THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ANDIDATES' ITEM RESPONSE ANALYSIS REPORT ON THE ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (ACSEE), 2025

CHEMISTRY

THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

CANDIDATES' ITEM RESPONSE ANALYSIS REPORT ON THE ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (ACSEE), 2025

132 CHEMISTRY

Published by:

The National Examinations Council of Tanzania,
P. O. Box 2624,
Dar es Salaam-Tanzania.

TABLE OF CONTENTS

FOREWORD v
1.0 INTRODUCTION 1
2.0 ANALYSIS OF CANDIDATES' PERFORMANCE ON EACH QUESTION 2
2.1 132/1-CHEMISTRY 1 2
2.1.1 Question 1: Aliphatic Hydrocarbons 3
2.1.2 Question 2: Chemical Bonding 7
2.1.3 Question 3: Chemical Equilibrium 14
2.1.4 Question 4: The Atom 18
2.1.5 Question 5: Gases 24
2.1.6 Question 6: Selected compounds of metals 30
2.1.7 Question 7: Energetics 35
2.1.8 Question 8: Relative Molecular Masses in Solution 41
2.1.9 Question 9: Aromatic Hydrocarbons 45
2.1.10 Question 10: Environmental Chemistry 51
2.2 132/2-CHEMISTRY 2 58
2.2.1 Question 1: Chemical kinetics and Electrochemistry 58
2.2.2 Question 2: Transition Elements and Polymers 66
2.2.3 Question 3: Extraction of metals and Periodic classification of elements 80
2.2.4 Question 4: Solubility, Solubility product and Ionic product 86
2.2.5 Question 5: Two components Liquid systems 97
2.2.6 Question 6: Carbonyl compounds, Carboxylic acids and Derivatives and Amines 106
2.3 132/3-CHEMISTRY 3 114
2.3.1 Question 1: Volumetric Analysis 115
2.3.1.1 Alternative 3A 115
2.3.1.2 Alternative 3B 116
2.3.1.3 Alternative 3C 117
2.3.2 Question 2: Physical Chemistry Analysis 144
2.3.2.1 Alternative 3A 144
2.3.2.2 Alternative 3B 145
2.3.2.3 Alternative 3C 146
2.3.3 Question 3: Qualitative Analysis 169
2.3.3.1 Alternative 3A 169
2.3.3.2 Alternative 3B 169

2.3.3.3 Alternative 3C 170
3.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE ON EACH TOPIC 191
4.0 CONCLUSIONS 192
5.0 RECOMMENDATIONS 193
APPENDIX A: Summary of the Candidates' Performance in the Theory Papers 196
APPENDIX B: Summary of the Candidates' Performance in the Practical Paper…………………………………………………………………..197

FOREWORD

This report presents an analysis of the Advanced Certificate of Secondary Education Examination (ACSEE) Chemistry examination, which was conducted in May 2025. The report examines candidates’ responses to each question and the performance across the topics covered in the examination. The report aims to shed light on the factors that influenced the candidates' performance in the Chemistry examination. Thus, it provides valuable feedback for various educational stakeholders, including teachers, students, secondary school heads, and educational administrators. The overall performance of the candidates in the 2025 Chemistry examination was excellent, with 97.23% of the candidates attaining the pass mark.

Factors that contributed to candidates' success in the examination include an effective grasp of the subject matter and the ability to understand the tasks of the questions.

On the other hand, the report ascertains factors that led some of the candidates to score low marks in the examination. Those factors include a lack of proficiency in writing chemical equations, insufficient skills in performing chemical calculations, and failure to adhere to the demands of the questions. In this report, the analysis is supported with sample extracts from the candidates' scripts.

In addition, the report gives recommendations for improvements. Thus, by addressing the identified challenges and building on the strengths, educational stakeholders can collectively work to improve performance in future examinations.

Finally, the National Examinations Council of Tanzania expresses its sincere gratitude to the examiners, examination officers, and all other stakeholders who contributed to the preparation of this report.

Prof. Said Ally Mohamed
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report provides a comprehensive analysis of the candidates' responses in the Chemistry subject of the Advanced Certificate of Secondary Education Examination (ACSEE) 2025. The examination comprised three papers: 132/1 Chemistry 1, 132/2 Chemistry 2, which were theory papers, and 132/3 Chemistry 3, which was the practical paper. The practical paper was offered in three equivalent alternative papers: 132/3A Chemistry 3A, 132/3B Chemistry 3B, and 132/3C Chemistry 3C, in which candidates were required to sit for only one of these alternatives.

Chemistry 1 paper had two sections, A and B, with a total of ten (10) questions. Section A consisted of seven (7) short-answer questions, with 10 marks each. Section B comprised three (3) structured essay questions, weighing 15 marks each. The candidates were required to answer all questions in Section A and only two questions from Section B. The Chemistry 2 paper comprised six (6) questions, each carrying 20 marks. The candidates were required to answer a total of five (5) questions. The Chemistry 3 paper comprised three (3) questions, of which question 1 carried 20 marks while questions 2 and 3 carried 15 marks each. The candidates had to respond to all three questions.

The Candidates' Item Response Analysis (CIRA) report employs a categorisation system based on the percentage of marks scored out of the allocated marks to assess the performance on each question. Performance is classified as good (60 – 100%), average (35 – 59%), or weak (0 – 34%), represented by green, yellow, and red colours, respectively.

The Chemistry examination was attempted by 46,762 candidates, out of which 45,395 (97.23%) candidates passed. Thus, the overall performance of candidates was good. In the previous year (2024), 38,715 candidates (97.43%) out of 39,917 passed the examination. Thus, by comparison, the candidates' performance has decreased by 0.20 per cent from the previous year.

This report consists of five sections. The Introduction outlines the structure and rubric of Chemistry papers and introduces the performance classification criteria for ACSEE 2025. It also compares the overall performance of candidates in the 2024 and 2025 Chemistry examinations.

The second section covers The Analysis of the Candidates' Performance on Each Question, which examines the candidates' responses to each question. Statistical data and samples of good and weak responses from the candidates support this analysis. Readers will gain insights into what the candidates were able or unable to do concerning the demands of the question. The section further analyses misconceptions observed during the marking of the candidates' scripts and therefore suggests solutions for future improvement.

The third section constitutes the Analysis of Candidates' Performance on Each Topic. Additionally, a comparison of candidates' performance topic-wise in 2024 and 2025 has been appended.

The fourth and fifth sections of the report comprise Conclusions and Recommendations, respectively. The conclusion part provides overall observations on the strengths and weaknesses of the candidates' responses to the examination questions. The recommendation part outlines appropriate measures to address the identified challenges from the candidates' responses aimed at improving future examinations.

2.0 ANALYSIS OF CANDIDATES' PERFORMANCE ON EACH QUESTION

This section analyses the candidates' responses to the question in Chemistry papers 1, 2, and 3. The analysis begins with the demands of a particular question, followed by data analysis, a detailed description of the candidates' responses, and relevant sample extracts of the candidates' scripts.

2.1 132/1-CHEMISTRY 1

This was a theory paper which consisted of sections A and B with a total of ten (10) questions. In section A, the candidates were required to answer all seven (7) questions, each weighing 10 marks, making a total of 70 marks. In section B, the candidates were required to answer two (2) out of the three (3) questions, each weighing 15 marks, making a total of 30 marks. The topics that were examined include *The Atom, Chemical Bonding, Relative Molecular Masses in Solution, Chemical Equilibrium, Gases, Energetics, Aliphatic Hydrocarbons, Environmental Chemistry, Selected Compounds of*

Metals, and *Aromatic Hydrocarbons*. The pass mark in section A was 3.5 marks, while that for section B was 5.5 marks.

2.1.1 Question 1: Aliphatic Hydrocarbons

The question had two parts: (a) and (b). In part (a), the candidates were required to describe five unique properties of carbon which enable it to form so many compounds. In part (b), the candidates were required to give structures and assign the correct names of the following organic compounds (i – v) according to IUPAC rules:

(i) 2,2-dimethyl-3-pentene

(ii) 3-ethyl-4-heptene

(iii) 2-methyl-4-heptene

(iv) 2,2,3-methylbutane

(v) 5-methyl-3-bromo-3-ethyl-hexane.

This question was attempted by 46,762 (100%) candidates. Among them, 15.35 per cent scored from 0 to 3 marks; 24.77 per cent scored from 3.5 to 5.5 marks, and 59.88 per cent scored from 6 to 10 marks. Thus, the candidates who scored 3.5 marks or above were 84.65 per cent, indicating good performance in this question. Figure 1 summarises the candidates' performance on this question.

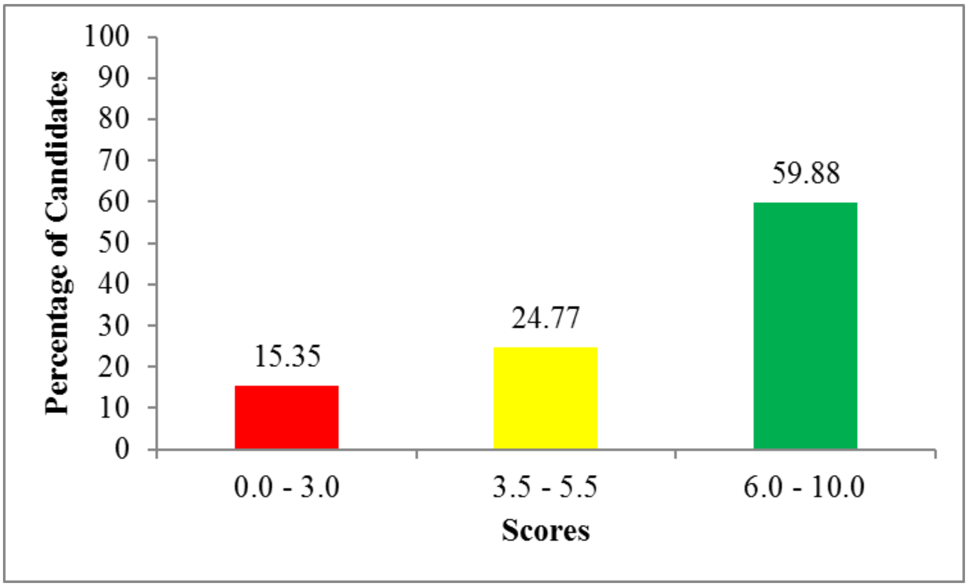


Figure 1: *Candidates' Performance on Question 1, Paper 1*

Candidates who scored high marks (59.88%) in this question had adequate knowledge of the unique properties of carbon, enabling it to form so many compounds as required in part (a) of the question. Additionally, in part (b), the candidates demonstrated a good understanding of the rules used in IUPAC naming of organic compounds, as evidenced by their correct naming of the compounds. Extract 1.1 is a sample of proper responses to question 1.

1. (a) (i) It can form multiple bonds

- It can form single, double or triple bonds

(ii) It can form long carbon chains

- By a process called catenation

(iii) It can form strong covalent bonds

- It can form strong covalent bonds with itself (carbon) and other non-metals

(iv) It can exist in various forms (allotropes)

- Diamond and graphite are both made of carbon

(v) It can undergo many different types of hybridisation

- It can undergo sp, sp^2 or sp^3 hybridisation

(b) (i)

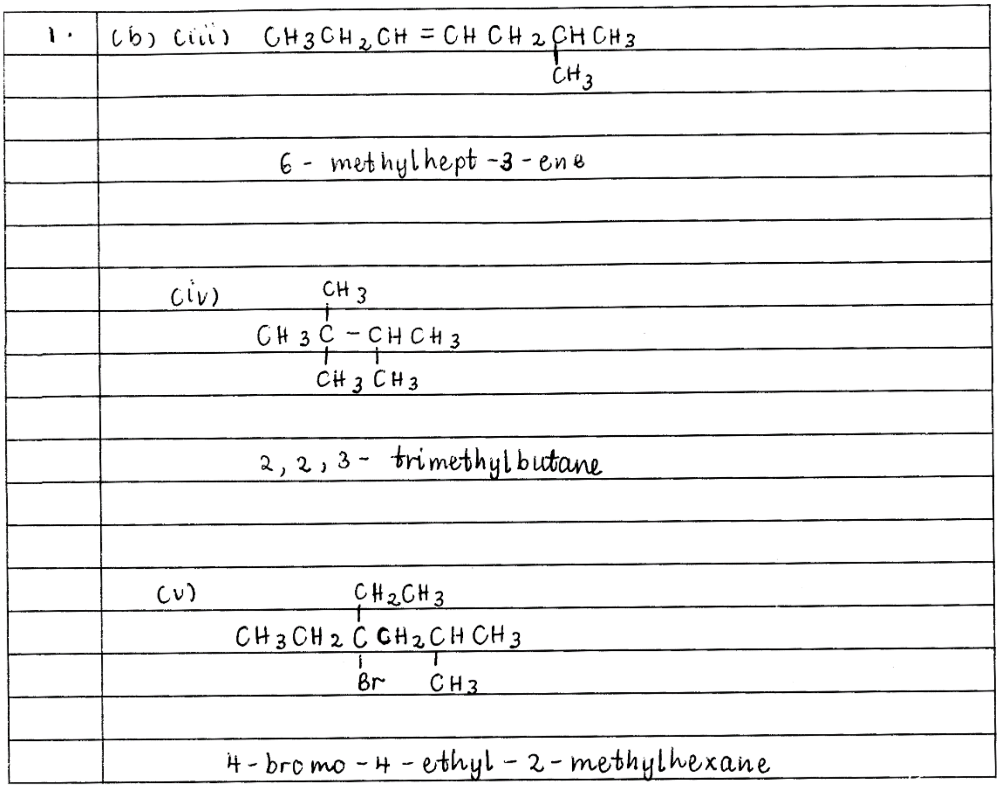
$$CH_3-\overset{\displaystyle CH_3}{\underset{\displaystyle CH_3}{\overset{|}{\underset{|}{C}}}}-CH=CH-CH_3$$

4,4 - dimethylpent-2-ene

(ii)

$$CH_3CH_2\underset{\displaystyle CH_2CH_3}{\underset{|}{C}}HCH=CHCH_2CH_3$$

5 - ethylhept-3-ene


1. (b) (iii) $CH_3CH_2CH=CHCH_2CH(CH_3)CH_3$

6-methylhept-3-ene

(iv) $CH_3C(CH_3)_2-CH(CH_3)CH_3$

2,2,3-trimethylbutane

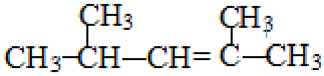
(v) $CH_3CH_2C(Br)(CH_2CH_3)CH_2CH(CH_3)CH_3$

4-bromo-4-ethyl-2-methylhexane

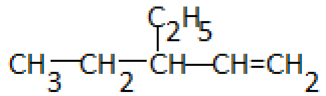
Extract 1.1: A sample of correct responses to question 1, paper 1

In Extract 1.1, the candidate correctly described five unique properties of carbon as a catalyst in part (a). In part (b), the candidate demonstrated good mastery of IUPAC rules of nomenclature by assigning correct names to all the organic compounds given.

On the other hand, candidates who scored low marks (15.35%) demonstrated inadequate knowledge of the properties of carbon and the naming of organic compounds. For instance, the candidates responded to part (a) by giving incorrect properties of carbon, such as *carbon is found in group IV, Carbon is a non-metal,* and *Carbon is black*, which are irrelevant to the uniqueness of carbon in terms of organic concept. In part (b), these candidates failed to draw the correct structural formulas of the compounds and, at the same time, lacked knowledge of the rules followed in IUPAC naming of organic compounds, hence giving incorrect names for the compounds. For instance, one candidate wrote the structure of 2,2-dimethyl-3-pentene as



and the corresponding IUPAC name as 2,4-dimethyl-3-pentene. Another candidate wrote the correct structural formula of 3-ethyl-4-heptene



with a corresponding incorrect IUPAC name as 3-ethyl-2-heptene. A sample of the incorrect responses to this question is shown in Extract 1.2

1a	Unique propertres of carbon atom
	i, Cabonation
	→ Carbon Is ~~cab~~ capable of holding charge of 4^+
	ii, Valency
	→ Carbon posses a ~~cb~~ valency of 4.
	iii, Ionization and Electron affinity.
	→ As Ionisation Increase decreases with electron affinity
	iv, Bond strength
	→ Carbon Is carbon of bonding with carbon Itself or
	other atom In a long chain e.g c-c-c-c-c
	v, It posses Pi bond In It's chain.
b,	Soln
i,	2,2-dimethyl-3-pentene
	Structure
	Correct IUPAC name;
ii,	3-ethyl-4-pheptene
	Structure
	Correct IUPAC name; methyl.

Extract 1.2: Sample of incorrect responses to question 1, Paper 1

In Extract 1.2, the candidate gave inappropriate chemical properties of carbon in part (a). In part (b), the candidate did not provide structures and wrote incorrect names, implying that they were unfamiliar with IUPAC rules of naming organic compounds.

2.1.2 Question 2: Chemical Bonding

The question had two parts: (a) and (b). In part (a), the candidates were expected to give 4 points justifying the statement that *"Hydrogen bonding is essential in sustaining life."* Part (b) (i), the candidates were required to give reasons as to why $AlCl_3$ is covalent while AlF_3 is ionic. In part (b) (ii), the candidates were required to identify the shapes of molecules given and the type of hybrid orbital shown by the underlined atom; $\underline{Be}F_2$, $\underline{N}O_3^-$, and $\underline{B}F_3$.

The question was attempted by 46,762 (100%) candidates. The analysis of statistical data shows that 27.07 per cent scored from 0 to 3 marks, 28.45 per cent scored from 3.5 to 5.5 marks and 44.48 per cent scored from 6 to 10 marks. The general performance on this question was good since 72.93 per cent of the candidates scored 3.5 marks or above. A summary of candidates'performance on this question is shown in Figure 2.

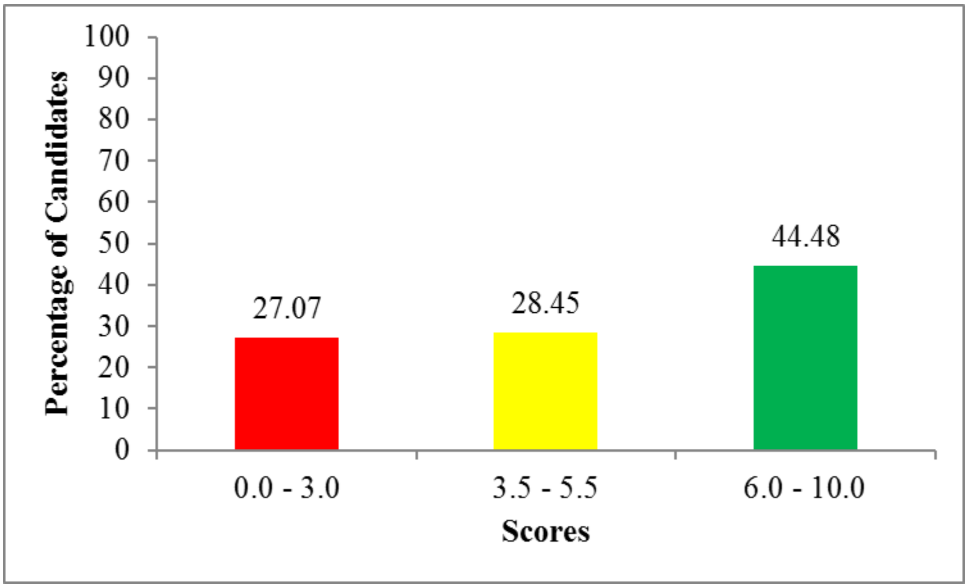


Figure 2: *Candidates' Performance on Question 2, Paper 1*

The candidates who performed well (44.49%) in this question gave four points reflecting the importance of hydrogen bonding in part (a). In part (b) (i), the candidates showed good mastery of the concept of polarizability of anions as they gave a correct explanation on the covalence nature of and the ionic nature of AlF_3. They applied the concepts of electronegativity difference and anion polarizability to respond to the question. Primarily, chlorine has higher polarizability than fluorine, making it more covalent and less AlF_3 ionic. In part (b) (ii), the candidates gave correct geometrical shapes of the molecules together with the hybridisation of the underlined atoms. Extract 2.1 is a sample of the proper responses to this question.

02@	Importanc of Hydrogen Bonding in sustaining life.
i)	Anomolous Behaviour of Water
	Hydrogen bonding Leads to the formation of Ice cubes which have less Density than that of water and Thus as a Result floats on water. This Behaviour Helps sea Animals To survive During winter and the sea or Ocean freezes on top but not at the bottom.
ii)	Hydrogen bond makes water to have High Boiling point High Boiling point signifies high latent of vapourization which Means for water to change to vapour state, high Amount of energy Is Needed. This play a basic function on cooling of an organism by sweating.
iii)	Due to Hydrogen bonding Many solute can dissolve In water by the formation of Hydrogen bond with water. This Enables Absorbtion of Nutrients In the body by water such as Mineral salts, water solubL Nutrients
iv)	Hydrogen bond Is Important In the formation of various bond in different molecules found in the body of an organisms such as In the DNA helix

2 b) (I) This is because Aluminium is a small cation and Chlorine is a large anion thus they will undergo high degree of polarisation making the resultant bond weak and hence covalent unlike Aluminium and Fluorine ions have generally small sizes and vary much in their electronegativity, hence electrons will be transfered from Aluminium to Fluorine resulting to ionic compound.

(II) $\underline{Be}F_2$ F − Be − F

Underlined atom :- Beryllium (Be)
Atomic number, Z = 4
Electronic configuration
At ground state [He] $2s^2$
At excited state [He] 2s $2p^1$

During hybridisation

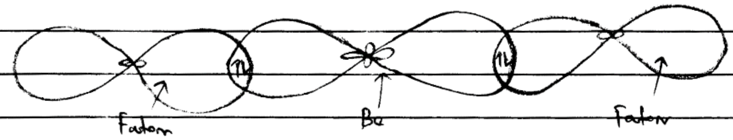
s p
| 1 | | 1 | | |

undergoes sp hybridisation

| 1 | 1 | | |

F F

Be will undergo sp hybridisation and thus have linear shape with sp hybrid orbital



BeF_2 molecule

2 b) (ii)

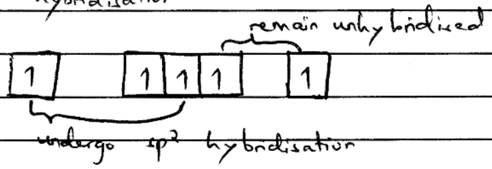
$\underline{N}O_3^-$

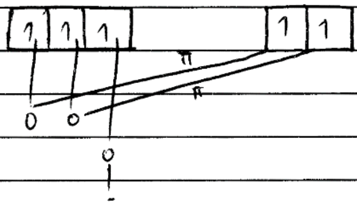
$$\overset{O^-}{\overset{|}{O=N=O}}$$

Underlined atom, Nitrogen (N)
Atomic number, Z = 7
Electronic configuration
At ground state [He] $2s^2$ $2p^3$

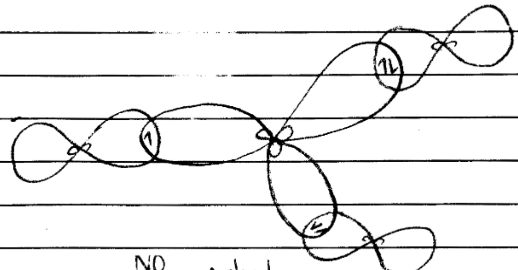
At excited state [He] $2s$ $2p^3$ $3s^1$

During hybridisation



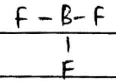


NO_3^- has undergone sp^2 hybridisation
Shape :- trigonal planar shape
Hybrid orbital :- sp^2 hybrid orbital



NO_3 molecule

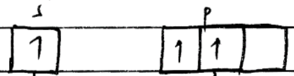
2 b) (ii) $\underline{B}F_3$



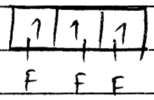
Underlined atom :- Boron (B)
Atomic number, $Z = 5$
Electronic configuration
At ground state $[He]\ 2s^2\ 2p^1$

At excited state $[He]\ 2s^1\ 2p^2$

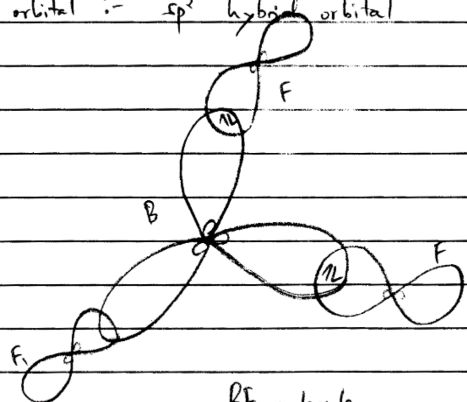
During hybridisation



undergo sp^2 hybridisation



BF_3 has undergo sp^2 hybridisation
Shape :- Trigonal planar shape
Hybrid orbital :- sp^2 hybrid orbital



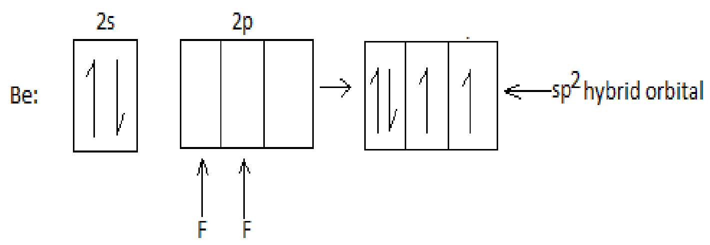
BF_3 molecule

Extract 2.1: Sample of correct responses to question 2, Paper 1

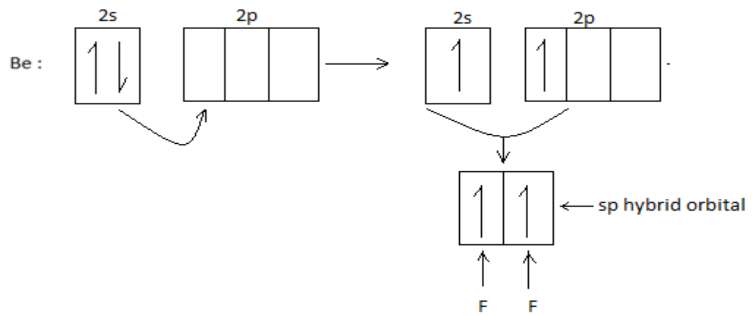
In Extract 2.1, the candidate gave correct points on the importance of hydrogen bonding in part (a). In part (b), the candidate properly used the concept of polarizability in explaining the covalency and ionic character of

$AlCl_3$ and AlF_3, respectively. They also provided the correct geometrical shapes and types of hybridisations of the given chemical species.

On the contrary, the candidates who scored low marks (31.23%) provided general effects of hydrogen bonding instead of specifying how it sustains life in part (a). In part (b) (i), they lacked knowledge to explain the two bonding states of the compounds. In sub-part (ii), the candidates did not know how to determine the type of hybridisation of the underlined atoms in the molecules, as well as their geometrical shapes. These candidates used the method of orbitals but failed to determine the correct hybridisation. These candidates were unable to write the proper electronic configuration of the valence shell of the underlined atoms. For example, some candidates sketched diagrams showing *sp*^{2} hybridisation for $\underline{Be}F_2$ as;



Instead of *sp* hybridisation as:



Extract 2.2 shows a sample of incorrect responses from one of the candidates in this question.

2.	a/ Hydrogen bonding, there is the reaction formed when most electro positive element are combine with hydrogen.
	The following are the importance of hydro gen bonds
	i/ It help in formation water which can be used by different organism for their life process.
	ii/ It help for the formation of clouds in the atmosphere.
	iii/ Helps in the chemical reaction process.
	iv/ Help in condensation and evaporation process on the body.
	b/ (i) $AlCl_3$ covalent while AlF_3 is ionic because $AlCl_3$ they have large structure than AlF_3 which have small structure.

2b(ii)	Be
	→trigonal planar
	N = tetrahedral
	B – linear.

Extract 2.2: Sample of incorrect responses to question 2, Paper 1

In Extract 2.2, the candidate had no idea of what hydrogen bonding is, hence gave an incorrect response in part (a). In part (b) (i) the candidate, gave a reason about size, which does not correspond to the different properties of the compounds. In part (b) (ii), the candidate assigned molecular geometry (shapes) instead of hybridisation to the underlined elements.

2.1.3 Question 3: Chemical Equilibrium

The question had two parts: (a) and (b). Part (a) of the question was as follows;

(a) A reaction to produce ammonia gas from nitrogen and hydrogen gas, was carried in 3.5 litres vessel at 375℃ and had a Kc value of 1.5 mol^2 dm^{-6} according to the following equation: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

A sample drawn from the vessel and analysed contains 0.25 moles of $N_2(g)$*, 0.0032 moles of* $H_2(g)$ *and* 6.42×10^{-4} *moles of* $NH_3(g)$

(i) Establish whether the reaction system has attained equilibrium or not when the sample was analysed.

(ii) State the direction of the reaction.

(b) Given the following system at equilibrium:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -188\ kJ\ mol^{-1}.$

Predict the changes in concentration of SO_3 *if;*

(i) The pressure of the system is increased

(ii) A noble gas is added such that the pressure of the system increases and the volume changes occur.

(iii) More SO_3 *is added to the system*

(iv) The temperature of the system is increased.

The question was attempted by 46,762 (100%) candidates. The analysis of statistical data indicates that 31.23 per cent scored from 0 to 3 marks, 24.68 per cent scored from 3.5 to 5.5 marks, while 44.09 per cent scored from 6 to 10 marks. The overall performance on this question was good as 68.77 per cent scored 3.5 marks or above, as shown in Figure 3.

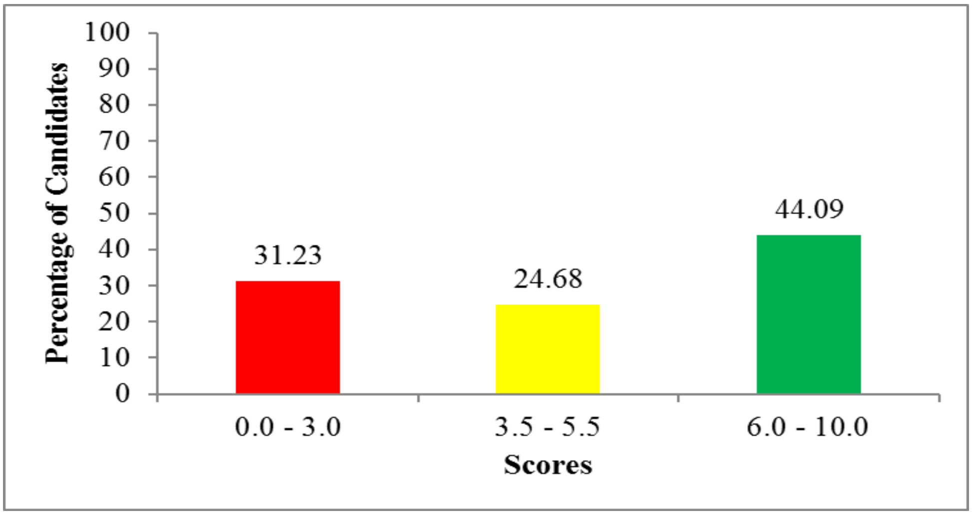


Figure 3: *Candidates' Performance on Question 3, in paper 1*

The candidates who performed well in this question (44.09%) had a good understanding of the general concept of chemical equilibrium. In part (a), the candidates carried out mathematical manipulations and determined the value of the reaction quotient (Q), which was greater than the equilibrium constant (Kc). Therefore, the candidates concluded that the reaction would shift towards the left as the system was not at chemical equilibrium. In part (b), the candidates applied the concept of Le-Chatelier's principle and responded appropriately to all parts of the question. Extract 3.1 shows a sample of correct responses to question 3.

$$RQ = \frac{[NH_3]^2}{[H_2]^3[N_2]}$$

but

$$[NH_3] = \frac{moles}{V} = \frac{6.42 \times 10^{-4}}{3.5}$$

$$[NH_3] = 1.834 \times 10^{-4}\ mol/dm^3$$

$$[N_2] = \frac{0.25}{3.5} = 0.0714\ mol/dm^3$$

$$[H_2] = \frac{0.0032}{3.5} = 9.1428\ mol dm^{-3} \times 10^{-4}$$

$$RQ = \frac{(1.834 \times 10^{-4})^2}{(9.1428 \times 10^{-4})^3 (0.0714)}$$

$$RQ = \frac{3.3635 \times 10^{-8}}{5.45677 \times 10^{-11}}$$

$$RQ = 616.389$$

(i) The reaction is not at equilibrium because the value of RQ is greater than Kc.

(ii) The direction of the reaction is Backward or left direction since the product concentrations are more compared to the reactants concentrations.

3 (b) (i) If pressure will be increased
iii) There will be increase in the
concentration of SO_3 since increase
in pressure will cause the position
of equilibrium to move foward
producing large amount of SO_3.

(iv) iii) If noble gas is added:-
- The concentration of SO_3 will increase
since the noble gas is inert gas
it cause the increase in pressure
which causes the foward reaction to
produce more SO_3.

(iii) If more SO_3 is added:-
- The concentration of SO_3 will decrease
since increases in concentration of SO_3
favours backward reaction to produce
SO_2 and O_2 hence the concentration
of SO_3 will be reduced.

(iv) If Temperature increased.
- The concentration of SO_3 will decrease
because increase in Temperature for
exothermic reaction, favours backward
reaction where SO_3 will dissociates
more to produce more SO_2 and O_2.

Extract 3.1: Sample of correct responses to question 3, Paper 1

In Extract 3.1, the candidate correctly calculated the value of Q and compared it with Kc in part (a). In part (b), the candidate precisely predicted the outcomes of varying the different factors, implying good mastery of Le Chatelier's principle.

On the contrary, some candidates (31.23%) did not perform well in this question. These candidates had inadequate knowledge of the general concept of chemical equilibrium and its related calculations. They were unable to determine the correct value of reaction quotient Q. They could not relate the value of Q obtained with the value of Kc to determine the equilibrium state and direction of equilibrium required in part (a). In this part, many candidates applied incorrect formula for calculating the reaction quotient as

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

$$Q = \frac{[NH_3]}{[N_2][H_2]}.$$

This formula is incorrect because the concentrations of NH_3 and H_2 should be raised to their stoichiometric coefficients, which are 2 and 3, respectively.

In part (b), the candidates failed to predict the changes in equilibrium positions when altering the conditions given. For instance, in part (b) (i), some of the candidates predicted that an increase in pressure would shift the equilibrium to the left instead of the right. This shows that candidates lacked adequate knowledge on how to apply Le Chatelier's principle. Similarly, other candidates failed to relate the heat change of the reaction to the equilibrium position. They suggested that an increase in temperature shifts the equilibrium to the right, without realising that since the reaction is exothermic, the equilibrium position would shift to the left. Extract 3.2 shows a Sample of incorrect responses to question 3.

Q3	(a) Data given.
	Volume = 3.5 Litre
	Temperature = 375°C + 273 = 648K
	Kc = 1.5 mol/1dm-6
	Equation $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
	mole (0.025 mole (N_2))
	mole (0.0032 (H_2g))
	mole (6.42 X10-4 (NH_3))
	i) The reaction system had attained attained Equilibrium is not equilibrium because Qc (50.313 is greater than the KC (6.5X10.
	(ii) The direction of the reaction will be charged because Qc is greater than Kc.
	$2NH_3 \rightleftharpoons N_{2(g)} + 3H_{2(g)}$.

03 (b)

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

(g)

(i) when the pressure of the system is increased the concentration of SO_3 will notbe affected since pressure does not affect the concentration of the gas

(ii) If a noble gas is added it does not react with any gas thus the change in volume of the system will lead to the change in concentration of SO_3.

(iii) If more SO_2 is added to a system this means that we increase the number of mole hence increase in concentration of SO_2 occurs.

(iv) when the temperature of the system is added / or increase the equilibrium will shift to backward direction thus decrease the concentration of SO_3

Extract 3.2: Sample of incorrect responses to question 3, Paper 1

In Extract 3.2, the candidate converted temperature on the Celsius scale into Kelvin, which was not necessary in part (a). The candidate skipped the calculation of the reaction quotient, thus failing to indicate the direction of the equilibrium position. Similarly, the predictions stated in part (b) were incorrect.

2.1.4 Question 4: The Atom

This question had two parts; (a) and (b) as follows:

(a) Determine the maximum number of electrons, that can be associated with each of the following sets of quantum numbers:

(i) $n = 4,\ \ell = 2$.

(ii) $n = 2,\ \ell = 1,\ m_\ell = -1$.

(iii) $n = 3$, $\ell = 2$, $m_\ell = -2$, $ms = -½$.

(b) *Excited hydrogen atom gives many emission lines. One of the series of lines called Bracket series occurs in the infrared region. It occurs when an electron jumps from higher energy level orbitals to energy level n = 4. Calculate the wavelength of the lowest energy lines of this series.*

The question was attempted by 46,762 (100%) candidates. Among them, 59.70 per cent scored from 0 to 3 marks, 22.77 per cent scored from 3.5 to 5.5 marks and 17.53 per cent scored from 6.0 to 10 marks. Thus 40.30 per cent scored 3.5 marks or above, implying that the overall performance of the candidates in this question was average. The summary of candidates' performance on this question is shown in Figure 4.

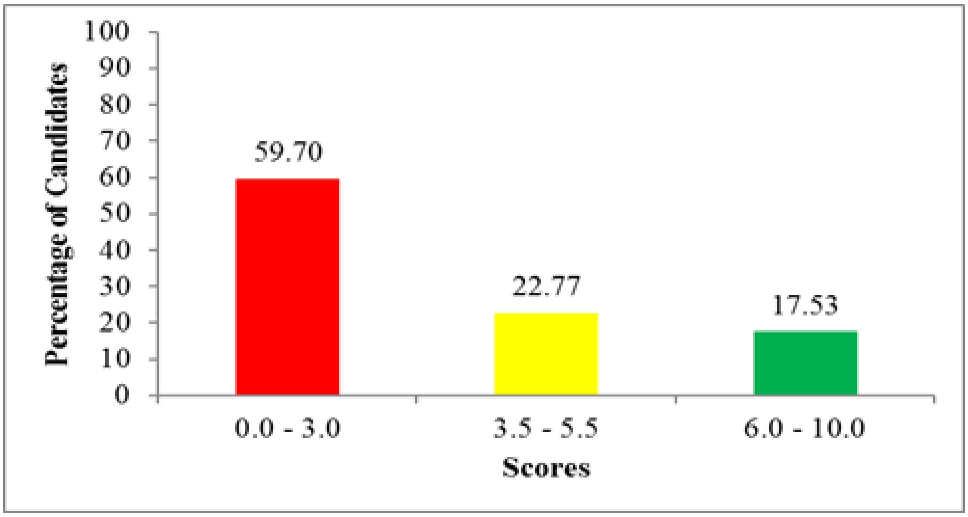


Figure 4: *Candidates' Performance on Question 4, in Paper 1*

The candidates who scored highly in this question, (17.53%) had good mastery of the general concept of quantum numbers and how they are inter-related, leading to correct responses in part (a). In part (b), the candidates had adequate understanding of hydrogen emission spectrum and correctly applied Rydberg's equation to calculate the required wavelength.

Extract 4.1 shows a sample of the correct responses to this question.

4a a. i. n: 4

n	4
l	2
ml	-2, -1, 0, 1, 2
ms	$\pm\frac{1}{2}$, $\pm\frac{1}{2}$, $\pm\frac{1}{2}$, $\pm\frac{1}{2}$, $\pm\frac{1}{2}$

∴ there are 10 electrons.

ii. n: 2, l: 1, ml: -1

n	2
l	1
ml	-1
ms	$\pm\frac{1}{2}$.

∴ there are (2) two electrons.

iii. n: 3, l: 2, ml, -2, ms $-\frac{1}{2}$

n	3
l	2
ml	-2
ms	$-\frac{1}{2}$

∴ there is one (1) electrons.

4. b. $n_1 = 4$

$n_2 = 5$

From.

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{4^2} - \frac{1}{5^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{16} - \frac{1}{25}\right)$$

$\frac{1}{\lambda} = 246825$

$\frac{1}{\lambda} = X\ 246825$

$\frac{246825\lambda}{246825} = \frac{1}{246825}$

$\lambda = 4.0515 \times 10^{-6}\ m.$

$\therefore$ the wavelength is $4.0515 \times 10^{-6}\ m.$

Extract 4.1: Sample of correct responses to question 4, Paper 1

In Extract 4.1, the candidate gave the correct number of electrons in each set of quantum numbers given in part (a). In part (b), the candidate correctly identified n=5 as the highest energy line as the source of the electron, and n=4 as the destination, thereafter calculating the correct wavelength.

On the other hand, the candidates who scored low marks (59.70%) gave incorrect responses in part (a) due to a lack of adequate knowledge on the concept of quantum numbers. For example, some candidates incorrectly used the formula $2n^2$ (which uses only the principal quantum number n) to determine the number of electrons, instead of relating n to the other quantum numbers, as follows: For n = 4 and l = 2, the relationship of the quantum numbers should be as follows.

n = 4																
l = 0	1			2					3							
m_l= 0	-1	0	+1	-2	-1	0	+1	+2	-3	-2	-1	0	+1	+2	+3	
m_s =	-			± ½	±½	±½	±½	±½							-	

total number of electrons = 10

In part (b), the candidates also used an incorrect formula to calculate the wavelength of the lowest energy line by assuming the lowest energy line as ∞ instead of n=5 as required. In the same way, some candidates mistakenly wrote Rydberg's formula, instead of leading to the wrong value of the wavelength. However, some candidates used the correct Rydberg's equation but substituted numbers by interchanging the values of n_1 and n_2, hence got incorrect answers. For instance, one candidate substituted the data as $\frac{1}{\lambda} = 1.097 \times 10^7 \left[\frac{1}{5^2} - \frac{1}{4^2} \right]$ which resulted in an incorrect wavelength. Extract 4.2 shows a sample of incorrect responses given by one of the candidates.

4.

(a)

(i)

n	4								
l	0	1			2				
ML	0	-1	0	1	-2	-1	0	1	2
MS	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$

∴ The total number of electrons is 18

(ii)

n	2			
l	0	1		
ML	0	-1	0	1
MS	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$	$\pm\frac{1}{2}$

∴ The total number of electrons is 4

(iii)

n	3								
l	0	1			2				
ML	0	-1	0	1	-2	-1	0	1	2
MS	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$

∴ The total number of electrons is 9

4\. b/

Soln

$n_1 = 1$

$n_2 = 4$

Required wavelength.

From

$$\frac{1}{\lambda} = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 m^{-1} \left[\frac{1}{1^2} - \frac{1}{4^2}\right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 m^{-1} \left[\frac{1}{1} - \frac{1}{16}\right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 m^{-1} \left(937.5 \times 10^{-3}\right)$$

$$\frac{1}{\lambda} = 10.28 \times 10^6$$

$$\lambda = \frac{1}{10.28 \times 10^6}$$

$$\lambda = 9.723 \times 10^{-8} A^\circ$$

∴ The wavelength of the lowest energy lines of this series are $9.723 \times 10^{-8} A^\circ$

Extract 4.2: Sample of incorrect responses to question 4, Paper 1

In Extract 4.2, the candidate indicated incorrect spin quantum numbers (m_s) of electrons in part (a). In part (b), the candidate used the correct Rydberg equation; however, they applied the incorrect energy levels in the Brackett series, resulting in an incorrect wavelength.

2.1.5 Question 5: Gases

The question had two parts: (a) and (b) as follows:

(a) *Use the kinetic equation to deduce the Graham's law.*

(b) (i) *At the ends of a horizontal glass tube, plugs of cotton wool soaked in concentrated ammonia solution and concentrated hydrochloric acid are inserted simultaneously. After a short time, a white ring of solid ammonium chloride forms at a certain point in the tube. If the distance between the inner surfaces of the cotton wool plugs is 50 cm, how far from the ammonia plug does the ammonium chloride ring form?*

(ii) *What is the molar mass of gas* ***Z****, if it takes 54.4 seconds for 100 cm^3 of gas* ***Z*** *to effuse through an aperture and 36.5 seconds for 100 cm^3 of oxygen gas to effuse through the same aperture?*

The question was attempted by 46,762 (100%) candidates. The data indicates that 39.48 per cent scored from 0 to 3 marks, 21.71 per cent scored from 3.5 to 5.5 marks and 38.82 per cent scored from 6 to 10 marks. The overall performance of the candidates on this question was good since 60.52 per cent of the candidates scored 3.5 marks or above. The candidates' performance in this question is summarised in Figure 5.

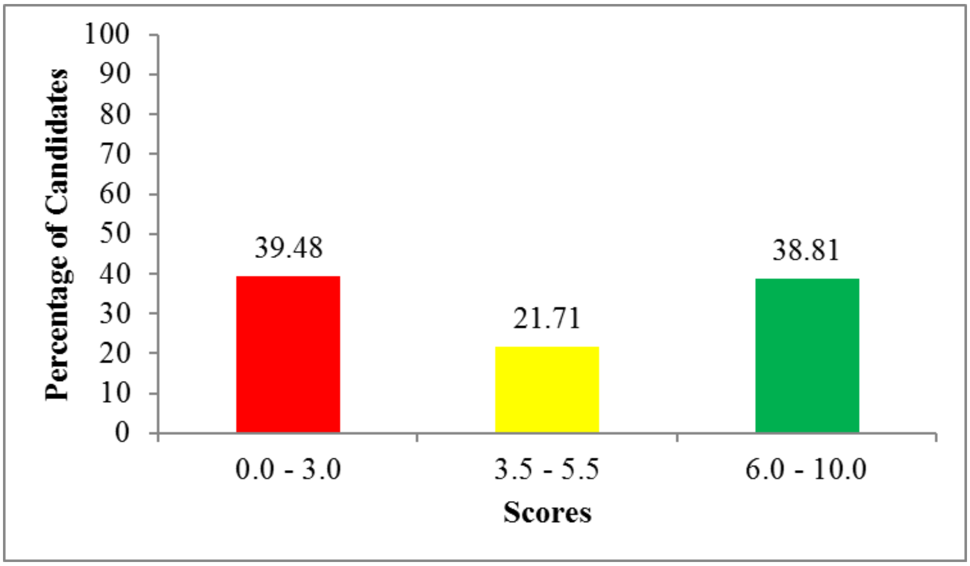


Figure 5: *Candidates' Performance on Question 5, Paper 1*

The candidates who scored high marks (38.82%) derived Graham's law based on the fact that the average velocity (v) of a gas is inversely proportional to the square root of the mass of the molecule m (which is related to the molar mass M) in part (a). Thus, they indicated that the rate of diffusion (r) of a gas is inversely proportional to the square root of its molar mass. In part (b), the candidates applied Graham's law to calculate the distance travelled by gases and the molar mass of gas Z. Extract 5.1 shows a sample of correct responses from a candidate who scored high marks in this question.

5 a. Grahams law

$$R \propto \frac{1}{\sqrt{\rho}}$$

From

$$PV = \frac{1}{3} Nm\bar{c}^2$$

But $m = \rho V$

$$P\cancel{V} = \frac{1}{3} N\rho \cancel{V} c^2$$

5 a

$$P = \frac{1}{3} N\rho\bar{c}^2$$

$\times 3$

$$\frac{3P}{N\rho} = \frac{N\rho\bar{c}^2}{N\rho}$$

$$\sqrt{c^2} = \sqrt{\frac{3P}{N\rho}}$$

$$c = \sqrt{\frac{3P}{N\rho}}$$

Rate = c

$$R = \sqrt{\frac{3P}{N\rho}}$$

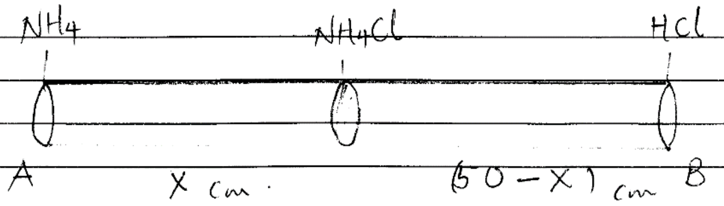
Whe $\frac{3P}{N}$ is constant

Whe $\frac{3P}{N}$ is constant

$R = k\sqrt{\frac{1}{\rho}}$

$R \propto \sqrt{1/\rho}$ hence shown

b



5 b) Soln.

From Graham's law

$$\frac{R_A}{R_B} = \sqrt{\frac{Mr_B}{Mr_A}}$$

$$\left(\frac{x}{50-x}\right)^2 = \left(\sqrt{\frac{36.5}{18}}\right)^2$$

$$\frac{36.5}{18} = \frac{x^2}{2500 - 50x - 50x + x^2}$$

$$\frac{36.5}{18} \times \frac{x^2}{2500 - 100x + x^2}$$

$$91250 - 3650x + 36.5x^2 = 18x^2$$

$$91250 - 3650x + 18.5x^2$$

By solving

$$x = 29.37 \text{ cm}$$

∴ The distance from ammonia plug was 29.37 cm.

ii Soln

Given

$t_z = 54.4$ sec

$t_o = 36.5$ sec

$Mr_o = 18.32$ g/mol

$M_z = ?$

5b	ii From graham's law
	$\frac{R_O}{R_Z} = \sqrt{\frac{Mr_Z}{Mr_O}}$
	But rate = $1/t$.
	& $\frac{t_Z}{t_O} = \sqrt{\frac{Mr_Z}{Mr_O}}$.
	$\left(\frac{54.4}{36.5}\right)^2 = \left(\sqrt{\frac{Mr_Z}{32}}\right)^2$
	$\frac{Mr_Z}{32} = \frac{\cancel{1.449}\ 2.221}{1}$ $\times$
	$Mr_Z = \cancel{47.169}$
	$Mr_Z = 71.08$ g/mol.
	∴ The molar Mass of Z = 71.08 g/mol.

Extract 5.1: Sample of correct responses to question 5, Paper 1

In extract 5.1, the candidate has derived Graham's law from the kinetic theory of gases in part (a). In part (b), the candidate has applied correct mathematical manipulations in addition to Graham's law, in calculating the relative distances of diffusion between two gases in subpart (i) and the molar mass of the unknown gas in subpart (ii).

On the contrary, the candidates who scored low marks (39.48%) had inadequate knowledge of the kinetic theory of matter, hence failed to deduce Graham's law from the kinetic theory equation of gases in part (a). Some of them used the relation $PV = {}^{2}/_{3}Nmu^2$ or PV= nRT instead of $PV = {}^{1}/_{3}Nmu^2$. The candidates failed to generate the root mean square velocity from the kinetic equation of gases. In part (b), the candidates were unable to integrate the given parameters with Graham's law. For instance, one candidate wrote the relation $\frac{R_1}{R_2} = \sqrt{\frac{M_1}{M_2}}$ instead of $\frac{R_1}{R_2} = \sqrt{\frac{M_2}{M_1}}$ in calculating the molar mass of the given gas. Other candidates wrote the correct formula but failed to substitute the provided data correctly, resulting in incorrect values of molar mass. Extract 5.2 shows a sample of incorrect responses from one of the candidates in this question.

5a Grahams law.

$$R \propto \sqrt{\frac{Mr}{1}} \qquad R \propto \sqrt{Mr}$$

From,

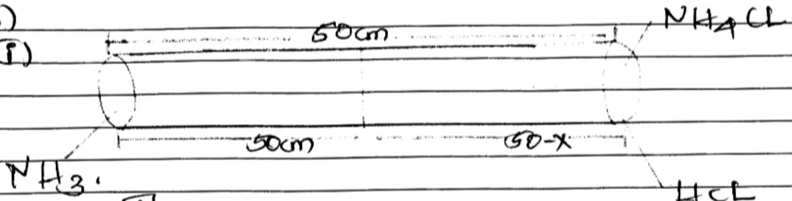
$$K.E = \frac{1}{2} m v^2 RT$$

$$V = C$$

$$K.E = \frac{1}{2} mc^2 RT$$

$$K.E = \frac{1}{3} NmC^2 RT$$

05. (b)
(i)



Then

$$\frac{50-x}{50} = \sqrt{\frac{mr_{\cancel{HCL}\,NH_3}}{mr_{\cancel{NH_3}\,HCL}}}.$$

$$\frac{50-x}{50} = \sqrt{\frac{17}{36.5}}$$

$$\frac{50-x}{50} = \sqrt{\frac{17}{36.5}}$$

$$\frac{50-x}{50} = 0.682$$

$$50 - x = 34$$

$$x = 16\ cm$$

Extract 5.2: Sample of incorrect responses to question 5, Paper 1

In extract 5.2, the candidate used incorrect formulae in part (a) by including the term RT. In part (b) the substitution of values was incorrect.

2.1.6 Question 6: Selected Compounds of Metals

The question had three parts: (a), (b) and (c) as follows:

(a) By using balanced chemical equations, explain the following observations:

(i) A dark brown colour is produced when dilute hydrochloric acid is added to solution containing potassium iodide and potassium iodate

(ii) Iodine is more soluble in aqueous solution of potassium iodide than in water.

(b) By using three specific examples, show that the solutions of salts formed from strong acids and weak bases are acidic.

(c) When a solution of barium hydroxide [$Ba(OH)_2$] is mixed with a solution of sulphuric acid, a white precipitate forms and the electrical conductivity of the solution decreases markedly.

(i) Write a balanced chemical equation for the reaction that occurs.

(ii) Account for decrease in electrical conductivity.

The question was attempted by 46,762 (100%) candidates in which those who scored from 0 to 3, were 93.24 per cent, 3.5 to 5.5 marks were 4.88 and those who scored from 6 to 10 marks were 1.88 per. Generally, the performance in this question was weak as only 6.76 per cent of the candidates scored 3.5 marks or above. The summary of the candidates' performance in this question is shown in Figure 6.

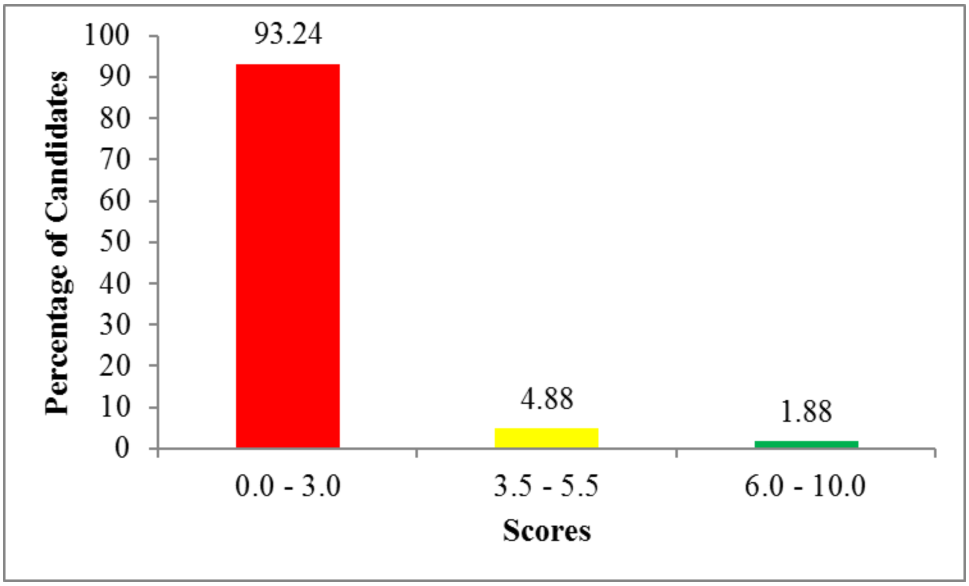


Figure 6: *Candidates' Performance on Question 6, Paper 1*

Candidates who scored low marks (93.24%) wrote incorrect balanced chemical equations for the reactions taking place between dilute HCl and KI, as well as KIO3, in part (a). For instance, some candidates wrote an incorrect chemical equation as $HCl + KI + KIO_3 \rightarrow KCl + H_2O + HI$ and hence were not able to deduce colour changes due to the formation of I_2. Other candidates wrote the formula of potassium iodate as KIO_2 instead of KIO_3. Similarly, other candidates suggested that iodine is less soluble in water because it is non-polar, which is not true. They wrote that iodine is non-polar, contrary to the fact that water, being a polar solvent, cannot dissolve a non-polar solute.

In part (b), these candidates lacked adequate knowledge of the formation of acidic salts from weak bases and strong acids. They also failed to write correct hydrolysis reaction equations to prove the acidic nature of the salts. For instance, some candidates wrote NH_4Cl as an acidic salt, but wrote the hydrolysis reaction equation as $NH_4{}^+ + H_2O \rightarrow NH_4OH$ instead of $NH_4{}^+ + H_2O \rightarrow NH_3 + H_3O^+$ in which the presence of H_3O^+ indicates the acidic nature of the salt. In part (c), most candidates gave incorrect products of the chemical reaction. For example, one of the candidates wrote the incorrect precipitation reaction equation as $Ba(OH)_2 + H_2SO_4 \rightarrow Ba(SO_4)_2 + H_2O$, in which the formula for barium sulphate was incorrect ($BaSO_4$). Furthermore, these candidates were unable to relate the precipitation process to the reduction of ions in solution, which lowers the electrical conductivity of the solution mixture. Extract 6.1 shows incorrect responses to question 6 given by one of the candidates.

6 a (i) A dark brown Colour is produced
Because,
The Iodide has a tendency of forming Complex Compound wich is dark brow in Colour with HCL solution

$HCl + KI_2 \longrightarrow ClI + KHI_2$

Dark Brown Colour

(ii) This is because Iodine is organic solvent it can be soluble in organic Solvent due to its Polority nature.

b. Strong Acids.

$2HCL + NaO \longrightarrow NaCl_2 + H_2O$

(salt)

$2HCl + CaO \longrightarrow CaCl_2 + H_2O$

(Salt)

$H_2SO_4 + MgO \longrightarrow MgSO_g + H_2O + O$

~~(Salt)~~

Weak bases.

$MgCO_3 + NaO \longrightarrow NaCO_3 + MgO$

salt.

6

C. i) $[Ba(OH)_2] + H_2SO_4 \longrightarrow BaSO_4 + 4H_2O + SO_2^{-2}$

White Precipitates

ii) The electrical Conductivity has decreased due to formation of white precipitate and $BaSO_2$ is a poor Conductor of electricity.

Extract 6.1: Sample of incorrect responses to question 6, Paper 1

In Extract 6.1, the candidate gave an incorrect formula and unbalanced equations in part (a). The candidate also gave an incorrect interpretation of the resulting products. The candidate failed to understand the source of the brown colour in the solution when there are iodide ions. In part (a)(ii), the candidate had insufficient knowledge of how complex compound formation affects the solubility of a substance. In parts (b) and (c), the candidate has demonstrated a complete lack of knowledge of the concepts being tested, such as solubility, acids, bases, and salts.

On the other hand, candidates who scored high marks in this question (1.88%) pointed out that the characteristic dark brown colour was due to iodine (I_2) produced in the redox reaction in part (a). In part (b), the candidates showed that solutions of salts formed from strong acids and weak bases are acidic because of proton-donor species (acidic ions) formed.
In part (c), the candidates gave the correct equation showing the reaction between $Ba(OH)_2$ and sulphuric acid. Additionally, the candidates explained that the formation of barium sulfate (a white precipitate) caused a decrease in ion concentration and, consequently, a reduction in the conductivity of the solution. Additionally, some candidates suggested that decreased conductivity occurs because hydroxide ions and hydrogen ions combine to form water.

Extract 6.2 shows a sample of the correct responses to this question.

6.b) Iron (iii) Chloride is an acidic salt.
Formed from:-
$3HCl_{(aq)} + Fe(OH)_{3(s)} \rightarrow FeCl_{3(aq)} + 3H_2O_{(l)}$.

$FeCl_3$ is acidic salt as shown below:-
It hydrolises in water to form hydroxonium ions (acidic).
$FeCl_3 + H_2O \rightarrow [Fe(OH)_6]^- + H_3O^+$
(acidic media)

Aluminium chloride is an acidic salt.
Formed from reaction of hydrochloric acid (strong acid) and weak base (aluminium hydroxide).

$3HCl_{(aq)} + Al(OH)_{3(aq)} \rightarrow AlCl_{3(aq)} + 3H_2O_{(l)}$

$AlCl_3$ hydrolises in water to give acidic media.

$AlCl_{3(aq)} + H_2O_{(l)} \rightarrow [Al(H_2O)_5OH]^{2+} + H_3O^+$
acidic.

6 b) - Ammonium chloride is an acidic salt.
It is formed from strong acid (HCl) and weak base NH_4OH.

$HCl_{(aq)} + NH_4OH_{(aq)} \rightarrow NH_4Cl_{(aq)} + H_2O_{(l)}$

~~NH_4OH /hydrolises in wa~~
NH_4Cl hydrolices in water to form acidic media.

$NH_4Cl_{(aq)} + H_2O_{(l)} \rightarrow NH_4OH_{(aq)} + Cl^- + H^+$

OR

$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightarrow NH_4OH_{(aq)} + H^+_{(aq)}$

shows acidic media

6c) i) $Ba(OH)_{2(aq)} + H_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2H_2O_{(l)}$.
(white precipitate)

ii) Electrical conductivity is lowered due to the decrease in free ions from $Ba(OH)_2$ as they will be reaching with sulphuric acid to form precipitate.
- Therefore charge carriers (ions) are ~~de~~ reduced hence decreasing electrical conductivity.

Extract 6.2: Sample of correct responses to Question 6, Paper 1

2.1.7 Question 7: Energetics

The question had two parts, namely (a) and (b).

(a) *Explain the applicability of Hess's law of constant heat summation.*

(b) (i) *Calculate the lattice energy ($\Delta H_{L.E}$) of a solid calcium chloride given the information that the heat of sublimation (ΔH sub) for calcium is +11 kJ mol-1 and its first and second ionisation potentials (ΔHip) are +33.5 kJ mol-1 and* $+ 65.2$ kJ mol^{-1}, *respectively. The heat of dissociation (ΔH_{diss}) for chlorine is* $+13.9$ kJ mol^{-1} *and the electron affinity (ΔH_{aff}) for the chlorine atom is –20.8 kJ mol^{-1}. The standard heat of formation (ΔH°_f) of* *the solid calcium chloride is* $-45.4 \text{ kJ mol}^{-1}$.

(i) *If* Ca^+ *and* Cl^- *ions formed a hypothetical crystal, CaCl(s) with its lattice similar to that of* $CaCl_2$, *the lattice energy for the hypothetical CaCl would be* $+43 \text{ kJ mol}^{-1}$. *Use this value to calculate the heat of formation of the hypothetical CaCl*

(ii) *Which of the two* $CaCl_2(s)$ *or CaCl(s) has a stable crystal lattice? Briefly explain your answer.*

Statistics show that 46,762 (100%) candidates attempted the question, in which 78.72 per cent scored from 0 to 3 marks, 13.45 per cent scored from 3.5 to 5.5 marks, and 7.83 per cent scored from 6 to 10 marks. Generally, the candidates' performance in this question was weak, as 21.28 per cent scored 3.5 marks or above. The summary of the candidates' performance in this question is shown in Figure 7.

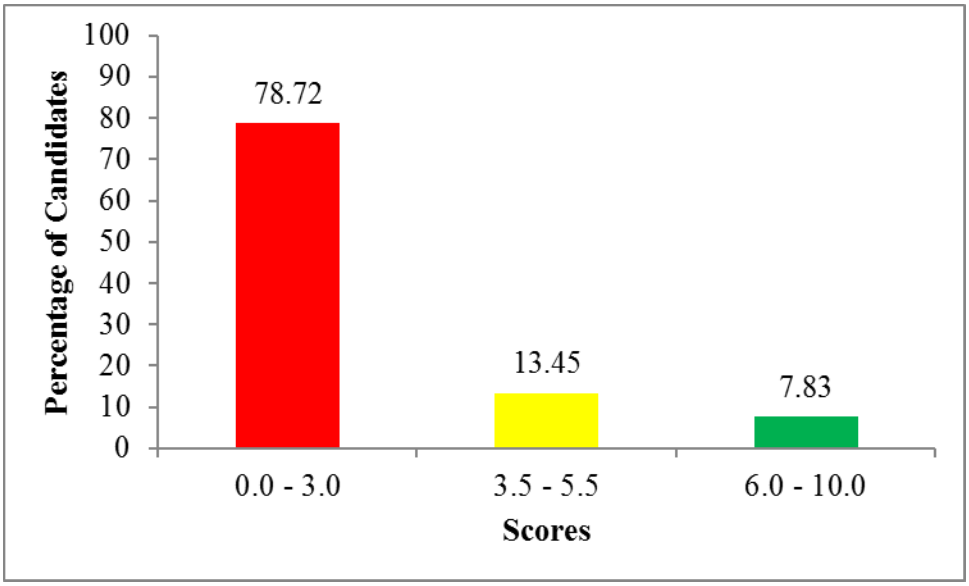


Figure 7: *Candidates' Performance on Question 7, Paper 1*

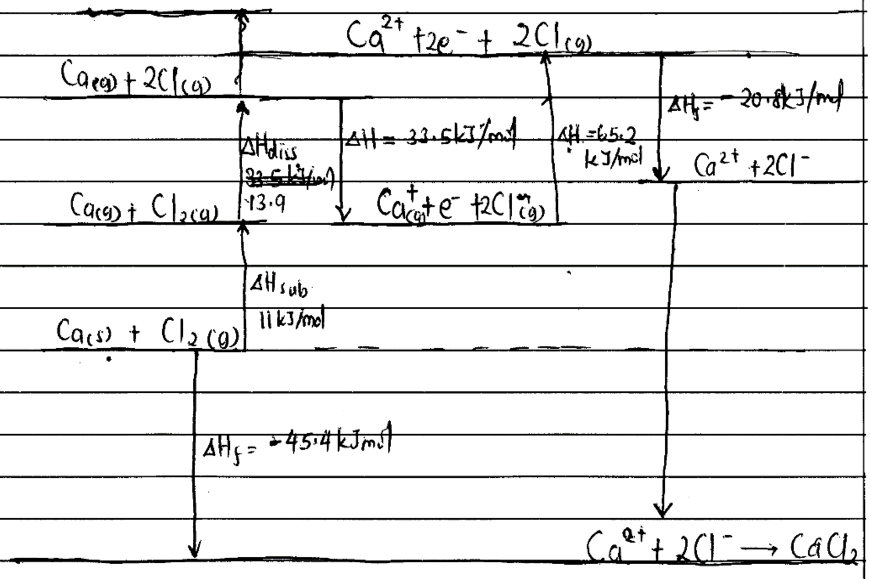
Candidates who scored low marks (78.72%) gave incorrect responses to most parts of the question.

In part (a), these candidates lacked enough knowledge of the applicability of Hess's law. For instance, some candidates resorted to stating Hess's law of heat summation. In part (b), they failed to use the correct formulas in the calculations, leading to incorrect values of lattice energy and heat of formation of the compound in question. In calculating lattice energy for $CaCl_2$ and CaCl, they were confused about when to divide the dissociation energy by two and when not to. For example, one candidate used $\frac{1}{2}\Delta H_{diss}$

of Cl_2 in determining lattice enthalpy for $CaCl_2$, and electron affinity for Cl_2 (E.A×1 and Cl (E.A×2) which were incorrect. For instance, in the formation of CaCl, some candidates used the dissociation energy instead of +6.95 kJ mol^{-1}. The candidates in this category also lacked knowledge of the relationship between the stability of a compound and the enthalpy of its formation, specifically the distinction between very stable (more negative) and unstable compounds (more positive). For instance, one candidate wrote CaCl is more stable because during its formation, more energy is absorbed. Extract 7.1 shows one of the incorrect responses in this question.

07(a) It is mostly applied in thermochemical equilibriums.
It is also applied in reactions involving final and initial states of reactants and products.

(b)(i)



Lattice energy = $H_f - (\Delta H_{sub} + \Delta H_{diss} + \Delta H_{ip_1} + \Delta H_{ip_2})$.

$= -45.4 - (102.8)$

$= -148.6$ kJ/mol

Lattice energy = -148.6 kJ/mol.

7(b)(ii)	
	Lattice energy = $H_f - (\Delta H_{sub} + \Delta H_{diss} + \Delta H_{ip})$.
	$+43 kJ/mol = H_f - (11 + 33.5 + 13.9) kJ/mol$
	$43 + 58.4 = H_f$
	$H_f = 101.4 kJ/mol$
	Heat of formation of hypothetical CaCl is 101.4kJ/mol
(iii)	$CaCl_2$ has a stable crystal lattice, because its rate of formation
	takes a long time compared to $CaCl_2$ and thus also its rate
	of breaking required shorter time and thus its lattice structure is
	not strong compared to CaCl.

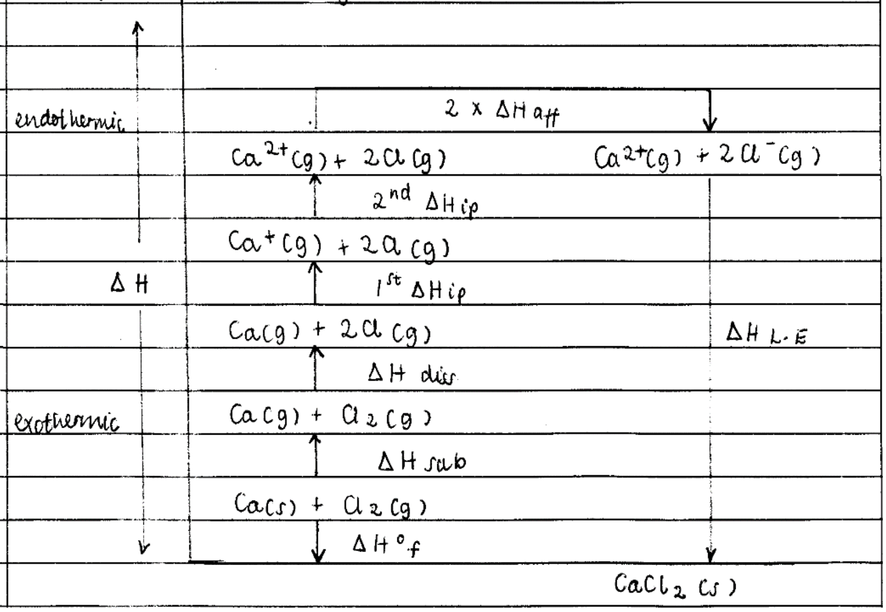
Extract 7.1: Sample of incorrect responses to question 7, Paper 1

In Extract 7.1, the candidate has provided incorrect applications of Hess's law, as well as incorrect formulas, in calculating the lattice energy and heat of formation. Again, the candidate does not know the relationship between stability and heat change. For instance, the candidate has explained stability in terms of the time it takes to form, rather than the enthalpy of formation.

Contrarily, candidates who scored high marks (7.82%) correctly attempted most parts of the question. In part (a), they gave the correct applicability of Hess's law, such as comparing fuel energies and estimating energy changes in metabolic pathways. In part (b) of the question, the candidates correctly applied Hess's law in calculating lattice energy (NaCl) and the heat of formation of the hypothetical compound (CaCl). They used the two values to determine the stability of the compound based on the evolution of heat (more stable) and the absorption of heat (less stable). This implies that they had sufficient knowledge of heat changes and their practical applications. Extract 7.2 shows a sample of the correct responses to this question.

7. (a) It is used to find the enthalpy change of a reaction since Hess's law of constant heat summation states that " The enthalpy change of a given reaction is the same independent of the route taken "

(b) (i) Born-Haber cycle for $CaCl_2$ (s)



7. (b)(i) From Hess's law of constant heat summation :

$\Delta H^\circ_f = \Delta H_{sub} + \Delta H_{diss} + 1^{st}\,\Delta H_{ip} + 2^{nd}\,\Delta H_{ip} + 2\Delta H_{aff} + \Delta H_{LE}$

$-45.4 = 11 + 13.9 + 33.5 + 65.2 + (2 \times -20.8) + \Delta H_{LE}$

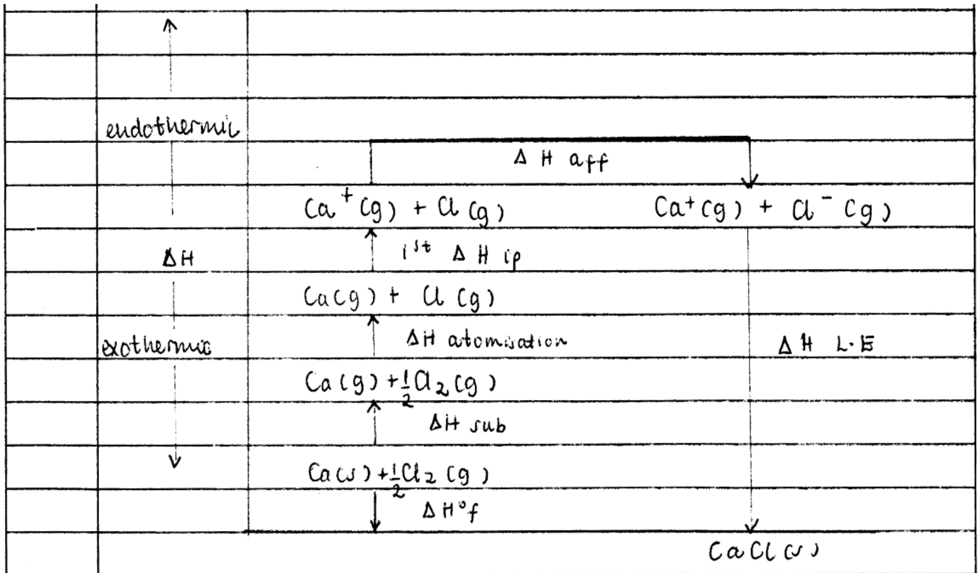
$-45.4 = 82 + \Delta H_{LE}$

$-127.4 = \Delta H_{LE}$

$\Delta H_{L.E} = -127.4 \text{ kJmol}^{-1}$

Lattice energy of a solid calcium chloride $= -127.4 \text{ kJmol}^{-1}$

(a) Born-Haber cycle for hypothetical CaCl (s)



$2 \times \Delta H$ atomisation $= \Delta H$ dissociation

ΔH atomisation $= \dfrac{\Delta H \text{ dissociation}}{2}$

7. (b) (ii) $\Delta H^\circ f = \Delta H sub + \dfrac{\Delta H\ diss}{2} + 1^{st}\ \Delta H\ ip + \Delta H\ aff + \Delta H\ L\cdot E$

$\Delta H^\circ f = 11 + \dfrac{13\cdot 9}{2} + 33\cdot 5 + (-20\cdot 8) + 43$

$\Delta H^\circ f = 73\cdot 65\ KJmol^{-1}$

Heat of formation of hypothetical CaCl $= 73\cdot 65\ KJmol^{-1}$

(iii) $CaCl_2(s)$ has a stable crystal lattice Because it has more negative enthalpy change, a lot of heat is required to break its bonds.

Extract 7.2: Sample of correct responses to question 7, Paper 1

In Extract 7.2, the candidate gave the correct application of Hess's law of constant heat summation in part (a). In part (b), the candidate used an appropriate formula, a diagram of the Born-Haber cycle and correct mathematical manipulations to obtain the required values.

2.1.8 Question 8: Relative Molecular Masses in Solution

The question had three parts, namely: (a), (b), and (c), which were as follows:

(a) (i) What are colligative properties?
(ii) Give two limitations of colligative properties.
(b) A sugar solution with a concentration of 2.5 g dm^{-3}, gave an osmotic pressure of 8.3×10^{-4} *atm at 25°C. Calculate the molecular mass of the solute.*
(c) A solution of Urea (CON_2H_4) contains 1.75 g dm^{-3} in isotonic at the same temperature with a solution of 10 g of a certain sugar in 1dm^3 of an aqueous solution. Calculate the relative molecular mass of the sugar.

The question was opted by 40,160 (85.88%) candidates. Statistics show that 20.27 per cent of the candidates scored from 0 to 5 marks, 22.19 per cent scored from 5.5 to 8.5 marks and 57.54 per cent scored from 9 to15 marks. The general performance on this question was good as 79.73 per cent of the candidates scored 5.5 marks or above. The summary of the candidates' performance in this question is shown in Figure 8.

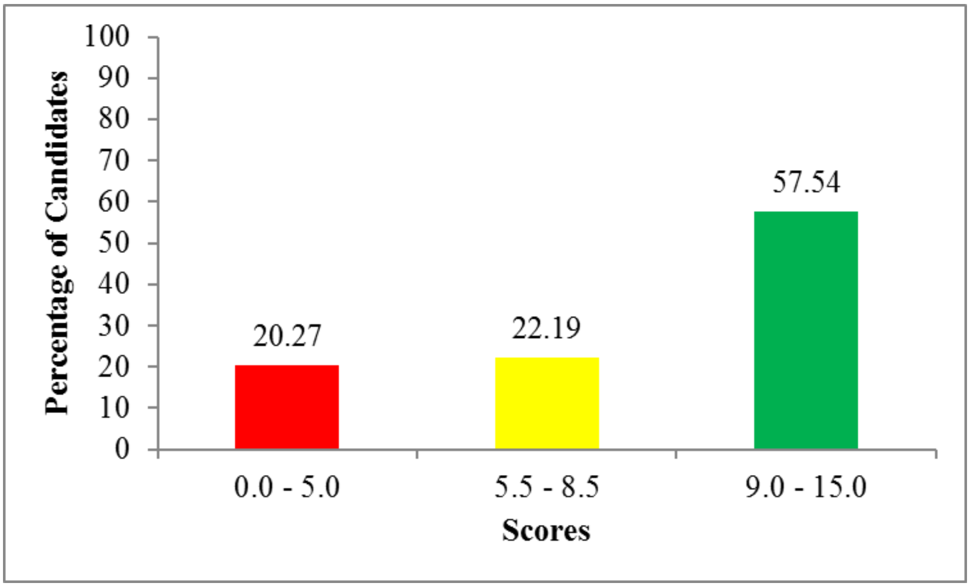


Figure 8: *Candidates' Performance on Question 8, Paper 1*

Candidates who performed well (57.53%) demonstrated a good understanding in part (a) about the general concept of colligative properties that depend on the number of solute particles rather than the nature of the particles. In part (b), the candidates were knowledgeable on the relationship between osmotic pressure and concentration of the solution, hence used correct mathematical manipulations to compute the molecular mass of sugar. In part (c), the candidates compared the osmotic pressure of the two given solutions by applying suitable mathematical manipulations and precisely obtained the molecular mass of the unknown gas. Extract 8.1 is a sample of the correct responses to question 8.

08 a)	i) Colligative properties are the properties that depend on the amount of solute and not the nature of the solute.
	ii) Limitations of colligative properties are.
	i) The solute should non-electrolyte.
	ii) The solution should be dilute.
b)	Given: Conc = $2.5\ gdm^{-3}$
	$P = 8.3 \times 10^{-4}$ atm.
	$T = 25°C // 298\ K$
	required Molecular mass = ??
	From $PV = nRT$.
	$PV = \frac{m}{Mr} RT$.
	$Mr = \frac{mRT}{PV}$

08 b) $Mr = \frac{mRT}{VP}$

but conc = m/v

$Mr = \frac{conc RT}{P}$

$Mr = \frac{2.5 \times 0.0821 \times 298}{8.3 \times 10^{-4}}$

Mr = 73692.1686g/mol.

∴ Molecular mass of the solute is 73692.16867 g/mol.

c) (CON_2H_4) = conc = $1.75 gdm^{-3}$

sugar of mass = 10g.

Vol = $1 dm^3$

required Mr of sugar.

Conc of sugar = $\frac{10g}{1dm^3}$

Conc = $10 gdm^{-3}$.

from CON_2H_4 its molar mass = 60 g/mol.

$\frac{x}{60 g mol} = \frac{10 gdm^{-3}}{1.75 gdm^{-3}}$

$x = \frac{60 g/mol \times 10 gdm^{-3}}{1.75 gdm^{-3}}$

x = 342.857 g/mol.

∴ Molar mass of the sugar will be 342.857 g/mol.

Extract 8.1: Sample of correct responses for Question 8, Paper 1

On the other hand, the candidates who scored low marks (20.27%) were unable to explain the meaning of colligative properties in part (a). For example, some of them incorrectly assumed that colligative properties depend on the nature of the solute rather than the number of solute particles. They also gave incorrect limitations of colligative properties due to a lack of adequate knowledge of the concept. In parts (b) and (c), the candidates applied incorrect mathematical manipulations to determine the molecular masses of the compounds. They also failed to account for similar osmotic pressures for isotonic solutions of urea and an unknown sugar as follows;

$$\pi_{sugar} = \pi_{urea}.$$

$$From\ \pi v = nRT\ or\ n = \frac{\pi v}{RT}$$

$$n_{sugar} = n_{urea}$$

since $n = \frac{m}{Mr}$, then, using the given masses of the solutions and the molar mass of urea, the molar mass of the unknown sugar could be calculated. This demonstrated a lack of mastery of the concept of osmotic pressure. Extract 8.2 shows a sample of incorrect responses to this question.

8. a) colligative properties ; Is the types properties of solute dissolved to form one mole of solvent of a substance.
Example of colligative properties categorized.
→ Osmotic pressure of the substance.
→ Lowering freezing point of a substance.
→ Boiling and melting of substance.

ii) The limitation of colligative properties.
→ It used in the limited osmotic pressure
→ It limited at a certain boiling point such as 100°c of water.

b). Molecular mass of solute.
Data given
Concentration = 2.5g/dm^{-3}.
Pressure = 8.3 x 10^{-4} atm.
Temperature = 25°C.

From the formula = $PV = \frac{nRT}{Mr}$
where by $Mr = \cancel{PV} = \frac{nRT}{\cancel{PV}}$.
$Mr = PRT$
$\therefore Mr = (8.3 \times 10^{-4})(0.0025)(25° + 273°)$

Conc = 2.5g dm^3.

Mr = $\frac{Con}{1000}$ = 2.5g dm ✗

Mr = (2500) (8.3×10^{-4}) (298). = 618.35.

∴ Molecular mass of solute is 618.35 g/mol

Mr.(CON_2H_4) = 60 mol.

c). Mass = 10 g.

Volume = 1 dm^3.

Concentration = 1.75g dm^{-3}

R.M.M = $\frac{\text{Concentration}}{\text{molar mass}}$.

$\frac{1.75g\ dm^{-3}}{1\ dm^3}$ = 1.75g.

R.M.M = $\frac{1.75\ g}{60\ mol}$ = 0.0291

∴ Relative molecular mass of the sugar is 0.0292g/mol

Extract 8.2: Sample of incorrect responses to question 8, Paper 1

In Extract 8.2, the candidate listed colligative properties instead of giving the limitations. In part (b), the candidate used the wrong formula to calculate molar mass, while in part (c), divided mass by volume instead of using the formula for calculating osmotic pressure.

2.1.9 Question 9: Aromatic Hydrocarbons

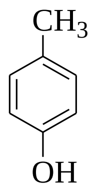
The question had three parts (a), (b) and (c) as follows:

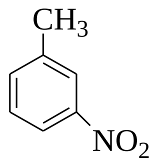
(a) Describe briefly the following with reference to substitution reactions on benzene

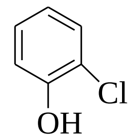
(i) Activators

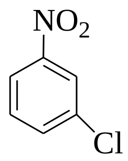
(ii) Deactivators

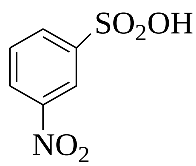
(b) State with reasons, the group which entered the benzene ring first from the following compounds:

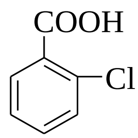
(i)


(ii)


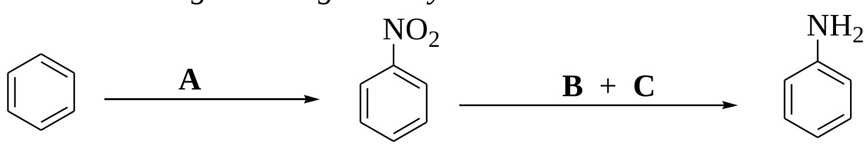
(iii)


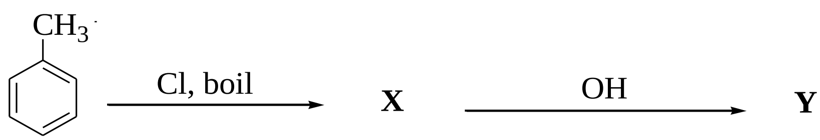
(iv)


(v)


(vi)


(c) Complete the following organic reactions by filling the missing structures and reagents designated by letters.

(i)


(ii)


The question was opted by 24,375 (52.13%) candidates. Analysis of the candidates' performance on this question showed that 13.40 per cent scored from 0 to 5 marks, 23.83 per cent scored from 5.5 to 8.5 marks and 62.87 per cent scored from 9 to 15 marks. These data indicate that 86.70 per cent scored 5.5 marks or above implying that the general performance on this question was good. The summary of the candidates' performance in this question is shown in Figure 9.

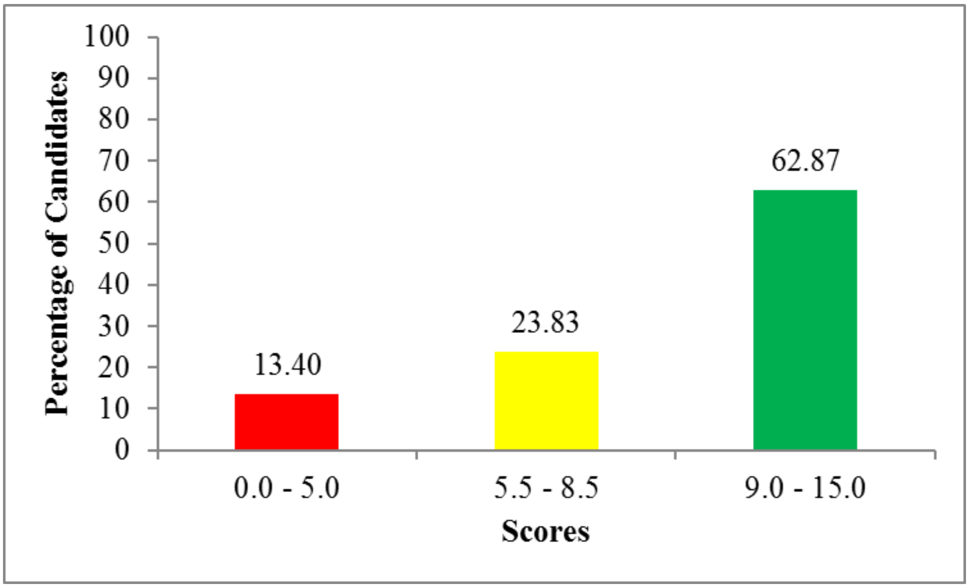


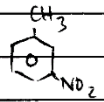
Figure 9: *Candidates' Performance on Question 9, Paper 1*

The candidates who scored high marks (62.87%) in this question described activators that increase the reactivity of benzene ring and deactivators that withdraw electron density from benzene ring thereby decreasing its reactivity in part (a). In part (b), the candidates applied the concepts of activators and deactivators and correctly predicted the groups that entered the benzene ring first. In part (c), the candidates identified the missing structures in relation to the reactions of benzene with various reagents. This implies that the candidates possessed adequate knowledge of different reaction conditions, including the nitration of benzene, reduction of nitrobenzene, chlorination of benzene, and substitution reactions. Extract 9.1 is a sample of the correct responses to this question.

9 b) (I)

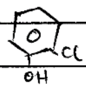
Either methyl (CH_3) or hydroxyl (OH) group has entered first as they are both activators hence either may have directed the other to the para position

(II)



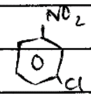
The Nitro (NO_2) group has entered first since it is a deactivator hence has directed methyl (CH_3) to the meta position

(III)



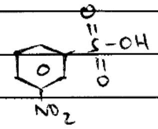
Either of the two groups has entered first since both OH^- and Cl^- are activators hence may direct each other to the ortho position

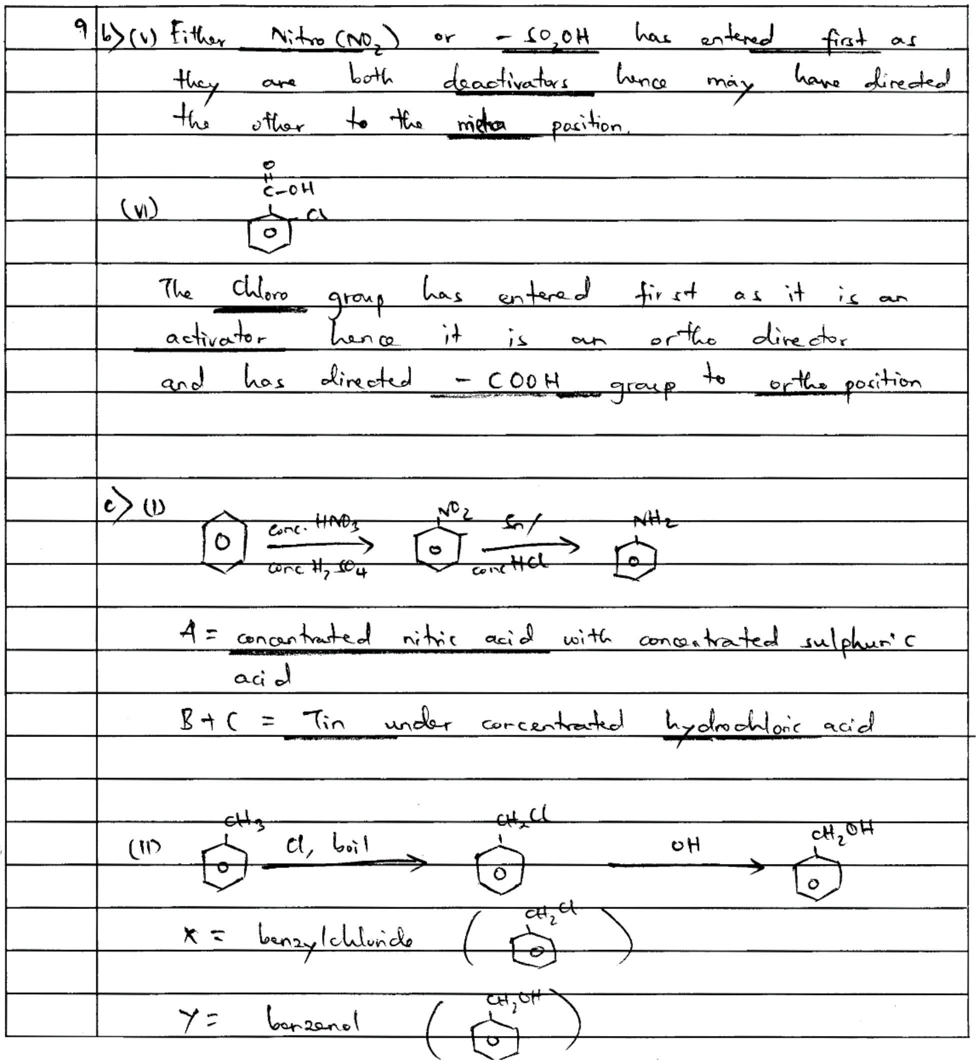
(IV)



The Nitro (NO_2) group has entered first as it is a deactivator hence has directed chloro (Cl) to the meta position

(V)





9 b) (v) Either Nitro (NO_2) or $-SO_3H$ has entered first as they are both deactivators hence may have directed the other to the meta position.

(vi) C–OH Cl

The Chloro group has entered first as it is an activator hence it is an ortho director and has directed – COOH group to ortho position

c) (i) conc. HNO_3 conc H_2SO_4 NO_2 Sn/ conc HCl NH_2

A = concentrated nitric acid with concentrated sulphuric acid

B + C = Tin under concentrated hydrochloric acid

(ii) CH_3 Cl, boil CH_2Cl OH CH_2OH

X = benzylchloride (CH_2Cl)

Y = benzenol (CH_2OH)

Extract 9.1: Sample of the correct responses to question 9, Paper 1

On the other hand, candidates who scored low marks (13.40%) gave incorrect answers to most parts of the question. In their responses to part (a), they lacked knowledge of which substituent increases or decreases electron density on the benzene ring by confusing the effects of activators and deactivators. Additionally, these candidates mixed up the directing effects of activators and deactivators as meta and ortho/para, respectively, instead of correctly assigning ortho/para and meta positions. In part (b), the candidates provided incorrect responses due to insufficient understanding of which substituents act as activators or deactivators, since halogens can be either, depending on whether their resonance effect or negative inductive effect dominates on the benzene ring. Consequently, they were unable to identify which substituent directs to which position or determine which substituent entered the benzene ring first. In parts (c) (i) and (ii), the candidates showed no mastery of benzene's reactivity with specific reagents under various conditions; for example, nitration of benzene occurs only in the presence of concentrated sulphuric acid, and the presence of B+C in the conversion of nitrobenzene to benzene amine indicates two reagents reacting to produce hydrogen, which acts as a reducing agent. Extract 9.2 displays a sample of the incorrect responses to this question.

09	(a) i- Activators. These refers to the compounds
	which tend to start the different chemical
	reaction of Benzene they are acting as the catalyst
	For example Zinc hence they are known as the
	activators.
	ii. Deactivators. Are the chemical compounds
	which tend to end up the chemical reaction
	between benzene and the other chemical
	substances.
	(b) i. The First group is OH, this is because the
	CH_3 is only the attached group to the benzene
	Containing OH known as phenol.
	ii. The First Group is NO_3, as the benzene
	Formely known as the Nitrobenzene but later
	on become attached with CH_3 and known as
	Methyl - Nitrobenzene.

09.	(b) iii. The First group to enter benzene is
	OH group which made benzene to be known
	as phenol and then become attached with Cl
	iv. The First group to enter benzen ring is
	NO_2 which made to be known as Nitrobenzene
	and become attached with Cl and being known as
	the Chloro Nitrobenzene .
	v. The First group is NO_2 .
	vi. The First group is .COOH .

Extract 9.2: Sample of the incorrect responses to question 9, Paper 1

In Extract 9.2, the candidate has demonstrated a lack of clear understanding of the chemical properties of aromatic hydrocarbons in parts (a) and (b). No correct explanations were provided for the activators and deactivators, as well as their directing effects on the benzene ring. In part (c), the candidate failed to fill in the gaps with appropriate reagents and conditions, indicating a lack of sufficient knowledge of electrophilic substitution reactions on the benzene ring and side chain reactions.

2.1.10 Question 10: Environmental Chemistry

The question had three parts (a), (b) and (c) as follows:

(a) What do you understand by the following terms?
(i) Global warming
(ii) Ozone layer

(b) Suppose you got a job at the National Environmental Management Council (NEMC) of Tanzania, and in one of the occasions, you are required to address the residents of a certain area on environmental issues. Briefly, explain the following:
(i) Meaning of the word incineration.
(ii) Two advantages and two disadvantages of incineration.
(iii) Three harmful effects of particulate pollutants.

(c) (i) *What would have happened if the greenhouse gases were totally missing in the earth's atmosphere? Briefly, explain.*
(ii) *Give four damaging effects of an acidic rainfall.*

The question was opted by 28,991 (62.00%) candidates. Analysis of the performance in this question showed that 12.53 per cent scored from 0 to 5 marks; 25.00 per cent scored from 5.5 to 8.5 and 62.47 per cent scored from 9 to 15 marks. The overall performance of candidates in this question was good in which 87.47 per cent of candidates scored 5.5 marks or above. The summary of the candidates' performance is shown in Figure 10.

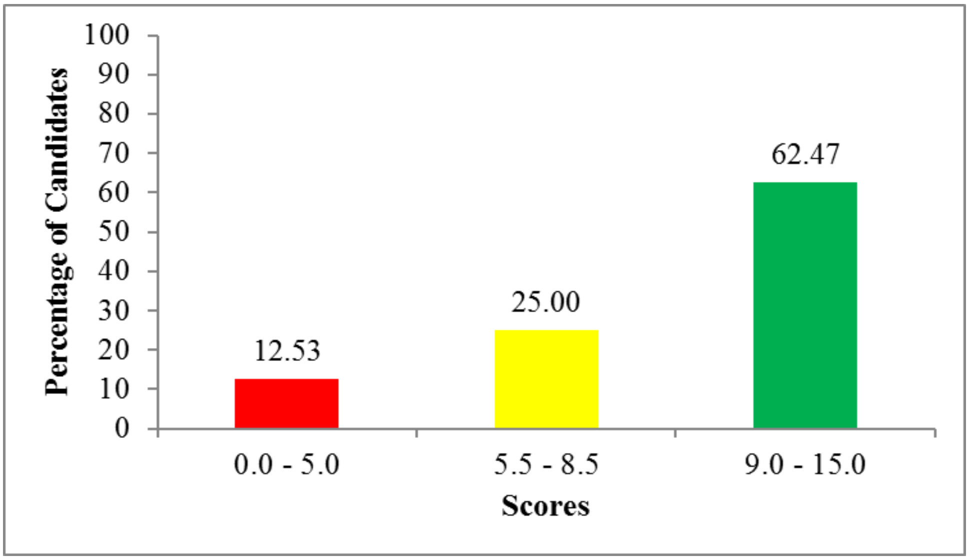


Figure 10: *Candidates' Performance on Question 10, Paper 1*

The candidates who scored high marks in this question (62.47%) had a good understanding of the concept of air pollution in accordance with the requirement of the question in part (a). They also demonstrated a good knowledge of solid waste management, particularly through incineration, and its detrimental effects, such as air pollution and the adverse impact of by-products, including ash, as required by part (b) of the question. In part (c), the candidates demonstrated knowledge of the adverse effects of the absence of greenhouse gases, such as a sudden drop in the Earth's atmospheric temperature, which is detrimental to both agriculture and the water cycle. On the same note, these candidates managed to describe the effects of acidic rainfall on plants, aquatic life, and buildings, which is highly corrosive. This demonstrates good mastery of the general concept of environmental conservation and management. Extract 10.1 is a sample of the correct responses to this question.

10 (a) Global warming refers to the abnormal increase in Temperature or heating effect on the Earth's surface due to various reasons like accumulation of the green house gases to the atmosphere.

(ii) Ozone layer is the protective layer above the Earth's surface which is responsible for absorption of harmful radiation from the sun.

10 (b) Incineration refers to the process which involves effective burning of waste materials especially non-degradable materials under the high Temperature within the inconerator.

(ii) Advantages

- i) Reduction of non-degradable waste materials in the environment
- ii) It ensures completely burning of waste materials

Disadvantage

- i) It cause air pollutions.
- ii) It causes increases of green house gases to the environment

(iii) Effects of particulate pollutant

- i) They cause breathing diseases like asthma diseases
- ii) They cause air pollution since they pollute the air.
- iii) They may cause acidic rainfall and depletion of ozone layer

10	(c) ii overcold of the Earth's surface since
	these gases reflect the sun ~~rays~~
	light hence warming of the Earth's
	surface.
	iii Reduction of the degree of hotness
	of the Earth's surface.
	(c) (ii) Effects of acidic rainfall
	ii) Crops destruction.
	ii) Acidification of water bodies
	iii) Death of microorganisms.
	iv) Acidification of the soil

Extract 10.1: A sample of correct responses to question 10, Paper 1

In Extract 10.1, the candidate has given correct explanations on the meaning of the terms provided in part (a). In parts (b) and (c), the candidate has correctly responded to all parts by thoroughly addressing the question's demands, including the meaning of incineration and its disadvantages, as well as the adverse effects of acidic rainfall and the impact of the absence of greenhouse gases in the atmosphere.

On the contrary, most of the candidates who scored low marks (12.53%) in this question showed inadequate knowledge on the general environmental conservation and management practices especially on aerial pollution, water pollution, and solid waste management. These candidates failed to give precise meaning of global warming, ozone layer, incineration and particulate pollutants. They also failed to relate the decrease in earth's temperature in the absence of greenhouse gases, instead they suggested increase in temperature. Extract 10.2 shows an example of the incorrect responses to question 10.

10 (a) i) Global warming refers to gradual changes of atmospheric temperature

ii) Ozone layer refers to blanket like shape which reduce passage of sun rays to meet earth's surface directly

(b)

i) incineration refers to the introduction of non manufactured fertilizers to the soil which needed to support plant growth in high quantity

ii) Advantages of incineration

- increase fertility of the soil hence increase productivity of the crops or plant where incineration occured

- It cheap to conduct than other which are costful which make many of farmer to use incineration process

Disadvantages of incineration

→ Are difficult to conduct cause take much time compared to other because need time for decomposition

→ pollute environment because of having some of dangerouses insects

10 b) ii) Harmful effects of particulate pollutants

- leads to attack of plants because of having some dangerous insect which attack plant or crops and cause to reduce productivity

- leads to destroy fertility of a soil due to addition of unwanted material on the soil which will lead to plant to not grow well hence wilt

- leads to increase of pH acidity because of addition of some chemicals which could lead to increase soil pH in acidity

c) i) - when ~~green hous~~ greenhouse gases missing will lead cold because no gas which will make allowing passage of sun light which bring hot to atmosphere

-when greenhouse gases missing totally

ii) Damage effects of an acidic rainfall

• leads to cause disease, this due to the acid which are on those rainfall may cause skin cancer due to killing of cell when accumulate those dead cell cause cancer

• leads to desertification, this due to not support plant growth which may leads to make difficult for rainfall formation due to low presence of vegetation cover

10 (a) (i) Global warming.
Refer to the Increase in temperature Than
The normal.

(ii) Ozone layer
Is The layer which found on ~~Strato~~ atmosphere
and its work is to ensure That
Sun rays are not reaching The earth directly

(b) (i) Incineration
Refers to the ~~process of~~ method of disposing
waste in which wastes are Carried to the
Damp and burned.

(ii) Advantage
(i) It removes waste.
(ii) It ensure The environment is clean

disadvantage.
(i) cause ~~smell~~ bad smell nearby people
(ii) it Can cause global warming.

(c) (i) There will be normal temperature on
The earth surface ~~as~~

(ii) - It kills plants
- It kills aquatic organisms.
- It cause sometimes death to people

Extract 10.2: A Sample of incorrect responses to question 10, Paper 1

In Extract 10.2, the candidate responses given in part (a) as the meaning of global warming and the ozone layer are incorrect. In part (b), the candidate did not know the meaning of incineration and particulate pollutants, hence gave incorrect responses in all parts. In part (c), the candidate has suggested that the absence of greenhouse gases increases the Earth's temperature, which is incorrect. Additionally, the candidate's response regarding the damaging effects of acidic rainfall suggested that acidic rainfall causes land pollution, which is wrong. Instead, the effect is felt more on the vegetation onto which it falls and also in the large water bodies (oceans, seas and lakes/rivers), thereby directly affecting the lives of aquatic animals.

2.2 132/2-CHEMISTRY 2

This was a theory paper consisting of six questions, out of which the candidates were required to answer a total of five questions only. Each question carried 20 marks, resulting in a cumulative 100 marks. The examination covered ten (10) topics, including: *Chemical Kinetics; Electrochemistry; Transition metals; Polymers; Extraction of Metals, Periodic Classification; Solubility, Solubility Products, and Ionic Products; Two Components Liquid System; Carboxylic Acids and Derivatives and Amines*. The analysis of each question in this paper is as follows:

2.2.1 Question 1: Chemical Kinetics and Electrochemistry

The question had two parts, (a) and (b) as follows;

*(a) The following results were obtained in a reaction between **X** and **Y** at 293K:*

Experiment No.	***[X]ₒ (mol dm^{-3})***	***[Y]ₒ (mol dm^{-3})***	***Initial rate (mol dm^{-3}s^{-1})***
1	2.1×10^{-6}	2.1×10^{-6}	1.6×10^{-5}
2	2.1×10^{-6}	4.2×10^{-6}	3.2×10^{-5}
3	2.1×10^{-6}	6.3×10^{-6}	4.8×10^{-5}
4	4.2×10^{-6}	6.3×10^{-6}	9.6×10^{-5}
5	6.3×10^{-6}	6.3×10^{-6}	14.4×10^{-5}

(i) From the initial concentrations and rates given in the table, find the rate law for the reaction.

(ii) Calculate the rate constant with its units (Use data from experiment 1).

(iii) Find the initial rate of the reaction when the initial concentrations are $\left[\mathrm{X}\right] = 9.0 \times 10^{-6} \mathrm{mol\ dm^{-3}}$ *and [**Y**] = 1.0 × 10^{-6} mol dm^{-3}.*

(b) *A metallic object to be coated with copper is placed in $CuSO_4$ electrolyte.*

(i) *To which electrode should the object be connected where a direct current power supply flows?*

(ii) *What mass of copper will be deposited if a current of 0.22 A flows through the cell for 1.5 hours?*

The question was attempted by 46,017 (98.42%) candidates, out of which 31,148 (67.68%) scored from 12 to 20 marks, 8,958 (19.47%) scored from 7 to 11.5 marks, and 5,911 (12.85%) scored from 0 to 6.5 marks. These data indicate that 40,106 (87.15%) of the candidates scored 7 marks or above, reflecting good performance. A summary of the performance is presented in Figure 11.

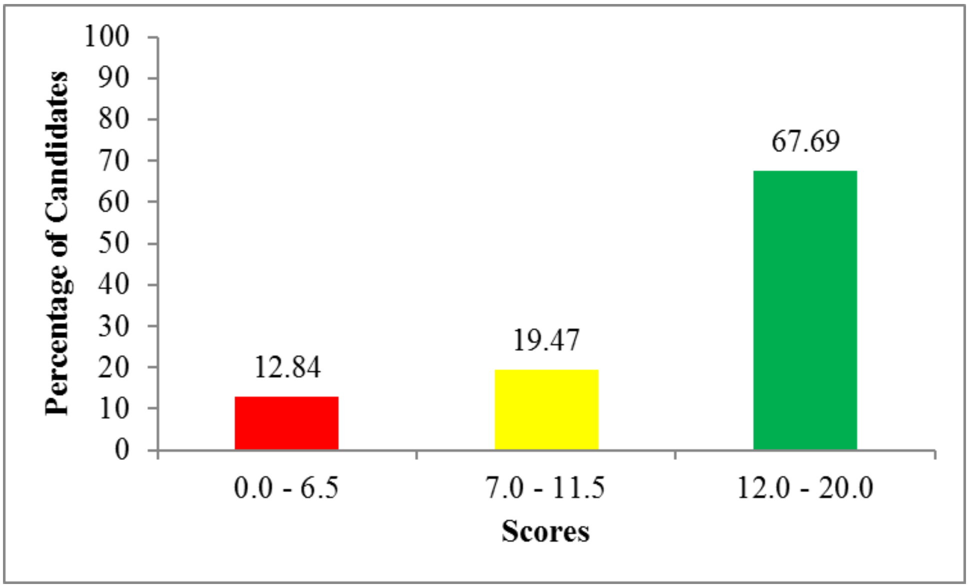


Figure 11: *Candidates' Performance on Question 1, Paper 2*

The candidates who scored high marks in this question (87.15%) demonstrated strong mastery of the concepts involved. In parts (a), they accurately applied the initial rate method to determine the rate law, the value of the rate constant and the initial rate of the reaction, respectively. They correctly formulated the rate law equation, deduced the order of the reaction with respect to each reactant and used accurate data substitution to obtain the required values, including the correct units for the rate constant.

In part (b) (i), the candidates showed a good grasp of the reduction half-reaction and its role in determining electrode placement during electrolysis. They correctly identified that copper undergoes reduction and connected it appropriately in the electrochemical setup. Additionally, in part (b) (ii), they effectively applied Faraday's first law of electrolysis and handled unit conversions properly to calculate the mass of copper deposited. Extract 11.1 provides an example of a correct response from one of the candidates.

1. Soln

(a) from Rate law

$$R = K[X]^a[Y]^b$$

a = Order of X

b = order of Y

Then by using experimen 1 and 2

$$R = K[X]^a[Y]^b$$

$$1.6\times10^{-5} = K[2.1\times10^{-6}]^a[2.1\times10^{-6}]^b \quad \text{--- (i)}$$

$$3.2\times10^{-5} = K[2.1\times10^{-6}]^a[4.2\times10^{-6}]^b \quad \text{--- (ii)}$$

Take eqn (i) ÷ (ii)

$$\frac{1.6\times10^{-5}}{3.2\times10^{-5}} = \frac{K[2.1\times10^{-6}]^a[2.1\times10^{-6}]^b}{K[2.1\times10^{-6}]^a[4.2\times10^{-6}]^b}$$

$$0.5 = \frac{[2.1\times10^{-6}]^b}{[4.2\times10^{-6}]^b}$$

$$0.5 = (0.5)^b$$

$$b = 1$$

By using experiment 3 and 4

$$R = K[X]^a[Y]^b$$

$$4.8\times10^{-5} = K[2.1\times10^{-6}]^a[6.3\times10^{-6}]^b \quad \text{--- (iii)}$$

$$9.6\times10^{-5} = K[4.2\times10^{-6}]^a[6.3\times10^{-6}]^b \quad \text{--- (iv)}$$

Divide eqn (iii) by (iv)

$$\frac{4.8\times10^{-5}}{9.6\times10^{-5}} = \frac{K[2.1\times10^{-6}]^a[6.3\times10^{-6}]^b}{K[4.2\times10^{-6}]^a[6.3\times10^{-6}]^b}$$

$$0.5 = 0.5^a$$

$$a = 1$$

1. (i) The order of X = 1

Y = 1

$R = K[X]^a[Y]^b$

$R = K[X]^1[Y]^1$

∴ The rate law is $R = K[X][Y]$

(ii) Soln

$R = K[X]^a[Y]^b$

$[X] = 2.1 \times 10^{-6}$ mol/dm3

$[Y] = 2.1 \times 10^{-6}$ mol/dm3

$R = 1.6 \times 10^{-5}$ mol dm^{-3}s^{-1}

$$K = \frac{R}{[X][Y]}$$

$$K = \frac{1.6 \times 10^{-5} \text{mol dm}^{-3}\text{s}^{-1}}{(2.1 \times 10^{-6} \text{mol/dm}^3)(2.1 \times 10^{-6} \text{mol/dm}^3)}$$

$K = 3.6281179 \times 10^{6}$ mol^{-1}dm^{3}s^{-1}

∴ The rate constant = 3.6281179×10^{6} mol^{-1}dm^{3}s^{-1}

(iii) Soln

R = ?

$[X] = 9.0 \times 10^{-6}$ mol/dm3

$[Y] = 1.0 \times 10^{-6}$ mol/dm3

from $R = K[X][Y]$

$R = 3.6281179 \times 10^{6}$ mol^{-1}dm^{3}s^{-1} $\times 9.0 \times 10^{-6}$ M $\times 1 \times 10^{-6}$ M

$R = 3.265306 \times 10^{-5}$ mol dm^{-3}s^{-1}

∴ The initial rate of the reaction = 3.265306×10^{-6} mol dm^{-3}s^{-1}

1. b) Soln

(i) The metallic object should be placed at cathode electrode so as to be coated with copper

(ii) Soln

$I = 0.22A$

$t = 1.5$ hours

$= (1.5 \times 60 \times 60)$ seconds

$= 5400$ seconds

$Cu^{2+} + 2\bar{e} \longrightarrow Cu_{(s)}$

from

$Q = It$

$Q = 0.22A \times 5400sec$

$Q = 1188C$

But $1F = 96500C$

$nF\ ? = 1188C$

$nF\ ? = \frac{1F \times 1188C}{96500C}$

$nF\ ? = 0.01231088F$

From the equation

$2F \longrightarrow 1mol$ of Cu

$0.01231088F \longrightarrow ?$

$? = \frac{0.01231088F \times 1moL}{2F}$

$? = 6.15544 \times 10^{-3}$ moles

But number of moles (n) $= \frac{\text{Mass (M)}}{\text{Molar mass (Mr)}}$

1. b) (ii) $M = n \times Mr$

$M = 6.15544 \times 10^{-3} \times 63.5g/moL$

$M = 0.39g$

$\therefore$ The mass of copper deposited will be 0.39g

Extract 11.1: Sample of correct responses to question 1, Paper 2

In Extract 11.1, the candidate correctly deduced the rate law, rate constant, and initial rate of the reaction in part (a). In part (b) (i), the candidate accurately identified the appropriate electrode to which a metallic object should be connected for copper coating. In part (b) (ii), she/he applied the correct formula to calculate the mass of copper deposited at the cathode, demonstrating competence in all the concepts tested.

On the contrary, the candidates who scored low marks (12.85%) in this question had inadequate knowledge of the experimental determination of the order of reaction. They failed to write the correct rate law expression and made errors in the mathematical manipulations required in part (a). Some candidates omitted the exponents in the rate law expression, which are essential to indicate the order of reaction with respect to each reactant. For instance, one candidate wrote the rate law as: Rate = $K[X]_O[Y]_O$.

In part (b) (i), several candidates gave incorrect explanations, indicating limited understanding of how half-cell reactions are used to predict the correct electrode connection during electrolysis. For example, one candidate stated that since Cu^{2+} ions are being oxidised, the object to be coated should act as the anode and be connected to the positive terminal, which is incorrect.

In part (b) (ii), many candidates used the wrong formula to calculate the mass of copper deposited at the cathode. One candidate, for instance, interchanged the relative atomic mass (RAM) and the valency of copper in the formula: $Mass\ of\ Cu = \dfrac{valency \times Current \times time}{RAM \times Faraday's\ constant}$.

Others failed to convert the time from 1.5 hours to seconds, resulting in incorrect final answers. Additionally, some candidates who applied the method using ionic equations and Faraday's law of electricity (involving moles of electrons) wrote an incorrect half-reduction equation for copper. One wrote: $Cu^{2+} + e^- \rightarrow Cu$ instead of the equation: $Cu^{2+} + 2e^- \rightarrow Cu$, thereby assuming that only one Faraday is required instead of two, leading to the wrong mass of copper deposited. Extract 11.2 shows an example of such incorrect responses.

1. a) i) required rate law,
solution

$R = \frac{k_2}{k_1} = k_3/k_2 = k_4/k_3 = k_4/k_5$,

$R = \frac{2.1 \times 10^{-6}}{2.1 \times 10^{-6}} = \frac{2.1 \times 10^{-6}}{2.1 \times 10^{-6}} = \frac{4.2 \times 10^{-6}}{2.1 \times 10^{-6}} =$

$\frac{4.2 \times 10^{-6}}{6.3 \times 10^{-6}}$.

$R = \frac{4.2 \times 10^{-6}}{2.1 \times 10^{-6}} = \frac{4.2 \times 10^{6}}{2.1 \times 10^{6}}$,

$R = 6.67 \times 10^{-3}$.

∴ The rate constant $= 6.67 \times 10^{-3}$ m,

ii) rate constant,

$\left(x/y\right) + \left(x/y\right) + \left(x/y\right) \left(x/y\right) \left(x/y\right)$.

$\left(\frac{2.1 \times 10^{-6}}{2.1 \times 10^{-6}}\right) \left(\frac{2.1 \times 10^{-6}}{4.2 \times 10^{-6}}\right) \left(\frac{2.1 \times 10^{-6}}{6.3 \times 10^{-6}}\right)$

$\left(\frac{4.2 \times 10^{-6}}{6.3 \times 10^{-6}}\right) \left(\frac{6.3 \times 10^{-6}}{6.3 \times 10^{-6}}\right)$

$k = \left(5 \times 10^{-13}\right) \left(3.3 \times 10^{17}\right) \left(6.6 \times 10^{-13}\right)$

$k = 11 \times 10^{-41}$

1.	iii) required initial rate of the reaction
	solution
	given,
	$[X] = 9.0 \times 10^{-6} mol dm^{-3}$.
	$[Y] = 1.0 \times 10^{-6} mol dm^{3}$.
	$\left(\frac{X}{Y}\right) = \left(\frac{9.0 \times 10^{-6}}{1.0 \times 10^{-6}}\right)$
	$\left(\frac{X}{Y}\right) = \left(\frac{9.0 \times 10^{-6}}{1.0 \times 10^{-6}}\right)$
	$\left(\frac{X}{y}\right) = 9 \times 10^{-12}$.
	= initial rate = $9 \times 10^{-12} moldm^{-3}$

1b.	i) The electrode to which the power flows is the positive electrode where by the current flows to the object when its being connected

ii, The mass of copper will be deposited if current of 0.22A flows through cell for 1.5 hours is obtained as follows.
solution.
given.
Current = 0.22A
time = 1.5 hours

Required the mass of copper deposited.
= 0.22A
1.5 hours.
= 0.22 A × 1.5 hours.
= 0.33
∴ The mass of copper is 0.33g

Extract 11.2: Sample of incorrect responses to question 1, Paper 2

In Extract 11.2, the candidate performed incorrect mathematical manipulations required to determine the order of reaction in part (a). In part (b) (i), the candidate showed no understanding of the flow of current in an electrolytic cell. Similarly, in part (b) (ii), the candidate used an incorrect formula to calculate the mass of copper deposited at the cathode electrode.

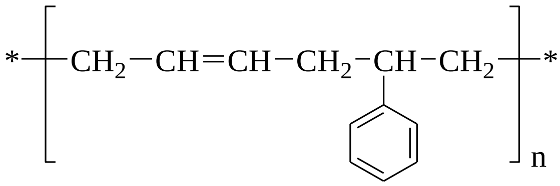
2.2.2 Question 2: Transition Elements and Polymers

This question had four parts, namely (a), (b), (c), and (d), as follows:

(a) *Iron is used as a catalyst in Haber process for the manufacture of ammonia from combination of nitrogen and hydrogen gas. Briefly, explain four properties that enables the iron metal to act as a catalyst.*

(b) With reference to nylon–6, 6, explain in detail how polyamides polymer are synthesized.

(c) Write the chemical equation for the preparation of styrene-butadiene rubber, whose structure is as follows:



(d) *Using polymerisation of vinyl chloride as an example, when forming poly (vinyl chloride), show the chain at;*
   (i) *initiation step.*
   (ii) *propagation step.*
   (iii) *termination step.*

The question was attempted by 35,587 (76.12%) candidates. Of these, 18,562 (52.17%) scored from 0 to 6.5 marks, 8,439 (23.71%) scored from 7 to 11.5 marks, and 8,586 (24.12%) scored from 12 to 20 marks. Overall, the candidates' performance was average, as 17,025 (47.83%) of them scored 7 marks or above. The summary of the performance is presented in Figure 12.

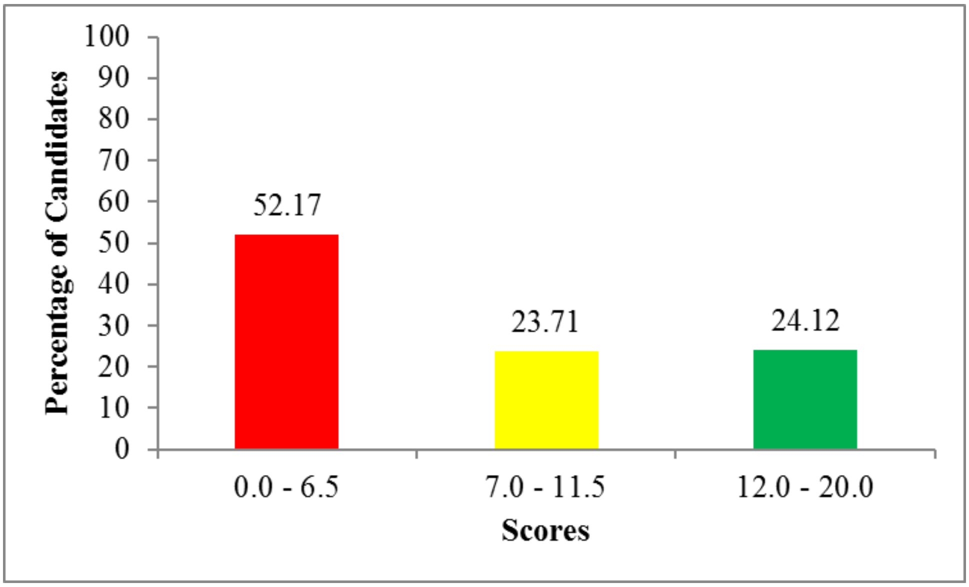


***Figure 12**: Candidates' Performance on Question 2, Paper 2*

The candidates who scored high marks (47.83%) in this question demonstrated good mastery of the basic concepts related to the properties of transition elements, specifically the catalytic property, as seen in part (a) of the question. They correctly identified the four key features that make iron a suitable catalyst. Similarly, in parts (b), (c), and (d), they demonstrated a sufficient understanding of polymer synthesis, accurately applying the principles of condensation and addition polymerisation. Extract 12.1 presents a sample of correct responses provided by one of the candidates.

2. (a) (i) Variable oxidation state. Iron can be Fe^{2+} or Fe^{3+} hence these ability enables it to act as a catalyst in the chemical reaction by being an alternative path provider of the chemical reaction.

(ii) Presence of defects: Defects are irregular arrangement of electrons thus this property enable iron to behave as a catalyst in the chemical reaction which provide an alternative path for the chemical reaction.

(iii) Presence of vacant d-orbitals. Iron has also the degenerate orbitals in d orbitals which are not filled with electron hence this enables it to act a catalyst.

(iv) Ability to provide a surface area where atoms can attach temporary during the chemical reaction. Atoms are attached temporarily to weight for some species to combine hence this ability makes an iron a catalyst.

2. (b) Polyamide are copolymers formed by condensation reaction between the monomers. Condensation reaction is the types of chemical reaction in which the monomers are combined and accompanied with evolvement of small molecules like water, HCl, NH_3 and HCN.

Nylon-6,6 is an example of a polyamide which is formed by condensation of hexan-1,6-diamine and hexan-1,6-dioic acid. The formation of nylon-6,6 is as follows.

Monomers

$$HOOC-(CH_2)_4-COOH \quad \text{and} \quad NH_2-(CH_2)_6-NH_2$$

Condensation reaction between the monomers

$$HOOC-(CH_2)_4-COOH + H-\underset{\displaystyle H}{\underset{|}{N}}-(CH_2)_6-NH_2 \xrightarrow{-H_2O} HOOC-(CH_2)_4-C-O-\underset{\displaystyle H}{\underset{|}{N}}-(CH_2)_6-NH_2$$

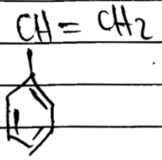
The repeating unit of nylon-6,6

$$\left[OC-(CH_2)_4-C-O-\underset{\displaystyle H}{\underset{|}{N}}-(CH_2)_6-\underset{\displaystyle H}{\underset{|}{N}}\right]_n$$

where n is the degree of polymerization

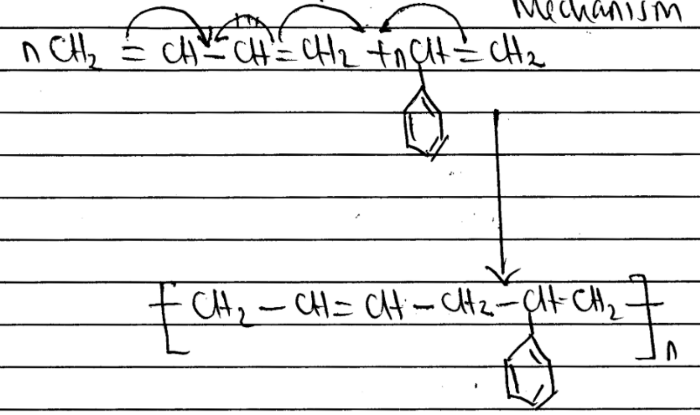
2. (c) Monomers are styrene and butan-1,4-diene

Styrene

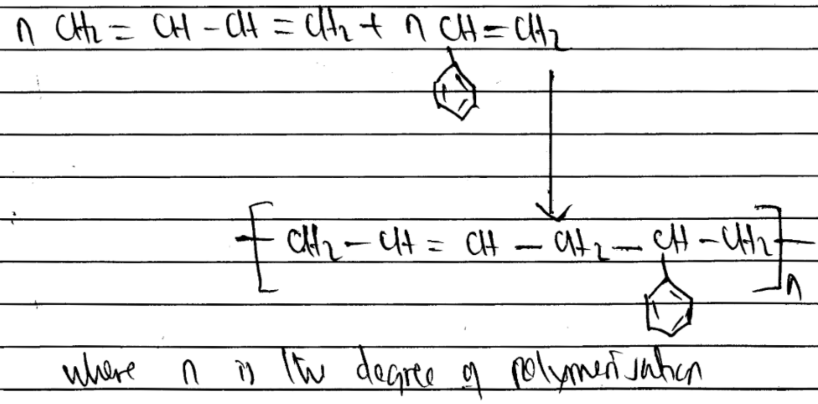


Butan-1,4-diene $CH_2=CH-CH=CH_2$

Mechanism



The overall equation



where n is the degree of polymerisation

2. (d) The monomer is polyvinylchloride

$$\underset{\displaystyle Cl}{\underset{|}{CH}} = CH_2$$

(i) Initiation step

$$ROOR \longrightarrow R\dot{O}$$

$$R\dot{O} + \underset{\displaystyle Cl}{\underset{|}{CH}} = CH_2 \longrightarrow RO - \underset{\displaystyle Cl}{\underset{|}{CH}} - \dot{C}H_2$$

(ii) Propagation step

$$RO - \underset{\displaystyle Cl}{\underset{|}{CH}} - \dot{C}H_2 + \underset{\displaystyle Cl}{\underset{|}{CH}} = CH_2 \longrightarrow RO - \underset{\displaystyle Cl}{\underset{|}{CH}} - CH_2 - \underset{\displaystyle Cl}{\underset{|}{CH}} - \dot{C}H_2$$

(iii) Termination step

$$RO - \underset{\displaystyle Cl}{\underset{|}{CH}} - CH_2 - \underset{\displaystyle Cl}{\underset{|}{CH}} - \dot{C}H_2 + \dot{C}H_2 - \underset{\displaystyle Cl}{\underset{|}{CH}} - OR$$

$$\downarrow$$

$$RO - \underset{\displaystyle Cl}{\underset{|}{CH}} - CH_2 - \underset{\displaystyle Cl}{\underset{|}{CH}} - CH_2 - CH_2 - \underset{\displaystyle Cl}{\underset{|}{CH}} - OR$$

The repeating unit of polyvinylchloride is

$$\left[- \underset{\displaystyle Cl}{\underset{|}{CH}} - CH_2 - \right]_n$$

The above steps show the formation of polyvinyl chloride using free radical as an initiator.

Extract 12.1: Sample of correct responses to question 2, Paper 2

In extract 12.1, the candidate managed to describe the characteristics which make iron metal act as a catalyst in part (a). In parts (b), (c) and (d), the candidate correctly showed strong mastery of the synthesis of Nylon-6, 6, styrene butadiene and poly (vinyl chloride) polymers from their monomers, respectively.

In this extract, the candidate also managed to describe the characteristics that make iron metal act as a catalyst in part (a). In parts (b), (c), and (d), the candidate demonstrated strong mastery in identifying the correct monomers and writing appropriate equations for the synthesis of Nylon-6,6, styrene-butadiene, and poly(vinyl chloride) polymers, respectively.

The candidates who scored low marks (52.17%) provided incorrect responses to most parts of the question, indicating a lack of sufficient knowledge of the catalytic properties of transition elements and the synthesis of polymers from their monomers.

In part (a), many candidates gave general properties of transition elements rather than focusing specifically on catalytic properties. For example, one candidate stated that iron is used as a catalyst because it forms complexes, while another incorrectly claimed that iron has 'empty electrons' instead of 'empty orbitals'.

In part (b), several candidates failed to explain how the polyamide polymer Nylon-6,6 is formed correctly. They were unfamiliar with the appropriate monomers and their chemical formulas, as well as the reaction involved. For instance, one candidate identified the monomers as $NH_2(CH_2)NH_2$ and $HOOC(CH_2)COOH$, which are incorrect.

Similarly, in part (c), some candidates used inappropriate monomers when attempting to construct the chemical equation for the synthesis of styrene-butadiene rubber. One candidate, for instance, wrote $CH_3CH{=}CHCH_3$ and $C_6H_5CH_2CH_2$ instead of the correct $CH_2{=}CHCH{=}CH_2$ and $C_6H_5CH{=}CH_2$, respectively.

In part (d), many candidates failed to write the chemical equation for the formation of poly (vinyl chloride) via the addition polymerisation of vinyl chloride. These errors reflect a general lack of mastery of monomers and polymerisation processes. Extract 12.2 illustrates one of the incorrect responses given by a candidate.

2. a) Properties of iron.

i) Iron have ability to speed up the rate of chemical reaction between Nitrogen and hydrogen;

Forexample:

$$N_{2(g)} + 3H_{2(g)} \xrightarrow{Fe^{3+}} 2NH_{3(g)}$$

$$N_{2(g)} + 3H_{2(g)} \xrightarrow{Fe^{3+}} 2NH_{3(g)}$$

ii): It donot have ability to affect the reaction; Forexample to form a product which is not required.

iii): It do works in equilibrium concentration of reactants; mean that the reactants must have the required concentration so as to form ammonia gas that is required:

iv). It consider the molecular masses of reactants: the molecular masses of reactant must be in the optimal amount

b): Nylon-6,6 can be synthesized from different simple molecules when are eliminated from a compound:

case I:

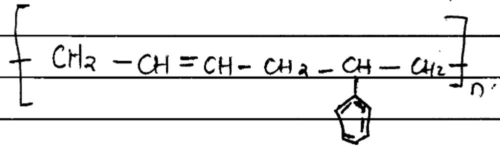
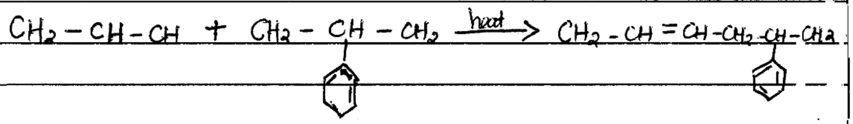
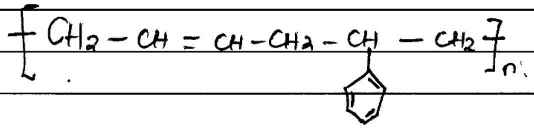
When H_2O is eliminated:

Nylon-6,6 will be: as follow.

$$\left[\overset{O}{\overset{\|}{C}} - (CH_2)_5 - \overset{H}{\overset{|}{N}} - \overset{O}{\overset{\|}{C}} - (CH_2)_5 - \overset{H}{\overset{|}{N}}\right]_n + (2n-1)\,H_2O$$

The monomers used are: $\left[\overset{O}{\overset{\|}{C}} - (CH_2)_5 - \overset{H}{\overset{|}{N}}\right]$

When HCl is removed from the compound it will be:

2	b) $\left[\overset{O}{\overset{\|}{C}} - (CH_2)_5 - \overset{H}{\overset{\|}{N}} - \overset{O}{\overset{\|}{C}} - (CH_2)_5 - \overset{H}{\overset{\|}{N}} \right] + (2n-1)\ HCl$
	so HCl is removed from the compound as the simple molecule.
	c) Given:
	
	The chemical equation is:
	
	The product is:
	
	d) Formation of poly Vinyl chloride (PVC).
	Its diagram is:
	$\left[CH_2 = \underset{Cl}{\underset{\|}{CH}} \right]_n$
	Stages:
	i) Initiation stage
	- Polyethene with chlorine react together.
	$\left[CH_2 = \underset{Cl}{\underset{\|}{CH}} = CHCl = \underset{Cl}{\underset{\|}{CH}} \right.$
	The monomers are $[CH_2 - CHCl - CHCl - CHCl]$

2. d) ii) Propagation step:

ethene and chlorine react together to form a calenation

$$CH_2 = \underset{Cl}{CH} = \underset{Cl}{C} = \underset{Cl}{CH}$$

iii) Termination step:

Ethenes and chlorine form a long chain of compounds;

$$\left[CH_2 = \underset{Cl}{CH} = CH_2 = \underset{Cl}{CH} \right]_n \longrightarrow$$

$$\left[CH_2 = \underset{Cl}{CH} \right]_n$$

The monomers used to form polyvinyl chloride are:

$$\left[CH_2 = \underset{Cl}{CH} \right]_n$$

Extract 12.2: Sample of incorrect responses to question 2, Paper 2

In Extract 12.2, in part (a), the candidate wrongly associated iron's catalytic ability with its molecular mass and concentration, showing a misconception about the actual properties that make iron a suitable catalyst. In part (b), the candidate failed to identify the correct monomers and their formulas used in the synthesis of Nylon-6,6. In part (c), the candidate used incorrect structures for styrene and butadiene when constructing the chemical equation for styrene-butadiene rubber. In part (d), the candidate was unable to write the correct polymerisation equation for the formation of poly (vinyl chloride) from vinyl chloride.

However, the candidates who scored high marks (47.83%) in this question demonstrated good mastery of the basic concepts related to the properties of transition elements, specifically the catalytic property, as seen in part (a) of the question. They correctly identified the four key features that make iron suitable as a catalyst. Similarly, in parts (b), (c) and (d), they showed sufficient understanding of polymer synthesis, accurately applying the principles of condensation and addition polymerization. Extract 12.1 presents a sample of correct responses provided by one of the candidates.

2. (a) (i) Variable oxidation state. Iron can be Fe^{2+} or Fe^{3+} hence there ability enables it to act as a catalyst in the chemical reaction by being an alternative path provider of the chemical reaction.

(ii) Presence of defects. Defects are irregular arrangement of electrons thus this property enable iron to behave as a catalyst in the chemical reaction which provide an alternative path for the chemical reaction.

(iii) Presence of vacant d-orbitals. Iron has also the degenerate orbitals in d orbital which are not filled with electron hence this enables it to act a catalyst.

(iv) Ability to provide a surface area where atoms can attach temporary during the chemical reaction. Atoms are attached temporarily to weight for some species to combine hence this ability makes an iron a catalyst.

2. (b) Polyamide are copolymers formed by condensation reaction between the monomers. Condensation reaction is the types of chemical reaction in which the monomers are combined and accompanied with evolvement of small molecules like water, HCl, NH_3 and HCN.

Nylon-6,6 is an example of a polyamide which is formed by condensation of hexan-1,6-diamine and hexan-1,6-dioic acid. The formation of nylon-6,6 is as follows.

Monomers

$$HOOC-(CH_2)_4-COOH \quad \text{and} \quad NH_2-(CH_2)_6-NH_2$$

Condensation reaction between the monomers

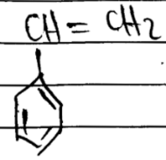
$$HOOC-(CH_2)_4-COOH + H-\underset{\displaystyle H}{\underset{|}{N}}-(CH_2)_6-NH_2 \xrightarrow{-H_2O} HOOC-(CH_2)_4C-O-\underset{\displaystyle H}{\underset{|}{N}}-(CH_2)_6-NH_2$$

The repeating unit of nylon-6,6

$$\left[OC-(CH_2)_4-C-O-\underset{\displaystyle H}{\underset{|}{N}}-(CH_2)_6-\underset{\displaystyle H}{\underset{|}{N}} \right]_n$$

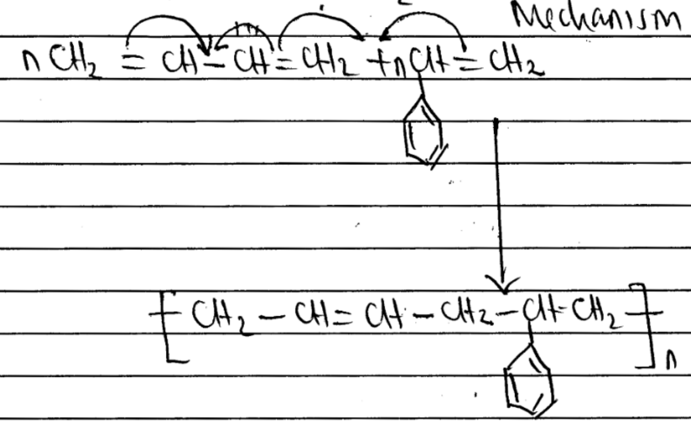
where n is the degree of polymerization

2. (c) Monomers are styrene and butan-1,4-diene

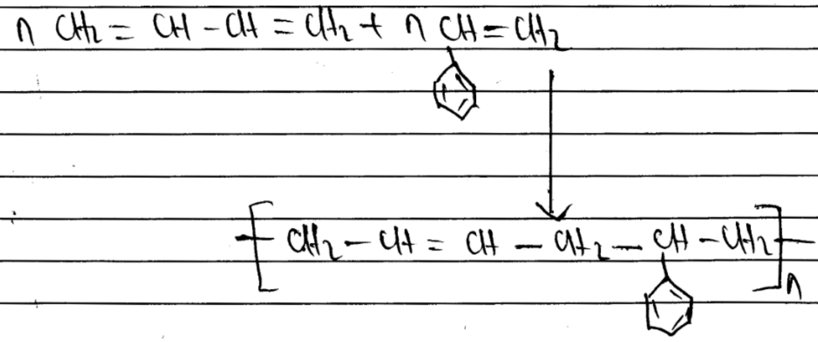
Styrene 

Butan-1,4-diene $CH_2=CH-CH=CH_2$

Mechanism



The overall equation



where n is the degree of polymerisation

2. (d) The monomer is polyvinylchloride

$$\underset{|}{CH}(Cl) = CH_2$$

(i) Initiation step

$$ROOR \longrightarrow R\dot{O}$$

$$R\dot{O} + \underset{Cl}{\underset{|}{CH}} = CH_2 \longrightarrow RO - \underset{Cl}{\underset{|}{CH}} - \dot{C}H_2$$

(ii) Propagation step

$$RO - \underset{Cl}{\underset{|}{CH}} - \dot{C}H_2 + \underset{Cl}{\underset{|}{CH}} = CH_2 \longrightarrow RO - \underset{Cl}{\underset{|}{CH}} - CH_2 - \underset{Cl}{\underset{|}{CH}} - \dot{C}H_2$$

(iii) Termination step

$$RO - \underset{Cl}{\underset{|}{CH}} - CH_2 - \underset{Cl}{\underset{|}{CH}} - \dot{C}H_2 + \dot{C}H_2 - \underset{Cl}{\underset{|}{CH}} - OR$$

$$\downarrow$$

$$RO - \underset{Cl}{\underset{|}{CH}} - CH_2 - \underset{Cl}{\underset{|}{CH}} - CH_2 - CH_2 - \underset{Cl}{\underset{|}{CH}} - OR$$

The repeating unit of polyvinylchloride is

$$\left[- \underset{Cl}{\underset{|}{CH}} - CH_2 - \right]_n$$

The above steps show the formation of polyvinyl chloride using free radical as an initiator.

Extract 12.1: A sample of correct responses to question 2, Paper 2

In extract 12.1, the candidate managed to describe the characteristics which make iron metal to act as catalyst in part (a). In part (b), (c) and (d), the candidate correctly showed strong mastery on the synthesis of Nylon-6, 6, styrene butadiene and poly (vinyl chloride) polymers from their monomers respectively.

In Extract 12.1, the candidate managed to describe the characteristics that make iron metal act as a catalyst in part (a). In parts (b), (c), and (d), the candidate demonstrated strong mastery in identifying the correct monomers and writing appropriate equations for the synthesis of Nylon-6,6, styrene-butadiene, and poly(vinyl chloride) polymers, respectively.

2.2.3 Question 3: Extraction of Metals and Periodic Classification of Elements

The question had three parts, namely (a), (b), and (c), as follows:"

(a) *Name two factors which are to be considered when choosing an appropriate method for metal extraction.*

(b) *Give a brief account for the extraction of aluminium, emphasizing the chemical principles involved. (Technical details are not required).*

(c) *Consider the following table which shows the variation in electronegativity across period II of the periodic table.*

Element	*Li*	*Be*	*B*	*C*	*N*	*O*	*F*
Electronegativity	*0.97*	*1.50*	*2.00*	*2.50*	*3.10*	*3.50*	*4.10*

Briefly, comment on the variation of electronegativity values shown in the table.

The question was answered by 33,300 (50.83%) candidates. The statistics show that 16,374 (49.17%) scored from 0 to 6.5 marks, 10,232 (30.73%) scored from 7 to 11.5 marks, and 6,694 (20.10%) scored from 12 to 20 marks. These data indicate that 16,926 (50.83%) of the candidates scored 7 marks or above, demonstrating that the overall performance on this question was average. A summary of the performance is presented in Figure 13.

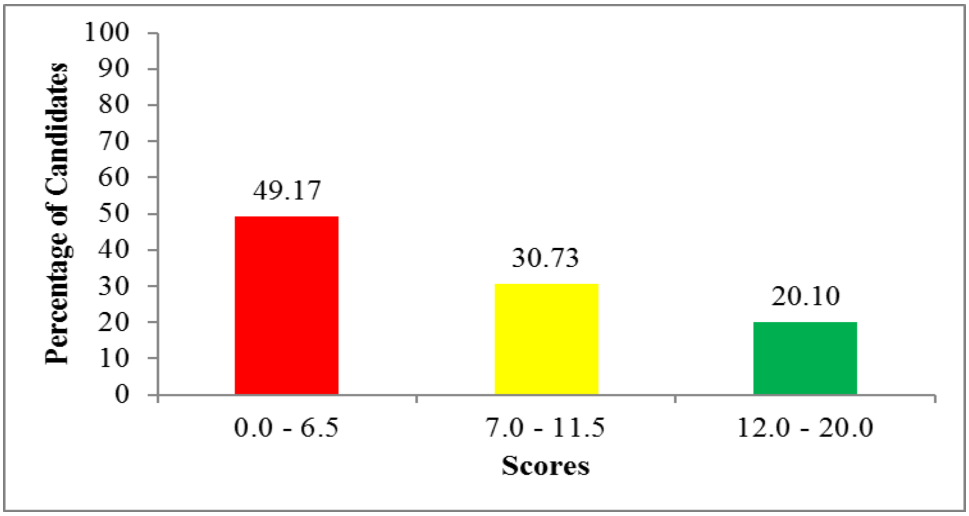


Figure 13*: Candidates' Performance on Question 3, Paper 2*

The candidates who scored high marks (50.83%) demonstrated a strong understanding of metal extraction, particularly the criteria for selecting appropriate extraction methods in part (a). In part (b), they systematically explained the stages involved in extracting aluminium from its main ore, using balanced chemical equations. In part (c), they correctly explained the trend of electronegativity across Period 2, showing good mastery of periodic properties. Extract 13.1 is an example of a correct response from one of the candidates.

3) a)	Factors to considere when choosing an appropriate method for metal extraction are;
	i) Chemical and physical properties of the metal
	ii) The Impurities which contain the chief ore of metal. to be extracted.
3) b)	Extraction of aluminium.
	i) The chief ore of aluminium is Bauxite ($Al_2O_3 \cdot 2H_2O$) and it is contaminated with iron (III) oxide, The major proce of extraction of it is Bayers process.
	ii, Crushing and pulvorizing of the ore in order to get fine powdered particles of the chief ore.
	iii, The fine powdered particles are subjected to magnetic field, where by impurities such as iron ore being remove out by magnetic separation. to get concentrated ore.

3) b) iv) The ore is the roasted by limited supply of oxygen to obtain aluminium (III) oxide and to remove water of crystalization

$$Al_2O_3 \cdot 2H_2O \xrightarrow{\Delta} Al_2O_{3(s)} + 2H_2O_{(l)}$$

v) The obtained aluminium (III) oxide is mixed with NaOH to obtain sodium aluminate

$$Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$$

vi) Sodium aluminate is filtered and in the filtrate Carbondioxide (CO_2) followed by water are passed through the filtrate. To obtained aluminium (III) hydroxide and sodium carbonate.

$$NaAlO_2 + CO_2 + H_2O \longrightarrow Al(OH)_3 + Na_2CO_3.$$

vii) Then aluminium (III) hydroxide is heated to remove water and obtain aluminium (III) oxide.

$$2Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + 3H_2O.$$

viii) The obtained Al_2O_3 is mixed with cryolite to lower its melting point and subjected to electrolysis for purification

ix) In eletrolytic cell then a Al_2O_3 is purified, where Aluminium is deposited at cathode.

At Cathode

$$Al^{3+} + 3e^- \longrightarrow Al_{(s)}$$

At Anode

$$2O^{2-} \longrightarrow O_{2(g)} + 4e^-$$

3) c)	The variation of electronegativity value across
	the period II of periodic table, is that;
	→ Across the period II atomic size goes on decreas
	ing. And as atomic size decreases the value
	of electronegativity goes on increasing. because
	of nuclear charge the atom gain electron much more
	as nuclear charge increase when atomic size decreases
	Hence higher electronegative.
	Therefore there are two factors
	I) Atomic size decrease along the period II
	making electronegativity to increasing
	II) Nuclear charge increases across the period
	making electronegativity to increase across period II

Extract 13.1: Sample of correct responses to question 3, Paper 2

In Extract 13.1, part (a), the candidate correctly outlined the factors to consider when selecting appropriate methods for metal extraction. In part (b), the candidate identified the primary ore for aluminium and systematically described the extraction steps with relevant chemical equations. In part (c), the candidate demonstrated a good mastery of the electronegativity trend across Period 2.

On the other hand, the candidates who scored low marks in this question (49.17%) lacked adequate understanding of the general concepts of the extraction of metals in parts (a) and (b). Most of them failed to identify the correct criteria for selecting appropriate extraction methods. For example, one candidate mentioned "availability of aluminium" as a factor, which is a misconception since aluminium is the metal to be extracted, not a method or criterion of extraction. This indicates confusion between the metal itself and the chemical principles used in selecting extraction techniques.

In part (b), many candidates presented lengthy and irrelevant essays on industrial procedures without addressing the specific stages required for the extraction of aluminium. Others failed to identify bauxite ($Al_2O_3 \cdot 2H_2O$) as the chief ore and used incorrect chemical symbols and formulas, such as Al_3O_2 instead of Al_2O_3. Some candidates also wrote unbalanced or vague half-cell equations for the electrolytic reduction of alumina, with unclear identification of reactions at the anode and cathode.

In part (c), some of the candidates demonstrated misconceptions regarding the periodic trend of electronegativity. They failed to link the trend to nuclear charge and atomic radius, which are the main influencing factors. Instead, some candidates incorrectly attributed the increase in electronegativity across Period 2 to unrelated concepts such as the "screening effect" or simply "ionisation energy" without establishing the correct cause-and-effect relationship. One candidate, for instance, claimed that electronegativity increases due to "an increase in ionisation energy, screening effect and atomic size," which reflects a misunderstanding of periodic trends and their explanations.

These misconceptions indicate that many candidates lacked both conceptual clarity and the ability to apply basic principles of periodicity and electrochemistry. Extract 13.2 illustrates an example of such incorrect responses.

3	a) factors which are to be considere when
	choosing an appropriate method for.
	metal extraction are.
	i) Type of metal to be extracted.
	when you want to extract metals you
	should consider which kind of metal
	your are required to extract. it may be
	silver metal, or gold metal.
	ii) Appropriate solution.
	each metal have their appropriate solutio
	n to which meta is imersed, so therefore
	the appropriate metal should be immersed
	to its appropriate solution.

b) EXTRACTION OF ALUMINIUM.

Aluminium is a metal present in the electrochemical series

-> The ~~ore~~ main ores present in the aluminium is bauxite (Al_3O_2).
During the extraction of Aluminium there are three method which can be considered. The methods are

i) Hall's method
This is the method which can be
Use the iron oxide as a main Impurities

ii) Beerger's method
- This is the method Used to remove Impurities in the alumina (Al_3O_2)

Chemical properties of aluminium.

i) Aluminium react with Hydrochloric acid (HCl)
$Al + HCl \longrightarrow AlCl + H_2$

ii) Aluminium react with concentrated sulphuric acid
$Al + H\,H_2SO_4 \longrightarrow AlSO_3 + H_2$

iii) Aluminium react with concentrated nitric acid
$Al + 2HNO_3 \longrightarrow Al(NO_3)_2 + H_2$

iv) Aluminium react with steam
$Al + H_2O(l) \longrightarrow AlO + H_2$

But ~~the~~ during the extraction of aluminium there are many Impurities present the main Impurity is iron oxide

The other Impurities Can not be Used because it has Unsignificant in aluminium.

3	c) The electronegativity values of period
	II - elements increases as the increase
	in atomic size of elements, since from
	the Lithium as you go forward the size of
	electron tend to increase, so therefore
	when the size of electron increases also
	electronegativity value tend to increase

Extract 13.2: Sample of incorrect responses to question 3, Paper 2

In Extract 13.2, in part (a), the candidate provided incorrect factors for selecting appropriate methods of metal extraction. In part (b), the candidate wrote an incorrect formula for the ore and outlined wrong steps in the extraction of aluminium, including inaccurate chemical equations. In part (c), the candidate failed to relate atomic size to the trend in electronegativity values across the given period.

2.2.4 Question 4: Solubility, Solubility Product and Ionic Product

The question had three parts namely (a), (b) and (c) as follows;

(a) (i) What is meant by a common ion effect?

(ii) Distinguish solubility and solubility product of a sparingly soluble salt.

(iii) How can you affect the solubility of a salt? Give four ways.

(b) Calculate the solubility of AgCl in:

(i) Pure water

(ii) 0.1 M NaCl

[Given that $K_{sp}(AgCl) = 2 \times 10^{-10}$ $mol^2\,dm^{-6}$].

(c) (i) Why precipitate forms when solutions of Na_2SO_4 and $Ca(NO_3)_2$ are Mixed? Explain briefly.

(ii) Exactly 50 cm^3 of a 0.0152 M Na_2SO_4 is added to 50 cm^3 of 0.0125 M $Ca(NO_3)_2$. Predict whether the precipitate of $CaSO_4$ will be formed or not. Given that the solubility product [$K_{sp}(CaSO_4) = 9.1 \times 10^{-6}$ mol^2dm^{-6}].

The question was answered by 45,672 candidates, representing 97.69 per cent of the total number of candidates. The performance data show that 22,412 candidates (49.07%) scored within the range of 12 to 20 marks, 15,684 candidates (34.34%) scored within the range of 7 to 11.5 marks, while 7,576 candidates (16.59%) scored within the range of 0 to 6.5 marks. These results indicate that 38,096 candidates (83.41%) scored 7 marks or above, reflecting good overall performance on this question. A summary of the performance is presented in Figure 14.

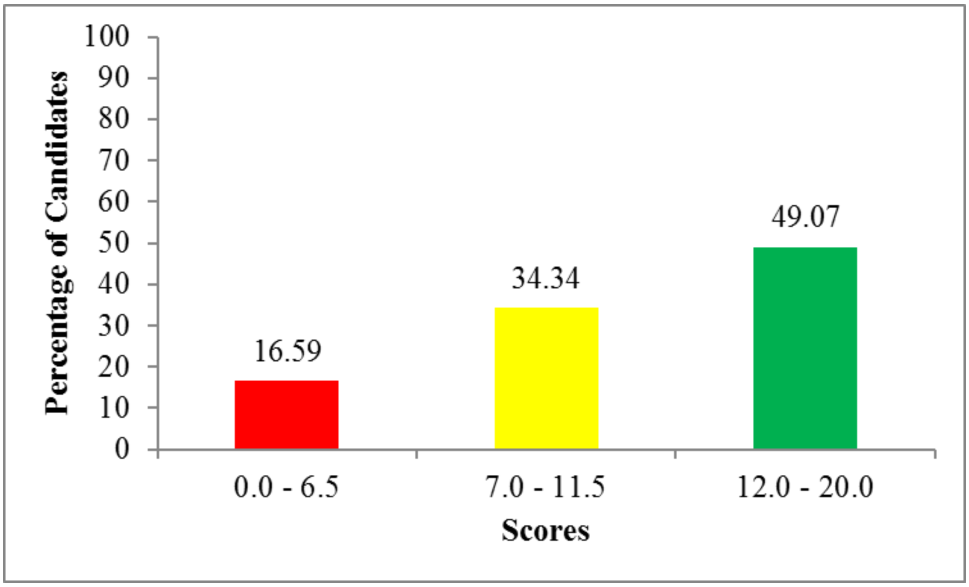


Figure 14: *Candidates' Performance on Question 4, Paper 2*

Based on the analysis, the candidates who scored high marks (83.41%) demonstrated a good understanding of the common ion effect, particularly in part (a) (i). In part (a) (ii), they accurately distinguished between solubility and solubility product of sparingly soluble salts. Additionally, in part (a) (iii), they clearly explained the factors affecting salt solubility, showing strong conceptual understanding. In part (b), the candidates applied correct mathematical procedures to calculate the solubility of AgCl both in the absence and presence of a common ion, reflecting a good grasp of how the common ion effect influences solubility. Furthermore, in part (c) (i), many candidates gave relevant explanations supported by balanced chemical equations. In contrast, in part (c) (ii), they correctly manipulated the provided data and units to compute the ionic product (Qsp) of $CaSO_4$. They compared it with Ksp to predict the possibility of precipitation. Extract 14.1 presents a sample of correct responses from one candidate.

4. (a) (i) Common - ion effect: is the phenomenon in which the solubility of a sparingly-soluble salt decreases on addition of another compound which have ions similar to that of the sparingly soluble salt.

(ii)

SOLUBILITY	SOLUBILITY PRODUCT
• Solubility is the mass of sparingly soluble salt dissolved to make 1L of the saturated solution.	Is the temperature dependent factor which is given as the product of the concentration of the ions of the sparingly soluble salt each raised to the power of their stoichiometric coefficients in the saturated solution.
• The SI unit of solubility is g/L	The SI unit of solubility product is mol^2dm^{-6}.

(iii) Factors Affecting solubility of a salt.

(a) Temperature.

Increase in temperature make the salt to dissolve more and hence increase the solubility of a salt and decrease in temperature lower the solubility of a salt.

(b) Common-ion effect.

On addition of the substance which have ions in common to the salt decreases the solubility of a salt, ~~white~~ as the reaction proceeds backward to form precipitates.

4. (a) (iii) (c) Nature of the salt.

Some salts do not hydrolyze into their respective ions and hence are insoluble, for this case such salts have lower solubility while ~~of~~ soluble salts hydrolyze completely into their respective ions and hence more soluble ~~strong~~

(d) Nature of the solvent.

Like dissolves like hence polar dissolves polar and non-polar dissolves non-polar. Hence polar salts dissolves in polar solvents and non-polar salts dissolve in the non-polar solvents.

(b) (i) Solution

In pure water:

$$AgCl \rightleftharpoons Ag^+ + Cl^-$$

let x be the molar solubility of AgCl.

Given:

$$K_{sp}(AgCl) = 2 \times 10^{-10}\ mol^2 dm^{-6}.$$

then:

Consider dissociation equation below:

$$\underset{(x)}{AgCl_{(s)}} \rightleftharpoons \underset{(x)}{Ag^+_{(aq)}} + \underset{(x)}{Cl^-_{(aq)}}$$

from:

$$K_{sp} = [Ag^+][Cl^-].$$

$$= [x][x].$$

$$\sqrt{K_{sp}} = \sqrt{[x]^2}.$$

$$[X] = \sqrt{2 \times 10^{-10}\ mol^2 dm^{-6}}.$$

4.	(b) (i) $[X] = 1.414 \times 10^{-5} mol dm^{-3} = [AgCl]$.
	Since:
	$[X] = [AgCl]$
	∴ The solubility of AgCl in water is $1.414 \times 10^{-5} mol dm^{-3}$.
	(ii) Solution.
	Given:
	0.1M NaCl
	$NaCl_{(s)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$
	0.1M 0.1M 0.1M
	then; dissociation of AgCl
	Let; X be the solubility of AgCl
	$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$
	X X $(x + 0.1) \approx 0.1$
	then;
	from:
	$Ksp = [Ag^+][Cl^-]$.
	$Ksp = [x][0.1]$
	$\frac{2 \times 10^{-10} mol^2 dm^{-6}}{[0.1]} = \frac{[0.1 x]}{[0.1]}$
	$[AgCl] = [X] = 2 \times 10^{-9} mol dm^{-3}$.
	∴ The solubility of AgCl in 0.1M NaCl is $2 \times 10^{-9} mol dm^{-3}$

4. (c) (i) Consider the balanced chemical reaction below:

$$Na_2SO_4\,(aq) + Ca(NO_3)_2\,(aq) \longrightarrow 2NaNO_3\,(aq) + CaSO_4\,(s)$$

This is due to the formation of $CaSO_4$ which is sparingly soluble salt where the $[SO_4^{2-}]$ exceeds the $[SO_4^{2-}]$ which is required to just start to precipitate $CaSO_4$ and hence precipitates of $CaSO_4$ are formed.

(ii) Solution.

Data given:

number of moles of Na_2SO_4 = Molarity x volume.

$= 0.0152M \times 50/1000\ dm^3.$

$\Rightarrow n_{Na_2SO_4} = 7.6 \times 10^{-4}$ moles.

Number of moles of $Ca(NO_3)_2$ = Molarity x volume.

$0.0125M \times 50/1000\ dm^3$

$n_{Ca(NO_3)_2} = 6.25 \times 10^{-4}$ moles.

Consider dissociation equation of Na_2SO_4

$$Na_2SO_4(s) \longrightarrow 2Na^+_{(aq)} + SO_4^{2-}(aq)$$

$(7.6 \times 10^{-4}$ moles$)$ $\quad$ $(7.6 \times 10^{-4}$ moles$)$.

$n_{SO_4^{2-}} = 7.6 \times 10^{-4}$ moles

4. (c) (ii) Consider dissociation equation of $Ca(NO_3)_2$.

$$Ca(NO_3)_{2\,(s)} \rightleftharpoons Ca^{2+}_{(aq)} + 2NO_3^{2-}{}_{(aq)}$$

$(6.25 \times 10^{-4} \text{ moles}) \quad (6.25 \times 10^{-4} \text{ mol})$.

From:

$Qsp = [Ca^{2+}][SO_4^{2-}]$.

But;

$[Ca^{2+}] = \dfrac{\text{number of moles}}{\text{Total volume}} = \dfrac{6.25 \times 10^{-4} \text{ moles}}{0.1 \text{ dm}^3}$

$[Ca^{2+}] = 6.25 \times 10^{-3} \text{ mol dm}^{-3}$.

$[SO_4^{2-}] = \dfrac{\text{number of moles}}{\text{Total volume.}} = \dfrac{7.6 \times 10^{-4} \text{ moles}}{0.1 \text{ dm}^3}$

$[SO_4^{2-}] = 7.6 \times 10^{-3} \text{ mol dm}^{-3}$

From:

$Qsp = [Ca^{2+}][SO_4^{2-}]$.

$= [6.25 \times 10^{-3}][7.6 \times 10^{-3}]$.

$Qsp = 4.75 \times 10^{-5} \text{ mol}^2 \text{dm}^{-6}$.

But;

$Ksp = 9.1 \times 10^{-6} \text{ mol}^2 \text{dm}^{-6}$.

∴ Since Qsp > ksp, then the precipitate of $CaSO_4$ will be formed.

Extract 14.1 Sample of correct responses to question 4, Paper 2

In Extract 14.1, the candidate accurately defined key concepts, correctly performed calculations involving solubility and the common ion effect, and properly balanced chemical equations. The candidate also successfully predicted precipitate formation by comparing Qsp and Ksp values. Overall, the responses reflect a strong understanding of the topic.

However, few candidates (16.59%) had weak performance on this question, reflecting a limited understanding of key concepts such as the common ion effect, solubility, solubility product, and ionic product. In part (a) (i), some candidates failed to define the common ion effect correctly. For example, one candidate wrote that it “causes the position of chemical equilibrium to shift from left to right as explained by Le Chatelier’s principle,” which reflects confusion between equilibrium shifts and the ion effect in solubility. In subpart (ii), many candidates were unable to distinguish between solubility and solubility product; some used unrelated concepts such as polarity, while others stated solubility product as “the product of solute and solvent.” In part (a) (iii), one candidate incorrectly identified “electricity” as a factor affecting solubility, stating that “salts dissolve more when current is passed through the solution.” In part (b) (i), candidates made conceptual and mathematical errors when writing the Ksp expression for AgCl. One incorrectly wrote the dissociation as $AgCl_2 \rightleftharpoons Ag^+ + 2Cl^-$ and calculated Ksp as $4s^3$, resulting in an incorrect solubility value. In part (b) (ii), many failed to incorporate the effect of additional Cl^- ions from NaCl into their calculation. In part (c), some candidates could not explain the formation of precipitate when Na_2SO_4 is mixed with $Ca(NO_3)_2$ and lacked proper mathematical handling to compute and compare Qsp and Ksp for $CaSO_4$. Extract 14.2 illustrates one such incorrect response.

4 a/

I/ Common ion effect; Is the effect caused by the number of ions either much concentrated or less concentrated causing variation in electronegativity, atomic radii atomic mass accross or down the Periodic table.

II/ Solubility refers to the ability of a solute to dissolve or being soluble in organic solvent to produce a certain organic solutions of a sparingly salt. Example; salt being soluble in water which cause the formation of salt solution.

WHILE

Solubility Product; is the product of concentration of the products of the chemical reaction with solubility constant called the Ksp but this varies according to the compound.

Example; solubility product of $CaSO_4 = 9.1 \times 10^{-6} mol^2 dm^{-6}$

4 a/ II/ and That of AgCl is $K_{sp} = 2 \times 10^{-10}$ $Mol^2 dm^{-6}$.

III/.

Ways on how to affect the solubility of a salt

i/ Changing the quantity (amount) of solvent in a vessel.

- from this opinion, when the level of solvent like water in the vessel is large/higher and the salt is less, Now the salt will dissolve all and when the level of salt is higher than the amount of water or solvent then the salt will remain insoluble in the small solvent.

ii/ Changing the type of liquid (solvent) for the salt to be dissolved.

- When dealing with this section, not in all solvents the salt can be soluble such as in honey, kerosene and other solvents hence this provides the suitable example to show that solubility of salt depends on some factors.

iii/ Decrease or increase in the amount of salt to be dissolved;

iv/ Changing the type of salt to be soluble.

- Here there are different types of salts which are like table salt, and those which are obtained from evaporation of water bodies in dams. These are seems to be larger in shape used to cure legs after long journey hence

4a) These can not be soluble in less solvent because they have large structure hence this cause the insoluble of salt in the solvent.

4 b) Solution

Given that AgCl

Required; to calculate solubility of AgCl in

(i) Pure water

from

$AgCl + H_2O \longrightarrow$

from solubility product $= [AgCl]\,[H_2O]$

solubility Product $= [AgCl]\,[H_2O]$

But

solubility Product of AgCl $= 2 \times 10^{-10}\ Mol^2 dm^{-6}$

Now

$2 \times 10^{-10}\ Mol^2 dm^{-6} = x$

$x = 2 \times 10^{-10}\ Mol^2 dm^{-6}$

4 b) ii): 0.1 M NaCl.

from:

$NaCl \longrightarrow Na^+ + Cl^-$

$0.1 \qquad x \qquad x$

$0.1 \longrightarrow x^2$

$Ksp = 0.1x$

$\frac{2 \times 10^{-10}}{0.1} = \frac{0.1x^2}{0.1}$

$x^2 = 2 \times 10^{-9}$

$x = \sqrt{2 \times 10^{-9}}$

$x = 4.47 \times 10^{-5}\ mol/dm^3$.

$\therefore$ The solubility is $4.47 \times 10^{-5}\ mol/dm^3$.

4c/

i/ This is because of the Presence of sulphur in the Na_2SO_4 because sulphur is solid in nature hence - when the mixture of Na_2SO_4 and $Ca(NO_3)_2$ are be ing mixed together, Precipitate is formed as a result of effects of sulphur in the Mixture.

II/ **Solution**

Given that

Volume of Na_2SO_4 = $50cm^3$

Molarity or Molar concentration of Na_2SO_4 = 0.0152M

Volume of $Ca(NO_3)_2$ = $50cm^3$

Molarity of $Ca(NO_3)_2$ = 0.0125 M

Required; to Predict whether the Precipitate of - $CaSO_4$ will be formed or not

4c/

Recall;

solubility Product = Product of concentration or Molarity of the compounds in the chemical reaction.

Now for the Precipitate to be formed, the Product of concentration or Molarity of compounds of Na_2SO_4 and $CaSO_4$ should be larger than solubility Product given in the question

Hence.

$9.1\times10^{-6}Mol^2dm^{-6} = 0.0125\,M \times 0.0152M$

$9.1\times10^{-6}Mol^2dm^{-6} = 1.9\times10^{-4}Mol/dm^3$

From the above calculation; solubility Product of $CaSO_4$ is greater than the solubility Product of Na_2SO_4 and $Ca(NO_3)_2$

$\therefore$ The Precipitate of $CaSO_4$ will not form as solubility Product of $CaSO_4$ is greater than solubility Product of Na_2SO_4 and $Ca(NO_3)_2$.

Extract 14.2: Sample of incorrect responses to question 4, Paper 2

In Extract 14.2, the candidate gave incorrect definitions of the common ion effect and failed to distinguish between solubility and solubility product. The candidate also mentioned wrong factors affecting solubility and applied incorrect formulas in calculating solubility and Qsp. Consequently, the candidate failed to determine the occurrence of precipitation.

2.2.5 Question 5: Two components Liquid systems

This question had three parts, namely (a), (b) and (c) as follows:

*(a) When 500 cm^3 of an aqueous solution containing 4 g of solute **G** per litre, was shaken with 100 cm^3 of pentan-1-ol, 1.5 g of the solute **G** was extracted. Assuming molecular state of the solute remains the same in both solvents, calculate;*

*(i) The partition coefficient of the solute **G** between pentan-1-ol and water.*

*(ii) The mass of the solute **G** which will remain in the aqueous solution after a further shaking with 100 cm^3 of pentan-1-ol.*

*(b) An aromatic compound **Z** was steam distilled at 98 ˚C and 1 atmosphere pressure. The distillate was found to contain 26 g of water and 7.5 g of the compound **Z**. If the saturated vapour pressure of water at 88 ^{0}C is 720 mmHg, calculate the molar mass of **Z**.*

(c) The vapour pressures of ethanol and phenol at 20˚C are 53.6 mm Hg and 85.2 mm Hg, *respectively. The mole fraction of ethanol in a mixture of phenol and ethanol at 20˚C is 0.45. Calculate the total vapour pressure of the mixture and the mole fraction of phenol in the vapour phase.*

This question was attempted by 45,513 candidates, representing 97.35% of all candidates. Of these, 11,367 candidates (24.98%) scored from 12.0 to 20.0 marks, 12,248 (26.91%) from 7.0 to 11.5 marks and 21,898 (48.11%) from 0.0 to 6.5 marks. Overall, the performance on this question was average, with 23,615 candidates (51.89%) attaining 7.0 marks or above. The candidates' performance is illustrated in Figure 15.

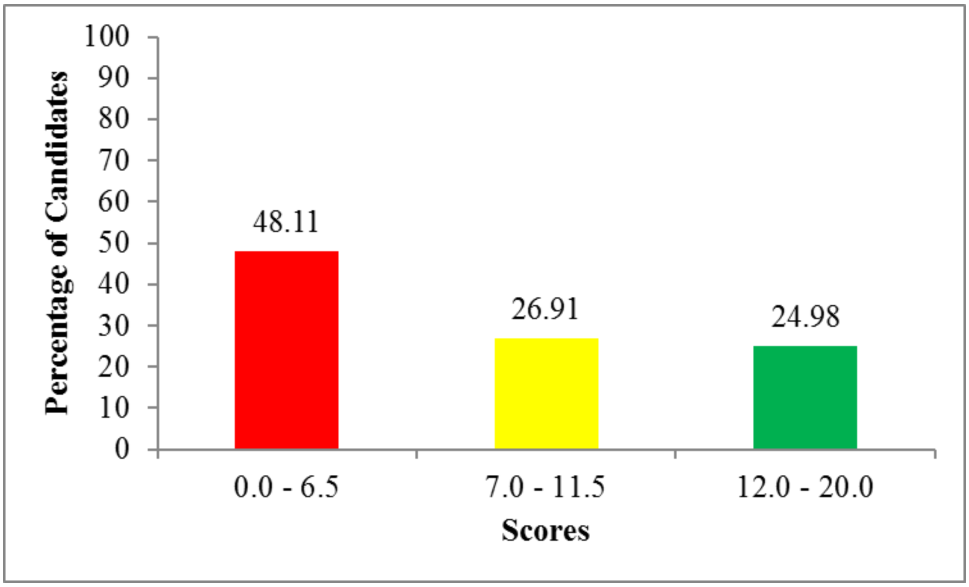


Figure 15: *Candidates' Performance on Question 5, Paper 2*

The candidates who scored high marks (51.89%) on this question demonstrated a sound understanding of two-component liquid systems, particularly in applying the distribution law in solvent extraction, steam distillation principles, and Raoult's law for vapour pressures of completely miscible liquids.

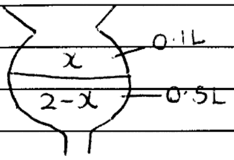
In part (a), these candidates correctly used appropriate formulas to calculate the partition coefficient of solute G between pentan-1-ol and water. They successfully determined the amount of solute remaining in the aqueous layer after further extraction with the organic solvent. In part (b), they accurately applied Dalton's law of partial pressures and executed proper mathematical procedures to calculate the molecular mass of an aromatic compound through the steam distillation method. In part (c), the candidates competently used Raoult's law and the concept of mole fractions to determine the total vapour pressure of a mixture of ethanol and phenol, as well as the mole fraction of phenol in the vapour phase. Their solutions reflected proper formula selection, correct substitution and accurate computation. Extract 15.1 illustrates one of the correct responses provided by a candidate for Question 5.

05. (a) Solution

$4g \longrightarrow 1L$

$? \longrightarrow 0.5L$

$\therefore$ mass $= 2g$



i) $KD = \dfrac{\text{Concentration of solute in pentan-1-ol}}{\text{concentration of solute in aqueous solution}}$

$K.D = \dfrac{x/0.1}{2-x/0.5}$

But

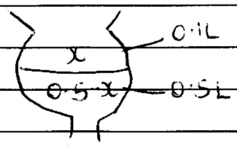
$x = 1.5$

$K.D = \dfrac{1.5/0.1}{2-1.5/0.5}$

$K.D = \dfrac{15}{1}$

$\therefore$ Partition coefficient between pentan-1-ol and water $= 15$

(ii)



$K.D = \dfrac{\text{concentration of solute in pentan-1-ol}}{\text{concentration of solute in aqueous solution}}$

$K.D = \dfrac{x/0.1}{0.5-x/0.5}$

05. (a)

ii)

$$15 = \frac{x}{0.1} \div \frac{(0.5-x)}{0.5}$$

$$15 = \frac{x}{0.1} \times \frac{0.5}{(0.5-x)}$$

$$15 = \frac{0.5x}{0.1(0.5-x)}$$

$$15 = \frac{0.5x}{0.05 - 0.1x}$$

$$0.5x = 0.75 - 1.5x$$

$$0.5x + 1.5x = 0.75$$

$$2x = 0.75$$

$$x = 0.75/2$$

$$x = 0.375g$$

Now, to get weight remain (W_r)

$$W_r = m - x$$

$$W_r = 0.5 - 0.375$$

$$W_r = 0.125g$$

$\therefore$ Mass remained in aqueous solution will be $0.125g$

(b) Solution

Mass of compound Z $(m_{su}) = 7.5g$

mass of water $(m_w) = 26g$

Molar mass of water $(M_w) = 18g/mol$

Vapour pressure of water $(P_{sv}) = 720mmHg$

Vapour pressure of Z $(P_z) = 760mmHg - 720mmHg = 40mmHg$

From

$$\frac{P^{\circ}_z}{P_w} = \frac{m_{su}}{M_{su}} \times \frac{M_w}{m_w}$$

05· (b)

$$\frac{40}{720} = \frac{7.5}{Mrsu} \times \frac{18}{26}$$

$$\frac{1}{18} = \frac{135}{26Mrsu}$$

$2430 = 26\,Mrsu$

$$\frac{2430}{26} = Mrsu$$

Maar mass = 93.46 g/mol

∴ The molar mass of Z = 93.46 g/mol.

(c) Solution

P^{o} ethanol = 53.6 mmHg

P^{o} phenol = 85.2 mmHg

Xethanol = 0.45

From

P'ethanol = P^{o}ethanol × Xethanol

P'ethanol = 53.6 × 0.45

P'ethanol = 24.12 mmHg

Then

Xethanol + Xphenol = 1

0.45 + Xphenol = 1

Xphenol = 0.55

P' phenol = P^{o}phenol × Xphenol

P' phenol = 85.2 × 0.55

P'phenol = 46.86 mmHg

∴ Total vapour pressure of the mixture = P'ethanol + P'phenol

Total vapour pressure = 24.12 + 46.86 = 70.48 mmHg

∴ Total vapour pressure of the mixture = 70.48 mmHg

05· (c)

$$C\,phenol = \frac{P^{o}phenol}{PT}$$

$$C\,phenol = \frac{46.86\,mmHg}{70.98\,mmHg}$$

Cphenol = 0.66

∴ Mole fraction of phenol in the vapour phase = 0.66

Extract 15.1: A sample of correct responses to question 5, Paper 2

In Extract 15.1, the candidate applied the correct formulas to all parts of the question and accurately computed the required answers.

On the contrary, the candidates who scored low marks (48.11%) exhibited limited understanding of the core principles underlying two-component liquid systems. In part (a), many candidates incorrectly used the total 4 g of solute present in 1 litre instead of calculating the amount present in the 500 cm^3 aqueous layer, leading to an inaccurate value of the partition coefficient (KD) and subsequent miscalculation of the amount of solute remaining after the second extraction. Some candidates also applied incorrect expressions for KD, interchanging the concentration terms of the upper and lower layers.

In part (b), candidates often applied the wrong formula to determine the molecular mass of the aromatic compound. One candidate, for example, incorrectly interchanged the mass of the compound and that of water in the equation, resulting in an erroneous answer.

In part (c), several candidates failed to correctly apply Dalton's law of partial pressures and mole fraction principles. Some simply added the vapour pressures of ethanol and phenol without performing proper calculations. Others failed to compute the mole fraction of phenol correctly, such as by omitting the step of subtracting ethanol's mole fraction from one ($1 - 0.45 = 0.55$). One candidate used the mole fraction of ethanol for both components, calculating partial vapour pressures as 0.45×53.6 mmHg for ethanol and 0.45×85.2 mmHg for phenol, and then summed them to obtain 62.46 mmHg, which is incorrect. Extract 15.2 illustrates one of the inaccurate responses submitted for this question.

5 (a) DATA GIVEN.

Volume of solute G = 500cm³.

Concentration of solute G = 4g/L

Volume of pentan-1-ol = 100cm³.

Concentration of solute G = 1.5g/L

(i) Partition coefficient of solute G.

$$KD = \frac{\text{Concentration}_1}{\text{Concentration}_2}$$

$$= \frac{4}{4 - \frac{x}{100}} = \frac{15\ g/L}{4\ g/L}$$

$$KD = 3.75$$

∴ The coefficient of solute G = 3.75.

(ii) $$X = m\left(\frac{V_1}{K_D V_2 + V_1}\right)^n$$

$$= 4\left(\frac{500}{(3.75 \times 100) + 500}\right)^1$$

$$= 4 \times \left(\frac{500}{875}\right)^1$$

$$= 4 \times 0.5714$$

$$= 2.286g$$

∴ The mass of solute G = 4g − 2.286g.

The mass of solute G. = 1.71g.

5 (b) DATA GIVEN

Temperature (T) = 98°C

Pressure (P) = 1atm.

Mass of water (M_w) = 26g.

Mass of solute (M_2) = 7.5g.

Vapour pressure (P°) = 720mmHg = 0.947atm.

Temperature (T) = 88°C

Molar mass of 2 = ?

solution

$$\frac{M_w}{M_2} = \frac{P^\circ \times M_{r2}}{P^\cdot \times M_{rw}}.$$

$$\frac{26g}{7.5g} = \frac{0.947 \times M_{r2}}{1 \times 18g/mol}.$$

$$M_{r_2} = \frac{26 \times 0.947 \times 18g/mol}{7.5 \times 1}$$

$$= \frac{443 g/mol}{7.5}.$$

$$M_{r_2} = 59g/mol$$

∴ The molar mass of 2 = 59g/mol

(c) DATA GIVEN

Vapour pressure of ethanol = 53.6mmHg

Vapour pressure of phenol = 85.2mmHg.

Mole fraction of phenol and ethanol = 0.45

Total vapour pressure = ?

Mole fraction of phenol = ?

5 (c) $P_T = P_e + P_p$

$P_e = X_e P_e^{\circ}$

$P_p = X_p P_p$.

$P_T = P_e + P_p$.

$P_T = X_e P_e + X_p P_p$.

$P_T = X_e \times 53.6 + X_p \times 85.2$.

$P_T = 53.6 X_e + 85.2 X_p$.

Also $X_e + X_p = 1$.

$X_p = 1 - X_e$.

$P_T = 53.6 X_e + 85.2 - 85.2 X_e$.

$P_T = 85.2 - 31.6 X_e$

$1 = 85.2 - 31.6 X_e$.

$\frac{31.6 X_e}{31.6} = \frac{84.2}{31.6}$

$X_e = 2.7$

$X_p = 1.7$.

$P_T = 2.7 \times 53.6 + 1.7 \times 85.2$.

$P_T = 289.6$ mmHg.

∴ The total vapour pressure = 289.6 mmHg

The mole fraction of phenol = 1.7

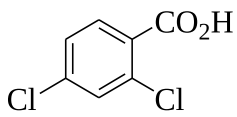
Extract 15.2: A Sample of incorrect responses to question 5, Paper 2

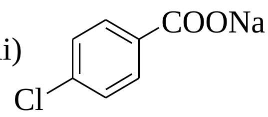
In Extract 15.2, the candidate used an incorrect mass value to calculate the distribution coefficient (KD) in parts (a). Additionally, the candidate mistakenly applied the total pressure of the system instead of the partial pressure of the organic compound in the relevant formula. In part (c), the candidate failed to derive the mole fraction of phenol from that of ethanol and incorrectly assumed the total vapour pressure to be 1, rather than calculating it based on partial pressures.

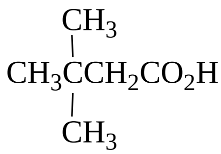
2.2.6 Question 6: Carbonyl Compounds, Carboxylic Acids and Derivatives and Amines

This question consisted of four parts; (a), (b), (c) and (d) as follows:

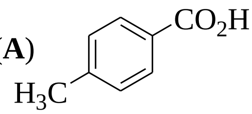
(a) *Write IUPAC names of each of the following organic compounds:*

(i) 

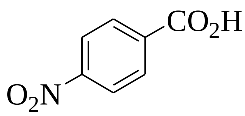
(ii) 

(iii) 

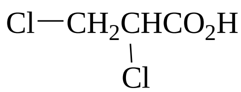
(b) *Arrange the following organic acids (**A-E**) in order of increasing acidity. Give reason(s) to support your order of arrangement.*

(**A**) 

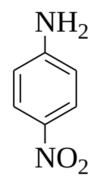
(**B**) $Cl_3C—CO_2H$

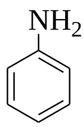
(**C**) 

(**D**) $Cl_2HC—CO_2H$

(**E**) 

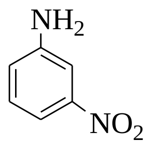
(c) *Giving reason(s), arrange the following organic compounds (**F-J**) in decreasing order of basic strengths.*

(**F**) 

(**G**) 

(**H**) CH_3NH_2

(**I**) NH_3

(**J**) 

(d) *Write equations for the laboratory synthesis of the following compounds. Use any suitable organic or inorganic reagent.*

(i) Propanoic acid from butanone.
(ii) Propanoic acid from 1-chloropropane.
(iii) Propanoic acid from 1-propanol.
(iv) Propanoic acid from propane.

This question was attempted by 27,681 (59.21%) candidates; of which 16,588 (59.93%) scored from 0 to 6.5 marks, 7,385 (26.68%) from 7 to 11.5 marks and 3,708 (13.40%) from 12 to 20 marks. The overall performance on this question was average, as 11,093 (40.08%) candidates scored 7 marks or above. Figure 16 summarises the performance of the candidates on this question.

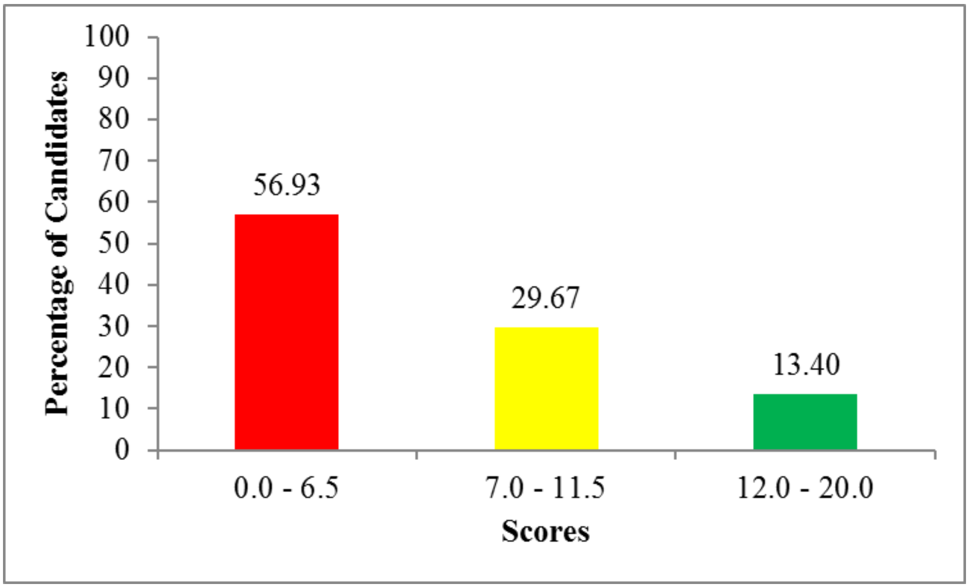


Figure 16: *Candidates' Performance on Question 6, Paper 2*

The candidate who scored high marks (40.08%) demonstrated a strong understanding of key concepts related to carboxylic acids, amines, and carbonyl compounds. In part (a), they correctly identified and wrote the IUPAC names of the given organic compounds, reflecting proper application of nomenclature rules. In part (b), many candidates were able to arrange the provided organic acids in order of increasing acidity and supported their responses with clear reasoning based on molecular structure and electron-withdrawing effects.

In part (c), those candidates correctly wrote the factors influencing the basic strength of amines, such as the nature of substituents and solvation effects. In part (d), most of them correctly outlined the conversions of various organic compounds to propanoic acid, demonstrating a sound understanding of the chemical reactions involving alcohols, aldehydes, and carboxylic acids, as well as the appropriate use of reagents and reaction conditions. Extract 16.1 illustrates a sample of correct responses.

6 (a) (i) 2, 4-dichlorobenzoic acid.

(ii) 4-Chloro sodium benzoate

(iii) 3, 3-dimethylbutanoic acid

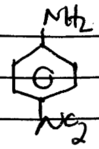
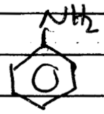
(b) A < C < E < D < B

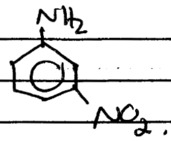
$\xrightarrow{\text{increase acidity}}$

(i) Because of negative inductive effect the compound B has high acidity because electrons are withdrawn.

(ii) For aromatic are less due to resonance effect

6 (c) Given

F ⇒  G ⇒  H ⇒ CH_3NH_2

I ⇒ NH_3 J ⇒ 

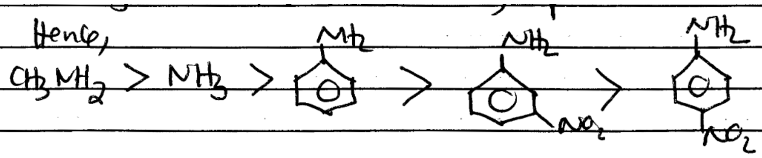
(i) Basicity (basic strength) of amine is determined by its ability of donating lone pairs.

(ii) presence of electron donating groups such as $-CH_3$ increases basic strength of amine.

(iii) Aryl group (Benzene rings) reduces the basic strength of amine since the lone pairs will not be available as a result of mesomerism.

(iv) In aryl amines (aromatic amines) the presence of electron withdrawing group at para position decreases basicity to a greater extent than any position

Hence,



$\longrightarrow$ Decreasing basic strength

OR using letters.

$H < I < G < J < F$

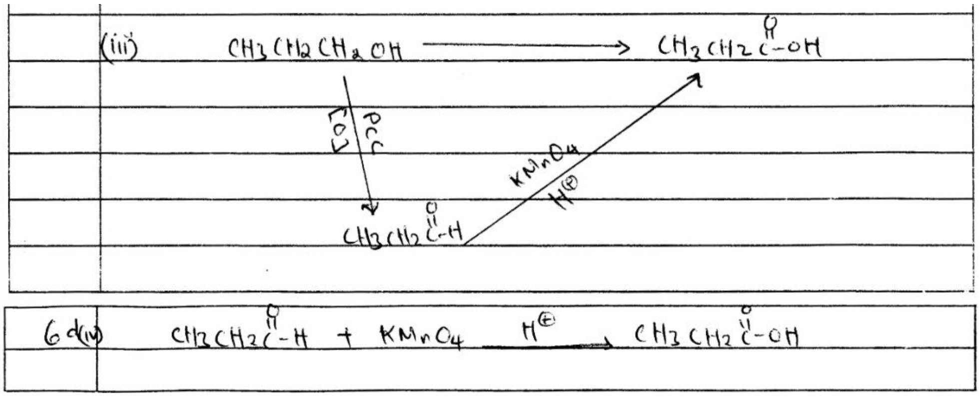
$\longrightarrow$ Decrease basic strength.

6 (d) (i) $CH_3CH_2\overset{O}{\overset{\|}{C}}-CH_3 \longrightarrow CH_3CH_2\overset{O}{\overset{\|}{C}}-OH$

$$CH_3CH_2\overset{O}{\overset{\|}{C}}-CH_3 \xrightarrow[H^{\oplus}]{LiAlH_4} CH_3CH_2\overset{OH}{\overset{|}{C}H}CH_3 \xrightarrow[\Delta]{H_2SO_4} CH_3CH_2CH{=}CH_2 \xrightarrow[\text{Zn dust}]{O_3,\ H_2O} CH_3CH_2\overset{O}{\overset{\|}{C}}-H \xrightarrow[H^{\oplus}]{KMnO_4} CH_3CH_2\overset{O}{\overset{\|}{C}}-OH$$

(ii) $CH_3CH_2CH_2Cl \longrightarrow CH_3CH_2\overset{O}{\overset{\|}{C}}-OH$

$$CH_3CH_2CH_2Cl \xrightarrow{KOH(aq)} CH_3CH_2CH_2OH \xrightarrow[\text{[O]}]{PCC} CH_3CH_2\overset{O}{\overset{\|}{C}}-H \xrightarrow[H^{+}]{KMnO_4} CH_3CH_2\overset{O}{\overset{\|}{C}}-OH$$



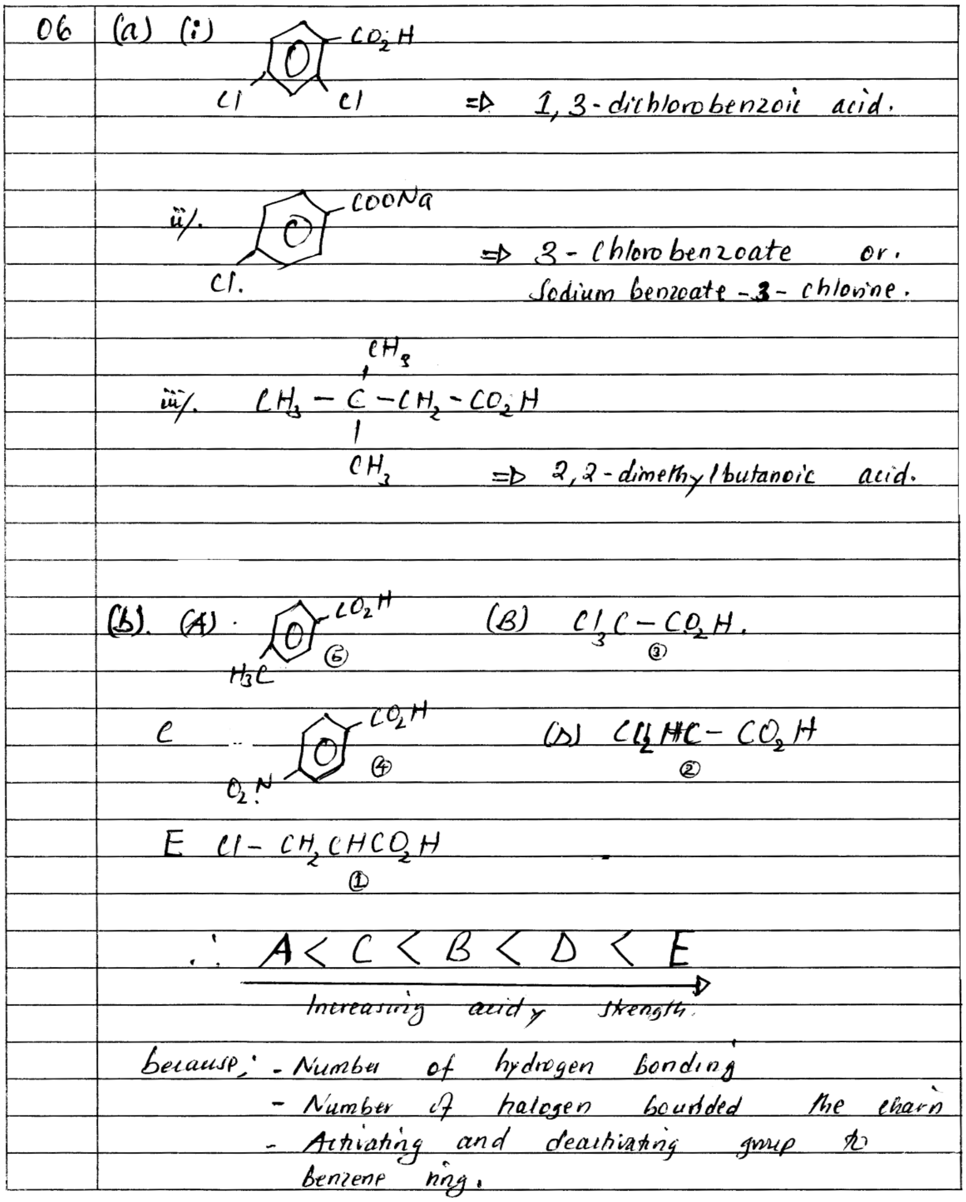
Extract 16.1: A sample of correct responses to question 6, Paper 2

In Extract 16.1, the candidate wrote the correct IUPAC names of the given compounds in part (a). In parts (b) and (c), the candidate provided the proper arrangements of the given compounds, respectively. Likewise, in part (d), the candidate wrote the correct chemical equations for the synthesis of the given organic compounds.

The candidates who scored low marks in this question revealed several notable misconceptions across various areas of organic chemistry, particularly in naming, acidity, basicity and synthesis. In part (a), many candidates demonstrated confusion in applying IUPAC naming rules. For instance, one candidate misidentified *2,4-dimethylbenzoic acid* as *4,6-dichlorobenzoic acid*, while another incorrectly named *4-chlorosodium benzoate* as *4-chloro sodium benzoic acid*. These errors indicate a misunderstanding of how to assign substituent positions and correctly name carboxylic acid salts. In part (b), candidates struggled to order organic acids by increasing acidity due to a lack of understanding of substituent effects, such as inductive and resonance effects, as well as how the position and type of substituents influence acidity.

In part (c), misconceptions were evident in candidates' explanations of amine basicity. For example, one candidate wrongly concluded that methylamine (CH_3NH_2) is the least basic because the alkyl group increase the reactivity of the lone pair, thus increasing "acidity", a statement that confuses acidity with basicity and misinterprets the inductive effect. Part (d) exposed conceptual errors in organic synthesis and an incorrect application of reagents. Some candidates attempted to oxidise ketones using reducing agents like $LiAlH_4$. In contrast, others wrongly assumed that water could convert alcohols directly into carboxylic acids, revealing a poor grasp of reaction conditions and redox principles.

Overall, the low scores were primarily due to conceptual deficiencies rather than procedural errors. The candidates' responses revealed fundamental gaps in their understanding of organic chemistry, especially in functional group transformations, proper reagent usage, acid-base behaviour and systematic nomenclature. Extract 16.2 shows one of the incorrect responses to question 6.


06 (a) (i) CO_2H Cl Cl ⇒ 1,3-dichlorobenzoic acid.

ii/. COONa Cl. ⇒ 3-Chlorobenzoate or. Sodium benzoate -3- chlorine.

iii/. $CH_3-C(CH_3)_2-CH_2-CO_2H$ ⇒ 2,2-dimethylbutanoic acid.

(b). (A) CO_2H H_3C ⑥ (B) Cl_3C-CO_2H. ③

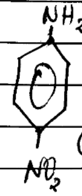
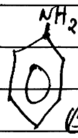
C CO_2H O_2N ④ (D) Cl_2HC-CO_2H ②

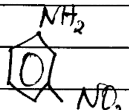
E $Cl-CH_2CHCO_2H$ ①

∴ A < C < B < D < E

Increasing acidy strength.

because: - Number of hydrogen bonding
- Number of halogen boudded the charn
- Activiating and deactiviating group to benzene ring.

06 (c) F.  ② (G)  ③ (H) CH_3NH_2. ④

(I) NH_3 ⑤ (J)  ①.

$$I > H > G > F > J$$

Dedreasing order of basic strength.

This is because.

⇒ The basic strength of amine depend on.

- Classification of amine that ~~prime~~ primary amine strong basic that tertiary amine and secondar

1° primary amine > 3° tertiary amine > 2° secondary amine.

- The benzene ring is less basic that chaining carbon.
- Amonia compound highly basic strength since is basic in nature.

(d) (i) Propanoic acid from butanone.

$$CH_3-CH_2-\overset{O}{\overset{\|}{C}}-CH_3 \longrightarrow CH_3CH_2COOH$$

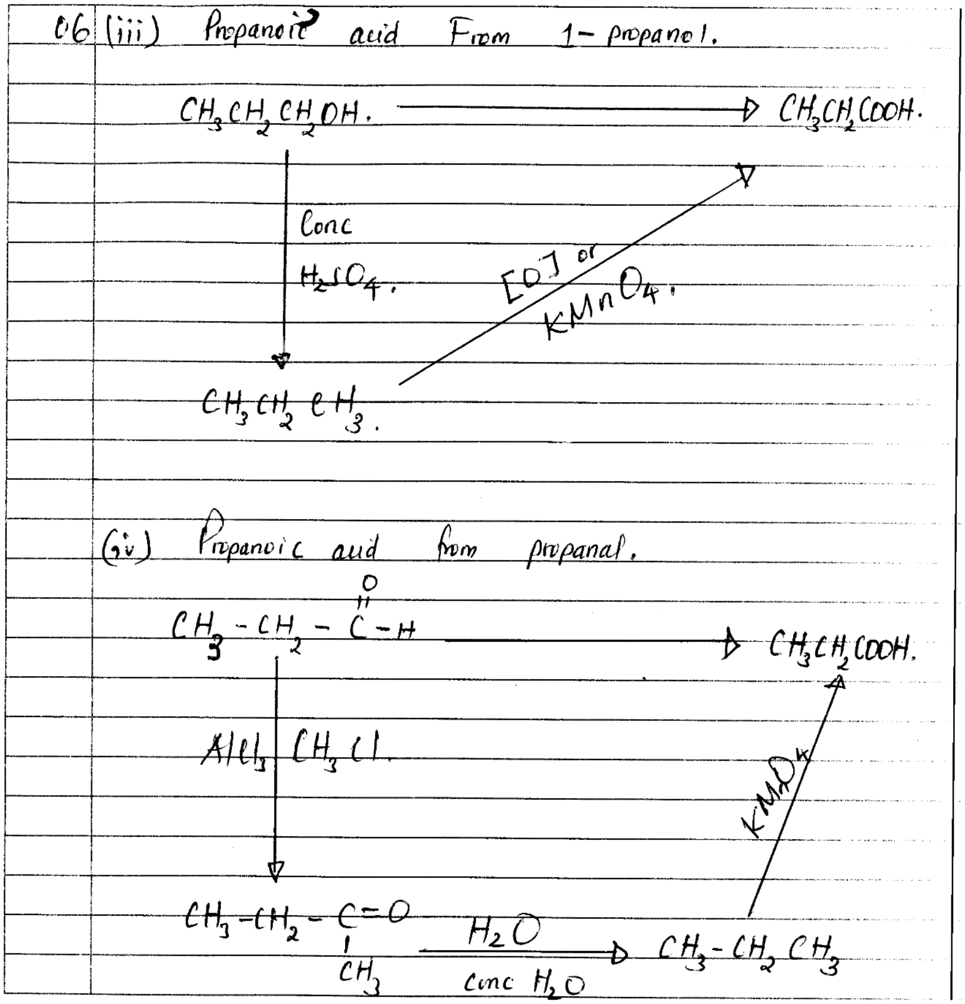
06 (d) $CH_3CH_2-\overset{\overset{O}{\|}}{C}-CH_3 \longrightarrow CH_3CH_2COOH.$

$$CH_3CH_2COCH_3 \xrightarrow{\text{Conc } H_2SO_4.} CH_3CH_2CH_2-CH_3. \xrightarrow{\text{dry ether Mg.}} CH_3CH_2CH_3 \xrightarrow[H_2O.]{KMnO_4.} CH_3CH_2COOH.$$

ii). Propanoic acid from 1- Chloropropane.

$CH_3CH_2CH_2Cl \longrightarrow CH_3CH_2COOH.$

$$CH_3CH_2CH_2Cl \xrightarrow{\cancel{AlCl_3.}\ CH_3Cl} CH_3CH_2CH_3 \xrightarrow{KMnO_4.} CH_3CH_2COOH.$$



Extract 16.2: A Sample of incorrect responses to question 6, Paper 2

In Extract 16.2, the candidate gave incorrect IUPAC names for the organic compounds in part (a). In parts (b) and (c), the candidate incorrectly arranged the given carboxylic acids and amines, respectively. Additionally, in part (d), the candidate used inappropriate reagents in the synthesis of carboxylic acids from the provided organic compounds.

2.3 132/3-CHEMISTRY 3

This was an actual practical examination paper presented in three equivalent alternatives: 132/3A Chemistry 3A, 132/3B Chemistry 3B and 132/3C Chemistry 3C. Candidates were required to attempt only one of these alternatives. Each paper consisted of three compulsory questions, carrying 50 marks. Question 1 carried 20 marks, while Questions 2 and 3 had 15 marks each. All three questions focused on subtopics under the main topic of Chemical Analysis. Specifically, Question 1 covered Volumetric Analysis, Question 2 focused on Physical Chemistry Analysis and Question 3 dealt with Qualitative Analysis. The minimum pass marks were 7.0 for Question 1 and 5.5 for both Questions 2 and 3. The following section presents the analysis of each question.

2.3.1 Question 1: Volumetric Analysis

2.3.1.1 Alternative 3A

The question was as follows:

You are required to demonstrate your analytical skills by doing iodometric titration, aiming at determining the number of molecules of water of crystallisation. Use the following reagents to accomplish the analysis.

U1: *solution of 0.04 M* $KMnO_4$*;*

U2: *solution of* $Na_2S_2O_3.XH_2O$ *made by dissolving 12.4 g in 0.5* dm^3 *of distilled water;*

U3: *solution of 10% KI;*

U4: *starch solution;*

U5: *solution of 1 M sulphuric acid.*

Theory

A quantitative reaction between potassium permanganate and potassium iodide in acidic medium involves production of iodine. During the titration process, molecules of iodine produced react with sodium thiosulphate.

Procedure

(i) *Fill the burette with **U2**.*

(ii) *Pipette 20* cm^3 *of **U1** into a conical flask. Add 20* cm^3 *of distilled water. Swirl the mixture gently and then add 20* cm^3 *of **U3** into the flask followed by 20* cm^3 *of **U5** into the same flask.*

(iii) *Titrate **U2** with the solution mixture in the conical flask until a pale yellow colour is observed. Add 2* cm^3 *of **U4** and continue to titrate until the dark blue colour is discharged to colourless.*

(iv) *Record the first titre value.*

(v) *Repeat steps (i) to (iv) three times to obtain three titre values.*

Questions

(a) Tabulate the results.

(b) Write the balanced chemical equation for the experiment which involved:

(i) production of iodine.

(ii) consumption of iodine.

(iii) the whole experiment.

*(c) Calculate the actual molarity of solution **U1** after dilution.*

*(d) Compute the value of **X** in the formula $Na_2S_2O_3.XH_2O$.*

(e) Explain what will happen when potassium permanganate is missing in this experiment.

2.3.1.2 Alternative 3B

The question was as follows:

A solution which contains iodine is commonly used to clean wounds. During this process, medical attendants may unpredictably smear iodine on their clothes. Cleanliness of these clothes requires the use of specific amount of thiosulphate solution. Perform titration technique and calculate the amount of sodium thiosulphate required for the laundry using the following reagents and the given apparatuses.

***Q1**: A solution of 0.04 M $KMnO_4$;*

***Q2**: A solution of $Na_2S_2O_3$;*

***Q3**: A solution of 10% KI;*

***Q4**: A starch solution;*

***Q5**: A solution of 1 M sulphuric acid.*

Theory

A quantitative reaction between potassium permanganate and potassium iodide in acidic medium involves production of iodine. Iodine reacts with sodium thiosulphate during titration process.

Procedure

*(i) Fill the burette with **Q2**.*

*(ii) Measure 10 cm^3 of **Q1** into a conical flask. Add 10 cm^3 of distilled water. Swirl the mixture gently, then add 10 cm^3 of solution **Q3** followed by 10 cm^3 of **Q5** into the mixture.*

*(iii) Titrate **Q2** against the mixture in the conical flask until a pale yellow colour is observed. Add 2 cm^3 of **Q4** into the conical flask and continue to titrate until the dark blue colour turn to colourless.*

(iv) Record the first titre value.

(v) Repeat steps (i) to (iv) three times and record the titre values.

Questions

(a) Tabulate your results.

(b) Write the balanced chemical equation for the whole experiment.

(c) Calculate the final molarity of potassium permanganate.

(d) Determine the concentration of sodium thiosulphate in g/dm^3.

(e) Suggest another suitable mineral acid apart from sulphuric acid that can be used in this experiment.

2.3.1.3 Alternative 3C

The question was as follows:

Use the reagents and apparatus given to demonstrate how you would analyse hydrated $Na_2S_2O_3$ to determine the number of molecules of water of crystallisation.

***W1**: A solution of 0.08 mole of $KMnO_4$ in 2000 cm^3;*

***W2**: A solution of $Na_2S_2O_3.XH_2O$ made by dissolving 14.88 g in 600 cm^3 of distilled water;*

***W3**: A solution of 10% KI;*

***W4**: A starch solution;*

***W5**: A solution of 1 M sulphuric acid.*

Theory

A quantitative reaction between potassium permanganate and potassium iodide in acidic medium leads to the production of iodine. During titration, iodine reacts with sodium thiosulphate in presence of starch which acts as an indicator.

Procedure

*(i) Fill a burette with **W2**.*

(ii) *Measure 10 cm^3 of **W1** into a conical flask. Add 10 cm^3 of distilled water. Swirl the mixture gently and add 10 cm^3 of **W3**. Add 10 cm^3 of **W5** into the mixture.*

(iii) *Titrate **W2** against the mixture until a pale yellow colour is observed. Add 2 cm^3 of **W4** and continue to titrate until the colour of the solution changes from dark blue to colourless.*

(iv) *Record the first titre value.*

(v) *Repeat steps (i) to (iv) three times and record the titre values.*

Questions

(a) *Tabulate the results.*

(b) *Write balanced redox chemical equations to represent the following:*

 (i) *Reaction between potassium permanganate and potassium iodide in the presence of sulphuric acid.*

 (ii) *Reaction between iodine and sodium thiosulphate.*

(c) *Calculate the concentration of potassium permanganate that reacted with potassium iodide.*

(d) *Determine the percentage composition of water in $Na_2S_2O_3.XH_2O$.*

(e) *Suggest another suitable substitute for potassium permanganate in this experiment.*

Question 1 was attempted by 46,748 candidates, and their performance is summarised in Figure 17.

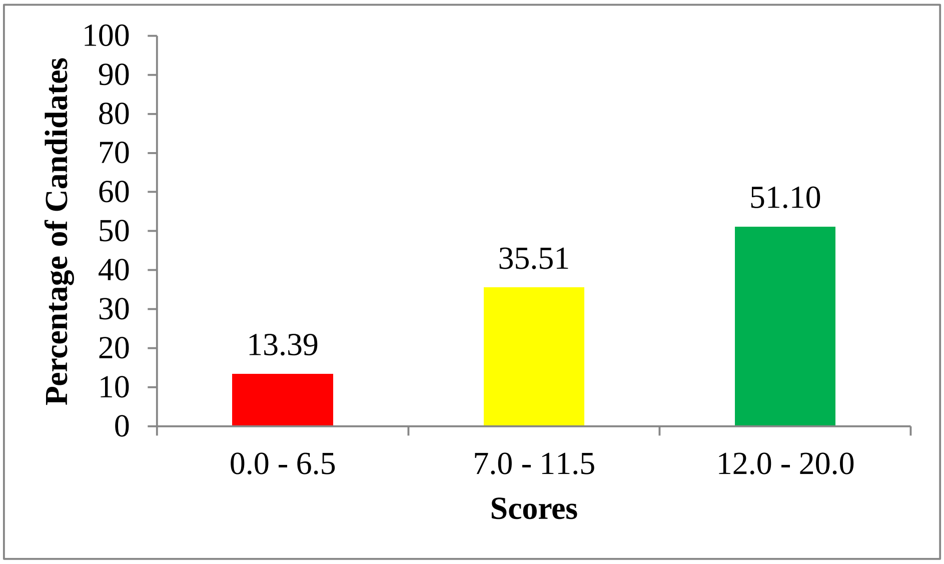


Figure 17: *Candidates' Performance on Question 2, Paper 3*

Table 1 shows that, the majority (86.61%) of candidates scored 7.0 marks or above. Their performance revealed both theoretical understanding and practical skill in titration procedures and in applying the dilution law. They also demonstrated competence in writing and balancing chemical equations, particularly those involving iodometric redox reactions

In Alternative A, candidates accurately standardized sodium thiosulphate solution using the iodine liberated from a reaction between potassium permanganate and potassium iodide in the presence of dilute sulphuric acid. This enabled them to correctly calculate the molarity, mass concentration, and the number of water of crystallization molecules in hydrated sodium thiosulphate ($Na_2S_2O_3{\cdot}XH_2O$). Furthermore, they showed a clear understanding of the redox process, recognising the role of potassium permanganate in liberating iodine, indicated by the characteristic dark brown colouration in the solution.

In Alternative B, the candidates applied the dilution law to calculate the molarity of a prepared potassium permanganate solution. They then performed a redox titration using sodium thiosulphate to determine its molarity and mass concentration. Additionally, they identified and justified the use of an alternative mineral acid other than sulphuric acid as a suitable acidic medium for the reaction.

In Alternative C, the candidates followed the prescribed experimental procedures to determine the number of moles of water of crystallisation in hydrated sodium thiosulphate. They carried out calculations based on titration data to accurately establish the percentage composition of water in the compound, demonstrating a high level of proficiency in quantitative analysis and mathematical manipulation. Furthermore, they proposed and justified an alternative reagent suitable for replacing potassium permanganate in the experimental setup.

Generally, high-scoring candidates exhibited excellent analytical skills and a strong understanding of the principles of volumetric analysis, particularly in iodometric titration. They followed the correct procedures and demonstrated accuracy in data recording and interpretation, enabling them to address the question's requirements effectively. Extracts 17.1, 17.2, and 17.3 illustrate correct responses to Question 1.

1(a) Table of results.

Experiment	PILOT	Titre 1	Titre 2	Titre 3
Final reading (cm3)	39.90	40.00	40.10	39.90
Initial reading (cm3)	0.00	0.00	0.00	0.00
Mean titre volume (cm3) used	39.90	40.00	40.10	39.90

Average volume used = $\frac{1+2+3}{3}$

Average volume used = $\frac{(40.00+40.10+39.90)}{3}$ cm^3

∴ Average volume used = 40.00 cm^3

1(b) (i) Half-reduction reaction:

$MnO_4^- + 8H^+ + 5\bar{e} \rightarrow Mn^{2+} + 4H_2O$

Half-oxidation reaction:

$2I^- \longrightarrow I_2 + 2\bar{e}$

Overall reaction:

$2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn^{2+} + 5I_2 + 8H_2O$

(ii) Half-reduction reaction:

$I_2 + 2\bar{e} \longrightarrow 2I^-$

Half-oxidation reaction:

$2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2\bar{e}$

Overall reaction:

$2S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I^-$

(iii)

$$\begin{cases} 1 & 2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn^{2+} + 5I_2 + 8H_2O \\ 5 & 2S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I^- \end{cases}$$

$$+\begin{cases} 2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn^{2+} + \cancel{5I_2} + 8H_2O \\ 10S_2O_3^{2-} + \cancel{5I_2} \longrightarrow 5S_4O_6^{2-} + \cancel{10I^-} \end{cases}$$

1(d) $18x = (248 - 158)$

$\frac{18x}{18} = \frac{90}{18}$

$x = 5$

$\therefore$ The value of X is 5.

(e) If potassium permanganate is missing there will be no liberation of iodine since there is no oxidizing agent for its oxidation

Extract 17.1: A sample of correct responses to question 1, Alternative Practical 3A

In Extract 17.1, the candidate accurately completed the table of results using two decimal places. The titre volumes were correctly calculated and fell within the acceptable range. Correct half-equations for the redox reactions were provided. The candidate identified the colour change from brown to colourless at the endpoint. All calculations to determine the water of crystallisation in $Na_2S_2O_3 \cdot XH_2O$ were accurate.

01. (b).

$$+\begin{cases} 2\,|\; MnO_4^-{}_{(aq)} + 8H^+_{(aq)} + 5e^- \longrightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)} \\ 5\,|\; 2I^-_{(aq)} \longrightarrow I_{2(g)} + 2e^- \end{cases}$$

$$2MnO_4^-{}_{(aq)} + 16H^+_{(aq)} + 10I^-_{(aq)} + \cancel{10e^-} \longrightarrow 2Mn^{2+}_{(aq)} + 5I_{2(aq)} + 8H_2O_{(l)} + \cancel{10e^-}.$$

$$\therefore 2MnO_4^-{}_{(aq)} + 16H^+_{(aq)} + 10I^-_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + 5I_{2(aq)} + 8H_2O_{(l)} \text{ ——— (iii).}$$

Case II: Reaction of Iodine with $Na_2S_2O_3$

Reduction half reaction.

$$I_{2(s)} \longrightarrow I^-_{(aq)}$$

$$I_{2(s)} \longrightarrow 2I^-_{(aq)}$$

$$I_{2(s)} + 2e^- \longrightarrow 2I^-_{(aq)} \text{ ——— (iv).}$$

Oxidation half reaction.

$$S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)}$$

$$2S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)}$$

$$2S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2e^- \text{ ——— (v)}$$

Overall reaction.

add equation (iv) and (v) we get.

$$+\begin{cases} I_{2(s)} + 2e^- \longrightarrow 2I^-_{(aq)} \\ 2S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2e^- \end{cases}$$

$$I_{2(s)} + 2S_2O_3^{2-}{}_{(aq)} + \cancel{2e^-} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2I^-_{(aq)} + \cancel{2e^-}.$$

$$\therefore I_{2(s)} + 2S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2I^-_{(aq)} \text{ ——— (vi).}$$

Case III: Equation for the whole experiment

multiply eqn (iii) by 1 and eqn (v) by 5 then add we get

$$+\begin{cases} 1\,|\; 2MnO_4^-{}_{(aq)} + 16H^+_{(aq)} + 10I^-_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + 5I_{2(s)} + 8H_2O_{(l)} \\ 5\,|\; I_{2(aq)} + 2S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2I^-_{(aq)} \end{cases}$$

Q1. (b) $2MnO_{4(aq)}^- + 16H^+_{(aq)} + \cancel{10I^-_{(aq)}} + \cancel{5I_{2(aq)}} + 10S_2O_{3(aq)}^{2-} \rightarrow 2Mn^{2+}_{(aq)} + \cancel{5I_{2(aq)}} + 8H_2O + 5S_4O_{6(aq)}^{2-} + \cancel{10I^-_{(aq)}}$

∴ $2MnO_{4(aq)}^- + 16H^+_{(aq)} + 10S_2O_{3(aq)}^{2-} \rightarrow 2Mn^{2+}_{(aq)} + 8H_2O_{(l)} + 5S_4O_{6(aq)}^{2-}$

$nMnO_4^- : nS_2O_3^{2-} = 2:10 = 1:5$.

∴ chemical equation is $2MnO_{4(aq)}^- + 16H^+_{(aq)} + 10S_2O_{3(aq)}^{2-} \rightarrow 2Mn^{2+}_{(aq)} + 8H_2O_{(l)} + 5S_4O_{6(aq)}^{2-}$

c) final molarity of $KMnO_4$ (Md).
since a solution of was diluted with water
we have.
molarity of pure $KMnO_4$ (Mc) = 0.04M.
Volume of pure $KMnO_4$ (Vc) = 10cm³.
Volume of diluted soln (Vd) = 10 + 10 = 20cm³.
Molarity of diluted $KMnO_4$ (Md) = ?
From dilution law.

$McVc = MdVd$.

$Md = \frac{McVc}{Vd}$.

$Md = \frac{0.04 \times 10}{20}$.

$Md = 0.02M$.

∴ final molarity of $KMnO_4$ was 0.02M.

Extract 17.2: A sample of correct responses to question 1, Alternative Practical 3B

In Extract 17.2, the candidate accurately recorded data and calculated the titre volumes. The candidate correctly applied the dilution law to compute the final molarity of potassium permanganate. The molarity of sodium thiosulphate was determined using the mole ratio concept. The candidate also proposed a suitable inert mineral acid alternative to sulphuric acid. Overall, the response demonstrated a clear understanding of the principles of redox titration.

1. (a) Volume of burette used was 50.00cm³

Volume of pipette used was 20.00cm³

TABLE OF RESULTS

Titration number	Pilot	1	2	3
Final volume (cm^3)	20.10	40.30	20.00	39.80
Initial volume (cm^3)	0.00	20.10	0.00	20.00
Volume used (cm^3)	20.10	20.20	20.00	19.80

$$\text{Average titre volume} = \frac{(\text{Volume 1} + \text{Volume 2} + \text{Volume 3})\,cm^3}{3}$$

$$= \frac{(20.20 + 20.00 + 19.80)\,cm^3}{3}$$

$$= \frac{60.00\,cm^3}{3}$$

∴ Average titre volume was 20.00cm³.

(b) (i) From conical flask.

$$2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn^{2+} + 5I_2 + 8H_2O.$$

(ii) Reaction between Iodine and sodium thiosulphate.

$$2S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I^-$$

(c) From dilution law.

$M_cV_c = M_dV_d$

Molarity before dilution (M_c) = 0.04 mol/dm³.

Volume before dilution (V_c) = 10.00cm³

Molarity after dilution (M_d) = {Required}.

Volume after dilution (V_d) = 20.00cm³

$$M_c = \frac{\text{number of moles (mol)}}{\text{volume}\ (dm^3)}$$

1(c)	Volume = 2000cm^3
	$1dm^3 = 1000cm^3$
	$? = 2000cm^3$
	$= \frac{1dm^3 \times 2000cm^3}{1000cm^3}$
	$= 2dm^3$.
	number of moles = 0.08 mole of $KMnO_4$.
	$Mc = \frac{0.08 \text{ moles}}{2dm^3}$
	$Mc = 0.04 mol/dm^3$.
	$Vd = Vc$ + volume of distilled water
	$= 10.00cm^3 + 10.00cm^3$
	$Vd = 20.00 cm^3$
	$Md = \frac{McVc}{Vd}$.
	$Md = \frac{0.04 mol/dm^3 \times 10.00cm^3}{20.00cm^3}$.
	$\therefore Md = 0.02 mol/dm^3$.
(d)	From reactions.
	$1\left(2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn^{2+} + 5I_2 + 8H_2O\right)$
	$5\left(2S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I^-\right)$
	$2MnO_4^- \cancel{+10I^-} + 16H^+ + 10S_2O_3^{2-} \cancel{+5I_2} \longrightarrow 2Mn^{2+} \cancel{+5I_2} + 8H_2O +$
	$5S_4O_6^{2-} \cancel{+10I^-}$
	$\therefore$ Balanced equation.
	$2MnO_4^- + 16H^+ + 10S_2O_3^{2-} \longrightarrow 2Mn^{2+} + 5S_4O_6^{2-} + 8H_2O$.

1(d) $nMnO_4 = 2moles$

$n S_2O_3 = 10moles$

$MMnO_4 = 0.02M$

$VMnO_4 = 20.00cm^3$

$MS_2O_3 = 20.00cm^3$

$MS_2O_3 = $ Required ?

from Titration formulae.

$$MS_2O_3 = \frac{nS_2O_3 \times MMnO_4 \times VMnO_4}{VS_2O_3 \times nMnO_4}$$

$$MS_2O_3 = \frac{10moles \times 0.02M \times 20.00cm^3}{20.00cm^3 \times 2moles}.$$

$$MS_2O_3 = 0.1mol/dm^3.$$

from

mass of $Na_2S_2O_3 \cdot xH_2O = 14.88g$

Volume of $Na_2S_2O_3 \cdot xH_2O = 600cm^3 = 0.6dm^3$.

$$\text{concentration} = \frac{\text{mass (g)}}{\text{Volume } (dm^3)}$$

$$= \frac{14.88g}{0.6dm^3}$$

concentration $= 24.8g/dm^3$.

from $\text{Molarity} = \frac{\text{mass concentration}}{\text{molar mass}}$.

$$\text{molarmass} = \frac{\text{mass concentration}}{\text{Molarity}}.$$

1(d)	Molar mass = $\frac{24.8 g/dm^3}{0.1 mol/dm^3}$
	Molar mass = 248 g/mol.
	From: $Na_2S_2O_3 \cdot XH_2O$ = 243g/mol.
	$Na_2S_2O_3 \cdot XH_2O$ = 248g/mol.
	$2(Na) + 2(S) + 3(O) + (H_2O)X$ = 248g/mol.
	158g/mol + (18X)g/mol = 248g/mol
	$\frac{(18X)g/mol}{18g/mol} = \frac{90g/mol}{18g/mol}$
	∴ X = 5
	Percentage composition = $\frac{\text{water composition}}{\text{~~total~~ hydrated } Na_2S_2O_3}$ × 100%
	water composition = $Na_2S_2O_3 \cdot 5H_2O$.
	= $5H_2O$
	= 5(18g/mol)
	= 90g/mol.
	Total hydrated $Na_2S_2O_3$ = 248g/mol.
	Percentage composition = $\frac{90g/mol}{248g/mol}$ × 100%
	= 0.3629 × 100%
	∴ Percentage composition of water in $Na_2S_2O_3 \cdot XH_2O$ was 36.29%
1(e)	Potassium dichromate ($K_2Cr_2O_7$) is another suitable substitute for potassium permanganate in this experiment.

Extract 17.3: A sample of correct responses to question 1, Alternative Practical 3C

In Extract 17.3, the candidate accurately recorded titre values to two decimal places, all of which fell within the acceptable range. They wrote balanced redox equations for reactions between potassium permanganate and iodide ions under acidic conditions. The dilution law was correctly applied to calculate the molarity of potassium permanganate. The candidate accurately calculated the percentage composition of water in $Na_2S_2O_3 \cdot XH_2O$. They also suggested a suitable alternative oxidising agent to replace potassium permanganate.

Conversely, a few candidates (13.39%) scored low marks, ranging from 0 to 6.5 in Question 1, as indicated in Table 1. These candidates displayed several key weaknesses. A common challenge was their inability to accurately identify the endpoint of the redox titration, which led to incorrect titration values and, consequently, erroneous calculations. Most of them demonstrated limited understanding of the dilution law, particularly in determining the molarity of the diluted potassium permanganate solution. This knowledge gap adversely affected subsequent calculations, including the determination of the number of moles of water of crystallisation in hydrated sodium thiosulphate ($Na_2S_2O_3 \cdot XH_2O$). Additionally, some candidates struggled to write balanced redox equations, leading to incorrect mole ratios between the oxidant and reductant. For instance, in Alternative A, several candidates incorrectly used the original molarity of potassium permanganate rather than the diluted molarity derived from the dilution law to calculate the concentration of sodium thiosulphate. Others failed to explain the significance of potassium permanganate in the redox reaction; for example, one candidate incorrectly stated that its role was to act as a self-indicator, which is not applicable in this context.

In Alternative B, several candidates failed to obtain the correct titre due to a lack of knowledge of the colour changes involved in the titration process. These transitions from brownish-yellow to yellow, pale yellow, blue, and finally colourless were either overlooked or misinterpreted, leading to inaccurate end-point detection. Additionally, there were issues with the presentation of the data. Some candidates did not adhere to the requirement of recording values to two decimal places or failed to organise results in a proper tabular form. One candidate, for instance, filled the results table using only one decimal place. Others misapplied the dilution formula, using expressions such as $Vd = VU1 + VU3$, which lack scientific validity.

In Alternative C, several candidates failed to write balanced redox equations relevant to iodometric titration. One such example was the incorrect balancing of thiosulphate ions as 1 mole instead of 2 moles in the reaction:

$$S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I^-$$

Some also wrote incorrect chemical formulas for reagents, resulting in unbalanced equations and flawed calculations. In terms of computation, others misapplied mathematical procedures, such as using the wrong formula for the percentage composition of water in the hydrated salt. These conceptual and procedural errors prevented them from arriving at the correct values. Extracts 17.4, 17.5, and 17.6 illustrate examples of such incorrect responses from candidates in this category.

1. (a)

Volume of burette = 50cm³

Volume of pipette = 20cm³

Titration value	Pilot	1	2	3
Final volume used(cm³)	29.00	28.07	28.40	28.1
Initial volume used(cm³)	0.00	0.00	0.00	0.00
Total volume used(cm³)	29.0	28.07	28.40	28.1

Volume used $= \frac{V_1+V_2+V_3}{3}$

Volume used $= \frac{28.07 + 28.40 + 28.1}{3}$

∴ The volume in the value = 28.4 cm³.

(b)

i) Production of Iodine.

$KI \longrightarrow I_2 + e^-$

$MnO_4 + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$.

$5KI \longrightarrow 5I_2 + \cancel{5e}$

$MnO_4 + 8H^+ + \cancel{5e} \longrightarrow Mn^{2+} + 4H_2O$

∴ $MnO_4 + 5KI + 8H^+ \longrightarrow Mn^{2+} + I_2 + 4H_2O$.

1. (b)

iii) The whole experiment.

$MnO_4 \longrightarrow Mn^{2+}$

$MnO_4 \longrightarrow Mn^{2+} + 4H_2O$

$MnO_4 + 8H^+ \longrightarrow Mn^{2+} + 4H_2O$

$MnO_4 + 8H + 5e^- \longrightarrow Mn^{2+} + 4H_2O$.

$\therefore$ The $MnO_4 + 8H + 5e \longrightarrow Mn^{2+} + 4H_2O$.

from $Na_2S_2O_3$.

$2.S_2O_3 \longrightarrow S_4O_6$

$\therefore 2S_2O_3 \longrightarrow S_4O_6$.

ii) Consumption of Iodine.

$KI \longrightarrow I_2 + e$

$\therefore KI \longrightarrow I_2$.

1. (c) Calculate

$$\text{Molarity} = \frac{\text{concentration}}{\text{molar mass}}.$$

Molarity = ?

$$\text{Concentration} = \frac{\text{mass}}{\text{volume}}$$

mass = 12.4g

Volume = 0.5

$$\text{Concentration} = \frac{12.4}{0.5}$$

$= 24.8\ g/dm$

from:

$$\text{Molarity} = \frac{24.8}{158} = 0.15M \text{ or } 0.15mol/dm^3$$

from:

$$\frac{MaVa}{MbVb} = \frac{na}{nb}$$

Molarity of acid (Ma) = 0.15M

Molarity of base (Mb) = ?

Volume of acid (Va) = $28.4cm^3$

Volume of base (Vb) = 20 cm^3

Number of mole of acid (na) = 6

Number of mole of base (nb) = 5

$$M_{MnO_4} = \frac{M_{S_2O_3} \times V_{S_2O_3} \times n_{MnO_4}}{V_{MnO_4} \times n_{S_2O_3}}.$$

1. (c)

$M_{MnO_4} = \frac{0.15M \times 28.4 \times 6}{20 \times 5}$

$= \frac{6.39}{100}$

$M_{MnO_4} = 0.0639 mol/dm^3$

hum.

$0.0639 - 0.04 = 0.0239 mol/dm^3$

∴ The molarity of U_1 = 0.0299 mol/dm³

(d)

$\frac{\text{Concentration of unhydrous}}{\text{Concentration of hydrated}} = \frac{\text{molar mass of unhydrous}}{\text{molar mass of hydrate}}$

Concentration = 0.0239 × 158

Concentration = 3.7762 mol/dm³

Then:

$\frac{3.7762}{24.8} = \frac{158 + 18x}{158}$

∴ The value of X = 7. $Na_2S_2O_3 \cdot 7H_2O$

(e)

⇒ When potassium permanganate is missing the experiment will no be Iodometric but it will be Iodine experiment.

Extract 17.4: A Sample of incorrect responses to question 1, Alternative Practical 3A

In Extract 17.4, the candidate recorded a titre value that was 11.60 cm³ below the acceptable range and used only one decimal place in Experiments 1 and 3. In part (b), she/he failed to balance the redox equations. In part (c), the candidate did not apply the dilution principle correctly, leading to an incorrect molarity of potassium permanganate. In part (d), the candidate computed the wrong value of *X* in $Na_2S_2O_3 \cdot XH_2O$. Instead of explaining the role of potassium permanganate, the candidate merely listed types of redox titrations.

01.

TABLE OF RESULTS.

@.

Burette reading	pilot	1	2	3
Final reading with no Q_4	08.50	9.20	8.90	8.90
Initial reading	0.00	0.00	0.00	0.00
Titre volume.	8.50	9.20	8.90	8.90
Final reading with Q_4	18.40	18.90	18.90	19.00
Initial reading with Q_4	8.50	9.20	8.90	8.90
Titre volume	9.90	9.70	10.00	10.10

Average titre value before adding Q_4

$$= \frac{9.20 + 8.90 + 8.90}{3}$$

$$= 9.00\,cm^3$$

∴ The volume used before addition of Q_4 is $9.00\,cm^3$

and when Q_4 is added the titre volume

$$= \frac{\cancel{9.90} + 9.70 + 10.00 + 10.10}{3}$$

$$= 9.90\,cm^3$$

∴ The volume used after addition of Q_4 is $9.90\,cm^3$

11(b) Balanced chemical equation for the whole experiment.

$KMnO_4 + KI \rightarrow Mn^{2+} + I^-$

$MnO_4^- + I_{2(g)} \rightarrow Mn^{2+} + 2I^-$

Reduction equation.

$MnO_{4(aq)}^- \rightarrow Mn_{(aq)}^{2+} + 4H_2O_{(l)}$

$MnO_{4(aq)}^- + 8H_{(aq)}^+ + 5e^- \rightarrow Mn_{(aq)}^{2+} + 4H_2O_{(aq)}$

$I_2 + 2e^- \rightarrow 2I^-$

$2MnO_4^- + 5I_{2(g)}\ 16H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10I^-$

2 : 5

$2I_{(aq)}^- + Na_2S_2O_{3(aq)} \rightarrow 2NaI_{(aq)} + SO_{2(g)} + S_{(g)}$

The balanced equations are.

$MnO_4^- + 5I_2 \rightarrow 2Mn^{2+} + I^-$

$KMnO_4 + KI \rightarrow Mn^{2+} + I^-$

1 : 1

$2I^- + Na_2S_2O_3 \rightarrow 2NaI + SO_{2(g)} + S_{(g)}$

2 : 1

1. (c) The final molarity of Potassium permanganate

from,

$$\frac{M_aV_a}{M_bV_b} = \frac{n_a}{n_b}$$

Molarity of acid (H_2SO_4) = 1M.

volume of acid = (V_a) = $8.5cm^3$

volume of base = $10cm^3$

Molarity of base = (M_b) = ?

n_a =

n_b =

$$\frac{1 \times 8.5}{M_b \times 10} = \frac{2}{10}$$

∴ Molarity of base = 4.25

from dilution law

~~M_aV_a = ...~~

$M_1V_1 = M_2V_2$

$= 4.25 \times 10 = 20 \times M_2$

$M_2 = 0.1$

∴ The final molarity of potassium permanganate is 0.1 mol/dm³

(d) Concentration of Sodium thiosulphate

from,

$$\frac{M_aV_a}{M_bV_b} = \frac{n_a}{n_b}$$

1 (d) Soln

$KMnO_4 + Na_2S_2O_3 \rightarrow NaMnO_4 + K_2S_2O_3$

$$\frac{M(KMnO_4) \times Volume(KMnO_4)}{M(Na_2S_2O_3) \times Volume(Na_2S_2O_3)} = \frac{n\,KMnO_4}{n\,Na_2S_2O_3}$$

$$\frac{0.1 \times 8.5}{M \times 10} = \frac{2}{10}$$

Molarity of $Na_2S_2O_3$ = 0.05 mol/dm³

$$Molarity = \frac{Concentration\ (g/dm^3)}{Molar\ mass\ (g/mol)}$$

Concentration = 158 g/mol × 0.05 mol/dm³
= 7.9 g/dm³

∴ The concentration of $Na_2S_2O_3$ is
7.9 g/dm³

(e) – Another suitable mineral acid that can be used in this experiment is Hydrochloric acid (HCl)

Extract 17.5*:* A Sample of incorrect responses to question 1, Alternative Practical 3B

In Extract 17.5, the candidate recorded a titre value of 11.0 cm³, which is below the acceptable range. In part (b), she/he wrote incorrect balanced chemical equations. In part (c), the candidate failed to apply the dilution principle, resulting in an incorrect concentration of sodium thiosulphate. In part (e), the candidate incorrectly suggested hydrochloric acid (HCl) as an alternative to sulphuric acid.

1. a) Table of Results.

EXPERIMENT	PILOT	1	2	3
Final reading (before W_4) cm^3	8.50	8.50	8.70	8.50
Initial reading (cm^3)	0.00	0.00	0.00	0.00
Volume used (cm^3)	8.50	8.50	8.70	8.50
Final reading (After W_4) cm^3	9.60	9.60	9.60	9.80
Initial reading (cm^3)	8.50	8.50	8.70	8.50
Volume used cm^3	1.10	1.10	0.90	1.30

(b) The redox chemical equations.

(i) Oxidation reaction.

$2I^- \longrightarrow I_2$

$2I^- \longrightarrow I_2 + 2e^-$

Reduction reaction.

$MnO_4^{2-} \longrightarrow Mn^{2+}$.

$MnO_4^{2-} + 8H^+ \longrightarrow Mn^{2+} + 4H_2O$.

$MnO_4^{2-} + 8H^+ + 4e^- \longrightarrow Mn^{2+} + 4H_2O$

1. (b)(i) overall,

$$\left.\begin{array}{l} 1 \\ 2 \end{array}\right\{ \begin{array}{l} MnO_4^{2-} + 8H^+ + 4e^- \longrightarrow Mn^{2+} + 4H_2O \\ 2I^- \longrightarrow I_2 + 2e^- \end{array}$$

$MnO_4^{2-} + 8H^+ + 4e^- \longrightarrow Mn^{2+} + 4H_2O$

$4I^- \longrightarrow 2I_2 + 4e^-$

but was under sulphuric acid

Overall;

$MnO_{4\,(aq)}^{2-} + 8H^+_{(aq)} + 4I^-_{(aq)} \longrightarrow Mn^{2+}_{(aq)} + 2I_{2\,(g)} + 4H_2O_{(l)}$

(ii) Reduction reaction,

$S_2O_3^{2-} \longrightarrow S_4O_6^{2-}$,

$S_2O_3^{2-} + 3H_2O + 6e^- \longrightarrow S_4O_6^{2-} + 6H^+$,

oxidation reaction,

$I^- \longrightarrow I_2$

$2I^- \longrightarrow I_2$,

$2I^- \longrightarrow I_2 + 2e^-$,

Overall reaction,

$$\left.\begin{array}{l} 1 \\ 3 \end{array}\right\{ \begin{array}{l} S_2O_3^{2-} + 3H_2O + 6e^- \longrightarrow S_4O_6^{2-} + 6H^+, \\ 2I^- \longrightarrow I_2 + 2e^- \end{array}$$

$S_2O_3^{2-} + 3H_2O + 6e^- \longrightarrow S_4O_6^{2-} + 6H^+$,

$6I^- \longrightarrow 3I_2 + 6e^-$

$\therefore$ Overall reation is

$S_2O_{3\,(aq)}^{2+} + 3H_2O_{(l)} + 6I^-_{(aq)} \longrightarrow S_4O_{6\,(aq)}^{2-} + 6H^+_{(aq)} + 3I_{2\,(g)}$

1. (c), Average volume used for first titration,

$$Av. = \frac{V_1 + V_2 + V_3}{3},$$

$$\text{Average volume} = \frac{8.6 + 8.5 + 8.6}{3},$$

Average volume used = 8.567 cm^3

Then, Also
Average volume used cm^3 when Wp was added is;

$$= \frac{V_1 + V_2 + V_3}{3},$$

$$= \frac{1.4 + 1.5 + 1.6}{3}$$

$= 1.5 cm^3$,

∴ Average volume used (cm^3) when Wp used is $1.5 cm^3$.

Required concentration of potassium permanganate that reacted with potassium Iodide,

from eqn.

$$MnO_4^{2-}{}_{(aq)} + 8H^+{}_{(aq)} + 4I^-{}_{(aq)} \rightarrow Mn^{2+}{}_{(aq)} + 2I_2{}_{(s)} + 4H_2O_{(l)}$$

from

$$\text{concentration} = \frac{\text{Mass}}{\text{Molar mass}}$$

But also

$$\text{Molarity} = \frac{\text{concentration}}{\text{Molar mass}},$$

1. But also from,

$$\frac{M_1V_1}{M_2V_2} = \frac{n_1}{n_2},$$

$$M_1 = \frac{M_2V_2n_1}{V_1n_2},$$

M_2 – molarity of potassium iodide
M_1 = molarity of potassium permanganate

$$M_1 = \frac{\text{Concentration}}{\text{Molar mass}},$$

Also

$$\text{Molarity} = \frac{\text{Number of moles}}{\text{Volume}},$$

$$\text{Molarity of } KMnO_4 = \frac{0.08 \text{ moles}}{2 \, dm^3}.$$

Molarity = 0.04 mol/dm^3,
Molarity of potassium permanganate = 0.04 mol/dm^3

Then from dilution Law:

$$M_1V_1 = M_2V_2,$$

$$M_2 = \frac{M_1V_1}{V_2},$$

$$M_2 = \left(\frac{0.04 \times 2}{1.5}\right) M,$$

$$M_2 = 0.053\,M$$

1.	Then
	Concentration = Molarity × Molar mass
	Molar mass of $KMnO_4$ = $(39+55+16\times4)$ g/mol
	= 158 g/mol
	Molar mass of $KMnO_4$ = 158 g/mol,
	then
	Concentration of = (0.053×158) g/dm³
	$KMnO_4$
	= 8.374 g/dm³
	∴ concentration of potassium that reacted
	with potassium iodide = 8.374 g/dm³.
	(d) percentage composition of $Na_2S_2O_3.xH_2O$

1· c) But,

Concentration in g/dm^3 = Molarity × Molar mass

Molar mass ($KMnO_4$) = 158g/mole

now

Concentration in g/dm^3 = 158g/mole × 0.02M.

concentration in g/dm^3 = 3.16g/dm³

∴ The concentration of $KMnO_4$ reacted with KI is 3.16g/dm³

d) solution.

Given,

$$14.88g \longrightarrow 600cm^3$$
$$h \longrightarrow 1000cm^3$$

now

$$h = \frac{14.88g \times 1000cm^3}{600cm^3}$$

$$h = 7.44g.$$

now,

Concentration of $Na_2S_2O_3 \cdot XH_2O$ is 7.44g/dm³

now,

From,

M_{KmnO_4} = 0.04M.

$M_{Na_2S_2O_3}$ = Needed.

V_{KmnO_4} = 10cm³.

but.

1. d) The average volume of $Na_2S_2O_3$ used,

$$= \frac{9.5+9.6+9.8+1.1+1.1+0.9}{3}$$

$$= \frac{32}{3}$$

Volume. $= 10.67 cm^3$

Now,

$$\frac{M_{KMnO_4} \times V_{KMnO_4}}{M_{Na_2S_2O_3} \times V_{Na_2S_2O_3}} = \frac{n_{KMnO_4}}{n_{Na_2S_2O_3}}.$$

~~Now,~~

~~Adding the overall equations for a general equation,~~

$\cancel{2MnO_4^{-}} + \cancel{16H^+} + \cancel{8I^-} \longrightarrow$

But,

The overall general equation is given by.

$2MnO_4^- + 16H^+ + 8I^- + 2S_2O_3^{2-} \longrightarrow 2Mn^{2+} + 4I_2 + 8H_2O +$

$S_4O_6^{2-}$.

now.

$n_{MnO_4^-} = 2$

$n_{S_2O_3^{2-}} = 2.$

Thus,

$$\frac{0.04M \times 10cm^3}{M \times 10.67cm^3} = \frac{2}{2}.$$

1.	d) Thus,
	$M = 0.037M.$
	Then,
	~~Concentration in g/dm³ = 0.037M × Mo~~
	From,
	$\text{Molarity} = \frac{\text{Concentration in g/dm}^3}{\text{Molar mass}}$
	$\text{Molar mass} = \frac{\text{Concentration in g/dm}^3}{\text{Molarity}}$
	$= \frac{7.44\,g/dm^3}{0.037M}$
	Molar mass $= 201.08\,g/mole$
	now,
	Molar mass $(Na_2S_2O_3 \cdot xH_2O) = 201\,g/mole.$
	$(23 \times 2) + (32 \times 2) + (16 \times 3) + 18x = 201$
	Now,
	$158 + 18x = 201$
	$18x = 201 - 158$
	$18x = 43$
	$x = 2.38$
	Now,
	$x = 2.$
	Thus,
	$xH_2O = 18 \times 2 = 36\,g/mole.$

1\. d) Percentage composition,

$$\% \text{ composition} = \frac{36\text{g/mole}}{201\text{g/mole}} \times 100\%$$

$$= 17.91\%$$

∴ The percentage composition of water is 17.91%

e) The suitable substitute for potassium permanganate in this experiment is KCr_2O_4

Extract 17.6: A Sample of incorrect responses to question 1, Alternative Practical 3C

In Extract 17.6, the candidate recorded incorrect data, resulting in an inaccurate mean titre volume. In part (b), she/he wrote the wrong formula for the permanganate ion and provided unbalanced equations. In part (c), the dilution principle was not applied correctly, resulting in errors in the thiosulphate concentration and water composition in part (d). In part (e), the candidate gave an inappropriate substitute for $KMnO_4$, by citing KCr_2O_4.

2.3.2 Question 2: Physical Chemistry Analysis

2.3.2.1 Alternative 3A

The question was as follows:

*Identification of the type of chemical reaction is an experimental parameter that requires chemical analysis skills. Using the reagents and apparatuses provided, determine whether the process of dissolving sample **PR** and **PK** is endothermic or exothermic:*

***PR**: 2 g ammonium chloride;*
***PK**: 2 g sodium hydroxide pellets;*
Thermometer.

Theory

When a solid chemical substance is dissolved in water, heat is either given out or absorbed. When heat is evolved to the surrounding, the reaction is exothermic and when heat is absorbed the reaction is endothermic.

Procedure

(i) *Measure 50 cm^3 of distilled water in 100 cm^3 plastic beaker and record the initial temperature.*

(ii) *Add **PR** in a beaker containing distilled water. Stir the mixture using thermometer and record the final temperature.*

(iii) *Repeat steps (i) – (ii) using **PK** and hence record the results as indicated in Table 1.*

Table 1: Experimental Results

Compound	***Final temperature °C***	***Initial temperature °C***	***Temperature change °C***	***Total volume (cm^3)***	***Mass of solution g***
PR					
PK					

Questions

(a) *Find the heat change for dissolution of:*

(i) *PR*

(ii) *PK*

(b) *Calculate the molar enthalpy change for dissolution of:*

(i) *PR*

(ii) *PK*

(c) *Giving a reason in each case, state the type of reaction (in relation to heat changes) for the dissolution of:*

(i) *PR*

(ii) *PK*

2.3.2.2 Alternative 3B

The question was as follows*:*

Chemists should control rate of chemical reactions in order to avoid explosion for the reactions whose rate is vigorous. This task is done by determining the rate constant of reaction. Determine the rate constant of the reaction using the following reagents:

F1*: 0.1 M hydrochloric acid;*

F2*: 0.15 M sodium thiosulphate;*

Distilled water.

Theory

The rate of reaction is expressed as: Rate $= \frac{-d\left[S_2O_3^{2-}\right]}{dt} = k\left[S_2O_3^{2-}\right]^x\left[H^+\right]^y$

Where ***x*** *is the order of reaction with respect to* $S_2O_3^{2-}$, ***y*** *is the order of reaction with respect to* H^+ *and* ***k*** *is the rate constant.*

Procedure

(i) *Place a small beaker of 100* cm^3 *on top of the "**X**" mark on the white paper.*

(ii) *Measure 25* cm^3 *of* ***F2*** *using measuring cylinder and pour into the beaker placed on the marked paper.*

(iii) *Measure 25* cm^3 *of* ***F1****, then add into the beaker containing* ***F2*** *and immediately start the stopwatch.*

(iv) *Record the time taken for the mark on white paper to be obscured.*

(v) *Repeat steps (i) to (iv) using the set of mixtures in Table 1.*

Table 1: Experimental Table

Exp	*Volume of F2 (cm^3)*	*Volume of distilled water (cm^3)*	*Volume of F1 (cm^3)*
1	25.00	0.00	25.00
2	20.00	5.00	25.00
3	15.00	10.00	25.00
4	10.00	15.00	25.00

Questions

(a) *Write the ionic equation for the reaction taking place in this experiment.*

(b) *Calculate the order of reaction with respect to* ***F2****, given that the volumes are directly proportional to their concentrations.*

(c) *If the value of* ***y = 1****, calculate the rate constant.*

2.3.2.3 Alternative 3C

The question was as follows:

Use the following reagents and the given apparatuses to determine the rate constant of the reaction:

R1: *Hydrogen peroxide solution;*

R2: *A solution made by dissolving 7.9 g of sodium thiosulphate in 1 dm^3 of distilled water;*

R3: *A solution made by dissolving 8.3 g of KI per litre in 0.5 M H_2SO_4;*

Starch solution;

Distilled water;

*100 cm^3 beakers labelled **I** and **II**;*

Stopwatch.

Theory

Hydrogen peroxide reacts with iodide ions in acidic medium to form iodine. The iodine produced reacts with thiosulphate ions as indicated in the following reaction equations:

$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(aq)$

$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

The initial rate of oxidation of iodide ions by hydrogen peroxide in acidic solution is found by measuring the time taken to liberate sufficient iodine to react with thiosulphate ions.

Procedure

*(i) Measure 15 cm^3 of **R3**, add few drops of starch followed by 5 cm^3 of distilled water and put in beaker **I**.*

*(ii) Using another measuring cylinder, measure 5 cm^3 of **R2** solution and 30 cm^3 of **R1** then put in beaker **II**.*

*(iii) Add mixture of beaker **II** into beaker **I** and start stopwatch.*

(iv) Swirl the mixture thoroughly.

(v) Record the time taken for the blue colour to appear and tabulate the results.

***(vi)** Repeat the steps (i) to (v) but this time change the volume of **R1** and distilled water as indicated in the Table 1. Each time keep the volume of **R2**, **R3** and starch solution as in the first experiment.*

Table 1: Table of Results

Volume of R1(cm^3)	*30*	*25*	*20*	*15*	*10*	*5*
Volume of distilled water (cm^3)	*5*	*10*	*15*	*20*	*25*	*30*
Time for blue colour to appear (sec)						
Rate (1/time) (sec^{-1})						

Questions

(a) *Plot a graph of (1/t) against (volume) of* ***R1****.*

(b) *What is the order of reaction with respect to* ***R1****?*

(c) *Calculate the rate constant for the reaction.*

A total of 46,748 candidates attempted the question. Of these, 28,587 candidates (61.15%) scored within the range of 9.0–15 marks, 11,938 (25.54%) within 5.5–8.5 marks, and 6,223 (13.31%) within 0–5.0 marks. The performance distribution is illustrated in Figure 18.

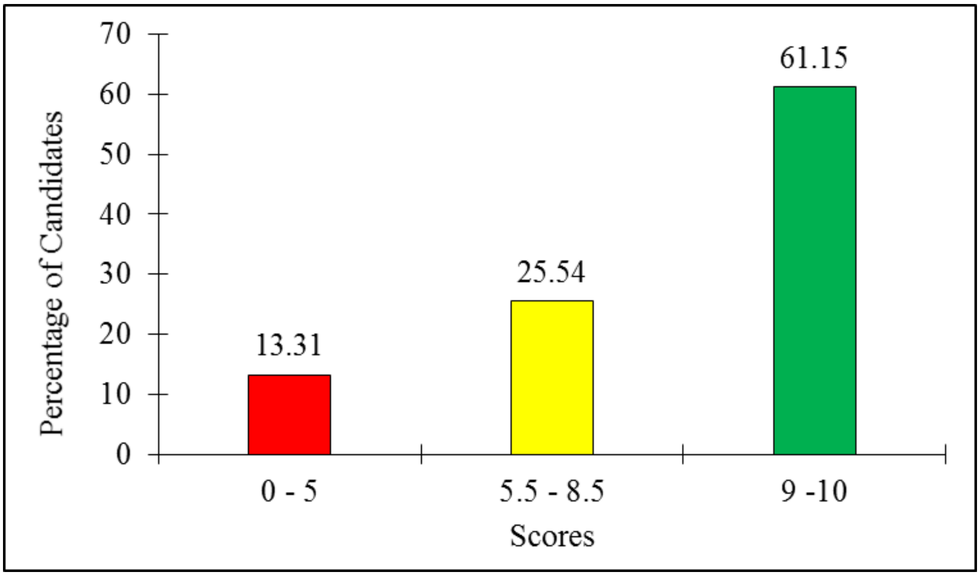


Figure 18: *Candidates' Performance on Question 2, Paper 3*

The overall performance of candidates was good, with 86.69% scoring the pass mark or above (≥ 5.5 marks). High-performing candidates demonstrated strong competence in Physical Chemistry Analysis across all three alternatives. In Alternative 3A, they correctly applied mathematical procedures to calculate the enthalpy change of dissolution and accurately identified that the dissolution processes were exothermic based on temperature changes. In Alternatives 3B and 3C**,** candidates effectively determined the order of reaction using experimental data, interpreted results appropriately, and calculated the rate constant with precision. Extracts 18.1, 18.2, and 18.3 present samples of well-constructed responses from candidates in Alternatives 3A, 3B, and 3C, respectively.

2.

Experimental Results.

Compound	Final Temperature, °C	Initial Temperature, °C	Temperature Change °C	Total Volume, cm^3	Mass of solution g.
PR	20	22	-2	50	50
PK	31	22	9	50	50

$$\Delta T = T_{final} - T_{initial}$$

a. heat change for dissolution of

i. PR

From

$$Q = -mc\Delta T$$

Where:

mass, m

Specific heat capacity of solution, $c = 4.18\,Jg^{-1}K^{-1}$

ΔT, temperature change.

$$\Delta T = T_{final} - T_{initial}$$

$$\Delta T = (20 - 22)°c$$

$$\Delta T = -2°c$$

but: mass = Density, ρ x volume, v.

so:

$$mass = 1g/cm^3 \times 50cm^3$$

$$mass = 50g$$

From:

$$Q = -50g \times 4.18\,Jg^{-1}K^{-1} \times -2K$$

$$Q = 418\,J$$

∴ Heat change for dissolution of PR = 418J.

2. a. ii. Heat change for dissolution of pK.

From: $Q = -mc\Delta T$

but:

$mass = Density, \rho \times Volume, cm^3$

$mass = 1g/cm^3 \times 50cm^3$

$mass = 50g$

Specific heat capacity, $c = 4.18 J g^{-1} K^{-1}$

Temperature change, $\Delta T = T_{final} - T_{initial}$

$\Delta T = 31°C - 22°C$

$\Delta T = 9K$

$Q = -50g \times 4.18 J g^{-1} K^{-1} \times 9K$

$Q = -1881 J$

$\therefore$ Heat change for dissolution of PK, $Q = -1881 J$

b. Molar heat change for dissolution of:

i. PR

From:

$Q = -mc\Delta T$

but:

$mass, m = Density, \rho \times volume, cm^3$

$mass = 1g/cm^3 \times 50cm^3$

$mass = 50g$

2. b. i.

Specific heat capacity, $c = 4.18 J g^{-1} K^{-1}$

Temperature(heat) change, $\Delta T = 20 - 22$

$\Delta T = -2 k$

$Q = - 50g \times 4.18 J g^{-1} K^{-1} \times -2 K.$

$Q = 418 J.$

but: Molar enthalpy change, ΔQ = $\frac{\text{heat change, Q}}{\text{Number of moles}}$

From: moles = $\frac{\text{mass, m}}{\text{Molar mass}}$

For 2g of NH_4Cl

Molar mass of NH_4Cl = $\sum$ atomic masses

$M_r = (14 + 1 \times 4 + 35.5) g/mol.$

$M_r = 53.5 g/mol.$

moles, $n = 2g / 53.5 g/mol$

moles, $n = 0.0374$ moles

$\Delta Q = \frac{418 J}{0.0374 \text{ moles}}$

$Q = 11181.5 J/mole$

$Q = 11.18 KJ/mole$

$\therefore$ Molar enthalpy change for dissolution of PR = 11.18 KJ/mole

2.	b. ii.
	PK
	From.
	Molar enthalpy change, $\Delta Q = \frac{Q}{n, moles}$
	From: heat change, $Q = -mc\Delta T$
	but
	mass = Density, ρ x volume, cm^3
	$m = 1g/cm^3 \times 50cm^3$
	mass = 50g.
	$Q = -50g \times 4.18 J g^{-1} K^{-1} \times \Delta T$
	$\Delta T = T_{final} - T_{initial}$
	$\Delta T = 31°c - 22°c$
	$\Delta T = 9°c$.
	$Q = -50g \times 4.18 J g^{-1} K^{-1} \times 9K$.
	$Q = -1881 J$
	but:
	moles, $n = \frac{mass, m}{Molar\ mass, M_r}$
	for PK → NaOH
	Molar mass of NaOH = $\sum$ atomic masses
	$M_r = (23 + 16 + 1) g/mol$
	M_r of NaOH = 40g/mol

2	b. ii.
	given: mass of NaOH = 2g.
	moles, $n = 2g / 40g/mol$
	$n = 0.05$ moles.
	From: $\Delta Q = \frac{\text{heat change}}{\text{moles.}}$
	$\Delta Q = \frac{-1881 J}{0.05 moles}$
	$Q = -37620$ J/mole
	$Q = -37.62 \times 10^3$ J/mole
	$Q = -37.62$ KJ/mole
	∴ Molar enthalpy change for dissolution of PK is, $\underline{Q = -37.62 \text{ KJ/mole.}}$
2	c. Type of Reaction for dissolution of:
	i. PR
	Endothermic Reaction.
	- Because heat is absorbed from the surrounding during dissolution of PR, which is evidenced by positive heat change (molar enthalpy) = 11.18 KJ/mole
2.	c. ii. PK.
	- Exothermic Reaction
	Because heat is given out / evolved to the surrounding during dissolution of PK, evidenced by negative molar enthalpy change

Extract 18.1: A sample of correct responses to question 2, Alternative Practical 3A

In Extract 18.1, the candidate correctly tabulated the experimental data, showing both initial and final temperatures with appropriate units and decimal places. In part (a), they calculated the heat change of dissolution using the formula $q = mc\Delta T$, substituting accurate values. In part (b), the candidate computed the molar enthalpy change by dividing the heat change by the number of moles of solute. In part (c), they correctly identified the reaction as exothermic, providing justification based on the temperature increase during dissolution.

2. TABLE OF RESULTS;

Exp.	Volume of F_2 (cm^3)	Volume of water (cm^3)	Volume of F_1 (cm^3)	t(s)	1/t (s^{-1})
1	25	0	25	62.5	0.016
2	20	5	25	78.13	0.013
3	15	10	25	104.17	0.010
4	10	15	25	156.25	0.006

(a). Ionic equation is;

$S_2O_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \longrightarrow H_2O_{(l)} + SO_{2(g)} + S_{(s)}$

(b). order of reaction with respect to F_2.

from;

$Rate\ (R) = K[S_2O_3^{2-}]^x[H^+]^y$.

then;

$R_1 = K[S_2O_3^{2-}]_1^x[H^+]_1^y$ ——— (i).

$R_2 = K[S_2O_3^{2-}]_2^x[H^+]_2^y$ ——— (ii).

divide the equation (ii) to equation (i).

$$\frac{R_1}{R_2} = \frac{K[S_2O_3^{2-}]_1^x[H^+]_1^y}{K[S_2O_3^{2-}]_2^x[H^+]_2^y}.$$

but;

$R \propto 1/t$

then;

$R_1 \propto 1/t_1$

$[\ ] \propto V$.

2 (b). where;

$[H^+]_1 = [H^+]_2$.

$$\frac{R_1}{R_2} = \frac{[S_2O_3^{2-}]_1}{[S_2O_3^{2-}]_1}$$

but.

$[S_2O_3] \propto V$.

$$\frac{R_1}{R_2} = \left(\frac{V_1}{V_2}\right)^x.$$

$$\frac{0.016}{0.013} = \left(\frac{25}{20}\right)^x.$$

$$1.25 = 1.25^x.$$

$$x = 1.$$

∴ the order of reaction with respect to $S_2(Na_2S_2O_3)$ is first order.

(c). Rate constant (K) = ?.

given $y = 1$.

from;

$R = K[S_2O_3^{2-}]^x[H^+]^y$.

but.

$R \propto 1/t$

also;

$[S_2O_3^{2-}] \propto V_{S_2O_3^{2-}}$

$[H^+] \propto V_{H^+}$.

2. Then: For experiment 1.

$$R_1 = K\,[V_{S_2O_3^{2-}}]^x\,[V_{H^+}]^y$$

where;

$x = 1$, $y = 1$. $R_1 = 0.016$.

$V_{S_2O_3^{2-}} = 25\,cm^3$ $V_{H^+} = 25\,cm^3$.

$$0.016\,s^{-1} = K_1 \times (25\,cm^3)^1 \times (25\,cm^3)$$

$$K_1 = \frac{0.016\,s^{-1}}{625\,cm^6}.$$

$$K_1 = 2.56 \times 10^{-5}\,cm^{-6}s^{-1}$$

For experiment (2).

$$k_2 = \frac{R_2}{(V_{S_2O_3^{2-}})_2 (V_{H^+})_2}.$$

$$= \frac{0.013\,s^{-1}}{20\,cm^3 \times 25\,cm^3}.$$

$$= 2.6 \times 10^{-5}\,cm^{-6}s^{-1}$$

$$k_2 = 2.6 \times 10^{-5}\,cm^{-6}s^{-1}.$$

For experiment (3).

$$k_3 = \frac{R_3}{(V_{S_2O_3^{2-}})_3 (V_{H^+})_3}.$$

$$= \frac{0.01}{15\,cm^3 \times 25\,cm^3}.$$

$$= 2.67 \times 10^{-5}\,cm^{-6}s^{-1}$$

$$k_3 = 2.67 \times 10^{-5}\,cm^{-6}s^{-1}$$

2\. (c). For experiment (4).

$$K_4 = \frac{R_4}{(V_{S_2O_3^{2-}})_4 (V_{H^+})_4}$$

$$= \frac{0.006\ s^{-1}}{10\ cm^3 \times 25\ cm^3}$$

$$K_4 = 2.4 \times 10^{-5}\ cm^{-6} s^{-1}$$

$$\text{Avarage } (k) = \frac{k_1 + k_2 + k_3 + k_4}{4}$$

$$k = \frac{(2.52\times10^{-5} + 2.6\times10^{-5} + 2.67\times10^{-5} + 2.4\times10^{-5})}{4}$$

$$k = 2.558 \times 10^{-5}\ cm^{-6} s^{-1}$$

$\therefore$ Rate constant $= 2.558 \times 10^{-5}\ cm^{-6} s^{-1}$.

Extract 18.2*:* A sample of correct responses to question 2, Alternative Practical 3B

In Extract 18.2, the candidate accurately recorded the experimental results and correctly completed the table of results with appropriate values and units. In part (a), she/he wrote the balanced ionic equation: $S_2O_3^{2-}(aq) + 2H^+(aq) \longrightarrow S(s) + SO_2(g) + H_2O(l)$. In part (b), the candidate analysed the time data from different experiments to determine the order of reaction with respect to sodium thiosulphate. In part (c), using the provided order with respect to H^+, they correctly applied the rate law equation to calculate the rate constant.

2. TABLE OF RESULTS

Volume of R_1 (cm^3)	30	25	20	15	10	5
Volume of distilled water (cm^3)	5	10	15	20	25	30
Time for blue colour to appear (sec)	11.54	17.44	21.43	27.12	43.59	96.37
Rate ($\frac{1}{time}$) sec^{-1}	0.087	0.057	0.047	0.037	0.023	0.010

a) Consider a graph of ($\frac{1}{t}$) against volume of R_1.

b) The order of reaction with respect to R_1 is the first order.

c) From.

$$R = K[H_2O_2]$$

$$y = mx$$

Slope (m) = K

From the graph

$$\text{slope } (m) = \frac{\Delta \frac{1}{t}(sec^{-1})}{\Delta V(cm^3)}$$

$$A(9.25cm^3, 0.0219\,sec^{-1})$$

$$\text{Slope} = B(27.5cm^3, 0.06424sec^{-1})$$

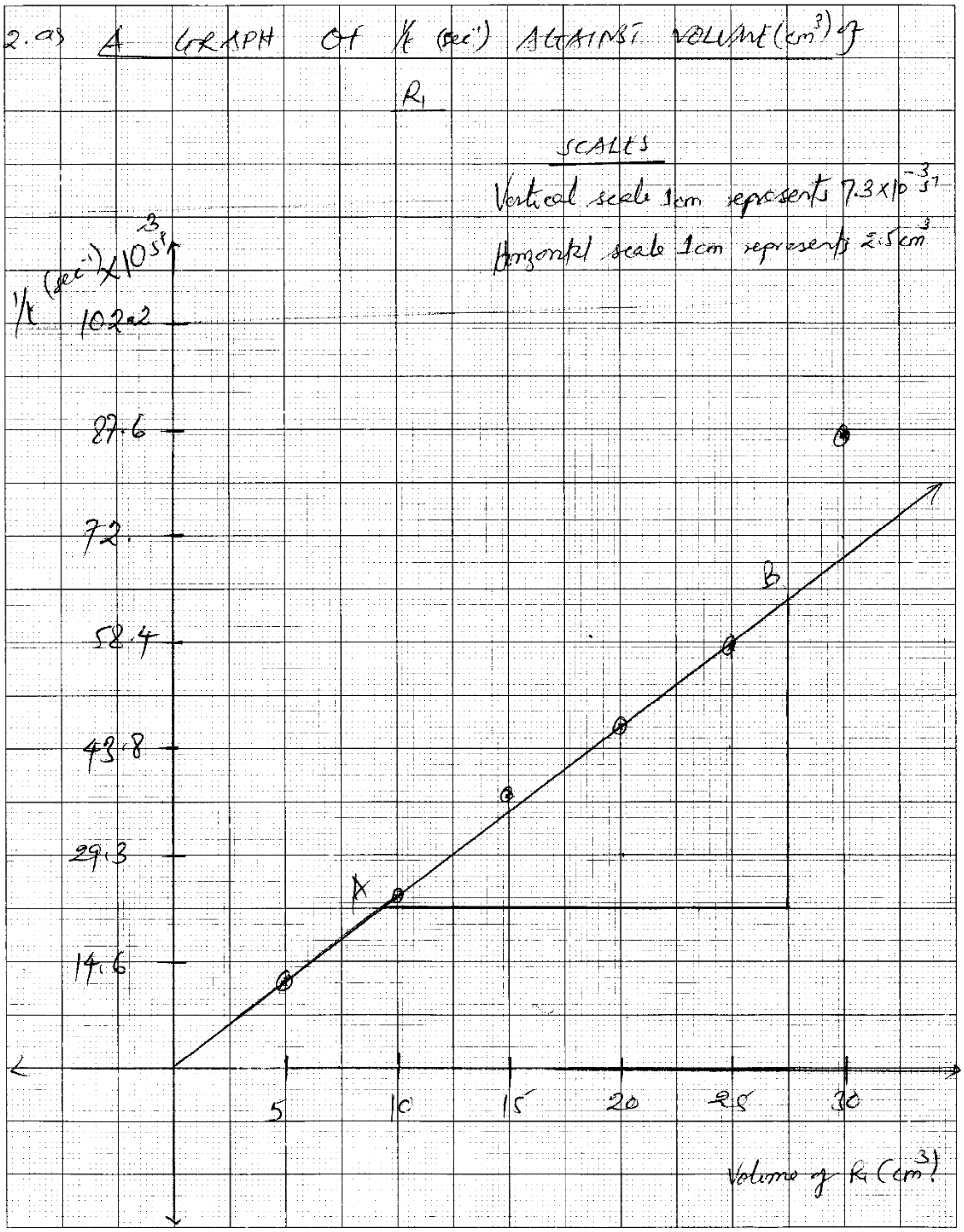
$$\text{Slope } (m) = \frac{0.06424sec^{-1} - 0.0219sec^{-1}}{27.5cm^3 - 9.25cm^3}$$

2. c) Slope (m) = $2.32 \times 10^{-3}\ s^{-1} cm^{-3}$

Rate constant (K) = slope (m)

∴ Rate constant for the reaction is

$2.32 \times 10^{-3}\ s^{-1} cm^{-3}$



Extract 18.3*:* A sample of correct responses to question 2, Alternative Practical 3C

In Extract 18.3, the candidate accurately recorded and organised the experimental data in a table. In part (a), the candidate correctly plotted the graph of 1/t (rate) against the volume of R1, ensuring proper labelling of axes and scales. In part (b), the candidate determined the order of reaction with respect to the volume of R1 by analysing the graph. In part (c), she/he correctly calculated the rate constant using the rate law and experimental data.

On the other hand, 13.31 per cent of the candidates, who scored low marks ranging from 0 to 5, demonstrated limited understanding of the experimental procedures and numerical calculations required to determine enthalpy changes, as well as the classification of the process as either exothermic or endothermic. These candidates struggled to apply the correct formula for heat change and failed to interpret temperature variations accurately. Moreover, many of these candidates demonstrated a limited understanding of how changes in volume or concentration affect reaction order. As a result, they were unable to determine the correct order of reaction as required. Additionally, several candidates lacked the skills to select appropriate scales when plotting graphs, which led to incorrect interpretations of the graphical relationships used to determine the order of reaction with respect to each reactant. For instance, in Alternative A, one candidate incorrectly applied the formula $q = mc\Delta T$ without considering the sign of the enthalpy change, which led to an incorrect conclusion about the reaction's nature. Another candidate omitted the entire formula, leaving the calculation incomplete.

In Alternative B, some candidates failed to write the correct ionic equation for the reaction. For example, one wrote an unrelated or incomplete equation. Others used incorrect rate law expressions, such as Rate = k[Reactant], without including the correct exponents to represent the reaction order, which resulted in incorrect rate constant calculations.

In Alternative C, some candidates did not obtain a straight-line graph due to inconsistent or inaccurate data plotting; for instance, one candidate drew a curved graph instead. This led to a misinterpretation of the reaction order. Another candidate did not apply the rate law formula correctly, which resulted in an incorrect value for the rate constant.

Extracts 18.4, 18.5, and 18.6 present examples of these inaccurate responses from candidates in Alternatives A, B, and C, respectively.

2.) Experimental result table.

Table of results.

Compound	Final(T)	Initial(T)	ΔT	T.V	M_s
PR.	13°C	17°C	4	100	2g.
PK.	21	17	-4	100	2g.

a.) Find the heat change for dissolution of:

(i) PR. (Ammonium chloride).

for PR (Ammonium chloride).

from common formula

$\Delta H = mc\Delta T$ where
m - mass
c - specific heat capacity.
T - Temperature.
ΔH - Heat change.

Heat change for PR (Ammonium chloride) is given by.

Temperature change = Final - Initial temperature

Temperature change = 13°C - 17°C

∴ Temperature change = 4°C.

2a(i)	So therefore heat change of the PR solution is $-4°c$. so when substituted into the formula.
	$\Delta H = mc\Delta T$.
	$\Delta H = 2 \times 4.18 \times -4$.
	$\Delta H = -33.44$ Joules.
	Heat change (ΔH) of (PR) is $= -33.44$ Joules
(ii)	PK (Sodium hydroxide pellets).
	for PK (Sodium hydroxide pellets).
	from common formula.
	$\Delta H = mc\Delta T$.
	where:
	m - mass of solution.
	c - specific heat capacity.
	T = Temperature.
	ΔH = Heat change.
	Heat change for PK (Sodium hydroxide pellets) is given by
	Temperature change = Final - initial temperature
	Temperature change = $17°c - 21°c = -4°c$.
	$\therefore$ Temperature change $= -4°c$

2a(iii) So, there fore heat change for the P/C solution is 4°C so when substituted into the formula.

$\Delta H = mc\Delta T.$
$\Delta H = 2 \times 4.18 \times 4.$
$\Delta H = 33.44$ Joules.

∴ Heat change (ΔH) of (P/C) is = 33.44 Joules.

NOTE: In the experimental table, or table of results the total volume is 100cm³ because we add the 50cm³ firstly measured and used before the addition of both (P/C) and (PR) to get initial readings and the 50cm³ of after the addition of P/C, and (PR) thus making it 100cm³.

2(c) Giving a reason in each case, state the type of reaction (in relation to heat changes) for the dissolution of.

(i) PR (Ammonium chloride.

(ii) P/C (Sodium hydroxide pellets).

9(c)(i) PR (Ammonium chloride).

→ The PR sample undergoes an exothermic reaction, because due to the fact that when ammonium chloride (PR) was added to distilled water it lost heat to the environment because of the temperature significant drop from 17°C initially, to 13°C meaning that it lost almost approximately -4°C to the environment confirming that it is an exothermic reaction.

(ii) PK (Sodium hydroxide pellets)

→ The PK sample undergoes an endothermic reaction, because due to the fact that when the Sodium hydroxide pellets were added to the distilled water it gained or absorbed heat from the environment because of the significant temperature increase of 4°C which it gained thus confirming it is an endothermic reaction.

Extract 18.4*:* A Sample of incorrect responses to question 2 in Alternative Practical 3A

In Extract 18.4, the candidate recorded the mass of the salt sample instead of the mass of the solution and reported an incorrect temperature change. In parts (a) and (b), she/he used the wrong mass value in the formula $q = mc\Delta T$, leading to an incorrect molar enthalpy. In part (c), the candidate incorrectly identified an endothermic reaction as exothermic. The conclusion did not align with the observed temperature change.

2.	EXP	V. F_2 cm³	V of di water(cm³)	F_1 cm³	Time
	1	25.00	0.00	25	3120 secon
	2	20.00	5.00	25	3881 second
	3	15.00	10.00	25	5475 second
	4	10.00	15.00	25	8890

(a) The ionic equation for the reaction taking place in this experiment

$$Na_2S_2O_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + SO_{2(g)} + S_{(s)}$$

$$2Na^+_{(aq)} + 2S^{3+}_{(aq)} + 3O^{2-}_{(aq)} + 2H^+_{(aq)} + 2Cl^-_{(aq)} \rightarrow 2Na^+_{(aq)} + 2Cl^-_{(aq)} + H_2O_{(l)} + SO_{2(g)} + S_{(s)}$$

$$2\cancel{Na^+_{(aq)}} + 2S^{2+}_{(aq)} + 3O^{2-}_{(aq)} + 2H^+_{(aq)} + 2\cancel{Cl^-_{(aq)}} \rightarrow 2\cancel{Na^+_{(aq)}} + 2\cancel{Cl^-_{(aq)}} + H_2O_{(l)} + SO_{2(g)} + S_{(s)}$$

(a) The ionic equation for the reaction taking place in this experiment

$$Na_2S_2O_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)} + SO_{2(g)} + S_{(s)}$$

$$2Na^+_{(aq)} + 2S^{3+}_{(aq)} + 3O^{2-}_{(aq)} + 2H^+_{(aq)} + 2Cl^-_{(aq)} \rightarrow 2Na^+_{(aq)} + 2Cl^-_{(aq)} + H_2O_{(l)} + SO_{2(g)} + S_{(s)}$$

$$2\cancel{Na^+_{(aq)}} + 2S^{2+}_{(aq)} + 3O^{2-}_{(aq)} + 2H^+_{(aq)} + 2\cancel{Cl^-_{(aq)}} \rightarrow 2\cancel{Na^+_{(aq)}} + 2\cancel{Cl^-_{(aq)}} + H_2O_{(l)} + SO_{2(g)} + S_{(s)}$$

2. (c) $K = \dfrac{\cancel{Rad}\ Rate}{[S_2O_3^{2-}]^x[H^+]^y}$

$K = \dfrac{0.52\ cm^3 s^{-1}}{(25)^2 (25)^1\ cm^6}$

$K = 3.328 \times 10^{-5}\ cm^{-3} s^{-1}$

Extract 18.5*:* A Sample of incorrect responses to question 2, Alternative Practical 3B

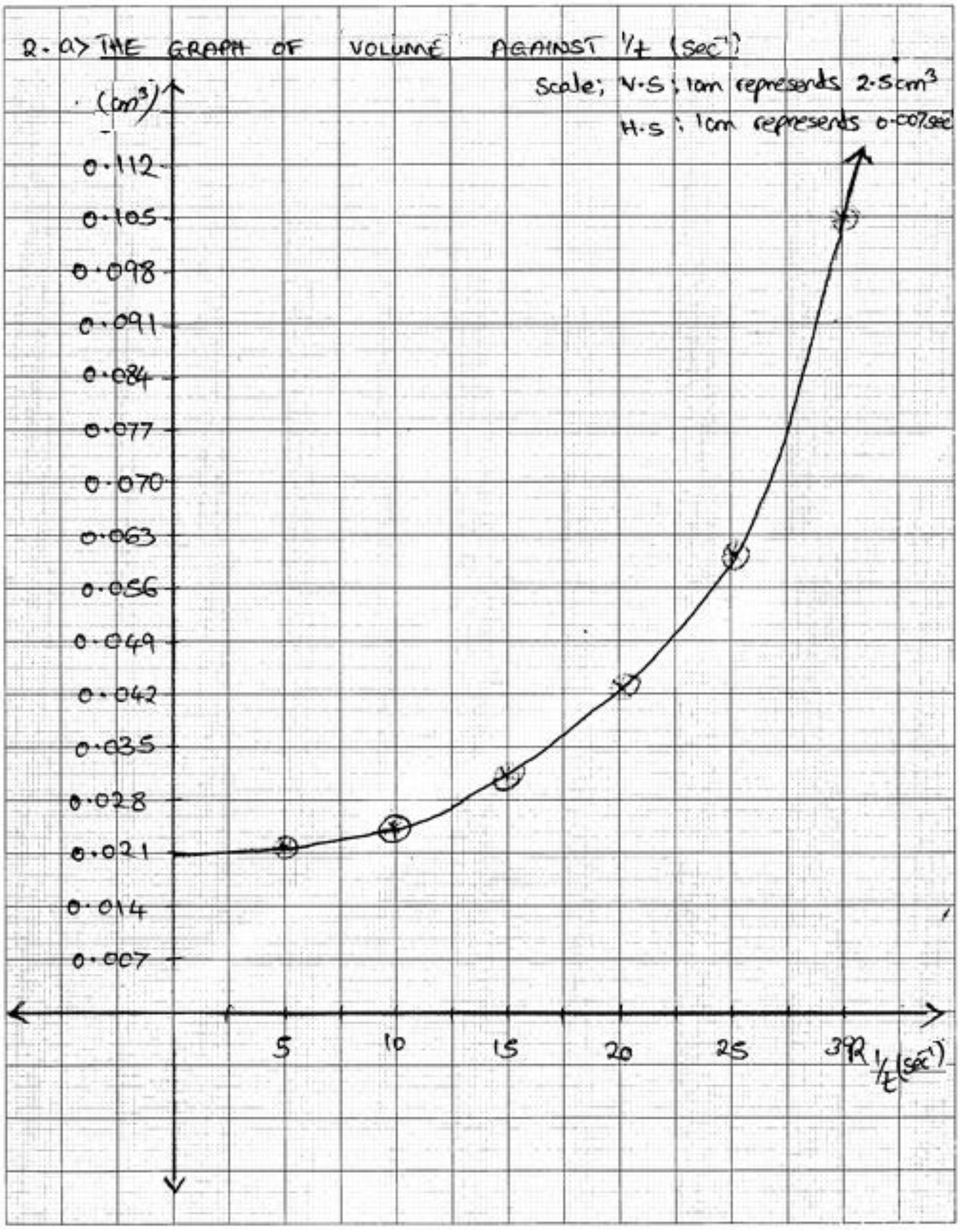
In Extract 18.5, the candidate recorded an incorrect reaction time that did not match the expected trend. In part (a), she/he wrote an incorrect ionic equation unrelated to the actual reaction. In part (b), the candidate used an inappropriate formula to calculate the order of reaction with respect to F2. In part (c), she/he applied a wrong rate law expression, resulting in an incorrect rate constant.

2. Table of Results.

Volume of R_1 (cm^3)	30	25	20	15	10	5
Volume of H_2O (cm^3)	5	10	15	20	25	30
Time for blue colour to appear (sec)	0.19	0.22	0.25	0.29	0.32	0.35
Rate (1/time) (sec^{-1})	5.26	4.54	4	3.45	3.13	2.86

Questions:

ⓐ Plot a graph of (1/t) against Volume R1



2.	b> From the Graph
	-> The order of reaction with respect to R_1
	is the second order of reaction.

2.	$\frac{\log 1.2}{0.8} = \frac{\log 0.8}{\log 0.8}$
	$X = 0$
	From
	$\frac{R_4}{R_3} = [\ ]$
	The order of reaction is zero order

2.	c) solution.
	For,
	$R_3 = \frac{\text{concentration}}{\text{Molar mass}}$
	$R_3 = \frac{8.3 g/dm^3}{166 g/mol}$
	$R_3 = 0.05 mol/dm^3$
	now,
	$Rate = K(R_1)(R_3)$
	$0.02 sec^{-1} = K(0.05)^2(0.05)$
	$K = \frac{0.02}{(0.05)^2}$
	$K = 8 mol^2 dm^{-6} sec^{-1}$
	$\therefore$ The rate constant of the reaction is $8 mol^2 dm^{-6} sec^{-1}$.

Extract 18.6: A Sample of incorrect responses to question 2, Alternative Practical 3C

In Extract 18.6, part (a), the candidate drew a curved graph instead of a straight line and incorrectly interchanged the axes by plotting volume on the y-axis and 1/t on the x-axis. In part (b), she/he failed to deduce the order of reaction from the graph. In part (c), the candidate failed to calculate the slope and was therefore unable to determine the rate constant.

2.3.3 Question 3: Qualitative Analysis

2.3.3.1 Alternative 3A

The question was as follows:

*Sample **RS** contains one cation and one anion. Analyse the sample using systematic qualitative analysis procedures. Carefully, record the experiments, observations and inferences as shown in Table 2. Finally, identify the anion and cation present in sample **RS**.*

Table 2: Experimental Data

S/N	*Experiments*	*Observations*	*Inferences*

Questions

(a) *What are the cation and anion in the sample?*

(b) *Write the molecular formula for the sample*

2.3.3.2 Alternative 3B

Question 3 was as follows:

*Sample **RK** contains one cation and one anion. Analyse the sample using systematic qualitative analysis procedures. Carefully, record your experiments, observations and inferences as shown in Table 2. Finally, identify the anion and cation present in sample **RK**.*

Table 2: Experimental Data

S/N	*Experiments*	*Observations*	*Inferences*

Questions

(a) *What are the cation and anion in the sample?*

(b) *Write the molecular formula for the sample*

2.3.3.3 Alternative 3C

Question 3 was as follows:

*Sample **RV** contains one cation and one anion. Using systematic qualitative analysis procedures analyse the sample. Carefully, record your experiments, observations and inferences as shown in Table 2. Finally, identify the anion and cation present in sample **RV**.*

Table 2: Experimental Table

S/N	***Experiments***	***Observations***	***Inferences***

Questions

(a) What are the cation and anion in the sample?

(b) Write the molecular formula for the sample.

The question was attempted by 46,748 candidates. Of these, 38,834 (83.07%) scored within the range of 9.0 to 15 marks, while 4,501 (9.63%) scored within the range of 5.5 to 8.5 marks. A total of 3,413 candidates (7.30%) scored within the range of 0 to 5.0 marks. Overall, the performance was good, with 43,335 candidates (92.70%) achieving the pass mark of 5.5 or above. A summary of the performance is presented in Figure 18.

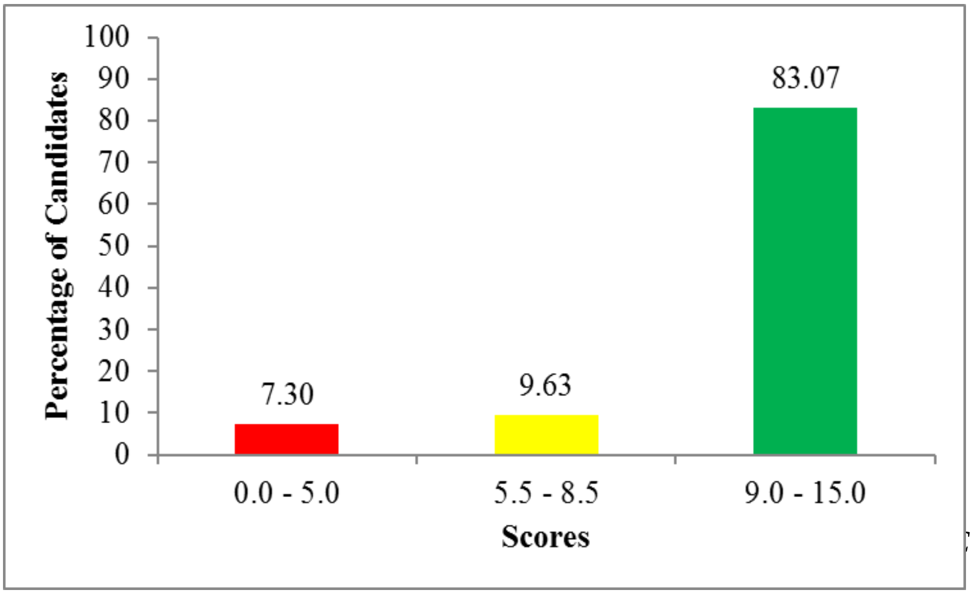


Figure 19: *Candidates' Performance on Question 3, Paper 3*

The candidates who performed well in this question (92.70%) demonstrated a firm grasp of systematic qualitative analysis procedures. They provided detailed analyses of the sample salts, including accurate observations and insightful inferences, to identify the constituent ions accurately. Additionally, these candidates demonstrated a strong understanding of the properties of transition elements, atomic spectra, periodic classification, solubility, and the formation of complex compounds. This expertise enabled them to accurately determine the cations and anions present in the samples upon addition of NaOH or NH_4OH. Extracts 19.1, 19.2, and 19.3 present exemplary responses to Question 3 in alternative practicals A, B, and C, respectively.

3. S/N	EXPERIMENT	OBSERVATIONS	INFERENCE
1.	Appearance of the sample i) Colour	White	Non-transition metals may be present
	ii) Texture	Crystalline form	NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^-, CH_3COO^-, $Cr_2O_7^{2-}$ may be present
	iii) Deliquescence	Absorbs water from the atmosphere to form solution	NO_3^-, Cl^-, SO_4^{2-} may be present
2.	Action of heat of sample RS A small amount of sample RS was transfered in a clean dry test-tube and heated gently then strongly	Colourless gas evolves which relights a glowing wooden splint	NO_3^- of Na^+, K^+ may be present
		residue that is yellow when hot and white when cold	Zn^{2+} may be present

3.	S/N	EXPERIMENT	OBSERVATIONS	INFERENCE
	3.	Flame test of sample RS Back side of the test-tube was dipped in concentrated HCl then heated in a non-luminous flame	Presence of the colour of non-luminous flame	Non-transition metals may be present
	4.	Solubility of sample RS A small amount of sample RS was transfered in a clean test-tube. Enough amount of distilled water was added so as the sample to be dissolved	Soluble in cold water	NO_3^-, CH_3COO^-, HCO_3^- may be present
	5	Action of dilute HCl on the solid sample RS Small amount of sample RS was transfered in a clean test-tube followed by a small amount of dilute HCl and warmed	No gas evolves	SO_4^{2-}, Cl^-, NO_3^- may be present
	6.	Action of concentrated H_2SO_4 on solid sample RS A small amount of sample RS was transfered in a clean and dry test-tube. A small amount of concentrated H_2SO_4 was added and warmed	Brown fumes evolve which turn moist blue litmus paper red and intensify on copper turnings	NO_3^- may be present

3. S/N	EXPERIMENT	OBSERVATION	INFERENCE
7.	Action of NaOH and NH_4OH on the solid sample RS		
	The solid sample RS was transfered in a clean dry-test tube followed by distilled water to make a solution. The solution was divided into four portions	White precipitate	Zn^{2+} may be present
	i) To the first portion NaOH was added dropwise		
	ii) To the second portion NaOH was added in excess	Precipitate dissolves	Zn^{2+} may be present
8.	CONFIRMATORY TEST OF SAMPLE RS		
	a) Confirmatory test for the cation of the Sample RS To the third portion dilute NaOH /NH_4OH was added until in excess	White precipitate soluble in excess	Zn^{2+} confirmed
	b) Confirmatory test for the anion of the sample RS A small amount of the solid sample RS was transfered in a test-tube then copper turnings were added followed by concentrated H_2SO_4 then warmed	Brown fumes evolve	NO_3^- confirmed

3a)	The cation of sample RS is Zn^{2+} (zinc)
	The anion of sample RS is NO_3^- (nitrate)
b)	The molecular formula of sample RS is $Zn(NO_3)_2$

Extract 19.1: A sample of correct responses to question 3, Alternative Practical 3A

In Extract 19.1, the candidate provided accurate qualitative observations, including the formation of a white precipitate upon the addition of NaOH and the absence of gas evolution. The candidate correctly inferred the presence of the Zn^{2+} cation and NO_3^- anion based on the observed reactions. Finally, she/he wrote the correct molecular formula of the salt as $Zn(NO_3)_2$.

3. Experimental Data .

S/N	Experiments	Observations	Inferentes
1.	Appearance of the Sample .		
	(i) Colour		
	The sample was observed using eyes .	The sample was white in colour	Non-transition metals may be present .
	(ii) Texture		
	The sample was touched using fingers of the arm .	The sample was powder in form .	CO_3^{2-} and HCO_3^- may be present except CO_3^{2-} of NH_4^+, K^+ and Na^+
2.	Flame Test		
	The cleaned glass rod was dipped in concentrated HCl, then to the sample followed by heating it on a flame	The bright yellow colour was observed	Na^+ may be present

3.

S/N	Experiments	Observations	Inference
3.	Action of Heat on a Solid sample. A small amount of about 0.5g of a sample was transferred into the dry test tube and then the content was heated gently and then strongly.	Colourless droplets were formed on the cooler parts of the test-tube. The droplets turned anhydrous $CuSO_4$ blue.	Hydrated salt, HCO_3^- may be present.
4.	Action of Dilute HCl on a solid sample. A small amount of the sample was transferred into the test tube followed by a small amount of dilute HCl. The the content was warmed gently.	There was effervescence of a colourless gas which turned lime water milky and moist litmus paper from blue to red.	CO_3^{2-}, HCO_3^- may be present.

3.	S/N E		
	5. Action of Concentrated H_2SO_4 on a Solid Sample. A small amount of a sample was transferred into a dry test tube and then small amount of concentrated H_2SO_4 was added	There wa effervencence of a colourless gas which turned lime water milky.	CO_3^{2-}, HCO_3^- may be present.
	6. Solubility of a Solid sample. A small amount of the sample was transferred into a clean test tube and then enough distilled water was added.	The sample was soluble in cold water.	(i) NO_3^-, CH_3COO^-, HCO_3^- may be present (ii) SO_4^{2-} may be present (iii) Cl^- may be present except of Ag^+ and Pb^{2+} (iv) Na^+, K^+, NH_4^+ may be present (v) CO_3^{2-} of Na^+, K and NH_4^+ may be present (vi) $C_2O_4^{2-}$ of Na^+, K^+, NH_4 may be present.

3.

S/N	Experiments	Observations	Inference
7.	Action of NaOH on sample solution The sample solution was devided into four portion. To the first portion two drops of NaOH was added.	No precipitate was formed	K^+, Na^+ may be present.
8.	Action of NH_4OH on sample solution To the second portion, two drops of NH_4OH was added	No precipitate was formed.	K^+, Na^+ may be present.
9.	Confirmatory Test for CO_3^{2-} and HCO_3^- A small amount of the solution of the original sample was transfered into the test tube add few drops of $MgSO_4$ was added.	White precipitate was formed after warming the contents	HCO_3^{2-} confirmed.
10.	Confirmatory Test for Na^+ and K^+ The supeinatant was evaporated and the obtained resdue was used to perform flame test	Golden-yellow flame was observed.	Na^+ confirmed.

3 (a)	The cation is Na^+
	The anion is HCO_3^-
3 (b)	The molecular formula of the sample is $NaHCO_3$.

Extract 19.2: A sample of correct responses to question 3 of Alternative Practical 3B

In Extract 19.2, the candidate accurately recorded observations, including effervescence upon the addition of acid, which indicates the release of a gas. He/she inferred the presence of HCO_3^- anion based on the gas test and correctly identified Na^+ as the cation due to the lack of precipitate with NaOH. The candidate then concluded by writing the correct molecular formula of the salt as $NaHCO_3$.

3. S/N	Experiments	Observations	Inference.
1.	Appearance of the Sample RV was observed	White Crystalline form was observed	Non-transition metals may be present.
			NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^-, CH_3COO^-, $Cr_2O_7^{2-}$ may be present.
2.	The glassrod was dipped in Concentrated HCl, then put to sample followed by heating it on a flame.	Blue colour was observed	Pb^{2+}, Sb^{2+} may be present.

	3.	A small amount of the sample RV was transfered to a clean dry test tube and then heated gently and strongly	Colourless gas evolved which turned moist litmus paper from blue to red and formed dense white fumes with ammonia gas	Cl^- may be present

3.	S/N	Experiments	Observations	inference
	4.	A small amount of sample RV was transfered to a cleaned testtube followed by small amount of dilute HCl. Then warmed	No gas evolved	SO_4^{2-}, Cl^-, NO_3^- may be present
	5.	A small amount of RV was transfered in a ~~clean~~ clean and dry testtube. Then a small ~~of~~ amount of Concentrated H_2SO_4 was added. and then warmed gently	Colourless gas with irritating smell evolved which turned moist litmus paper from blue to red and formed dense white fumes with ammonia gas	Cl^- may be present.
	6.	A small amount of a sample RV was transfered in testtube, then enough amount of distilled water was added to dissolve it. then warmed The solution of sample was divided into four portions.	A solid sample RV was soluble in hot water	Cl^- of Pb^{2+} may be present

3. S/N	Experiment	Observation	inference
7.	A small volume of the extract ~~into~~ was transfered into testtube, then dilute HNO_3 was added followed by $AgNO_3$ solution then $NH_{3(aq)}$	White precipitate soluble in dilute ammonia solution was formed.	Cl^- may be present
8.	A small volume of the original sample RV solution the pottasium dichromated K_2CrO_4 was added.	Yellow precipitated was formed	Pb^{2+} may be present

3 S/N	Experiment.	Observation	inference
9.	A small volume of the extract was transfered into testtube then dilute HNO_3 was added followed by $AgNO_3$ solution then $NH_{3(aq)}$	White precipitate soluble in dilute amonia solution was formed.	Cl^- was confirmed
10.	To a small volume of the original sample solution, then pottasium dicromate K_2CrO_4 was added.	Yellow precipitate was formed	Pb^{2+} was confirmed.

3(a) Cation is lead(II) ion [Pb^{2+}]

Anion is Chlorine ion [Cl^-]

3(b) Molecular formular.

from Pb^{2+} Cl^-

$PbCl_2$.

∴ The molecular formular is $PbCl_2$

Extract 19.3: A sample of correct responses to question 3, Practical Alternative 3C

In Extract 19.3, the candidate recorded accurate observations, such as the formation of a white precipitate with dilute hydrochloric acid and its partial solubility in hot water. Based on these results, she/he correctly inferred the presence of Pb^{2+} as the cation and Cl^{-} as the anion. The candidate concluded by writing the correct molecular formula of the salt as $PbCl_2$.

On the other hand, a small proportion of candidates, 3,413 (7.30%), who scored low marks exhibited various weaknesses, as reflected in their incorrect observations and inappropriate inferences during the preliminary, solution and confirmatory tests. Many of these candidates demonstrated a limited understanding of solubility rules and the formation of complex compounds. This led to misinterpretation of reactions involving the addition of NaOH or NH_4OH to the sample solution. Some candidates also demonstrated insufficient knowledge of the characteristic behaviours of transition elements, resulting in inaccurate identification of compounds during qualitative analysis.

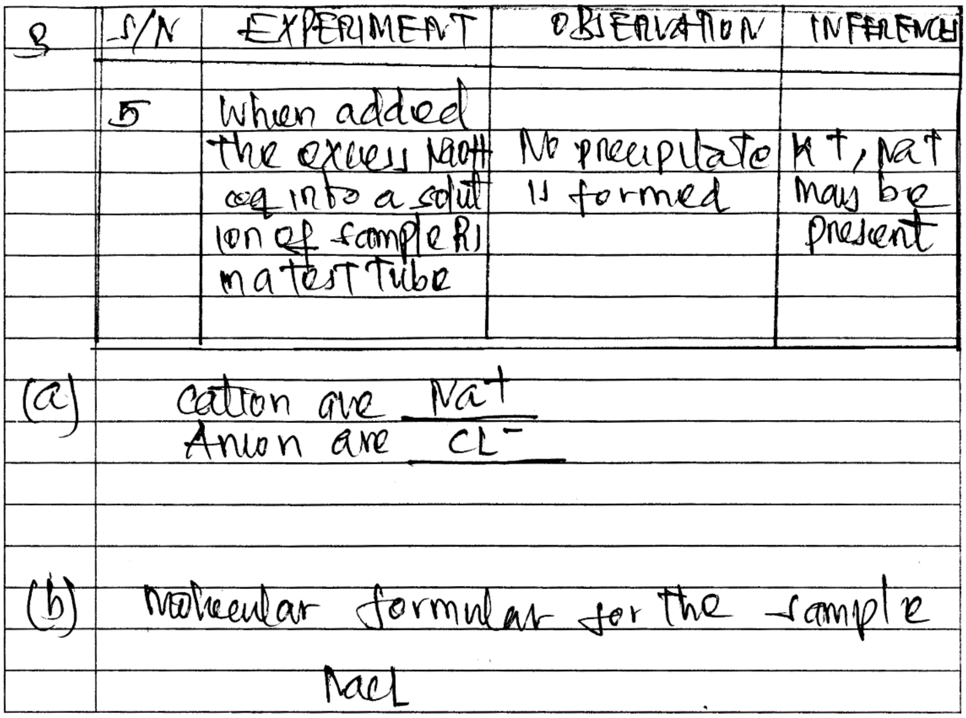
Furthermore, several candidates lacked sufficient knowledge of atomic spectra and periodic classification, which contributed to errors during the flame tests. This was evident in observations that failed to align with expected flame colours corresponding to specific metal ions. Additionally, many candidates were unfamiliar with the correct chemical formulas of common ionic compounds, which led to incorrect identification of the salts present in the given samples.

For instance, in Alternative A, one candidate recorded the observation "white precipitate insoluble in excess" after adding NaOH, and inferred the presence of Ca^{2+}, Sr^{2+}, or Ba^{2+}. The correct observation should have been "white precipitate dissolves in excess," indicating the presence of Zn^{2+}, Sn^{2+}, or Pb^{2+}. Another candidate mistakenly observed a "yellow colouration" after adding copper turnings, rather than the expected "brown fumes." These errors indicate a lack of understanding of redox reactions and analytical chemistry.

In Alternative B, one candidate reported that the evolution of a colourless gas forming dense white fumes with ammonia indicated the presence of Cl^{-} ions. This misinterpretation revealed a lack of understanding of the reaction between bicarbonates and mineral acids. Another candidate incorrectly confirmed the presence of CO_3^{2-} instead of HCO_3^{-} due to insufficient knowledge of how carbonates and bicarbonates react differently with magnesium sulphate.

In Alternative C, a candidate noted "yellow sparks" when a glass rod moistened with concentrated hydrochloric acid and dipped into the sample was placed in a non-luminous flame. The correct observation should have been a “blue flame,” corresponding to a specific line spectrum. This error revealed an inadequate understanding of atomic spectra and the principle that each element emits a characteristic colour in a flame. Extracts 19.4, 19.5, and 19.6 illustrate examples of incorrect responses to question 3 in alternative practicals A, B, and C, respectively.

3	S/N	Experiments	observation	Inferences
	1	appearance of the sample	Absorbs water from the atmosphere to form solution	NO_3^-, Cl^-, SO_4^{2-} may be present
	2.	when a solid sample Rs in a clean dry test tube are heated in the flame test	Colourless gas evolves which turn moist litmus paper from blue to red and form dens white fumies with ammonia gas	Cl^- may be present
	3.	when a solid sample Rs added a dilute HCL on a solid sample in a test tube	No gas evolves	SO_4^{2-}, Cl^-, NO_3^- may be present
	4	when a solid sample in a test tube add amount of distilled water to dissolvent	they are soluble in cold water	Na^+, K^+, NH_4^+ may be present



Q	S/N	EXPERIMENT	OBSERVATION	INFERENCE
	5	When added the excess NaOH aq into a solution of sample R1 in a test Tube	No precipitate is formed	K+, Na+ may be present

(a) cation are Na+
Anion are CL⁻

(b) molecular formular for the sample
NaCL

Extract 19.4*:* A Sample of incorrect responses to question 3, Alternative Practical 3A

In Extract 19.4, the candidate provided incorrect descriptions, stating that the sample was white and odourless. The candidate observed a colourless gas upon adding copper turnings and concentrated sulphuric acid instead of the expected brown fumes. Based on this, the candidate wrongly inferred the presence of Na^+ and Cl^- ions, reflecting a poor understanding of redox reactions and confirmatory analysis.

3.	EXPERIMENT DATA		
S/N	Experiment	Observation	Inferences
1.	Appearance of the sample (i) colour	White	Non transition metals may be present
	(ii) Texture	Solid sample	NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^-, CH_3COO^-, $Cr_2O_7^{2-}$ may be present
2.	Flame test A nichrome wire or glass rod was dip in concentrated HCl then heated in a non Luminous flame	Blue	Pb^{2+}, Sb^{2+} may be present.
3	Action of Heat on a Solid sample Small amount of a sample was transfered in a clean and dry test tube and heated gently and strongly	Colourless gas evolved which turn moist Litmus paper from blue to red and form dense white fumes with Ammonia gas	Cl^- may be present
4	Action of dilute HCl on a Solid sample - Small amount of sample transferedin a clean and dry test tube followed by Small amount of dilute HCl	No gas was evolued	SO_4^{2-}, Cl^-, NO_3^- may be present

3.	EXPERIMENT	OBSERVATION	INFERENCE
5.	Action of Concentrated H_2SO_4 on a Solid sample - Small amount of sample in a clean and dry test tube was transfered then concentrated H_2SO_4 was added	- Colourless gas with irritating smell was evolved which turns moist litmus paper from blue to red and forms dense white fumes with Ammonia gas	Cl^- may be present
6.	Solubility of Solid Sample - Small amount of a Sample ~~in a clean test~~ tube was transfered in a clean test tube then enough amount of distilled water added to dissolve it.	The solution was soluble in hot water	Cl^- or Pb^{2+} may be present
7.	Action of NaOH and NH_4OH on a Sample solutions - Small amount of sample solution was transfered in a clean test tube followed by addition of excess NaOH	Precipitate was dissolved	Cd^{2+} may be present
	Then addition of Excess Amonium Hydroxide	Insoluble precipitate was formed	Cd^{2+} may be present

3.

S/N	EXPERIMENT	OBSERVATION	INFERENCES
8.	Confirmatory test for cations		
	- Dilute HCl was added to the solution of the sample followed by H_2S gas	Yellow precipitate insoluble in yellow ammonium sulphide	Cd^{2+} confirmed
	- Dilute Ammonia solution was added to the solution of the sample	White precipitate insoluble in yellow ammonium sulphide	Cd^{2+} confirmed
9.	Confirmatory test for Anions.		
	- Confirmatory test for Cl^- - Small volume was transfered into test tube and dilute HNO_3 followed by $AgNO_3$ solution then $NH_{3(aq)}$ was added	White precipitate soluble in dilute Ammonia solution was formed	Cl^- confirmed

a) Cation = Cd^{2+}
Anion = chloride [Cl^-]

b) Molecular formula is $CdCl_2$

Extract 19.5: A Sample of incorrect responses to question 3, Alternative Practical 3B

In Extract 19.5, the candidate correctly identified the colour of the salt but incorrectly described its texture by confusing it with the state of matter, stating it was simply "solid." He/she failed to observe effervescence upon the addition of dilute HCl, missing a key reaction clue. The candidate also recorded inappropriate observations and drew incorrect inferences when NaOH and NH_4OH were added, as well as during confirmatory tests, ultimately failing to identify both the cation and anion present in the sample salt.

S/N	Experiment	Observation	Inference.
a.	Appearance of sample, RU.		
	i) colour	white	Non-transition metal may be present.
	ii) texture.	powder form	- CO_3^{2-}, and HCO_3^- may be present except of NH_4^+, K^+, and Na^+
	iii) Odour	- odourless	absence of NH_4^+ and CH_3COO^-.
	iv) Deliquescence	- does not absorb water	- absence of NO_3^-, Cl^- SO_4^{-2}
b	a. Action on heat of solid sample. - Small amount of solid sample are taken into clean and dry test tube and heated	- colourless droplets forming on the cooler part of test tube.	- hydrated salt, HCO_3^- may be present.

	c.	Action of Dilute HCl on a solid sample - Taking small amount of solid sample was taken into clean and dry test tube followed by addition of dilute HCl.	- Effervescence of colourless gas which turns lime water milky and moist litmus paper from blue to red	- CO_3^{2-}, HCO_3^- may be present
	d.	Action of concentrated H_2SO_4 on a solid sample. Small amount of a sample are transfered in a clean and dry test tube followed by addition of H_2SO_4 in small amount	- Effervescence of colourless gas which turns lime water milk.	- CO_3^{2-}, HCO_3^- may be present
	e.	Solubility of sample in water - Small amount of ~~solid~~ solid sample was taken into cleaned and dry test tube followed by addition of water.	- Sample does not dissolve in both hot or cold water	- CO_3^{2-} may be present except those of Na^+, K^+ and NH_4^+

7.	- flame test.		
	- Dip a glass rod in concen trated H_2SO_4 then heat to the flame of non-luminous	- Brick red color observed	- Ca^{2+} may be present.
8.	confirmatory test for anion.		
	- small amount of the original sample was transfer ed in clean and dry test tube followed by addit ion of small volume of dilute HNO_3	- Effervescency of colourless gas which turn lime water milky	- CO_3^{2-} confirmed.
H.	- Perform flame test	- Brick red flame observed.	Ca^{2+} conf irmed.

Question.

(a) what are the cations and anions

cation → Ca^{2+}

anions → CO_3^{2-}

(b) The molecular formular

$CaCO_{3(s)}$

Extract 19.6: A Sample of incorrect responses to question 3, Alternative Practical 3C

In Extract 19.6, the candidate correctly described the sample as “white’ but incorrectly noted the texture. During the flame test, the candidate reported the flame colour as “brick-red” instead of blue. Upon adding concentrated hydrochloric acid to the sample, the candidate noted the gas as “colourless with pungent smell” but did not mention the formation of dense white fumes with ammonia. The candidate inferred the presence of Ca^{2+} and

SO_4^{2-} ions, showing a misunderstanding of the correct solubility behaviour and flame test interpretation.

3.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE ON EACH TOPIC

The 2025 ACSEE Chemistry examination comprised 23 topics, divided across three papers. Chemistry Paper 1 covered 10 topics: *Relative Molecular Masses in Solution; Gases; Chemical Bonding; Chemical Equilibrium; Selected Compounds of Metals; Environmental Chemistry; The Atom; Aromatic Hydrocarbons; Aliphatic Hydrocarbons* and *Energetics*.

Chemistry Paper 2 included 10 topics: *Two Components Liquid System; Chemical Kinetics; Carbonyl Compounds; Carboxylic Acids and their Derivatives; Hydroxyl Compounds; Polymers; Periodic Classification; Extraction of Metals; Amines* and *Electrochemistry*.

In Practical Papers 3A, 3B, and 3C, candidates were tested on Volumetric Analysis, Physical Chemistry Analysis, and Qualitative Analysis, which are subtopics under Chemical Analysis.

Chemical Analysis was the highest-performed topic, with 92.70 per cent of the candidates scoring average marks or above. Other topics with high performances were *Environmental Chemistry* (97.47%), *Chemical Kinetics* and *Electrochemistry* (87.15%), *Aromatic Hydrocarbons* (86.6%), *Aliphatic Hydrocarbons* (84.65%), *Acids, bases and salts/ Solubility, Solubility Product and Ionic Product* (83.41%), *Relative Molecular Masses in Solution* (79.73%), *Chemical Bonding* (72.93%), *Chemical Equilibrium* (68.77%) and *Gases* (60.52%)

The candidates who excelled in these topics demonstrated a clear understanding of the question requirements and exhibited strong competencies in the tested concepts. Their good performance reflects a firm command of the underlying principles and the ability to apply acquired skills effectively.

Further, the analysis revealed that the topics of *Two Components Liquid System* (51.89%), *Periodic Classification and Extraction of Metals (50.83%),* Polymers (47.83%), *The Atom (40.3%),* and *Carbonyl*

Compounds, Carboxylic Acids and their Derivatives (40.07%) were performed on average. While some candidates demonstrated adequate knowledge of these topics, a significant portion provided partial answers and lacked the attentiveness necessary to understand the requirements of the questions fully. Consequently, their performance on these topics remained at an average level.

On the other hand, weak performance was observed in the topics of *Energetics* (21.28%) and *Selected Compounds of Metals* (6.76%). Analysis of responses from the candidates revealed a lack of sufficient knowledge of the subject matter, resulting in errors in formulas, chemical equations, and calculation approaches related to the topics.

When comparing the 2025 performance to that of 2024, improvements were observed in the topics of *Environmental Chemistry, Chemical Kinetics and Electrochemistry, Aromatic Hydrocarbons, Aliphatic Hydrocarbons, Acids, bases and salts/ Solubility, Solubility Product and Ionic Product, Periodic Classification and Extraction of Metals, Polymers and Transition Elements, The Atom and Energetics*.

However, there were declines in the performance of the topics of *Energetics* and *Selected Compounds of Metals*. A comprehensive summary of the candidates' performance on various topics covered in the theoretical and practical papers is provided in Appendices A and B, respectively.

4.0 CONCLUSIONS

The 2025 Chemistry examination demonstrated a strong level of performance, with a pass rate of 97.23 per cent. The analysis of candidates’ responses across both theory and practical components indicated effective engagement with the subject matter, particularly in the application of valuable skills. Educators are encouraged to integrate more experiential learning and utilise locally available resources to enhance conceptual understanding and student outcomes further.

Conversely, responses from lower-performing candidates revealed conceptual weaknesses and knowledge gaps. Addressing these through reinforced foundational instruction and targeted academic interventions will be essential in supporting student progress. This evaluative summary provides key insights to inform instructional planning and promote sustained academic achievement in the subject.

5.0 RECOMMENDATIONS

To enhance performance in the tested topics, a collaborative effort between teachers and students is essential. Based on the analysis of candidates' responses, the following targeted recommendations are proposed:

(a) Energetics

Teachers should reinforce thermodynamic concepts by focusing on energy changes, especially enthalpy changes associated with chemical reactions. Calorimetric experiments should be conducted to give students hands-on experience in measuring heat changes and applying calorimetry equations. Furthermore, students should be guided through energy cycles such as Hess's Law and the Born–Haber cycle, which are essential in calculating bond and lattice enthalpies in both ionic and covalent compounds.

(b) Selected Compounds of Metals

Teachers should emphasise the chemical properties, reactions, and uses of selected metallic compounds. Practical demonstrations and discussions should be used to reinforce the theoretical content.

(c) The Atom

To improve students' understanding of atomic structure, teachers should emphasise the fundamental concepts such as electron configurations, atomic models and quantum numbers. Incorporating visual tools, such as interactive simulations and physical models, can effectively illustrate atomic orbitals, electron shells, and atomic spectra. Additionally, providing historical context by discussing the development of atomic theory through key experiments such as Thomson's cathode ray tube and Rutherford's gold foil experiment will enhance conceptual engagement and retention.

(d) Acids, Bases, and Salts/Solubility, Solubility Product, and Ionic Product

Teaching in this area should focus on connecting theory with practice. Laboratory experiments involving acid-base titrations, buffer solutions, and solubility equilibria are crucial for reinforcing classroom instruction. Teachers should also guide students through practical calculations involving pH, pOH, Ka, Kb, and Ksp using real-world scenarios to build analytical skills. Furthermore, integrating environmental chemistry case studies, such as acid rain, ocean acidification and equilibrium in aqueous systems, will help students appreciate the relevance and application of the topic.

(e) Aromatic Hydrocarbons

To strengthen competence in aromatic chemistry, teachers should encourage students to work in groups to discuss the factors that activate or deactivate the benzene ring and how these influence substitution orientations. This collaborative approach deepens understanding of structural analysis. Moreover, teachers should guide students through the synthesis of polymers by emphasising both condensation and addition polymerisation reactions, thereby bridging theoretical knowledge with practical outcomes.

(f) Periodic Classification/Extraction of Metals

In this topic, students should be taught to recognise periodic trends, such as electronegativity, atomic radius, and ionisation energy, across periods and groups. Teachers should also emphasise the practical applications of the periodic table, including its use in predicting chemical reactivity, oxidation states, and the behaviour of elements. This approach will help students utilise the periodic table as a powerful tool for understanding element properties and chemical trends.

(g) Aliphatic Hydrocarbons

Teaching strategies in this topic should include a review of systematic IUPAC naming rules and the concept of structural isomerism across alkanes, alkenes, and alkynes. Additionally, students should explore addition and substitution reactions of aliphatic hydrocarbons, with emphasis on the underlying mechanisms. This will promote a deeper understanding of the reactivity and transformation of organic molecules.

(h) Volumetric Analysis

Teachers should provide students with hands-on practice in titration experiments that involve diluting solutions to adjust their concentrations. This approach will strengthen students' competence in performing accurate volumetric calculations.

To implement the above recommendations effectively, teachers should employ a range of instructional strategies. These may include inquiry-based learning (e.g., case studies, research projects and group discussions), practical demonstrations, the use of educational videos to visualise scientific processes and contextual learning through locally available resources. Such methods are instrumental in simplifying complex topics and enhancing students' overall understanding of chemistry.

Appendix A

Summary of the Candidates' Performance in the Theory Papers

S/N	Topic	2024 Question Number	2024 Percentage of Candidates who Scored an Average of 35 or Above	2024 Remarks	2025 Number of Questions	2025 Percentage of Candidates who Scored an Average of 35 or Above	2025 Remarks
1.	*Environmental Chemistry*	10 (P1)	58.21	Average	10 (P_1)	87.47	Good
2.	*Chemical Kinetics and Electrochemistry*	1 (P_2)	63.16	Good	1 (P_2)	87.15	Good
3.	*Aromatic Hydrocarbons*	9 (P_1)	31.15	Weak	9 (P_1)	86.70	Good
4.	*Aliphatic Hydrocarbons*	1 (P_1)	23.61	Weak	1 (P_1)	84.65	Good
5.	*Acids, bases and salts/ Solubility, Solubility Product and Ionic Product*	4 (P_2)	30.61	Weak	4 (P_2)	83.41	Good
6.	*Relative Molecular Masses in Solution*	8 (P_1)	87.37	Good	8 (P_1)	79.73	Good
7.	*Chemical Bonding*	2 (P_1)	81.81	Good	2 (P_1)	72.93	Good
8.	*Chemical Equilibrium*	3 (P_1)	80.88	Good	3 (P_1)	68.77	Good
9.	*Gases*	5 (P_1)	82.59	Good	5 (P_1)	60.52	Good
10.	*Two Components Liquid system*	5 (P_2)	67.12	Good	5 (P_2)	51.89	Average
11.	*Periodic Classification and Extraction of Metals*	3 (P_2)	27.32	Weak	3 (P_2)	50.83	Average
12.	*Polymers and Transition Elements*	2 (P_2)	43.31	Average	2 (P_2)	47.83	Average
13.	*The Atom*	4 (P_1)	32.09	Weak	4 (P_1)	40.30	Average
14.	*Carbonyl Compounds; Carboxylic Acids and its Derivatives*	6 (P_2)	54.31	Average	6 (P_2)	40.07	Average
15.	*Energetics*	7 (P_1)	18.06	Weak	7 (P_1)	21.28	Weak
16.	*Selected Compounds of Metals*	6 (P_1)	75.81	Good	6 (P_1)	6.76	Weak

Appendix B

Summary of the Candidates' Performance in the Practical Paper

S/N	Subtopic	2024			2025		
		Question Number	**Percentage of Candidates who Scored an average of 35 or Above**	**Remarks**	**Number of Questions**	**Percentage of Candidates who Scored an Average of 35 or Above**	**Remarks**
1.	Qualitative Analysis	3	92.53	Good	1	92.07	Good
2.	Volumetric Analysis	1	87.55	Good	1	86.61	Good
3.	Physical Chemistry Analysis	2	87.17	Good	1	86.69	Good