.2 How will this affect the initial emf of the cell?
Choose from INCREASES, DECREASES or NO EFFECT. (1)

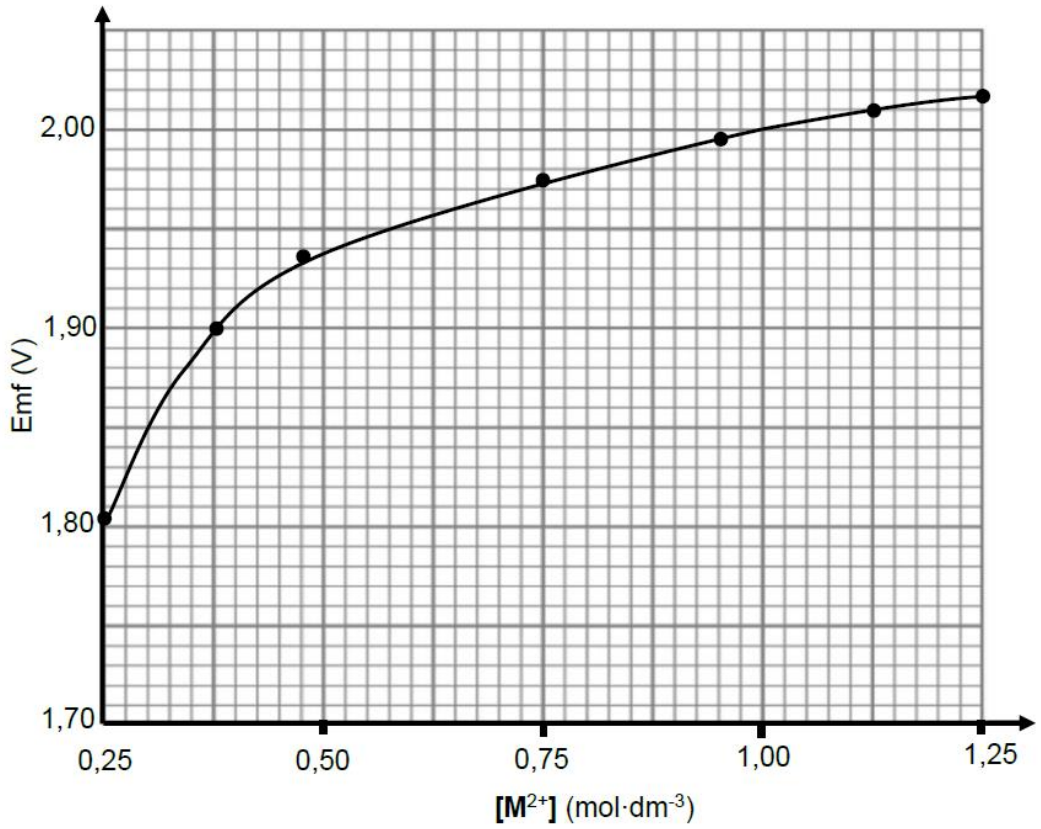
**[12]**

**QUESTION 4**

The relationship between the concentration of the electrolyte and the cell potential is investigated using the following electrochemical cell represented by the cell notation:

$$A\ell(s) / A\ell^{3+}(aq) // M^{2+}(aq) / M(s)$$

The concentration of $M^{2+}$ is changed and the corresponding emf is measured. The concentration of $A\ell^{3+}(aq)$ and the temperature are at standard conditions. The graph below shows the results of this investigation.

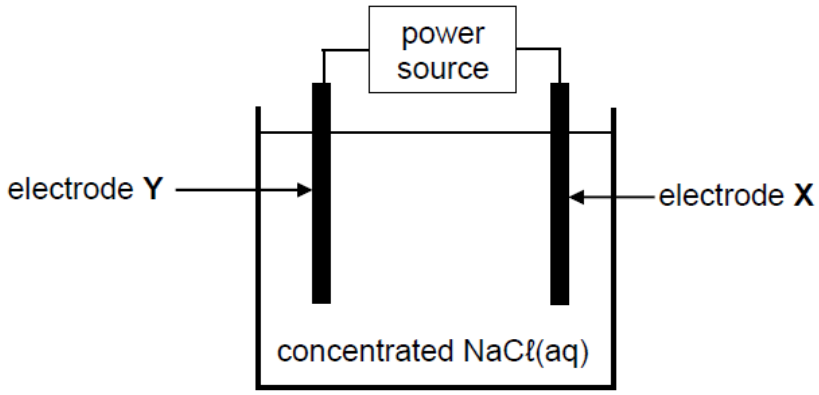



4.1 Identify the reducing agent in this cell. (1)
4.2 Determine the concentration of $M^{2+}(aq)$ that will produce an emf of 1,87 V. (2)
4.3 How will the concentration of $M^{2+}(aq)$ be affected as the cell operates?
Choose from INCREASES, DECREASES or REMAINS THE SAME.
Give a reason for the answer. (2)
4.4 Potassium nitrate, $KNO_3(aq)$, is used in the salt bridge of this cell.
To which electrode will the $K^+$ ions move in the salt bridge (Aℓ or M)? (1)
4.5 Identify metal **M** with the aid of a calculation. (6)
4.6 Metal **M** is now replaced with magnesium, Mg.
4.6.1 Which electrode, Aℓ or Mg, will be the anode? (1)
4.6.2 Refer to the relative strengths of the oxidising agents to explain the answer. (2)
**[15]**

## B. THE ELECTROLYTIC CELL

### QUESTION 1

The simplified diagram below represents an electrochemical cell used for the electrolysis of a concentrated sodium chloride solution, NaCℓ(aq).
**X** and **Y** are carbon electrodes.




1.1 Define the term electrolysis. (2)

1.2 Chlorine gas, $C\ell_2(g)$, is released at electrode **X**.
Write down the:

1.2.1 Letter (**X** or **Y**) of the electrode where oxidation takes place. (1)

1.2.2 Half-reaction that takes place at electrode **Y**. (2)

1.2.3 Direction in which electrons flow in the external circuit.
Choose from **X** to **Y** OR **Y** to **X**. (1)

1.2.4 Balanced equation for the net (overall) cell reaction that takes place in the cell. (3)

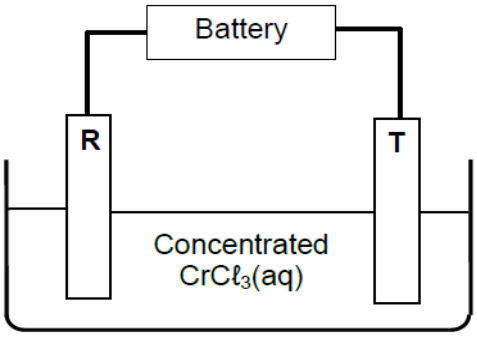
1.3 How will the pH of the electrolyte change during the reaction?
Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

1.4 Give a reason for the answer to QUESTION 1.3. (1)

**[11]**

**QUESTION 2**

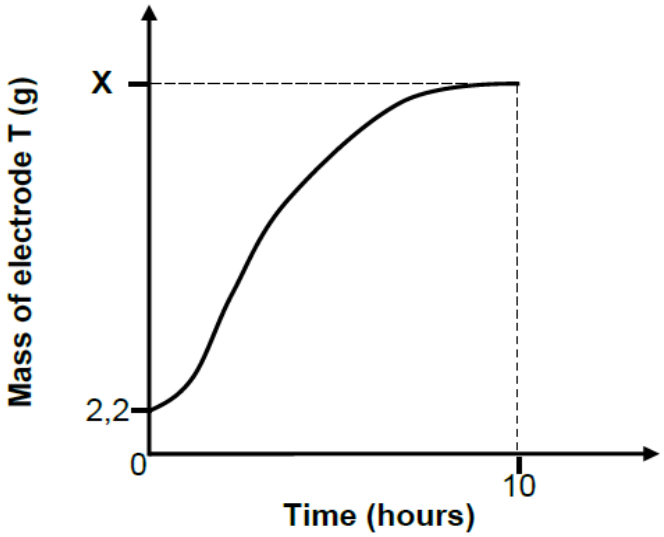
The diagram below represents a simplified cell used for the electrolysis of CONCENTRATED chromium(III) chloride, $CrC\ell_3(aq)$.
Electrodes **R** and **T** are made of carbon.




The net cell reaction is: $2CrC\ell_3(aq) \rightarrow 2Cr(s) + 3C\ell_2(g)$

2.1 Define the term electrolysis. (2)

2.2 The graph below, NOT drawn to scale, represents the changes in the mass of electrode **T** during electrolysis.




2.2.1 Write down the half-reaction that takes place at electrode **T**. (2)

A current of 2,5 A passes through the cell for 10 hours.

Calculate the:

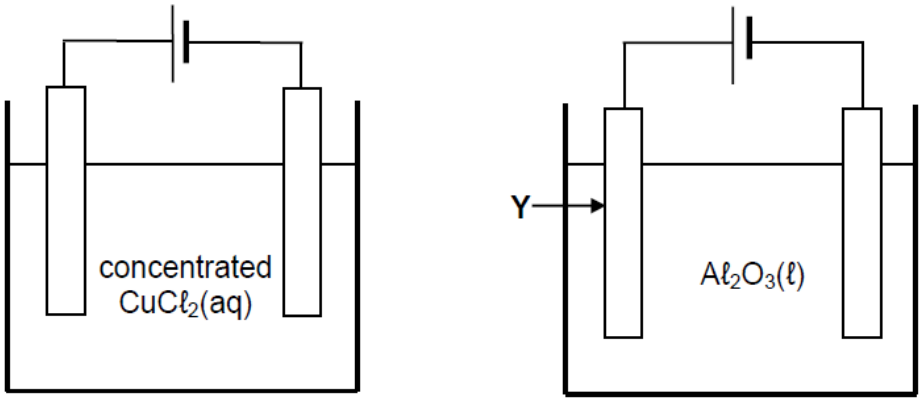
2.2.2 Total charge that flows through the cell during this time. (3)

2.2.3 Value of **X** as shown on the graph. (6)

**[13]**

**QUESTION 3**

The diagrams below show two electrochemical cells in which carbon electrodes are used. In cell **A**, concentrated copper (II) chloride solution is used and in cell **B**, liquid aluminium oxide is used.




**Cell A** **Cell B**

3.1 What type of electrochemical cell, ELECTROLYTIC or GALVANIC, is shown above? Give a reason for the answer. (2)

3.2 Write down the:

3.2.1 Half-reaction that takes place at the anode of cell **A**. (2)

3.2.2 Half-reaction that takes place at the cathode of cell **B**. (2)

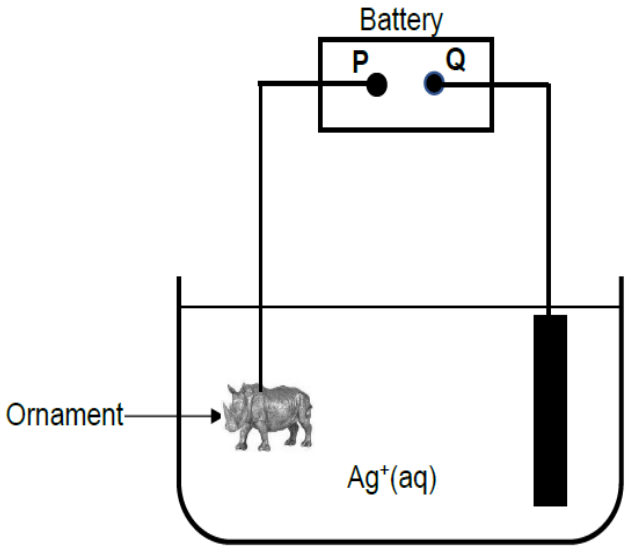
3.2.3 NAME or FORMULA of the product formed at the cathode of cell **A**. (1)

3.3 Give a reason why the mass of electrode **Y** decreases after a while. (1)

**[8]**

**QUESTION 4**

The simplified diagram below represents the cell used for electroplating ornaments with silver, Ag. **P** and **Q** are the two terminals of the battery.




4.1 State the energy conversion that takes place in this cell. (1)

4.2 Which terminal of the battery (**P** or **Q**) is negative? (1)

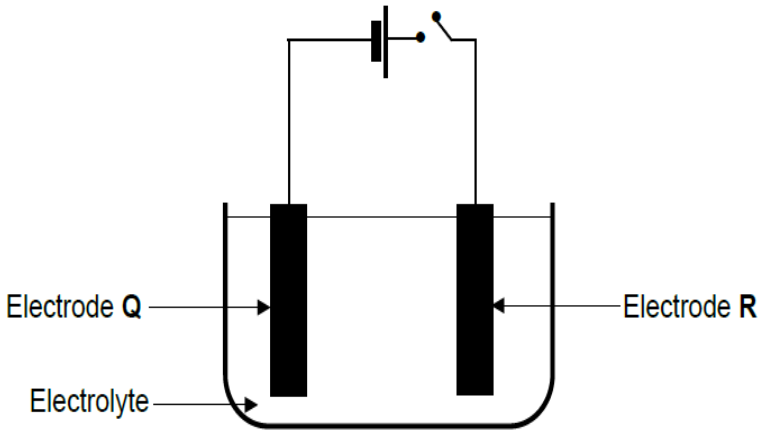
4.3 Write down the equation for the half-cell reaction that takes place at the cathode. (2)

4.4 Calculate the current needed to electroplate the ornament with 3,25 g of silver in 30 minutes. (5)

**[9]**

**QUESTION 5**

The diagram below represents a cell used for the refining of copper.




The unrefined copper contains zinc as the only impurity.

5.1 Is this an ELECTROLYTIC or a GALVANIC cell? (1)

5.2 When the switch is closed, it is found after T hours that the amount of $Cu^{2+}(aq)$ ions in the electrolyte changed by 0,05 moles and 0,15 moles of Cu(s) were deposited on electrode **Q**.

5.2.1 How will the concentration of the zinc ions in the electrolyte be affected during the refining of the copper?
Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

5.2.2 Will the amount of $Cu^{2+}(aq)$ ions INCREASE or DECREASE?
Explain the answer in terms of the relative strengths of the oxidising agents present. (3)

5.2.3 Calculate the change in mass of electrode **R** after **T** hours. (6)
**[11]**

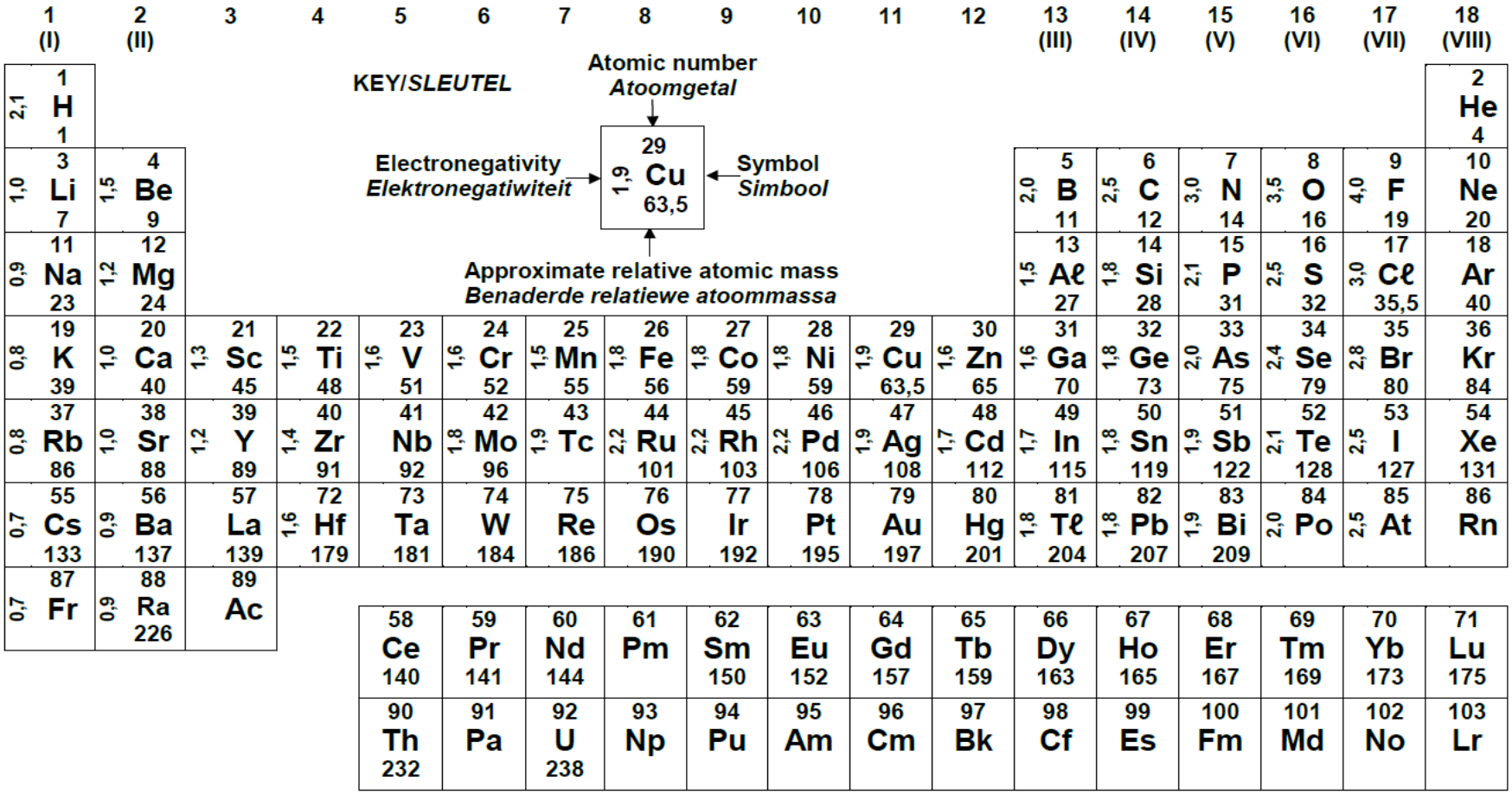
**TABLE 1: PHYSICAL CONSTANTS/*TABEL 1: FISIESE KONSTANTES***

| NAME/*NAAM* | SYMBOL/*SIMBOOL* | VALUE/*WAARDE* |
|---|---|---|
| Standard pressure<br>*Standaarddruk* | 1 | $1{,}013 \times 10^5$ Pa |
| Molar gas volume at STP<br>*Molêre gasvolume by STD* | $V_m$ | 22,4 $dm^3 \cdot mol^{-1}$ |
| Standard temperature<br>*Standaardtemperatuur* | $T^\theta$ | 273 K |
| Charge on electron<br>*Lading op elektron* | e | $1{,}6 \times 10^{-19}$ C |
| Avogadro's constant<br>*Avogadro-konstante* | $N_A$ | $6{,}02 \times 10^{23}$ $mol^{-1}$ |

**TABLE 2: FORMULAE/*TABEL 2: FORMULES***

| | |
|---|---|
| $n = \frac{m}{M}$ | $n = \frac{N}{N_A}$ |
| $c = \frac{n}{V}$ or/*of* $c = \frac{m}{MV}$ | $n = \frac{V}{V_m}$ |
| $\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$ | $pH = -\log[H_3O^+]$ |
| $K_w = [H_3O^+][OH^-] = 1 \times 10^{-14}$ at/*by* 298 K | |
| $E^\theta_{cell} = E^\theta_{cathode} - E^\theta_{anode}$ /$E^\theta_{sel} = E^\theta_{katode} - E^\theta_{anode}$<br>or/*of*<br>$E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$/$E^\theta_{sel} = E^\theta_{reduksie} - E^\theta_{oksidasie}$<br>or/*of*<br>$E^\theta_{cell} = E^\theta_{oxidising\ agent} - E^\theta_{reducing\ agent}$ /$E^\theta_{sel} = E^\theta_{oksideermiddel} - E^\theta_{reduseermiddel}$ | |

## TABLE 3: THE PERIODIC TABLE OF ELEMENTS
## *TABEL 3: DIE PERIODIEKE TABEL VAN ELEMENTE*

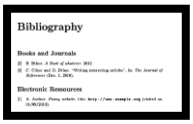


## TABLE 4B: STANDARD REDUCTION POTENTIALS
## *TABEL 4B: STANDAARD-REDUKSIEPOTENSIALE*

Increasing strength of oxidising agents /*Toenemende sterkte van oksideermiddels* ↓

Increasing strength of reducing agents /*Toenemende sterkte van reduseermiddels* ↑

| Half-reactions/*Halfreaksies* | $E^{\ominus}$(V) |
|---|---|
| $Li^+ + e^- \rightleftharpoons Li$ | − 3,05 |
| $K^+ + e^- \rightleftharpoons K$ | − 2,93 |
| $Cs^+ + e^- \rightleftharpoons Cs$ | − 2,92 |
| $Ba^{2+} + 2e^- \rightleftharpoons Ba$ | − 2,90 |
| $Sr^{2+} + 2e^- \rightleftharpoons Sr$ | − 2,89 |
| $Ca^{2+} + 2e^- \rightleftharpoons Ca$ | − 2,87 |
| $Na^+ + e^- \rightleftharpoons Na$ | − 2,71 |
| $Mg^{2+} + 2e^- \rightleftharpoons Mg$ | − 2,36 |
| $A\ell^{3+} + 3e^- \rightleftharpoons A\ell$ | − 1,66 |
| $Mn^{2+} + 2e^- \rightleftharpoons Mn$ | − 1,18 |
| $Cr^{2+} + 2e^- \rightleftharpoons Cr$ | − 0,91 |
| $2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$ | − 0,83 |
| $Zn^{2+} + 2e^- \rightleftharpoons Zn$ | − 0,76 |
| $Cr^{3+} + 3e^- \rightleftharpoons Cr$ | − 0,74 |
| $Fe^{2+} + 2e^- \rightleftharpoons Fe$ | − 0,44 |
| $Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$ | − 0,41 |
| $Cd^{2+} + 2e^- \rightleftharpoons Cd$ | − 0,40 |
| $Co^{2+} + 2e^- \rightleftharpoons Co$ | − 0,28 |
| $Ni^{2+} + 2e^- \rightleftharpoons Ni$ | − 0,27 |
| $Sn^{2+} + 2e^- \rightleftharpoons Sn$ | − 0,14 |
| $Pb^{2+} + 2e^- \rightleftharpoons Pb$ | − 0,13 |
| $Fe^{3+} + 3e^- \rightleftharpoons Fe$ | − 0,06 |
| **$2H^+ + 2e^- \rightleftharpoons H_2(g)$** | **0,00** |
| $S + 2H^+ + 2e^- \rightleftharpoons H_2S(g)$ | + 0,14 |
| $Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$ | + 0,15 |
| $Cu^{2+} + e^- \rightleftharpoons Cu^+$ | + 0,16 |
| $SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2(g) + 2H_2O$ | + 0,17 |
| $Cu^{2+} + 2e^- \rightleftharpoons Cu$ | + 0,34 |
| $2H_2O + O_2 + 4e^- \rightleftharpoons 4OH^-$ | + 0,40 |
| $SO_2 + 4H^+ + 4e^- \rightleftharpoons S + 2H_2O$ | + 0,45 |
| $Cu^+ + e^- \rightleftharpoons Cu$ | + 0,52 |
| $I_2 + 2e^- \rightleftharpoons 2I^-$ | + 0,54 |
| $O_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2O_2$ | + 0,68 |
| $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ | + 0,77 |
| $NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2(g) + H_2O$ | + 0,80 |
| $Ag^+ + e^- \rightleftharpoons Ag$ | + 0,80 |
| $Hg^{2+} + 2e^- \rightleftharpoons Hg(\ell)$ | + 0,85 |
| $NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO(g) + 2H_2O$ | + 0,96 |
| $Br_2(\ell) + 2e^- \rightleftharpoons 2Br^-$ | + 1,07 |
| $Pt^{2+} + 2e^- \rightleftharpoons Pt$ | + 1,20 |
| $MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O$ | + 1,23 |
| $O_2(g) + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ | + 1,23 |
| $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$ | + 1,33 |
| $C\ell_2(g) + 2e^- \rightleftharpoons 2C\ell^-$ | + 1,36 |
| $MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$ | + 1,51 |
| $H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$ | +1,77 |
| $Co^{3+} + e^- \rightleftharpoons Co^{2+}$ | + 1,81 |
| $F_2(g) + 2e^- \rightleftharpoons 2F^-$ | + 2,87 |




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| 10 | June 2021 |
| 11 | September 2021(2) |