



THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY
NATIONAL EXAMINATIONS COUNCIL OF TANZANIA



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

CHEMISTRY



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032 CHEMISTRY

Published by:

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

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FOREWORD

This Candidates' Item Response Analysis (CIRA) report has been prepared to provide feedback to teachers, candidates, parents, policymakers, and the public in general about the performance of candidates who sat for Chemistry examination in the Certificate of Secondary Education Examination (CSEE) 2025.

The Certificate of Secondary Education Examination is a four-year summative evaluation that shows the effectiveness of the education system in general and the education delivery system in Tanzania. Essentially, candidates' responses to the examination questions indicate what the education system was able or unable to offer to candidates during their four years of secondary education.

The analysis presented in this report provides understandings of candidates' performance in Chemistry examination. The analysis indicates that the candidates who scored high marks had adequate knowledge of the tested concepts in Chemistry and managed to apply both conceptual and mathematical skills in responding to the questions. However, those who scored low marks lacked sufficient knowledge of the subject matter in question and failed to identify the demands of most of the questions. In addition, the candidates who scored low marks had insufficient mathematical manipulation skills and inadequate English language proficiency.

The feedback provided in this report will enable education stakeholders in Tanzania to identify and implement the recommended measures to improve candidates' performance in future examinations administered by the Council.

The National Examinations Council of Tanzania appreciates the valuable contributions of all individuals who participated in preparing this report in various capacities.



Prof. Said Ally Mohamed
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report analyses the performance of the candidates who sat for the Certificate of Secondary Education Examination (CSEE) 2025 in the Chemistry subject. The examination was set according to the 2022 CSEE format, developed from the 2007 Chemistry syllabus for ordinary-level secondary education.

The examination consisted of a theory paper (032/1 Chemistry 1) and practical paper (032/2 Chemistry 2). The theory paper comprised sections A, B, and C. Section A consisted of two objective questions in which question 1 consisted of ten multiple-choice items and question 2 consisted of six matching items. Each item in section A carried 01 mark. Section B consisted of six short answer questions carrying 09 marks each. Section C comprised three structured essay questions carrying 15 marks each. The candidates were required to answer all questions in sections A and B and only two questions from section C; making a total of 10 questions.

The practical examination was presented into three alternative papers: 032/2A Chemistry 2A, 032/2B Chemistry 2B and 032/2C Chemistry 2C. Each alternative paper consisted of two compulsory questions, weighing 25 marks each. The combined scores of each candidate in Chemistry were obtained by dividing the sum of paper 1 and paper 2 by 1.5.

A total of 178,047 candidates sat for the Chemistry examination in CSEE 2025. The overall performance was good, as 96.88 per cent passed the examination. By comparison, the candidates' performance in 2025 has increased by 0.52% relative to 2024, which was 96.36 per cent. Further analysis of candidates' performance is shown in Table 1.

Table 1: Performance of Candidates in each Grade in CSEE 2025

Grade	A	B	C	D	F
Number of candidates	10,583	26,579	94,904	39,990	5,547

Table 1 shows that most of the candidates (94,904) who passed the examination in 2025, attained grade C. A few of them (5,547) attained an F grade.

This analysis report comprises four sections. The first section provides the introduction, which covers the background information, rubric, and summary of the candidates' general performance. The second section analyses the candidates' performance in each question in which extracts of candidates' responses have been appended for clarity. The third section covers the analysis of candidates' performance in different topics, while the fourth section offers conclusion and recommendations.

2.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE IN EACH QUESTION

The analysis of the candidates' performance in each question has been categorised into percentages of full marks in the intervals of 0 – 29, 30 – 64, and 65 – 100, which are classified as weak, average, and good respectively.

2.1 032/1 CHEMISTRY 1

This theory paper had a total of 11 questions in which candidates were ought to attempt.

2.1.1 Question 1: Multiple Choice Items

The question consisted of 09 (10) multiple-choice items constructed from ten (10) topics: Matter; Formula, Bonding and Nomenclature; Hydrogen; Oxygen; Fuels and Energy; Water; Mole Concept and Related Calculations; Non-metals and Their compounds and Air, Combustion, Rusting and Fire Fighting.

In each item, the candidates were required to choose the correct response from the given alternatives, A to E, and write its letter beside the item number in the answer booklet provided.

A total of 178,039 candidates attempted the question. The analysis of the candidates' performance indicates that 13.18 per cent scored from 0 to 2 marks, 66.38 per cent scored from 3 to 6 marks and 20.44 per cent scored from 7 to 10 marks. Generally, the performance in this question was good since 86.82 per cent of the candidates scored 3 marks or above. The candidates' performance in this question is summarised in Figure 1.

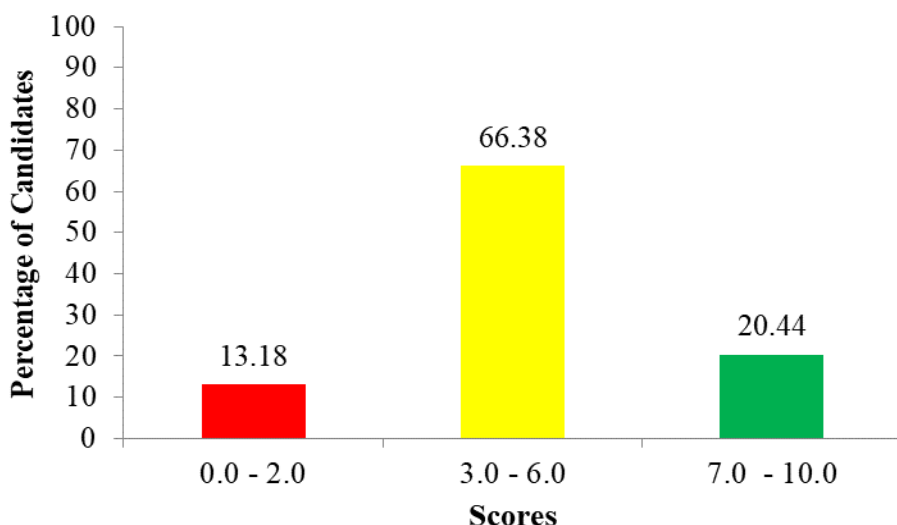


Figure 1: *Candidates' Performance in Question 1*

The majority (66.38%) of the candidates scored average (3 to 6 marks), while the minority (13.18%) scored low (0 to 2 marks).

Candidates who scored high marks (20.44%) in this question were well knowledgeable about the tested concepts across the topics covered. Conversely, the candidates who scored low marks (13.18%) failed to attempt most items correctly. This portrays that they had inadequate knowledge of the basic concepts, theories, terminologies, experiments, and principles in Chemistry based on the topics from which the items were composed.

In item (i), the question tested candidates' understanding of the existence of water in the three states of matter. The item was as follows:

Which relationship supports the existence of water in three states of matter?

- A $\text{Ice} \rightarrow \text{Gas} \rightarrow \text{Solid}; \text{Solid} \rightarrow \text{Gas} \rightarrow \text{Ice}$
- B $\text{Liquid} \rightarrow \text{Ice} \rightarrow \text{Gas}; \text{Gas} \rightarrow \text{Ice} \rightarrow \text{Liquid}$
- C $\text{Gas} \rightarrow \text{Ice} \rightarrow \text{Liquid}; \text{Liquid} \rightarrow \text{Ice} \rightarrow \text{Gas}$
- D $\text{Ice} \rightarrow \text{Gas} \rightarrow \text{Liquid}; \text{Liquid} \rightarrow \text{Gas} \rightarrow \text{Ice}$
- E $\text{Ice} \rightarrow \text{Liquid} \rightarrow \text{Gas}; \text{Gas} \rightarrow \text{Liquid} \rightarrow \text{Ice}$

The correct response was E. Candidates who chose the correct response understood the general concept of the change of matter from one state to the other. The candidates who opted for the other alternatives were not aware that ice is water in solid state and also confused the sequence of the transition or change of states of water.

In item (ii), the question tested candidates' ability to calculate both the empirical and the molecular formula of an organic compound. The item was as follows:

Which one is the molecular formula of a hydrocarbon having 20% hydrogen and vapour density of 15?

- A CH_3
- B H_3C
- C H_6C_2
- D C_2H_6
- E C_3H_6

The correct response was D, C_2H_6 . Candidates who chose the correct response had good mastery of the mathematical skill in calculating empirical formula, and use of vapour density to obtain the molecular mass of the compound. Furthermore, they related empirical formula with molar mass hence obtained correct molecular formula. The candidates, who chose incorrect alternatives, had inadequate knowledge on the relationship between empirical formula, Vapour density and molecular mass of the compound. (*molecular mass = $2 \times \text{Vapour density}$*), then (*Mass of empirical formula*)_n = *Molecular mass*. They also lacked skills of writing molecular formula of organic compounds.

In item (iii), the candidates were tested on their competence in identifying the role of zinc in reduction and oxidation process given. The question was as follows:

A chemist prepared hydrogen gas by mixing zinc granules with dilute hydrochloric acid. Which one of the following is correct about zinc reaction?

- A *It is oxidized*
- B *It is an oxidizing agent*
- C *It undergoes both oxidation and reduction*
- D *It is reduced*
- E *It undergoes decomposition*

The correct response was A, *It is oxidized*. Candidates who chose the correct response had adequate knowledge on oxidation states of elements. Candidates who opted for the distractors lacked knowledge on the oxidation-reduction processes based on increase or decrease in the oxidation number of the elements.

In item (iv) candidates were tested on their knowledge of testing the presence of water by using anhydrous copper (II) sulphate. The question was as follows:

A student exposed anhydrous copper(II) sulphate crystals in a watch glass over a whole night. In the next morning, the colour of copper(II) sulphate had changed from L to M. Which pair represents the colours of L and M?

- A L-green and M-blue
- B L-blue and M-green
- C L-white and M-blue
- D L-blue and M-white
- E L-white and M-green

The correct response was C, *L-white and M-blue*. The candidates who chose this response had adequate knowledge on the chemical test of water. These candidates knew that, white colour of anhydrous copper (II) sulphate change to blue due to absorption of atmospheric moisture. The candidate who opted for the other alternatives had no idea of the colours of both anhydrous and hydrated copper (II) sulphate. They also did not know that the anhydrous salt is hygroscopic salt, absorbs water from the atmosphere and change its colour.

Item (v) focused on testing candidates' knowledge on best method for extinguishing fire. The question was as follows:

Suppose a truck carrying flammable gas gets an accident and unfortunately fire breaks out. How will you extinguish the fire?

- A By using water and foam extinguisher.
- B By using dry powder and carbon dioxide extinguisher.
- C By using dry powder extinguisher and water.
- D By using wet chemical extinguisher and foam extinguisher.
- E By using water and carbon dioxide extinguisher.

The correct answer was B, *by using dry powder and carbon dioxide extinguisher*. The candidates who chose the correct answer had adequate knowledge on the different classes of fire and the respective methods of

how they can be extinguished. Those who opted for the other distractors had insufficient knowledge on the solubility of flammable gas in water. Moreover, they were not aware that flammable gases are less dense than water thus, using water will spread the flame.

In item (vi) candidates were tested on the ability to identify a good fuel for domestic and industrial use. The question was as follows:

Why is methane used as a source of fuel at homes and industries?

- A *It burns in air to give out energy*
- B *It burns in air to give out water vapour*
- C *It burns in air to absorb energy*
- D *It burns in air to absorb water vapour*
- E *It burns in air to give out carbon dioxide*

The correct response was A, *it burns in air to give out energy*. The candidates who chose the correct answer were knowledgeable about the properties of a good fuel. The candidates who opted for the other distractors B and E did not realize that fuel burns or undergoes combustion reaction to produce useful energy which is suitable for domestic uses. Basically, the candidates lacked adequate knowledge on the characteristics of a good fuel.

Item (vii) tested the candidates' knowledge on collection of pure oxygen gas during its preparation in the laboratory. The question was as follows:

Why is it essential to allow the first supply of oxygen gas to escape during laboratory preparation of oxygen?

- A *The gas jar contains impurities*
- B *The gas jar contains hydrogen peroxide*
- C *The gas jar contains some air in it*
- D *The gas jar is wet*
- E *The gas jar does not have a lid*

The correct response was C; *the gas jar contains some air in it*. The candidates who opted for this response had the knowledge that initially the gas jar contained mixture of gases, thus to obtain pure oxygen gas these gases should be removed first. On the contrary, those who chose the other distractors had no knowledge of the fact that the first oxygen prepared mixes up with other gases which were initially in the gas jar hence should be allowed to escape, so as to remain with pure oxygen in the gas jar.

In item (viii), the candidates were tested on application of mole ratios in calculating the reacting moles of reactants during chemical reaction. The question was as follows:

A mass of zinc metal weighing 90 g was reacted with hydrochloric acid. The reaction stopped after 7 minutes; 17.5 g of zinc remained unreacted. How many moles of hydrochloric acid reacted with zinc?

- A 1.13 moles
- B 2.23 moles
- C 3.33 moles
- D 4.43 moles
- E 5.53 moles

The correct response was B, 2.23 moles. The candidates who chose the correct response wrote a correct chemical equation for the reaction between HCl acid and zinc and then related well the moles of the reactants to obtain correct number of moles of HCl that reacted. Those who opted for other distractors failed to write correct chemical equation, ($\text{Zn(s)} + 2\text{HCl(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{(g)}$), giving correct mole ratios of the reactants and also failed to use correct formula, ($\text{moles} = \frac{\text{mass}}{\text{molar mass}}$) in calculating the number of moles of reacting species, showing insufficient knowledge of the mole concept and related calculations.

In item (ix), the candidates were tested in their knowledge about the alternative sources of energy. The question was as follows:

Why is wind said to be the promising source of energy for the future?

- A It does not produce harmful gases.
- B It can easily be stored.
- C It is harnessed without chemical reaction.
- D It is a renewable source of energy.
- E It is the cheapest source

The correct response was D, *it is a renewable source of energy*. The candidates who chose this response understood the requirement of the question which was based on energy for future use, with wind being renewable. The candidates who chose the other alternatives, did not base their argument on the future availability of the source of energy showing inadequate knowledge on the alternative source of energy for future use.

In item (x), the candidates were tested on their knowledge in laboratory preparation of ammonia gas. The question was as follows:

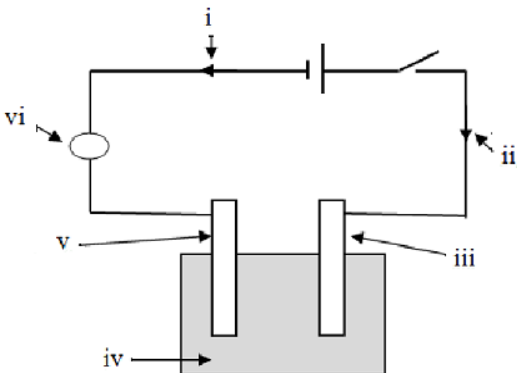
Why is calcium oxide useful during preparation of ammonia?

- A It removes water from the reaction.
- B It prevents the removal of water in the reaction.
- C It removes nitrogen gas from the reaction.
- D It prevents the loss of nitrogen from the reaction.
- E It increases the production of ammonia.

The correct response was A, *it removes water from the reaction*. The candidates who chose the correct response had sufficient knowledge of the preparation of ammonia gas in which calcium oxide is used as drying agent. Also, they were aware that calcium oxide is basic in nature hence, cannot react with ammonia gas. The candidates who opted for other distractors lacked understanding that ammonia gas dissolve in water to form ammonia solution; hence water should be removed during the preparation of the gas.

2.1.2 Question 2: Matching Items

The question was constructed from the topic of Ionic theory and Electrolysis. The candidates were asked to match the parts of the electrolytic cell in **List A** with the respective terms in **List B** by writing the letter of the correct response beside the item number in the answer booklet provided.

List A	List B
	A Anode
	B Electrolysis
	C Cathode
	D Current
	E Ammeter
	F Electrons
	G Electrolyte
	H Cell

The question was attempted by 178,036 candidates. Those who scored from 0 to 1 mark were 17.20 per cent while 36.76 per cent scored from 2 to 3 marks. Candidates who scored from 4 to 6 marks were 46.04 per cent. Generally, the candidates' performance in this question was good as 82.80 per cent scored 2 marks or above. The summary of candidates' performance in this question is shown in Figure 2.

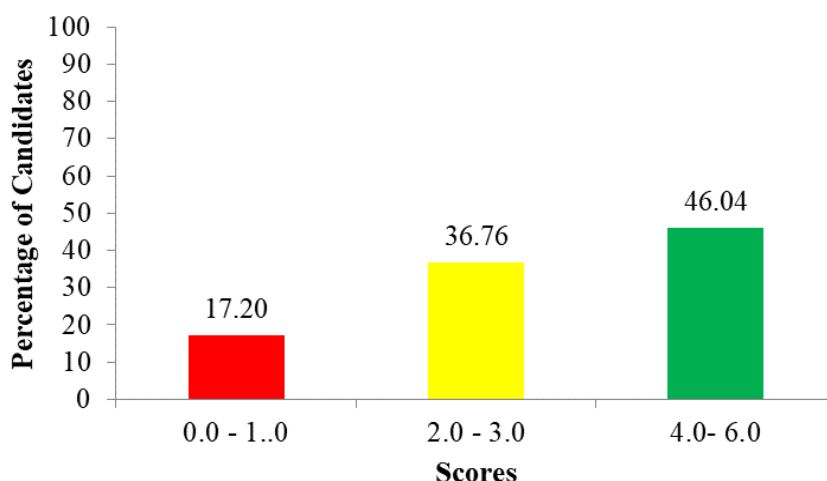


Figure 2: *Candidates' Performance in Question 2*

The candidates who scored high marks (46.04%) correctly matched most of the given parts of electrolytic cell. This indicates that they had sufficient knowledge on the mechanism of electrolysis and parts of electrolytic cell.

However, the candidates who scored low marks (17.20%) failed to identify correctly the parts of the electrolytic cell indicating lack of enough knowledge on set up of electrolytic cell including electrolyte and its component parts. For example, some of these candidates interchanged anode and cathode, which was represented by the flow of electrons. Others confused terms such as electrolyte with electrolysis and electrons flow with current flow.

2.1.3 Question 3: Water

In this question, the candidates were required to briefly explain six economic activities that depend on water.

A total of 178,040 candidates attempted this question in which 2.40 per cent scored from 0 to 2 marks. Candidates who scored from 2.5 to 5.5 marks were 10.22 per cent while those who scored from 6 to 9 marks were 87.38 per cent. Thus, the general performance was good because 97.60 per cent of the candidates scored 2.5 marks or above. Figure 3 gives a summary of the candidates' performance in question 3.

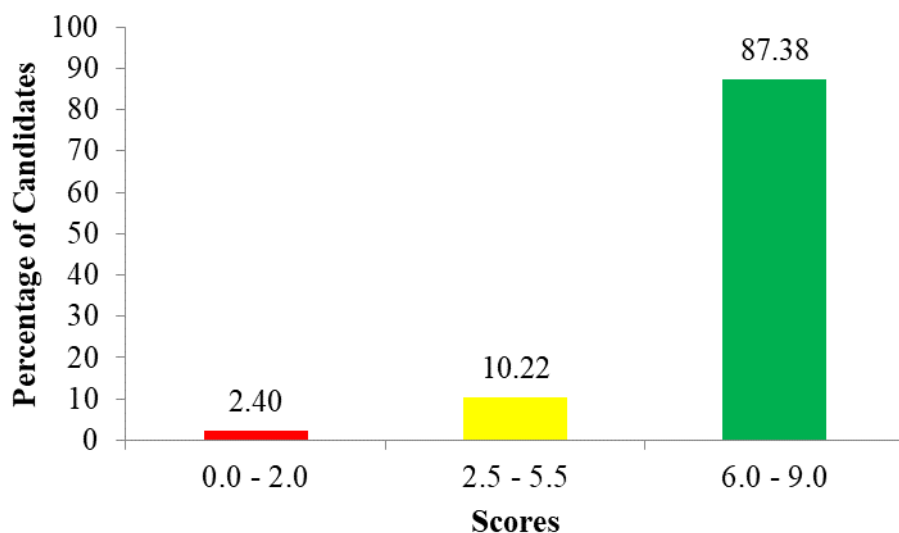


Figure 3: *Candidates' Performance in Question 3*

The candidates who scored high marks (87.38%) had wide knowledge of economic activities which depends on water in various fields such as agriculture, construction, transport, mining and energy production. Extract 3.1 shows a sample of correct responses from one of the candidates.

3.ii	Industrial activities.
	- In industries water is used in cooling of machines which have been operating. Also water can be used in industries to have been used to clean and run some of the machine parts.
iii	Mining sectors.
	Also water is used in mining sector to operate and used in cleaning up minerals which have been found underground in the way of mining.
iii	Recreational areas.
	- Also another economic activity which depend on the water is recreational areas have been the major and most valuable in swimming and refreshing purposes. Example: Swimming areas.
iv	Agriculture sectors.
	- Also agriculture sector depend on water for the purpose of watering crops for their growing purpose. Without water there will be no growing crops.
v	Fishing sector.
	Also fishing sector depend much on water because fishing activity involve the catching of organism in the water bodies e.g. lakes, rivers, and oceans.
vi	Marine transport.
	Also marine or water transport depend much on the water through transporting of raw materials and goods for the way which we could be accessed. This help to transport goods and people through crossing seas and oceans.

Extract 3.1: A sample of correct responses to question 3

In extract 3.1, the candidate has clearly explained the economic activities which directly depend on water.

Conversely, some candidates who scored low marks (2.40%) gave incorrect explanations regarding the areas in which water is used for economic gain. Many candidates who attempted this question simply explained mere domestic uses of water. For example, one candidate wrote that water is used for washing clothes and cooking at home. Another candidate wrote that water is used for drinking. Additionally, another candidate wrote that water used for washing hand. These are not economic in nature, hence incorrect responses. Extract 3.2 shows a sample of incorrect responses from one of the candidates.

3	(i) Rivers and Streams
	Water in rivers flow and obtained for use
	eg River Ruvu, Rufiji and Wami.
	(ii) Oceans
	Ships travel in ocean from country to another. Eg. Hind and Pacific oceans
	(iii) Lakes
	For example lake Victoria and Natron
	Water is available there
	(iv) Dams
	We have dams in Tanzania for storing water. Eg Nyumbaya Mungu and Hale dam. Also there is electricity
	(v) Wells and Tankes
	Wells and tanker eg sim tank and kiboko help to get water at homes from pipes and accumulate there

Extract 3.2: Sample of incorrect responses to question 3

In Extract 3.2, the candidate wrote names of water bodies and their examples instead of giving economic activities which depend on water.

2.1.4 Question 4: Periodic classification

The question had two parts and was as follows:

- (a) (i) *Justify the fact that hydrogen has got both properties of group I and group VII elements. Give two points.*
- (ii) *Why hydrogen is placed in group I rather than group VII in the Periodic Table?*
- (b) *Given that element **G** has electronic arrangement of 2:8:8:7 and another element **H** has atomic number 17, place element **G** in its suitable period and compare the reactions of sodium metal with element **G** and **H**.*

The question was attempted by 178,024 candidates. Candidates who scored from 0 to 2 marks were 65.21 per cent, from 2.5 to 5.5 marks were 33.03 per cent and only 1.76 per cent scored from 6 to 9 marks. Generally, the performance of the candidates in this question was average as 34.79 per cent scored 3 marks or above. Summary of the candidates' performance in this question is shown in Figure 4.

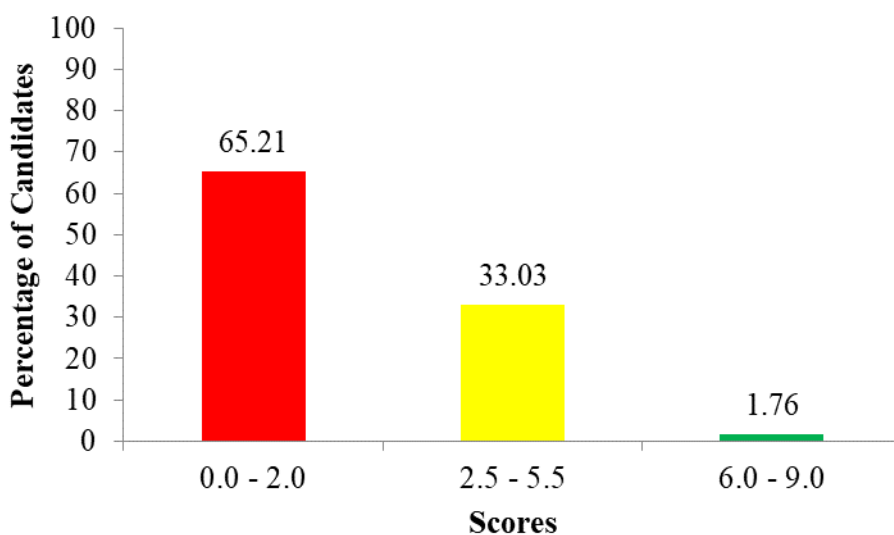


Figure 4: *Candidates' Performance in Question 4*

The candidates who scored high marks gave correct justification of the resemblance of hydrogen with group I and group VII elements in terms of its properties as required in (a) part (i). In part (ii) of the question, the candidates explained the use of modern periodic law to explain why

hydrogen is placed in group I and not VII. This shows a good understanding of relationship between electronic configuration and position of elements in periodic Table. In part (b) of the question, candidates who scored high marks related the electronic configuration to the period of the element and also, managed to relate the periodic trends such atomic radius and electronegativity to explain the reaction between sodium metal and the given elements G and H. This shows good understanding of the general concept of periodic trends of the physical properties. Extract 4.1 shows a sample of correct responses from one of the candidates.

4.	a) i	Hydrogen has Group I properties because hydrogen has only one electron in its outermost shell just like other Group I elements like sodium hence possessing Group I properties.
4 a.	ii.	This is because in the periodic table elements are arranged in order of their increasing atomic number. Therefore hydrogen having atomic number of 1 becomes the first element in group I rather than group VII.
	b)	G - 2 : 8 : 8 : 7 H - atomic number 17 - 2 : 8 : 7 Element G is in Period 4.
		The reaction of sodium metal with H will be more vigorous than the reaction of sodium and G.
		This is because H is more electronegative than G and therefore H attracts the electron from sodium easily than G.

Extract 4.1: A sample of correct responses to question 4

In extract 4.1, part (a), the candidate has clearly justified the features that hydrogen shares with group I and group VII elements and the reason for placement of hydrogen in its suitable group. In part (b), the candidate

correctly related the electronic configuration to the period of the element and used the physical periodic trend of atomic parameters to explain reactivity of sodium and the two elements (H and G)

On the other hand, the candidates who scored low marks (65.25%) in (a) part (i) and (ii), were not knowledgeable on concept of periodicity and electronic configuration. Hence, they gave similarities of hydrogen with both Groups I and VII elements. For instance, one candidate wrote that hydrogen is similar to group I elements because it is alkali metal. Another candidate wrote that hydrogen is similar to group VII elements because it is a halogen. Other candidates used incorrect physical properties of hydrogen gas as criteria to place hydrogen in group I. For example, one candidate wrote hydrogen is less dense than air thus resembles group I elements. In part (b) of the question, the candidates failed to relate electronic configuration to the correct period of the element. Some of the candidates wrote element G should be placed in period 7 as per the number of electrons in the outer most shell. Others used the atomic number to deduce the period. Citing an example, one candidate wrote element G is found in period 25 which was obtained by summing up the total number of electrons in each shell. Likewise, another candidate asserted that element G is found in period 17. Generally, this displays insufficient knowledge on the modern periodic law and application of electronic configuration to locate the position of elements in the periodic table. Extract 4.2 shows a sample of incorrect responses from one of the candidates.

4.	q. 1) The following are the reasons to - why hydrogen has got both properties - of group I and group VII element. explain. (a) Because its last shell is not fullfilled. (b) Because hydrogen it is a non-metal. (ii) Hydrogen is placed in group I rather - than group VII Because its last shell is not fullfilled. (b) Given that. Element G: 2:8:8:7 Element H: Has atomic number 17.
----	---

4.	b) Its period of element G. is period 2. The reaction of sodium metal and element H, H = Cl Na. $\text{Na} + \text{Cl} \longrightarrow \text{NaCl}$ $2\text{Na} + \text{Cl}_2 \longrightarrow 2\text{NaCl}$ $2\text{Na} + \text{Cl}_2 \longrightarrow 2\text{NaCl} \cdot \text{X}$ balanced. The reaction between sodium metal and element G. Na Br $\text{Na} + \text{Br} \longrightarrow \text{NaBr}.$
----	---

Extract 4.2: A sample of incorrect responses to question 4

In Extract 4.2, the candidate gave incorrect responses in all parts of the question. The candidate failed to use the concept of electronic configuration in placing elements in their correct positions in the periodic table, according to *the modern periodic law; the properties of elements are a periodic function of their atomic numbers*. This led to incorrect comparison of the reaction of sodium and element H and G as per the requirement of the question.

2.1.5 Question 5: The Scientific Procedure

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

(a) A laboratory technician investigated the solubility of sodium chloride by dissolving different amounts of sodium chloride in a fixed volume of water while altering the temperature of the water. Categorize each variable in this experiment.

(b) Identify six steps to follow when conducting a scientific investigation.

This question was attempted by a total of 178,039 candidates. Statistics show that 6.86 per cent of the candidates scored from 0 to 2 marks, 21.92 per cent scored from 2.5 to 5.5 marks, and 71.22 per cent scored from 6 to 9 marks respectively. Generally, the performance of the candidates in this question was good, as 93.14 per cent scored 2.5 marks or above. Summary of the candidate's performance in this question is shown in Figure 5.

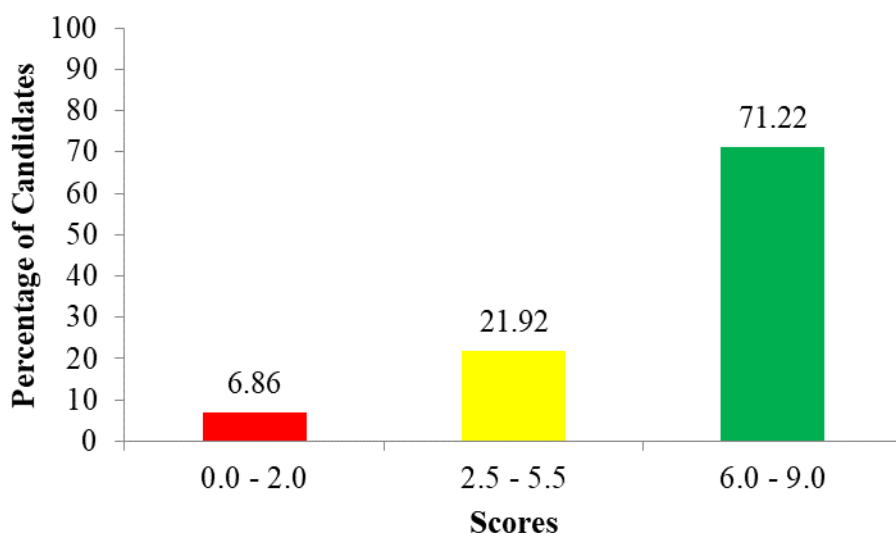


Figure 5: *Candidates' Performance in Question 5*

Candidates who scored high marks (71.22%) gave correct relationship between the types of variables and the corresponding experimental variables, showing good mastery on the concept of application of scientific procedures in carrying out experiments required in part (a). In part (b) of the question, these candidates gave correct explanation of the chronological steps used in scientific procedure. Extract 5.1 shows a sample of correct responses from one of the candidates.

5.	a) i) Dependent variable in the Experiment is Solubility of Sodium chloride.
	ii) Independent variable in the Experiment is the temperature of the water.
	iii) Control variable in the experiment is a Volume of water.
	b) i) Problem identification.
	ii) Hypothesis formulation.
	iii) Experimentation.
	iv) Data collection.
	v) Data interpretation and analysis.
	vi) Conclusion.

Extract 5.1: A sample of correct responses to question 5

In extract 5.1, the candidate clearly categorized the variables with respective examples and also gave correct chronological order of scientific procedures for conducting experiment as per the requirement of the question.

Conversely, the candidates who scored low marks (6.86%) had inadequate knowledge of the types of variables and the related experimental variables in part (a). In most cases, the candidates explained factors affecting the solubility of salts. For example, one candidate wrote that the type of variables is high pressure, while another wrote that the experimental variables are NaCl is ionic and water is a solvent. Some candidates confused the types of variables with experimental variables.

Types of variables	Experimental variable
(i) Dependent variable	water
(ii) Controlled variable	temperature

Moreover, another candidate wrote, “independent variable is water and dependent is temperature”. In part (b) of the question, candidates who scored low marks (6.86%) were unable to arrange the scientific procedures chronologically. Some candidates interchanged hypothesis formulation with identification of the problem. One candidate separated experimentation from observation, while another wrote “*laboratory work*” in step (iii) instead of experimentation and observation. Overall, these candidates demonstrated inadequate knowledge of the steps of the scientific procedures. Extract 5.2 shows a sample of incorrect responses in question 5.

5.	(a) There are three variables of the experiment which are.
	i) Dependent variable, This is the variable which does not depend on other variables. It is depending on its self.
	ii) Independent variables; These are variables which depend on other variables and can not function without other variables hence needs the aid from other variables so as may function.
5.	(a) iii) Controlled variables; These are variables which does not change hence are kept on constant without changing.
5	(b) (i) Carefully and through observation
	(ii) accurate recording of what has been observed
	(iii) collecting data
	(iv) Hypothesis
	(v) Formulating observation
	(vi) Conclusion of observation

Extract 5.2: A sample of incorrect responses to question 5

In Extract 5.2, part (a), the candidate gave definitions of variables instead of categorizing the variables given. In part (b), the candidate interchanged all the steps hence the chronological order of the scientific procedure was not followed.

2.1.6 Question 6: Hydrogen

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

- (a) A certain chemist proposed the use of hydrogen gas as a fuel in vehicles. Suggest three advantages and three disadvantages of using the gas as a fuel.
- (b) Why chemists prefer zinc granules and dilute hydrochloric acid to pure zinc and concentrated hydrochloric acid in the laboratory preparation of hydrogen gas?

A total of 178,023 candidates attempted this question. The candidates' performance indicates that 68.26 per cent scored from 0 to 2 marks, 28.05 per cent scored from 2.5 to 5.5 marks, and 3.69 per cent scored from 6 to 9 marks. Generally, the performance in this question was average because 31.74 per cent of the candidates scored 2.5 marks or above. The summary of the candidates' performance in this question is as shown in Figure 6.

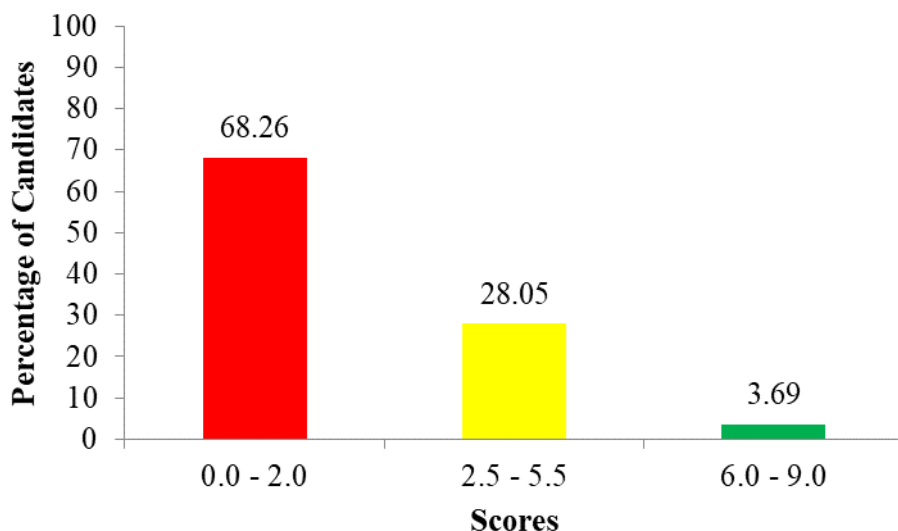


Figure 6: *Candidates' Performance in Question 6*

The candidates who scored high marks (3.69%) gave correct advantages and disadvantages of using hydrogen as fuel in vehicles. This signifies that the candidates had adequate knowledge of the characteristics of a good fuel as per the requirement of part (a) of the question. In part (b), the candidates correctly explained the use of zinc granules with large surface area in preparation of hydrogen when reacted with dilute HCl, with more replaceable hydrogen ions than concentrated HCl. This shows good mastery of the reactivity of hydrochloric acid in dilute form and concentrated form as well as effect of surface area on rate of reaction. Extract 6.1 shows a sample of correct responses to question 6.

6.	a) ADVANTAGES .
	i) It does not produce non-combustible materials,
	In which when hydrogen burns it does not form ash or soot which can harm the environment.
	ii) It does not produce hazardous gases ,
	In which when hydrogen burns it does not produce gases such as carbon dioxide which is harmful to human health or even smoke
	iii) It has a high energy value ,
	In which this is to say when hydrogen is used as a fuel it gives out a lot of energy per unit mass hence being a good fuel.

6.	DISADVANTAGES
	i) It is very flammable hence making it not safe. For presence of heat or not careful handling can lead to an explosion.
	ii) It is not easily available, for it exists in high atmospheres for it is light and mostly in reactions with compounds hence one can't easily access the gas.
	iii) It is not easily affordable, for it is quite expensive to prepare, extract and use it as a fuel.

6.	b) i) Zinc granules have a large surface area than pure zinc, hence it increases the rate of reaction with hydrochloric acid by exposing more zinc particles to react with the acid for maximum formation of products. ii) The reaction of pure zinc and concentrated hydrochloric acid is highly violent and exothermic so, instead, for laboratory safety, dilute hydrochloric acid and the zinc granules are used to ensure safety in the laboratory. Also, concentrated hydrochloric acid is highly corrosive hence dilute hydrochloric acid is used.
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Extract 6.1: A sample of correct responses to question 6

In Extract 6.1, the candidate gave correct explanation of the properties of zinc granules favouring its high reactivity with dilute HCl acid. The candidate also explained the absence of ions in concentrated HCl, hence low reactivity compared to dilute HCl.

On the contrary, candidates who scored low marks (68.26%) in this question failed to provide the advantages and disadvantages of hydrogen as a fuel in vehicles as required in part (a). This indicates a lack of sufficient knowledge of the characteristics of a good fuel in relation to the properties of hydrogen. Some candidates wrote properties of hydrogen instead of characteristics of a good fuel. For example, one candidate wrote hydrogen gas is slightly soluble in water, while another candidate stated it is less dense than air. Likewise, some candidates gave uses of hydrogen fuel in other fields instead of vehicles. For instance, one candidate wrote “hydrogen fuel used for cooking at home”. Another one stated that it is used in production of electricity in industry. In part (b), these candidates lacked knowledge on the difference between granular zinc and pure zinc as well as the nature of concentrated HCl and dilute HCl. One of the candidates wrote that zinc granule is preferred to pure zinc because granular zinc is easily available than pure zinc. Another candidate wrote that concentrated HCl is highly reactive than dilute HCl hence produces hydrogen gas faster. Extract 6.2 shows a sample of incorrect responses to question 6.

6a	ADVANTAGES
	① It used in industry
	② It used for cooking
	③ It used for light
	DISADVANTAGES
	① It cause death
	② It cause pollution of environment
	③ It cause effect of health
6b	Chemists prefer Zinc granules and dilute hydrochloric acid to pure zinc and concentrated hydrochloric acid in the laboratory preparation of hydrogen gas because it's support to make a hydrogen gas due to insoluble in water easily.

Extract 6.2: A sample of incorrect responses to question 6

In Extract 6.2, the candidate wrote general properties of hydrogen instead of those of a fuel. In part (b), the candidate wrote chemical reaction equation instead of explaining the effect of surface area and dilution on the reactivity of Zinc and HCl in the preparation of hydrogen.

2.1.7 Question 7: Heat Sources and Flames

The question had two parts as follows:

- (a) *Identify six steps to follow in lighting the Bunsen burner so as to produce a non-luminous flame.*
- (b) *Give four uses of non-luminous flame and for each use indicate the property of the flame that is concerned.*

A total of 178,039 candidates attempted this question. The analysis shows that 39.22 per cent scored from 0 to 2 marks, 37.47 per cent scored from 2.5 to 5.5 marks, and 23.31 per cent scored from 6 to 9 marks. The general performance of the candidates in this question was good because 60.78 per cent of the candidates scored 2.5 marks or above. The candidates' performance in this question is shown in Figure 7.

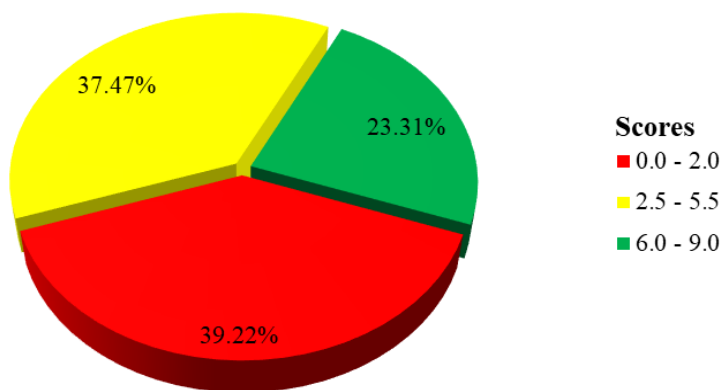


Figure 7: *Candidates' Performance in Question 7*

The candidates who scored high marks (23.31%) correctly identified, all the six steps in chronological order which are necessary to be followed when lighting a Bunsen burner in order to produce a non-luminous flame. This indicates a good level of competence in using a Bunsen burner, particularly in the correct adjustment of the collar to obtain a non-

luminous flame. In part (b), these candidates correctly gave the uses of non-luminous flame in relation to the property of the flame. This showed good understanding of the characteristics of non-luminous flame. Extract 7.1 shows a sample of correct responses in question 7.

7 a>i>	Total closing of the air hole .
	ii> Connecting the bunsen burner to a gas supply system

7 a>iii>	lighting the match stick
	iv> Turn on the gas supply to ensure presence of fuel in the barrel
	v> Keeping the fire match stick on the chimney with ones face away from the burner
	vi> Adjusting the air hole by opening it fully so as to get a non-luminous flame .
b>i>	In welding activities because it produce a very hot flame {Oxyhydrogen flame}
	ii> In flame tests because it is very hot and produces no soot .
	iii> In heating substance in laboratory because it is very hot . The flame is used to boil and heat solids and liquids .
	iv> In cooking because it is very hot . Through the use of gas stove to cook at home .

Extract 7.1: A sample of correct responses to question 7

In Extract 7.1, the candidate gave correct chronological order of the steps followed when lighting a Bunsen burner in part (a) as well as the correct uses of non- luminous flame in relation to the properties of the flame as per the requirement of part (b) of the question.

However, candidates who scored low marks (39.22%) failed to identify the correct steps followed in lighting Bunsen burner in part (a). Some candidates gave the steps but not in chronological order. This showed insufficient knowledge of the working operations of the Bunsen burner. One candidate gave differences between luminous and non-luminous flames, showing a lack of understanding of the requirements of the question. Another candidate wrote the first step as lighting a match stick. In part (b), some candidates gave uses of luminous flame instead of non-luminous flame. One candidate gave one use as lighting the room because it is large in size. Another candidate wrote that non luminous flame is useful because it is noisy. Extract 7.2 shows a sample of incorrect responses in question 7.

7	i) Take the bunsen burner and put it on top of the table in the laboratory
	ii) Connect a wire to the bunsen burner through the gas inlet
	iii) then connect the from the gas inlet of the bunsen burner to the Gas source or heat source
	iv) Adjust the collar to open the air holes of the bunsen burner for getting non- luminous flame.

7	as v put on the gas source to allow the gas to pass through the wire to the bunsen burner through gas inlet.
	vi) Then the gas will reach the barrel chimney of the bunsen burner where the flame which is non- luminous flame will be formed and produced.

7	b) i) Source of heat
	ii) Produce high heat
	iii) It support combustion.
	iv) It has three zone.

Extract 7.2: A sample of incorrect responses to question 7

In Extract 7.2, the candidate responded to part (a) by presenting the required steps in non-chronological order. In part (b), the candidate wrote the properties of non-luminous flame instead of its uses.

2.1.8 Question 8: Hardness of Water

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

- (a) *A Form Four student needed hard water for an experiment. Unfortunately, only soft water was available in the laboratory. What are the four alternative chemicals can be added to the available water so as to perform the experiment?*
- (b) *Explain each of the following cases with support of ionic equation:*
- (i) *Temporary hardness of water can be removed by boiling.*
 - (ii) *Permanent hardness of water can be removed by addition of washing soda.*
- (c) *Explain three advantages of hardness of water in daily life.*

The question was attempted by a total of 178,037 candidates. Statistics show that 42.03 per cent of the candidates scored from 0 to 2 marks, 48.56 per cent scored from 2.5 to 5.5 while 9.41 per cent scored from 6 to 9 marks. Generally, the performance was average as 57.97 per cent of the candidates scored 2.5 marks or above. The performance of the candidates in this question is summarised in Figure 8.

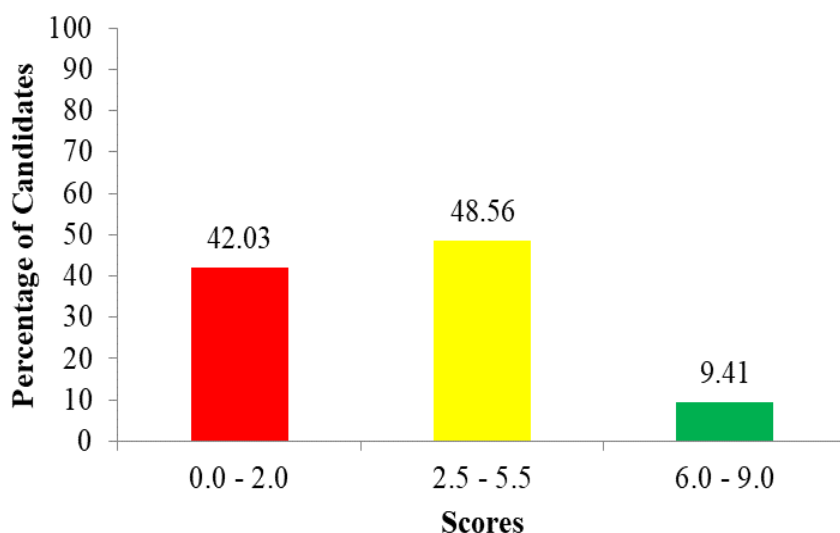
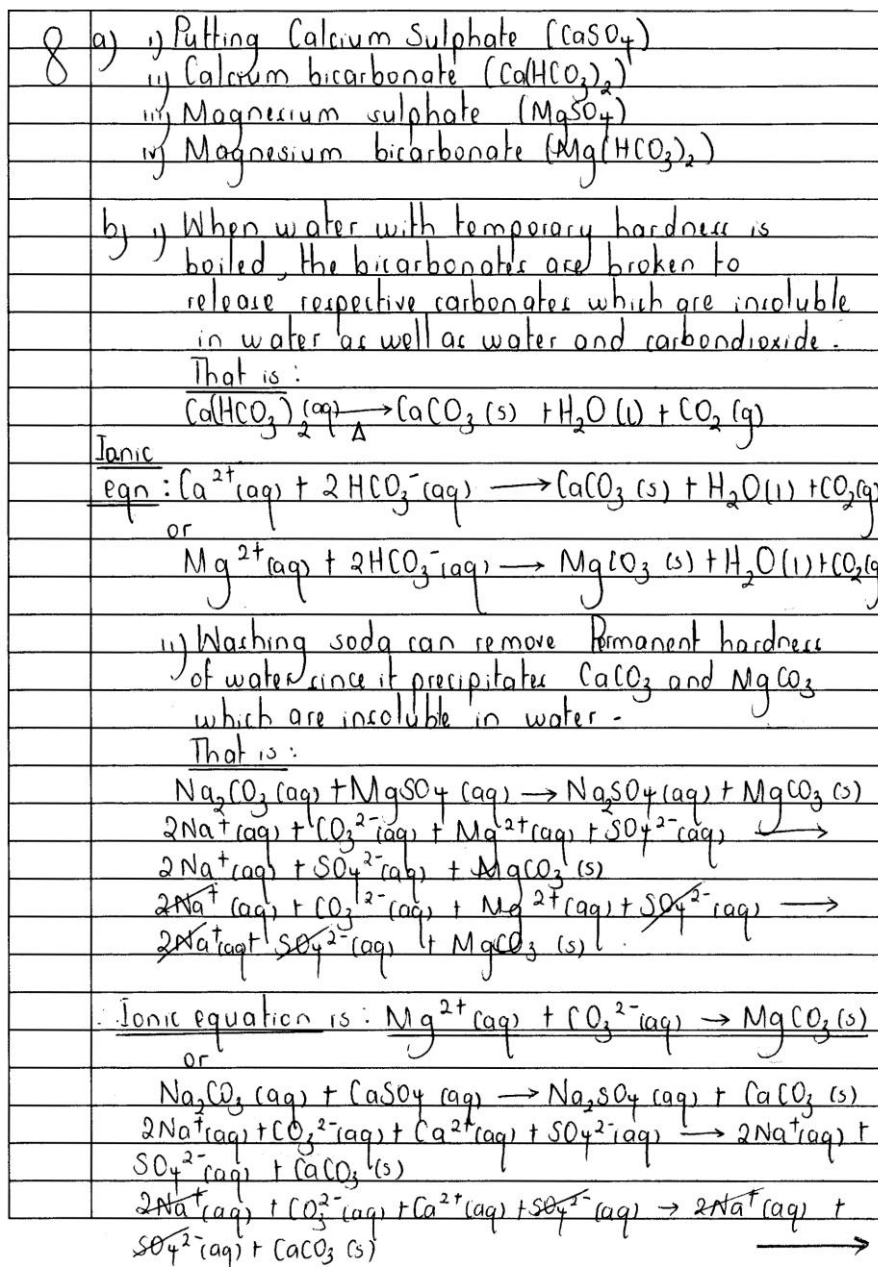


Figure 8: *Candidates' Performance to Question 8*

The candidates who scored high marks (9.41%) correctly wrote the appropriate chemicals which cause hardness of water. This shows good knowledge of the ions which cause hardness of water as required in part (a). In part (b), the candidates wrote correct ionic equations showing methods used in removal of both temporary and permanent hardness of water. These candidates showed good understanding of the concept of removal of hardness of water using different chemicals and by boiling. In part (c) of the question, the candidates gave adequate advantages of hardness of water in daily life. Extract 8.1 shows a sample of correct responses to question 8.



8	by) Ionic equation is: $\text{Ca}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{CaCO}_3(\text{s})$ c) i) It strengthens bones and teeth Through drinking hard water, one's bones and teeth become stronger and grow well. Due to various minerals. <u>Example: Calcium</u> ii) It helps to prevent metal poisoning through covering metal pipes. Pipes for domestic water supply are sometimes metallic, so hard water create coatings which prevent direct contact of water and pipes. <u>Example: It prevents lead poisoning.</u> iii) It has a better taste. Most people prefer drinking hard water as it contains minerals which give it a distinctive better taste. <u>Example: Water containing CaCl_2.</u>
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Extract 8.1: A sample of correct responses to question 8

In extract 8.1, the candidate provided correct responses for all parts of the question, including identifying the salts/ions that can cause hardness in water and writing the equations for the removal of the hardness. Additionally, the practical uses of hard water were well-articulated.

On the other hand, the candidates who scored low marks on this question (42.03%) provided incorrect responses in most parts of the question. In part (a), the candidates had inadequate knowledge on the ions responsible for causing hardness of water. Most candidates wrote incorrect chemicals which cause hardness of water. For instance, one candidate wrote NaCl , while another candidate wrote CaCO_3 instead of $\text{Ca}(\text{HCO}_3)_2$. In part (b), these candidates failed to write correct ionic equations for the removal of both temporary and permanent hardness. For example, one candidate wrote $\text{CaCO}_3 \xrightarrow{\text{boiling}} \text{Ca} + \text{CO}_2$, while another candidate wrote $\text{CaSO}_4 + \text{Na}_2\text{CO}_3 \rightarrow \text{CaCO}_2 + \text{NaSO}_4$. These responses demonstrated a lack of knowledge regarding the ionic equations for the removal of hardness in water. In part (c) of the question the candidates failed to explain the advantages of hardness of water. Most of the candidates

wrote general uses of water instead of hardness of water. For example, one candidate wrote hardness of water causes teeth to be brown. Another candidate wrote that hardness of water is useful in car radiators. Extract 8.2 shows a sample of the incorrect responses to question 8.

8	(a) (i) Addition of aqueous ammonia
	(ii) Using washing power.
	(iii) Exchanging ion solution.
	(iv) Boiling
	(b) (i) Temporary hardness of water can be removed by boiling or using calcium or magnesium of hydrogen carbonate for decomposition and heating
	$\text{Ca}(\text{HCO}_3)_2 \xrightarrow{\Delta} \text{CaCO}_3 + \text{H}_2\text{O}$
	$\text{Mg}(\text{HCO}_3)_2 \xrightarrow{\Delta} \text{MgCO}_3 + \text{H}_2\text{O}$
	(ii) Permanent hardness of water can be removed by washing power (CaCO_3).
	$\text{Mg}(\text{HCO}_3)_2 + \text{CaCO}_3 \longrightarrow \text{MgCO}_3 + \text{H}_2\text{O} + \text{CaCO}_3$
	(c) hardness of water using in manufacturing electricity.
	(ii) hardness of water using in domestic activities for washing clothes, clothes etc.
	(iii) hardness of water using in hospital and medical centers

Extract 8.2: A sample of incorrect responses to question 8

In Extract 8.2 part (a), the candidate wrote incorrect salts methods of removing hardness of water. In part (b) the candidate failed to write the ionic equation while in part (c) they gave incorrect uses of hardness of water.

2.1.9 Question 9: Chemical Kinetics, Equilibrium and Energetics

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

- (a) *Briefly explain Le Chateliers' principle.*
- (b) *A certain company wants to increase production of one of its products, Z. Product Z is formed by reacting substance X and Y as shown in the following equation:*
- $$X(g) + Y(g) \rightleftharpoons Z(g)$$

By applying Le Chateliers' principle, explain four technical ways through which the company can achieve the high yield of product Z.

The question was attempted by 142,463 candidates. Statistics show that 38.02 per cent of the candidates scored from 0 to 4 marks, 27.61 per cent scored from 4.5 to 9.5 marks, and 34.37 per cent scored from 10 to 15. Hence, the overall performance of the candidates was average because only 61.98 per cent of them scored 4.5 marks or above. The summary of the candidates' performance is presented in Figure 9.

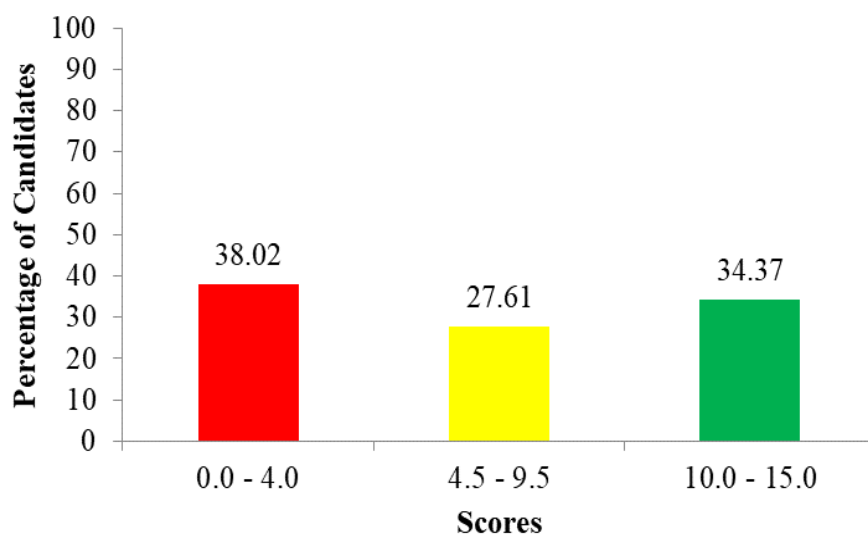


Figure 9: *Candidates' Performance in Question 9*

The analysis of the candidates' responses shows that candidates who scored high marks (34.37%) demonstrated adequate knowledge on the concept of Le Chatelier's principle by giving adequate explanation of principle as well as correct statement of the principle in part (a). Moreover, in part (b) of the question, they clearly explained the ways

through which the rate of production of Z would be increased, showing good understanding on concept of factor affecting position of chemical equilibrium. Extract 9.1 shows a sample of correct responses to question 9 from one of the candidates.

09	
(a)	Le Chatelier's principle states that:
	"When a system at equilibrium is subjected to change (stress), the system readjusts itself to minimize/counteract the effect of stress."
	• More Explanation:
	- This principle applies to any closed system of reversible reactions at equilibrium level in which if any changes are brought to it such as increase or decrease of pressure, temperature and concentration the equilibrium position shifts to the left or right depending on the effect so that the equilibrium position is maintained.

09	
(b)	
	→ Given chemical equation:
	$X(g) + Y(g) \rightleftharpoons Z(g) \quad \Delta H = +ve \text{ kJ mol}^{-1}$
	→ In order to increase the yield of product Z the equilibrium position has to be shifted to the right direction. The following are these technical ways.
	i) Increasing the temperature in the system. Due to positive enthalpy change the forward reaction is an endothermic reaction so it requires more heat energy from the surrounding to produce more 'Z(g)'. Hence by rising the initial temperature the equilibrium position shifts to the right thus increasing the production of Z.
	ii) Increasing the pressure in the system. The reactant (left hand) side has more moles of gases (which is 2) than the product side (has 1) hence by increasing pressure it will favour the side producing fewer moles of gases.
	iii) Increasing the concentration of X or Y reactants. By increasing the concentration of either of the two reactants the equilibrium position shifts to the right side thus favouring the production of product Z.
	iv) Decreasing the concentration of product Z (collecting the product product Z). The company may decide to remove the collected product Z after some time so that there is shortage in the product side thus favouring the forward reaction. This will further the yield of product Z than before.

Extract 9.1: A sample of correct responses to question 9

In extract 9.1, the candidate provided correct responses for all parts of the question by explaining Le Chatelier's principle in relation to the high production of the product. All the factors affecting the position of equilibrium are also explained.

On the other hand, candidates who scored low marks (38.02%) failed to explain Le Chatelier's principle. Instead, they merely stated the principle

without providing explanation. This indicates misinterpretation of the question, particularly the requirement in part (a). In part (b) the candidates failed to explain the techniques /ways to maximize the production of Z such as increasing pressure, temperature and concentration of reactants, demonstrating inadequate knowledge of the factors affecting chemical equilibrium in relation to industrial production of the given product. Some candidates mistakenly explained or discussed factors affecting the rate of reaction rather than equilibrium. For example, one candidate wrote that increasing surface area increases the production of Z, while another stated that nature of solvent increase production of Z. Other candidates explained factors affecting equilibrium but not in relation to high production of product Z. For example, one candidate wrote that *increase in concentration of Z increases rate of reaction*. Another candidate wrote *decrease in pressure*, which will favour decomposition of the product Z instead of producing it. Extract 9.2 shows a sample of incorrect responses in question 9.

9.	le chateliers principle : stated that the amount of reactant was the equal to amount of product produced. Example: $2B + 2C \rightarrow 2BC$
(b)	These are the chemical ways through achieve the high yields
	(i) Concentration
	(ii) Pressure
	(iii) catalyst
	(iv) Temperature.

Extract 9.2: A sample of incorrect responses to question 9

In Extract 9.2, the candidate gave incorrect responses in all parts of the question. In part (a), he/she failed to explain Le Chatelier's principle. Also, in part (b), the candidate failed to identify and explain the factors which would increase rate of production of the product Z.

2.1.10 Question 10: Organic Chemistry

In this question, the candidates were required to describe the chemical properties of ethanol with respect to each of the following treatments:

- (a) Combustion in air.
- (b) Reaction with sodium metal.
- (c) Reaction with concentrated sulphuric acid at 170 °C.
- (d) Oxidation by acidified potassium dichromate (VI).
- (e) Reaction with ethanoic acid.

A total of 70,002 candidates representing 39.32 per cent attempted this question. Analysis of the candidates' performance indicates that 72.92 per cent scored from 0 to 4 marks 12.99 per cent scored from 4.5 to 9.5 marks, and 14.09 per cent scored from 10 to 15. Overall performance was weak as only 27.08 per cent of the candidates scored 4.5 marks or above. This was the most difficulty item as 60.68 per cent avoided it, and it was the least performed. Figure 10 summarizes the candidates' performance on question 10.

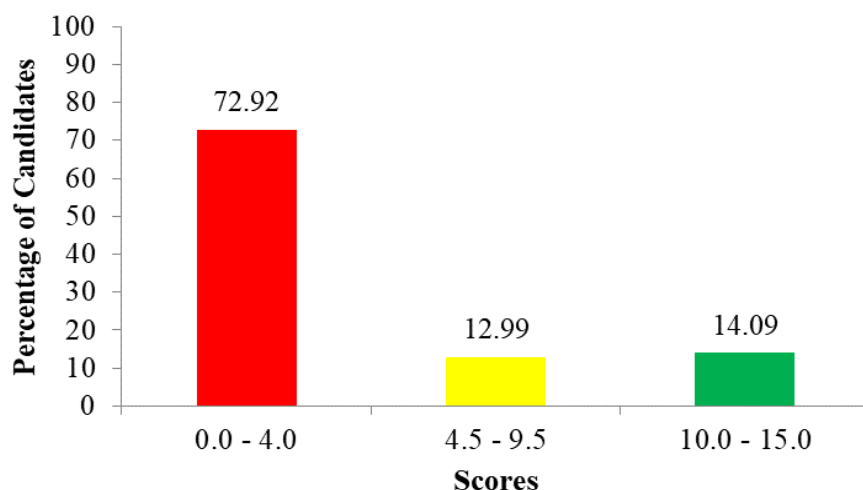


Figure 10: *Candidates' Performance in Question 10*

Candidates who scored low marks (72.92%) gave responses which demonstrated lack of understanding of the properties of alcohol. They failed to give correct description of the reactions of ethanol and given reagents under the respective conditions. Some of the candidates did not realize the formula of ethanol. For example, one candidate wrote the formula of ethanol as CH_3OH , while another wrote ethanol as CH_3-O-CH_3 . In part (a), some candidates simply combined O atom to ethanol as combustion reaction, $CH_3CH_2OH + O_2 \rightarrow CH_3CH_2OHO$. In part (b),

these candidates did not know that sodium metal displaces hydrogen atom from ethanol, thus gave incorrect equation, $\text{CH}_3\text{CH}_2\text{OH} + \text{Na} \rightarrow \text{CH}_3\text{CH}_2\text{Na} + \text{OH}$. Another candidate wrote the equation as $\text{CH}_3\text{CH}_2\text{OH} + \text{Na} \rightarrow \text{CH}_3\text{CH}_2\text{NaOH}$. In part (c), the candidates were not knowledgeable on the dehydration property of concentrated sulphuric acid which converts ethanol to ethene at the given condition of temperature. Some of the candidates suggested the reaction produces ethane instead of ethene. For example, one candidate wrote. $\text{CH}_3\text{CH}_2\text{OH} \xrightarrow{\text{conc H}_2\text{SO}_4} \text{CH}_3\text{CH}_3 + \text{H}_2\text{O}$. The candidates also had no knowledge of the oxidizing property of potassium dichromate. They failed to obtain correct oxidation reaction to give an acid as part (d) of the question demands. In part (e), the reaction is esterification. The candidates failed to give correct description of the reaction, *alcohol + acid* $\rightarrow$ *ester + water*. Some of the candidates wrote incorrect formula of the ester produced during the reaction. For example, one candidate wrote $\text{CH}_3\text{CH}_2\text{COOCH}_3$ instead of $\text{CH}_3\text{COOCH}_2\text{CH}_3$. Another candidate wrote incorrect reaction equation as $\text{CH}_3\text{CH}_2\text{OH} + \text{CH}_3\text{COOH} \xrightarrow{\text{H}^+} \text{CH}_3\text{CH}_2\text{COHCOOH}$. Extract 10.1 shows a sample of incorrect responses from one of the candidates in question10.

10 i/	Combustion in air
	$C_2H_5OH + O_2 \rightarrow H_2CO_4$
	$O_2 + C_2H_5OH \rightarrow H_2CO_4$
	$\therefore$ The chemical properties is H_2CO_4
ii/	Sodium metal
	Soluble
	$NaOH + C_2H_5OH \rightarrow Na_2C_2H_5O$
	$\therefore$ The chemical properties is $Na_2C_2H_5O$
iii/	Concentrated sulphur acid at $170^\circ C$
	Soluble
	$Conc\ H_2SO_4 \xrightarrow{170^\circ C} C_2H_5OH \rightarrow$
	$6H_2O + H_2C_2S_4$
	$\therefore 6H_2O + H_2C_2S_4$
iv/	Potassium dichromate (VII)
	Soluble
	$K_2Cr_2O_7 + C_2H_5OH \rightarrow K_2Cr_2O_7 + H_2C_2$
v/	Ethanoic acid
	$CH_3COOH + C_2H_5OH \rightarrow CH_3CH_2COOH + H_2O$

Extract 10.1: A sample of incorrect responses to question 10

In Extract 10.1, the candidate gave incorrect descriptions in all parts of the question. The formulas of the organic compounds as well as the equations of their reactions, are all incorrect.

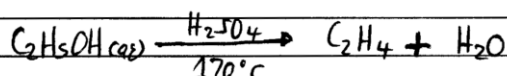
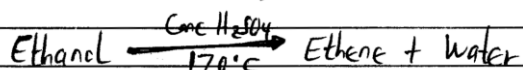
On the other hand, candidates who scored high marks (14.09%) demonstrated an adequate understanding of the chemical reactions of ethanol by providing correct description of its reactions with the respective chemicals given in parts (a) to (e). These candidates gave correct explanations as well as balanced chemical equations. They were knowledgeable about the necessary conditions for reactions of alcohol and therefore identified the correct products in all the reactions. Extract 10.2 shows a sample of correct responses from one of the candidates in question 10.

10	
(a)	Combustion of ethanol in air
	- Just like other hydrocarbons ethanol burns in the presence of air (oxygen gas) to produce carbon dioxide gas and water vapour as its products.
	- The following balanced chemical equation shows the reaction process.
	$\text{Ethanol} + \text{Oxygen gas} \longrightarrow \text{Carbon dioxide gas} + \text{Water vapour}$
	$\text{C}_2\text{H}_5\text{OH}_{(l)} + 3\text{O}_{2(g)} \longrightarrow 2\text{CO}_{2(g)} + 3\text{H}_2\text{O}_{(g)}$
(b)	Reaction of ethanol with sodium metal
	- Ethanol reacts when in contact with sodium metal to produce sodium ethanoate and hydrogen gas.
	- The reacting vessel shows formation of bubbles which are the hydrogen gas produced.
	- The following balanced equation shows the reaction process.
	$\text{Ethanol} + \text{sodium} \longrightarrow \text{sodium ethanoate} + \text{Hydrogen gas}$
	$2\text{C}_2\text{H}_5\text{OH}_{(l)} + 2\text{Na}_{(s)} \longrightarrow 2\text{C}_2\text{H}_5\text{ONa}_{(aq)} + \text{H}_{2(g)}$

10

- (c) Reaction of ethanol with concentrated sulphuric acid at 170°C
- When ethanol reacts in this condition it dehydrates to produce ethene and water. The concentrated sulphuric acid draws water molecules in ethanol and that high temperature maintains a dehydration process.

- The following reaction equations show the process.

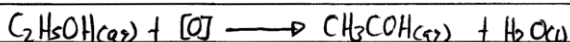
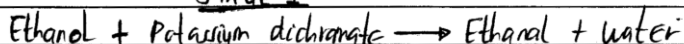


- (d) Oxidation of ethanol by acidified potassium dichromate(VI)

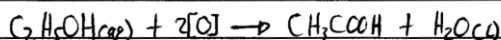
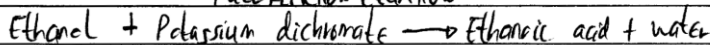
- Oxidation of ethanol by acidified $\text{K}_2\text{Cr}_2\text{O}_7$ takes place in two stages.
- The first stage produces an intermediate compound called ethanal which is an aldehyde and water.
- The second stage involves oxidation of ethanal to produce ethanoic acid and water.

- The following equations show the formation of ethanal and complete formation of ethanoic acid.

STAGE I



FULL REACTION EQUATION



10	
(e)	Reaction of ethanol with ethanoic acid
	- This is <u>esterification</u> reaction whereby when ethanol and ethanoic acid react they produce sweet smelling compounds called <u>esters</u> that are highly used in making fragrances.
	- The reaction leads to production of ethyl ethanoate and water, in the presence of sulphuric acid.
	- The following equation(s) show the reaction process.
	Ethanol + Ethanoic acid $\xrightarrow{\text{conc. H}_2\text{SO}_4}$ Ethyl ethanoate + water
	$\text{CH}_3\text{CH}_2\text{OH}_{(\text{aq})} + \text{CH}_3\text{COOH}_{(\text{aq})} \xrightarrow{\text{conc. H}_2\text{SO}_4} \text{CH}_3\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O}_{(\text{w})}$

Extract 10.2: A sample of correct responses to question 10

In extract 10.2, the candidate gave correct descriptions of all the required chemical reactions of ethanol based on all the conditions given.

2.1.11 Question 11: Non-metals and Their Compounds

The question consisted of parts (a) to (d) and were framed as follows:

A certain person who has no background in Chemistry is interested to invest in extraction of sulphur. How can you guide the investor to extract the sulphur based on the following points?

- The equipment needed for the extraction. Support your answer with a well-drawn diagram.*
- The process involved during extraction.*
- Conversion of rhombic sulphur to monoclinic sulphur.*
- Two commercial uses of sulphur.*

A total of 143,582 candidates attempted this question. Analysis of the candidates' performance indicates that 55.56 per cent scored from 0 to 4 marks, 29.65 per cent scored from 4.5 to 9.5 marks, and 14.79 per cent scored from 10 to 15 marks. Overall performance of candidates was average, with 44.44 per cent scoring 4.5 marks or above. Figure 11 summarises the candidates' performance in question 11.

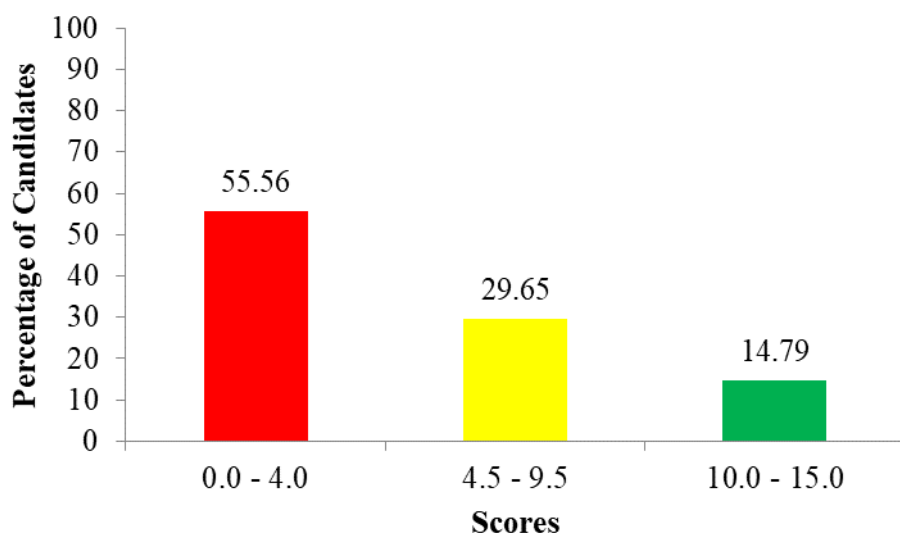


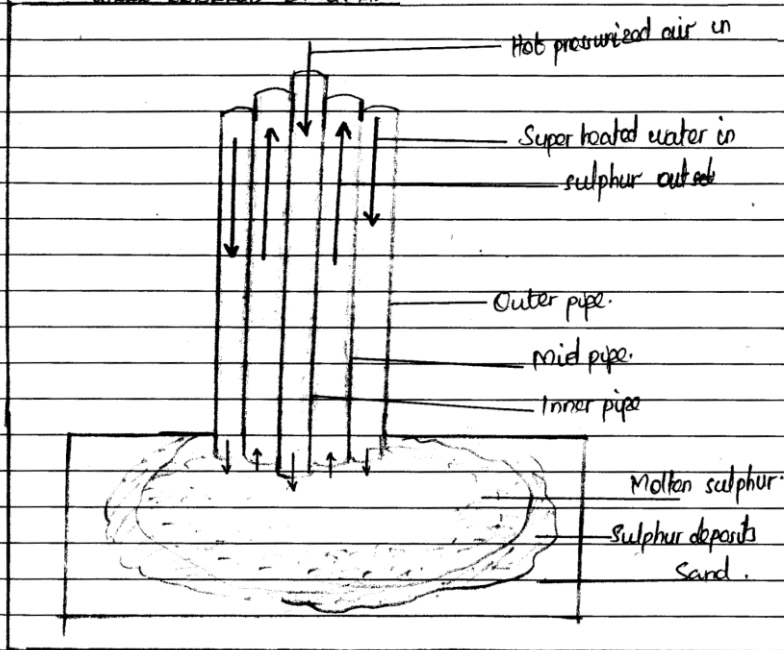
Figure 11: *Candidates' Performance in Question 11*

Candidates who scored high marks (14.79%) gave correct explanation of the equipment required for the extraction of sulphur as well as well labelled diagram showing concentric pipes. This demonstrated a good mastery of the extraction of sulphur using Frasch process as required in parts (a) and (b) of the question. In part (c), the candidates showed good understanding of the allotropic forms of sulphur and their interconversion at transition temperature. They also stated the correct use of sulphur as per the requirement in part (d). Extract 11.1 shows a sample of correct responses from one of the candidates in question11.

11

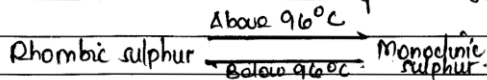
a/ The equipment needed in the extraction of sulphur is a Frasch equipment (concentric pipes)

A WELL LABELED DIAGRAM OF FRASCH EQUIPMENT



b/ The process involved during extraction is Frasch process which involves the entering of superheated water in the outer pipe followed by hot pressurized air through the inner pipe and the collecting the molten sulphur and water through the middle pipe.

c/ Rhombic sulphur can be converted to monoclinic sulphur when it is heated above 96°C the rhombic sulphur changes to monoclinic sulphur.



d/ i/ It is used in production of medicine

ii/ It is used in industries for production of rubber

Extract 11.1. A sample of correct responses to question 11

In extract 11.1, the candidate has given correct responses in all parts of the question including well drawn labelled diagram of the Frasch process.

However, candidates who scored low marks (55.56%) had inadequate knowledge on the concept of Frasch process used for the extraction of sulphur. They gave incorrect responses in most parts of the question. In part (a), some candidates identified incorrect equipment. For example, one candidate mentioned a blast furnace, while another stated that “sulphur extracted from electrolytic cell”. Additionally, some candidates failed to draw the correct diagram showing the concentric pipes involved in the process and did not label them appropriately. . In part (b), some candidates failed to explain roles of inner, outer and middle pipes in the process involved during extraction of sulphur. For example, one candidate wrote the froth is forced to the earth surface through inner pipe instead of middle pipe. Another candidate stated that hot water is forced down through the middle pipe instead of inner pipe. In part (c), some candidates failed to write the correct transition temperature (96°C). For example, one candidate wrote that rhombic sulphur is converted to monoclinic sulphur at 94°C , while another wrote that the conversion occur below 80°C . In part (d), some candidates wrote incorrect uses of sulphur. For example, one candidate wrote that sulphur is used to make soft drinks, while another stated that sulphur is used in production of hydrochloric acid. Extract 11.2 shows a sample of incorrect responses from one of the candidates in question11.

11	a
(b)	Process of extraction sulphur Crushing and grinding - This is the process of divide the large particle of iron contain sulphur into small particles. ii Concentration. - This is the process of filter the particles of sulphur due to using the dressing. iii Calcination - This is the process of extracting the sulphur by using the calcination. iv Reduction of metal oxide. - The reduction of metal oxide is the process of extracting the sulphur.
11	(c)
$S + H_2O \rightarrow H_2S$	
(d) Uses of sulphur.	
i The sulphur is used to create the ornaments	
ii used to coloring the metal	

Extract 11.2: A sample of incorrect responses to question 11

In Extract 11.2, the candidate gave incorrect descriptions in all parts of the question. The concentric pipes were not correctly labeled and the Frasch process was not described, instead, the candidate described the Down Cell (extraction of sodium). Furthermore, both the equations given as well as the uses of sulphur were incorrect.

2.2 032/2 CHEMISTRY 2 (PRACTICALS)

This paper had three alternative papers: 032/2A Chemistry 2A, 032/2B Chemistry 2B, and 032/2C Chemistry 2C. Each paper consisted of two questions, weighing 25 marks each. Question 1 was on Volumetric Analysis, while question 2 was on Qualitative Analysis.

2.2.1 Question 1: Volumetric Analysis

The question was attempted by 177,940 candidates attempted the question. The analysis indicates that 7.69 per cent of the candidates scored from 0 to 7 marks, 32.22 per cent scored from 7.5 to 16.5 marks, and 60.09 per cent scored from 16.5 to 25 marks. The candidates' performance in this question was generally good as 92.31 per cent scored 7.5 marks or above. The summary of the performance is shown in Figure 15.

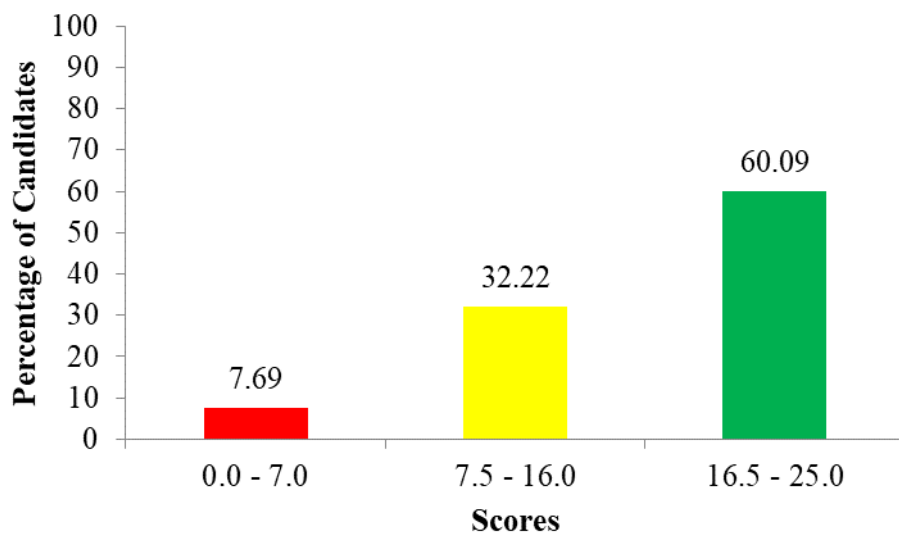


Figure 15: *Candidates' Performance in Question 1*

2.2.1.1 Alternative 2A

The question was as follows:

You are required to conduct an experiment involving a monovalent metal carbonate solution D. This solution is made by dissolving 3.45 g of the metal carbonate in distilled water to make 250 cm³ solution. To analyse the carbonate content, you will perform a titration using solution N, which contains 1.46 g of hydrochloric acid per 0.2 dm³ of solution. Additionally, you are provided with a methyl orange (MO) indicator. Follow the outlined procedure and answer the questions based on your observation and calculations.

Procedure

- (i) *Pour solution N into the burette.*
- (ii) *Pipette 25 cm³ or 20 cm³ of D and transfer into conical flask.*
- (iii) *Add 2 to 3 drops of MO indicator into the flask and titrate the resulting mixture with N until colour change.*
- (iv) *Repeat procedure (ii) and (iii) three more times and record your results in tabular form.*

Questions

- (a) *What is the colour change of the reaction?*
- (b) *What volume of the acid required for complete reaction with the carbonate?*
- (c) *Identify the type of reaction in this experiment.*
- (d) *Write a balanced chemical equation for the reaction between D and N.*
- (e) *Calculate;*
 - (i) *the molarity of N.*
 - (ii) *the molarity of D.*
 - (iii) *the molecular weight of the carbonate.*
 - (iv) *the atomic mass of the monovalent metal in the carbonate.*
- (f) *Write the ionic symbol for the metal in D.*

The analysis indicates that the candidates who scored high marks completed the table of results correctly, using two decimal places and ensuring appropriate data accuracy. Also, they followed the titration procedures correctly to obtain correct burette readings by spotting colour

change at end point of the reaction and recorded the correct volume of acid used as required in part (a) and (b). Moreover, the candidates identified the type of reaction and wrote a well-balanced chemical equation for the reaction between metal carbonate and hydrochloric acid as required in part (c) and (d). This indicates good understanding of neutralisation reactions. In part (e), the candidates used correct formulas to calculate the molarities of acid and metal carbonate, indicating their sufficient skills of manipulation of units in the mole concept. Furthermore, the candidates correctly determined the molecular mass of the metal carbonate and hence atomic mass of the monovalent metal in the carbonate. Finally, in part (f), the candidate identified correctly the unknown metal and wrote its ionic symbol in the metal carbonate demonstrating high understanding of the concept of chemical equation and volumetric analysis.

Generally, these candidates were well-acquainted with the concepts of volumetric apparatus and mole concept manipulations. Extract 12.1 shows a sample of correct responses in question 1, alternative 2A.

Qn 01 a, The Colour change in the reaction is that when Methyl orange (MO) was added to the base, the whole mixture become YELLOW.

→ Then the Colour changed from YELLOW to RED when acid was titrated and when the reaction had completed.

b. TABLE OF RESULTS.

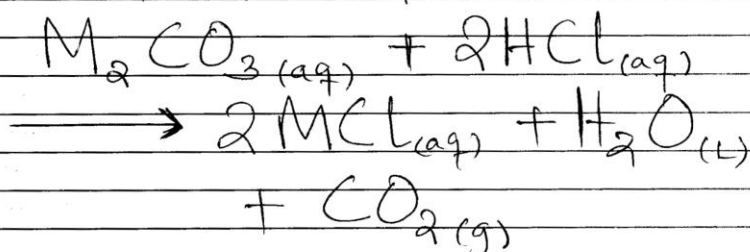
Experiment	PILOT	1	2	3
Final burette reading (cm ³)	<u>25.00</u>	<u>50.00</u>	<u>25.00</u>	<u>50.00</u>
Initial burette reading (cm ³)	<u>0.00</u>	<u>25.00</u>	<u>0.00</u>	<u>25.00</u>
Volume of acid used / Titre Value (cm ³)	<u>25.00</u>	<u>25.00</u>	<u>25.00</u>	<u>25.00</u>

Then

$$\text{Average Titre Volume (cm}^3\text{)} = \frac{V_1 + V_2 + V_3}{3}$$

Qn 01	b;	$\frac{\text{Average titre}}{\text{Volume (cm}^3\text{)}} = \frac{(25.00 + 25.00 + 25.00)}{3} \text{ cm}^3$
		$\frac{\text{Average titre}}{\text{Volume (cm}^3\text{)}} = \frac{75.00}{3} \text{ cm}^3$
		$\frac{\text{Average titre}}{\text{Volume (cm}^3\text{)}} = 25.00 \text{ cm}^3$
		$\therefore 25.00 \text{ cm}^3$ of the Acid was required for complete reaction with the Carbonate
Qn 01	c;	The type of reaction in this experiment is <u>NEUTRALIZATION REACTION</u> .
		Because; It involves the reaction between an acid and a base.
Qn 01	d;	Since
	D $\rightarrow$	Monovalent Metal Carbonate (M_2CO_3)
	N $\rightarrow$	Hydrochloric Acid (HCl)

Ans 1 then Balanced chemical reaction between D and N is



Ans 1 e; To Calculate:

① Solution.

As calculated before.

$$\text{Mass of HCl (m)} = 1.46\text{g}$$

$$\text{Unit Volume of a solution (V)} = 0.2\text{ dm}^3$$

$$\text{Molar mass of the Acid (HCl)} = 36.5\text{ g/mol}$$

then

$$\text{Molality} = \frac{\text{Concentration of acid of acid}}{\text{Molar mass of acid}}$$

But

$$\text{Concentration of an acid} = \frac{\text{Mass dissolved}}{\text{Unit Volume}}$$

Q₁₁

e,

then

$$\text{Molarity of an acid} = \frac{(\text{Mass dissolved})}{(\text{unit Volume})}$$

Molar mass of HCl

$$M_A = \frac{(1.46 \text{ g} / 0.2 \text{ dm}^3)}{36.5 \text{ g/mol}}$$

$$M_A = 0.2 \text{ M.}$$

$$\therefore \underline{\text{Molarity of N is } 0.2 \text{ M.}}$$

⑪ Molarity of D.

Solution.

Data Provided.

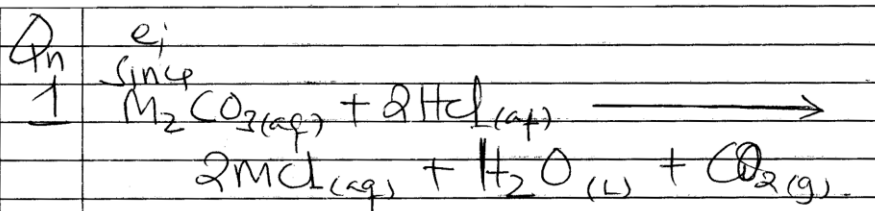
$$M_A = 0.2 \text{ M} \quad V_A = 25.00 \text{ cm}^3$$

$$M_B = ? \quad V_B = 25.00 \text{ cm}^3$$

From; the Above balanced chemical equation.

$$n_A = 2$$

$$n_B = 1$$



Then;
From Molar ratio

$$\frac{n_A}{n_B} = \frac{M_A V_A}{M_B V_B}$$

$$\frac{2}{1} = \frac{0.2 M \times 25.00 \text{ cm}^3}{M_B \times 25.00 \text{ cm}^3}$$

$$\frac{2}{1} = \frac{0.2 M \times 25.00 \text{ cm}^3}{M_B \times 25.00 \text{ cm}^3}$$

$$M_B = \frac{0.2 M \times 25.00 \text{ cm}^3}{2 \times 25.00 \text{ cm}^3}$$

$$M_B = 0.1 M.$$

Molarity of D is

$$\underline{0.1 M}$$

Qn
1

c
iii

Solution.

from.

$$\text{Molar Mass of Carbonate} = \frac{\text{Concentration of Carbonate}}{\text{Molarity of Carbonate}}$$

$$M_r = \frac{13.8 \text{ g/dm}^3}{0.1 \text{ M}}$$

$$M_r = 138 \text{ g/mol}$$

$\therefore$ Molecular Weight of the Carbonate = 138 g/mol.

iv

Solution.

Since

$$M_2CO_3 = 138 \text{ g/mol}$$

but

$$R \cdot M \cdot M = R \cdot A \cdot M = 138$$

then

$$C = 12 \quad O = 16$$

$$M = ?$$

From

$$M_2CO_3 = 138$$

$$2M + C + 3O = 138$$

	$2M + 12 + (3 \times 16) = 138$
	$2M + 12 + 48 = 138$
	$2M + 60 = 138$
	$2M + 60 - 60 = 138 - 60$
	$2M = 78$
	$M = 78/2$
	$M = 39.$
	<u>$\therefore$ Atomic Mass of Monovalent Metal is 39</u>
Qn 1	f; Ionic Symbol for Metal in D is <u>K^+</u>
	Since: The metal with atomic mass of 39 is <u>potassium (K)</u> .

Extract 12.1: A sample of correct responses to question 1, paper 2A

In extract 12.1, the candidate has given correct responses to all parts of the question, following all the necessary volumetric analysis procedures to identify the metal in the metal carbonate and hence its correct ionic symbol as required by the question.

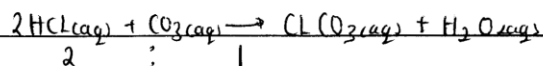
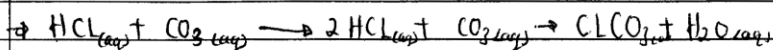
However, candidates who scored low marks (0 - 7) in this question failed to fill the table of results to two decimal places. They also could not determine the correct end point by noting the colour change. Hence, they obtained incorrect titre volumes and colour change resulting in incorrect

title volumes and colour observations as per the requirement in part (a) and (b) of the question. Some candidates wrote the colour change was from *orange* to *yellow*, while others wrote that the indicator changed from yellow to colourless. This shows inadequate knowledge of the theory of indicators and their colour changes at end point of acid – base titration.

In part (c), some candidates wrote incorrect types of reactions. For example, one candidate described it as *an endothermic reaction*, while another called it a *simple combination*. These candidates' responses indicate insufficient knowledge of reaction types. In part (d), some candidates wrote wrong chemical equations with wrong mole ratios. For example, one candidate wrote $M_2CO_3 + HCl \longrightarrow MCl_2 + H_2O$ omitting carbon dioxide among the products and others did not comply or follow the IUPAC rules, writing CO_3 instead of CO_2 . $MCO_3 + HCl \longrightarrow MCl_2 + H_2O + CO_3$. Several candidates failed to balance the chemical equation correctly; For example one candidate wrote $HCl + MCO_3 \longrightarrow MCl + CO_2 + H_2O$. These errors suggest these candidates are unfamiliarity with chemical equations, valence, radicals, and oxidation states. In part (e), The candidates used incorrect formulas in calculating concentrations of reactants, respective molarities and failed to determine the atomic mass of the unknown metal in the metal carbonate. For example, one candidate used the formula $concentration = \frac{mass(g)}{volume(cm^3)}$. The volume used should have been in litres and not cm^3 . Another candidate also used the formula for calculating molarity as $molarity = \frac{molar\ mass}{concentration}$. Also some candidates interchanged the moles of acid and base. They used the formula $M_b = \frac{M_a V_a n_a}{V_b n_b}$ instead of $M_b = \frac{M_a V_a n_b}{V_b n_a}$. The incorrect molarities resulted in an incorrect molecular mass of the metal carbonate and, consequently an incorrect atomic mass of the metal. Extract 12.2 shows a sample of incorrect responses.

1. a) Colour change at the reaction is M.O → orange to yellow				
b) Volume of acid required for complete reaction with the carbonate:				
Burette reading	Pilot	1	2	3
Final reading	24.00	23.05	23.00	45.5
Initial reading	0.00	0.00	0.00	25.0
Volume used	24.00	23.05	23.00	20.5
volume used				
	$\frac{\text{volume 1} + \text{volume 2} + \text{volume 3}}{3}$			
	$V = \frac{V_1 + V_2 + V_3}{3}$			
	$V = \frac{23.05 + 23.00 + 20.5}{3} = \frac{67}{3} \frac{1}{4}$			
	$V = 20.00 \text{ cm}^3 \text{ or } 25.00 \text{ cm}^3$			
	volume of the acid required for complete reaction is 20.00 cm^3			
c) Type of reaction in this experiment:				
	→ <u>Endothermic reaction</u>			

d) Write a balanced chemical equation for the reaction between D and B



e) the molarity of N

$$\text{molarity} = \frac{\text{mass}}{\text{volume}}$$

$$\text{molarity} = \frac{0.2 \text{ dm}^3}{2}$$

$$\text{molarity is } 0.1 \text{ M}$$

∴ molarity of N is 0.1 M

ii) the molarity of D

molarity of D

$$\text{molarity D} = \text{mass} \times \text{volume}$$

	$D = 3.45g$
	Water distilled $250cm^3$
	$M_A V_A = M_B V_B$
	Soln $M_B V_B = M_B$
	<u>Data- given.</u>
	$1mm = 250cm$ $\times 10000$
	$= \frac{250cm^3}{10000} = 0.025$
	$3.45g \times 0.025$ <u>$D = 0.08625cm^3$</u>
	iii) The molecular weight of the carbonate:
	$\frac{mass}{volume}$ $m = \frac{3.45}{1.46} = 2.36$
	$\therefore$ molecular weight carbonate is $2.36g/cm^3$
	iv) The atomic mass of the monovalent metal in the carbonate:
	$H = 1, C = 12, O = 16, Na = 23$

	$2 HCl \cdot xCO_2$
	Soln
	$2y = H \times 1 + 12 + 3 \times 1 + 12 \times (16 \times 3) = 128$
	$2y = 1 + 12 + 3 + 12 + (16 \times 3) = 128$
	$2y = 16 + 12 + 48 = 128$
	$2y = 128$
	$\frac{2y}{2} = \frac{128}{2}$
	$y = 64$
	$\therefore$ atomic mass of the monovalent metal in the carbonate is <u>64</u>

Extract 12.2: A sample of incorrect responses to question 1, paper 2A

In Extract 12.2, the candidate recorded to two decimal places, however some of the recorded data were out of expected range. The candidate calculated the average volume correctly. Furthermore, the candidate wrote incorrect chemical equation resulting in the wrong mole ratio. Moreover, the candidate used incorrect formula to calculate molarities of hydrochloric acid, metal carbonate and concentration of the metal carbonate as well as its molecular mass, which lead to an incorrect atomic mass of the metal in part (e). Furthermore, the candidate failed to identify correctly the unknown metal in the metal carbonate which resulted to incorrect symbol of its ion as required in part (f).

2.2.1.2 Alternative 2B

The question appeared as follows:

*A household sewage discharges 1000 litres of waste water in a day. The waste water also contains an acidic contaminant which releases one hydrogen ion in aqueous solution, hence it requires pretreatments before being released to the environment. The process is done by adding calcium carbonate in the sewage tank. A bottle of filtered waste water labeled **AA** is brought into your school laboratory for analysis. Other substances present in the laboratory include the following solutions:*

BB: 0.1 M sodium hydroxide.

CC: Methyl orange.

Procedure

- (a) Put **AA** into a clean burette.
- (b) Pipette 25 cm³ or 20 cm³ portion of **BB** into a conical flask.
- (c) Titrate the flask content with **AA**, by using **CC** indicator.
- (d) Perform three more titrations and record the results in tabular form.

Questions

- (a) Calculate the volume of waste water that requires 25 cm³ or 20 cm³ of **BB** for complete neutralization.
- (b) What was the colour of the conical flask content at the end point of the reaction?
- (c) Why the first titration is ignored in the calculations?
- (d) Calculate:
 - (i) the concentration of the contaminant in moles/dm³.

- (ii) *the number of moles of hydrogen ions (H^+) present in a single day waste water discharge.*
- (iii) *the mass of calcium carbonate needed to neutralize the whole acid in a single day discharge.*

The candidates who scored high marks (16.5 -25%) were able to calculate the volume of wastewater required for complete neutralization in part (a) and correctly identified the colour change at the end point in part (b). In part (c), they were able to explain why the first titration was excluded from subsequent calculations. For (d), they applied the correct formulas and unit conversions to determine the concentration of the contaminant, number of moles of hydrogen ions, and ultimately, mass of calcium carbonate needed to neutralize the total acid in a day's discharge. This indicates that, these candidates had adequate knowledge of stoichiometry, titration procedures and mole concept to give correct responses in part (d). Extract 13.1 presents a sample of correct responses to question 1 (alternative 2B) from one of the candidates.

1. THE TABLE OF RESULTS:

Experiment:	pilot	1	2	3
Final reading (cm ³):	19.00	18.00	36.00	18.10
Initial reading (cm ³):	0.00	0.00	18.00	0.00
Volume used (cm ³):	19.00	18.00	18.00	18.10

(a) The Volume of waste water (V_a) = ?
from;

$$V_a = V_1 + V_2 + V_3$$

but,

$$V_1 = 18.00 \text{ cm}^3$$

$$V_2 = 18.00 \text{ cm}^3$$

$$V_3 = 18.10 \text{ cm}^3$$

Then,

$$V_a = \frac{18.00 \text{ cm}^3 + 18.00 \text{ cm}^3 + 18.10 \text{ cm}^3}{3}$$

$$V_a = \frac{54.1 \text{ cm}^3}{3}$$

$$V_a = 18.033 \text{ cm}^3 \approx 18 \text{ cm}^3$$

∴ The Volume of waste water that requires 25 cm³ of BB for Complete neutralization is 18 cm³

(b). The Colour of the flask Content at the end point of the reaction is RED COLOUR, because the Colour of the flask Content was changed from yellow colour to red Colour.

1. (C) The first titration is ignored in the Calculations because always Conducted roughly as to attract the attention of a person who do, so as termed as PILOT and is not Experiment one. Therefore first titration is ignored due to its readings that may vary largely from the accurate readings so is ignored in order to escape some errors and to get the accurate readings (volume).

(d). Solution:

Data:

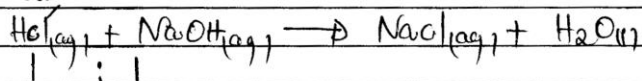
Molarity of NaOH (M_b) = 0.1M

Volume of NaOH (V_b) = 25cm³

Molarity of HCl (M_a) = ? Required

Volume of HCl (V_a) = 18cm³

from the neutralisation chemical equation below



$n_a = 1$ and $n_b = 1$

Then, required?

(i). Molarity (moles/dm³) of the Contaminant (M_a) = ?
from,

$$\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$$

$$M_a = \frac{M_b V_b n_a}{V_a n_b}$$

Then.

1. d) (i) Then,

$$M_a = \frac{0.1 \text{ m} \times 258 \text{ cm}^3 \times 1}{18 \text{ cm}^3 \times 1}$$

$$M_a = \frac{2.58 \text{ m}}{18}$$

$$M_a = 0.13889 \text{ m}$$

$\therefore$ The Concentration of the Contaminant in moles/dm³ is $0.13889 \text{ mol dm}^{-3}$.

(ii). The number of moles (n),
from,

$$\text{Molarity (mol/dm}^3\text{)} = \frac{\text{Number of moles (mol)}}{\text{Volume (dm}^3\text{)}}.$$

but given,

$$\text{Volume} = 1000 \text{ litres} = 1000 \text{ dm}^3$$

$$\text{Molarity} = 0.13889 \text{ mol/dm}^3$$

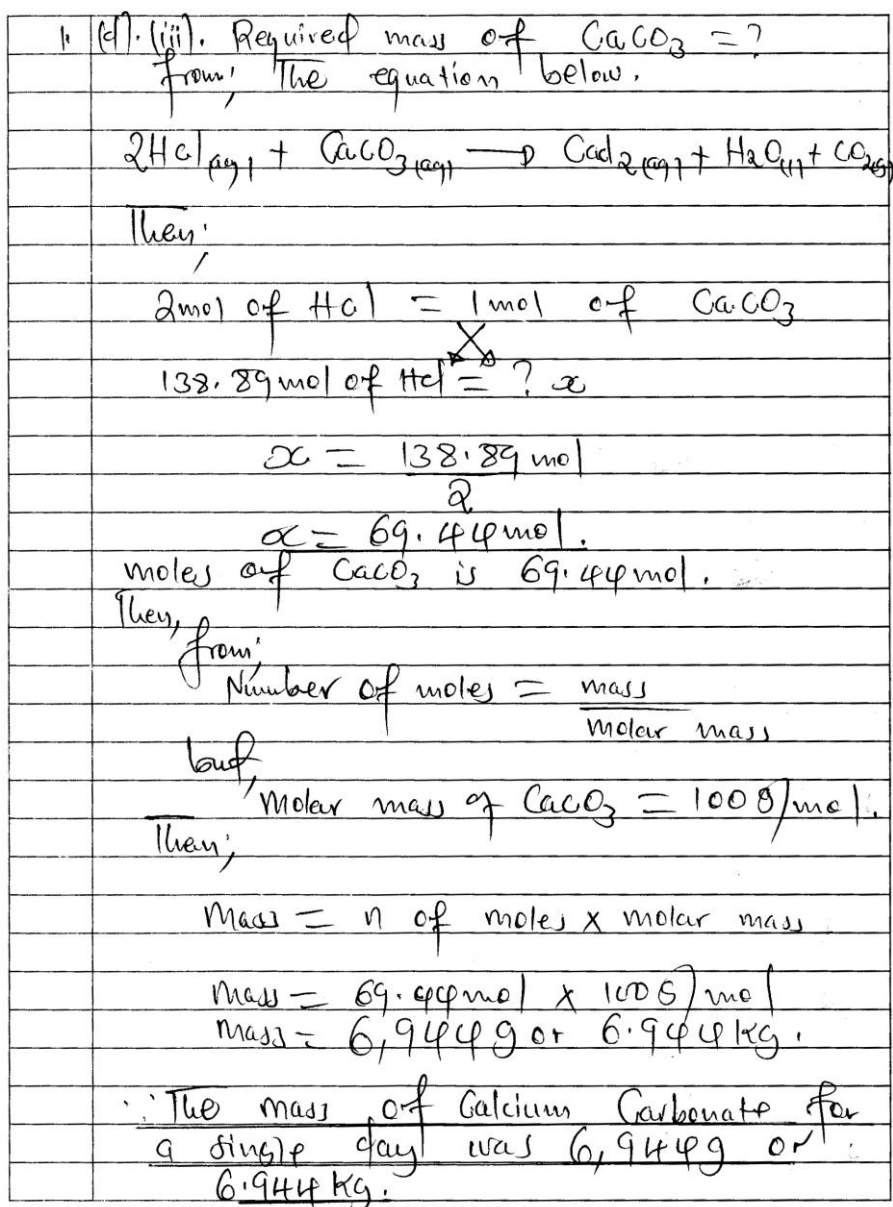
$$\text{Number of moles} = ?$$

Then,

$$0.13889 \text{ mol/dm}^3 = \frac{n}{1000 \text{ dm}^3}$$

$$n = 138.89 \text{ mol}.$$

$\therefore$ The number of moles for single day was 138.89 mol .



Extract 13.1: A sample of correct responses to question 1, paper 2B

In extract 13.1, the candidate filled burette volumes correctly and used the mean titre volume to calculate the mass of CaCO_3 required to neutralize the whole acid for a day's discharge.

In contrast, the candidates who scored low marks (0-7) failed to calculate the volume of wastewater required for complete neutralization in part (a). In part (b), some candidates failed to complete the table of results correctly as they did not record values to two decimal places to ensure the required accuracy. For example, one candidate recorded the volume of acid used as “25.04 cm³” while another recorded it as “25.1 cm³”. Additionally these candidates failed correctly to identify the colour change of the indicator at end point of the titration. For example, one candidate wrote that the colour of the conical flask content at the end point of the reaction was pink, while another candidate wrote the colour change at end point was red. This indicates insufficient competence on the concept of colour change of indicators during titration. In part (c), these candidates were unable to give valid reason for excluding the pilot titration when determining the average volume which leads to incorrect titre values. In part (d), some candidates used incorrect approach to calculate the concentration of the contaminant acid. They applied incorrect formulas and failed to manipulate units appropriately. For example, one candidate used incorrect formula to calculate the concentration of contaminated water in moles per litre as follows:

$$\text{Molarity of acid} = \frac{M_b V_b n_b}{V_a n_a}, \text{ in which the mole ratio of acid and base are}$$

interchanged. The candidates also failed to calculate the correct number of moles of H⁺ ions, and used incorrect mole ratio in determining the moles of CaCO₃ and hence incorrect mass of CaCO₃. Extract 13.2 shows a sample of incorrect responses to question 1 (alternative 2B).

01. table of result				
TITRATION	plot	1	2	3
Final reading	19.70	19.70	21.30	22.50
Initial reading	0.00	0.00	0.00	0.00
total volume reading	19.70	19.70	21.30	22.50
(a) total average $= \frac{V_1 + V_2 + V_3}{3}$ $= \frac{19.70 + 21.30 + 22.50}{3}$ $= 63.5 = 21$				
∴ The total average is 21 cm ³				
b) the color change into yellow and the color formed pink color				

01	Q Because of to get the inferance of the experiment.
	d i)
	Data given
	$v_a = 21.17 \text{ cm}^3$
	$v_b = 25 \text{ cm}^3$
	Waste water = 100L
	$\text{NaOH} + \text{CaCO}_3 \rightarrow$
	$n_a = 1$
	$n_b = 1$
	$M_a = 0.1 \text{ M}$
	$M_b = M_a v_a n_b$
	$v_b n_a$
	$M_b = 0.1$
	$M_b = 0.001$
	Form
	conc in mol/dm^3
	titration
	Number of mole = 0.01
	concentration =
	<u>0.01 mole/dm³</u>
	ii) Number of mole = $\frac{\text{volume}}{\text{Molar Mass}}$
	$\frac{22.4 \text{ dm}^3}{21.17}$
	$= 0.9 \text{ mol}$
	<u>Number of mole = 0.9 mol.</u>
01	d iii) solution
	Form
	$n_1 = \text{Mass}$
	$= \text{Molar M}$
	$= 1 \times 100 \text{ g}$
	Mass of calcium carbonate was
	100g for neutralizing acid.

Extract 13.2: A sample of incorrect responses to question 1, paper 2B

In Extract 13.2, part (a), the candidate failed to calculate the volume of

wastewater for complete neutralization of the base. In part (b), the candidate wrote incorrect colour change of the indicator as *pink*. Also in part (c), the candidate failed to explain why the pilot volume is ignored in calculations. Also, the candidate used incorrect formula of obtaining molarity of acid, number of moles of acid as well as molar mass of CaCO_3 and hence the mass of CaCO_3 as required in part (d).

2.2.1.3 Alternative 2C

The question appeared as follows:

*The rain water at Kitabu village contains an acidic contaminant (H_2A) which releases two hydrogen ions in aqueous solution. Thus, the rain water requires pretreatments before being used for domestic activities. The process is done by adding sodium carbonate in the tank containing rain water. A bottle of filtered rain water labeled **TT** is brought into your school laboratory for analysis. Other substances present in the laboratory include the following solutions:*

LL: 0.08 M Sodium hydroxide.

NN: Phenolphthalein indicator.

Procedure

- (i) Put **TT** into a clean burette.
- (ii) Pipette 25 cm^3 or 20 cm^3 portion of **LL** into a conical flask.
- (iii) Titrate the flask content with **TT**, by using **NN** indicator.
- (iv) Perform three more titrations and record the results in tabular form.

Questions

- (a) Prepare the table of result.
- (b) Calculate the volume of **TT** that requires 25 cm^3 or 20 cm^3 of **LL** for complete neutralization.
- (c) What was the colour of the conical flask content at the end point of the reaction?
- (d) Write the chemical equation for the reaction between **LL** and **TT**.
- (e) Write the ionic equation for the reaction between rain water and sodium carbonate
- (f) Calculate the:
 - (i) concentration of acid contaminant (H_2A) in mol/dm^3 .

- (ii) *mass of sodium carbonate needed to neutralize the whole acid in a full tank whose dimension is 2 meter by 1 meter by 2 meter.*

The candidates who scored high marks (16.5-25%) showed strong competence in filling the table of results correctly, recording volumes to two decimal places as required in part (a). Similarly, in part (b) they correctly calculated the mean titre volume of the acid required for complete neutralization of the base, and accurately identified the end point colour change as colorless. These candidates correctly wrote well-balanced chemical equations for the reaction between sodium hydroxide and dibasic acid (H_2A) in rain water, as well as the ionic equation for the reaction between sodium carbonate and dibasic acid in rain water in parts (d) and (e) respectively. In part (f), candidates applied correct formulas including appropriate unit conversions, to determine the concentration of the acid and the mass of sodium carbonate. Extract 14.1 shows a sample of correct responses to question 1 (alternative 2C).

1 a) Table of result.

Burette reading,	Pilot	1	2	3
Final reading (cm ³)	19.80	19.90	20.00	20.10
Initial reading (cm ³)	00.00	00.00	00.00	00.00
Volume used (cm ³)	19.80	19.90	20.00	20.10

b) Volume of TT.

Soln.

from,

$$V_{TT} = \frac{V_1 + V_2 + V_3}{3}$$

$$V_{TT} = \frac{19.90 \text{ cm}^3 + 20.00 \text{ cm}^3 + 20.10 \text{ cm}^3}{3}$$

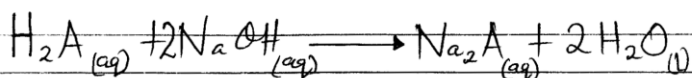
$$V_{TT} = \frac{60.00 \text{ cm}^3}{3}$$

$$\underline{V_{TT} = 20.00 \text{ cm}^3}$$

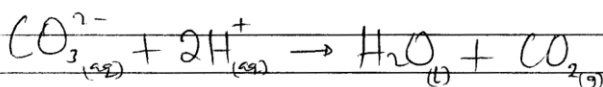
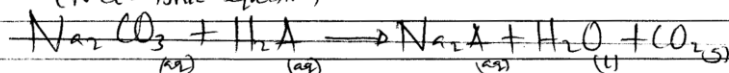
Therefore, the total volume required is 20.00 cm³

01. c) The content in the conical flask at the end point of the reaction was colourless. This is because it changed from pink to colourless.

d) Chemical equation between LL and TT



e) Reaction between rain water and Sodium Carbonate
(Net-ionic equation)



f) i)

Soln.

Data.

$$M_b = 0.08 \text{ M}$$

$$V_b = 25 \text{ cm}^3$$

$$V_a = 20 \text{ cm}^3$$

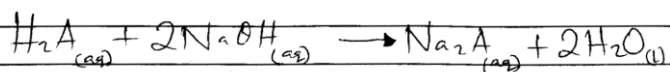
$$M_a = ?$$

from,

$$\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$$

01. f i)

Consider the equation.



$$\text{Ratio} = \text{Acid} : \text{Base}$$

$$1 : 2$$

$$\text{Then } n_a = 1$$

$$n_b = 2$$

Recall,

$$\frac{M_a V_a}{M_b V_b} = \frac{n_a}{n_b}$$

$$\frac{M_a \times 20 \text{ cm}^3}{0.08 \text{ M} \times 25 \text{ cm}^3} = \frac{1}{2}$$

$$M_a = \frac{0.08 \text{ M} \times 25 \text{ cm}^3 \times 1}{20 \text{ cm}^3 \times 2}$$

$$M_a = \frac{2}{40}$$

$$\underline{M_a = 0.05 \text{ M}}$$

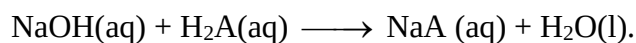
Therefore, the concentration of (H_2A) in mol/dm^3 is 0.05 mol/dm^3

01	f) ii)	Sln.
		Data.
		$M_a = 0.05M$
		$V_a = 20cm^3$, $T.V_a = 4m^3$ or $4,000,000cm^3$
		Required to find mass of Na_2CO_3 .
		from,
		$M = \frac{n}{V}$
		$n = M \times V$
		$n = 0.05M \times 20cm^3$
		$n = 0.05M \times 0.02$
		$n = 1 \times 10^{-3} \text{ mol}$
		then,
		$Na_2CO_{3(aq)} + H_2A_{(aq)} \rightarrow Na_2A_{(aq)} + H_2O_{(l)} + CO_{2(s)}$
		Ratio = Acid : Base
		1 : 1
		$n_b = 0.001 \text{ mol}$
		then
		$n = \frac{m}{M_r}$
		$m = 0.001 \times 106$
		$m = 0.106g$
		Then,
		0.106g was required to $20cm^3$ of acid
		? = $4m^3$ of acid
		$0.106g \rightarrow 20cm^3$
		? y $\leftarrow 4,000,000cm^3$
		$y = \frac{4,000,000 \times 0.106g}{20} = 21,200g$
		<u>Therefore, mass of the Na_2CO_3 needed were 21,200g</u>

Extract 14.1: A sample of correct responses to question 1, paper 2C

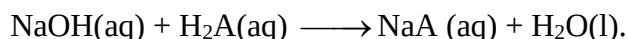
In Extract 14.1 the candidate correctly, recorded data in tabular form with accuracy and determined the average titre value. Moreover, the candidate noted correctly colour change during chemical reaction. Also, he/she used well balanced chemical equations and mole ratio equation for acid-base reaction to calculate molarity of H_2A .

However, some of the candidates who scored low marks(0-7) failed to fill the table of results correctly. For instance, in part (a), one candidate did not record volumes to two decimal places, writing 20.1 cm³ instead of 20.10 cm³. Another candidate recorded an incorrect burette volume of “20.52 cm³” instead of “20.50 cm³”. Another candidate wrote the volume used as –20.10 cm³ by subtracting final volume from the initial volume, instead of the correct order of final volume minus initial volume. In part (b), some candidates calculated the average volume of solution **TT** required to neutralize the base (solution **LL**) incorrectly. For example, one candidate included pilot volume in calculating the average volume. In part (c), some candidates misidentified the end point for titration. For instance, one candidate wrote the end point of the reaction was orange instead of colorless, indicating a lack of skills of using indicators. In part (d) candidates wrote unbalanced chemical equation for the reaction between sodium hydroxide and dibasic acid (H₂A). For example, one candidate wrote the chemical equation



Similarly, in part (e) , some candidates wrote incorrect ionic equation between sodium carbonate and dibasic acid (H₂A), One candidate wrote; $\text{Na}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{A (aq)} \longrightarrow \text{NaOH (aq)} + \text{H}_2\text{O(l)} + \text{CO}_2(\text{g})$. Other candidates wrote balanced ionic equation without including the required state symbols of the ions involved. For example, one candidate wrote the chemical equation; $\text{CO}_3^{2-} + 2\text{H}^+ \longrightarrow \text{CO}_2 + \text{H}_2\text{O}$ instead of $\text{CO}_3^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \longrightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O (l)}$. These errors suggest that candidates had inadequate knowledge on the concepts of oxidation state, chemical equations and procedures of writing ionic equations.

In part (f) (i), some candidates used correct mole ratio formula to calculate molarity of a dibasic acid (H₂A) but relied on unbalanced chemical equation, leading to incorrect mole ratios and, ultimately wrong molarity values. For example, one candidate wrote unbalanced chemical equation as;



This equation shows a mole ratio of 1:1 instead of 2:1 for the balanced one. Other candidates wrote a correct balanced chemical equation but

interchanged volumes of acid and base when applying the mole ratio formula to calculate the molarity of dibasic acid (H₂A). For example, one candidate used a incorrect formula $M_a = \frac{M_b V_a n_a}{V_b n_b}$ instead of

$$M_a = \frac{M_b V_b n_a}{V_a n_b} \text{ to calculate molarity of an acid hence getting wrong}$$

answer. In part (f) (ii) some candidates failed to use the dimensions of the tank to determine its volume, which is equal to the volume of a dibasic acid in the tank. They used the average volume of the acid from titration data instead of 4000 dm³ to determine the number of moles of a dibasic acid which in turn were used to determine the number of moles of sodium carbonate stoichiometrically and hence mass of sodium carbonate. For instance, one candidate used the average volume of an acid which is 20.1 cm³ as the volume of a dibasic acid in the tank instead of 4000 dm³ to determine the mass of sodium carbonate. Also, other candidates correctly calculated the volume of the tank which is equal to the volume of a dibasic acid in the tank using the dimensions of the tank but they failed to convert that volume from m³ to dm³ hence they got a wrong mass of sodium carbonate. For example, one candidate used 4 m³ instead of 4000 dm³ as the volume of a dibasic acid in the tank; hence he/she got a wrong answer. Furthermore, other candidates used correct steps and mathematical equations to calculate the mass of sodium carbonate yet they used wrong chemical species in the chemical equation led them to obtain a wrong answer. For instance, one candidate used sodium bicarbonate instead of sodium carbonate in the chemical reaction with a dibasic acid as; $2\text{NaHCO}_3(\text{aq}) + \text{H}_2\text{A}(\text{aq}) \longrightarrow \text{Na}_2\text{A}(\text{aq}) + 2\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$ instead of the correct equation: $\text{Na}_2\text{CO}_3(\text{aq}) + \text{H}_2\text{A}(\text{aq}) \longrightarrow \text{Na}_2\text{A}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$.

Generally, these candidates demonstrated insufficient knowledge of stoichiometry, neutralization reactions, and the mole concept. Extract 14.2 shows a sample of incorrect responses in this question (alternative 2C).

01.		PILOT	I	II	III
a.	Final reading	25.00	20.4	20.2	20.3
	Initial reading	0.00	0.00	0.00	0.00
	Volume of acid,	25.00	20.4	20.2	20.3
b.	Average volume of II soln.				
	From				
	Average volume = $\frac{V_1 + V_2 + V_3}{3}$				
	$\frac{20.4 + 20.2 + 20.3}{3}$				
	Average volume = 20.3				
	$\therefore \underline{\text{Volume} = 20.3 \text{ cm}^3}$				
c.	Colour was turned to <u>colourless</u> at the end point of the reaction.				
d.	$\text{NaOH}_{(aq)} + \text{H}_2\text{O}_{(aq)} \rightarrow \text{NaOH} + \text{H}_2\text{O}_{(l)} + \text{H}_2(g)$				
e.	$\text{NaCO}_3 + \text{H}_2\text{O} \rightarrow \text{NaO} + \text{H}_2\text{O} + \text{CO}_2$				

F.	To calculate concentration of H_2A in mol/dm^3
I.	Soln.
	$\frac{0.08 \times 25 \times 1}{20}$
	$= 0.1$
	$\therefore \text{concentration} = 0.1 \text{ mol/dm}^3$
II.	Mass required
	Soln.
	Data
	concentration = 0.1
	Volume = $2 \times 2 \times 1 = 4 \rightarrow 0.004 \text{ dm}^3$
	mass = ?
	$\therefore \text{mass required} = ?$
	$m = 8.48 \times 4000 \text{ dm}^3$
	$m = 33920 \text{ g}$
	$\therefore \text{Mass} = 33920 \text{ g}$

Extract 14.2: A sample of incorrect responses to question 1, paper 2C

In Extract 14.2, the candidate failed to fill the table of results due to lack of compliance to the requirement of recording values into two , not taking into consideration two decimal places. They also wrote incorrect chemical equations leading to wrong mole ratios. Furthermore, the use of incorrect chemical formulas resulted in erroneous calculation of molarity of the acid in the rain water as well as the moles of the base. This resulted to incorrect mass of Na_2CO_3 .

2.2.2 Question 2: Qualitative Analysis

The question was attempted by 177,940 candidates. The analysis shows that 5.68 per cent of the candidates scored from 0 to 7 marks, 22.90 per cent scored from 7.5 to 16.5 marks and 71.42 per cent scored from 17 to 25 marks. Overall, the candidates' performance in this question was good because 94.32 per cent scored 7.5 marks or above. A summary of the candidates' performance is presented in Figure 16.

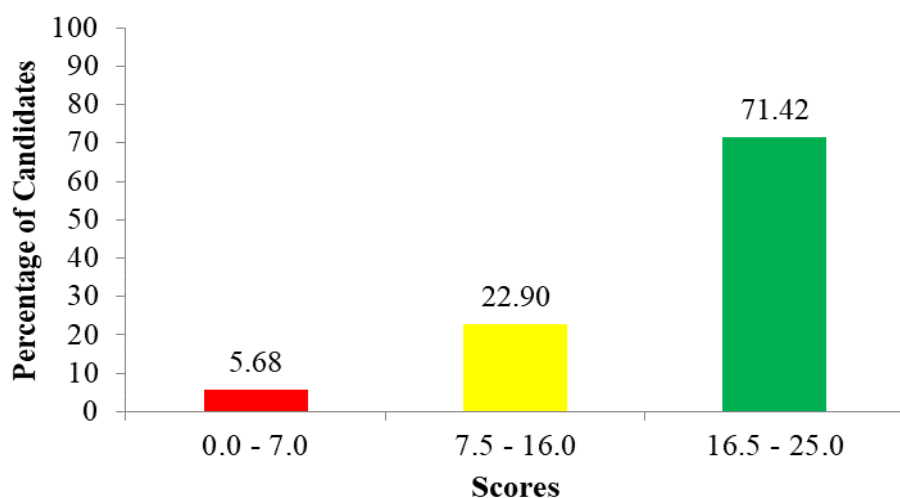


Figure 16: *Candidates' Performance in Question 2*

2.2.2.1 Alternative 2A

The question was structured as follows:

*A cat has been found dead after consuming a certain solid chemical from opened bottle in the laboratory. It is unfortunate that the bottle label was also destroyed by rats and the investigator decided to name the solid residues as sample **T**. Carry out qualitative analysis experiments to identify the ions present in the sample which killed the cat based on the following tests:*

- (i) *Appearance of the sample **T**.*
- (ii) *Action of heat on the sample **T**.*
- (iii) *Solubility of the sample **T**.*
- (iv) *Action of dilute hydrochloric acid on the solid sample **T**.*
- (v) *Action of concentrated sulphuric acid on the solid sample **T**.*
- (vi) *Action of aqueous sodium hydroxide on the solution sample **T**.*
- (vii) *Action of barium chloride on the solution sample **T**.*
- (viii) *Do confirmatory test for the cation and anion.*

Questions

- (a) *Prepare a table showing the qualitative analysis results.*
- (b) *Identify the cation and the anion in the solid.*
- (c) *Write the chemical formula of the solid.*
- (d) *Write a balanced chemical equation for the reaction in experiment (ii).*
- (e) *Write two uses of sample **T** in daily life.*

The analysis indicates that the candidates who scored high marks (16.5 - 25) followed systematic procedures investigating sample **T** starting with preliminary tests, followed by tests in solutions, and finally confirmatory tests. During the preliminary tests, candidates carried all important steps in investigating the solid sample. They realized that observation from the action of heat and appearance of sample could give clues about the cation present in sample **T**. Additionally, the candidates were conversant with action of acids on solid sample to identify the anions present in the sample by observing the gases evolved.

Furthermore, in the second part of experiment (tests in solution) the candidates realized that the action of sodium hydroxide solution on sample solution **T** was to identify the cation present. This was done by observing the reaction between hydroxide ion (OH^-) and the cation without formation of precipitate. In the third part of the experiment (confirmatory tests) the candidates had satisfactory competence on the concept of compounds of metals and non-metals. Finally, the candidates identified correctly the cation as NH_4^+ and anion as Cl^- present in solid sample **T**. Extract 15.1 shows one of the correct responses to question 2 (alternative 2A).

2. TABLE OF RESULT			
	Experiment	Observation	Inference
	i) Appearance of sample T		
	a) Colour	White colour was observed	NH_4^+ , Na^+ , Ca^{2+} , Zn^{2+} , Pb^{2+} may be present or Transition metals Fe^{2+} , Fe^{3+} , Cu^{2+} may be present.
	b) Texture	Crystalline form was observed	NO_3^- , SO_4^{2-} , Cl^- may be present
	ii) Action of heat on sample T was performed. A small amount of solid sample T was transferred in a dry test tube and the content was heated	White sublimate and a colourless gas evolved, which turned moist litmus paper from red to blue	NH_4^+ may be present

2.	Experiment	Observation	Inference
	ii)	Colourless gas evolved which gives dense white fumes with ammonia gas	Cl^- or hydrated Ca^{2+} , Zn^{2+} , Cu^{2+} , Fe^{2+} , Fe^{3+} salts may be present
	iii) A small amount of solid T was transferred in a test tube followed by enough cold water	Soluble forming a colourless solution was observed	Na^+ , NH_4^+ , NO_3^- may be present CO_3^{2-} , HCO_3^- of Na^+ , NH_4^+ may be present $\oplus \text{Cl}^-$ of Zn^{2+} or Ca^{2+} may be present SO_4^{2-} of Zn^{2+} may be present
	iv) A small amount of solid T was transferred in a test tube followed by 3 drops of dilute HCl	No gas evolved	SO_4^{2-} , NO_3^- , Cl^- may be present

2.	Experiment	Observation	Inference
v.	A small amount of solid P was transferred in a dry test tube followed by small amount of concn. treated H_2SO_4 .	Colourless gas with irritating smell evolved which turned moist litmus paper blue to red and formed dense white fumes with ammonia gas.	Cl^- may be present
vi.	A small volume of original sample solution was transferred in a test tube followed by sodium hydroxide solution drop wise until in excess	No precipitate was formed, on warming a colourless gas with a choking smell which turned moist litmus paper from red to blue evolved	NH_4^+ may be present
vii.	A small volume original sample solution was transferred in a test tube followed by BaCl_2 solution then followed by dilute HCl or barium nitrate followed by dilute HNO_3	No white precipitate, insoluble in dilute HCl or dilute HNO_3 was formed	SO_4^{2-} unconfirmed

2.	Experiment	Observation	Inference.
	Viii. Confirmatory test for NH_4^+		
	A small amount of original solid sample I was transferred in a test tube followed by sodium hydroxide, just to cover the whole solid then the content was warmed	Colourless gas evolved which turned moist litmus paper from red to blue	NH_4^+ confirmed.
	Confirmatory test for Cl^-		
	A small volume of original solution sample I was transferred in a test tube, followed by 3 drops of dilute nitric acid followed by 3 drops of silver nitrate solution and then excess ammonia solution was added	White precipitate soluble in excess ammonia solution was formed.	Cl^- confirmed.
2.	b) Cation in the solid was <u>NH_4^+</u>		
	Anion in the solid was <u>Cl^-</u>		

2.	c) Chemical formula of solid T was
	<u>NH_4Cl</u>
	d) $\text{NH}_4\text{Cl} \rightleftharpoons \text{NH}_3(\text{g}) + \text{HCl}(\text{g})$
	e) i) It is used as an acidifier. Ammonia chlorides may be used as an acidifier since it also acidic in nature.
	ii) It is used in dry batteries. Ammonia chlorides may be used as a component of dry battery such as an electrolyte.

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

On contrary, the candidates who scored low marks(0 - 7) failed to identify the cation and the anion present on the solid sample T, demonstrating insufficient competence in applying the general systematic procedures for investigating ions in a given salt sample. Some of these candidates gave incorrect observations and inferences during the preliminary tests. For example, in part (i) of the question, one candidate wrote.

Experiment	Observation	Inference
Appearance • Texture	Powdered	CO_3^{2-} , HCO_3^- may be present

This indicates that these candidates lack sufficient knowledge about the concept of texture. In part (iii), some candidates failed to make clear observations on solubility of the solid sample T. For example, one candidate wrote that;

Experiment	Observation	Inference
(iii) Solubility of the sample T	The sample was insoluble in cold water but dissolved on warming, crystal reappear on cooling	Cl^- of Pb^{2+} may be present.

These candidates failed to comprehend that; all salts of ammonium are soluble in cold water. Also, in part (v), some candidates observed that, no gas was evolved on action of concentrated sulphuric acid on the solid sample **T**. For instance, one candidate wrote that;

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>(v) Action of concentrated sulphuric acid on the solid sample T.</i>	<i>No gas was evolved.</i>	<i>SO_4^{2-} may be present.</i>

These candidates were not aware that, when ammonium chloride reacts with concentrated sulphuric acid, hydrogen chloride gas is evolved which change blue litmus paper to red. Similarly, some candidates wrote incorrect observation about action of sodium hydroxide. For example, one candidate wrote;

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>Dilute NaOH solution was added to the sample solution.</i>	<i>White precipitate dissolved in excess.</i>	<i>Zn^{2+} may be present.</i>

Another candidate wrote:

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>Dilute NaOH solution was added to the sample solution.</i>	<i>White precipitate dissolved insoluble in excess.</i>	<i>Pb^{2+} may be present.</i>

These candidates were not familiar with role of alkali in identifying cations from their solutions. Thus, they failed to recognise that ammonium ions do not form a solid precipitate with hydroxide ion from sodium hydroxide. In the third part (Confirmatory tests), some candidates gave incorrect observations and inferences. For example, one candidate wrote confirmatory test of anion as:

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>Addition of barium chloride to the sample solution</i>	<i>White precipitate observed</i>	<i>SO_4^{2-} confirmed</i>

In part (a) candidates gave incorrect cation and anion present in sample **T**. For instance, one candidate wrote *Cation is Cu^{2+} and anion is SO_4^{2-} .*

Another candidate wrote Ni^{2+} and SO_4^{2-} . These candidates used incorrect appearance of the sample to identify ions without confirming them. Moreover, for the case of anion, they recorded incorrect observation for the reaction between barium chloride and ammonium chloride that is white precipitate formed, without seeing it. Thus, they confirmed SO_4^{2-} . In part (c) some candidates gave incorrect molecular formula of sample T. These candidates wrote NH_3Cl . Another candidate wrote $(\text{NH}_4)^+\text{Cl}^-$. This signifies that, these candidates failed to differentiate ammonia gas and ammonium ion. Likewise, they wrote cation and anion interchangeably. One candidate wrote cation as Cl^- instead of NH_4^+ and anion as NH_4^+ instead of Cl^- . In part (d) some candidates wrote incorrect equation as , $\text{NH}_4\text{Cl} \rightarrow \text{N}_2 + \text{HCl}$, while another candidate wrote $\text{NH}_4\text{Cl} \rightarrow \text{NH}_3 + \text{Cl}_2$. other candidates gave incorrect uses of ammonium chloride in part (e). For instance, one candidate wrote that *ammonium chloride is used as liming material*, while another wrote that *it is used in production of nitrogen gas when heated*. Generally, these candidates had insufficient knowledge and skills in carrying out preliminary tests on unknown samples, testing of solutions and carrying out confirmatory tests for cations and anions as well as uses of different metal compounds. Extract 15.2 shows a sample of incorrect responses to this question (alternative 2A).

Preliminary test:		
2. a)	Experiment	Observation
		Inferences:
i)	Appearance of solid sample	White
		Transition metal Fe^{2+} , Fe^{3+} , Cu^{2+} may be present.
	Texture	powder
		NO_3^- , SO_4^{2-} , Cl^- may be present
	Experiment	Observation
		Inferences:
ii)	Action of heat on the sample T	- Colourless gas evolves which turn lime water milky and moist litmus paper from blue to red
		CO_3^{2-} , HCO_3^- may be present.
	Experiment	Observation
		Inferences
iii)	Solubility of the sample T	

	Experiment	Observation	Inference:
2 ✓	Action of dilute hydrochloric acid on the solid sample T of HCl	- Effervescence of a colourless gas evolves which turns lime water milky and moist litmus paper from blue to red	- CO_3^{2-} or HCO_3^- may be present.
	Experiment	Observation	Inference:
✓	Action of concentrated sulphuric acid on the solid sample T.	- Colourless gas with irritating smell evolves, which turns moist litmus paper from blue to red and forms dense white fumes with ammonia gas	- Cl^- may be present.
	Experiment	Observation	Inference:
✓	Action of aqueous sodium hydroxide on the solution on sample T	- Reddish-brown precipitate is formed, which is insoluble in excess	- Fe^{3+} may be present.

	Experiment	Observation	Inference:
2.	vii) Action of barium chloride on the solution in sample T	- No precipitate is formed	- Ca^{2+} , Na^+ may be present.
	Experiment	Observation	Inference:
viii)	No confirmatory test for the cation and anion.	→ Deep blue precipitate	- Fe^{2+} confirmed
	Confirmatory test for the cation		
	Experiment	Observation	Inference:
	Confirmatory test for the anion	→ White precipitate soluble in excess ammonia solution is formed	- Cl^- confirmed.

b)	Identify the cation and the anion in the solid.
	$\rightarrow \text{Fe}^{3+}\text{Cl}_2 \rightarrow \text{FeCl}_2$
	Cation
	$\rightarrow \text{Fe}^{3+}$
	Anion
	Cl^-
c)	Write the chemical formula of the solid
	$\begin{array}{ccc} \text{Fe}^{3+} & & \text{Cl}^- \\ & \swarrow \quad \searrow & \\ \text{Fe}^{3+} & & \text{Cl} \end{array}$
	$\rightarrow \text{Fe}^{3+}\text{Cl}_2 \rightarrow \text{FeCl}_2$

Extract 15.2: A sample of incorrect responses to question 2, paper 2A

In Extract 15.2 the candidate wrote the correct observation for the colour of the sample as white, but made an incorrect inference in experiment 1. The wrong observations made in most parts of the question led to incorrect inferences throughout. The candidate identified incorrect cation and anion, which resulted in an incorrect formula for the salt in the sample and as a result the candidate failed to write correct equation for the reaction when the sample is heated.

2.2.2.2 Alternative 2B

The question was as follows:

*A pharmaceutical company investigates the composition of a cough medicine which has lost its identity. A pharmacist gives a temporary identity **M**, and brings to your school laboratory for analysis. Follow the procedure given in the table and identify the composition of the medicine and answer the questions that follow:*

S/N	Experiments	Observations	Inferences
(a)	Observe the appearance of sample M .		
(b)	Heat a little amount of sample M in a dry test tube.		
(c)	Transfer a little amount of sample M into a dry test tube and add dilute hydrochloric acid.		
(d)	Transfer a little amount of sample M into a dry test tube and add distilled water. Stir the contents.		
(e)	Transfer a little amount of sample M into a dry test tube and add NaOH solution then warm.		
(f)	Transfer a little amount of a mixture prepared in experiment (d) into a dry test tube and add MgSO ₄ solution.		

Questions

- Identify the ions present in sample **M**.
- Write the molecular formula of the component in the medicine.
- Write the IUPAC name of the component in the medicine.
- Write the balanced chemical equation on what happened in experiment (b).

The candidates who scored high marks (16.5-25) demonstrated a clear understanding the aim of the experiment which was to investigate and identify chemical species present in sample **M**. These candidates followed systematic procedures, starting with preliminary tests, followed by tests in solutions, and ultimately confirmatory tests. During the preliminary tests, they carried out six steps to investigate the solid sample. They correctly interpreted the observations from the action of heat and the appearance of the solid sample as the key or clues for identifying the cation present in sample **M**. Similarly, the candidates

observed the evolution of gases by the action of acids on the solid sample to identify the anions present. Moreover, in the second part of the experiment (tests in solution), the candidates studied the action of sodium hydroxide on sample solution **M** to identify the cation present. This was done by observing the precipitate formed during the reaction between hydroxide ion (OH^-) and cation. In the third part (confirmatory tests), the candidates recorded more scientific evidences and finally correctly identified the cation and anion present in sample **M**. Extract 16.1 shows a sample of correct responses to question 2 (alternative 2B).

Q2.	S/N	Experiments	Observations	Inferences
	(a)	Observe the appearance of sample M		
		i) Colour	White	NH_4^+ , Na^+ , Ca^{2+} , Zn^{2+} , Pb^{2+} may be present
		ii) Texture	Crystalline form	NO_3^- , SO_4^{2-} , Cl^- may be present
		iii) Odour	Chocking smell	NH_4^+ may be present
	(b)	Heat a little amount of sample M in a dry test tube	White sublimate and a colourless gas evolves, which turns moist litmus paper from red to blue	NH_4^+ may be present
			Colourless gas evolves, which turns lime water milky and moist litmus paper from blue to red	CO_3^{2-} , HCO_3^- may be present
	(c)	Transfer a little amount of sample M into a dry test tube and add dilute hydrochloric acid	Effervescence of a colourless gas evolves, which turns lime water milky and moist litmus paper from blue to red	CO_3^{2-} , HCO_3^- may be present

Q2.	S/N	Experiments	Observations	Inference
	(d)	Transfer a little amount of sample M into a dry test tube and add distilled water. Stir the contents	Soluble forming a colourless solution	CO_3^{2-} , HCO_3^- or Na^+ , NH_4^+ may be present
	(e)	Transfer a little amount of sample M in a dry test tube and add NaOH solution then warm	No precipitate is formed on warming, a colourless gas with a choking smell which turns moist litmus paper from red to blue evolves	NH_4^+ confirmed
	(f)	Transfer a little amount of a mixture prepared in experiment (d) into a dry test tube and add MgSO_4 solution	White precipitate is formed before warming the contents	CO_3^{2-} confirmed.

Question

(i) Cation is NH_4^+
Anion is CO_3^{2-}

(ii) Molecular formula is $(\text{NH}_4)_2\text{CO}_3$

(iii) IUPAC name in the medicine is Ammonium carbonate

Extract 16.1: A sample of correct responses to question 2, paper 2B

In extract 16.1, the candidate made correct observations and inferences throughout all experiments, leading to accurate identification of the ions present in the given sample and correct responses to the subsequent questions

However, the candidates who scored low marks failed to identify chemical species present in sample **M**. Some candidates gave incorrect observation and inference in preliminary tests. For instance, in part (a)

candidate wrote.

(i) Texture	Salt Q was powder	NO_3^- , SO_4^{2-} , Cl^- may be present
-------------	--------------------------	---

Another candidate in solubility step wrote,

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>solubility</i>	<i>insoluble in cold water</i>	<i>CO_3^{2-} of Ca^{2+}, Pb^{2+}, Zn^{2+}, Fe^{2+}, Fe^{3+}, Cu^{2+} may be present</i>

This candidate had inadequate knowledge on the concept of solubility.

Another candidate wrote:

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
Small portion of the sample was heated in a dry test tube.	Reddish brown fume observed	NO_3^- may be present.

This candidate was not competent on the concept of decomposition reaction of compounds of metal by action of heat. In second part (Tests in solution) candidates wrongly wrote observations and inferences. Giving an example, one candidate responded;

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>Dilute NaOH solution was added to the sample solution.</i>	<i>Blue precipitate.</i>	<i>Cu^{2+} may be present</i>

In third part (Confirmatory tests) some candidates gave incorrect observations and inferences. For example, one candidate wrote confirmatory test of anion as:

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>Action of magnesium sulphate to the sample solution</i>	<i>No white precipitate, formed when heated</i>	<i>HCO_3^- maybe present</i>

This candidate used the correct chemicals for confirming CO_3^{2-} but wrote incorrect observation and inference. In part (i), some candidates identified incorrect cations and anions. For example, some candidates indicated Pb^{2+} as the cation and HCO_3^- as the anion. In part (b) some candidates wrote names of sample **M** instead of molecular formula. In part (c) some candidates gave wrong IUPAC name such as ammonia

carbonate, calcium carbonate, copper carbonate. These candidates had inadequate knowledge on the concepts of compounds of metal. Generally, the candidates demonstrated unsatisfactory competence in carrying out preliminary tests on unknown sample, test of solutions and confirmatory tests for the cations and anions. Extract 16.2 shows a sample of incorrect responses in this question (alternative 2B).

2	S/N	Experiments	Observations	Inferences
	a.	Observe the appearance of sample M.	Colourless gas evolves which relights glowing pin.	NO_3^- or Na may be present.
	b.	Heat a little amount of sample M in a dry test tube	Reddish-brown precipitate is formed which is insoluble in excess.	Fe^{3+} may be present.
	c.	Transfer a little amount of sample M into a dry test tube and add dilute hydrochloric acid.	Effervescence of a colourless gas evolves, which turns lime water milky and moist litmus paper from blue to red.	CO_3^{2-} , HCO_3^- may be present.
	d.	Transfer a little amount of sample M into a dry test tube and add distilled water. Stir the contents.	White sublimate and a colourless gas evolves, which turns moist litmus paper from red to blue.	NH_4^+ may be present.

s/n	Experiment	Observation	Inference.
e.	Transfer a little amount of sample M into a dry test tube and add NaOH solution then warm.	white precipitate is formed soluble in excess Blue precipitate is formed insoluble in excess.	Zn^{2+} Pb^{2+} may be present
f.	Transfer a little amount of a mixture prepared in experiment (d) into a dry test tube and add $MgSO_4$ solution.	soluble forming a colourless solution	Cl^- or Zn^{2+} or Ca^{2+} may be present.
2	Questions.		
i,	Anion - CO_3		
	Cation - NH_4^+		
2	ii NH_4^+ CO_3^-		
	NH_4CO_3		
	iii, Ammonium Carbonate		
2	$ \begin{array}{ccccccc} \frac{1}{2} (NH_4)_2CO_3 & + & O_2 & \xrightarrow{\Delta} & 2NH_4OH & + & CO_2 \\ (aq) & & (g) & & (aq) & & (g) \end{array} $		

Extract 16.2: A sample of incorrect responses to question 2, paper 2B

In Extract 16.2, the candidate wrote incorrect observations and inferences in several parts of experiment. Additionally, during the preliminary

stage, the candidate wrote colourless gas which relights a glowing splint, instead of writing the actual colour and texture of the sample. Moreover, the wrong observations made in most parts of the experiments, resulted to incorrect identification of the ions. The candidate also failed to write correct formulas of the ions, hence incorrect equations of reaction.

2.2.2.3 Alternative 2C

The question was as follows:

The school laboratory has a bottle containing an unknown salt labeled Q. Carry out a qualitative analysis experiment to identify salt Q present in a container by following the procedures in the following table and then answer the given questions.

S/N	Experiments	Observations	Inferences
(a)	Observe appearance of Q		
(b)	Transfer a little amount of Q in a clean and dry test tube then heat it gently.		
(c)	Transfer a little amount of Q in a clean and dry test tube then add few drops of concentrated H_2SO_4 , followed by warming the content.		
(d)	Transfer about 1 g of Q in a test-tube and add distilled water. Stir the contents and divide the obtained mixture into four similar portions in different test tubes.		
	(i) To the first portion add aqueous ammonia drop-wise, then in excess.		
	(ii) To the second portion add NaOH drop-wise, then in excess.		
	(iii) To the third portion add potassium hexacyanoferrate(II) solution.		
	(iv) To the fourth portion add dilute HCl followed by $BaCl_2$.		

Questions

- (i) Identify the cation and anion present in salt sample Q.*
- (ii) Write the molecular formula of Q.*
- (iii) Give a name of the salt sample Q.*
- (iv) Write a net ionic equation of the reaction that took place in experiment (d) (ii).*

Candidates who scored high marks (16.5-25) had an understanding of the aim of experiment, which was to investigate and identify chemical species present in sample **Q**. These candidates followed systematic procedures, starting with preliminary tests, followed by tests in solutions and finally confirmatory tests.

In the preliminary tests, the candidates carried out six steps involved in examining the solid sample. These candidates were proficient in all steps to be carried in investigating a solid sample. They realized that the action of heat and appearance of solid sample would give observations which indicate the chance of identifying a cation present in sample **Q**. Additionally, the candidates were knowledgeable that the action of acids on solid sample was intended to identify the anions present in the sample through observing the gases evolved. In the second part of experiment (tests in solution) the candidates recognized that the action of sodium hydroxide on sample solution **Q** was to identify the cation present. This was achieved by observing the precipitate formed during the reaction of hydroxide ion (OH^-) with the cation. In the third part of the experiment (confirmatory tests), the candidates identified correctly the cation and anion present in sample **Q** with the aid of confirmatory tests. Extract 17.1 presents a sample of the correct responses to question 2 (alternative 2C).

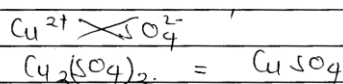
Q2.	SN	Experiments	Observation	Inferences
		(a) Sample Q was appeared as follow		
		(i) Colour	Sample Q was Blue in colour	Cu^{2+} may be present
		(ii) Texture	Sample Q was Crystalline form	NO_3^- , SO_4^{2-} , Cl^- may be present
		b) To transfer a little amount of Sample Q in clean and dry test tube then heated gently	Colourless gas with pungent smell evolve, which turns moist blue litmus paper to red.	SO_4^{2-} may be present
		(c) To transfer a little amount of Sample Q in a clean and dry test tube then was added few drops of concentrated H_2SO_4 followed by warming the content.	Blue crystals turn white even without warming	SO_4^{2-} of hydrated Cu^{2+} may be present.

	S/N	Experiment	Observation	Inferences
02	(d)	To transfer the same small amount of Sample Q in a test tube and was added distilled water to dissolve the solid sample.	Sample Q was soluble forming blue solution	Cu^{2+} may be present
	(i)	To a small volume of the original Sample Q solution was added ammonia solution drop wise until in excess.	Pale blue precipitate is formed, soluble in excess forming a deep blue solution	Cu^{2+} may be present
	(ii)	To a small volume of the original Sample Q solution, was added sodium hydroxide solution drop wise until in excess	Blue precipitate is formed insoluble in excess	Cu^{2+} may be present
	(iii)	To a small volume of the sample Q solution was added few drops of potassium hexacyanoferrate(II) solution.	Reddish brown precipitate was formed in solution sample Q	Cu^{2+} confirmed.

Q2.	SN	Experiment	Observation	Inference.
	(iv)(d)	To transfer a small volume of original Sample Q solution into the test-tube was added dilute HCl followed by the Barium chloride BaCl_2 .	white precipitate Insoluble in dilute HCl	SO_4^{2-} was confirmed.

(i) Cation was Cu^{2+}
Anions was SO_4^{2-}

(ii) The molecular formula of sample Q



The molecular formula of Q was CuSO_4

(iii) The name of the salt sample Q CuSO_4
Copper Sulphate or hydrated Copper Sulphate

Qn 2	iv from
	$\text{CuSO}_4(aq) + 2\text{NaOH}(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + \text{Cu}(\text{OH})_2(s)$
	$\text{Cu}^{2+}(aq) + \text{SO}_4^{2-}(aq) + 2\text{Na}^+(aq) + 2\text{OH}^-(aq) \rightarrow 2\text{Na}^+(aq) + \text{SO}_4^{2-}(aq) + \text{Cu}(\text{OH})_2(s)$
	$\text{Cu}^{2+}(aq) + \text{SO}_4^{2-}(aq) + 2\text{Na}^+(aq) + 2\text{OH}^-(aq) \rightarrow 2\text{Na}^+(aq) + \text{SO}_4^{2-}(aq) + \text{Cu}(\text{OH})_2(s)$
	$\text{Cu}^{2+}(aq) + 2\text{OH}^-(aq) \rightarrow \text{Cu}(\text{OH})_2(s)$
	Therefore the net ionic equation for the reaction is
	$\text{Cu}^{2+}(aq) + 2\text{OH}^-(aq) \rightarrow \text{Cu}(\text{OH})_2(s)$

Extract 17.1: A sample of correct responses to question 2, paper 2C

In extract 17.1, the candidate correctly observed the appearance of the sample, made correct interpretations of the experimental observation to correctly identify the ions present in the sample. He/she then gave correct

formula of the salt in the sample and wrote correct equations required by the question.

On contrary, the candidates who scored low marks failed to identify chemical species present in sample **Q**. Some candidates gave incorrect observations and inferences in preliminary tests. For instance, one candidate wrote.

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
Action of heat on a solid sample	Reddish brown residue	Fe^{2+} may be present

The candidate confused reddish brown colour of Fe_2O_3 over black residue of CuO . This candidate had insufficient knowledge of the concept of compounds of metals. Moreover, another candidate on addition of concentrated sulphuric acid to solid sample **Q** wrote:

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
Action of concentrated H_2SO_4 and warming on sample Q	Effervescence of colourless gas observed.	CO_3^{2-} or HCO_3^- may be present

Others, in conducting tests of solutions, identified anions instead of cations. Those candidates failed to realize that the role of an alkaline solution is to identify cations. For example, one candidate wrote:

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
Action of excess NaOH solution on sample solution	Green precipitate was formed insoluble in excess.	Fe^{2+} may be present

Another candidate wrote

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
Action of excess Ammonia solution on sample solution	Green precipitate was formed insoluble in excess.	Fe^{2+} may be present

Finally, these candidates identified incorrect cations and anions. For example, one candidate stated that;

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>Action of a few drops of potassium hexacyanoferrate (II) solution</i>	<i>Reddish-brown precipitates were formed</i>	<i>Fe³⁺ confirmed</i>

This candidate wrote correct observation but incorrect inference. Another candidate wrote;

<i>Experiment</i>	<i>Observation</i>	<i>Inference</i>
<i>Action of dilute HCl followed by addition of BaCl₂ on sample Q</i>	<i>Bluish white precipitate insoluble in Dilute HCl</i>	<i>Zn²⁺ confirmed</i>

Generally, the candidates demonstrated unsatisfactory competence on carrying out tests on unknown sample for identification of the cations and anions. Extract 17.2 shows a sample of incorrect responses in this question (alternative 2C).

2	Experiments	Observations	Inferences
	a) Appearance of solid sample	White, crystalline or powder	NH_4^+ may be present
	b) Action of heat on a solid sample	White sublimate and a colourless gas evolves, which turns wet litmus paper from red to blue	NH_4^+ may be present
	c) Action of concentrated H_2SO_4 on a solid sample	Evolution of brown fumes, which turn wet litmus paper from blue to red and intensify on addition of copper turnings	NO_3^- may be present
	d) i) To the first portion add aqueous ammonia drop wise; then in excess	Colourless gas evolves which gives fumes ammonia	Fe^{3+} may be present
	ii) To the second portion add NaOH drop-wise then in excess	Blue colour gas was present in the test tube	Zn^{2+} may be present
	iii) To the third portion add potassium hexacyanoferrate (II) solution	Brown colour gas from the test tube	Cl^- may be present
	iv) To the fourth portion add dilute HCl followed by BaCl_2	No gas	SO_4^{2-} may be

	b) Cation = HCl
	Anion = NH_3
	ii) $\text{NH}_4\text{Cl} = \text{NH}_3 + \text{HCl (aq)}$ (aq)
	iii) Name is NH_4
	iv) $(\text{NH}_4)_2\text{CO}_3 \xrightarrow{\text{Heat}} 2\text{NH}_3 + \text{H}_2\text{O} + \text{CO}_2$

Extract 17.2: A sample of incorrect responses to question 2, paper 2C

In Extract 17.2, the candidate skipped some steps of the systematic qualitative analysis. Additionally, he/she gave incorrect observations, which led to wrong inferences and consequently the identification of an incorrect cation and anion instead of the specific ones as required by the question. The candidate was unable to write correct formula of the sample salt, resulting in an incorrect equation of reaction asked in the question.

3.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE IN EACH TOPIC

Chemistry papers 1 and 2 consisted of 13 questions covering 21 topics. The analysis indicates that 5 topics attained good performance. Water (97.60%), Qualitative Analysis (94.32%), Scientific Procedure (93.14%), Volumetric Analysis (92.31%) and Ionic Theory and Electrolysis (82.80%). Question 1 covered nine topics, which achieved good performance rate of 86.82%. The question comprised the following topics: Matter; Formula, Bonding and Nomenclature; Water; Air, Combustion, Rusting and Fire Fighting; Non-metals and Their Compounds; Hydrogen; Fuels and Energy; Oxygen; and The Mole Concept and Related Calculations.

Furthermore, the analysis reveals that 6 topics attained average performance. Chemical Kinetics, Equilibrium and Energetics (61.98%), Heat Sources and Flames (60.78%), Hardness of water (57.97%), Non-metals and their compounds (44.44%). Periodic Classification (34.79%) and Hydrogen (31.74%).

However, the analysis indicates that the candidates performed weakly in the topic of Organic Chemistry (27.08%). The weak performance in this topic was attributed by the following:

- (i) Failure of candidates to demonstrate understanding of the results of oxidizing organic compounds such as ethanol where carbon dioxide gas and water are produced.
- (ii) Inability to determine the product formed by oxidation of ethanol using acidified potassium dichromate (VI).
- (iii) Inability to distinguish between the reaction of ethanol with mineral acids (such as sulphuric acid) and its reaction of ethanol with organic acids (such as ethanoic acid).

The performance of the candidates in different topics is summarised in Appendix I.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Generally, the candidates' performance in Chemistry CSEE 2025 was good since the majority (96.88%) passed the examination.

Such performance of the candidates in chemistry subject was contributed by adequate knowledge of various concepts tested on different topics. On the other hand, some candidates had weak performance, which the following reasons may have caused:

- (a) Inadequate skills in writing chemical equations: This was noted in several questions, including question 10, in which the candidates failed to indicate the reaction of ethanol with different reagents.
- (b) Inadequate skills in describing some concepts in Chemistry with diagrams. For example, in question 11 many candidates failed to sketch a diagram of the concentric pipes. Similarly, in question 4 they failed to use electronic configuration so as to locate hydrogen in the correct group.
- (c) Inadequate skills of carrying out titration experiments: This was noted in 2A, 2B and 2C in which candidates failed to record the

correct colour change at the end point and titre value. Moreover, candidates failed to manipulate the unit especially in paper 2C in calculating volume of acidic rain water.

4.2 Recommendations

The following are recommended to improve the candidates' performance in future examinations:

- (a) Teachers are encouraged to guide students in conducting experiments that examine the colour changes of various indicators during acid–base titrations, as well as experiments involving the determination of relative atomic mass in acidic or alkaline solutions.
- (b) Teachers are encouraged to use chemical equations to emphasise the chemical properties of alcohol when teaching the topic of organic chemistry.
- (c) Students are encouraged to practice exercises of demonstrating the extraction of metals and non-metals including well labelled diagram of the equipment involves in the process.

Appendix I: Analysis of Performance of Candidates in Each Topic

S/N	Topic	Question Number	% of the Candidates who Scored an Average of 30% or Above	Remarks
1	Water	3	97.60	Good
2	Qualitative Analysis	2 (Practical)	94.32	Good
3	Scientific Procedure	5	93.14	Good
4	Volumetric Analysis	1 (Practical)	92.31	Good
5	Matter; Formula, Bonding and Nomenclature; Water; Air, Combustion, Rusting and Fire Fighting; Non-metal and Their Compound; Hydrogen; Fuels and Energy; Oxygen: The Mole Concept and Related Calculations.	1	86.82	Good
6	Ionic Theory and Electrolysis	2	82.80	Good
7	Chemical Kinetics, Equilibrium and Energetics	9	61.98	Average
8	Heat Sources and Flames	7	60.78	Average
9	Hardness of water	8	57.97	Average
10	Non-metals and Their Compounds	11	44.44	Average
11	Periodic Classification	4	34.79	Average
12	Hydrogen	6	31.74	Average
13	Organic Chemistry	10	27.08	Weak

The first part of the paper discusses the importance of understanding the local context in which a project is implemented. This includes a thorough analysis of the social, cultural, and economic factors that may influence the success or failure of the intervention. It is essential to engage with the community from the outset, ensuring that their voices are heard and their needs are addressed. This participatory approach not only fosters a sense of ownership and commitment among the community members but also allows for the identification of potential challenges and the development of strategies to mitigate them.

The second part of the paper explores the role of leadership in driving change. Effective leaders are those who are able to inspire and motivate others, to set a clear vision, and to create a supportive environment for innovation and growth. They are also skilled in building strong relationships and in fostering a culture of collaboration and trust. Leadership is not a static role; it evolves over time and is shaped by the needs and circumstances of the community. Therefore, it is important to invest in leadership development and to provide ongoing support and training for leaders at all levels.

The third part of the paper examines the impact of external factors on the implementation of a project. These factors can include government policies, funding availability, and the overall state of the economy. While these factors are often beyond the control of the project team, it is important to stay informed about them and to adapt the project accordingly. For example, if funding is cut, it may be necessary to seek alternative sources of support or to scale back the project. Similarly, if government policies change, it may be necessary to adjust the project's goals and objectives.

The fourth part of the paper discusses the importance of monitoring and evaluation (M&E) in assessing the impact of a project. M&E is a systematic process of collecting, analyzing, and using data to inform decision-making and to improve the effectiveness of the intervention. It involves setting clear indicators of success, collecting data in a timely and accurate manner, and using the data to identify areas for improvement and to celebrate successes. M&E is not a one-time exercise; it is an ongoing process that should be integrated into all aspects of the project.

The fifth part of the paper concludes by emphasizing the need for a holistic and sustainable approach to development. This means addressing the root causes of poverty and inequality, rather than just the symptoms. It involves working with the community to build their capacity and resilience, to create opportunities for economic growth, and to ensure that the benefits of development are shared by all. This is a long-term process that requires patience, persistence, and a commitment to the well-being of the community.