THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

CANDIDATES' ITEM RESPONSE ANALYSIS REPORT ON THE ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (ACSEE), 2023

CHEMISTRY

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132 CHEMISTRY

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FOREWORD

This report presents the Candidates' Item Response Analysis (CIRA) in the Chemistry subject on the Advanced Certificate of Secondary Education Examination (ACSEE) which was conducted in May 2023. The report aims at providing feedback on the candidates' responses to the examination items and performance attained in Chemistry subject. The ACSEE is a summative evaluation that assesses the learners' knowledge and ability to pursue further education in higher learning institutions.

The general performance of the candidates in this subject was good. Factors that contributed to candidates' success in the examination include sufficient knowledge of concepts, ability to conduct experiments precisely, mastery of the skills for interpreting observation; and mastery of numerical skills. Conversely, some candidates scored low marks due to inadequate knowledge of concepts, limited ability to conduct experiments, inability to justify scientific facts, low ability to write chemical equations and poor mastery of numerical skills.

This analysis presents the justification for the candidates' performance in the Chemistry subject and thus serves as a tool that education stakeholders can use to improve the teaching and learning of Chemistry at advanced level. In order to address the weaknesses of candidates who scored low marks, recommendations have been included in this report. Thus, the Council believes that education stakeholders will consider all the recommendations given to improve teaching and learning of Advanced Chemistry.

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

Dr. Said Ally Mohamed
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report presents a comprehensive analysis of the candidates' responses in the Chemistry subject in the Advanced Certificate of Secondary Education Examination (ACSEE) 2023. The examination comprised three papers. These included two theory based papers, namely 132/1 Chemistry 1 and 132/2 Chemistry 2; and one practical paper, namely 132/3 Chemistry 3. The practical paper was offered in three equivalent alternative papers (132/3A Chemistry 3A, 132/3B Chemistry 3B, and the 132/3C Chemistry 3C), and the candidates were required to sit for only one alternative paper.

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

The report employs a categorization system based on the percentage of marks scored out of the allocated marks to assess the performance on each question and topic. Performance is classified as weak (0 – 34%), average (35 –59%) or good (60 –100%), represented by red, yellow or green colours respectively in figures and tables.

The Chemistry examination was attempted by a total of 37,726 candidates, out of which 36,944 (97.93%) passed. Thus, the overall performance of candidates was good. In the previous year a total of 34,747 out of 33,731 candidates (97.48%) passed the examination. Therefore, the candidates' performance has increased by 0.45 per cent from the previous year.

This report consists of five sections. The first section is the introduction which outlines the structure and rubric of Chemistry papers and introduces the performance classification criteria for ACSEE, 2023. It also compares the overall performance of candidates in the 2022 and 2023 Chemistry examinations.

The second section presents the analysis of the candidates' performance in each question; it examines the candidates' responses to each question. This analysis is supported by statistical data and samples of good and weak responses given by the candidates. Readers will gain insights into what the candidates were able or unable to do in relation to the requirements of the questions. The section further analyses misconceptions observed during marking of the candidates' scripts and suggests solutions for future improvement.

The third section presents analysis of candidates' performance in each topic. Additionally, it presents comparison of candidates' performance in each topic in 2023 and 2022.

The fourth and fifth sections of the report provide conclusion and recommendations, respectively. The conclusion part provides overall observations on the strengths and weaknesses of the candidates' responses to the examination questions. The recommendations part outlines appropriate measures to address the challenges observed in the candidates' responses in order to improve future examinations.

2.0 ANALYSIS OF CANDIDATES' PERFORMANCE IN EACH QUESTION

This section analyses the candidates' responses to the question in Chemistry papers 1, 2 and 3. The analysis begins by explaining the requirement of a particular question as it appeared in the examination paper. This is followed by data analysis, a detailed description of candidates' responses, and presentation of appropriate samples of extracts.

2.1 132/1-CHEMISTRY 1

This was a theory paper which consisted of sections A and B with a total of ten (10) questions. The candidates were required to answer 2 out of 3 questions from Section B and all 7 questions in Section A. The questions in section A weighed 10 marks each while those in section B weighed carried 15 marks each. The topics which were examined are *The Atom; Chemical Bonding; Relative Molecular Masses in Solution; Chemical Equilibrium; Gases; Energetics; Aliphatic Hydrocarbons; Soil Chemistry; Selected Compounds of Metals* and *Aromatic Hydrocarbons.* The pass mark for Section A was 3.5 marks while that for Section B was 5.5 marks.

2.1.1 Question 1: Gases

This question had three parts; (a), (b) and (c) which read as follows:

(a) *A person swallowed a drop of liquid oxygen, O_2 (l), which has a density 1.149 g/cm^3. Assuming the drop has a volume of 0.050 cm^3, calculate the volume of a gas that will be produced in the person's stomach at body temperature (37^{o}C) and a pressure of one (1) atmosphere.*

(b) *A compound contains only nitrogen and hydrogen and is 87.4% nitrogen by mass. A gaseous sample of the compound has a density of 0.977 g/L at 710 mmHg and 100^{o}C Determine the molecular formula of the compound.*

(c) *A total volume of 2.50×10^2 cm^3 of chlorine gas was collected over water at 20^{o}C and a total pressure of 1 atm. Calculate the mass of chlorine collected at the given temperature if the vapour pressure of water was 17.5 mmHg.*

This question was attempted by all 37,805 candidates. Among them, 13,918 (36.9%) scored from 0–3 marks; 11,297 (29.9%) from 3.5–5.5 marks and 12,511 (33.2%) from 6–10 marks. Thus, the candidates who scored a pass mark or above (≥3.5 marks) were 2,116 (63.1%), which indicates a good performance. Figure 1 summarizes the candidates' performance in this question.

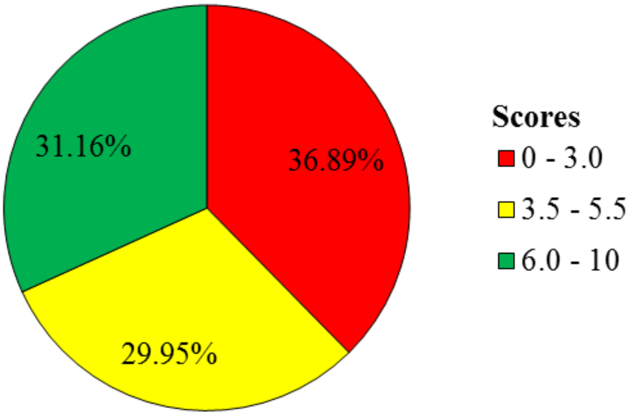
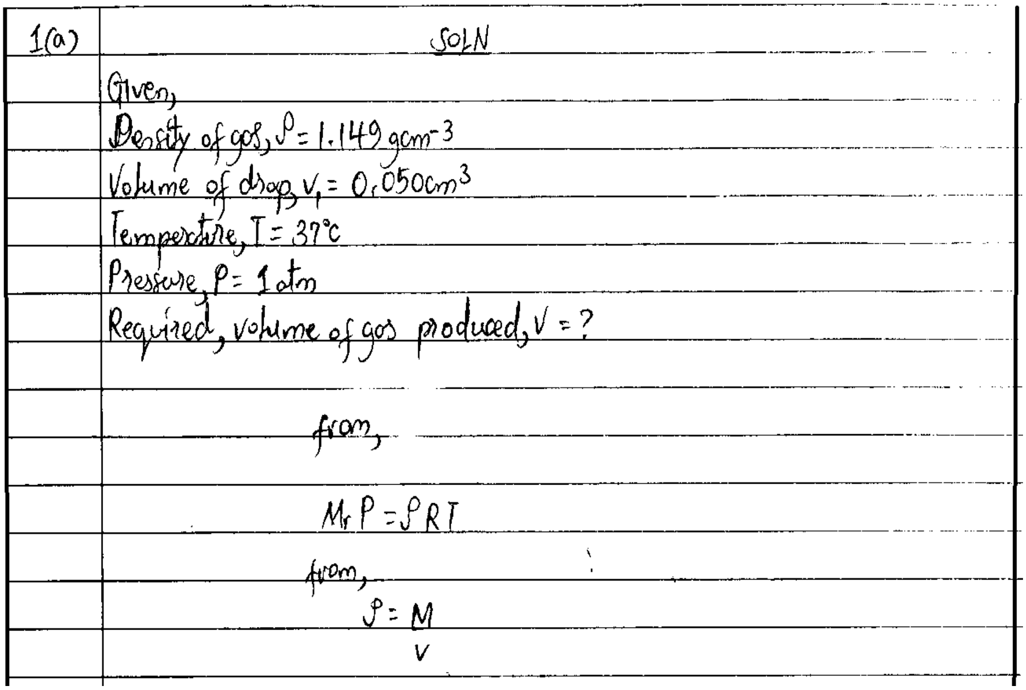


Figure 1: *Candidates' Performance in Question 1 Paper 1*

The candidates who scored high marks in this question had sufficient knowledge of the gas laws especially the application of the ideal gas equation, *(PV=nRT)*. In part (a), the candidates used the relationship between density, volume and mass *(m=ρv)* to obtain the mass of liquid oxygen swallowed, then used the mass to determine the number of moles ($n = {}^{m}\!/_{M_r}$). The candidates substituted the value of n obtained into the ideal gas equation and performed appropriate mathematical manipulations and consequently obtained the required volume of oxygen. In part (b), the candidates applied the correct method of determining empirical formula from the percentage abundances of the gases given (N = 87.4% and H= (100% – 87.4%) = 12.6%) which resulted in the simplest ratio of NH_2. They then used the ideal gas equation and the data given to obtain the molecular mass of the compound ($M_r = \frac{\rho RT}{p}$).

In part (c), the candidates who scored full marks calculated the pressure of Cl_2 gas from Dalton's law of partial pressure ($P_T = P_{water\ vapour} + P_{Chlorine}$). The value of $P_{Chlorine}$ obtained was then substituted into the rearranged ideal gas equation to get the correct mass of chlorine gas (i.e $m = \frac{PVM_r}{RT}$). Extract 1.1 is a sample of the correct response to question 1.



1(a) SolN

Given,

Density of gas, $\rho = 1.149\ gcm^{-3}$

Volume of drop, $V_1 = 0.050\ cm^3$

Temperature, $T = 37°C$

Pressure, $P = 1\ atm$

Required, volume of gas produced, $V = ?$

from,

$M_r P = \rho RT$

from,

$\rho = \frac{M}{V}$

$M = 1.149 \times 0.050$

$M = 0.05745g$

then, $PV = \frac{mRT}{M_r}$

$V = \frac{mRT}{PM_r}$

$V = \frac{0.05745 \times 0.0821 \times 310}{1 \times 32}$

$V = 0.0457 dm^3$

$\therefore$ Volume of gas produced is $0.0457 dm^3$

1(b) SolN

Given,

Composition of N_2 = 87.4%

Density of compound, $\rho = 0.977 g/L$

Pressure, $P = 710 mmHg$

Temperature, $T = 273 + 100 = 373K$.

Required, Molecular formula of compound, M_{rf} = ?

Empirical formula of compound,

COMPOUND	N	H
Percentage Composition	87.4	12.6
Relative Atomic Mass (RAM)	87.14	1
Divide their composition by their Atomic Masses	$\frac{87.40}{14}$	$\frac{12.6}{1}$
Divide by the smallest Ratio.	$\frac{6.24}{6.24}$	$\frac{12.6}{6.24}$
Convert it into whole numbers	1 ≈ 1	2.01 ≈ 2

Empirical formula is NH_2

from,

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

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

$$Mr = \frac{0.977 \times 0.0821 \times 373}{0.934}$$

$$Mr = 32\ gmol^{-1}$$

1(b)

$$(NH_2)n = 32 gmol^{-1}$$

$$(14+2)n = 32$$

$$\frac{16n}{16} = \frac{32}{16}$$

$$n = 2$$

Molecular formula

N_2H_4

∴ Molecular formula of compound is N_2H_4

1(c) SOLN

Given,

Volume of chlorine gas $= 2.50 \times 10^2 cm^3$

$= 0.25 dm^3$

Temperature, $T = 20°c + 273 = 293K$

Total pressure, $P_T = 1atm$

Pressure of water, $P_W = 17.5 mmHg = 0.023 atm$

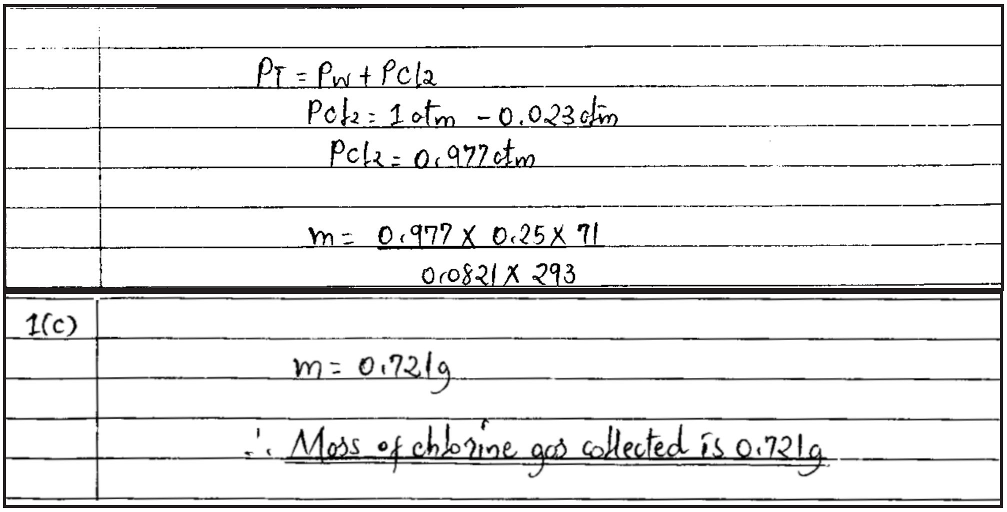
Required; Mass of chlorine, $m = ?$

from,

$$PV = nRT$$

$$PV = \frac{mRT}{Mr}$$

$$m = \frac{PV\,Mr}{RT}$$



$P_T = P_W + P_{Cl_2}$

$P_{Cl_2} = 1\,atm - 0.023\,atm$

$P_{Cl_2} = 0.977\,atm$

$m = \frac{0.977 \times 0.25 \times 71}{0.0821 \times 293}$

1(c)

$m = 0.721g$

∴ Mass of chlorine gas collected is 0.721g

Extract 1.1: A sample of correct responses to Question 1 Paper 1

In Extract 1.1, the candidate correctly calculated the mass of the liquid oxygen swallowed, the correct number of moles from the mass and substituted into the ideal gas equation, thereby obtaining the required volume of oxygen. In part (b), the candidate showed a step by step calculation of empirical formula, and used the calculated molecular weight from the ideal gas equation to obtain the correct molecular formula. In part (c), the candidate manipulated the ideal gas equation to suit the data given (the value of n in terms of mass and molar mass) thereby obtaining the correct mass of chlorine.

On the contrary, 13,918 (36.9%) candidates failed to answer this question correctly, hence, they scored low marks. These candidates failed to interpret the question correctly and to use the ideal gas equation appropriately. For example, the candidates failed to appropriately apply the relations $\rho = {}^{m}/_{v}$, $pv = nRT$, $n = {}^{m}/_{Mr}$ and $P_T = P_{water\,vapour} + P_{Chlorine}$. which are key in gas laws calculations. The analysis also indicates that some of the candidates confused the use of the molar gas constant (R) in relation to the units stated in pressure and volume, for example, when to use 8.31 and when to use 0.0821. Some of the candidates also failed to apply Dalton's law of partial pressure $(P_T = P_{water\ vapour} + P_{Chlorine})$ to calculate the pressure of chlorine gas. The incorrect responses of candidates were a result of lack of competence in the concept of gas laws and their interrelationships. A sample of the incorrect responses to this question is shown in Extract 1.2

1 (a) Volume = 0.05 cm³.

Temperature = 37°C

pressure = 1 atm

Volume H_2O = ?

from,

Boyle's law.

volume (V) ∝ 1/pressure (P

$$V = \frac{k}{P}$$

$VP = k$.

$V_1P_1 = V_2P_2$

$0.05\,cm^3 \times 1\,atm = V_2 \times 1\,atm$.

$V_2 = 0.05\,cm^3$.

Volume = $0.05\,cm^3$.

(c) Data

volume = $2.5 \times 10^2\,cm^3 = 0.25\,dm^3$

Temperature = 20°C = 293K

pressure = 1 atm.

Mass = ?

Vapour pressure = 17.5 mmHg

= 23×10^{-3} atm

from

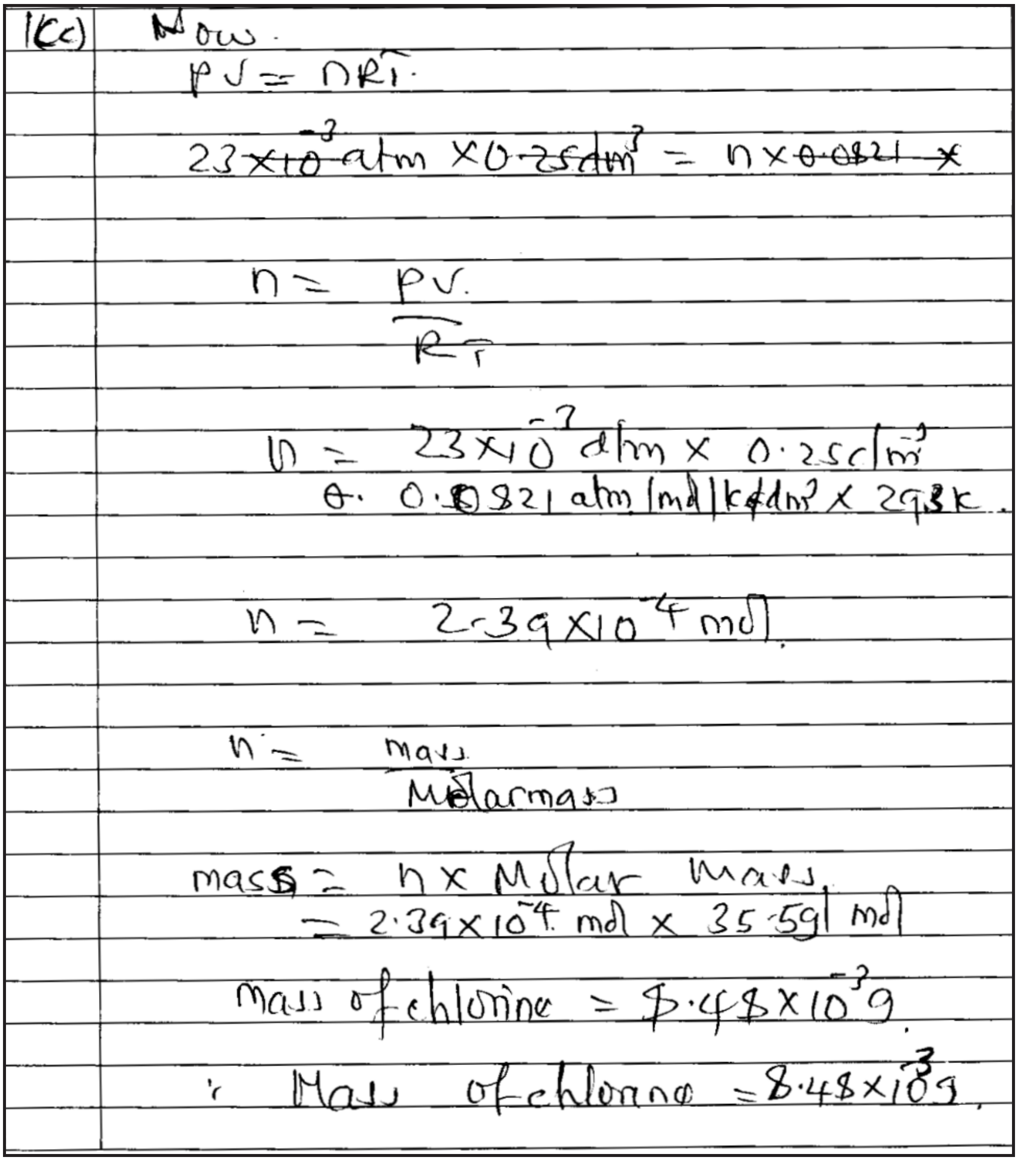
Ideal gas equation

$PV = nRT$

where P - pressure

V - volume

R - Redybarg n - mole.



1(c) Now.

$PV = nRT$.

$23 \times 10^{-3}\,atm \times 0.25\,dm^3 = n \times 0.0821 \times$

$n = \frac{PV}{RT}$

$n = \frac{23 \times 10^{-3}\,atm \times 0.25\,dm^3}{0.0821\,atm/mol/k/dm^3 \times 298\,K}$.

$n = 2.39 \times 10^{-4}\,mol$.

$n = \frac{mass}{Molar\,mass}$

$mass = n \times Molar\,mass$

$= 2.39 \times 10^{-4}\,mol \times 35.5\,g/mol$

Mass of chlorine $= 8.48 \times 10^{-3}\,g$.

∴ Mass of chlorine $= 8.48 \times 10^{-3}\,g$.

Extract 1.2: A sample of the incorrect responses to Question 1 Paper 1

In Extract 1.2, the candidate failed to calculate the mass of oxygen gas and the number of moles, and consequently failed to determine the volume of gas correctly. Again the candidate applied Boyle's law, $V \alpha \frac{1}{P}$, in part (a), which is not applicable, and skipped part (b). In part (c) the candidate wrote the correct ideal gas equation, but failed to substitute the correct values.

2.1.2 Question 2: Relative Molecular Masses in Solution

The question had two parts: (a) and (b). In part (a), the candidates were required to give brief comments on the following four observations:

(i) *Sodium chloride solution freezes at a lower temperature than that of pure water but boils at higher temperature than pure water.*

(ii) *A driver adds ethylene glycol to water in a car radiator during winter season.*

(iii) *The blood cells which are isotonic with 0.9% sodium chloride solution are placed in 1.2% sodium chloride solution.*

(iv) *When dehydrated fruits and vegetables are placed in water, they slowly swell and return to their original forms.*

Part (b) of the question had two sub items; (i) and (ii). In item (i), the candidates were given the following statement: *Eighteen grams (18 g) of glucose,* $C_6H_{12}O_6$ *(molar mass =180 g/mol) are dissolved in 1 kg of water in a sauce pan.* They were required to determine the temperature at which the solution boils, given that the Kb for water = 0.52 kg/mol. In item (ii) the candidates were required *to calculate the elevation in boiling point that is expected in alcohol when* $5\,g$ *of urea* $\left(molar\ mass\ =\ 60\,g/mol\right)$ *are dissolved in 75 g of it, given that the molal elevation constant for alcohol =1.15 K/m.*

The analysis of the performance shows that this question was attempted by 37,805 candidates, of which, 10,557 (27.92%), 10,610(28.07%) and 16,638 (44.01%) candidates scored 0–3, 3.5–5.5 and 6–10, respectively. The general performance in this question was good since 27,248 (72.08%) candidates scored 3.5 marks or above. A summary of the candidates' performance in this question is shown in Figure 2.

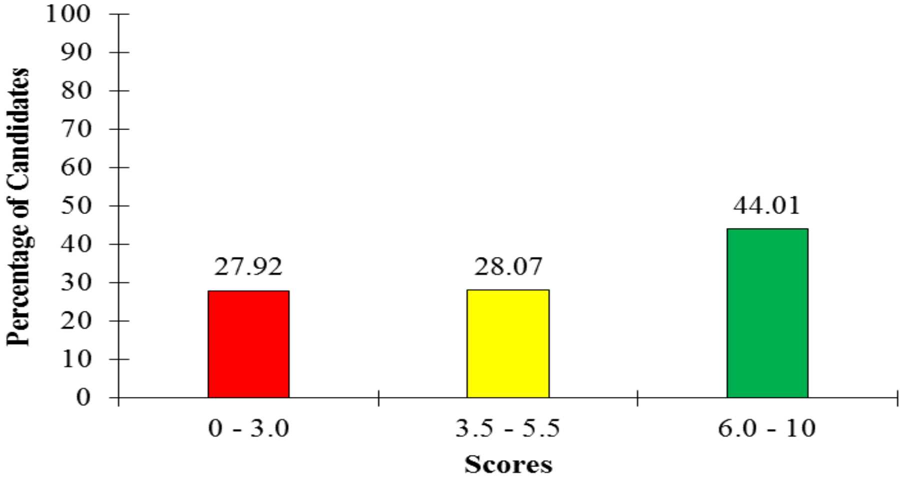
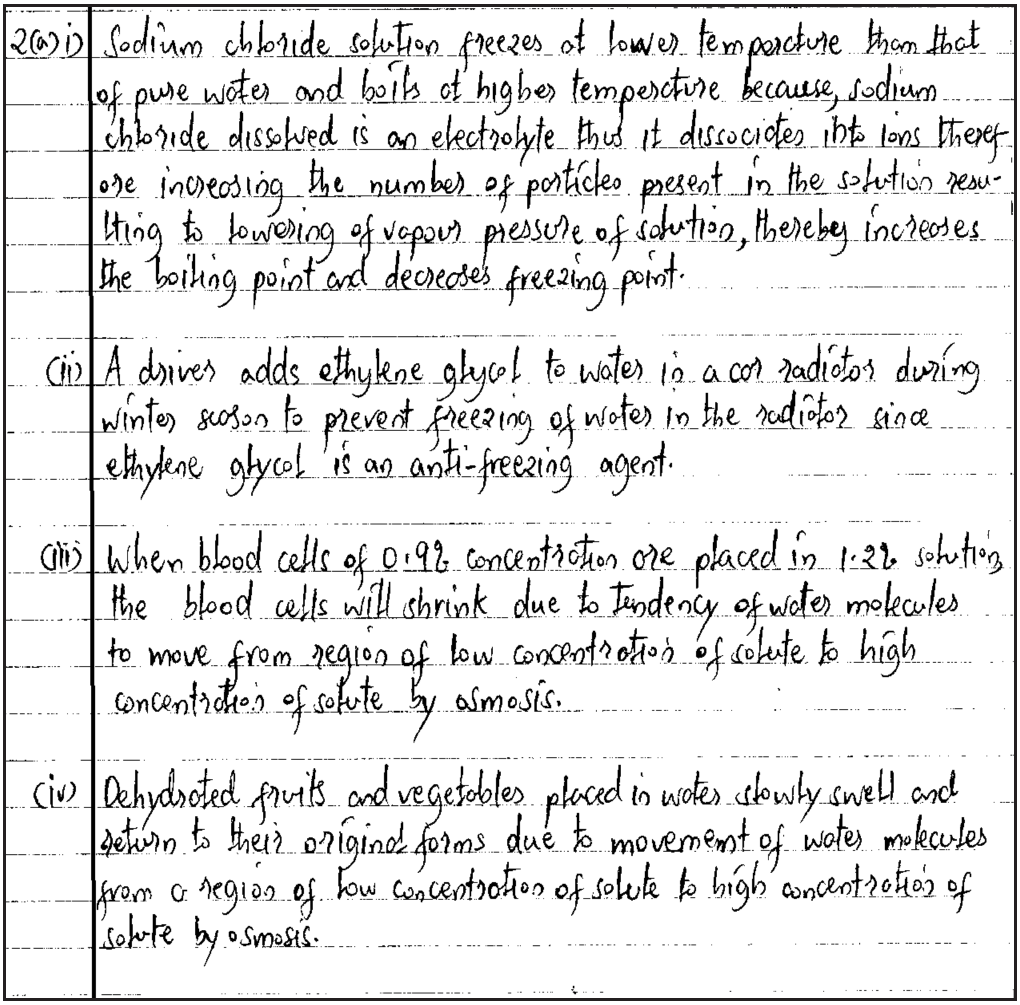
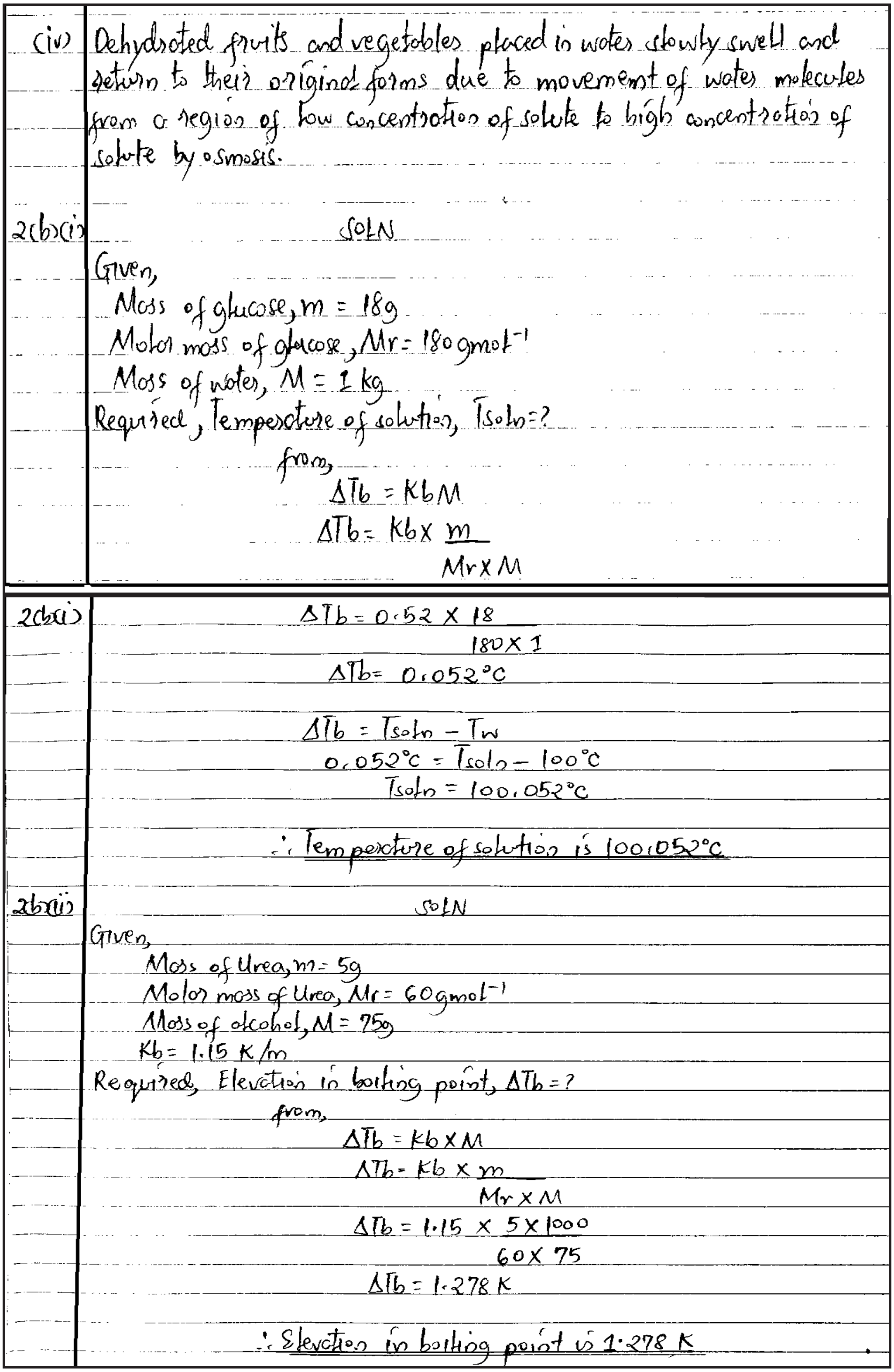


Figure 2: *Candidates' Performance in Question 2 Paper 1*

The candidates who performed well (44.01%) understood the concept of colligative properties and their applications. In part (a), they gave observations which were based on freezing point depression, boiling point elevation and elevation of osmotic pressure. These candidates had sufficient knowledge on these concepts *(lowering of vapour pressure increases boiling point and vice versa)* hence they gave appropriate responses. In part (b) (i) and (ii), the candidates applied the correct formula for the calculation of elevation in boiling point, $\Delta T_b = \dfrac{K_b \times W_s}{M_s \times W_o}$ with correct substitutions of the values. They showed that, the boiling point of solution is obtained from the relation *ΔTb = (Tsolution – Tpure solvent)*. Extract 2.1 is a sample of the correct responses to this question.



2(a) i)	Sodium chloride solution freezes at lower temperature than that of pure water and boils at higher temperature because, sodium chloride dissolved is an electrolyte thus it dissociates into ions therefore increasing the number of particles present in the solution resulting to lowering of vapour pressure of solution, thereby increases the boiling point and decreases freezing point.
(ii)	A driver adds ethylene glycol to water in a car radiator during winter season to prevent freezing of water in the radiator since ethylene glycol is an anti-freezing agent.
(iii)	When blood cells of 0.9% concentration are placed in 1.2% solution the blood cells will shrink due to tendency of water molecules to move from region of low concentration of solute to high concentration of solute by osmosis.
(iv)	Dehydrated fruits and vegetables placed in water slowly swell and return to their original forms due to movement of water molecules from a region of low concentration of solute to high concentration of solute by osmosis.


(iv) Dehydrated fruits and vegetables placed in water slowly swell and return to their original forms due to movement of water molecules from a region of low concentration of solute to high concentration of solute by osmosis.

2(b)(i) SOLN

Given,

Mass of glucose, $m = 18g$

Molar mass of glucose, $Mr = 180\,gmol^{-1}$

Mass of water, $M = 1\,kg$

Required, Temperature of solution, $T_{soln} = ?$

from,

$$\Delta T_b = K_b M$$

$$\Delta T_b = K_b \times \frac{m}{Mr \times M}$$

2(b)(i)

$$\Delta T_b = 0.52 \times \frac{18}{180 \times 1}$$

$$\Delta T_b = 0.052°C$$

$$\Delta T_b = T_{soln} - T_w$$

$$0.052°C = T_{soln} - 100°C$$

$$T_{soln} = 100.052°C$$

$\therefore$ Temperature of solution is 100.052°C

2(b)(ii) SOLN

Given,

Mass of Urea, $m = 5g$

Molar mass of Urea, $Mr = 60\,gmol^{-1}$

Mass of alcohol, $M = 75g$

$K_b = 1.15\ K/m$

Required, Elevation in boiling point, $\Delta T_b = ?$

from,

$$\Delta T_b = K_b \times M$$

$$\Delta T_b = K_b \times \frac{m}{Mr \times M}$$

$$\Delta T_b = 1.15 \times \frac{5 \times 1000}{60 \times 75}$$

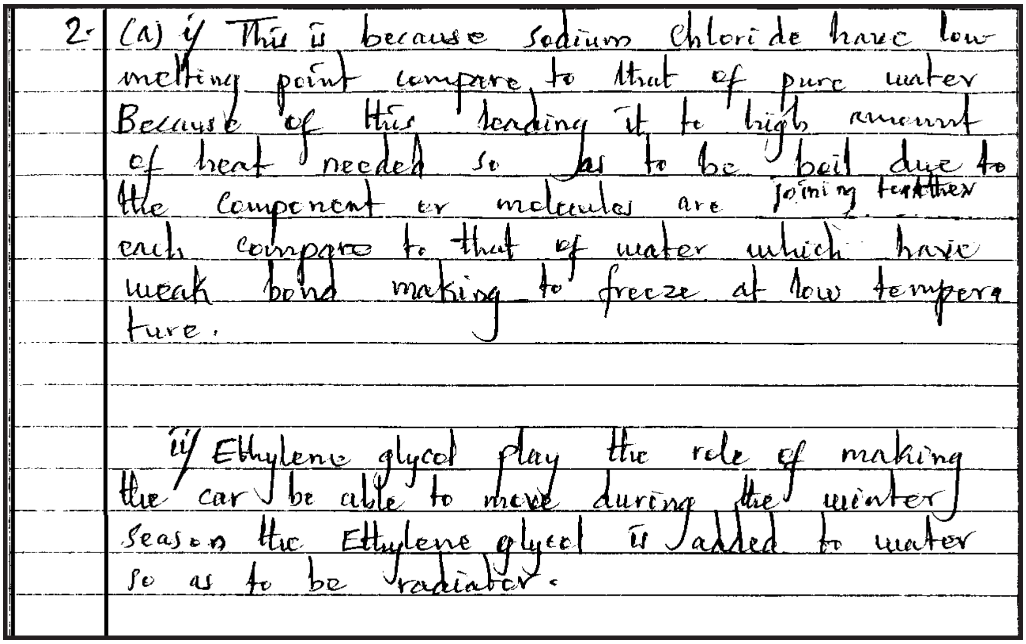
$$\Delta T_b = 1.278\ K$$

$\therefore$ Elevation in boiling point is 1.278 K

Extract 2.1: A sample of the correct responses to Question 2 Paper 1

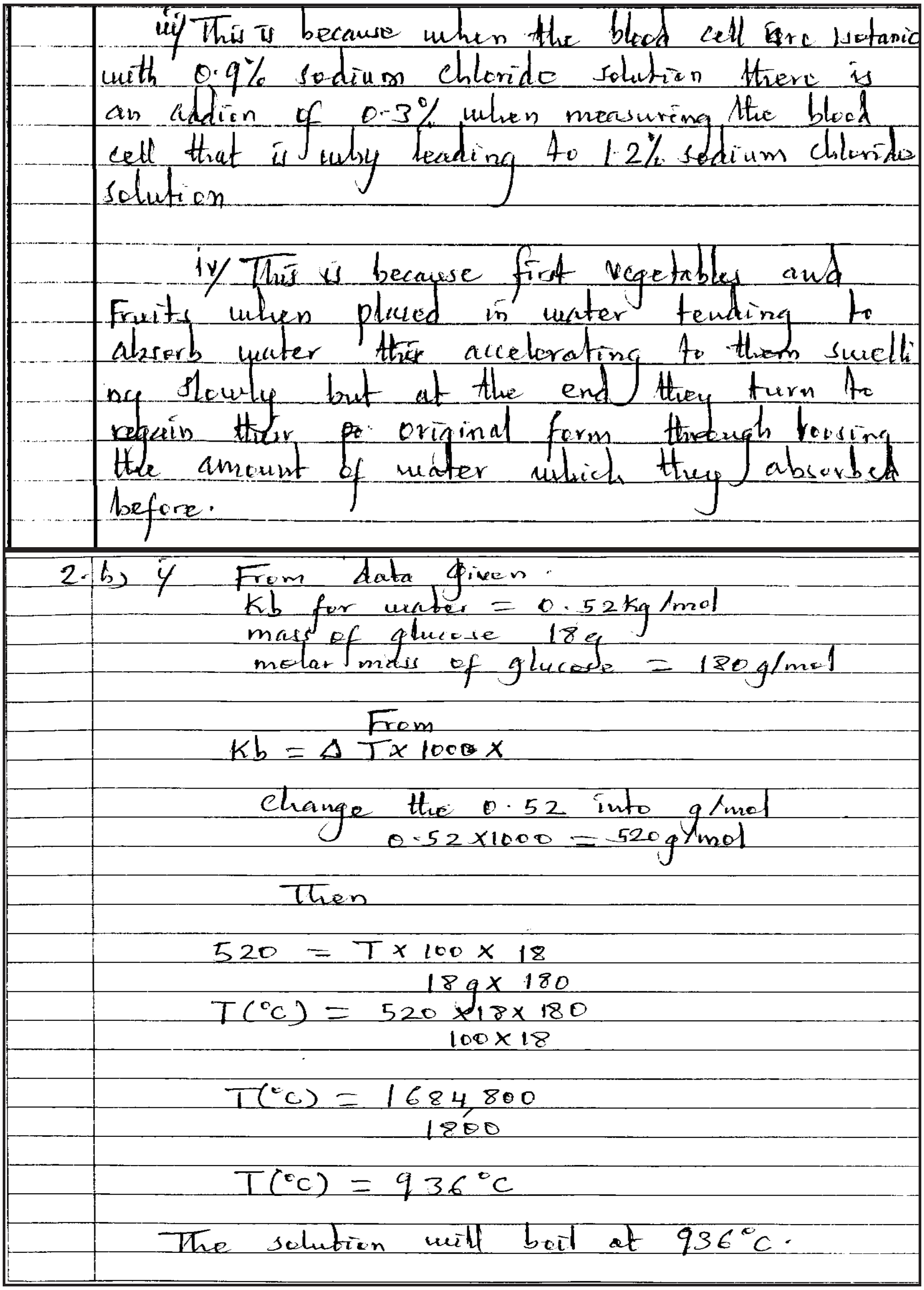
In Extract 2.1 the candidate gave correct comments on the observations based on colligative properties regarding the resulting vapour pressure, boiling points and freezing points of the liquid, osmosis and osmotic pressure. In part (b), the candidate showed good mastery of the formula for calculation of elevation in boiling point of solution upon addition of non-volatile solute (ΔT_b) and used the value in determining the boiling point of the resulting solution as required in both sub parts (i) and (ii).

Contrarily, 10,557 candidates (27.92%), scored low marks in this question due to lack of adequate knowledge on the general concept of colligative properties. The candidates failed to explain correctly the observations in part (a). Some of them gave inappropriate reasons and incorrect statements. For example, in attempting item (a)(i) there were candidates who suggested that sodium chloride ions undergo association instead of dissociation. The candidates also failed to use correct formula for calculation of the elevation of boiling points in parts (b) while others failed to manipulate correctly the given data to get correct answer. For instance, in sub part (ii), some of the candidates did not convert the given mass of solvent (75 g) into kilogram (0.075 kg), thus got incorrect values. Other candidates interchanged the mass of solute (5 g) with that of solvent (75 g), hence, got incorrect answer too. Extract 2.2 shows a sample of incorrect responses from one of the candidates in this question.



2. (a) i/ This is because sodium chloride have low melting point compare to that of pure water Because of this leading it to high amount of heat needed so as to be boil due to the component or molecules are joining together each compare to that of water which have weak bond making to freeze at low temperature.

ii/ Ethylene glycol play the role of making the car be able to move during the winter season the Ethylene glycol is added to water so as to be radiator.



iii/ This is because when the blood cell are isotanic with 0.9% sodium chloride solution there is an addion of 0.3% when measuring the blood cell that is why leading to 1.2% sodium chloride solution

iv/ This is because first vegetables and Fruits when placed in water tending to absorb water their accelerating to them swelling slowly but at the end they turn to regain their ~~pe~~ original form through loosing the amount of water which they absorbed before.

2. b) i/ From data given.

Kb for water = 0.52kg/mol

mass of glucose 18g

molar mass of glucose = 180g/mol

From

Kb = Δ T x 1000 x

change the 0.52 into g/mol

0.52 x 1000 = 520g/mol

Then

$$520 = \frac{T \times 100 \times 18}{18g \times 180}$$

$$T(°C) = \frac{520 \times 18 \times 180}{100 \times 18}$$

$$T(°C) = \frac{1684800}{1800}$$

$$T(°C) = 936°C$$

The solution will boil at 936°C.

Extract 2.2: A sample of the incorrect responses to Question 2 Paper 1

In Extract 2.2, the candidate gave incorrect explanations for each phenomenon in part (a). In part (b), he/she used incorrect formula and substituted erroneous data, leading to incorrect answer.

2.1.3 Question 3: Chemical Bonding

The question had parts (a), (b) and (c). In part (a), the candidates were required to *give brief explanation of the two conditions necessary for the formation of hydrogen bonding.*

In part (b), the candidates were required to study the chemical structures of two compounds *I (ortho nitrophenol)* and *II (p-nitrophenol)* given and then answer the questions that followed in sub parts (i), (ii) and (iii) by giving reasons in each case as follows.

(i) *What type of hydrogen bonding is exhibited in each compound?*

(ii) *Which of the two compounds is expected to have higher melting point that the other?*

(iii) *Which compound is likely to be more soluble in a polar solvent?*

In part (c), the candidates were required to indicate the types of bonds present in NH_4NO_3 and state the mode of hybridization of the N atom in the NO_3^- *ion.*

The question was attempted by 37,805 candidates (100%). The analysis of statistical data indicates that 8,617 (22.79%) candidates scored from 0–3 marks, 23,389 (61.87%) from 3.5–5.5 marks and 5,799 (15.34%) from 6–10 marks (Figure 5). The overall performance on this question was good as 29,188 candidates (77.21%) scored a pass mark or above (≥3.5 marks) as shown in Figure 3.

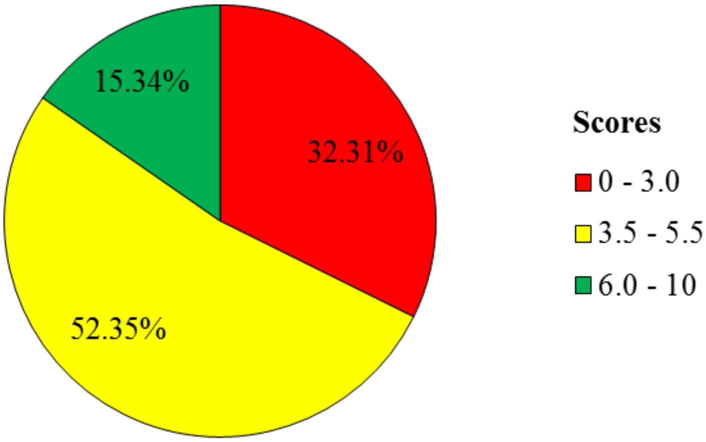
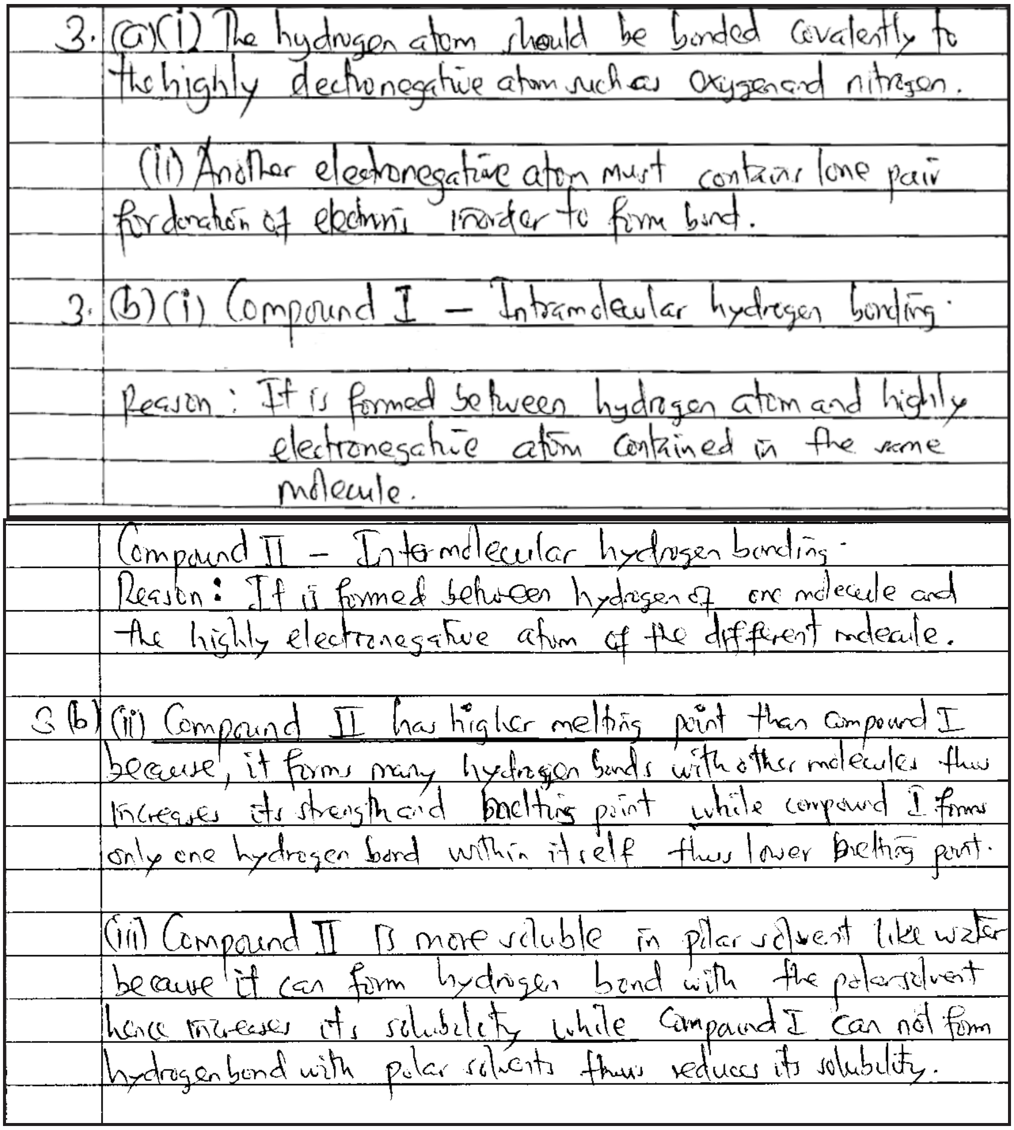


Figure 3: *Candidates' Performance in Question 3 Paper 1*

The candidates who performed well in this question demonstrated good understanding of the general concept of hydrogen bonding as required in parts (a) and (b). They also had general knowledge of chemical bond formation and hybridization processes on central atom in compounds. The candidates gave correct explanations of the conditions necessary for the formation of hydrogen bonding in part (a) and cited the types and effects of hydrogen bonding on melting points of compounds exhibiting hydrogen bonding and solubility of compounds in polar solvents in parts (b). In part (c) the candidates correctly determined the type of hybridization of the central atom in the compound implying that they had mastered the types of bonds. Extract 3.1 shows a sample of correct responses to question 3.



3. (a)(i) The hydrogen atom should be bonded covalently to the highly electronegative atom such as Oxygen and nitrogen.

(ii) Another electronegative atom must contain lone pair for donation of electrons in order to form bond.

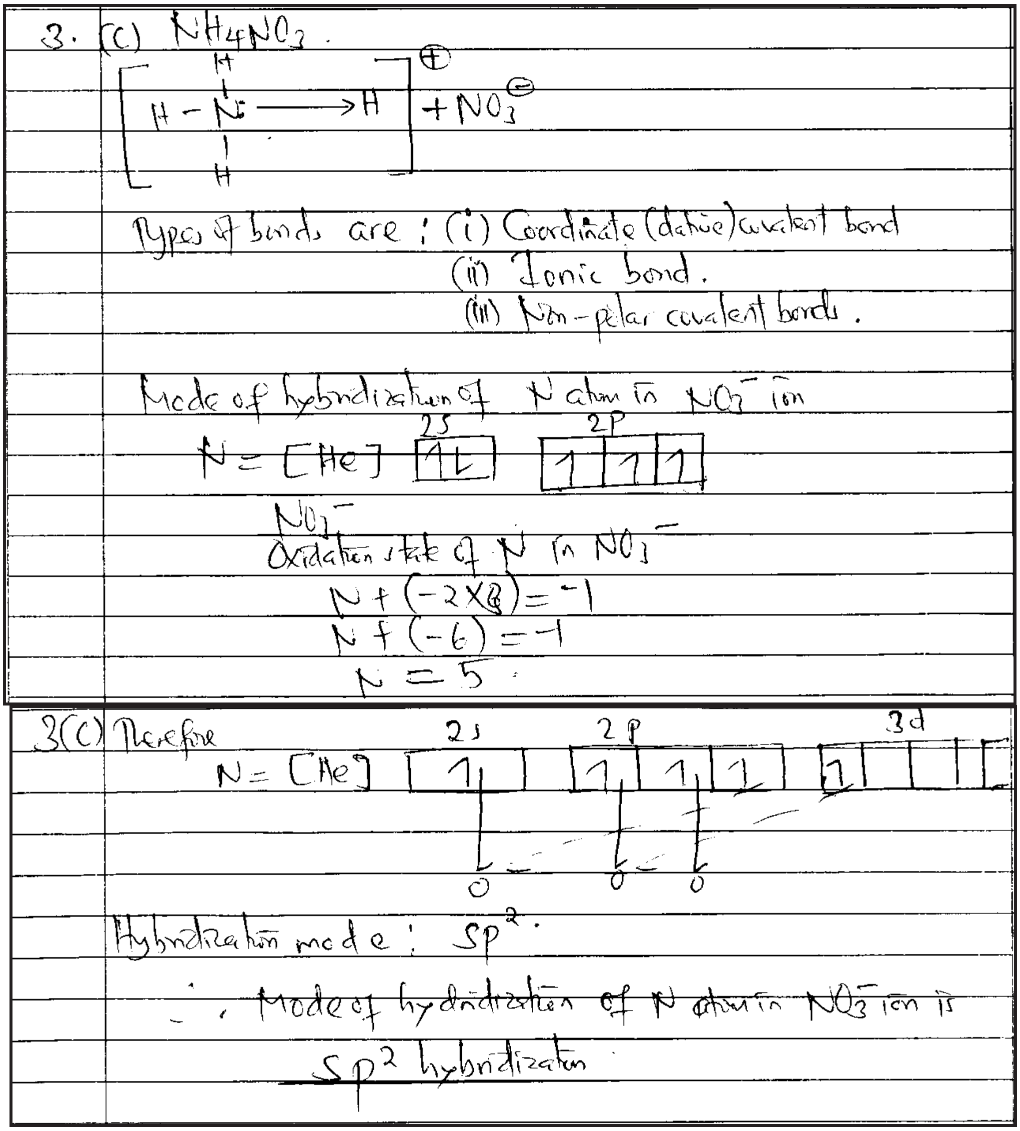
3. (b)(i) Compound I – Intramolecular hydrogen bonding.

Reason: It is formed between hydrogen atom and highly electronegative atom contained in the same molecule.

Compound II – Intermolecular hydrogen bonding.
Reason: It is formed between hydrogen of one molecule and the highly electronegative atom of the different molecule.

3 (b) (ii) Compound II has higher melting point than compound I because, it forms many hydrogen bonds with other molecules thus increases its strength and melting point while compound I forms only one hydrogen bond within itself thus lower melting point.

(iii) Compound II is more soluble in polar solvent like water because it can form hydrogen bond with the polar solvent hence increases its solubility while Compound I can not form hydrogen bond with polar solvents thus reduces its solubility.



3\. (c) NH_4NO_3 .

$$\left[H - \overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{N:}}}} \longrightarrow H \right]^{\oplus} + NO_3^{\ominus}$$

Types of bonds are ; (i) Coordinate (dative) covalent bond

(ii) Ionic bond.

(iii) Non-polar covalent bonds .

Mode of hybridization of N atom in NO_3^- ion

$N = [He]$ 2s $\boxed{\uparrow\downarrow}$ 2p $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

NO_3^-

Oxidation state of N in NO_3^-

$N + (-2 \times 3) = -1$

$N + (-6) = -1$

$N = 5$.

3(c) Therefore

$N = [He]$ 2s $\boxed{\uparrow}$ 2p $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$ 3d $\boxed{\uparrow}\boxed{\ }\boxed{\ }\boxed{\ }$

O O O

Hybridization mode : sp^2 .

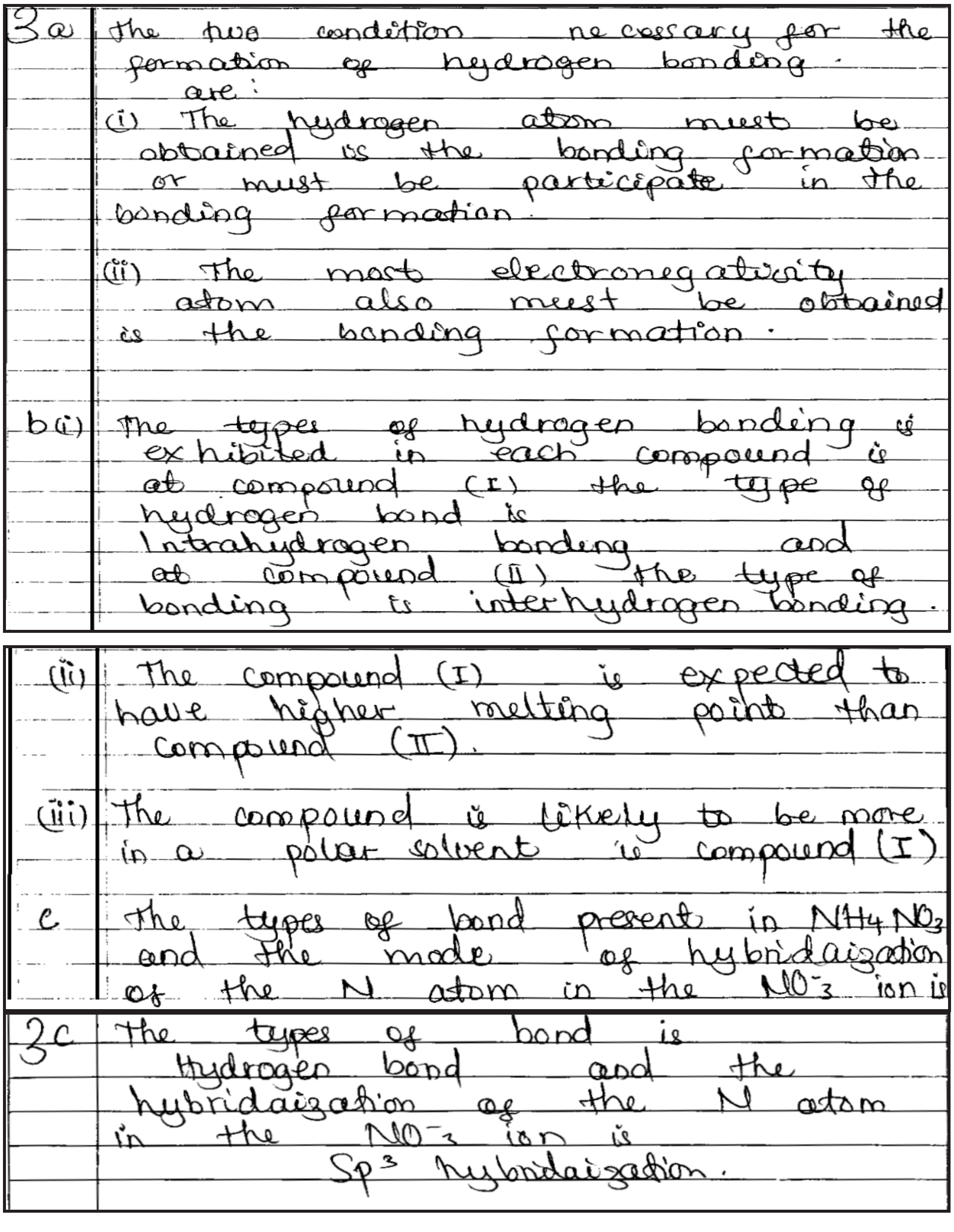
∴ Mode of hydridization of N atom in NO_3^- ion is sp^2 hybridization

Extract 3.1: A sample of the correct responses to Question 3 Paper 1

In Extract 3.1, the candidate demonstrated good understanding of the concepts tested. These include conditions necessary for the formation of hydrogen bonding, types of hydrogen bonding (*ortho and para H-bonding*) and the effects of hydrogen bonding on the physical properties of compounds *(melting point and solubility)* in parts (a) and (b). In part (c), the candidate stated the types of chemical bonds present in the compound given (*ionic, dative and normal covalent bonding)* together with the hybridization process of the central atom, N in NO_3^- .

On the other hand, some candidates (22.79%) did not perform well in this question. They demonstrated lack of knowledge on the general concept of hydrogen bonding by failing to give the conditions necessary for the bond formation and explain the types and effects of hydrogen bonding. These candidates failed to understand that the highly electronegative atom must possess at least one lone pair for the formation of hydrogen bond. For example, in H_2O, O has two lone pairs of electrons and in NH_3, N has one lone pair, hence both H_2O and NH_3 form hydrogen bonding. Also, the candidates could not give difference between *o-nitrophenol* and *p-nitrophenol* as intra and inter-hydrogen bonding respectively. They also failed to explain their effects on the properties of compounds. The candidates failed to recognize that *p-nitrophenol* forms many hydrogen bonds while *o-nitrophenol* forms only one hydrogen bond, thus causing differences in their effects on the physical properties of compounds.

In part (c), the candidates gave wrong types of bonds present in the compound. This means that they lacked knowledge of the concept of chemical bonding especially dative bond formed by N *(in NH_3)* donating lone pair of electrons to H^+ to form NH_4^+. The candidates were not conversant with the rules and processes for hybridization, hence they could not determine the type of hybridization of the central atom in part (c). Similarly, these candidates failed to identify N as the central atom and gave wrong types of hybridization due to failure to realize the correct electronic configuration. Extract 3.2 shows a sample of incorrect responses to question 3.



3a the two condition necessary for the formation of hydrogen bonding are:
(i) The hydrogen atom must be obtained is the bonding formation or must be participate in the bonding formation.
(ii) The most electronegativity atom also must be obtained is the bonding formation.

b(i) The types of hydrogen bonding is exhibited in each compound is at compound (I) the type of hydrogen bond is Intrahydrogen bonding and at compound (II) the type of bonding is interhydrogen bonding.

(ii) The compound (I) is expected to have higher melting point than compound (II).

(iii) The compound is likely to be more in a polar solvent is compound (I)

c The types of bond present in NH_4NO_3 and the mode of hybridaization of the N atom in the NO^-_3 ion is

3c The types of bond is hydrogen bond and the hybridaization of the N atom in the NO^-_3 ion is Sp^3 hybridaization.

Extract 3.2: A sample of incorrect responses to Question 3 Paper 1

In Extract 3.2, the candidate outlined the nature of atoms produced in bonding instead of giving conditions for the formation of hydrogen bonding in part (a). In part (b)(i), he/she wrote intrahydrogen and interhydrogen bonding instead of intramolecular and intermolecular hydrogen bonding respectively. The rest of the responses in part (b) were incorrect as well. In part (c), the candidate did not write the ground state electronic configuration of nitrogen which is the first step in hybridization process. He/she finally assigned nitrogen sp^3 hybridization instead of sp^2 hybridization.

2.1.4 Question 4: The Atom

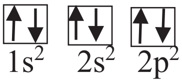
This question had three parts: (a), (b) and (c) as follows:

(a) *All radiations are associated with wave nature and differ from one another in terms of wavelength, frequency, velocity and energy. Give the relationship between the following:*

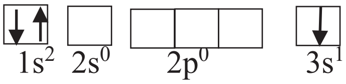
(i) *Frequency and wavelength*
(ii) *Wavelength and wavenumber*
(iii) *Energy and frequency*
(iv) *Energy and wavelength*

(b) *Indicate whether the following electronic configurations are possible or impossible. For the impossible ones, specify the rules which have been violated.*

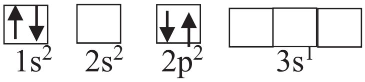
(i)



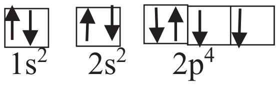
(ii)



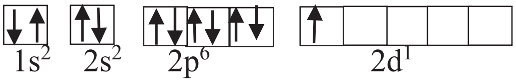
(iii)



(iv)



(v)



(c) *How many orbitals are there in each of the following subshells?*

(i) *2p*
(ii) *3d*

The question was attempted by 37,805 (100%) candidates. Among them, 3,369 (8.91%) scored 0–3 marks, 7,365 (19.48%) scored 3.5–5.5 marks, and 27,071 (71.61%) scored 6.0–10 marks. The data show that 34,436 (91.09%) passed as they scored 3.5 marks or above, implying that the overall performance of the candidates in this question was good. A summary of candidates' performance in this question is shown in Figure 4.

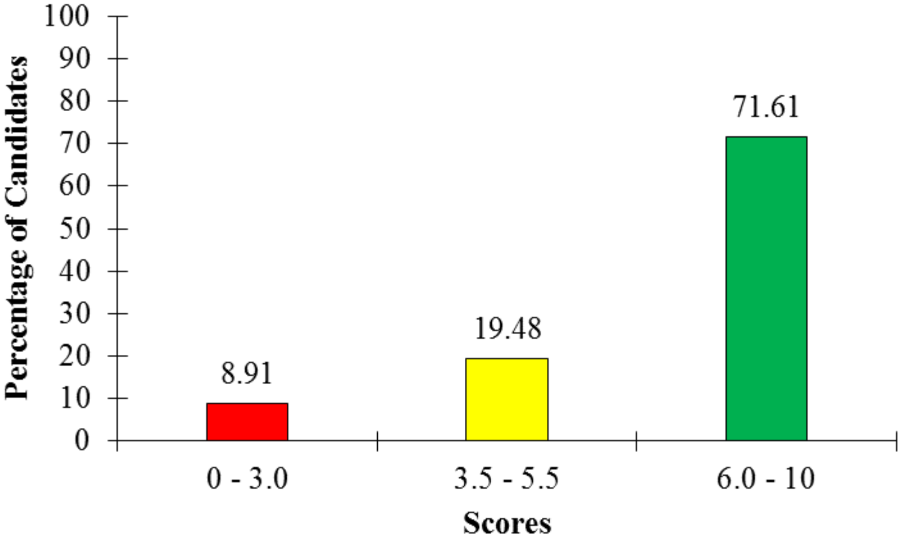


Figure 4: *Candidates Performance in Question 4 Paper 1*

The candidates who scored highly in this question (71.61%) had a good understanding of wave parameters such as *wavelength, frequency, energy* and *wave number* ($E = h\nu,\ where\ \nu = c \times \frac{1}{\lambda}$) in part (a). The candidates were also knowledgeable about the rules governing filling of electrons in the atomic orbitals which are Aufbau's principle and Hund's rule of maximum multiplicity. Through this, the candidates identified the possible and the impossible electrons configurations in part (b). In part (c), the candidates correctly applied the concept of quantum numbers; hence, they gave the correct number of orbitals present in 2p and 3d sub-shells. Extract 4.1 shows one of the correct responses to this question.

4. (a)(i) The relation frequency and wavelength

from

$c = \lambda F$.

$F = c/\lambda$.

Therelation is frequency is inversily to wavelength . hence .

$F = c/\lambda$.

(ii) Wavelength and wave number

$\frac{1}{\lambda} = \bar{v}$

wave number is inversily proportional to wale length . hence .

$1/\lambda = \bar{v}$

(iii). Energy and frequency .

from $E = hf$.

The energy is directly proportional to frequency hence .

$E = hf$.

(iv). Energy and wavolength

from $E = hf$ but $f = c/\lambda$.

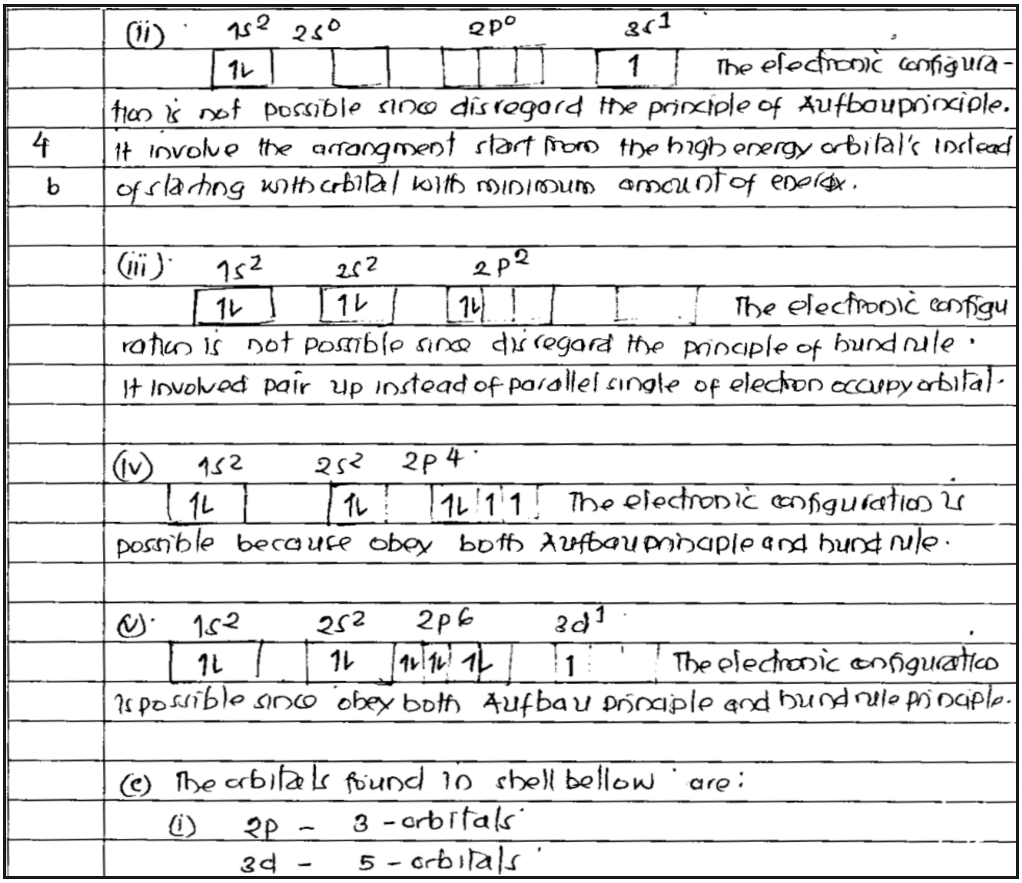
$E = \frac{hc}{\lambda}$.

the energy is inversily proportional to wavolength, hence

$E = \frac{hc}{\lambda}$

(b). (i). $1s^2$ $2s^2$ $2p^2$

$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$, The electronic configuration is not possible since violet or dis regard the principle of hund rule . at orbital 2P .



(ii) $1s^2$ $2s^0$ $2p^0$ $3s^1$

↑↓ | | | | | ↑ The electronic configura-
tion is not possible since disregard the principle of Aufbauprinciple.
4 It involve the arrangment start from the high energy orbital's instead
b of starting with orbital with minimum amount of energy.

(iii) $1s^2$ $2s^2$ $2p^2$

↑↓ | ↑↓ | ↑↓ | | The electronic configu
ration is not possible since disregard the principle of hund rule.
It involved pair up instead of parallel single of electron occupy orbital.

(iv) $1s^2$ $2s^2$ $2p^4$

↑↓ | ↑↓ | ↑↓ ↑ ↑ The electronic configuration is
possible because obey both Aufbau principle and hund rule.

(v) $1s^2$ $2s^2$ $2p^6$ $3d^1$

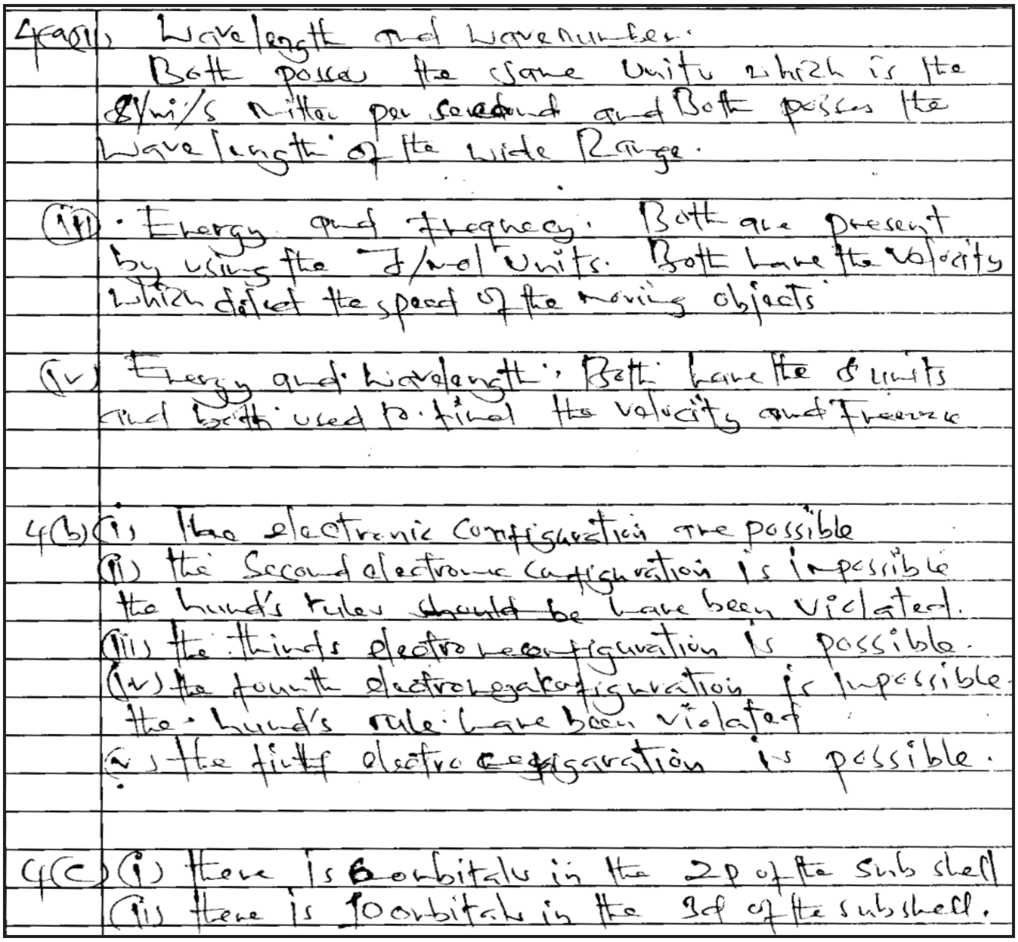
↑↓ | ↑↓ | ↑↓ ↑↓ ↑↓ | ↑ | | The electronic configuration
is possible since obey both Aufbau principle and hund rule principle.

(c) The orbitals found in shell bellow are:
(i) 2p - 3 - orbitals
3d - 5 - orbitals

Extract 4.1: A sample of the correct responses to Question 4 Paper 1

In Extract 4.1, the candidate correctly showed the relationship between the wave parameters, justified the possible and impossible electronic configuration, and gave the correct number of orbitals.

On the other hand, 8.91 per cent of the candidates gave incorrect responses due to lack of knowledge on the concept of hydrogen spectrum in relation to its wave parameters in part (a). In part (b), most of them confused the rules governing electronic distribution in atomic orbitals and consequently failed to identify the possible and impossible electronic configurations. Furthermore, in part (c), some of the candidates incorrectly indicated that 2p sub-shell has got 2 instead of 3 orbitals while others indicated that there are 3 instead of 5 orbitals in subshell 3d. Generally, the candidates demonstrated poor knowledge of the concept of quantum numbers. Extract 4.2 shows one of the incorrect responses given by a candidate.



4(a)(i) Wavelength and wavenumber.
Both posses the same Units which is the ~~8~~ m/s mitter per ~~seco~~ second and Both posses the wavelength of the wide Range.

(iii) • Energy and Frequency. Both are present by using the J/mol Units. Both have the velocity which defect the speed of the moving objects

(iv) Energy and wavelength: Both have the J units and both used to find the velocity and Freeze

4(b)(i) the electronic Configuration are possible
(ii) the Second electronic configuration is impossible the hund's rules ~~should~~ ~~be~~ have been violated.
(iii) the thirds electro ~~neco~~ configuration is possible.
(iv) the fourth electronegatconfiguration is impossible. the hund's rule have been violated
(v) the fifth electro ~~co~~ configaration is possible.

4(c)(i) there is 6 orbitals in the 2p of the sub shell
(ii) there is 10 orbitals in the 3d of the subshell.

Extract 4.2: A sample of the incorrect responses to Question 4 Paper 1

Extract 4.2 show that, in part (a) the candidate gave incorrect similarities instead of mathematical relationships between the wave parameters. In part (b), the candidate swapped the possible and impossible electronic distributions and cited inappropriate rules' violation. In part (c), the candidate gave 6 and 10 orbitals instead of 3 and 5 for subshells *2p* and *3d* respectively.

2.1.5 Question 5: Selected Compounds of Metals

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

(a) In the process of manufacturing chemicals, in one of the emerging chemical industries in Tanzania, a chemist performed the following activities:

(i) Exposed sodium metal to air followed by addition of water.

(ii) Burned sodium metal in air followed by addition of water.
Briefly, explain the chemical processes that took place while supporting your answer with balanced chemical equation in each case.

(b) Using balanced chemical equations, describe the reactions between the oxides of lead, aluminium and calcium with dilute;

(i) Sulphuric acid

(ii) Nitric acid

The question was attempted by 37,805 (100%) candidates. The analysis of statistical data indicates that 29,585 (78.26%) scored from 0–3 marks, 6,567 (17.37%) scored from 3.5–5.5 marks and 1,653 (4.37%) scored from 6–10 marks. The overall performance of the candidates on this question was weak since only 8,220 (21.74%) candidates scored 3.5 marks or above. The candidates' performance in this question is summarized in Figure 5.

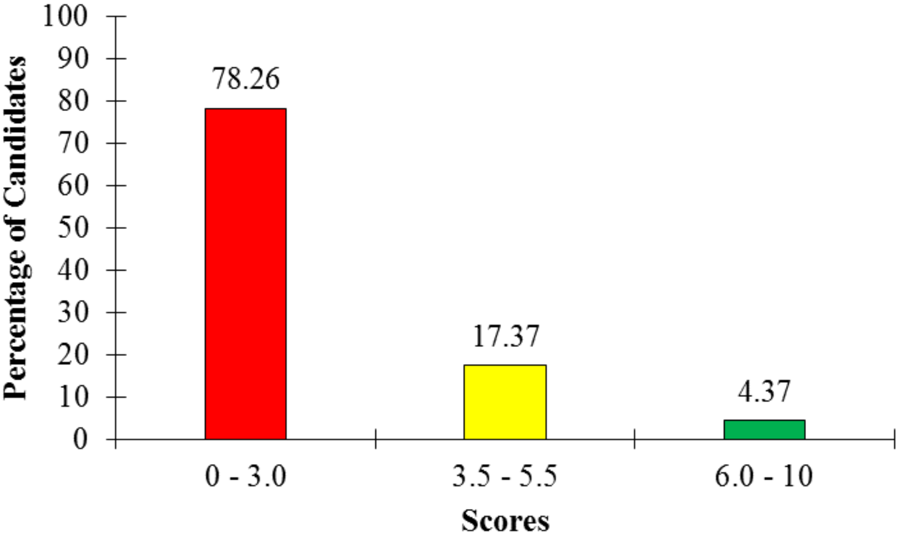
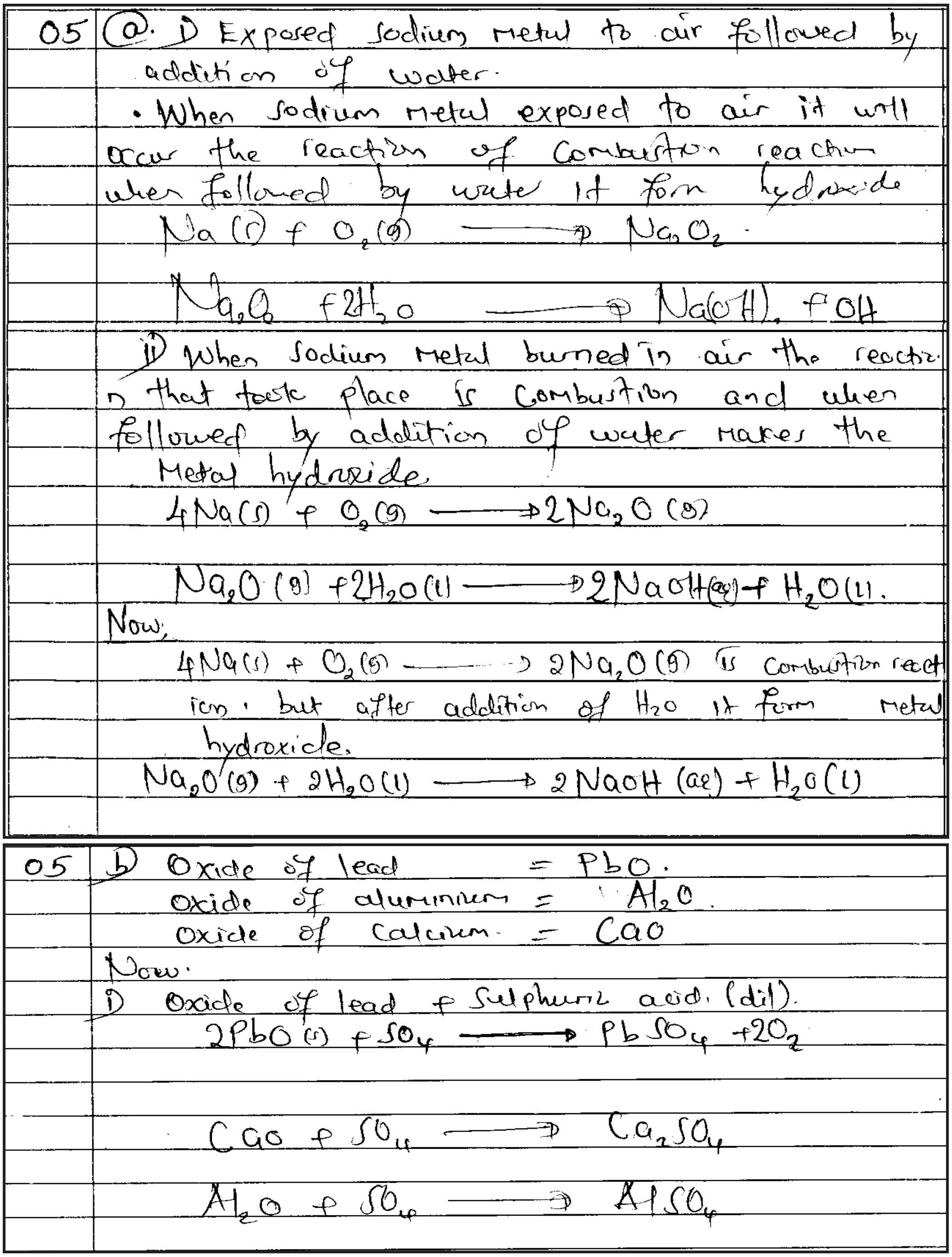


Figure 5: *Candidates' Performance in Question 5 Paper 1*

The candidates who scored low marks (78.26%) failed to give balanced chemical equations for the chemical reactions stated in parts (a) and (b). The analysis shows that some candidates who responded to part (a) (i) by giving sodium hydroxide instead of sodium oxide as the product formed after exposing the metal in air. However, other candidates indicated sodium oxide instead of sodium peroxide as the product of heating sodium. This means that the candidates had sufficient knowledge of the concept of preparation of oxides of reactive metals by direct method. In part (b), the candidates failed to write balanced chemical equations describing the chemical reactions between the given metal oxides and the dilute acids. For example, some of the candidates wrote incorrect chemical formulas for the products such as AlO_3 (for aluminium oxide), $AlSO_4$ (for aluminium sulphate) and Pb_2O (for lead oxide) instead of Al_2O_3, $Al_2(SO_4)_3$ and PbO. Extract 5.1 shows incorrect responses from one of the candidates.



05 @. i) Exposed sodium metal to air followed by addition of water.

- When sodium metal exposed to air it will occur the reaction of combustion reaction when followed by water it form hydroxide

$Na (s) + O_2(g) \longrightarrow Na_2O_2$.

$Na_2O_2 + 2H_2o \longrightarrow Na(OH)_2 + OH$

ii) When sodium metal burned in air the reaction that took place is combustion and when followed by addition of water makes the Metal hydroxide.

$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$

$Na_2O(s) + 2H_2o(l) \longrightarrow 2NaOH(aq) + H_2O(l)$.

Now,

$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$ is combustion reaction. but after addition of H_2o it form metal hydroxide.

$Na_2O(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2O(l)$

05 b) Oxide of lead = PbO.
Oxide of aluminium = Al_2O.
Oxide of calcium = Cao

Now.

i) Oxide of lead + sulphuric acid. (dil).

$2PbO(s) + SO_4 \longrightarrow PbSO_4 + 2O_2$

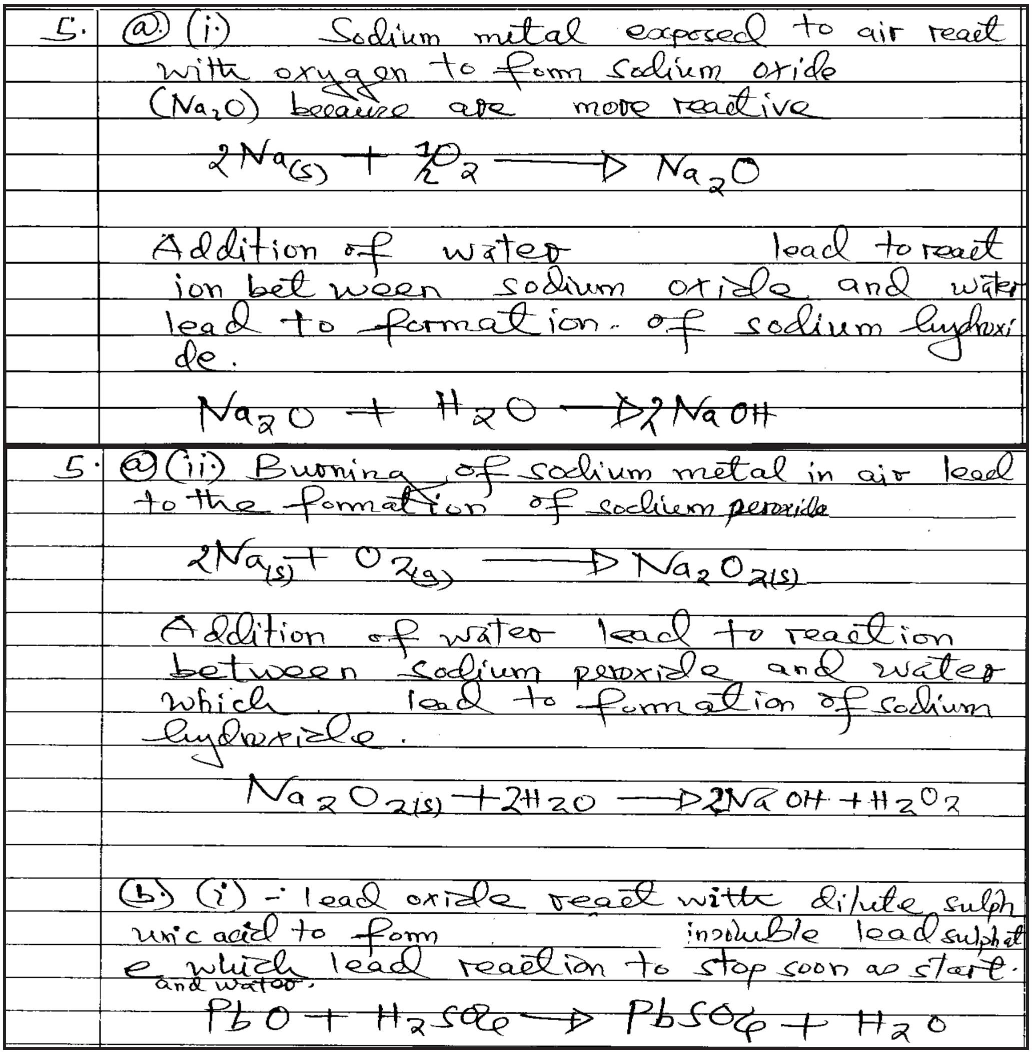
$Cao + SO_4 \longrightarrow Ca_2SO_4$

$Al_2O + SO_4 \longrightarrow AlSO_4$

Extract 5.1: A sample of the incorrect responses to Question 5 Paper 1

In Extract 5.1, the candidate gave incorrect chemical equations and wrote chemical formulas incorrectly by using small letter “o” instead of capital letter O for oxygen in compounds such as water, aluminium oxide and calcium oxide.

The candidates who scored high marks (4.37%) had sufficient knowledge about the preparation of reactive metal oxides by direct method and their subsequent reactions with water and dilute acids. The candidates indicated Na_2O (for sodium oxide) and Na_2O_2 (for sodium peroxide) formed by exposure of sodium metal to air and burning it in air respectively, and the different products formed (oxides) were then reacted with water. Extract 5.2 shows a sample of good responses from a candidate who scored highly in this question.



5. (a) (i) Sodium metal exposed to air react with oxygen to form sodium oxide (Na_2O) because are more reactive

$$2Na_{(s)} + \frac{1}{2}O_2 \longrightarrow Na_2O$$

Addition of water lead to reaction between sodium oxide and water lead to formation of sodium hydroxide.

$$Na_2O + H_2O \longrightarrow 2NaOH$$

5. (a) (ii) Burning of sodium metal in air lead to the formation of sodium peroxide

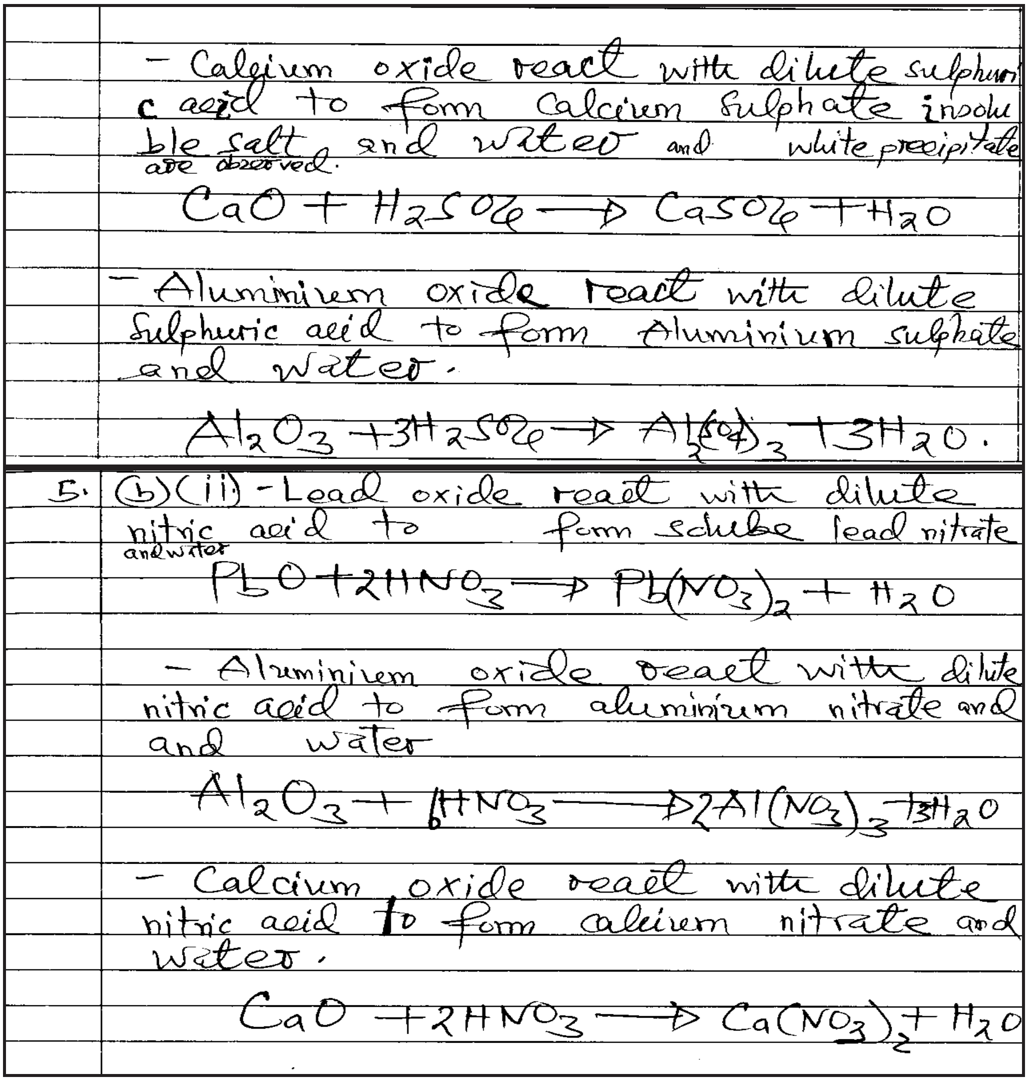
$$2Na_{(s)} + O_{2(g)} \longrightarrow Na_2O_{2(s)}$$

Addition of water lead to reaction between sodium peroxide and water which lead to formation of sodium hydroxide.

$$Na_2O_{2(s)} + 2H_2O \longrightarrow 2NaOH + H_2O_2$$

(b) (i) - lead oxide react with dilute sulphuric acid to form insoluble lead sulphate and water which lead reaction to stop soon as start.

$$PbO + H_2SO_4 \longrightarrow PbSO_4 + H_2O$$



- Calcium oxide react with dilute sulphuric acid to form Calcium Sulphate insoluble salt and water and white precipitate are observed.

$CaO + H_2SO_4 \rightarrow CaSO_4 + H_2O$

- Aluminium oxide react with dilute sulphuric acid to form Aluminium sulphate and water.

$Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$.

5. (b)(ii) - Lead oxide react with dilute nitric acid to form soluble lead nitrate and water

$PbO + 2HNO_3 \rightarrow Pb(NO_3)_2 + H_2O$

- Aluminium oxide react with dilute nitric acid to form aluminium nitrate and and water

$Al_2O_3 + 6HNO_3 \rightarrow 2Al(NO_3)_3 + 3H_2O$

- Calcium oxide react with dilute nitric acid to form calcium nitrate and water.

$CaO + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O$

Extract 5.2: A sample of the correct responses to Question 5 Paper 1

In Extract 5.2, part (a), the candidate explained the chemical processes with the aid of balanced chemical equations. In part (b), he/she correctly wrote balanced chemical equations for the reactions between each of the given metal oxides and the two dilute acids.

2.1.6 Question 6: Energetics

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

(a) Differentiate between the two terms given in sub parts (i) and (ii)
  (i) Born-Haber cycle and enthalpy of formation.
  (ii) Heat of neutralization and heat of solution.

(b) *You are given an equation representing hydrogenation of ethene as $C_2H_4(g) + H_2(g) \rightarrow CH_3CH_3(g)$. What would be the value of standard enthalpy of hydrogenation of ethene (in kJ) if the bond enthalpies were: C–H = 416, C=C =612, C–C = 348 and H–H =436?*

The question was attempted by all 37,805 (100%) candidates and their performance was as follows: 9,417 (24.91%) candidates scored from 0–3 marks, 7,511 (19.87%) scored from 3.5–5.5 marks and 20,877 (55.22%) scored from 6–10 marks. Generally, the candidates' performance in this question was good since 28,388 (67.77%) candidates scored 3.5 marks or above. A summary of the candidates' performance in this question is shown in Figure 6.

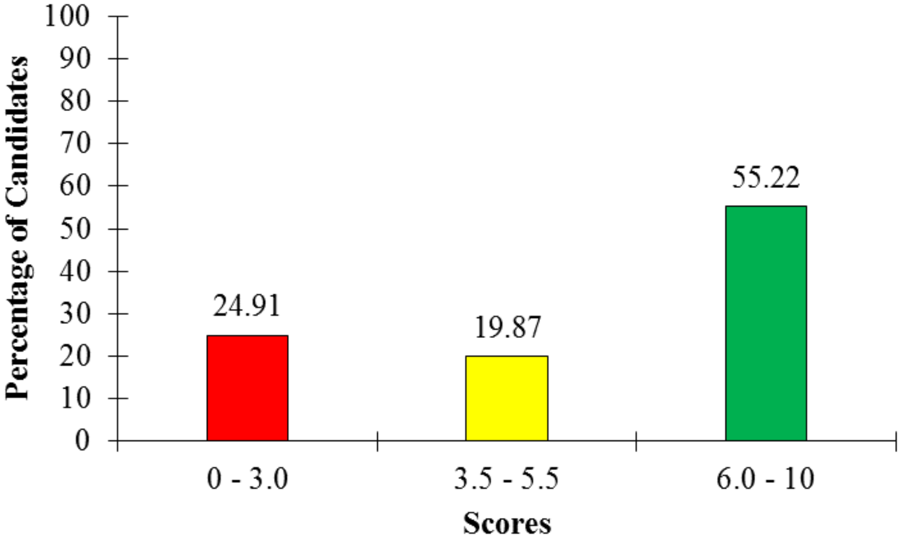


Figure 6: *Candidates' Performance in Question 6 Paper 1*

A total of 20,877 (55.22%) candidates who scored high marks in this question demonstrated good mastery of the general terms used in energetics, such as heat absorbed and heat released, hence they managed to differentiate the terms given in part (a). In part (b), the candidates used correct mathematical manipulations in relating heat of formations and bond enthalpies,
$\Delta Hr = \Sigma_{bond\ energies\ of\ reac\tan ts} - \Sigma_{bond\ energies\ of\ products}$. Thus, they got the correct values of the enthalpies required. Extract 6.1 shows a sample of the correct responses to this question.

6. a) i) Born Haber cycle is the cycle of enthalpy changes used in determining the lattice energy for the formation of ionic crystals.

WHILE;

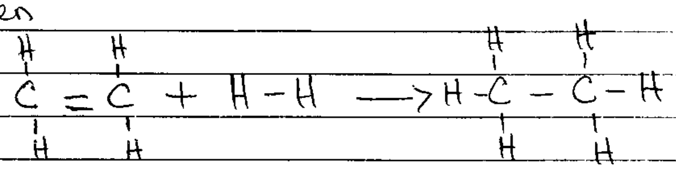
Enthalpy of formation is the heat change when one mole of a substance is formed from it's constituent elements in their normal physical states under given conditions of temperature and pressure.

(ii) Heat of neutralization is the energy evolved when one mole of H^+ from acid is completely neutralized by one mole of OH^- from base to form one mole of water under given conditions of temperature and pressure.

WHILE;

Heat of solution is the amount of heat change when one mole of a substance dissolves in the water to form solution under given conditions of temperature and pressure.

(b) Given



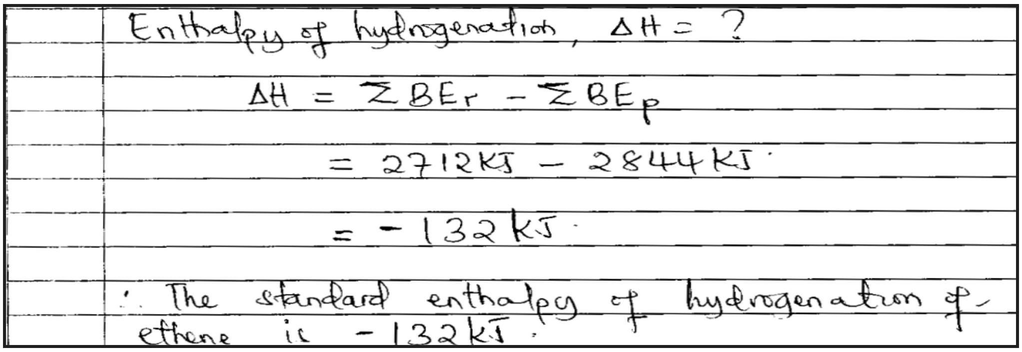
$$H_2C=CH_2 + H-H \longrightarrow H_3C-CH_3$$

To find sum of bond energies of the reactants $\sum BE_r$.

$$\sum BE_r = 1(C=C) + 4(C-H) + 1(H-H)$$
$$= (612 + 4 \times 416)\ kJ + 436$$
$$\sum BE_r = 2276\ kJ + 436$$
$$= 2712\ kJ.$$

6. (b) To find sum of BE of products.

$$\sum BE_p = 1(C-C) + 6(C-H).$$
$$= (348 + 6 \times 416)\ kJ.$$
$$\sum BE_p = 2844\ kJ.$$



Enthalpy of hydrogenation, $\Delta H = ?$

$\Delta H = \Sigma BE_r - \Sigma BE_p$

$= 2712KJ - 2844KJ$.

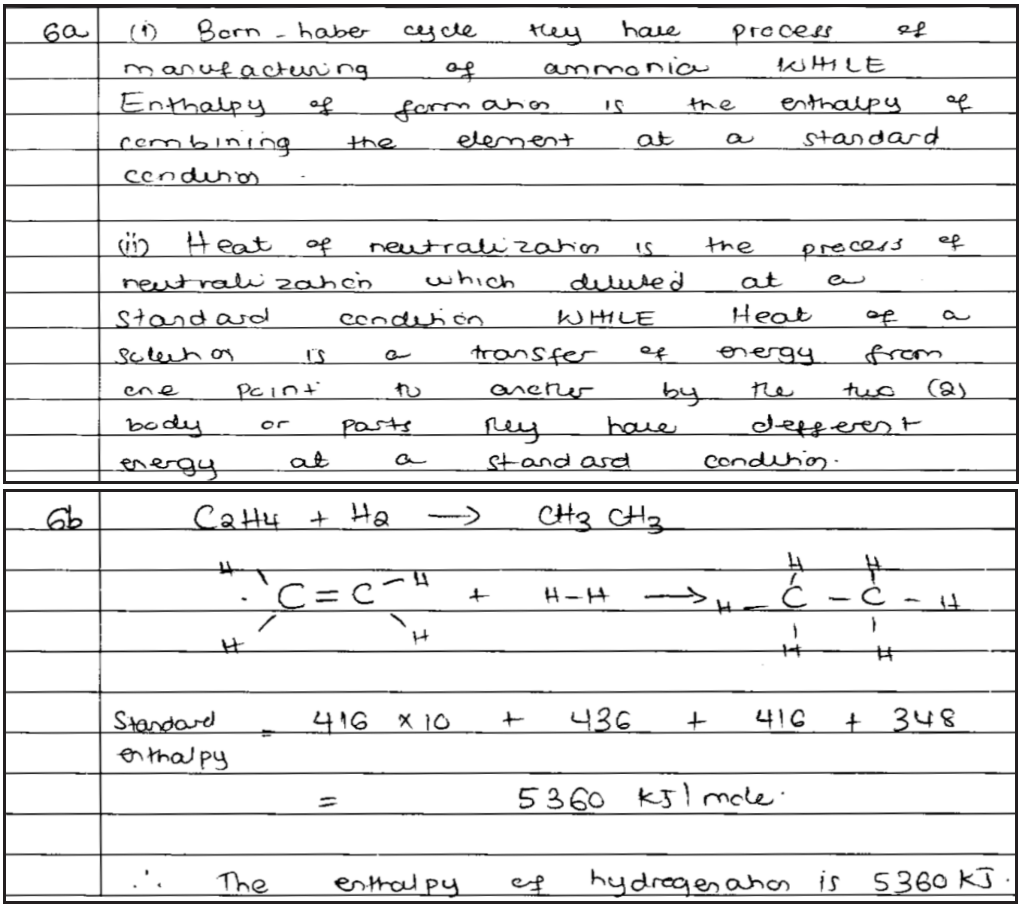
$= -132 KJ$.

∴ The standard enthalpy of hydrogenation of ethene is $-132KJ$.

Extract 6.1: A sample of the correct responses to Question 6 Paper 1

In Extract 6.1, the candidate correctly distinguished the two sets of terms given and applied the correct formula and got standard enthalpy of reaction correctly.

On the other hand, 9,417 (24.91%) candidates scored low marks. Most of these candidates failed to differentiate between the given sets of terms in part (a). For instance, one candidate responded to item (a) (ii) that *heat of neutralization is involved when one litre of acid reacts with one litre of base while heat of solution is when one gram of salt is dissolved in one litre water to form a solution.* In part (b), the candidates used a wrong formula to calculate the standard enthalpy of hydrogenation of ethene. In most cases, the candidates subtracted bond energies of reactants from bond energies of the products instead of doing vice-versa. Other candidates failed to identify the types of bonds present in ethane and consequently multiplied the bond enthalpies with incorrect numbers. For instance, some candidates who multiplied the enthalpy for double bond by 3 instead of 1 and thus failed. Extract 6.2 shows incorrect responses given by one of the candidates.



6a (i) Born - haber cycle they have process of manufacturing of ammonia WHILE Enthalpy of formation is the enthalpy of combining the element at a standard cendition.

(ii) Heat of neutralization is the process of neutralization which diluted at a standard condition WHILE Heat of a solution is a transfer of energy from one point to another by the two (2) body or parts they have defferent energy at a standard condition.

6b $C_2H_4 + H_2 \longrightarrow CH_3CH_3$

Standard enthalpy = 416 x 10 + 436 + 416 + 348

= 5360 kJ/mole.

∴ The enthalpy of hydrogenation is 5360 kJ.

Extract 6.2: A sample of the incorrect responses to Question 6 Paper 1

In Extract 6.2, the candidate distinguished between Haber process and enthalpy of formation instead of Born Haber cycle and enthalpy of formation in part (a) (i). In part (a) (ii), the candidate defined heat of neutralization as a process instead of a quantity. In part (b), the candidate manipulated the values of bond enthalpies incorrectly, however, he/she correctly indicated the structures of the molecules involved.

2.1.7 Question 7: Aliphatic Hydrocarbons

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

(a) Using one chemical test, distinguish the following organic compounds:

(i) $CH_3CH{=}CH_2$ and $CH_3CH_2CH_3$

(ii) $CH_3C{\equiv}CCH_3$ and $CH_3CH_2C{\equiv}CH$

(b) Predict the major product in each of the following organic reactions:

(i) $CH_3C \equiv CCH_3(g) + H_2O(g) \xrightarrow[Hg/H_2SO_4]{H_2SO_4}$

(ii) $CH_3CH_2Br + Na \xrightarrow{dry\ ether}$

(iii) $CH_3CH_3 + Conc.HNO_3 \xrightarrow{heat}$

(iv) $CH_3CH = CH_2 + Br_2 \xrightarrow{U.V.light}$

(c) *A form six student wanted to arrange the following organic compounds in order of increasing acidity of their terminal hydrogen atoms.* $CH{\equiv}CH$; $CH_3C{\equiv}CH$; $(CH_3)_3CC{\equiv}CH$; $ClC{\equiv}CH$; $NO_2C{\equiv}CH$. *Suggest a correct sequence required by the student and give two reasons for your choice of arrangement.*

The analysis show that 37,803 (99.99%) candidates attempted this question and scored as follows: 23,286 (61.60%) scored from 0–3 marks, 8,000 (21.16%) scored from 3.5–5.5 marks and 44,323 (17.24%) scored from 6–10 marks. Generally, the candidates' performance in this question was average as 52,322 (38.40%) candidates scored 3.5 marks or above. A summary of the candidates' performance in this question is shown in Figure 7.

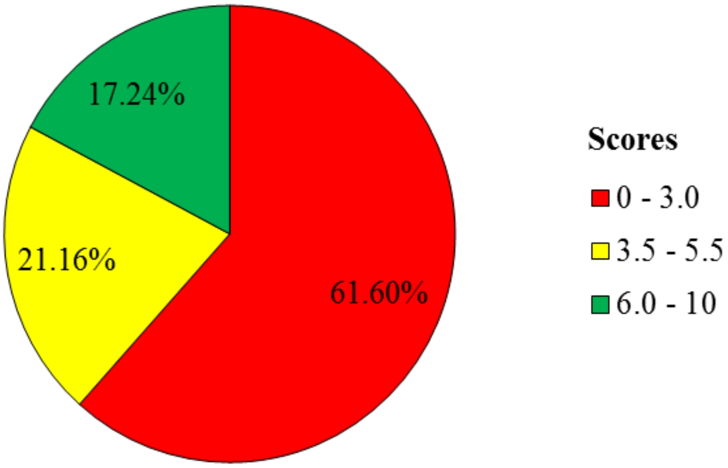
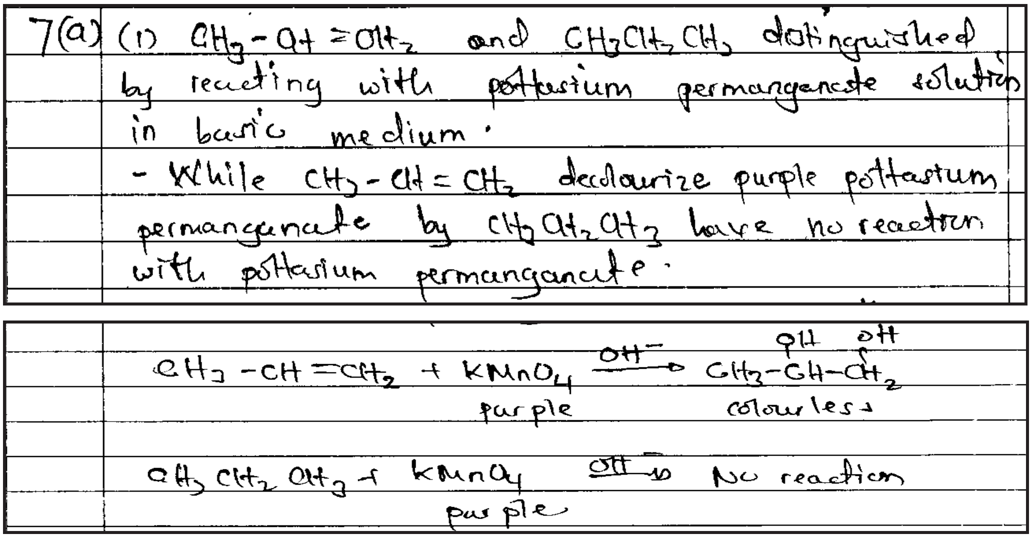


Figure 7: *Candidates' Performance in Question 7 Paper 1*

A total of 44,323 (17.24%) candidates scored high marks in this question as they gave appropriate chemical tests to distinguish between the given sets of aliphatic hydrocarbons (compounds) in part (a). Some of the appropriate reagents mentioned by the candidates include, bromine water, conc. sulphuric acid, potassium permanganate, ammoniacal silver nitrate and copper (I) chloride. In part (b), the candidates predicted the major product from each of the chemical reactions in (i) - (iv). In part (c), the candidates correctly arranged the organic compounds in order of increasing acidity. This implies that the candidates had mastery of the physical properties of aliphatic hydrocarbons due to attached groups. Extract 7.1 shows a sample of the correct responses to this question.

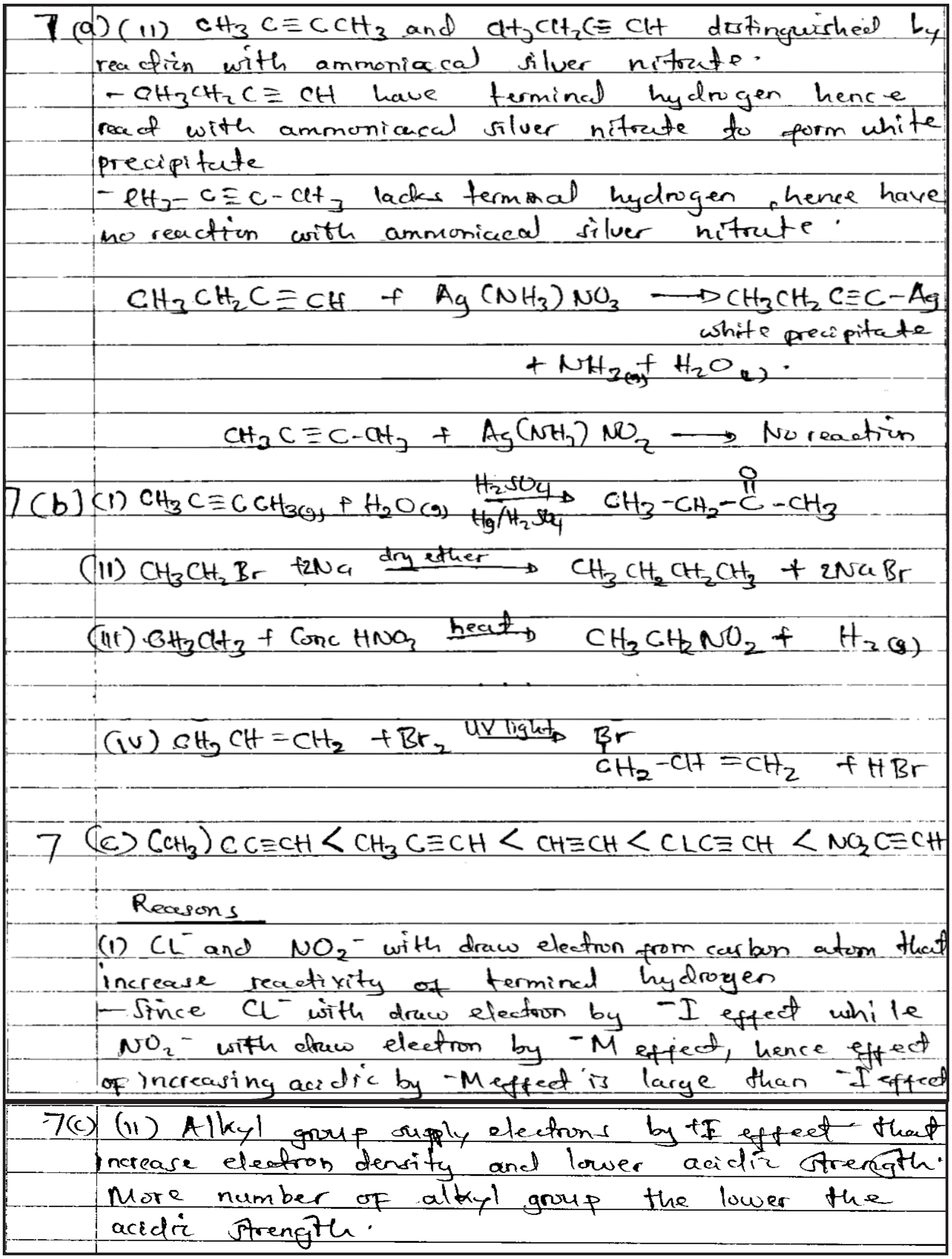


7(a) (i) $CH_3-CH=CH_2$ and $CH_3CH_2CH_3$ distinguished by reacting with pottasium permanganate solution in basic medium.

- While $CH_3-CH=CH_2$ decolourize purple pottasium permanganate by $CH_3CH_2CH_3$ have no reaction with pottasium permanganate.

$$\underset{}{CH_3-CH=CH_2} + \underset{\text{purple}}{KMnO_4} \xrightarrow{OH^-} \underset{\text{colourless}}{CH_3-\overset{OH}{CH}-\overset{OH}{CH_2}}$$

$$CH_3CH_2CH_3 + \underset{\text{purple}}{KMnO_4} \xrightarrow{OH^-} \text{No reaction}$$



7 (a) (ii) $CH_3C\equiv CCH_3$ and $CH_3CH_2C\equiv CH$ distinguished by reaction with ammoniacal silver nitrate.

- $CH_3CH_2C\equiv CH$ have terminal hydrogen hence react with ammoniacal silver nitrate to form white precipitate

- $CH_3-C\equiv C-CH_3$ lacks terminal hydrogen, hence have no reaction with ammoniacal silver nitrate.

$$CH_3CH_2C\equiv CH + Ag(NH_3)NO_3 \longrightarrow CH_3CH_2C\equiv C-Ag$$

white precipitate

$$+ NH_{3(g)} + H_2O_{(l)}.$$

$$CH_3C\equiv C-CH_3 + Ag(NH_3)NO_3 \longrightarrow \text{No reaction}$$

7 (b) (i) $CH_3C\equiv CCH_{3(g)} + H_2O_{(g)} \xrightarrow[Hg/H_2SO_4]{H_2SO_4} CH_3-CH_2-\overset{O}{\overset{\|}{C}}-CH_3$

(ii) $CH_3CH_2Br + 2Na \xrightarrow{\text{dry ether}} CH_3CH_2CH_2CH_3 + 2NaBr$

(iii) $CH_3CH_3 + \text{Conc } HNO_3 \xrightarrow{\text{heat}} CH_3CH_2NO_2 + H_{2(g)}$

(iv) $CH_3CH=CH_2 + Br_2 \xrightarrow{\text{UV light}} \overset{Br}{CH_2}-CH=CH_2 + HBr$

7 (c) $(CH_3)CC\equiv CH < CH_3C\equiv CH < CH\equiv CH < ClC\equiv CH < NO_2C\equiv CH$

Reasons

(i) Cl^- and NO_2^- withdraw electron from carbon atom that increase reactivity of terminal hydrogen

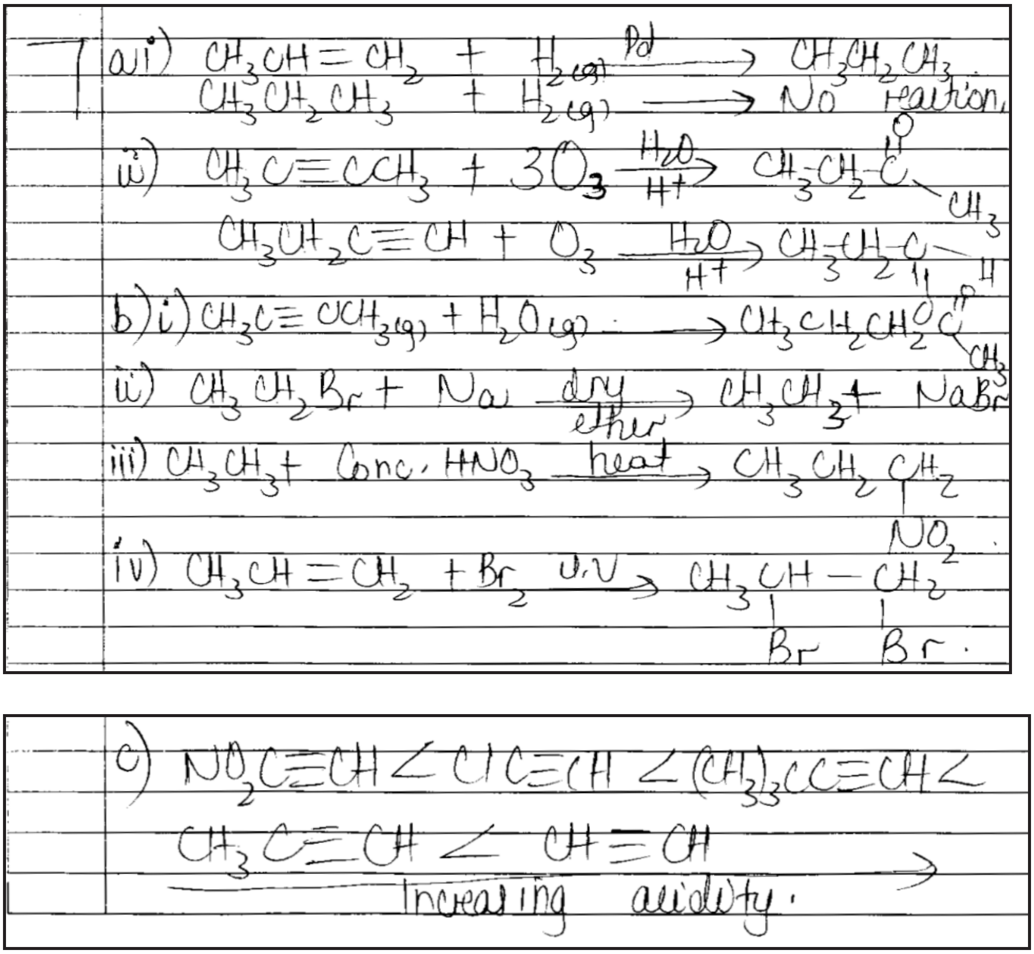
- Since Cl^- withdraw electron by $-I$ effect while NO_2^- withdraw electron by $-M$ effect, hence effect of increasing acidic by $-M$ effect is large than $-I$ effect

7(c) (ii) Alkyl group supply electrons by $+I$ effect that increase electron density and lower acidic strength. More number of alkyl group the lower the acidic strength.

Extract 7.1: A sample of the correct responses to Question 7 Paper 1

In Extract 7.1, the candidate gave appropriate chemical tests to distinguish between the sets of organic compounds in part (a). In part (b), he/she predicted the major organic products for each reaction. In part (c), the candidate correctly arranged the given sets of organic compounds in the required order with justification of how the attached group affects the bond strength.

On the contrary, 23,286 (61.60%) candidates scored low marks because they gave incorrect responses to most parts of the question. Some of them suggested improper chemical tests in part (a). For instance, some of the candidates suggested the use of alkyl halide to distinguish propene from propane in item (i), which is not correct. In part (b), some of the candidates predicted minor instead of the major products. Few candidates wrote both products without specifying the major ones. Similarly, some candidates gave incorrect products that cannot be formed from the reactions due to several reasons. For example, some candidates confused the conditions for the bromination of alkene under U.V with that of bromination of alkene in darkness, thus they gave quite different products. In addition, in the reaction between alkene and water, the candidates gave incorrect product of *2-butanol* (alcohol) instead of *2-butanone* (ketone). In part (c), some of the candidates arranged the compounds in order of decreasing acidity while others arranged them in order of increasing number of carbon atoms. The candidates had poor understanding of the effect of the attached groups (CH_3, Cl *and* NO_2), the size of alkyl groups and electronegativity differences on the acidic character of the hydrocarbons. Extract 7.2 shows one of the incorrect responses to this question.



7 (a) i) $CH_3CH=CH_2 + H_{2(g)} \xrightarrow{Pd} CH_3CH_2CH_3$.

$CH_3CH_2CH_3 + H_{2(g)} \longrightarrow$ No reaction.

ii) $CH_3C\equiv CCH_3 + 3O_3 \xrightarrow[H^+]{H_2O} CH_3-CH_2-\overset{O}{\overset{\|}{C}}-CH_3$

$CH_3CH_2C\equiv CH + O_3 \xrightarrow[H^+]{H_2O} CH_3-CH_2-\underset{\|}{C}-H$

b) i) $CH_3C\equiv CCH_{3(g)} + H_2O_{(g)} \longrightarrow CH_3CH_2CH_2\overset{O}{\overset{\|}{C}}-CH_3$

ii) $CH_3CH_2Br + Na \xrightarrow[ether]{dry} CH_3CH_3 + NaBr$

iii) $CH_3CH_3 + Conc.\ HNO_3 \xrightarrow{heat} CH_3CH_2\underset{NO_2}{\underset{|}{CH_2}}$.

iv) $CH_3CH=CH_2 + Br_2 \xrightarrow{U.V} CH_3\underset{Br}{\underset{|}{CH}}-\underset{Br}{\underset{|}{CH_2}}$.

c) $NO_2C\equiv CH < ClC\equiv CH < (CH_3)_3CC\equiv CH <$
$CH_3C\equiv CH < CH\equiv CH$

$\longrightarrow$ Increasing acidity.

Extract 7.2: A sample of the incorrect responses to Question 7 Paper 1

In Extract 7.2, the candidate wrote inapropriate chemical tests (*hydrogenation and ozonolysis reaction*) to distinguish between the given sets of aliphatic hydrocarbons in part (a). He/she predicted incorrect products for reactions (i) to (iv). In part (c), the candidate positioned nitroethyne as the least acidic instead of the most acidic compounds. Also, other compounds were incorrectly positioned in the series.

2.1.8 Question 8: Chemical Equilibrium

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

(a) (i) A chemical system at equilibrium is dynamic. Explain briefly the meaning of this statement.

(ii) The equilibrium constant K_p for the reaction

$CCl_4(g) \rightarrow C(s) + 2Cl_2(g)$ is 0.76 atm at 978 K. Calculate the initial pressure of carbon tetrachloride that will produce a total equilibrium pressure of 1.28 atm at 978 K.

(b) (i) Why the solubility of CO_2 in soft drinks like Coca-Cola decreases with rise in temperature? Briefly explain.

(ii) What happens to the equilibrium in a reversible reaction if a catalyst is added to it? Explain briefly.

(iii) What happens to equilibrium constant of an exothermic reaction if temperature is raised? Explain briefly.

(c) When a yellow solution of iron(III) chloride and a colorless solution of potassium thiocyanate (KSCN) are mixed in a test tube, a red color appears according to the following equilibrium:

$$Fe^{3+}(\mathrm{aq}) + \mathrm{SCN}^{-}(aq) \rightleftharpoons [Fe(SCN)]^{2+}(aq)$$

red solution

(i) What would be the effect on Fe^{3+} ions upon addition of KSCN to the equilibrium?

(ii) What would happen to the equilibrium position when the pressure of the system was to be doubled? Briefly explain.

(iii) The red color faded when the test tube containing the equilibrium mixture was placed in an ice-water bath. Briefly explain whether the value of Kc for this reaction is high or low and whether the reaction is exothermic or endothermic.

The question was answered by 27,970 (73.98%) candidates. Statistics show that 16,169 (57.81%) of the candidates scored from 0–5 marks, 511 (30.43%) scored from 5.5–8.5 marks and 3,290 (11.76%) scored from 9–15 marks. Overall, 1,801 (42.19%) candidates scored from 5.5–15 marks. The general performance of the candidates in this question was average.

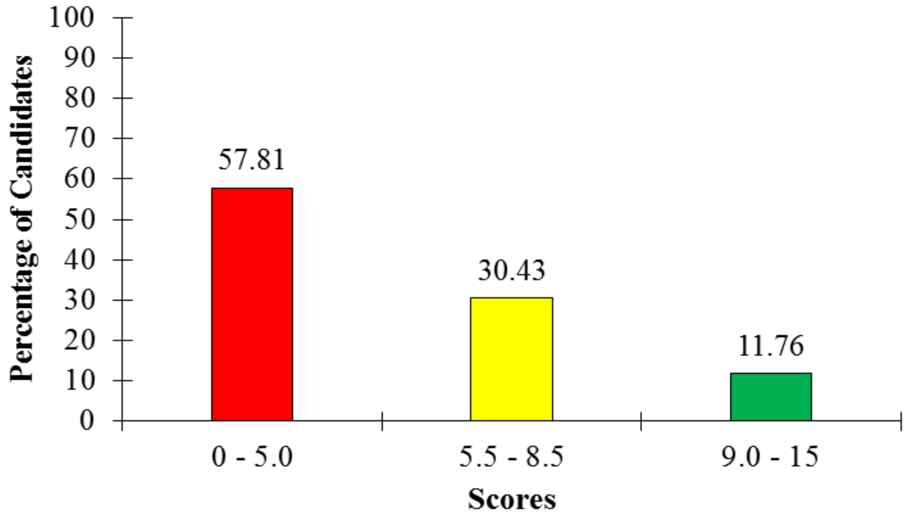


Figure 8: *Candidates Performance in Question 8 Paper 1*

The candidates who performed well (11.76%) explained the dynamic nature of a chemical system at equilibrium in part (a). They also calculated the initial pressure of carbon tetrachloride based on the law of mass action. In part (b) and (c), the candidates gave correct explanations which suggested they had mastered the factors affecting chemical equilibrium and application of Le-Chatelier's principle. Extract 8.1 is a sample of the correct responses to question 8.

8(a) i/ Dynamic equilibrium mean that both foward and backward reaction still proceed but in a very low rate that concetration seem to remain constant.

ii/ $CCl_{4(g)} \rightleftharpoons C_{(s)} + 2Cl_{2(g)}$.

from

$$Kp = \frac{(P_{Cl_2})^2}{P_{CCl_4}}$$

but $Kp = 0.76$ atm.

$P_T = 1.2$ atm

let initial pressure be x.

$CCl_{4(g)} \rightleftharpoons C_{(s)} + 2Cl_{2(g)}$.

Initial;	x	0	0
Change;	$x - y$	0	$+2y$.
Equilibrium;	$x - y$	0	$2y$

but

Total pressure $P_T = x - y + 2y$.

$1.2 = x + y$. – – –(i)

$$0.76atm = \frac{(2y)^2}{x-y} \text{ atm.}$$

$0.76(x - y) = 4y^2$. – – –(ii)

From equation(i)

$x = 1.2 - y$.

$0.76(1.2 - y - y) = 4y^2$.

$0.76(1.2 - 2y) = 4y^2$.

$0.912 - 1.52y = 4y^2$.

$4y^2 + 1.52y - 0.912 = 0$

$y = 0.324$ atm and -0.7atm

since no negative pressure

8a ii) $y = 0.324$ atm.

from

$x = 1.2 - y$

$x = 1.2 - 0.324$ atm

$x = 0.876$atm

∴ The initial pressure is 0.876 atm.

8b i/ Because dissolving of CO_2 in soft drinks is an exothermic process therefore when temperature rises the reverse process is favoured and so CO_2 became insoluble in soft drinks.

ii/ Catalyst has no effect on a reversible reaction since it affects both forward and backward reaction and so equilibrium remains the same.

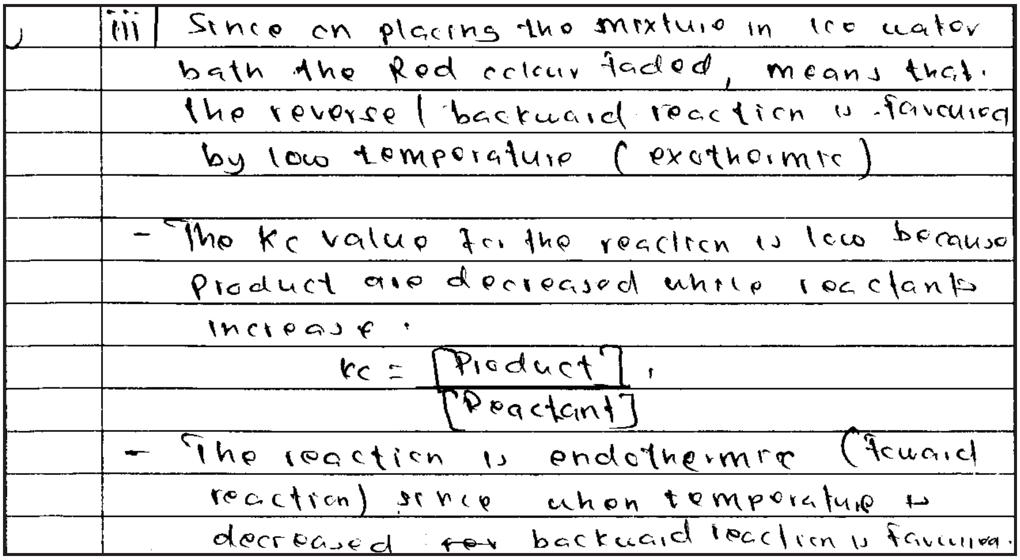
iii/ If temperature is raised the equilibrium constant is decreased.
Because $Kc = \frac{[\text{Products}]}{[\text{Reactants}]}$
when temperature is raised then the amount of reactants is increased while that of products is decreased making equilibrium constant is lowered

8c $Fe^{3+}_{(aq)} + SCN^-_{(aq)} \rightleftharpoons [Fe(SCN)]^{2+}_{(aq)}$

i/ Upon addition of KSCN, the concentration of SCN^- increases and so as to maintain equilibrium, it is shifted towards right. This make Fe^{3+} ions to <u>Decrease</u>. Since they react with excess SCN^-

ii/ Upon adding / doubling pressure there will be no effect observed
Because.
Pressure has effect only on gaseous reactants as gases also exert pressure. So in the given reaction pressure has no effect.

iii/ Since on placing the mixture in ice water bath the Red colour faded, means that the reverse / backward reaction is favoured by low temperature (exothermic)



iii Since on placing the mixture in ice water bath the Red colour faded, means that. the reverse / backward reaction is favouring by low temperature (exothermic)

- The Kc value for the reaction is low because Product are decreased while reactants increase.

$$K_c = \frac{[\text{Product}]}{[\text{Reactant}]}$$

- The reaction is endothermic (forward reaction) since when temperature is decreased ~~for~~ backward reaction is favoured.

Extract 8.1: A sample of the correct responses to Question 8 Paper 1

On the contrary, 57.81% of the candidates who attempted this question gave incorrect explanations in part (a) (i). Some of them explained reversible reaction instead of dynamic equilibrium. For instance, one candidate wrote "*Equilibrium is dynamic when the products can form reactants again*". In item (a) (ii) some of the candidates calculated reaction quotient instead of initial concentration of carbon tetrachloride. In part (b), the candidates gave explanations that are not true while others gave vague ones. For instance, in item (b)(i), one candidate wrote "*Rise in temperature causes viscosity of coca cola to increase*". The candidate introduced the concept of viscosity instead of exothermic process and solubility. In item (b) (ii), the candidates gave a wrong explanation on the incorrect function of catalyst in a reversible reaction. For instance, some of them explained that catalyst lowers the activation energy. The candidates interpreted a catalyst as a factor affecting the rate of chemical reactions instead of position of chemical equilibrium. In part (c), the candidates gave responses that do not comply with the Le-Chatelier's principle. For example, several candidates responded to item (c)(ii) by explaining that pressure would affect the position of the equilibrium. They failed to recall that pressure has no effect on aqueous solutions because they cannot be compressed easily. Extract 8.2 shows incorrect responses given by one candidate to this question.

8 a) i) Dynamic equilibrium is the equilibrium which have the same phases.

ii) Solution.

$CCl_{4(g)} \rightarrow C_{(s)} + 2Cl_{2(g)}$

Given $kp = 0.76$.

From.

$kp = \frac{(PCl_2)^2 (PC_{(s)})}{(PCCl_4)}$.

$CCl_4 \rightarrow C_{(s)} + 2Cl_{2(g)}$

x. x $2x$

$0.76 = \frac{(x^2)(x)}{x}$

$x = \sqrt{0.76}$

$x = 0.87$.

∴ The initial pressure is

$0.76 = \frac{(x^2)(x)}{x}$

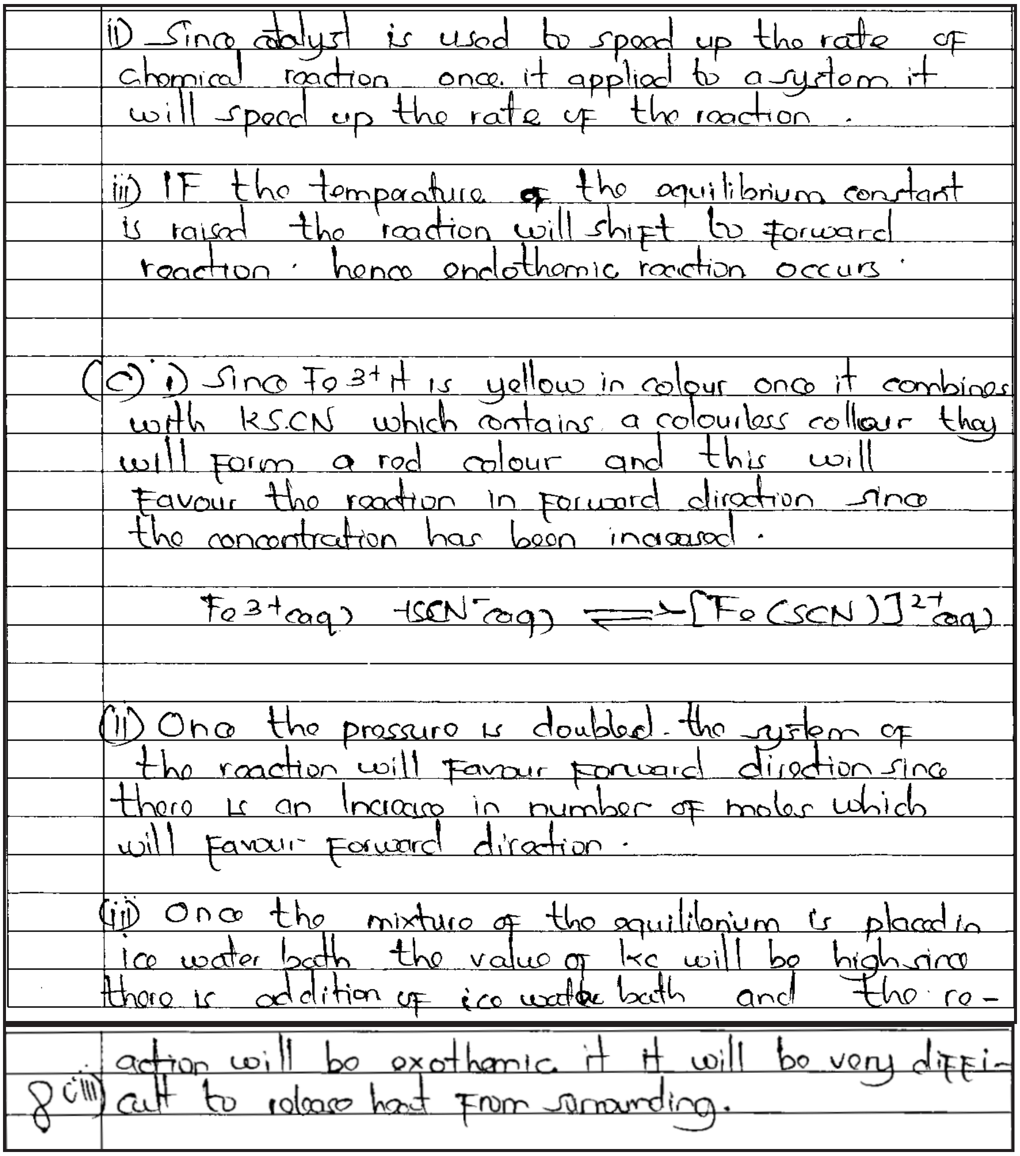
$0.76 = x^2(1.2)^2$

$\sqrt{\frac{0.76}{1.44}} = x$

$x = 0.72$.

∴ The initial pressure is 0.72 atm.

8 b) i) The solubility of CO_2 in soft drinks like coca-cola decrease with rise in temperature since the solubility is inversly proportional to temperature once temperature is increased the solubility of a substance coca-color decreases.



ii) Since catalyst is used to speed up the rate of chemical reaction once it applied to a system it will speed up the rate of the reaction .

iii) IF the temperature ~~of~~ the equilibrium constant is raised the reaction will shift to forward reaction ' hence endothermic reaction occurs '

(c) i) Since Fe 3+ it is yellow in colour once it combines with KSCN which contains a colourless colour they will form a red colour and this will Favour the reaction in forward direction since the concentration has been increased .

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons [Fe(SCN)]^{2+}(aq)$$

(ii) Once the pressure is doubled. the system of the reaction will Favour forward direction since there is an Increase in number of moles which will Favour Forward direction .

(iii) Once the mixture of the equilibrium is placed in ice water bath the value of Kc will be high since there is addition of ice water bath and the reaction will be exothermic it it will be very difficult to release heat From surrounding.

8 c(iii)

Extract 8.2: A sample of the incorrect responses to Question 8 Paper 1

In Extract 8.2, the candidate calculated partial pressure without involving the value of the total equilibrium pressure and thus got a wrong answer in part (a). Additionally, the candidate did not include the decomposition reaction equation that would have included the initial pressure, change in pressure and pressure at equilibrium. In part (b)(iii), he/she termed the reaction endothermic instead of exothermic process. The rest of the responses were also incorrect.

2.1.9 Question 9: Soil Chemistry

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

(a) *After a successful completion of your Secondary Education, some farmers in your area of residence invite you to give a talk as far as the concept of Soil Chemistry is concerned. Briefly, explain each of the following terms while citing one example in each case:*

- *(i) Soil reaction*
- *(ii) Soil colloids*
- *(iii) Liming*
- *(iv) Organic fertilizers*
- *(v) Artificial fertilizers*

(b) *Why is it necessary to measure soil pH? Briefly explain by giving two reasons.*

(c) *A farmer was advised to supply 200 kg of nitrogen on the paddy farm. What would be the mass of a fertilizer with 60% by mass of* $Ca(NO_3)_2$ *which the farmer has to buy in order to meet the nitrogen requirement of the farm?*

The question was attempted by 32,517 (86.01%) out of 37,805 candidates. Analysis of the candidates' performance in this question showed that 8,382 (25.78%) scored from 0–5 marks, 13,624 (41.90%) scored from 5.5–8.5 marks and 10,511 (32.32%) scored from 9–15 marks. Further statistical analysis indicates that 24,135 (74.22%) candidates who attempted this question scored 5.5 marks or above. Thus, the candidates' general performance In this question was good.

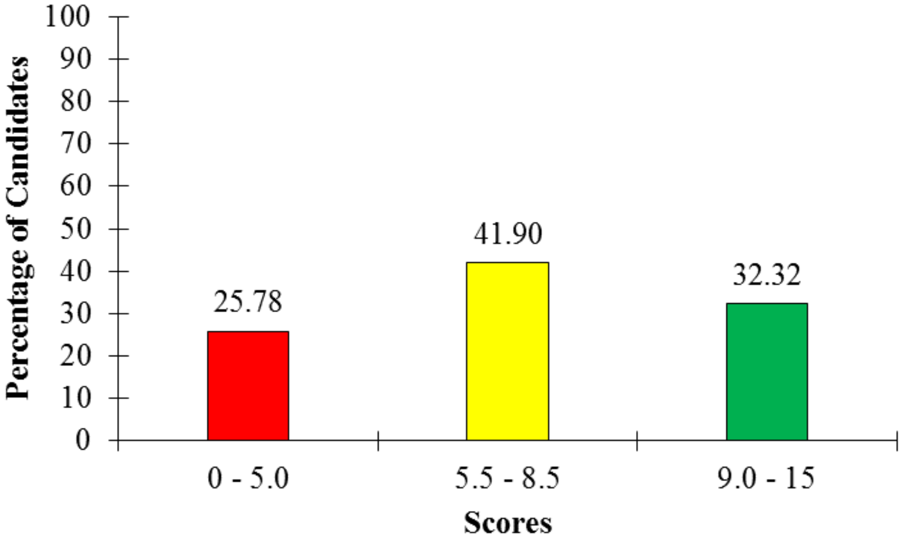
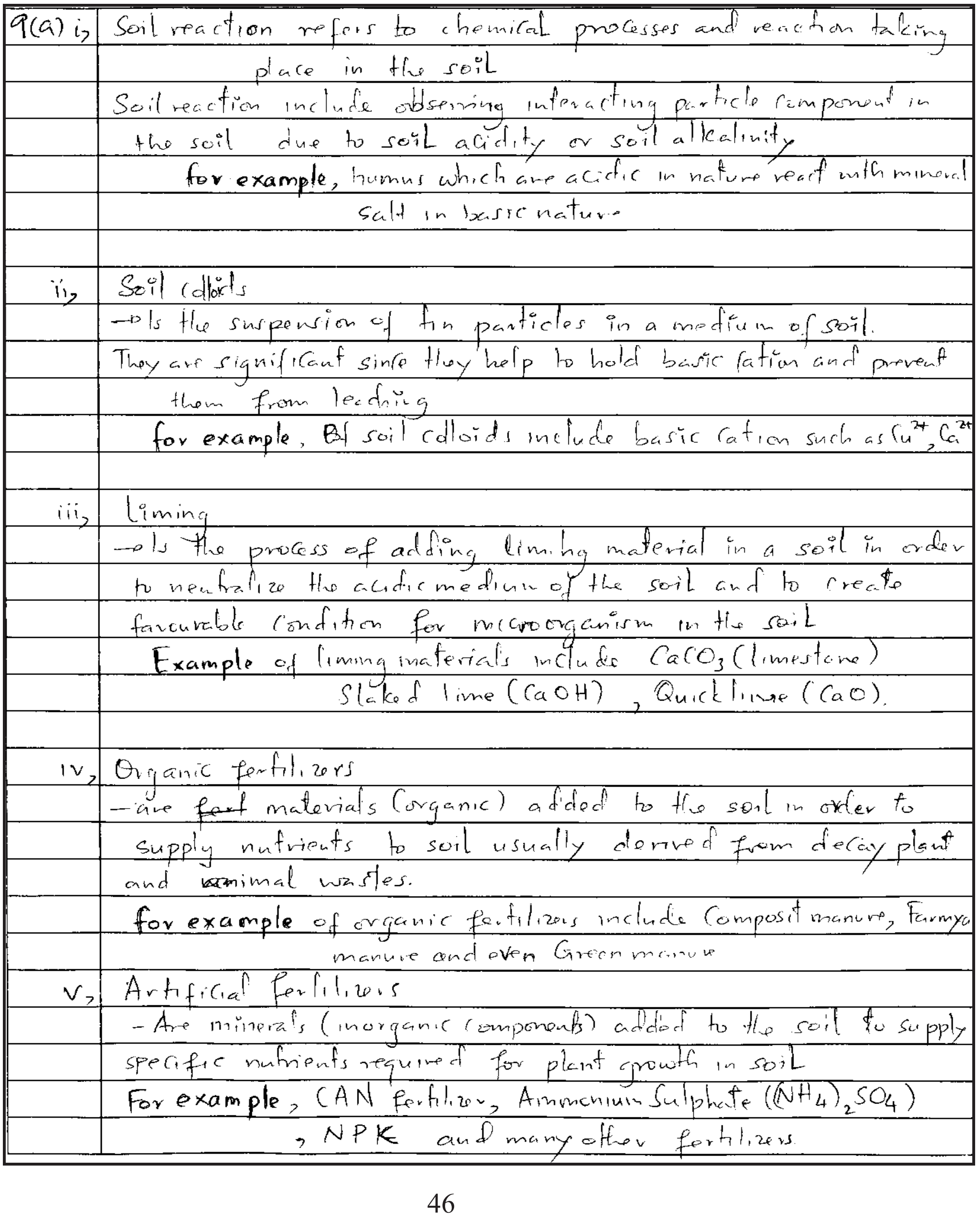


Figure 9: *Candidates' Performance in Question 9 Paper 1*

The candidates (32.32%) who scored high marks in this question demonstrated good mastery of the terminologies used in soil chemistry. They managed to give correct explanations of the terms given together with appropriate examples as was required in part (a). In part (b), the candidates gave clear explanations of the significance of soil pH especially on *redox potential of the soil, activities of the micro-organisms, availability of nutrients and the type of crops to be grown on a particular soil*. In part (c), these candidates followed correct mathematical procedures in calculating the required mass of the fertilizer. Extract 9.1 is a sample of the correct responses to this question.



9(a) i, Soil reaction refers to chemical processes and reaction taking place in the soil

Soil reaction include observing interacting particle component in the soil due to soil acidity or soil alkalinity

for example, humus which are acidic in nature react with mineral salt in basic nature

ii, Soil colloids

→ Is the suspension of fin particles in a medium of soil.

They are significant since they help to hold basic cation and prevent them from leaching

for example, soil colloids include basic cation such as Cu^{2+}, Ca^{2+}

iii, Liming

→ Is the process of adding liming material in a soil in order to neutralize the acidic medium of the soil and to create favourable condition for microorganism in the soil

Example of liming materials include $CaCO_3$ (limestone) Slaked lime (CaOH), Quick lime (CaO).

iv, Organic fertilizers

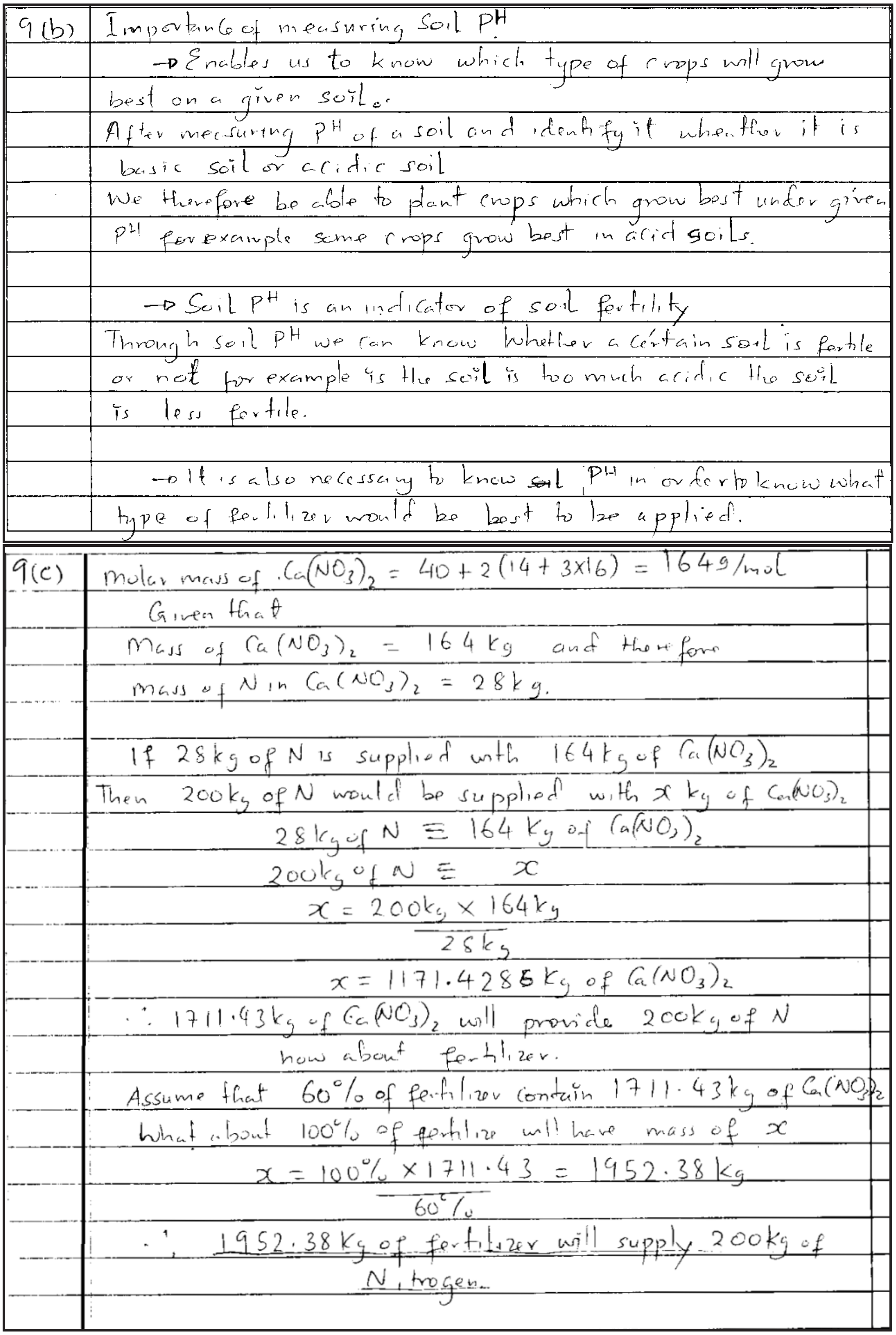
– are ~~fert~~ materials (organic) added to the soil in order to supply nutrients to soil usually derived from decay plant and animal wastes.

for example of organic fertilizers include Composit manure, Farmyard manure and even Green manure

v, Artificial fertilizers

– Are minerals (inorganic components) added to the soil to supply specific nutrients required for plant growth in soil

For example, CAN fertilizer, Ammonium Sulphate ($(NH_4)_2SO_4$), NPK and many other fertilizers.



9 (b) Importance of measuring Soil PH

→ Enables us to know which type of crops will grow best on a given soil.

After measuring PH of a soil and identify it whether it is basic soil or acidic soil

We therefore be able to plant crops which grow best under given PH for example some crops grow best in acid soils.

→ Soil PH is an indicator of soil fertility

Through soil PH we can know whether a certain soil is fertile or not for example is the soil is too much acidic the soil is less fertile.

→ It is also necessary to know ~~soil~~ PH in order to know what type of fertilizer would be best to be applied.

9(c) molar mass of $Ca(NO_3)_2 = 40 + 2(14 + 3 \times 16) = 164 g/mol$

Given that

Mass of $Ca(NO_3)_2$ = 164 kg and therefore

mass of N in $Ca(NO_3)_2$ = 28kg.

If 28kg of N is supplied with 164kg of $Ca(NO_3)_2$

Then 200kg of N would be supplied with x kg of $Ca(NO_3)_2$

28kg of N $\equiv$ 164 kg of $Ca(NO_3)_2$

200kg of N $\equiv$ x

$$x = \frac{200kg \times 164kg}{28kg}$$

x = 1171.4285 kg of $Ca(NO_3)_2$

∴ 1711.43kg of $Ca(NO_3)_2$ will provide 200kg of N

how about fertilizer.

Assume that 60% of fertilizer contain 1711.43kg of $Ca(NO_3)_2$

What about 100% of ~~fertilize~~ will have mass of x

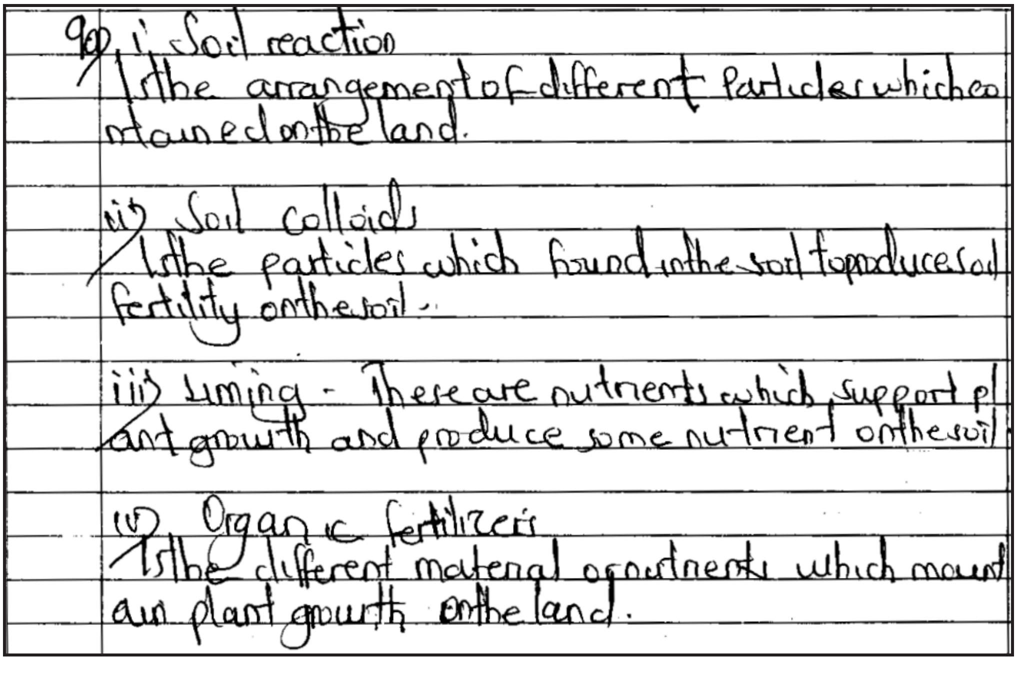
$$x = \frac{100\% \times 1711.43}{60\%} = 1952.38 kg$$

∴ 1952.38 kg of fertilizer will supply 200kg of Nitrogen.

Extract 9.1: A sample of the correct responses to Question 9 Paper 1

In Extract 9.1, the candidate correctly explained the given terms together with the appropriate examples in part (a). Also, the candidate gave a clear explanation of the significance of soil pH in terms of type of crop to be grown and amendments to be done in part (b). In part (c), the candidate applied the concept of fertilizer application ratios and used correct mathematical manipulations to obtain the required mass of the fertilizer (1952.3 kg).

On the other hand, the candidates who scored low marks (25.78%), gave incorrect responses to most parts of the question. These candidates lacked general mastery of the terms used in soil chemistry as required in part (a). For instance, some candidates mentioned NPK as the type of organic fertilizers (instead of artificial fertilizer) while others cited manure as among the artificial fertilizers (instead of organic fertilizer). In part (b), some candidates wrote the pH range instead of explaining the importance of measuring soil pH. Similarly, few candidates defined soil pH without explaining its significance. In part (c), some of the candidates calculated the mass of the fertilizer namelly. For instance, some of them calculated 60 per cent of 200 kg and obtained 120 kg, which was incorrect. The candidates were supposed (among other parameters) to use the molar mass of calcium nitrate. Failure of the candidates in this question was mainly due to insufficient knowledge of soil chemistry and poor mathematical skills. Extract 9.2 shows the sample of the incorrect responses to this question.

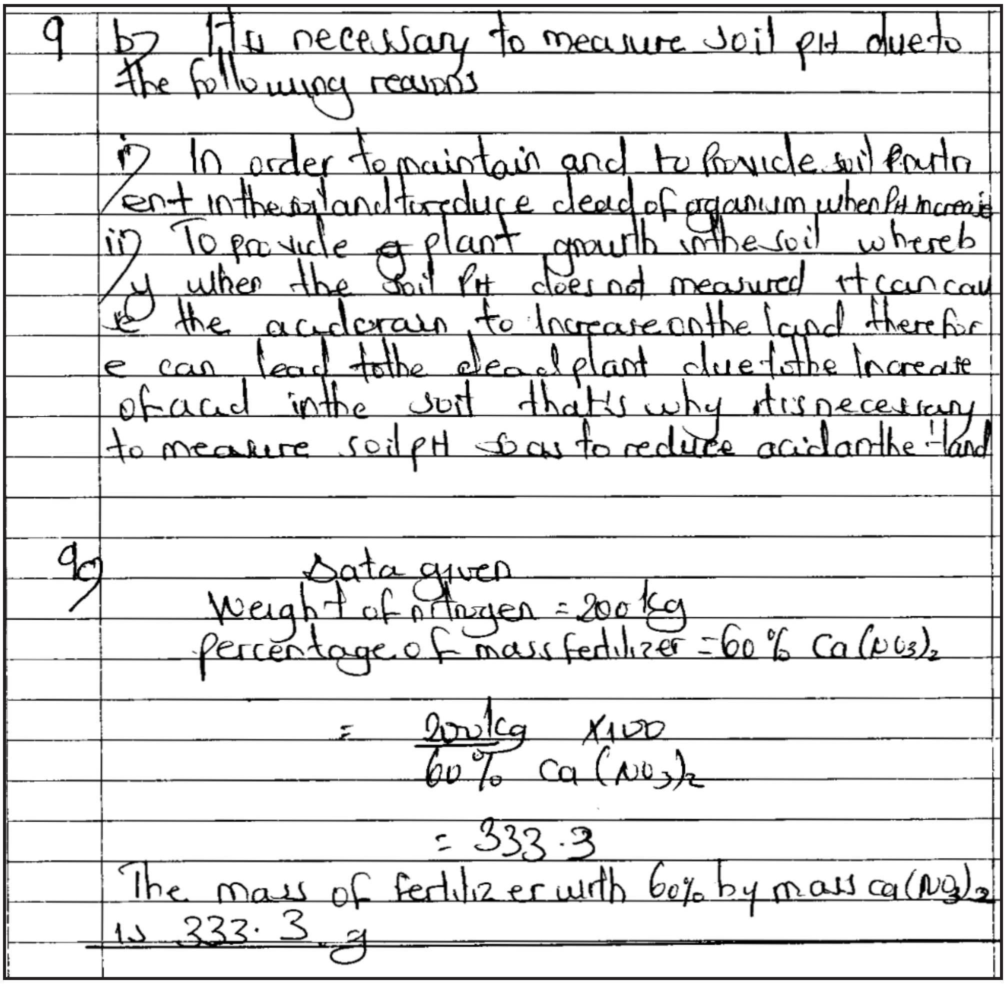


9(a) i. Soil reaction
Is the arrangement of different particles which contained on the land.

ii) Soil colloids
Is the particles which found in the soil to produce soil fertility on the soil.

iii) Liming - There are nutrients which support plant growth and produce some nutrient on the soil.

iv) Organic fertilizers
Is the different material or nutrients which maintain plant growth on the land.



9 b) It is necessary to measure soil pH due to the following reasons

i) In order to maintain and to provide soil partment in the soil and to reduce dead of organism when pH increasing

ii) To provide ~~a~~ plant growth in the soil whereby when the soil pH does not measured it can cause the acid rain to increase on the land therefore can lead to the dead plant due to the increase of acid in the soil that's why it is necessary to measure soil pH ~~so~~ so as to reduce acid on the land

9c) Data given

Weight of nitrogen = 200 kg

percentage of mass fertilizer = 60 % $Ca(NO_3)_2$

$$= \frac{200\,kg \times 100}{60\%\ Ca(NO_3)_2}$$

$= 333.3$

The mass of fertilizer with 60% by mass $Ca(NO_3)_2$ is 333.3 g

Extract 9.2: A sample of the incorrect responses to Question 9 Paper 1

In Extract 9.2, the candidate gave incorrect definitions of the terms given in part (a) and failed to give examples. In part (b), the candidate explained that soil *pH* reduces death of organisms, which is not correct. In part (c), the candidate incorrectly divided the product of 200 kg and 100 with 60%. Additionally, he/she failed to manipulate the units as he/she wrote 333.3 *g* instead of 333.3 kg.

2.1.10 Question 10: Aromatic Hydrocarbons

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

(a) *(i)* *What are the two effects of substituent groups on the reactivity of benzene ring?*

(ii) *By giving one example in each case, briefly justify the statement*

"Despite the fact that both benzene are unsaturated hydrocarbons, benzene undergoes electrophilic substitution reactions whereas alkenes undergo electrophilic addition reactions"

(b) *Why do activators when attached to benzene ring direct the incoming electrophile to ortho and para positions? Briefly explain.*

(c) *Why are the products of nitration of methylbenzene obtained at a shorter time than those of sulphonation of benzene? Explain briefly and support your answer with a chemical equation in each case.*

The question was answered by 15,072 (39.87%) candidates. Analysis of the performance in this question showed that 8,915 (11.65%) scored from 0– 5 marks 4,401 (29.20%) scored from 5.5–8.5 marks and 1,756 (59.15%) scored from 9–15 marks. The overall performance of the candidates in this question was average since 6,157 (40.85%) candidates scored 5.5 marks or above. A summary of the candidates' performance is shown in Figure 10.

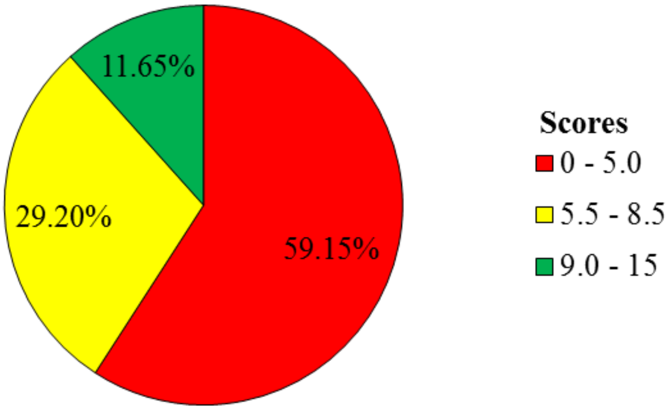
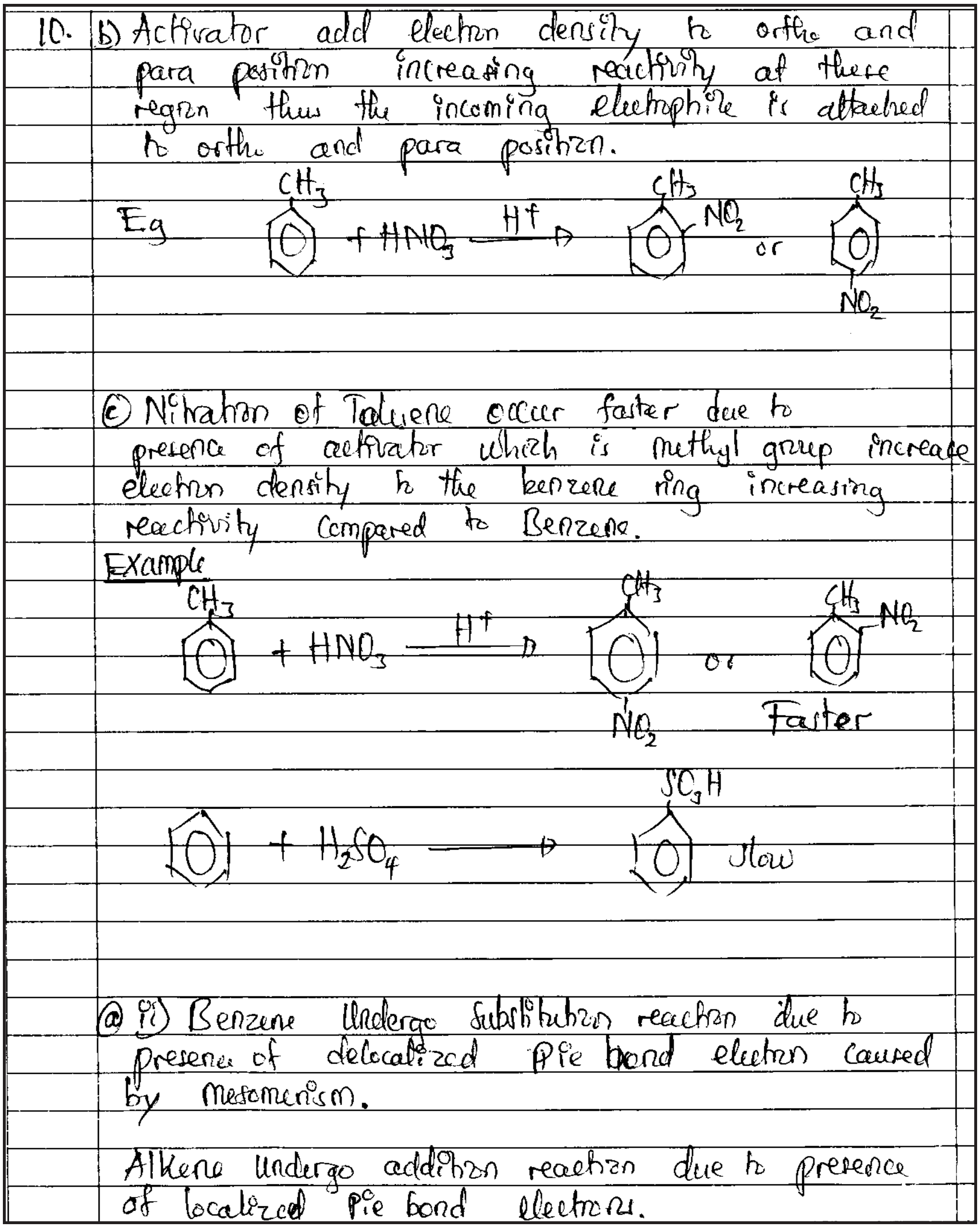


Figure 10: *Candidates' Performance on Question 10 Paper 1*

The candidates who scored high marks in this question (11.65%) had good understanding of the concept of effects of substituent group on the reactivity of benzene. Thus, they gave correct explanations as required in parts (a) and (c). For instance, in part (a)(i), the candidates recognized that activators increase electron density on the benzene ring thereby making it more susceptible to electrophilic attack, hence high reactivity. Similarly, in part (b), the candidates correctly explained the effect of the activators on the benzene ring, that they activate the ortho and para positions increasing the stability of the intermediate carbonium ion. In part (c), the candidates used chemical equation to illustrate why nitration of benzene is faster than sulphonation process. Extract 10.1 is an example of the correct responses to this question.



10. b) Activator add electron density to ortho and para position increasing reactivity at these region thus the incoming electrophile is attached to ortho and para position.

Eg CH_3 + HNO_3 $\xrightarrow{H^+}$ CH_3 NO_2 or CH_3 NO_2

c) Nitration of Toluene occur faster due to presence of activator which is methyl group increase electron density to the benzene ring increasing reactivity compared to Benzene.

Example

CH_3 + HNO_3 $\xrightarrow{H^+}$ CH_3 NO_2 or CH_3 NO_2

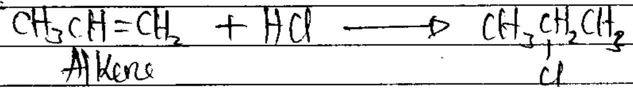
Faster

$+ H_2SO_4 \longrightarrow$ SO_3H Slow

a) ii) Benzene Undergo substitution reaction due to presence of delocalized Pie bond electron caused by mesomerism.

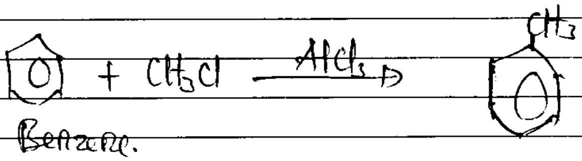
Alkene Undergo addition reaction due to presence of localized Pie bond electrons.

10 ⓐ i) Example:



$CH_3CH=CH_2 + HCl \longrightarrow CH_3\underset{Cl}{CH}CH_3$

Alkene



$AlCl_3$

Benzene.

ii) These effects are
- Inductive effect
- Mesomeric effect.

ⓐ Inductive effect:

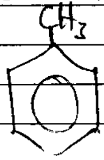
Is the effect caused by partial movement of bonded electron toward the high electronegative atom.

It is divided into two types which are
- Positive inductive effect
- Negative inductive effect.

- Positive inductive effect

Involve partial movement of electron toward the benzene ring by the attached substituent. This increase reactivity of benzene since increase electron density to benzene ring.

Example:



Alkyl grup.

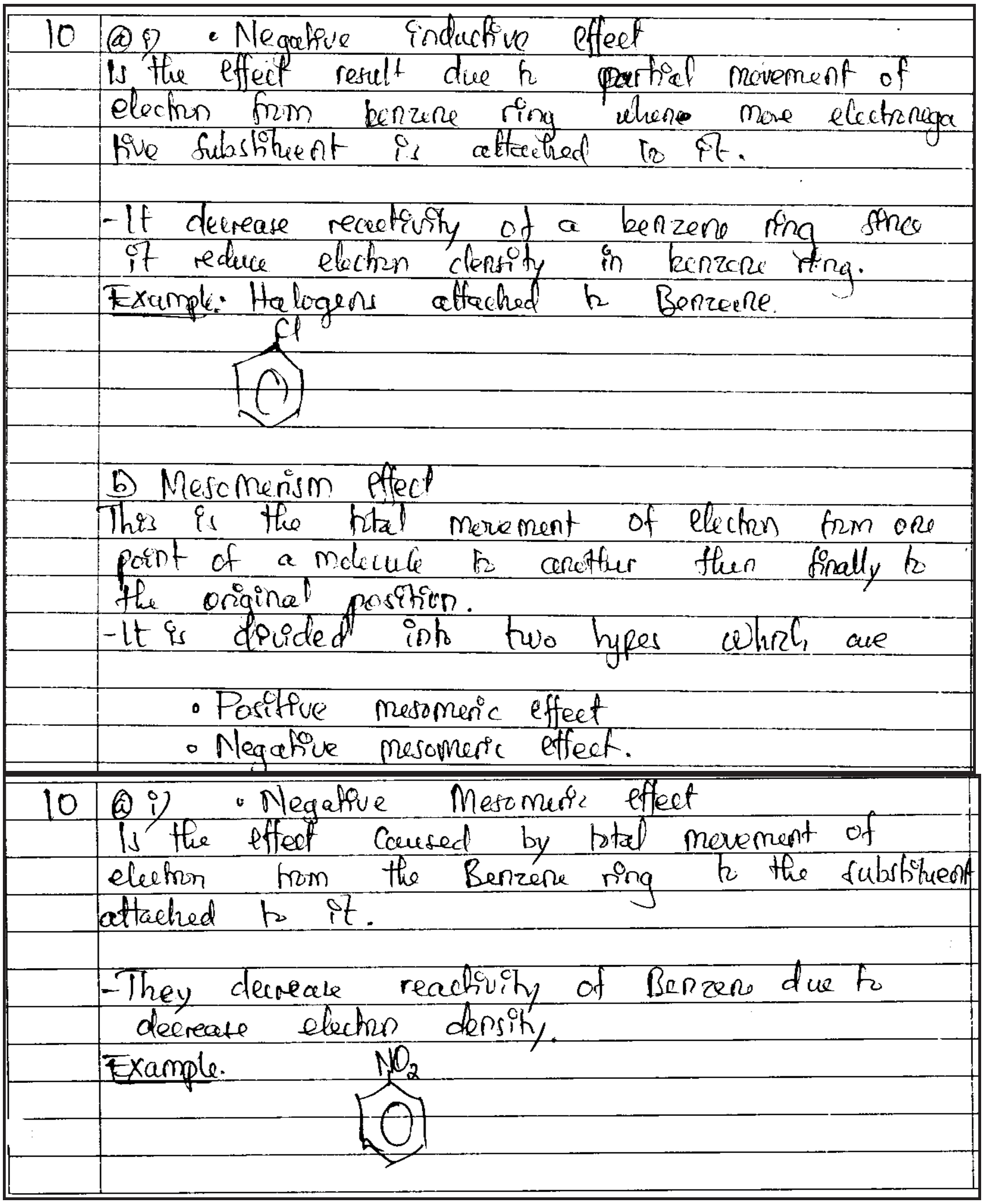
---

10 ⓐ ii) • Negative inductive effect

Is the effect result due to partial movement of electron from benzene ring when more electronegative substituent is attached to it.

- It decrease reactivity of a benzene ring since it reduce electron density in benzene ring.

Example: Halogens attached to Benzene.



10 a) i) • Negative inductive effect

Is the effect result due to partial movement of electron from benzene ring where more electronegative substituent is attached to it.

- It decrease reactivity of a benzene ring since it reduce electron density in benzene ring.

Example: Halogens attached to Benzene.

b) Mesomerism effect

This is the total movement of electron from one point of a molecule to another then finally to the original position.

- It is divided into two types which are

  - Positive mesomeric effect
  - Negative mesomeric effect.

10 a) i) • Negative Mesomeric effect

Is the effect caused by total movement of electron from the Benzene ring to the substituent attached to it.

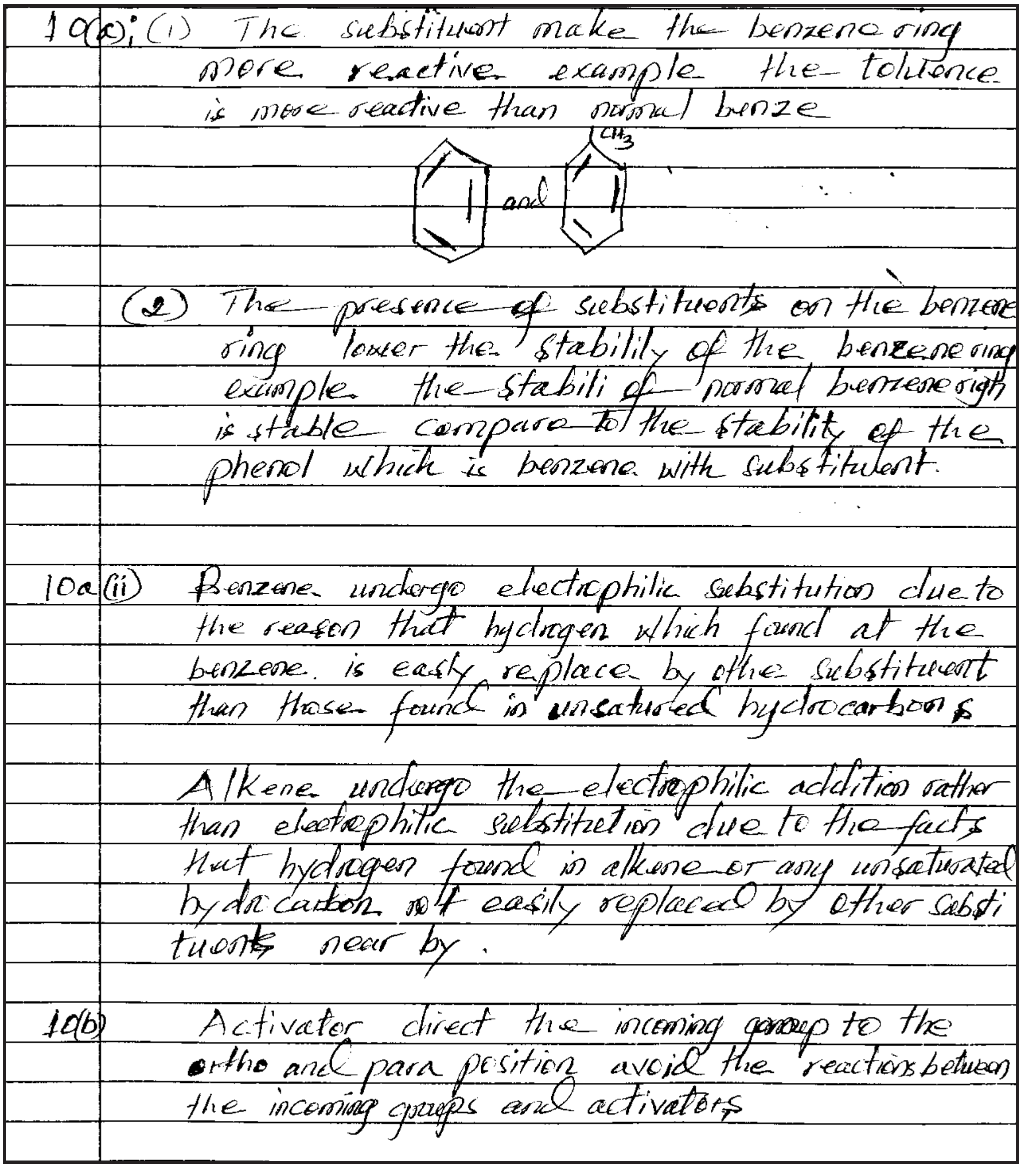
- They decrease reactivity of Benzene due to decrease electron density.

Example.

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

In Extract 10.1, the candidate explained the effect of substituent group (in relation to mesomeric and inductive effects) on the reactivity of the benzene ring in parts (a) and (c). In part (b), the candidate explained the effects of activators on the benzene ring by increasing the electron density at ortho and para positions.

On the other hand, most of the candidates (59.15%) who scored low marks gave incorrect responses in parts (a) and (c). This shows that the candidates lacked knowledge on the reactivity of benzene in terms of the effect of the substituent group attached to the ring. For example, some of the candidates confused the formula for methyl cyclohexane with methylbenzene (toluene), hence they wrote incorrect chemical equations while responding to part (a). In part (b), the candidates had insufficient knowledge on the directing effect of the activator on the benzene ring. Consequently, they failed to give sufficient explanation required demanded in the question. Extract 10.2 shows an example of the incorrect responses to the question.



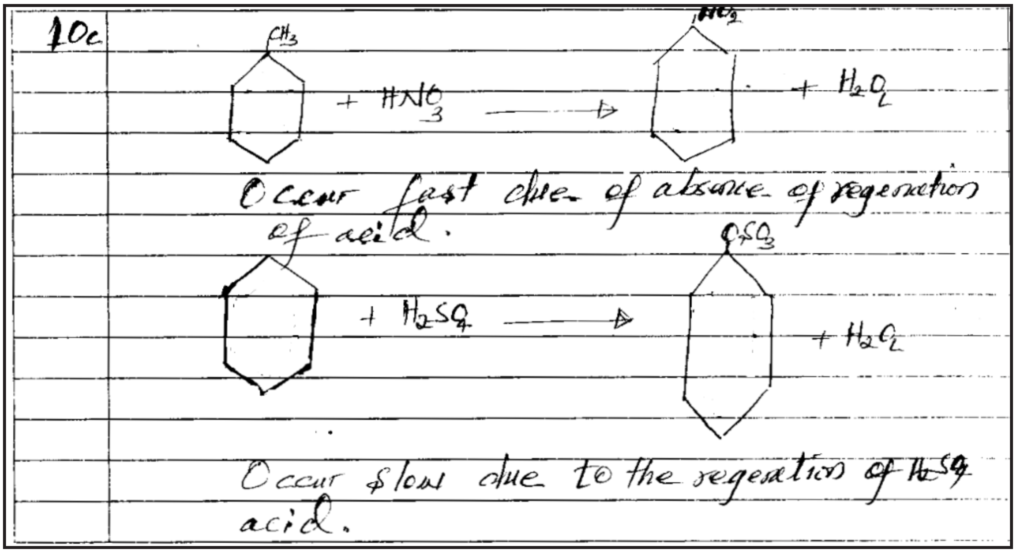
10(c); (1) The substituent make the benzene ring more reactive example the toluence is more reactive than normal benze

(2) The presence of substituents on the benzene ring lower the stability of the benzene ring example the stabili of normal benzene righ is stable compare to the stability of the phenol which is benzene with substituent.

10a (ii) Benzene undergo electrophilic substitution due to the reason that hydrogen which found at the benzene. is easly replace by othe substituent than those found in unsatured hydrocarbons

Alkene undergo the electrophilic addition rather than electrophilic substitution due to the facts that hydrogen found in alkene or any unsaturated hydrocarbon not easily replaced by other substituents near by.

10(b) Activator direct the incoming group to the ortho and para position avoid the reactions between the incoming groups and activators



10c

+ HNO_3 → + H_2O

Occur fast due of absence of regeneration of acid.

+ H_2SO_4 → + H_2O

Occur slow due to the regeation of H_2SO_4 acid.

Extract 10.2: A sample of incorrect responses to Question 10 Paper 1

In Extract 10.2, the candidate did not highlight the effects of inductive and mesomeric effects on the benzene ring or delocalization of π bond, which undergoes mesomerism and delocalization. The candidate failed to apply the concept of mesomeric and inductive effect which causes the increase of electron density on benzene, hence, increases reactivity of the benzene ring. In addition, the candidate used incorrect structure of cyclohexane instead of benzene. In part (b), the candidate misconceived the concept of directing effect of the activators hence failed to give a clear explanation as to why activators direct the incoming electrophile to ortho and para positions when attached to benzene ring. The candidate stated that the activators do so in order to avoid reactions between the incoming groups, which was not correct.

2.2 132/2-CHEMISTRY 2

This was a theory paper which comprised six (6) questions of which the candidates were required to answer five (5). The questions carried equal weight of 20 marks each. The topics covered in this paper were *Acids, Bases, and Salts; Chemical Kinetics; Carbonyl Compounds; Amines; Carboxylic Acids and its Derivatives; Transition Elements; Polymers; Periodic Classification; Extraction of Metals* and *Two Component Liquid Systems*.

2.2.1 Question 1: Two Component Liquid Systems

The question was asked as follows:

(a) *(i)* *Can azeotropic mixtures be separated by distillation? Briefly, explain.*

(ii) *Mixing of acetone with chloroform takes place with reduction in volume. Identify the type of deviation from Raoult's law.*

(b) *Two liquids **M** and **N** are mixed to form an ideal solution. The vapour pressure of the solution containing 3 moles of **M** and 1 mole of **N** is 550 mm Hg. When 4 moles of **M** and 1 mole of **N** are mixed, the vapour pressure of the solution formed is 560 mm Hg. What will be the vapour pressure of the pure **M** and **N** at this temperature?*

(c) *(i)* *Briefly explain five conditions that govern the distribution law.*

(ii) *The experiment was set to assess the solubility of succinic acid in water and ether at 15 °C. It was found that, 20 cm^3 of the ether layer contained 0.092 g of the acid. If the distribution coefficient for succinic acid between ether and water is 5.2, find the weight of the acid which was present in 20 cm^3 of the aqueous solution when the experiment was left at equilibrium.*

This question was selected by 37,467 (99.12%) of the candidates. Among them, 9,118 (24.33%) scored 0–6.5 marks, 12,209 (32.59%) scored 7–11.5 marks and 16,140 (43.08%) scored from 12–20 marks. Thus, the data indicate that 28,349 (75.67%) candidates scored 7.5 marks or above which is a good performance. The summary of the performance is shown in Figure 11.

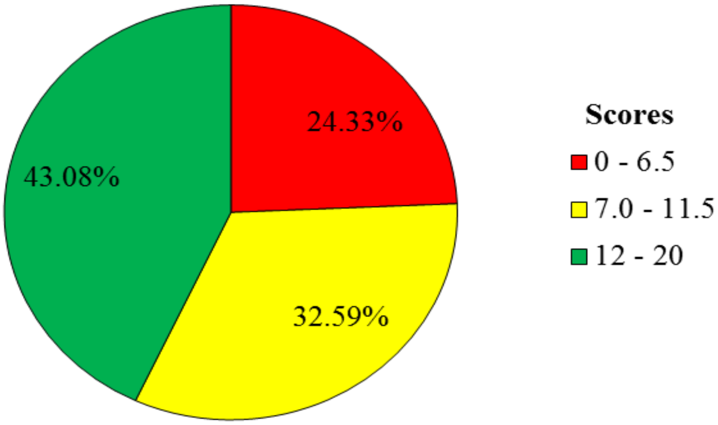
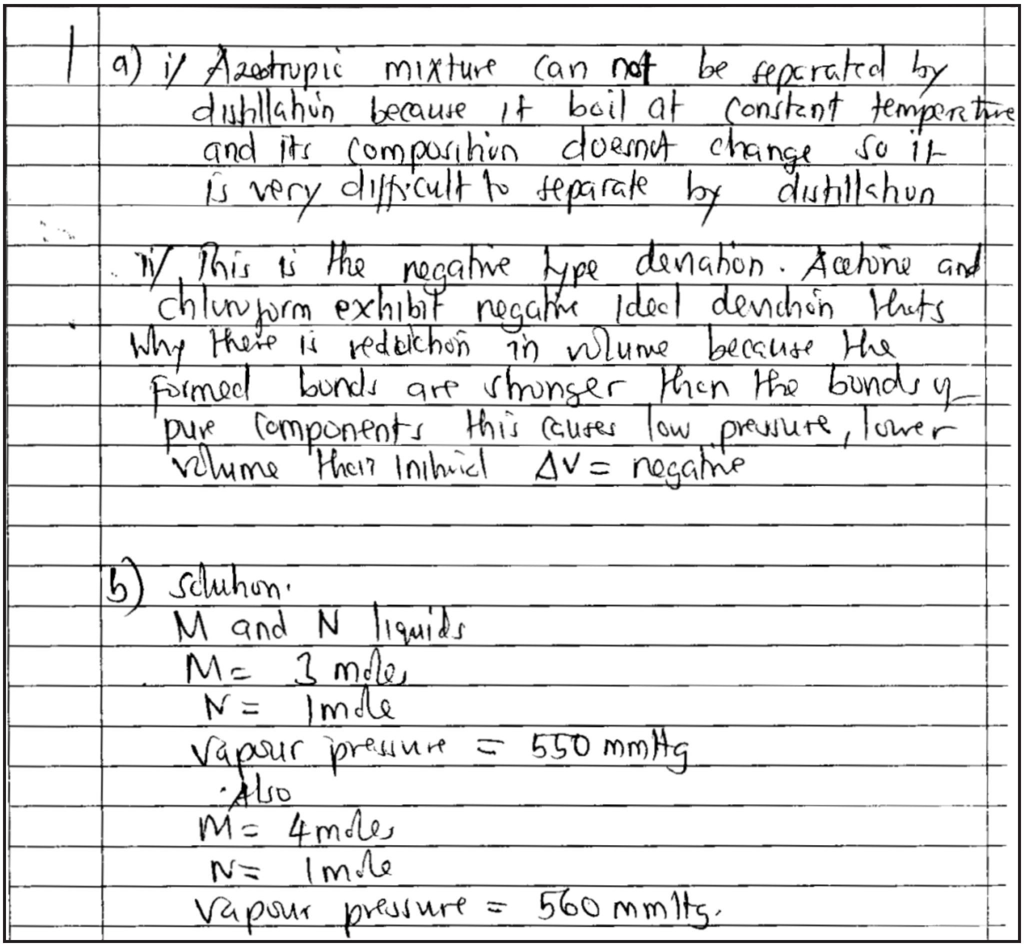


Figure 11: *Performance of the Candidates in Question 1 Paper 2*

The candidates who scored high marks in this question (43.08%) correctly explained the reason why azeotropic mixtures cannot be separated by distillation method in part (a). Moreover, they explained that the mixture of acetone with chloroform occurs with reduction in volume, based on the properties of non – ideal solutions. In part (b), the candidates calculated the pure vapour pressures of liquids **M** and **N**. These candidates had sufficient knowledge of Raoult's law of pure vapour pressures of volatile liquids. In addition, the candidates correctly applied the distribution law to calculate the weight of succinic acid in the aqueous layer (solution) in part (c). The candidates' ability to solve numerical problems and units contributed significantly to their good performance. Extract 11.1 is an example of the correct responses to this question.



1 a) i/ Azeotropic mixture can not be separated by distillation because it boil at constant temperature and its composition doesnot change so it is very difficult to separate by distillation

ii/ This is the negative type deviation. Acetone and chloroform exhibit negative ideal deviation thats why there is reduction in volume because the formed bonds are stronger then the bonds of pure components this causes low pressure, lower volume their initial $\Delta V =$ negative

b) Solution.
M and N liquids
M = 3 moles
N = 1 mole
vapour pressure = 550 mmHg
·Also
M = 4 moles
N = 1 mole
Vapour pressure = 560 mmHg.

1 b) $550\,mmHg = \frac{3}{4}P^{o}_{m} + \frac{1}{4}P^{o}_{N}$

Also

$X_{2M} = \frac{4}{5}$ moles

$X_{N} = \frac{1}{5}$ moles.

$560\,mmHg = \frac{4}{5}P^{o}_{m} + \frac{1}{5}P^{o}_{N}$.

Solving simultaneously

$550 = \frac{3}{4}P^{o}_{m} + \frac{1}{4}P^{o}_{N}$

$560 = \frac{4}{5}P^{o}_{m} + \frac{1}{5}P^{o}_{N}$

$P^{o}_{m} = 600\,mmHg$.

$P^{o}_{N} = 400\,mmHg$.

∴ Vapour pressure of Pure

M = 600mmHg

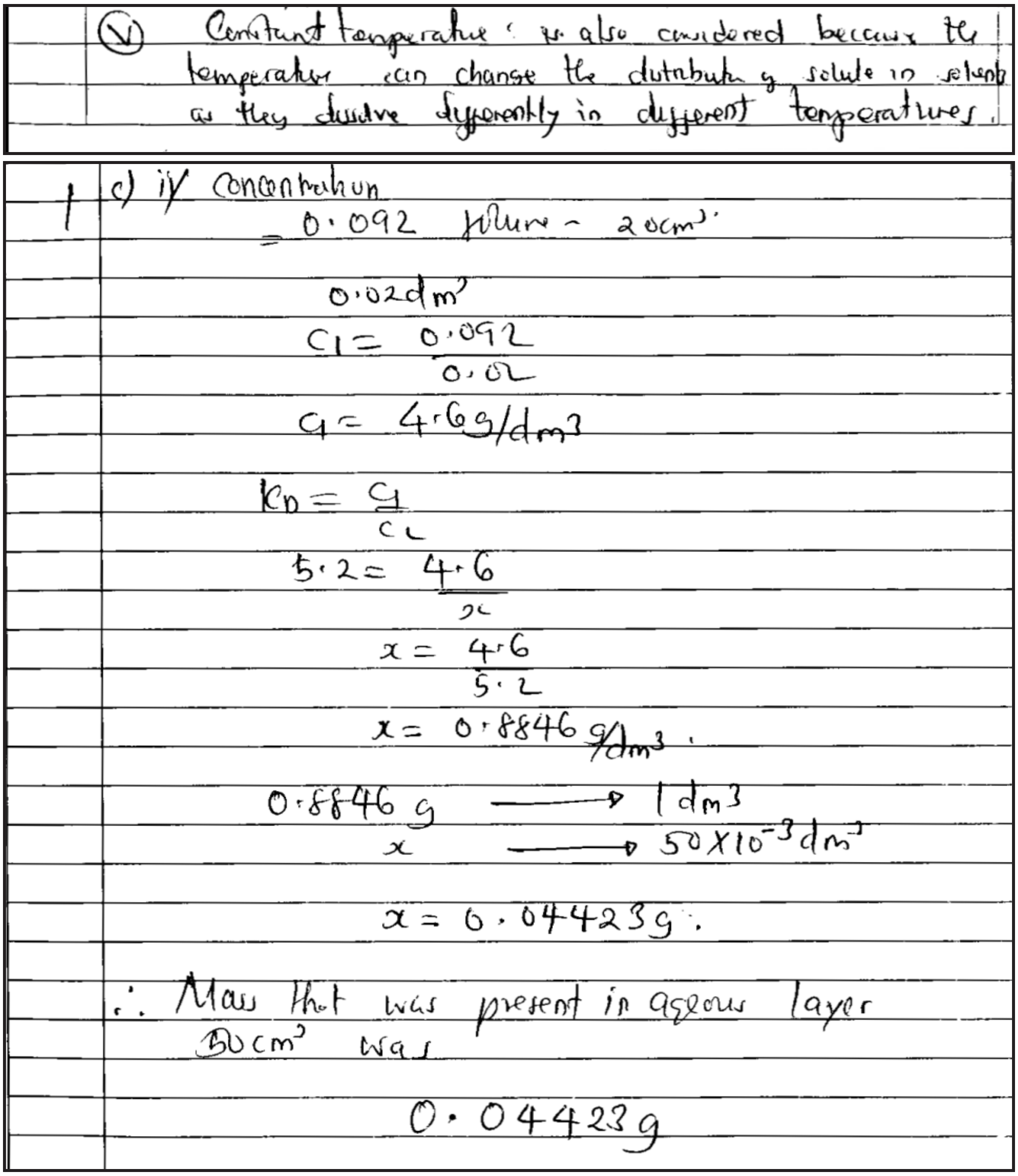
N = 400 mmHg.

C(i) ① Solvents must be immisible so that the concentrate or distribution of solute is not altered in the two solvents.

(ii) Equilibrium Concentration; There solvents must be shaken to equilibrium concentration so as to obtain correct value of distribution constant Kd.

(iii). Molecular state of solute should be maintained or not change and it must be not volatile so as to distribute easily.

(iv) Very dilute solution: is very important so as to not affect the ~~solut~~ distribution of solute in both solvents.



(v) Constant temperature : is also considered because the temperature can change the distribution of solute in solvents as they dissolve differently in different temperatures.

1 c) ii) concentration

= 0.092 volume - 20cm³

0.02dm³

$C_1 = \frac{0.092}{0.02}$

$C_1 = 4.6 g/dm^3$

$K_D = \frac{C_1}{C_2}$

$5.2 = \frac{4.6}{x}$

$x = \frac{4.6}{5.2}$

$x = 0.8846 g/dm^3$.

$0.8846 g \longrightarrow 1 dm^3$

$x \longrightarrow 50 \times 10^{-3} dm^3$

$x = 0.04423 g$.

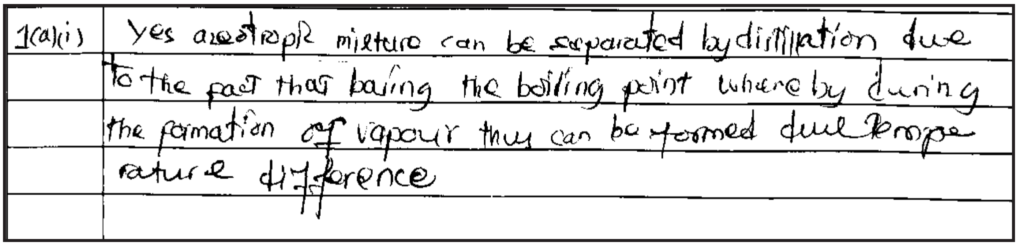
∴ Mass that was present in aqueous layer 50cm³ was

0.04423 g

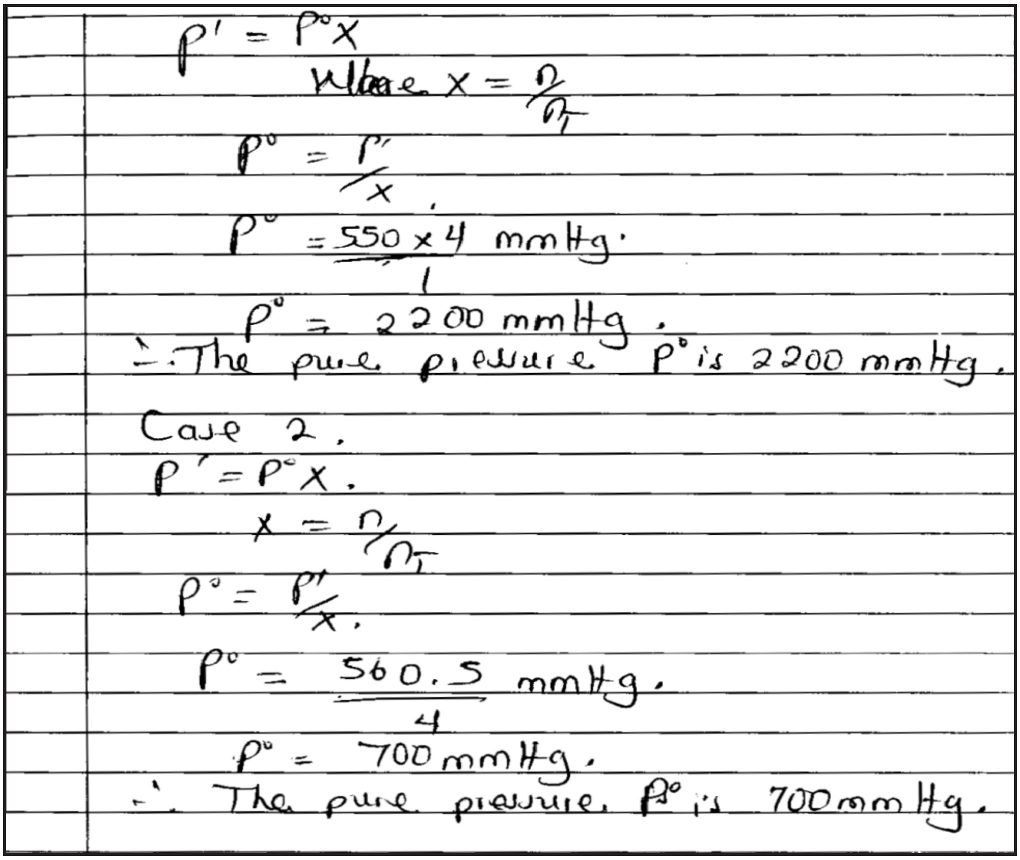
Extract 11.1 A sample of the correct responses to Question 1 Paper 2

Extract 11.1 shows that, in part (a) (ii), the candidate correctly predicted the type of deviation expected if acetone and chloroform were mixed together. In part (c) (i), they identified and explained the conditions necessary for distribution law. The rest of the responses given were also correct.

However, the candidates (24.33%) who scored low marks gave incorrect responses. For instance, in part (a)(i), one of the candidates wrote *Azeotropic mixture can be separated based on differences in boiling points* which is not correct. Similarly, another candidate wrote that, *Azeotropic mixtures can be* *separated by chromatograph method because they are have different colours.* In part (b), the candidates calculated vapour pressure by applying incorrect formulas. For instance, some candidates calculated the vapour pressure of M or N by summing up the two values of vapour pressure given. Others used the correct formula (according to Raoult’s law), but did a wrong substitution of data. In part (c), some candidates explained incorrect conditions that do not adhere to the partition law, (for instance, colligative properties) instead of conditions that govern the distribution law of immiscible liquids (solvents). This shows that, these candidates had insufficient knowledge about mixtures and separation techniques. Extract 11.2 is an example of the correct responses to this question.



1(a)(i) Yes azeotrope mixture can be separated by distillation due
to the fact that baing the boiling point whereby during
the formation of vapour they can be formed due tempe-
rature difference



$P' = P^{\circ}X$

Where $X = \frac{n}{n_T}$

$P^{\circ} = \frac{P'}{X}$

$P^{\circ} = \frac{550 \times 4}{1}$ mmHg.

$P^{\circ} = 2200$ mmHg.

∴ The pure pressure P° is 2200 mmHg.

Case 2.

$P' = P^{\circ}X$.

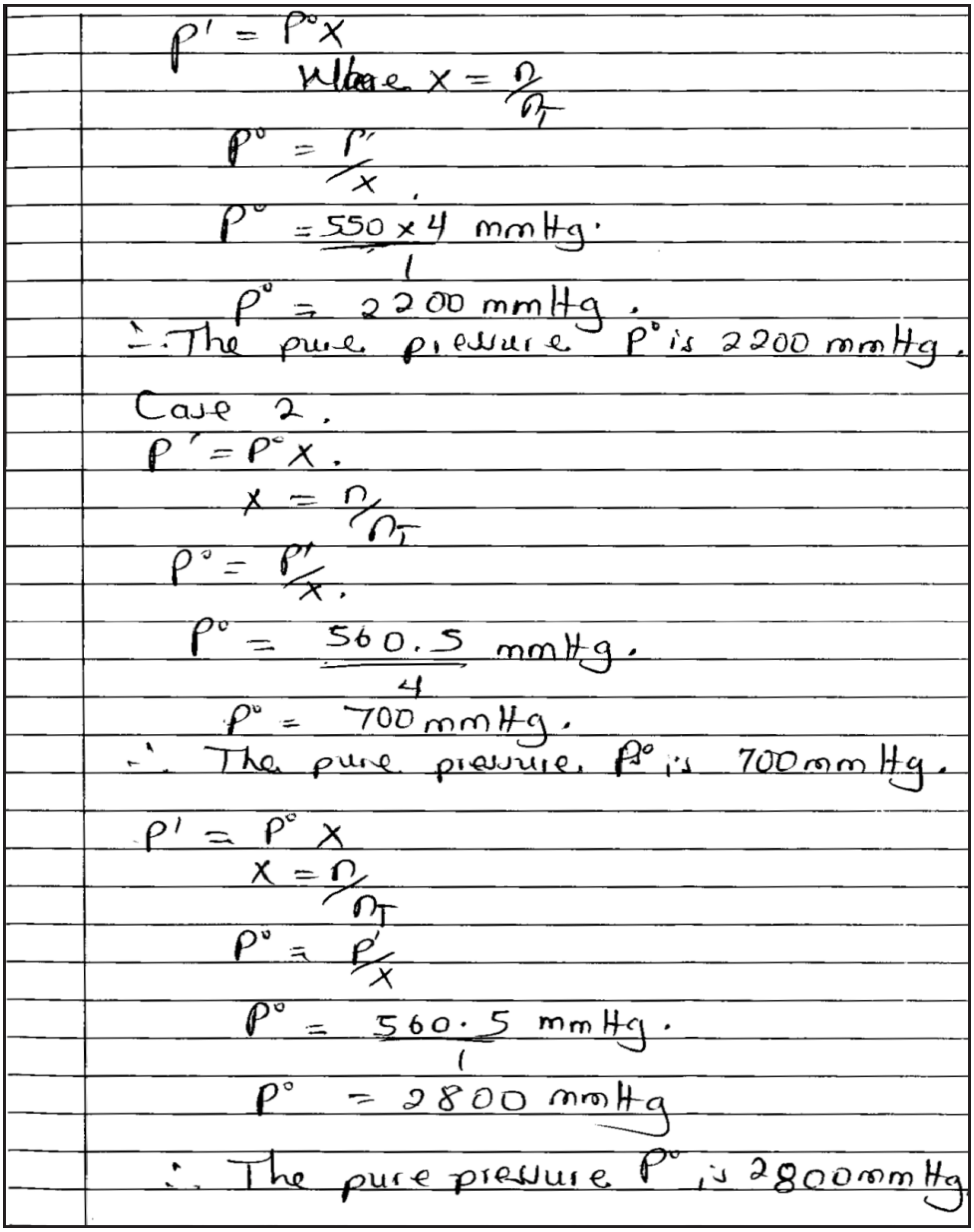
$X = \frac{n}{n_T}$

$P^{\circ} = \frac{P'}{X}$.

$P^{\circ} = \frac{560.5}{4}$ mmHg.

$P^{\circ} = 700$ mmHg.

∴ The pure pressure. P° is 700 mmHg.



$p' = P^{\circ}X$

Where $X = \frac{n}{n_T}$

$P^{\circ} = \frac{P'}{X}$

$P^{\circ} = \frac{550 \times 4}{1}$ mmHg.

$P^{\circ} = 2200$ mmHg.

∴ The pure pressure P° is 2200 mmHg.

Case 2.

$P' = P^{\circ}X$.

$X = \frac{n}{n_T}$

$P^{\circ} = \frac{P'}{X}$.

$P^{\circ} = \frac{560.5}{4}$ mmHg.

$P^{\circ} = 700$ mmHg.

∴ The pure pressure P° is 700 mmHg.

$P' = P^{\circ}X$

$X = \frac{n}{n_T}$

$P^{\circ} = \frac{P'}{X}$

$P^{\circ} = \frac{560.5}{1}$ mmHg.

$P^{\circ} = 2800$ mmHg

∴ The pure pressure P° is 2800 mmHg

Extract 11.2: A sample of the incorrect responses to Question 1 Paper 2

In Extract 11.2, the candidates stated that distillation method is appropriate for separating Azeotropic mixture, which is not true. In the calculation part, he/she incorrectly calculated the pure vapour pressures by the multiplying given partial pressures with number of moles of liquids M and N.

2.2.2 Question 2: Acids, Bases and Salts

The question was asked as follows:

(a) *Comment briefly on the following statements:*

(i) *Lewis concept of acids and bases overruled Arrhenius concepts of acids and bases.*

(ii) HSO_4^- *is an amphiprotic.*

(iii) *When rain is accompanied by thunderstorm, the collected rain water will have a pH value slightly lower than that of rain water without thunderstorm.*

(b) (i) *Calculate the pH of a mixture when 1* cm^3 *of a 0.5 M* H_2SO_4 *is mixed with 2* cm^3 *of 0.1 M HCl, provided that no reaction occurred in the mixture.*

(ii) *A 0.1 M ethanoic acid contains 0.0001 M* H_3O^+. *What would be the Ka for this acid?*

(c) *How much volume of a 0.1 M HCN should be added to a 50* cm^3 *of 0.2 M of NaCN solution to prepare a buffer solution with a pH value of 4.91? (pKa of HCN is 4.76).*

The question was answered by 34,239 (90.57%) candidates. Among them, 25,089 (73.27%) scored from 0–6.5 marks, 7,042 (20.57%) scored from 7–11.5 marks and 2,108 (6.16%) scored from 12–20 marks. Generally, the candidates' performance was weak since only 9,150 (26.73%) candidates scored 7 marks or above. The summary of the performance is shown in Figure 12.

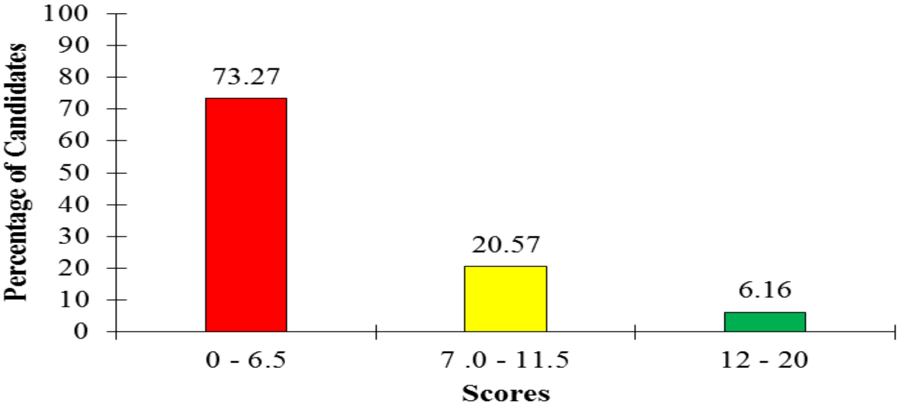
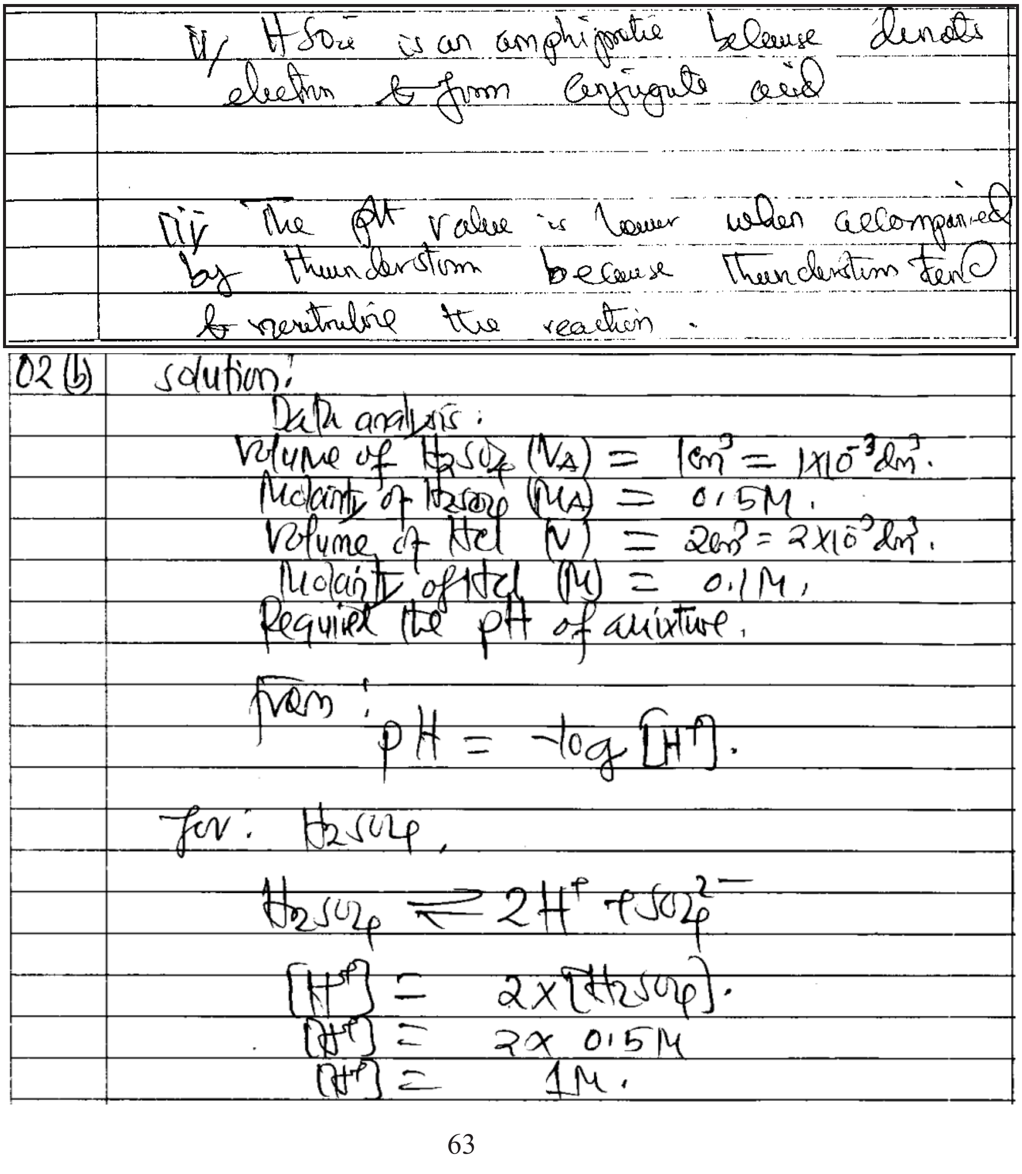


Figure 12: *Candidates' Performance in Question 2 Paper 2*

The candidates (73.27%) who scored low marks failed to show with examples the superiority of the concept of Lewis acids and bases over that of Arrhenius in part (a) (i). In item (a) (ii), the candidates gave incorrect explanations about the concept of amphiprotic substance. This implies that the candidates had insufficient knowledge on the concept of relative strengths of acids and bases using Lewis and Arrhenius concepts. In part (b), the candidates used inappropriate formula to calculate the volume of the acid required to prepare the buffer solution. For instance, some of the candidates reciprocated the Henderson Hasselbalch equation for acidic buffer solution instead of placing the concentration of the conjugate base (or salt) on the numerator part and the concentration of acid on the denominator part. Extract 12.1 shows a sample of incorrect responses to this question.



ii/ HSO_4^- is an amphiprotic because donate electron to form conjugate acid

iii/ The pH value is lower when accompanied by thunderstom because thunderstom tend to neutralize the reaction.

02 (b) solution:

Data analysis:

Volume of H_2SO_4 (V_A) = $1cm^3 = 1\times10^{-3}dm^3$.

Molarity of H_2SO_4 (M_A) = 0.5M.

Volume of HCl (V) = $2cm^3 = 2\times10^{-3}dm^3$.

Molarity of HCl (M) = 0.1M,

Required the pH of mixture.

From:

$pH = -\log[H^+]$.

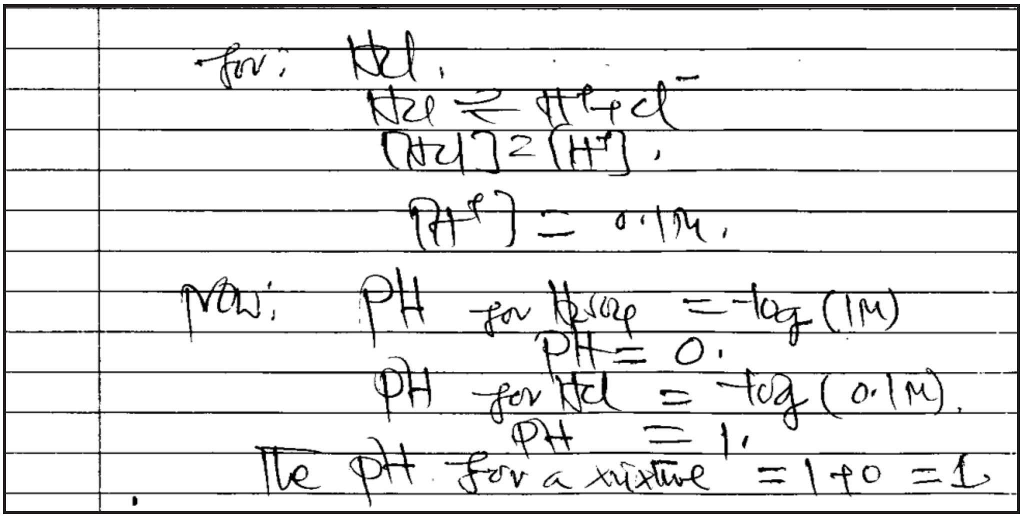
For: H_2SO_4,

$H_2SO_4 \rightleftharpoons 2H^+ + SO_4^{2-}$

$[H^+] = 2\times[H_2SO_4]$.

$[H^+] = 2\times 0.5M$

$[H^+] = 1M$.



for: HCl.

$HCl \rightleftharpoons H^+ + Cl^-$

$[HCl] = [H^+]$.

$[H^+] = 0.1M$.

Now: PH for H_2SO_4 = $-\log(1M)$

PH = 0.

PH for HCl = $-\log(0.1M)$.

PH = 1.

The pH for a mixture = 1 + 0 = 1

Extract 12.1: A sample of the incorrect responses to Question 2 Paper 2

In Extract 12.1, the candidate responded to part (a) by giving an incorrect explanation on the concepts of acids/ bases. For instance, he/she explained that thunderstorm neutralizes reaction of rainwater, which is misleading. In part (b) (i), he/she used a wrong formula to calculate the pH of the mixture.

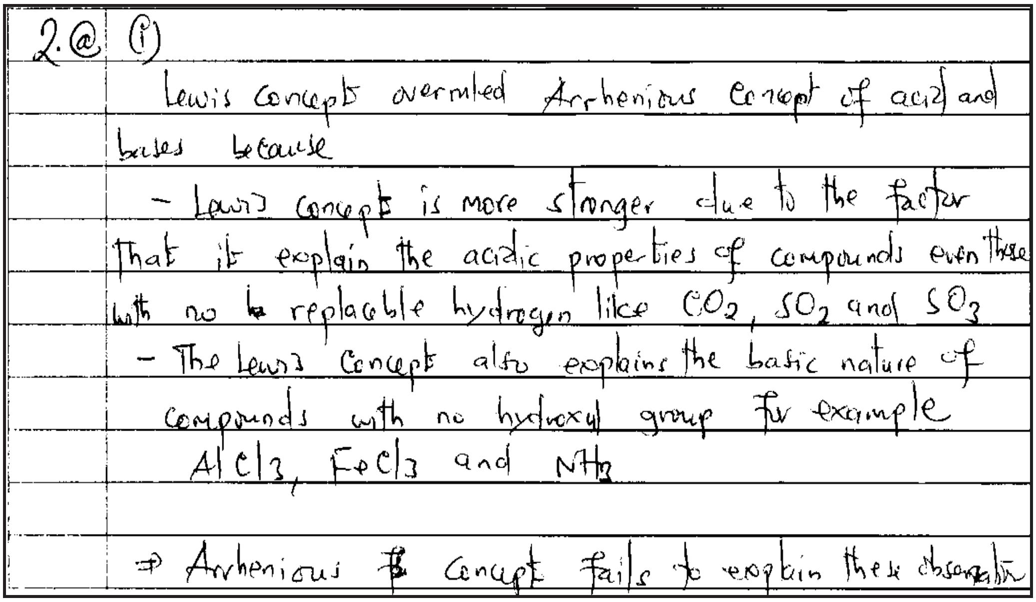
The candidates (6.16%) who scored high marks managed to explain correctly with examples the strengths of Lewis concepts of acids and bases over Arrhenius concepts of acids and bases in part (a) (i). In part (a) (ii), the candidates correctly explained the term amphiprotic species. In part (a) (iii), they identified the acidic oxides which are formed as the result of thunderstorm and showed how these acidic oxides react with oxygen in air and rain water to form acidic rain which decreases the pH of water. They gave correct reasons by comparing the pH of rain water in the presence of thunder storm and rain water without a thunderstorm.

In part (b) (i) of the question, the candidates correctly calculated the value of pH of mixture of two strong mineral acids (H_2SO_4 and HCl) which do not chemically react by using dilution law ($M_1 \times V_1 = M_2 \times V_2$). They also correctly wrote the dissociation equations for these mineral acids, which shows that they were knowledgeable about the concepts of acids and bases.

In part (b) (ii) of this question, the candidates got the responses correctly as they understand the requirements of the question. They were able to calculate the value of dissociation constant of ethanoic acid through the application of

Ostwald's Dilution Law for Weak Electrolytes and the Law of Mass Action. Also, the candidates wrote correctly the equation for the dissociation of ethanoic acid in aqueous solution.

In part (c), the candidates correctly used the Henderson Hasselbalch equation for acidic buffer solution, $pH = pka + \log\left(\frac{M_{salt} \times V_{salt}}{M_{weak\ acid} \times V_{weak\ acid}}\right)$ to calculate the volume of an acid required to prepare a buffer solution. The good performance in this question suggests that the candidates were conversant with the concept of acids and bases. Extract 12.2 shows a sample response from a candidate who performed well in this question.



2. ⓐ (i)

Lewis concept overruled Arrhenious concept of acid and bases because

- Lewis concept is more stronger due to the factor That it explain the acidic properties of compounds even those with no replacable hydrogen like CO_2, SO_2 and SO_3

- The Lewis concept also explains the basic nature of compounds with no hydroxyl group for example $AlCl_3$, $FeCl_3$ and NH_3

⇒ Arrhenious concept fails to explain these observation

ii) HSO_4^- is amphiprotic as it can recieve or donate proton as shown below.

$$HSO_4^-(aq) \longrightarrow SO_4^{2-}(aq) + \underset{\uparrow \text{donate proton}}{H^+(aq)}$$

$$HSO_4^-(aq) + \underset{\uparrow \text{recieve proton}}{H^+(aq)} \longrightarrow H_2SO_4(aq)$$

That satisfies the definition of amphiprotic substance that is the substance that can release or recieve a proton.

(a) iii) - This is because thunderstom causes the reaction between Nitrogen and oxygen in the atmosphere to form nitrogen dioxide. Because nitrogen dioxide is acidic it dissolves in rain water to form a weak acid solution

$$NO_2(g) + H_2O(l) \rightleftharpoons HNO_3 \rightleftharpoons H^+ + NO_3^-$$

- Hence the rainwater become more acidic during thunderstorm.

2 (b) (i) Given

Volume of sulphuric acid = $1cm^3$.

Concetration of sulphuric acid = $0.5M$.

Volume of HCl = $2cm^3$

Concetration of ~~sulph~~ HCl = $0.1M$.

From:

Reaction

$H_2SO_4 \rightarrow$ ~~H~~SO_4^{-} + $2H^+$

From

no.mole of H_2SO_4 = 2no.mole of H^+

Thus:

no.mole of H_2SO_4 = Molarity of H_2SO_4 × Volume

= $0.5 \times 1\times10^{-3}$

no.mole of H_2SO_4 = 5×10^{-4} mol. in H_2SO_4

Thus no.mole of ~~of~~ H^+ = 1×10^{-3} mol

no.mole of HCl = no.mole of H^+

From HCl $\rightarrow$ H^+ + Cl^-

Then.

no.mole of H^+ = Molarity of HCl × Volume

= $2\times10^{-3} \times 0.1$

no.mole of H^+ = 2×10^{-4} in HCl

Thus.

Total number of H^+ in solution = $2\times10^{-4} + 1\times10^{-3}$

Total number of H^+ = 1.2×10^{-3}.

Then. Concetration of solution = $\frac{\text{Total moles } H^+}{\text{Total volume}}$

$= \frac{1.2\times10^{-3}}{0.003}$

Concetration of H^+ = $0.4 mol/dm^3$

From $pH = -\log[H^+]$

$pH = -\log[0.4]$

∴ $pH = 0.3979$. of solution.

2 (b) (ii) Given

Concetration of ethanoic acid = 0.1M

Concetration of H_2O^+ = 0.001M.

From.

$$CH_3COOH + H_2O \longrightarrow CH_3COO^- + H_3O^+$$

From.

$$Ka = \frac{[CH_3COO^-] \times [H_3O^+]}{[CH_3COOH]}.$$

But $[H_3O^+] = [CH_3COO^-]$

$$Ka = \frac{[H_3O^+]^2}{[CH_3COOH]}.$$

Then.

$$Ka = \frac{(0.001)^2}{(0.1)}$$

$$Ka = 1 \times 10^{-5} \text{ mol/dm}^3.$$

(c) Given: ~~Ger~~

Concentration of HCN = 0.1M.

Volume of NaCN = 50cm3.

Concentration of NaCN = 0.2M.

pH = 4.91

pKa = 4.76.

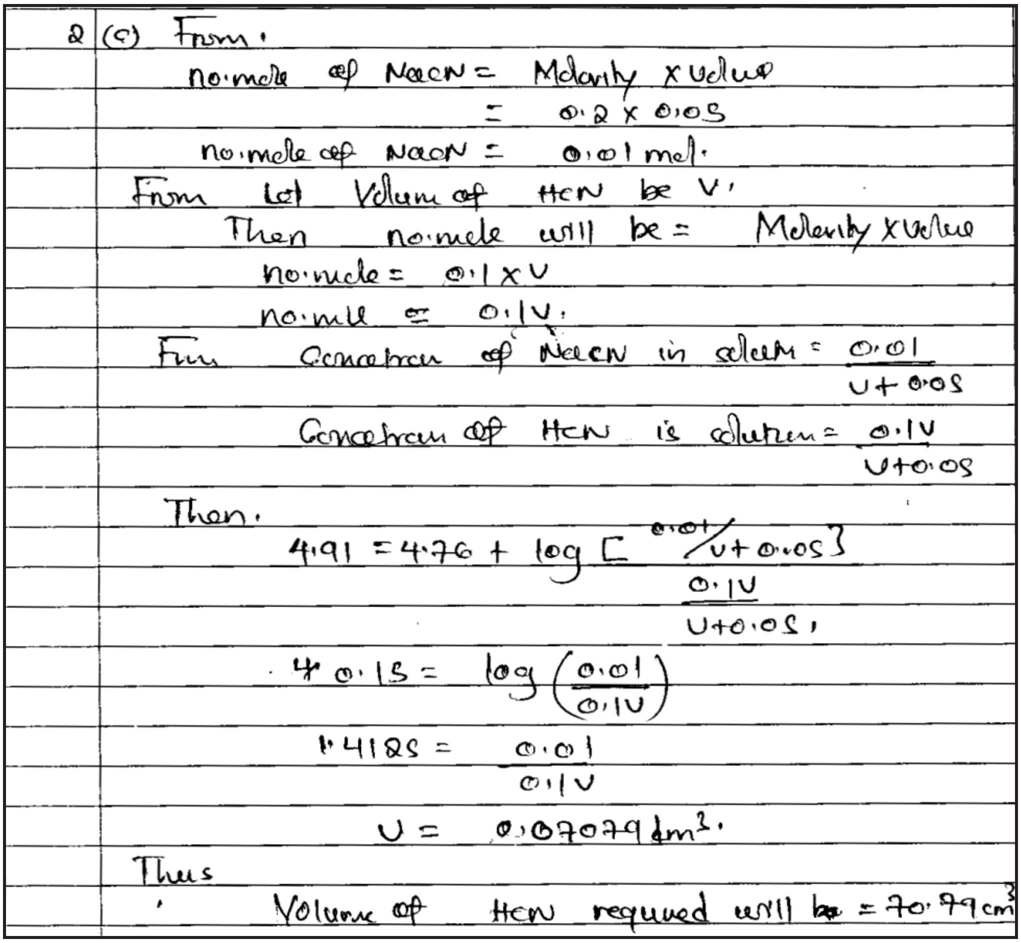
From. $NaCN + H_2O \longrightarrow HCN + OH^-$

From equation

$$pH = Pka + \log\frac{[salt]}{[acid]}.$$

Thus

$$4.91 = 4.76 + \log\frac{[salt]}{[acid]}.$$



2 (c) From.

no.mole of NaCN = Molarity x Volume

$= 0.2 \times 0.05$

no.mole of NaCN = 0.01 mol.

From let Volum of HCN be V.

Then no.mole will be = Molarity x Volume

no.mole = $0.1 \times V$

no.mole = $0.1V$.

From Concentration of NaCN in solution = $\frac{0.01}{V+0.05}$

Concentration of HCN is solution = $\frac{0.1V}{V+0.05}$

Then.

$$4.91 = 4.76 + \log\left[\frac{0.01/V+0.05}{\frac{0.1V}{V+0.05}}\right]$$

$$0.15 = \log\left(\frac{0.01}{0.1V}\right)$$

$$1.4125 = \frac{0.01}{0.1V}$$

$$V = 0.07079\,dm^3.$$

Thus

Volume of HCN required will be $= 70.79\,cm^3$

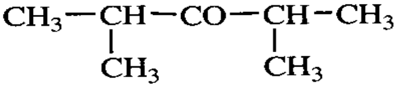
Extract 12.2: A sample of the correct responses to Question 2 Paper 2

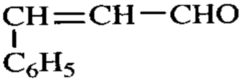
In Extract 12.2, the candidate correctly showed how Lewis concept of acids and bases is superior over Arrhenius in part (a) (i). Moreover, the candidate correctly showed how hydrogen sulphate ion acts as an amphiprotic substance in part (a) (ii) and in part (a) (iii), the candidate explained how thunderstorm causes acidity in rain water. In part (b) (i) the candidate used the correct approach to calculate the pH of the mixture. He/she managed to calculate Ka of ethanoic acid and correctly manipulated the units in part (b) (ii). Furthermore, the candidate correctly used Anderson-Hasselbalch equation to calculate the volume of an acid in acidic buffer system.

2.2.3 Question 3: Carbonyl Compounds/ Carboxylic Acids and its Derivatives/ Amines

The question was set from three topics, namely Carbonyl Compounds, Carboxylic Acids and its Derivatives and Amines. The question was asked as follows:

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

(i)

$CH_3-\underset{CH_3}{\underset{|}{CH}}-CO-\underset{CH_3}{\underset{|}{CH}}-CH_3$

(ii)

$\underset{C_6H_5}{\underset{|}{CH}}=CH-CHO$

(b) *(i)* *An organic compound **E** with molecular formula $C_9H_{10}O$ forms 2,4–dinitrophenylhydrazine (2,4-DNP) derivative. Also, it reduces Tollen's reagent and undergoes Cannizzaro's reaction. Upon vigorous oxidation, compound **E** gives 1,4–benzene dicarboxylic acid. Determine the chemical structure of compound **E**.*

(ii) *Why do aldehyde and ketones have lower boiling points than their corresponding alcohols and carboxylic acids? Explain briefly.*

(iii) *A compound **B** (C_2H_4O) on oxidation gives compound **C** ($C_2H_4O_2$). Compound **B** undergoes haloform reaction. On treatment with HCN, compound **B** forms a product **Z** which on hydrolysis, gives 2–hydroxypropanoic acid. Write the equations for all the reactions involved.*

(c) *Briefly explain the following observations:*

(i) *Methylamine has lower boiling point than methanol.*

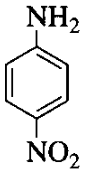
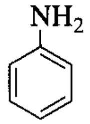
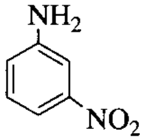
(ii) *Aniline does not undergo Friedel– Craft alkylation.*

(d) *(i)* *Identify the structure of compounds **A**, **B**, **C** and **D** in the following sequential conversions:*

$$\mathbf{A}\xrightarrow[0\text{-}5°C]{NaNO_2/HCl}CH_3OH\xrightarrow{SOCl_2}\mathbf{B}\xrightarrow{KCN}$$

$$\mathbf{C}\xrightarrow{LiAlH_4}\mathbf{D}$$

(ii) *Giving reasons, arrange the following organic compounds in decreasing order of basic strengths.*

 ,  , CH_3NH_2 , NH_3 and 

(iii) *How can ethylamine be prepared from propionic acid? Give two steps.*

This question was answered by 20,593 (54.47%) out of 37,804 candidates who sat for the paper. The candidates' performance in this question was as follows: 12,396 (60.19%) scored from 0–6.5 marks, 5,883 (28.57%) scored from 7–11.5 marks and 2,314 (11.24%) scored from 12–20 marks. These data indicate that 39.81 per cent of the candidates scored 7 marks or above. Therefore the candidates' overall performance in this question was average in the lower margin. A summary of the performance is shown in Figure 13.

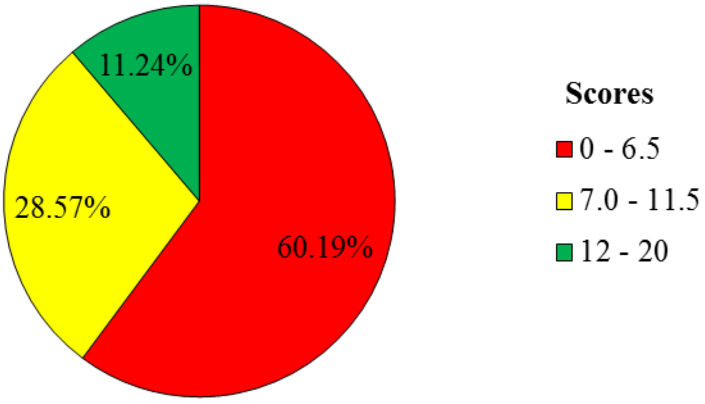
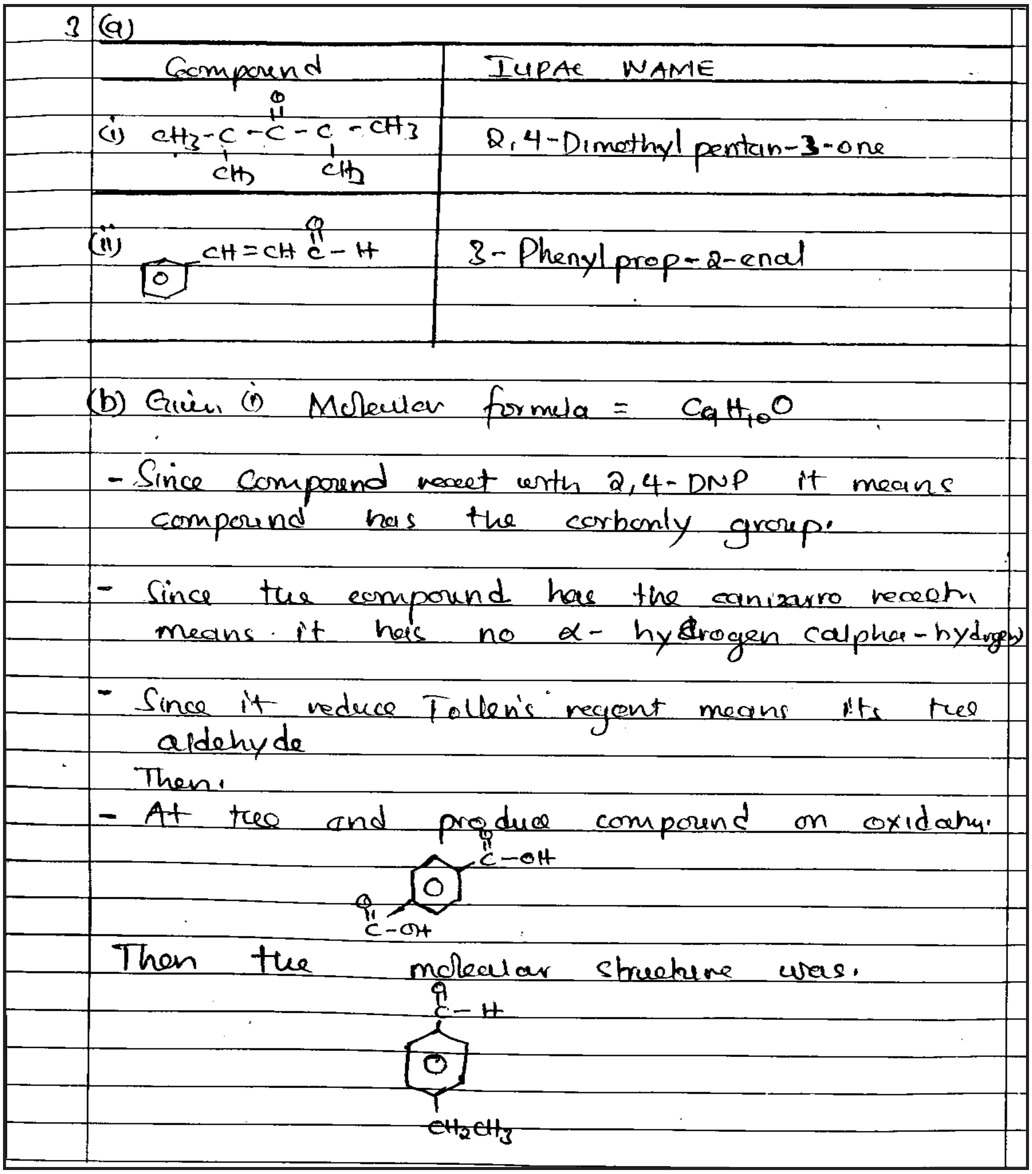


Figure 13: *Candidates' Performance in Question 3 Paper 2*

The candidates who scored high marks (11.24%) correctly named the given organic molecules in part (a). In part (b) (i), the candidates correctly identified structure of compound **E** ($C_9H_{10}O$). In part (b (ii) They also used the concept of hydrogen bonding to explain the reason why carbonyl compounds are more associated with lower boiling points than their corresponding alcohols and carboxylic acids. In part (b) (iii), the candidates wrote all the chemical reaction equations correctly and eventually identified the names and structure of compounds **B** (C_2H_4O), **C** ($C_2H_4O_2$) and **Z**.

In part (c), the candidates explained why methanol has a higher boiling point than methylamine, and why aniline does not undergo Friedel– Crafts alkylation reaction. In part (d), the candidates deduced the structures of the compounds, arranged the compounds in order of decreasing basic strength and gave two steps of preparing propionic acid from ethylamine with the aid of chemical. The correct responses suggest that, the candidates had sufficient knowledge of carbonyl compounds, alcohols, amines, carboxylic acids and their derivatives. Extract 13.1 shows a sample responses of from candidates who performed well in this question.



3 (a)

Compound	IUPAC NAME
(i) $CH_3-\underset{CH_3}{C}-\overset{O}{\overset{\|}{C}}-\underset{CH_3}{C}-CH_3$	2,4-Dimethyl pentan-3-one
(ii) $-CH=CH\overset{O}{\overset{\|}{C}}-H$	3- Phenyl prop-2-enal

(b) Given (i) Molecular formula = $C_9H_{10}O$

- Since Compound react with 2,4-DNP it means compound has the corbonly group.
- Since the compound has the canizarro reaction means it has no α- hydrogen (alpha-hydrogen)
- Since it reduce Tollen's regent means it's free aldehyde

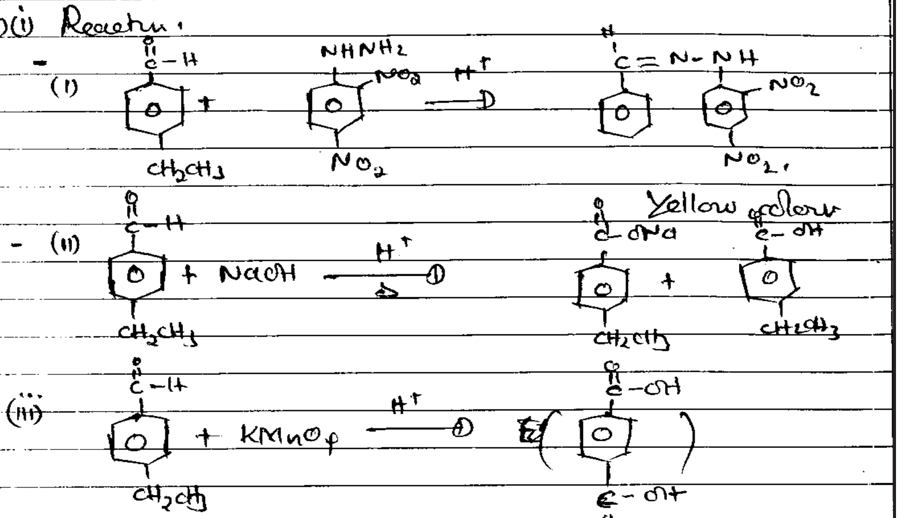
Then,

- At free and produce compound on oxidation.

Then the molecular structure was.

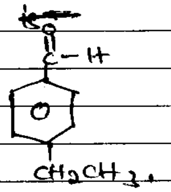
CH_2CH_3

8 (b)(i) Reaction.



~~Then~~ Then this proves

Thus structure of E ~~is~~



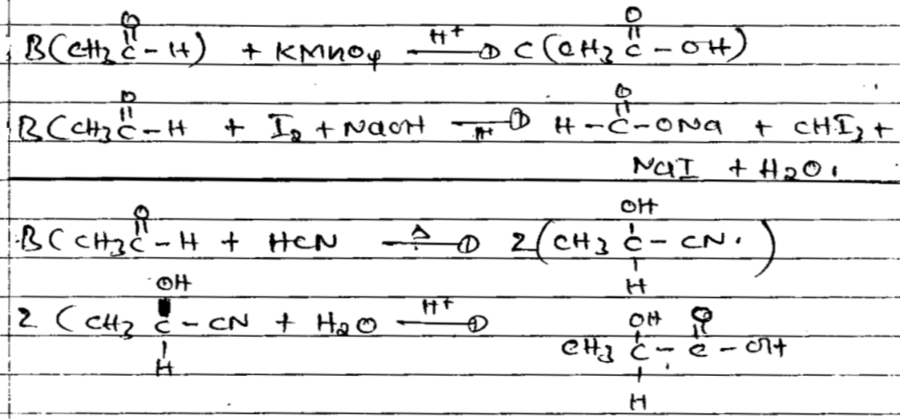
(ii) Alcohol and carboxylic acid has ability to form the hydrogen bonding thus it makes it to have high boiling point while in the aldehyde and Ketone weak hydrogen bond is formed hence it has low boiling point

3 (b) (iii)

- Since compound B undergo helloform reaction means ih the aldehyde thus

B(C_2H_4O) has struchere $CH_3\overset{O}{\overset{\|}{C}}-H$.

Reaction involued includes:-



$$B(CH_3\overset{O}{\overset{\|}{C}}-H) + KMnO_4 \xrightarrow{H^+} C(CH_3\overset{O}{\overset{\|}{C}}-OH)$$

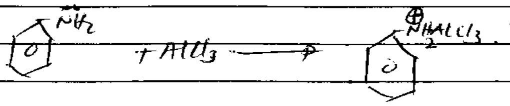
$$B(CH_3\overset{O}{\overset{\|}{C}}-H + I_2 + NaOH \xrightarrow[H^+]{} H-\overset{O}{\overset{\|}{C}}-ONa + CHI_3 + NaI + H_2O.$$

$$B(CH_3\overset{O}{\overset{\|}{C}}-H + HCN \xrightarrow{\Delta} 2(CH_3\overset{OH}{\underset{H}{C}}-CN.)$$

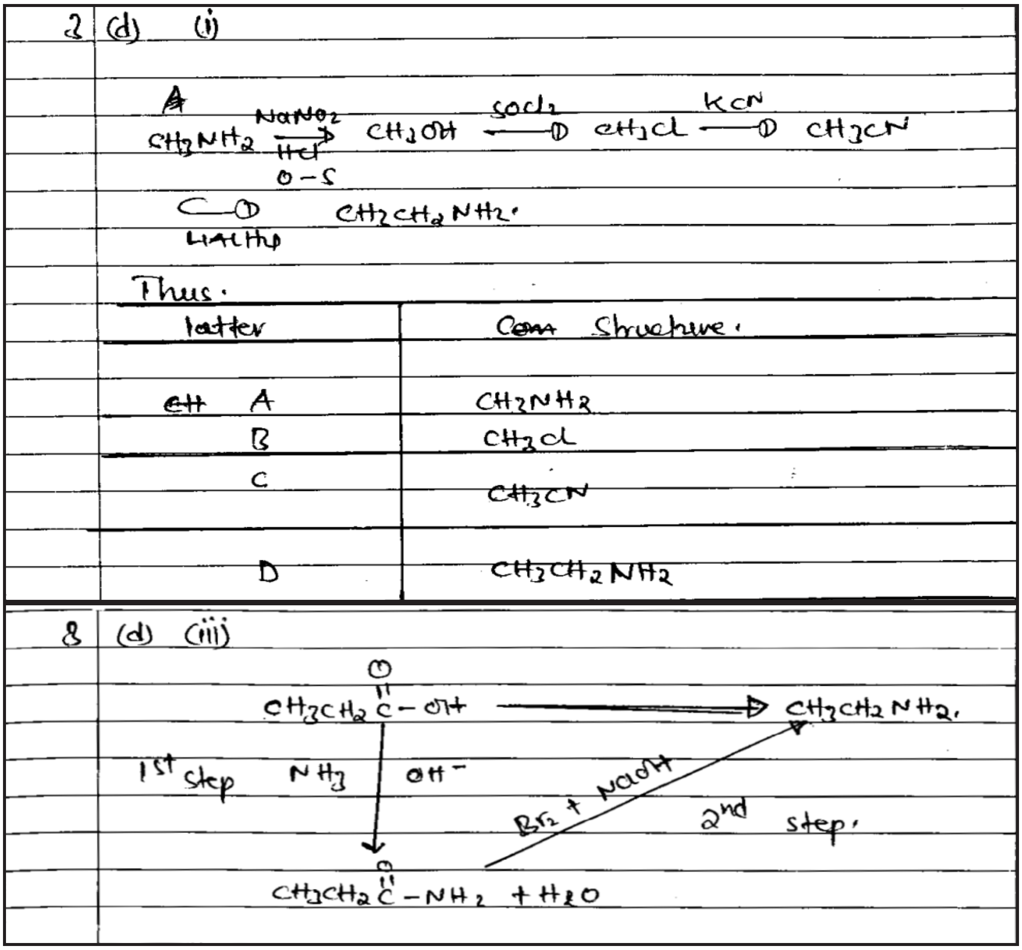
$$2(CH_3\overset{OH}{\underset{H}{C}}-CN + H_2O \xrightarrow{H^+} CH_3\overset{OH}{\underset{H}{C}}-\overset{O}{\overset{\|}{C}}-OH$$

8 (c) (i) Methylamine has lower boiling point than methanol since methanol form tee strong hydrogen bonding hence makes it to have high boiling point than methylamine

3 (c)(ii) friedel craff alkylation takes place in the presence of lewis acid Acid, $AlCl_3$. Aniline contains lone pair hence it is Lewis base. Therefore during the process of reaction Aniline will react with $AlCl_3$ to form salts instead of reacting with haloalkane.



This make Aniline not undergo friedel Craft acylation.



3 (d) (i)

A

$CH_3NH_2 \xrightarrow[HCl,\ 0-5]{NaNO_2} CH_3OH \xrightarrow{SOCl_2} CH_3Cl \xrightarrow{KCN} CH_3CN$

$C \xrightarrow[LiAlH_4]{} CH_3CH_2NH_2$.

Thus.

letter	Com Structure.
~~CH~~ A	CH_3NH_2
B	CH_3Cl
C	CH_3CN
D	$CH_3CH_2NH_2$

3 (d) (iii)

$CH_3CH_2\overset{O}{\overset{\|}{C}}-OH \longrightarrow CH_3CH_2NH_2$.

1st step NH_3 OH^-

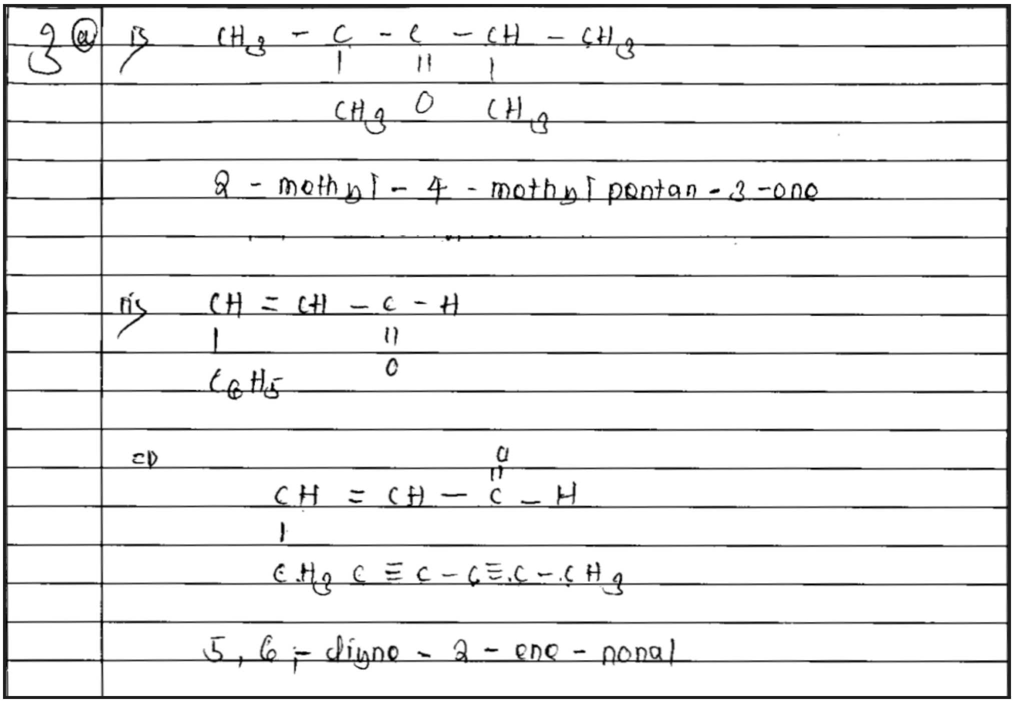
$CH_3CH_2\overset{O}{\overset{\|}{C}}-NH_2 + H_2O$

$Br_2 + NaOH$ 2nd step.

Extract 13.1: A sample of correct responses to Question 3 Paper 2

In Extract 13.1, the candidate responded very well to most parts of the question. He/she gave the correct explanations and supported them with relevant chemical equations. However, the candidate skipped item (d)(ii).

The candidates (60.19%) who scored low marks in this question lacked knowledge on carbonyl compounds, amines, alcohols and carboxylic acids. The candidates failed to apply IUPAC rules'. For instance, in part (a), some of the candidates incorrectly named the compounds as alkenes and alcohols instead of carbonyl compounds. This means that they failed to identify functional groups of organic compounds. In part (b), the candidates gave incorrect structures in (b)(i), incorrect explanations in(b)(ii) and incorrect chemical equations in(b)(iii). For instance, one candidate wrote a chemical equation for the reaction between compound **B** and water instead of oxidizing agent to form compound **C**. In part (c), the candidates failed to explain that hydrogen bonding as the reason behind the boiling point of methylamine being lower than that of methanol. In part (d), the candidates gave incorrect structures, incorrect preparation of ethylamine, and inappropriate order of basic strengths. For instance, in item (d)(i), one candidate identified compound **D** as CH_4 instead of $CH_3CH_2NH_2$. Another candidate responded to item (d)(iii) by reacting propanoic acid with alcohol instead of ammonia. Extract 13.2 shows a sample of incorrect responses to this question.



3 (a) i)

$$CH_3-\underset{\substack{|\\CH_3}}{C}-\underset{\substack{\|\\O}}{C}-\underset{\substack{|\\CH_3}}{CH}-CH_3$$

2 - methyl - 4 - methyl pentan - 3 - one

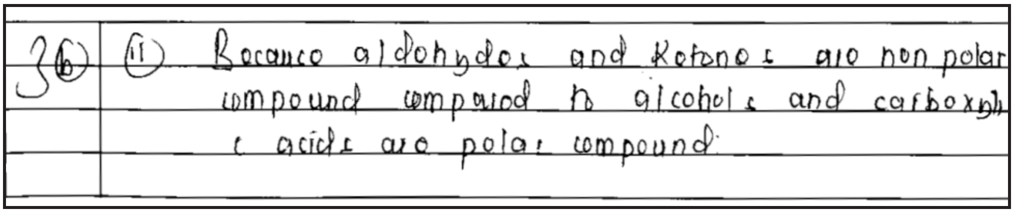
ii)

$$\underset{\substack{|\\C_6H_5}}{CH}=CH-\underset{\substack{\|\\O}}{C}-H$$

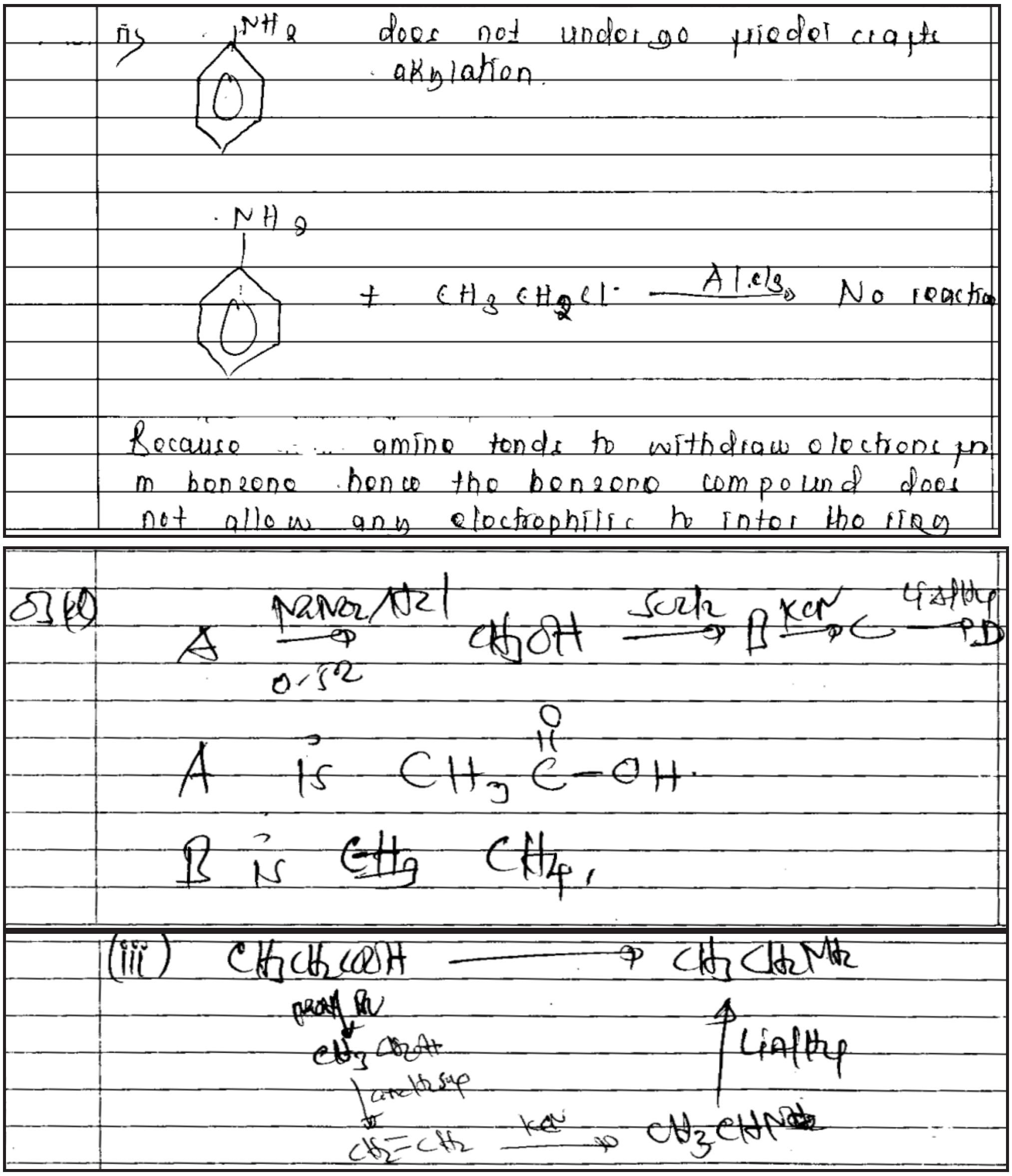
iii)

$$\underset{\substack{|\\CH_3C\equiv C-C\equiv C-CH_3}}{CH}=CH-\overset{\substack{O\\\|}}{C}-H$$

5, 6 - diyne - 2 - ene - nonal



3 (b) (ii) Because aldehydes and ketones are non polar compound compared to alcohols and carboxylic acids are polar compound.



ii) NH_2 does not undergo friedel crafts alkylation.

NH_2 + $CH_3CH_2Cl \xrightarrow{AlCl_3}$ No reaction

Because amino tends to withdraw electrons from benzene hence the benzene compound does not allow any electrophilic to enter the ring

3(d) $A \xrightarrow[0-5]{NaNO_2/HCl} CH_3OH \xrightarrow{SOCl_2} B \xrightarrow{KCN} C \xrightarrow{LiAlH_4} D$

A is $CH_3\overset{O}{\overset{\|}{C}}-OH$.

B is ~~CH_3~~ CH_4,

(iii) $CH_3CH_2COOH \longrightarrow CH_3CH_2NH_2$

[illegible] ↓ CH_3COOH

↓ [illegible]

$CH_2=CH_2 \xrightarrow{KCN} CH_3CH_2CN$ ↑ $LiAlH_4$

Extract 13.2: A sample of incorrect responses to Question 3 Paper 2

In Extract 13.2, the candidates attempted part (a) by writing incorrect names of the molecules given. In part (b)(i), the candidate cited the concept of polarity of compounds instead of hydrogen bonding. The candidate gave incorrect reason in (b)(ii) and skipped part (c). In part (d), the candidate identified compounds **A** and **B** as ethanoic acid and methane instead of methylamine and chloromethane, respectively. In the last item, the candidate wrote a conversion procedure involving four instead of two reaction steps.

2.2.4 Question 4: Transition Elements / Polymers

The question was as follows:

(a) *Given the following complex compound* $K_3[Fe(NH_3)_6]$*;*

(i) *Give the IUPAC name of the compound.*

(ii) *What is the number of electrons in the d-orbital in the central metal atom?*

(iii) *Give the geometric structure and hybridization of the complex.*

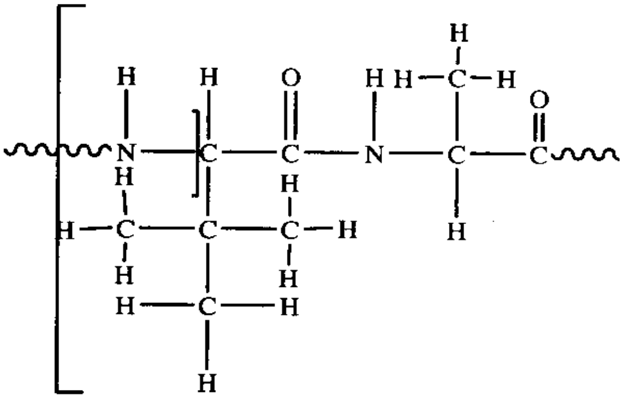
(iv) *Is the complex cationic, anionic or neutral? Briefly, explain.*

(b) *Briefly, comment on the following statements:*

(i) *Silver nitrate can react with* $[Cu(NH_3)_5Cl]Cl$ *but not with* $[Cu(NH_3)_5Cl_2]$

(ii) *The complex compounds of cobalt have different colours;* $[Co(CN)_6]^{3-}$ *is yellow,* $[Co(NH_3)_6]^{3+}$ *is orange while* $[Co(H_2O)_6]^{3+}$ *is blue.*

(c) *Protein is the polymer of amino acid produced naturally by plants and has the formula;*



(i) *Name the polymer.*

(ii) *Suggest two monomers which might have been used to synthesize this polymer.*

(iii) *Is this an addition polymer or condensation polymer? Give reasons for your answer.*

(iv) *Write the reaction equation to show how this polymer is formed.*

(d) (i) *Suppose you are a chemist in one of the synthetic industries and you are required to synthesize a polymer using acrylonitrile ($CH_2=CH–CN$) monomers. What type of polymerization process will you employ in order to synthesize the required polymer? Give a reason for your answer.*

(ii) *With an example in each, distinguish homopolymer from co–polymer.*

This question was attempted by 34,106 (90.22%) candidates and their performance was as follows: 19,228 (56.38%) scored from 0–6.5 marks, 10,867 (31.86%) scored from 7–11.5 marks and 4,011 (11.76%) scored from 12–20 marks. The candidates' overall performance in this question was average as 14,878 (43.62%) candidates scored 7 marks or above. A summary of performance of candidates is shown in Figure 14.

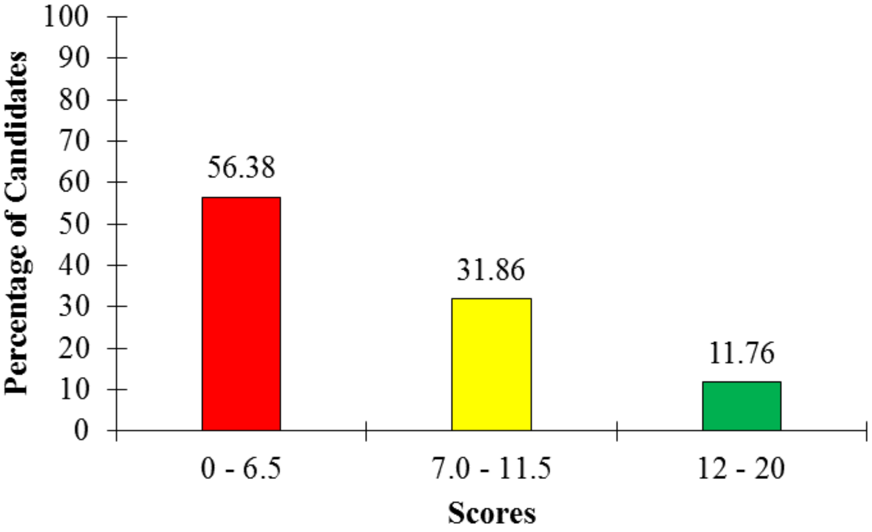
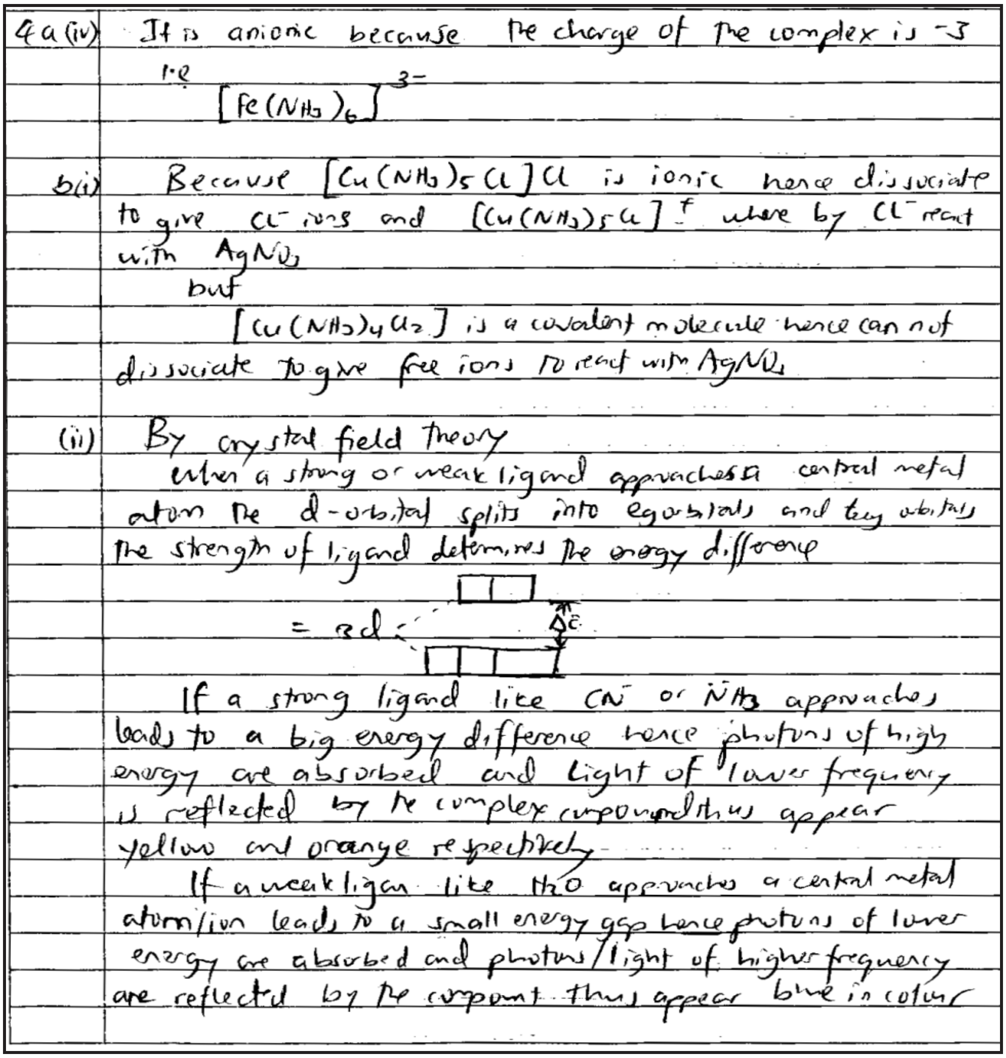


Figure 14: *Candidates' Performance In Question 4 Paper 2*

The candidates (11.76%) who scored high marks named the complex compound (according to IUPAC system) and identified the number of electrons in d-subshell of the central metal atom (ion) in part (a). Similarly, they identified the geometric structure, hybridization and the type of complex compound.

In part (b), the candidates appropriately commented on the observations in (i) and (ii). In part (c), the candidates named the polymer and identified its monomers and type of polymerization process involved. Moreover, the candidates distinguished homopolymer from co-polymer with the aid of examples. A sample of correct responses is shown in Extract 14.1.



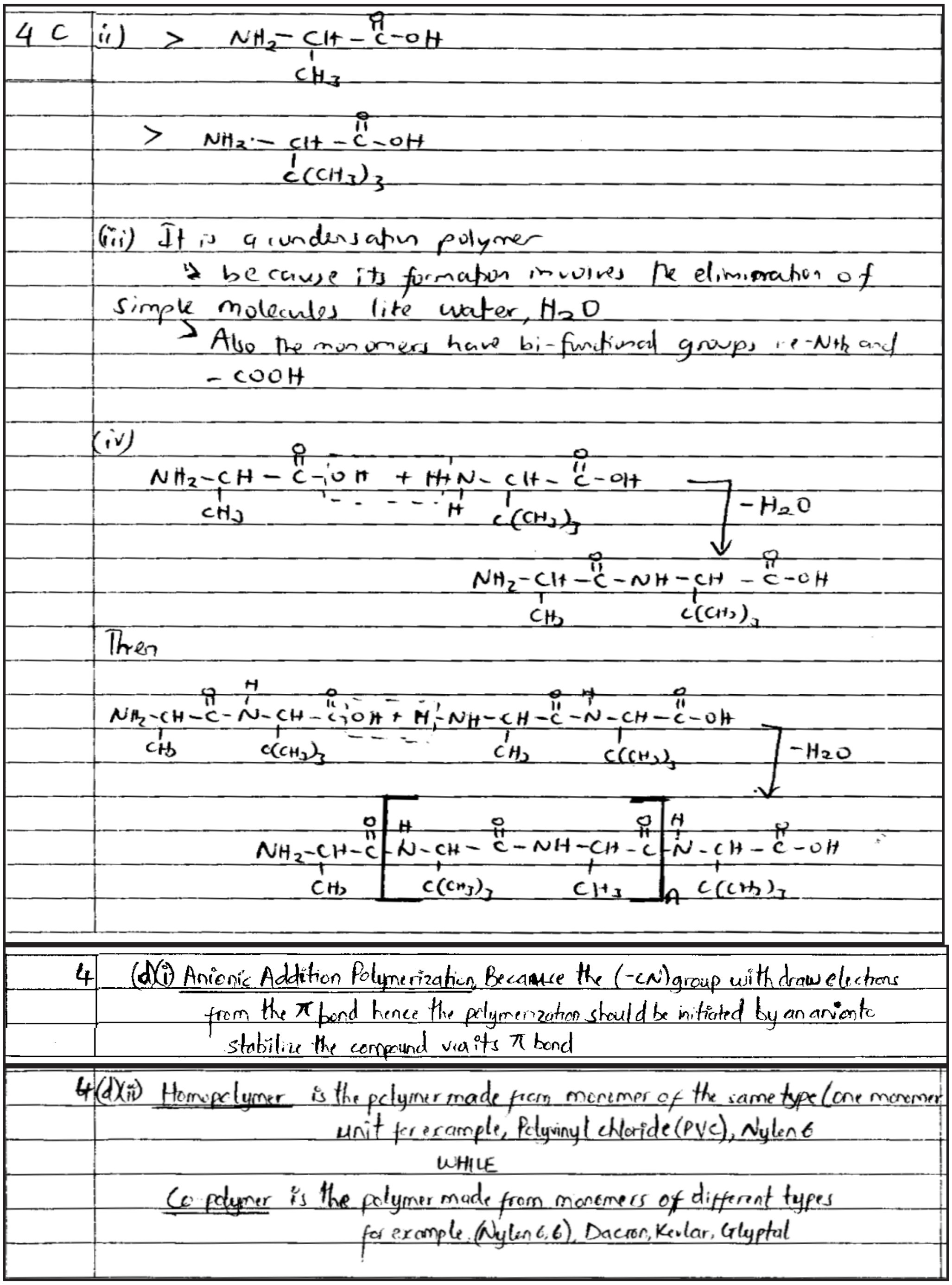
4a (iv) It is anionic because the charge of the complex is -3
i.e
$[Fe(NH_3)_6]^{3-}$

b(i) Because $[Cu(NH_3)_5Cl]Cl$ is ionic hence dissociate to give Cl^- ions and $[Cu(NH_3)_5Cl]^+$ where by Cl^- react with $AgNO_3$
but
$[Cu(NH_3)_4Cl_2]$ is a covalent molecule hence can not dissociate to give free ions to react with $AgNO_3$

(ii) By crystal field theory
when a strong or weak ligand approaches a central metal atom the d-orbital splits into eg orbitals and t2g orbitals the strength of ligand determines the energy difference

= 3d
Δo

If a strong ligand like CN^- or NH_3 approaches leads to a big energy difference hence photons of high energy are absorbed and light of lower frequency is reflected by the complex compound thus appear yellow and orange respectively
If a weak ligan like H_2O approaches a central metal atom/ion leads to a small energy gap hence photons of lower energy are absorbed and photons/light of higher frequency are reflected by the compount thus appear blue in colour



4 C (ii) > $NH_2-\underset{CH_3}{CH}-\overset{O}{\overset{\|}{C}}-OH$

> $NH_2-\underset{C(CH_3)_3}{CH}-\overset{O}{\overset{\|}{C}}-OH$

(iii) It is a condensation polymer

> because its formation involves the elimination of simple molecules like water, H_2O

> Also the monomers have bi-functional groups i.e -NH_2 and -COOH

(iv)

$$NH_2-\underset{CH_3}{CH}-\overset{O}{\overset{\|}{C}}-OH + H-\underset{H}{N}-\underset{C(CH_3)_3}{CH}-\overset{O}{\overset{\|}{C}}-OH \xrightarrow{-H_2O} NH_2-\underset{CH_3}{CH}-\overset{O}{\overset{\|}{C}}-NH-\underset{C(CH_3)_3}{CH}-\overset{O}{\overset{\|}{C}}-OH$$

Then

$$NH_2-\underset{CH_3}{CH}-\overset{O}{\overset{\|}{C}}-\overset{H}{N}-\underset{C(CH_3)_3}{CH}-\overset{O}{\overset{\|}{C}}-OH + H-NH-\underset{CH_3}{CH}-\overset{O}{\overset{\|}{C}}-\overset{H}{N}-\underset{C(CH_3)_3}{CH}-\overset{O}{\overset{\|}{C}}-OH \xrightarrow{-H_2O}$$

$$NH_2-\underset{CH_3}{CH}-\overset{O}{\overset{\|}{C}}\left[-\overset{H}{N}-\underset{C(CH_3)_3}{CH}-\overset{O}{\overset{\|}{C}}-NH-\underset{CH_3}{CH}-\overset{O}{\overset{\|}{C}}-\right]_n\overset{H}{N}-\underset{C(CH_3)_3}{CH}-\overset{O}{\overset{\|}{C}}-OH$$

4 (d)(i) Anionic Addition Polymerization, Because the (-CN) group withdraw electrons from the π bond hence the polymerization should be initiated by an anion to stabilize the compound via its π bond

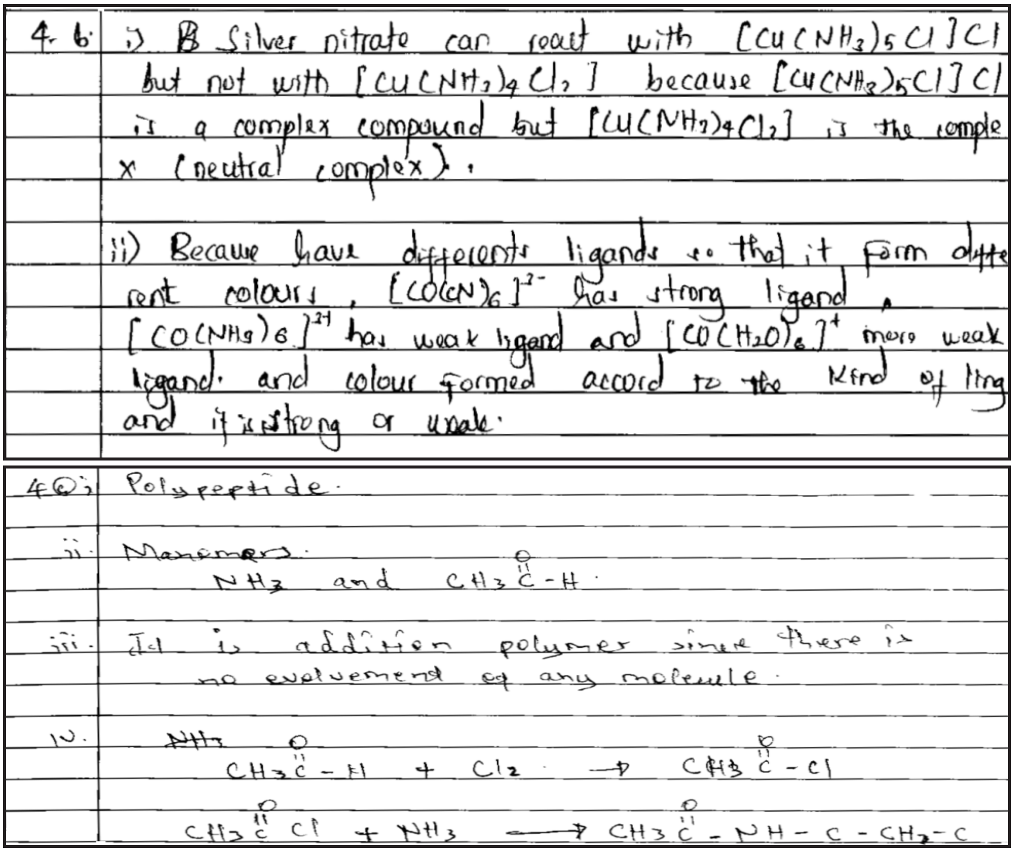
4(d)(ii) Homopolymer is the polymer made from monomer of the same type (one monomer unit for example, Polyvinyl chloride (PVC), Nylon 6

WHILE

Co-polymer is the polymer made from monomers of different types for example. (Nylon 6,6), Dacron, Kevlar, Glyptal

Extract 14.1 A sample of the correct responses to Question 4 Paper 2

However, some of the candidates (56.38%) lacked competences on complex compounds and polymers. For example, in part (a), some of them gave incorrect names of the compound. Others incorrectly identified the complex compound as a *neutral* or *cationic* instead of stating the fact that it was *anionic* compound. In part (b)(i), the candidates failed to explain the ionization of *$[Cu(NH_3)_5Cl]Cl$* in aqueous solution to give the chloride ions which later react with silver ions from silver nitrate to give white precipitates of silver chloride. Similarly, they failed to explain that compound *$[Cu(NH_3)_5Cl_2]$* does not ionize in aqueous solution since the chloride ions are bound inside the shell. In part (b)(ii), the candidates failed to recall the concept of strength of ligands as the factor causing the difference in colours of the complex compounds. In part (c), the candidates gave incorrect name of the protein and suggested inappropriate monomers. Generally, the candidates had did not have sufficient knowledge on the amino and the carboxylic parts of amino acids. Also, the candidates failed to write the reaction equation for the formation of the polymer. In part (d) the candidates gave incorrect type of polymerization process. They also failed to distinguish homopolymer from co-polymer. The candidates failed to realize that a homopolymer is made up monomers of one type while a co-polymer is made up of monomers of different types. A sample of incorrect responses is shown in Extract 14.2.



4. b. i) ~~B~~ Silver nitrate can react with $[Cu(NH_3)_5Cl]Cl$ but not with $[Cu(NH_3)_4Cl_2]$ because $[Cu(NH_3)_5Cl]Cl$ is a complex compound but $[Cu(NH_3)_4Cl_2]$ is the complex (neutral complex).

ii) Because have differents ligands so that it form different colours, $[Co(CN)_6]^{3-}$ has strong ligand, $[Co(NH_3)_6]^{3+}$ has weak ligand and $[Co(H_2O)_6]^{+}$ more weak ligand. and colour formed accord to the kind of ling and if is strong or weak.

4 (c) i Polypeptide.

ii. Monomers.
NH_3 and $CH_3\overset{O}{\overset{\|}{C}}-H$.

iii. It is addition polymer since there is no evolvement of any molecule.

iv. ~~NH_3~~
$CH_3\overset{O}{\overset{\|}{C}}-H + Cl_2 \rightarrow CH_3\overset{O}{\overset{\|}{C}}-Cl$
$CH_3\overset{O}{\overset{\|}{C}}Cl + NH_3 \longrightarrow CH_3\overset{O}{\overset{\|}{C}}-NH-C-CH_2-C$

Extract 14.2: A sample of incorrect responses to Question 4 Paper 2

In Extract 14.2, the candidate stated that ammonia is a weak ligand instead of stating it is a a strong one. In addition, the candidate gave the name of the class to which the protein belongs (polypeptide) instead of giving the specific name of the protein. Moreover, the candidate skipped parts (a) and (d).

2.2.5 Question 5: Periodic Classification / Extraction of Metals

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

(a) *Briefly describe four characteristics of p–block elements.*

(b) *In four ways, briefly explain the factors affecting ionization energy.*

(c) *How do oxides of period 3 elements react with water? Explain briefly and support your answer with appropriate chemical equations.*

(d) *You have been asked to extract sodium metal from sea water through electrolysis. What will be the drawback and how would you overcome it? Explain briefly and support your answer with appropriate chemical equations.*

This question was attempted by 29,839 (78.93%) candidates; out of whom, 24,458 (81.96%) scored from 0–6.5 marks, 4,997 (16.75%) scored from 7–11.5 marks and 384 (1.29%) scored from 12–20 marks. The general performance in this question was weak since only 5,381 (18.04%) candidates scored 7 marks or above. Figure 15 summarizes the performance in the candidates on this question.

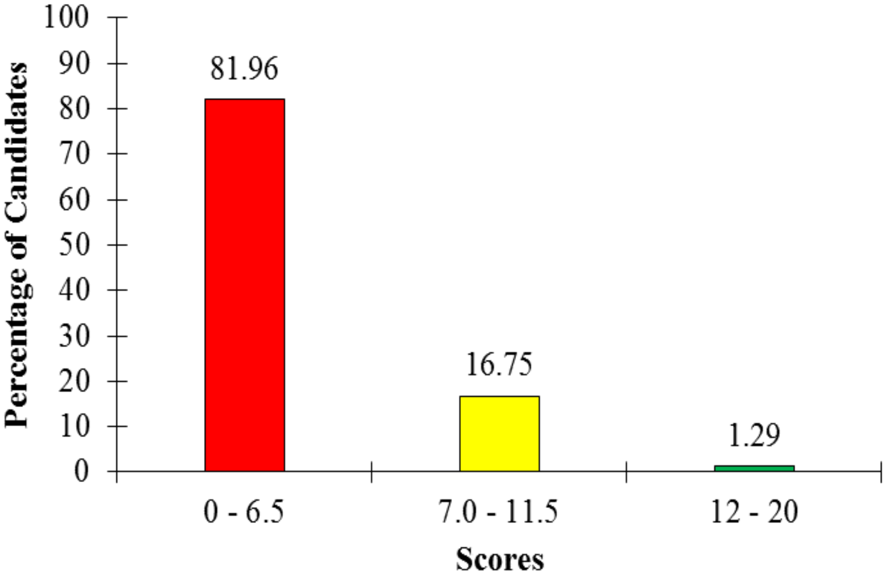
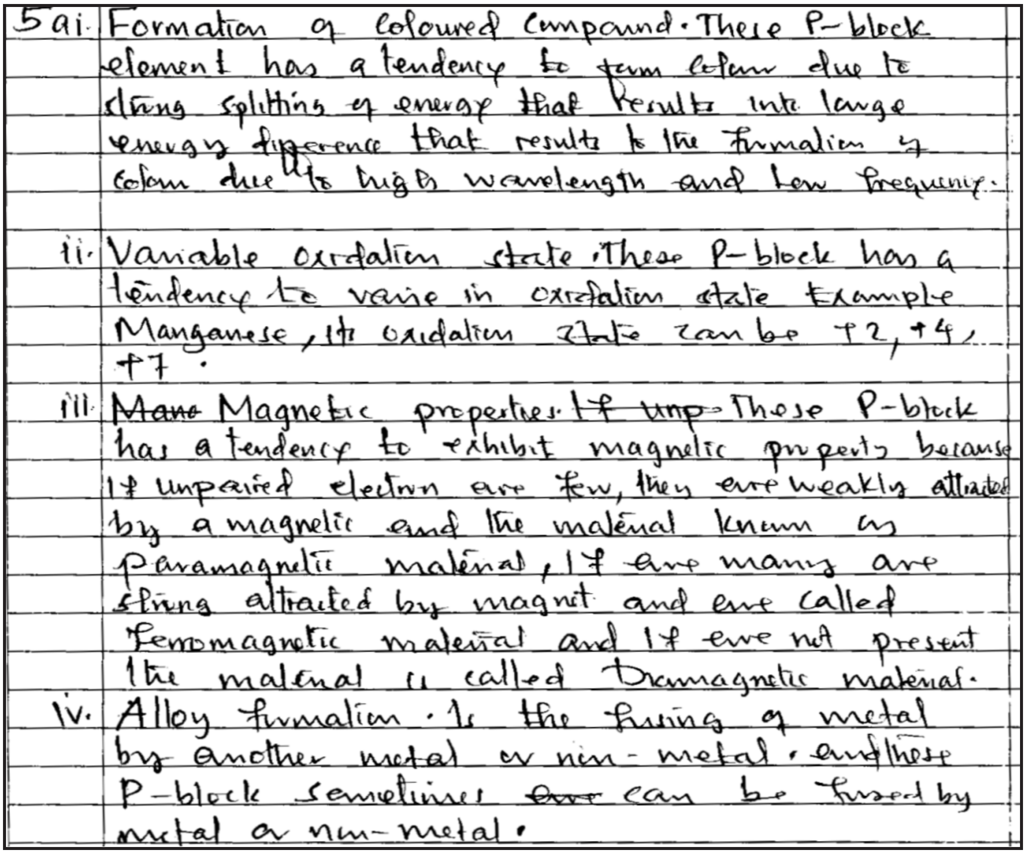


Figure 15: *Candidates' Performance in Question 5 Paper 2*

The candidates (81.96%) who scored low marks described incorrect characteristics of *p*-block elements in part (a). For instance, some candidates wrote the characteristics of d-block elements instead of those of p-block elements. Others wrote the general formula for the outer electronic configuration of p-block elements, $ns^{1-2}(n-1)d^{1-10}$ which in this sense is not considered as a characteristic. In part (b), the candidates failed to explain the factors affecting ionization energy. The common misconceptions include boiling point, freezing point, temperature and electronegativity. In part (c), the candidates failed to explain the reactions of oxides of period 3 elements with water. Some of the candidates mentioned incorrect products such as formation of oxygen gas and free elements. Others wrote chemical reactions of elements of group III elements with water. In part (d), the candidates failed to explain the drawback of extracting sodium metal from sea water by electrolysis. Some candidates wrote the half equation for the deposition of sodium at the cathode without pointing the drawback. Other candidates stated that electrolysis is very expensive hence, low voltage should be used so as to minimize cost. A sample of incorrect responses is shown in Extract 15.1.

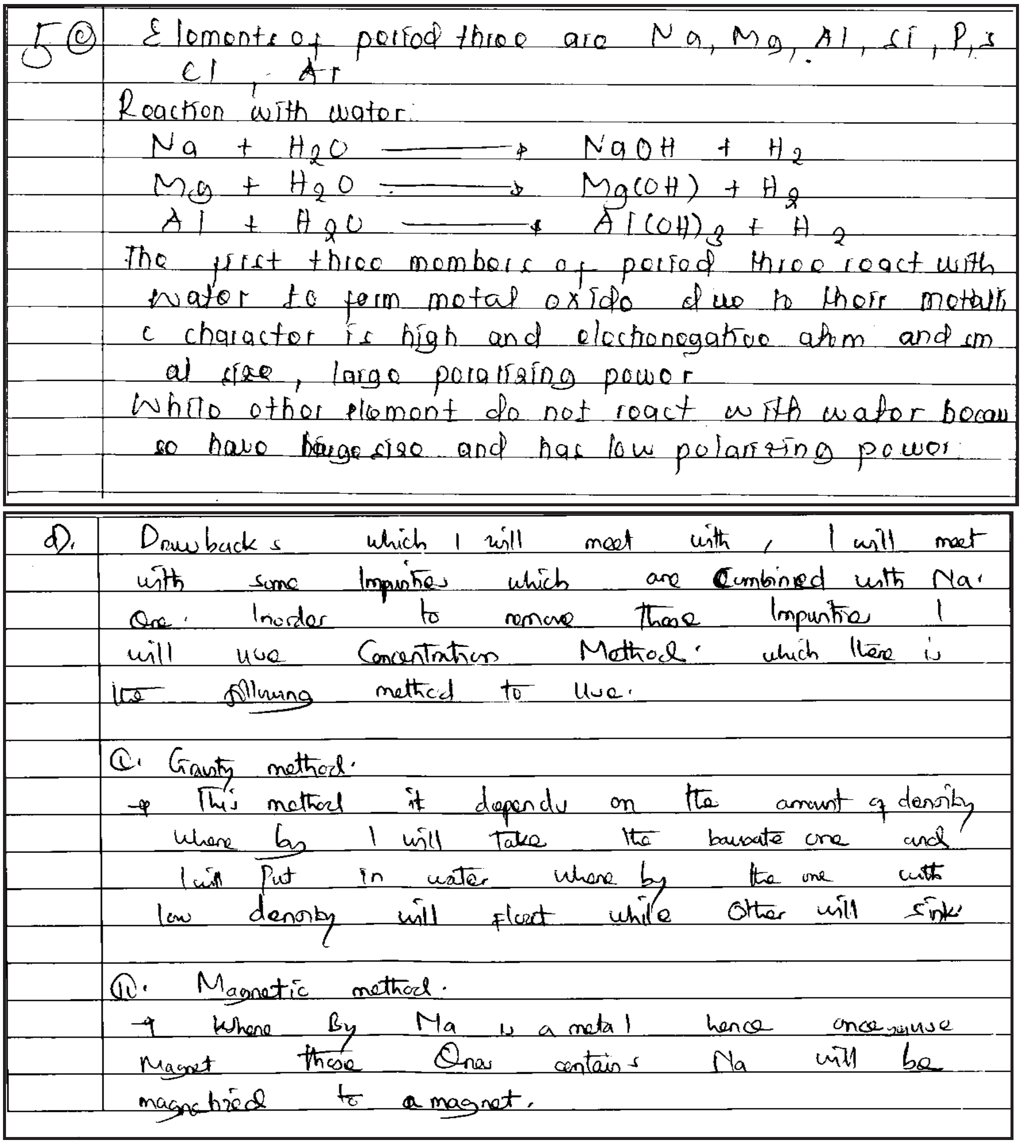


5 a i. Formation of coloured compound. These P-block
element has a tendency to form colour due to
strong splitting of energy that results into large
energy difference that results to the formation of
colour due to high wavelength and low frequency.

ii. Variable oxidation state. These P-block has a
tendency to varie in oxidation state Example
Manganese, its oxidation state can be +2, +4,
+7.

iii. ~~Mano~~ Magnetic properties. ~~If unp~~ These P-block
has a tendency to exhibit magnetic property because
if unpaired electron are few, they are weakly attracted
by a magnetic and the material known as
paramagnetic material, if are many are
strong attracted by magnet and are called
Ferromagnetic material and if are not present
the material is called Diamagnetic material.

iv. Alloy formation. Is the fusing of metal
by another metal or non-metal. and these
P-block sometimes ~~are~~ can be fused by
metal or non-metal.



5 (c) Elements of period three are Na, Mg, Al, Si, P, S
Cl, Ar
Reaction with water:
$Na + H_2O \longrightarrow NaOH + H_2$
$Mg + H_2O \longrightarrow Mg(OH) + H_2$
$Al + H_2O \longrightarrow Al(OH)_3 + H_2$
The first three members of period three react with
water to form metal oxide due to their metalli
c character is high and electronegative atom and sm
al size, large polarising power
While other element do not react with water becau
se have large size and has low polarising power.

d). Drawbacks which I will meet with, I will meet
with some Impurities which are Combined with Na.
Ore. Inorder to remove these Impurities I
will use Concentration Method. which there is
the following method to use.

(i). Gravity method.
→ This method it depends on the amount of density
where by I will take the bauxite one and
I will Put in water where by the one with
low density will float while Other will sink.

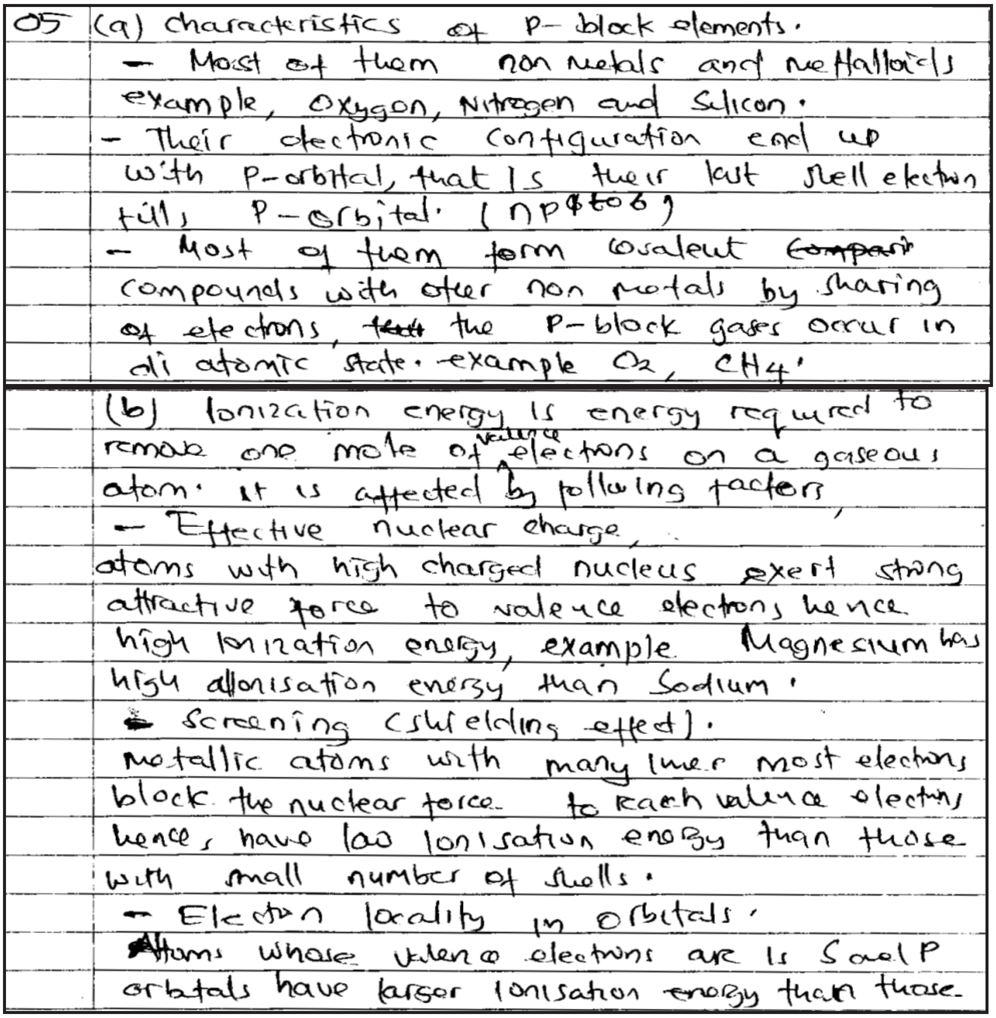
(ii). Magnetic method.
→ Where By Na is a metal hence once you use
Magnet these Ores contains Na will be
magnetized to a magnet.

Extract 15.1: A sample of incorrect responses to Question 5 Paper 2

In Extract 15.1, the candidate wrote properties of transition elements instead of p-block elements in part (a). In part (c), the candidate wrote reaction of water with period 3 elements instead of oxides of period 3 elements. In part (d), he/she cited presence of impurities instead of the unsuitability of using aqueous solution of sodium in electrolysis. Thus the candidate explained methods of purifying metal ores instead of the need to use fused instead of aqueous sodium.

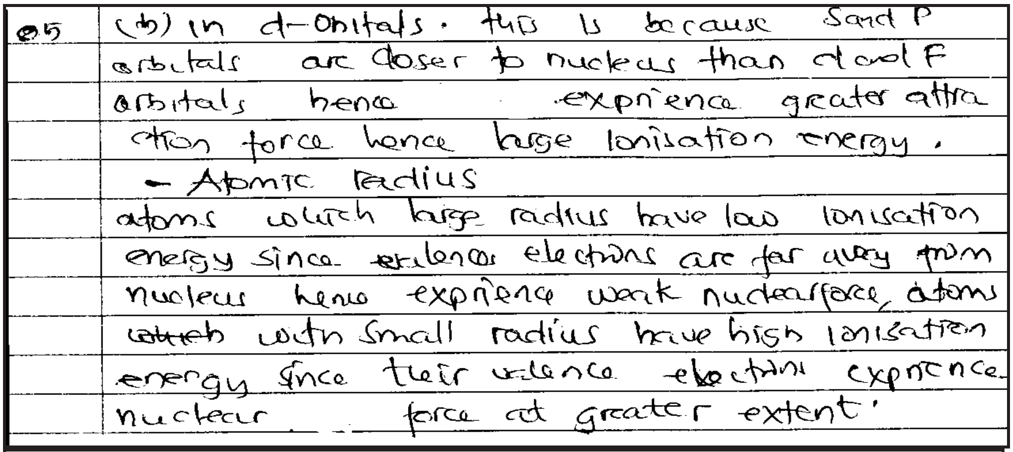
The candidates (1.29%) who scored high marks gave the characteristics of p-block elements and the factors affecting the ionization energy of elements.

They also gave relevant explanations and chemical equations of how oxides of elements of period 3 react with water. Furthermore, they explained the extraction of sodium metal from sea water by means of electrometallurgy technique (by means of electrolysis) with the aid of relevant half oxidation and reduction reactions at the electrodes as shown in Extract 15.2.



05 (a) characteristics of P- block elements.
- Most of them non metals and metalloids
example, Oxygon, Nitrogen and Silicon.
- Their electronic configuration end up
with P-orbital, that is their last shell electron
fill, P-orbital. ($np^{\phi\,to\,6}$)
- Most of them form covalent ~~compon~~
compounds with other non metals by sharing
of electrons, ~~that~~ the P-block gases occur in
di atomic state. example O_2, CH_4.

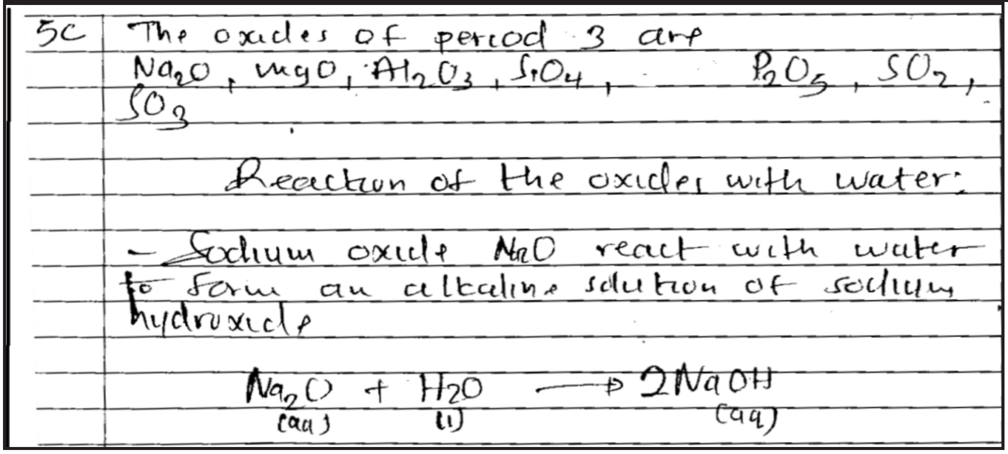
(b) Ionization energy is energy required to
remove one mole of valence electrons on a gaseous
atom. it is affected by following factors,
- Effective nuclear charge,
atoms with high charged nucleus exert strong
attractive force to valence electrons hence
high ionization energy, example Magnesium has
high allonisation energy than Sodium.
- Screening (shielding effect).
metallic atoms with many inner most electrons
block the nuclear force to reach valence electrons
hence, have low ionisation energy than those
with small number of shells.
- Electron locality in orbitals.
Atoms whose valence electrons are is S and P
orbitals have larger ionisation energy than those



Q5 (b) in d-orbitals. this is because s and p orbitals are closer to nucleus than d and F orbitals hence exprience greater attraction force hence large ionisation energy.

- Atomic radius

atoms which large radius have low ionisation energy since ~~va~~lence electrons are far away from nucleus hence exprience weak nuclearforce, atoms ~~which~~ with small radius have high ionisation energy since their valence electrons exprience nuclear force at greater extent.



5C The oxides of period 3 are

Na_2O, MgO, Al_2O_3, SiO_4, P_2O_5, SO_2, SO_3

Reaction of the oxides with water:

- Sodium oxide NaO react with water to form an alkaline solution of sodium hydroxide

$$Na_2O_{(aq)} + H_2O_{(l)} \longrightarrow 2NaOH_{(aq)}$$

5C - Magnesium oxide reacts slowly with water to form a weak base of - magnesium hydroxide as per equation

$$MgO_{(s)} + H_2O_{(l)} \longrightarrow Mg(OH)_{2\,(aq)}$$

- Aluminium oxide reacts with water to form aluminium hydroxide solution which is alkaline

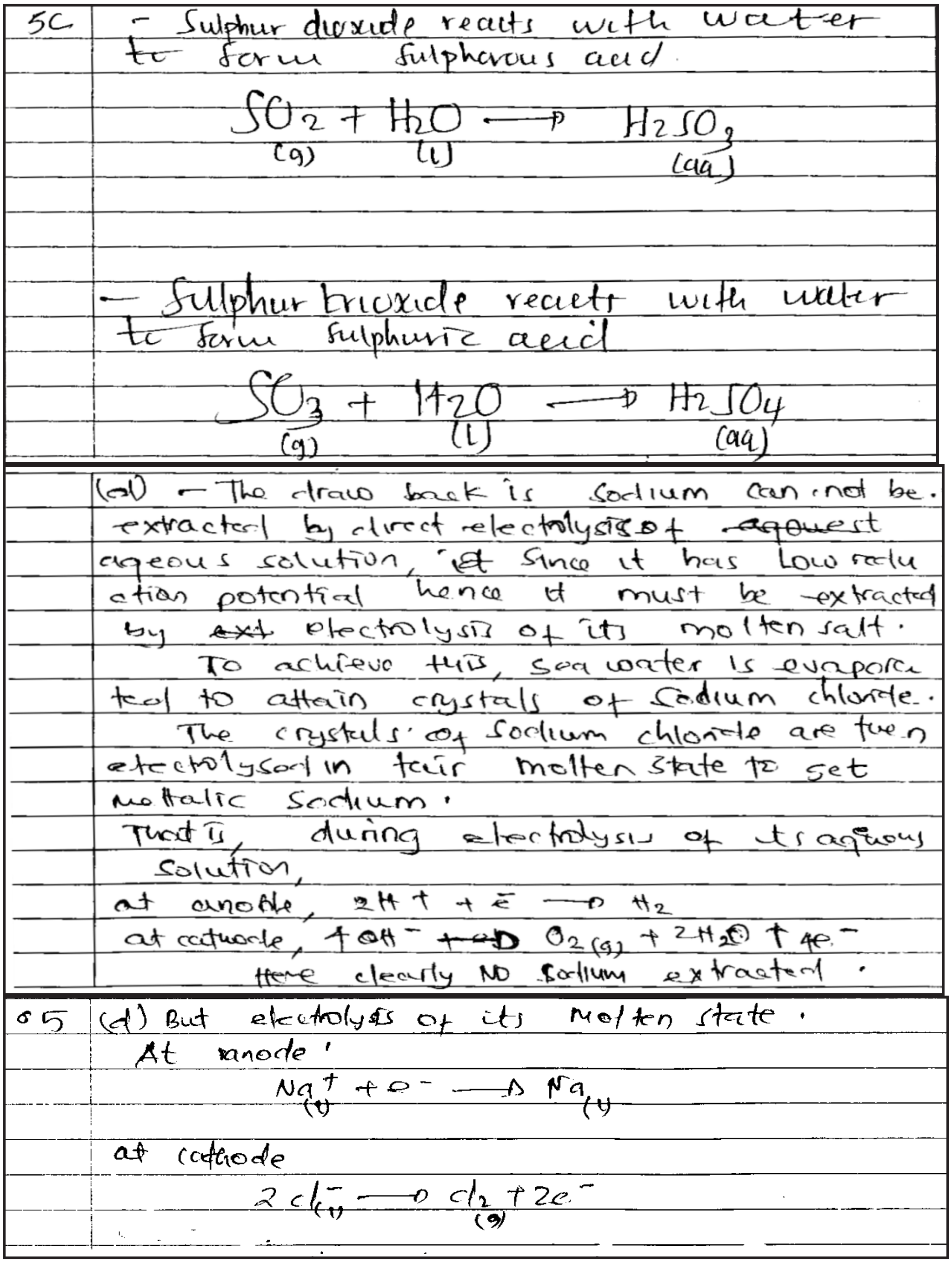
$$Al_2O_{3\,(s)} + 3H_2O_{(l)} \longrightarrow 2Al(OH)_{3\,(aq)}$$

- Silicon (IV) oxide has no reaction with water since it is a giant molecule with high melting and boiling par

$$SiO_2 + H_2O \longrightarrow \text{No reaction}$$

- Phosphorus pentoxide P_2O_5 reacts with water to form phosphoric acid

$$P_2O_{5\,(s)} + 4H_2O \longrightarrow 2H_4PO_3$$



5C – Sulphur dioxide reacts with water to form sulphurous acid.

$$SO_{2(g)} + H_2O_{(l)} \longrightarrow H_2SO_{3(aq)}$$

– Sulphur trioxide reacts with water to form sulphuric acid

$$SO_{3(g)} + H_2O_{(l)} \longrightarrow H_2SO_{4(aq)}$$

(d) – The draw back is sodium can not be extracted by direct electrolysis of ~~aqouest~~ aqeous solution, ~~it~~ since it has low reduction potential hence it must be ~~extracted~~ by ~~ext~~ electrolysis of its molten salt.

To achieve this, sea water is evaporated to attain crystals of sodium chloride.

The crystals of sodium chloride are tuen electrolysed in teir molten state to get metalic sodium.

That is, during electrolysis of its aqueous solution,

at anode, $2H^+ + e^- \longrightarrow H_2$

at cathode, $4OH^- \longrightarrow O_{2(g)} + 2H_2O + 4e^-$

here clearly NO sodium extracted.

05 (d) But electrolysis of its molten state.

At anode:

$$Na^+_{(l)} + e^- \longrightarrow Na_{(l)}$$

at cathode

$$2Cl^-_{(l)} \longrightarrow Cl_{2(g)} + 2e^-$$

Extract 15.2: A sample of the correct responses to Question 5 Paper 2

2.2.6 Question 6: Chemical Kinetics

This question consisted of three parts: (a), (b) and (c). The question was as follows:

(a) *The decomposition of dinitrogen pentoxide is of first order being governed by the reaction equation* $2N_2O_5(g) \longrightarrow 4NO_2(g) + O_2(g)$. *When this reaction was allowed to proceed at 40°C, the following data were collected:*

$[N_2O_5]$M	*Time (min)*
0.400	*0.00*
0.289	*20.0*
0.209	*40.0*
0.151	*60.0*
0.109	*80.0*

Calculate;

(i) *The rate constant at the given temperature without using graph.*

(ii) *The concentration of* N_2O_5 *after 10 minutes.*

(b) *In the Arrhenius equation for a certain reaction, the value of* ***A*** *and* ***Ea*** *are* 4×10^{13}/s *and 98.6 kJ* mol^{-1}, *respectively. If the reaction is of first order, calculate the temperature at which its half – life period will be 10 min.*

(c) *The following data were obtained during the first order thermal decomposition of* SO_2Cl_2 *at constant volume,* $SO_2Cl_2 \xrightarrow{\Delta} SO_2(g) + Cl_2(g)$.

Experiment	***Time*** (s^{-1})	***Total pressure /atom***
1	*0*	*0.5*
2	*100*	*0.6*

Calculate the rate of the reaction when total pressure is 0.65 atmosphere.

This question was attempted by 32,776 (86.70%) of the candidates. Out of whom, 21,410 (65.32 %) scored from 0–6.5 marks, 7,447 (22.72%) scored from 7–11.5 marks and 3,919 (11.96%) scored from 12–20 marks. The general performance in this question was weak since only 11,366 (34.68%) of the candidates scored 7 marks or above. Figure 16 summarizes the candidates' performance on this question.

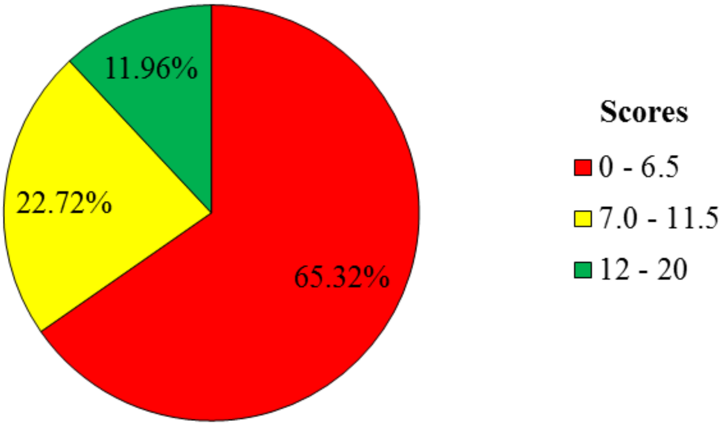
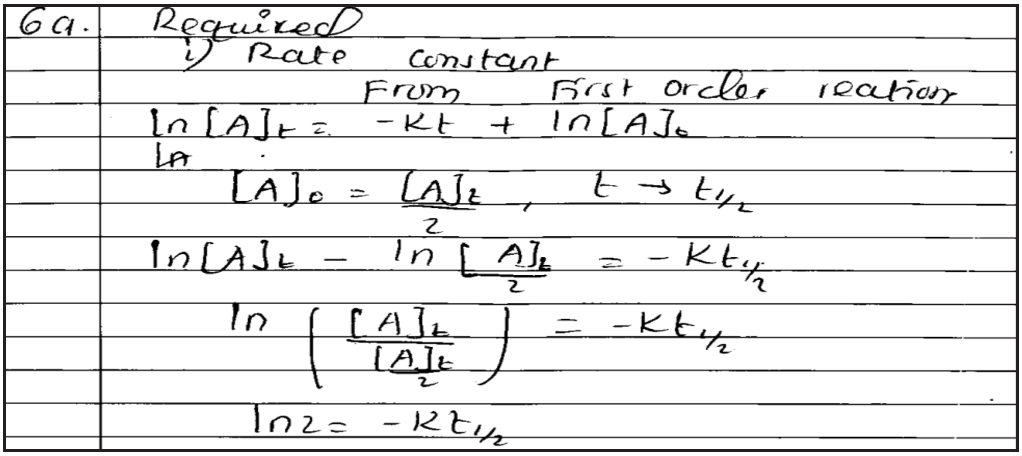


Figure 16: Candidates' *Performance in Question 6 Paper 2*

The candidates (65.32%) who scored low marks failed to calculate both the rate constant of the reaction and the concentration of dinitrogen pentoxide after 10 minutes in part (a). Some of the candidates applied the concept of cross multiplication instead of the rate law to calculate the concentration of dinitrogen pentoxide. In part (b), most of the candidates failed to able to apply the Arrhenius equation. Some candidates wrote the equation correctly but made wrong substitution of data. Others wrote the equation wrongly by swapping initial and final concentration symbols. In part (c), some of the candidates calculated the rate of reaction at a pressure of 0.6 instead of 0.65 atmosphere. Others wrote the formula for equilibrium constant (Kp) which was not appropriate since the reaction was not a reversible process. A sample of incorrect responses is shown in Extract 16.1.



6a. Required

i) Rate constant

From First order reation

$\ln[A]_t = -kt + \ln[A]_0$

ln

$[A]_0 = \frac{[A]_t}{2}$, $t \to t_{1/2}$

$\ln[A]_t - \ln\left[\frac{A]_t}{2}\right. = -kt_{1/2}$

$\ln\left(\frac{[A]_t}{\frac{[A]_t}{2}}\right) = -kt_{1/2}$

$\ln 2 = -kt_{1/2}$

$$k = \frac{-\ln 2}{t_{1/2}}$$

$$k = \frac{-\log 2}{20}$$

$k = -0.03466\ s^{-1}$

hence the rate constant will be

$\underline{-0.03466\ s^{-1}}$

ii) $[N_2O_5]$ required after 10min

From

$\ln[A]_t = -kt + \ln[A]_0$

$\ln[A]_t = -(-0.03466) \times 10 + \ln(0.4)$

$\ln[A]_t = -0.56972$

$[N_2O_5] = 0.567M$

hence the concentration of $[N_2O_5]$ is $\underline{0.567M}$.

6b data given

$A = 4 \times 10^{13}\ s$

$Ea = 98.6\ kJ\ mol^{-1}$

$t_{1/2} = 10min$

From

$K = Ae^{-RT}$

$\frac{1}{10\times60\,s} = 4$

From

$$k = \frac{\ln 2}{10\times60}$$

$k = 1.155 \times 10^{-3}\ s^{-1}$

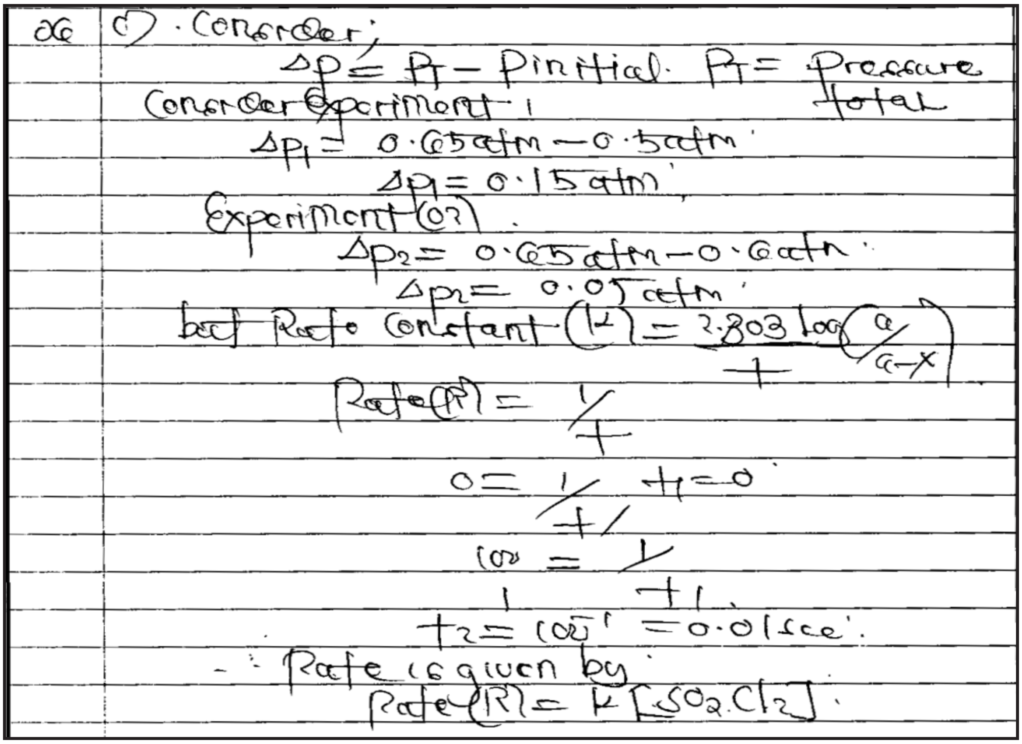
~~K~~

$Ea = KAe^{RT}$

$$T = \frac{Ea}{KA} = \frac{98.6\ kJ\ mol^{-1}}{1.155\times10^{-3} \times 4\times10^{13}} \times 0.0821\text{ATO}$$

$T = 17K$

hence The temperature will be 17K



6 (c) · Consider;

$\Delta P = P_T - P_{initial}$ · P_T = Pressure Total

Consider Experiment 1

$\Delta P_1 = 0{\cdot}65atm - 0{\cdot}5atm$

$\Delta P_1 = 0{\cdot}15atm$

Experiment (02).

$\Delta P_2 = 0{\cdot}65atm - 0{\cdot}6atm$

$\Delta P_2 = 0{\cdot}05atm$

but Rate Constant (K) $= \frac{2.303}{t} \log\left(\frac{a}{a-x}\right)$

Rate(R) $= \frac{1}{t}$

$0 = \frac{1}{t_1}$, $t_1 = 0$

$\frac{10s}{1} = \frac{1}{t_1}$

$t_2 = 10s^{-1} = 0{\cdot}01sec$

∴ Rate is given by

Rate(R) $= K[SO_2Cl_2]$

Extract 16.1: A sample of the incorrect responses to Question 6 Paper 2

In Extract 16.1, the candidate got a negative value for the rate constant in part (a) (i). In item (a) (ii), the candidate obtained incorrect value which is greater (it should be smaller) than the initial concentration of N_2O_5. In part (b), the candidate used incorrect Arrhenius expression to calculate the temperature of the reaction. In part (c), the candidate failed to associate partial with concentration in the rate of chemical reaction.

On the other hand, candidates (11.96%) who scored high marks calculated the value of rate constant of the reaction without using graphical method in part (a). In part (b), the candidates also calculated the temperature of the reaction by using Arrhenius equation. Moreover, in part (c), they correctly calculated the rate of reaction and the total pressure of the reaction by using integrated rate law equation for the first order reaction. A sample of correct responses is shown in Extract 16.2.

6(a). 1st order Reaction.

from,

$$\ln\left(\frac{[A_0]}{[A]}\right) = kt$$

$[A_0]$ = Initial Concentration.

$[A]$ = Concentration at time t

from data provided.

$$\ln\left(\frac{0.4}{0.289}\right) = K \times 20$$

$$K_1 = 16.25 \times 10^{-3}\ \text{min}.$$

for 2nd experiment.

$$\ln\left(\frac{0.4}{0.209}\right) = 40K.$$

$$K_2 = 16.22 \times 10^{-3}\ \text{min}^{-1}$$

3rd experiment.

$$\ln\left(\frac{0.4}{0.151}\right) = 60K.$$

$$K_3 = 16.23 \times 10^{-3}\ \text{min}^{-1}$$

$$\text{Average} = \left(\frac{K_1 + K_2 + K_3}{3}\right).$$

$$= \frac{(16.23 + 16.22 + 16.25) \times 10^{-3}}{3}$$

$$= 16.23 \times 10^{-3}\ \text{min}^{-1}$$

$\therefore$ Rate Constant $= 16.23 \times 10^{-3}\ \text{min}^{-1}$.

6(a) (ii) Conc of N_2O_5 After 10mins.

from.

$$\ln\left(\frac{[N_2O_5]_0}{[N_2O_5]_t}\right) = Kt.$$

$$\frac{[N_2O_5]_0}{[N_2O_5]_t} = e^{Kt}.$$

$$[N_2O_5]_t = \frac{[N_2O_5]_0}{e^{Kt}}$$

plugging data.

$$= \frac{0.4}{e^{(16.23\times10^{-3}\times 10)}}.$$

$$= 0.34\ M.$$

∴ Concentration of N_2O_5 = 0.34 M.

(b) given.

$A = 4\times10^{13}/s$.

$E_a = 98.6\ KJmol^{-1} = 98600\ Jmol^{-1}$.

1st order.

Half-life = 10min = 600s.

required; Temperature

from

Svante Arrhenius equation

$$K = Ae^{-E_a/RT} \quad \text{— (i)}$$

6(b). but, for 1st order reaction.

$$t_{1/2} = \frac{\ln 2}{K}$$

from which

$$K = \frac{\ln 2}{t_{1/2}} \quad \text{—(ii)}$$

equating equation (ii) and (i)

$$\frac{\ln 2}{t_{1/2}} = Ae^{-Ea/RT}$$

plugging data to equation above.

$$\left(\frac{\ln 2}{600}\right) = 4\times10^{13} e^{(-98600/8.31T)}$$

$$\frac{(1.155\times10^{-3})}{4\times10^{13}} = e^{(-98600/8.31T)}$$

$$2.888\times10^{-17} = e^{(-98600/8.31T)}$$

Apply Natural Logarithm.

$$\ln(2.888\times10^{-17}) = \frac{-98600}{8.31T} \ln e.$$

$$T' = \frac{-98600}{8.31 \ln(2.888\times10^{-17})}$$

$$= 311.56K.$$

$\therefore$ Temperature = 311.56K.

06(c) Given $SO_2Cl_2 \xrightarrow{\Delta} SO_{2(g)} + Cl_{2(g)}$

For reaction ration ; reactants : Product = 1 : 2

Thus Initial pressure : final pressure = 1 : 2 (at point of completion)

From first order;

$$K = \frac{1}{t} \ln \left[\frac{[a]}{[a-x]}\right]$$

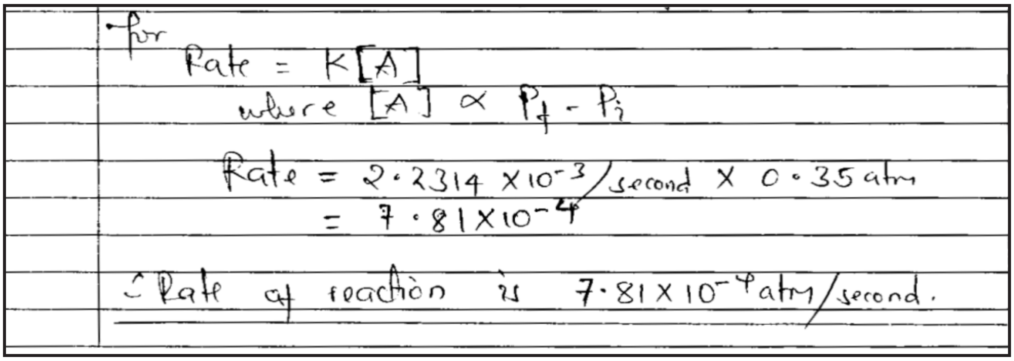
Where $a \propto P_f - P_1$

$a - x \propto P_f - P_t$

Thus $P_f = 2\times P_i$ (pressure at 0)

$= 2\times0.5 = 1$

$$K = \frac{1}{100} \ln\left(\frac{1-0.5}{1-0.6}\right) = 2.2314\times10^{-3}/\text{min}$$



- for

$Rate = K[A]$

where $[A] \propto P_f - P_i$

$Rate = 2\cdot2314 \times 10^{-3}/second \times 0\cdot35\,atm$

$= 7\cdot81 \times 10^{-4}$

$\therefore$ Rate of reaction is $7\cdot81 \times 10^{-4}\,atm/second$.

Extract 16.2: A sample of the correct responses to Question6 Paper 2

2.3 132/3-CHEMISTRY 3

This was the actual practical paper which was in three equivalent alternatives, namely 132/3A Chemistry 3A, 132/3B Chemistry 3B and 132/3C Chemistry 3C. The candidates were required to sit for one of the alternative papers. Each alternative paper consisted of three compulsory questions which carried a total of 50 marks. Question one weighed 20 marks while questions 2 and 3 carried 15 marks each. Each alternative practical paper covered three sub-topics under the topic of *Chemical Analysis*. Questions 1, 2 and 3 were set from the sub-topics of *Volumetric Analysis*, *Physical Chemistry Analysis* and *Qualitative Analysis* respectively. The pass marks for questions 1, 2 and 3 were 7.0, 5.5 and 5.5 marks respectively. The analysis of each question is as follows:

2.3.1 Question 1: Volumetric Analysis

2.3.1.1 Alternative 3A

The question was as follows:
You are provided with the following solutions:
***T1**: A solution containing a mixture of NaOH and* Na_2CO_3*;*
***T2**: 0.2 M hydrochloric acid;*
***POP**: Phenolphthalein indicator;*
***MO**: Methyl orange indicator.*

Procedure

(i) Pipette 20 or 25 cm^3 *of **T1** into a clean conical flask.*

*(ii) Add 3 drops of **POP** into **T1** in (i) and titrate the mixture against **T2** until a colour change is observed.*

(iii) Record the first titre value.

(iv) *After the first end point in step (ii), add 3 drops of* ***MO*** *in the solution mixture and continue titrating until the second colour change is observed.*

(v) *Record the second titre value.*

(vi) *Repeat the procedures (i) to (v) three times. Record your results in a tabular form.*

Table 1: Table of Results

Burette Readings (cm^3)	***Pilot***	***1***	***2***	***3***
Second end point				
First end point				
Initial reading				
First titre volume				
Second titre volume				

Summary

___________________ *cm^3 of* ***T1*** *required*______*cm^3 of* ***T2*** *in the presence of* ***POP*** *and*___________*cm^3 of* ***T2*** *in the presence of* ***MO*** *for complete reaction.*

Questions

(a) *Explain the colour change observed for the reaction taking place between:*

  (i) ***T1*** *and* ***T2*** *in the presence of* ***POP****.*

  (ii) ***T1*** *and* ***T2*** *in the presence of* ***MO****.*

(b) *Write a balanced chemical equation for the reaction taking place in:*

  (i) *Procedure (ii).*

  (ii) *Procedure (iv).*

(c) *Calculate;*

  (i) *the concentration of sodium carbonate in g/dm^3.*

  (ii) *the concentration of sodium hydroxide in g/dm^3.*

  (iii) *the percentage composition of each component in* ***T1****.*

2.3.1.2 Alternative 3B

The question was as follows:

You are provided with the following:

J: *A solution made by dissolving 1.58 g of $KMnO_4$ in a distilled water to form a 0.5 dm^3 of an aqueous solution;*

K: *A solution made by dissolving 7.91 g of $Na_2S_2O_3.XH_2O$ in a distilled water to form 0.25 dm^3 of an aqueous solution;*

L: *A solution of 10% KI;*

M: *A starch solution;*

N: *Dilute H_2SO_4 solution;*

Theory

A quantitative reaction between potassium permanganate, $KMnO_4$ and potassium iodide, KI can be represented by the reaction: $MnO_4^-(aq) + I^-(aq) \longrightarrow Mn^{2+}(aq) + I_2(aq)$............(i). *The liberated iodine, I_2 is titrated against sodium thiosulphate, $Na_2S_2O_3$. The reaction taking place during this titration can be represented as follows:* $I_2 + 2S_2O_6^{2-} + 2I^-$...................$(ii)$

Procedure

(i) *Pipette 20 or 25 cm^3 of **J** into a conical flask. Add an equal volume of (20 cm^3 or 25 cm^3) of **L**, followed by another equal volume (20 cm^3 or 25 cm^3) of **N** in the same flask.*

(ii) *Titrate the mixture in (i) with **K**, until the colour change is observed. Add 2 cm^3 of **M** and continue titrating until a permanent colour change is observed.*

(iii) *Repeat the procedures (i) and (ii) three more times and record your results in a tabular form.*

Summary

(a) *The volume of pipette used was_________.*

(b) *__________ cm^3 of **J** liberated iodine that required _________ cm^3 of **K** for complete reaction.*

Questions

(a) *State the function of **M** in this experiment.*

(b) *State the main purpose of adding **L** into the conical flask containing acidified **J**.*

(c) *Why is it advisable to add **M** just close to the end point in this experiment?*

(d) *Write an overall balanced reaction equation for the whole experiment.*

(e) *Calculate the;*

  (i) *concentration of $KMnO_4$ in g/dm^3.*

  (ii) *molarity of $KMnO_4$.*

  (iii) *concentration of $Na_2S_2O_3.XH_2O$ in g/dm^3.*

  (iv) *molarity of $Na_2S_2O_3$.*

  (v) *concentration of $Na_2S_2O_3$ in g/dm^3.*

(f) *Find the value of **X** in $Na_2S_2O_3.XH_2O$.*

2.3.1.3 Alternative 3C

The question was as follows:

B1: *A solution of H_2O_2 prepared by diluting 1.00 cm^3 with distilled water to form 250 cm^3 of an aqueous solution;*

B2: *A solution of $KMnO_4$ made by dissolving 0.79 g in distilled water to form a 250 cm^3 of an aqueous solution.*

B3: *A dilute H_2SO_4;*

Procedure

(i) *Pipette 20 or 25 cm^3 of **B1** into a conical flask. Add 10 cm^3 of **B3**.*

(ii) *Titrate the mixture from step (i) against **B2** until a pink colour is observed.*

(iii) *Repeat the procedures (i) and (ii) three more times and record your results in tabular form.*

Summary

(i) The volume of pipette used was ____ cm^3.

*(ii) ______ cm^3 of solution **B1** required ______ cm^3 of **B2** for complete reaction.*

Questions

(a) Write the two half reaction equations for the experiment.

(b) Write a balanced ionic equation for the whole process

(c) *Calculate the concentration of the original solution of hydrogen peroxide in g/dm^3.*

(d) *Calculate the volume of oxygen gas produced at s.t.p when* ***B1*** *reacted with an acidified* ***B2***.

The questions was attempted by 37,726 candidates (100%). The analysis indicates that 9.95 per cent of the candidates scored from 0 to 6.5 marks, 29 per cent scored from 7 to11.5 marks and 60.26 per cent scored from 12 to 20. Generally, the candidates' performance in this question was good because 90.16 per cent scored 7.0 marks or above. The summary of the performance is shown in Figure 17.

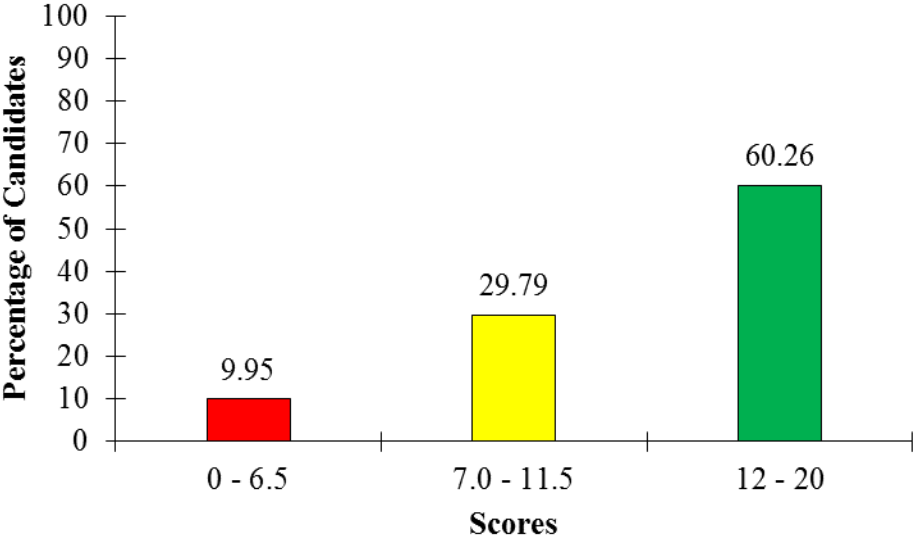


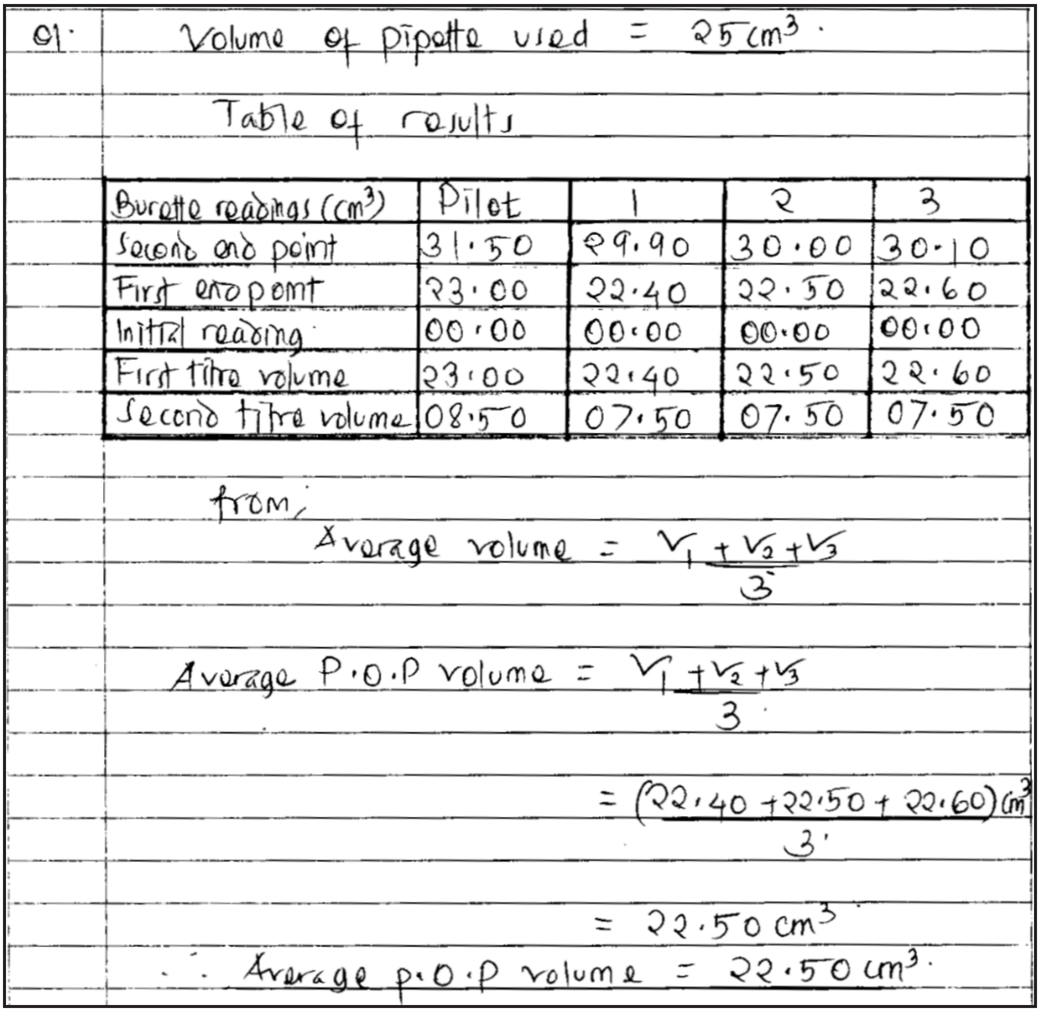
Figure 17: *Candidates' Performance in Question 1 paper 3*

The candidates who scored high marks in these questions filled correctly the table of results by considering two decimal places, and accuracy of the data. This means that they followed correctly titrating procedures to obtain correct readings. Similarly, the candidates read the volume of pipette used and recorded it correctly.

In alternative 3A, the candidates correctly wrote balanced chemical equation for the chemical reaction-taking place in procedure (ii) and (iv) that is between NaOH with HCl and $NaHCO_3$ with HCl. The candidates also correctly calculated the concentration of sodium carbonate and sodium hydroxide in g/dm^3 and finaly, the candidates calculated the percentage composition of Na_2CO_3 and NaOH using the double indicator method.

However, in alternative 3B, the candidates exhibited a strong grasp of the concept of iodometry titration, which involves the reaction between indirectly generated iodine against sodium thiosulphate. They efficiently standardized sodium thiosulphate through a two-step reaction with acidified potassium permanganate. The first step involved liberation of iodine gas, followed by the reaction between the liberated I_2 (iodine gas) and sodium thiosulphate. Finally, the candidates calculated molarity and concentration of $KMnO_4$ and $Na_2S_2O_3$ respectively.

In in alternative 3C, the candidates successfully standardized hydrogen peroxide (analyte) using potassium permanganate (titrant). Their understanding of balancing redox reactions and stoichiometric coefficients was evident, enabling them to calculate the volume of oxygen gas produced at standard temperature and pressure (STP) during the reaction between potassium permanganate and hydrogen peroxide, considering the limiting reactant. Furthermore, these candidates were well-versed in the dilution law, allowing them to calculate the original concentration of hydrogen peroxide. Extracts 17.1, 17.2 and 17.3 show samples of the correct responses to question 1 in Alternative Practical A, B, and C, respectively.



Q1. Volume of pipette used = 25 cm^3.

Table of results

Burette readings (cm^3)	Pilot	1	2	3
Second end point	31.50	29.90	30.00	30.10
First end point	23.00	22.40	22.50	22.60
Initial reading	00.00	00.00	00.00	00.00
First titre volume	23.00	22.40	22.50	22.60
Second titre volume	08.50	07.50	07.50	07.50

from;

$$\text{Average volume} = \frac{V_1 + V_2 + V_3}{3}$$

$$\text{Average P.O.P volume} = \frac{V_1 + V_2 + V_3}{3}$$

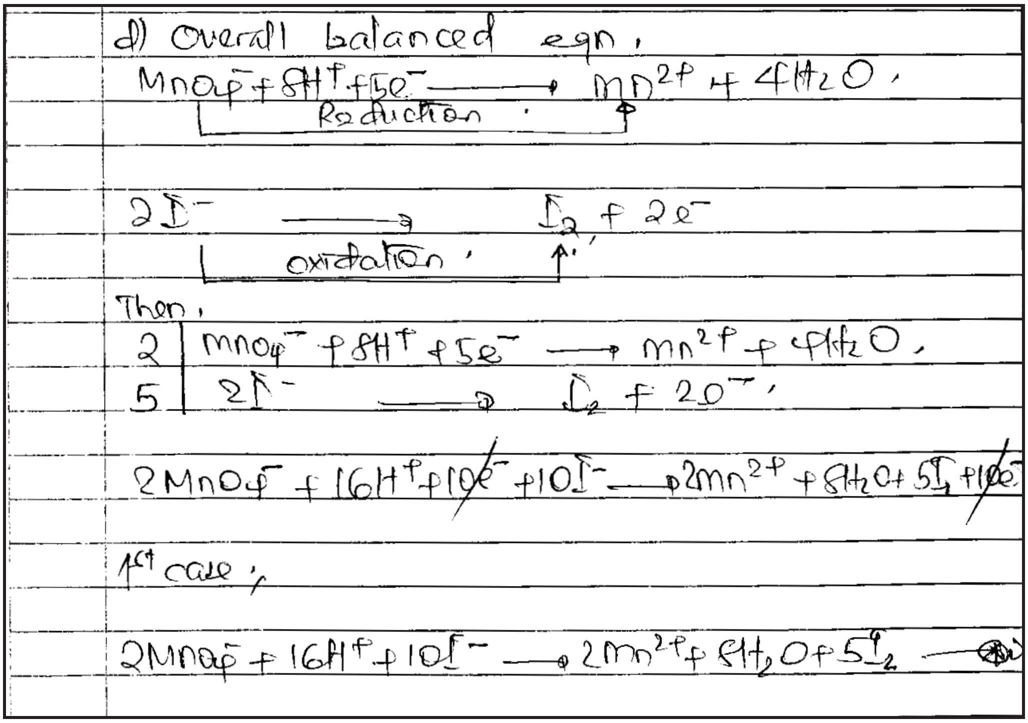
$$= \frac{(22.40 + 22.50 + 22.60)\,cm^3}{3}$$

$$= 22.50\ cm^3$$

$\therefore$ Average p.O.P volume = 22.50 cm^3.

Extract 17.1: A sample of correct responses to Question 1 in Alternative Practical 3A

In Extract 17.1, the candidate correctly completed the table of results by observing the required two decimal places. Additionally, she/he correctly calculated the titre volume, which fall within the acceptable range when compared to the expected value.



d) Overall balanced eqn,

$$\underbrace{MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+}}_{\text{Reduction}} + 4H_2O,$$

$$\underbrace{2I^- \longrightarrow I_2}_{\text{oxidation}} + 2e^-$$

Then,

$$\begin{array}{c|l} 2 & MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O, \\ 5 & 2I^- \longrightarrow I_2 + 2O^-, \end{array}$$

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

1st case,

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

1 1. d) 2nd case : Liberated Iodine gas reacts with $S_2O_3^{2-}$

$$\underbrace{I_2 + 2e^- \longrightarrow 2I^-}_{\text{Reduction}}$$

$$\underbrace{2S_2O_3^{2-} \longrightarrow S_4O_6^{2-}}_{\text{oxidation}} + 2e^-$$

$$+\left|\begin{array}{l} I_2 + 2e^- \longrightarrow 2I^- \\ 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2e^- \end{array}\right.$$

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

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

Then, Take eqn I and ii

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

$$+\left|\begin{array}{l} 2MnO_4^- + 16H^+ + \cancel{10I^-} \longrightarrow 2Mn^{2+} + 8H_2O + \cancel{5I_2} \\ \cancel{5I_2} + 10S_2O_3^{2-} \longrightarrow \cancel{10I^-} + 5S_4O_6^{2-} \end{array}\right.$$

$$2MnO_4^- + 16H^+ + 10S_2O_3^{2-} \longrightarrow 2Mn^{2+} + 8H_2O + 5S_4O_6^{2-}$$

Therefore overall balanced eqn is

$$2MnO_4^- + 16H^+ + 10S_2O_3^{2-} \longrightarrow 2Mn^{2+} + 8H_2O + 5S_4O_6^{2-}$$

1 e)

i) conc of $KMnO_4$ in g/dm^3 = ?

From

Conc = $\frac{\text{mass}}{\text{volume}}$ (g/dm^3),

given m = 1.58g

V = 0.5dm^3.

Then,

Conc = $\frac{m}{V}$

Conc = $\frac{1.58g}{0.5dm^3}$

conc is 3.16 g/dm^3.

∴ conc of $KMnO_4$ is 3.16g/dm^3.

ii) Molarity of $KMnO_4$.

From

Molarity = $\frac{\text{concentration}}{\text{~~volume~~ molar mass}}$

Mr of $KMnO_4$ = 39 + 55 + 4(16)

∴ Mr of $KMnO_4$ = 158g/mol.

Then,

Molarity = $\frac{3.16g/dm^3}{158g/mol}$,

∴ Molarity of $KMnO_4$ is 0.02 Moldm^{-3}.

11 e)

iii) Conc of $Na_2S_2O_3 \cdot XH_2O$,

from

Mass concentration = $\frac{\text{mass}}{\text{volume}}$,

given, $m = 7.91g$ $V = 0.25dm^3$.

Then,

$$\text{Conc} = \frac{7.91g}{0.25dm^3},$$

$$\text{Conc} = 31.64\ g/dm^3$$

∴ Conc of $Na_2S_2O_3 \cdot XH_2O$ is 31.64 gdm^{-3},

iv) molarity of $Na_2S_2O_3$,

from balanced eqn,

$$2MnO_4^- + 16H^+ + 10S_2O_3^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 5S_4O_6^{2}$$

Mole ratio $2MnO_4^- : 10S_2O_3^{2-}$,

Therefore

mole ratio ⇒ 2 : 10. ⟶ 1,

Then, from

$$\frac{MaVa}{MbVb} = \frac{na}{nb}$$

let.

M_1 be molarity of MnO_4^-,

M_2 be molarity of $S_2O_3^{2-}$

n_1 - no of moles of MnO_4^-

V_1 - volume of MnO_4^-.

n_2 - no of moles of $S_2O_3^{2-}$

1 e) ii) V_2 - volume of $S_2O_3^{2-}$ '

Then:

$$\frac{M_1V_1}{M_2V_2} = n_1/n_2 ,$$

Req: M_2 .

$$M_2 = \left(\frac{M_1V_1}{n_1}\right)\left(\frac{n_2}{V_2}\right)$$

$$M_2 = \frac{0.02\,M \times 20\,cm^3 \times 10}{2 \times 20.5\,cm^3}$$

$M_2 = 0,09756\,Mol/dm^3$ '

$M_2 = 0,097\,Mol/dm^3$ '

Therefore;

∴ Molarity of $Na_2S_2O_3$ is $0.097\,Mol dm^{-3}$.

v) conc of $Na_2S_2O_3$ in g/dm^3

from

$$\text{molarity} = \frac{\text{conc}}{Mr}$$

Mr of $Na_2S_2O_3 = (23 \times 2) + 64 + 48$
$= 158\,g/mol$,

Then,

Conc = Molarity x Molar mass

Conc = $0.097\,M \times 158\,g/mol$,

Conc = $15.326\,g/dm^3$

∴ Concentration of $Na_2S_2O_3$ is $15.326\,g/dm^3$.

1 1 (f) value of X, in $Na_2S_2O_3 \cdot XH_2O$,

$$\text{Molarity} = \frac{\text{conc}}{Mr},$$

$$\frac{\text{conc of hydrous}}{\text{Mr of hydrous}} = \frac{\text{conc of anhydrous}}{\text{mr of anhydrous}} = \text{constant}$$

Then,
$$\frac{M_h}{Mr_h} = \frac{M_{an}}{Mr_{an}},$$

But

~~Mass of anhyd.~~

$$C_h / Mr_h = C_{an} / Mr_{an},$$

But Conc of hydrous = $31.64 g/dm^3 (C_h)$

Conc of anhydrous = $15.326 g/dm^2 (C_{an})$

Mr of hydrous = ? (Required)

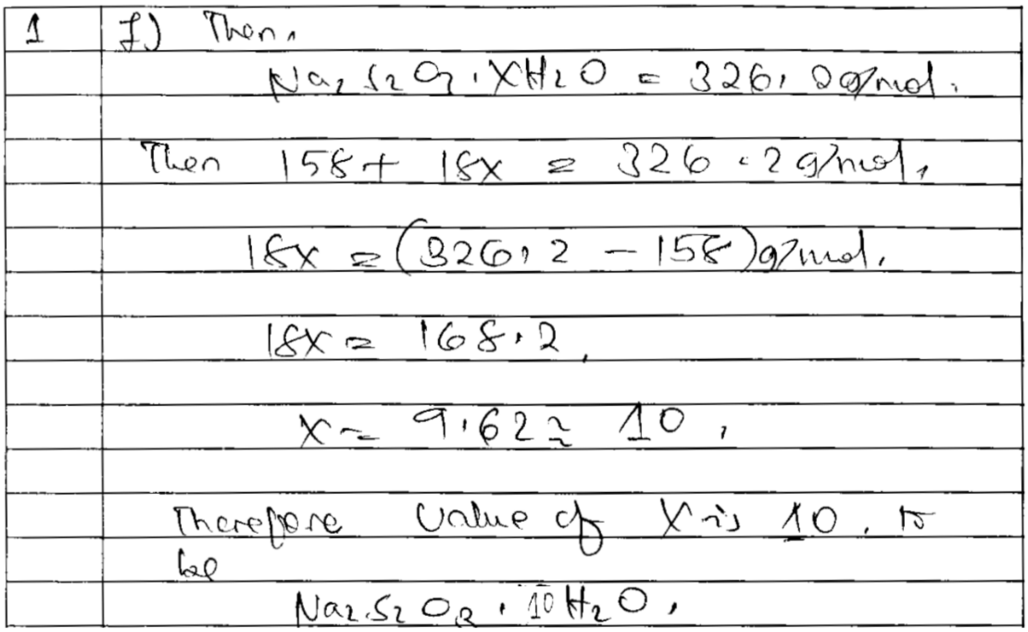
Mr of anhydrous = 158g/mol (Mr_{an})

Then,
$$Mr_h = \frac{C_h Mr_{an}}{C_{an}}$$

$$Mr_h = \frac{31.64 g/dm^3 \times (158g/mol)}{15.326 g/dm^3}$$

$$Mr_h = 326.2 g/mol,$$

∴ Molar mass of hydrous is 326.2g/mol,



1 f) Then,

$Na_2S_2O_3 \cdot XH_2O = 326.2 g/mol.$

Then $158 + 18x = 326.2 g/mol,$

$18x = (326.2 - 158) g/mol,$

$18x = 168.2,$

$x \simeq 9.62 \simeq 10,$

Therefore value of X is 10, to be

$Na_2S_2O_3 \cdot 10H_2O,$

Extract 17.2: A sample of correct responses to Question 1 in Alternative Practical 3B

In Extract 17.2, the candidate correctly wrote the overall chemical equation. Furthermore, he/she successfully calculated the molarity, concentration of sodium thiosulphate and the number of molecules of water of crystallization in hydrated sodium thiosulphate ($Na_2S_2O_3.XH_2O$).

Q1) (c) soln,

Asked, The original concentration of hydrogen peroxide mol/dm³.

From, The Molarity of $KMnO_4$,

Given,

$M = 0.79g$,

Volume = 0.25 dm³,

Then

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

$$= \frac{0.79g}{0.25dm^3}$$

$$= 3.16 \, g/dm^3$$

∴ The concentration of $KMnO_4$ = 3.16 g/d

Again, Molarity of $KMnO_4$ = $\frac{\text{Concentration}}{\text{Molar mass}}$

but conc of $KMnO_4$ = 3.16 g/dm³

Mr of $KMnO_4$ = $(39 + 55 + 16 \times 4) \, g/mol$,

$= 158 \, g/mol$,

From

$$\text{Molarity} = \frac{\text{Concentration}}{\text{Molar mass}}$$

$$= \frac{3.16 \, g/dm^3}{158 \, g/mol},$$

$$= 0.02 \, mol/dm^3.$$

∴ The Molarity of $KMnO_4$ = 0.02 M

01. (a) from ~~The~~ balanced ionic equation,

$2MnO_4^- + 6H^+ + 5H_2O_2 \longrightarrow 2Mn^{2+} + 8H_2O + 5O_2$,

$n_o = 5$,

$n_r = 2$,

$M_o = ?$

$M_r = 0.02M$,

$V_o = 25cm^3$,

$V_r = 24.8cm^3$,

Again, from mole ratio formula,

$$\frac{M_o V_o}{n_o} = \frac{M_r V_r}{n_r},$$

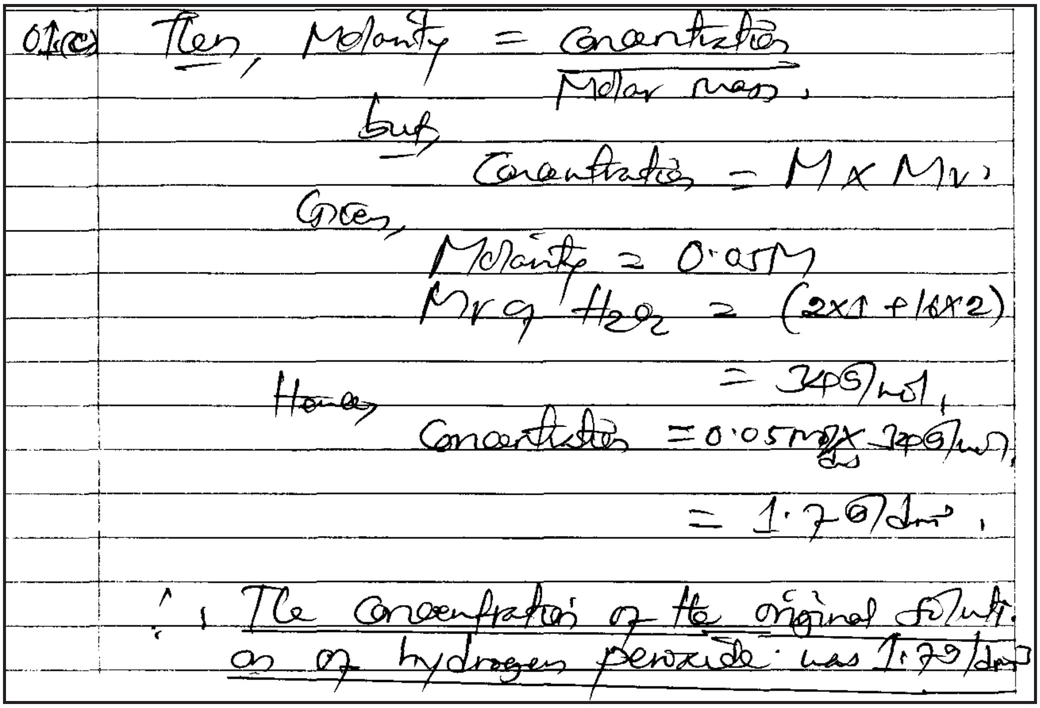
$$M_o = \frac{M_r V_r n_o}{V_o n_r},$$

$$M_o = \frac{0.02M \times 24.80 \times 5}{25cm \times 2},$$

$$M_o = \left(\frac{2.48}{50}\right)$$

$= 0.0496M, \simeq 0.05M,$

∴ Molarity of hydrogen peroxide (H_2O_2) $= \underline{0.05M}$.



01.(c) Then, Molarity = $\frac{\text{Concentration}}{\text{Molar mass}}$.

but,

Concentration = M x Mr.

Given,

Molarity = 0·05M

Mr of H_2O_2 = (2x1 + 16x2)

= 34g/mol.

Hence,

Concentration = 0·05 mol/dm³ x 34g/mol

= 1·7g/dm³.

∴ The concentration of the original solution of hydrogen peroxide was 1·7g/dm³

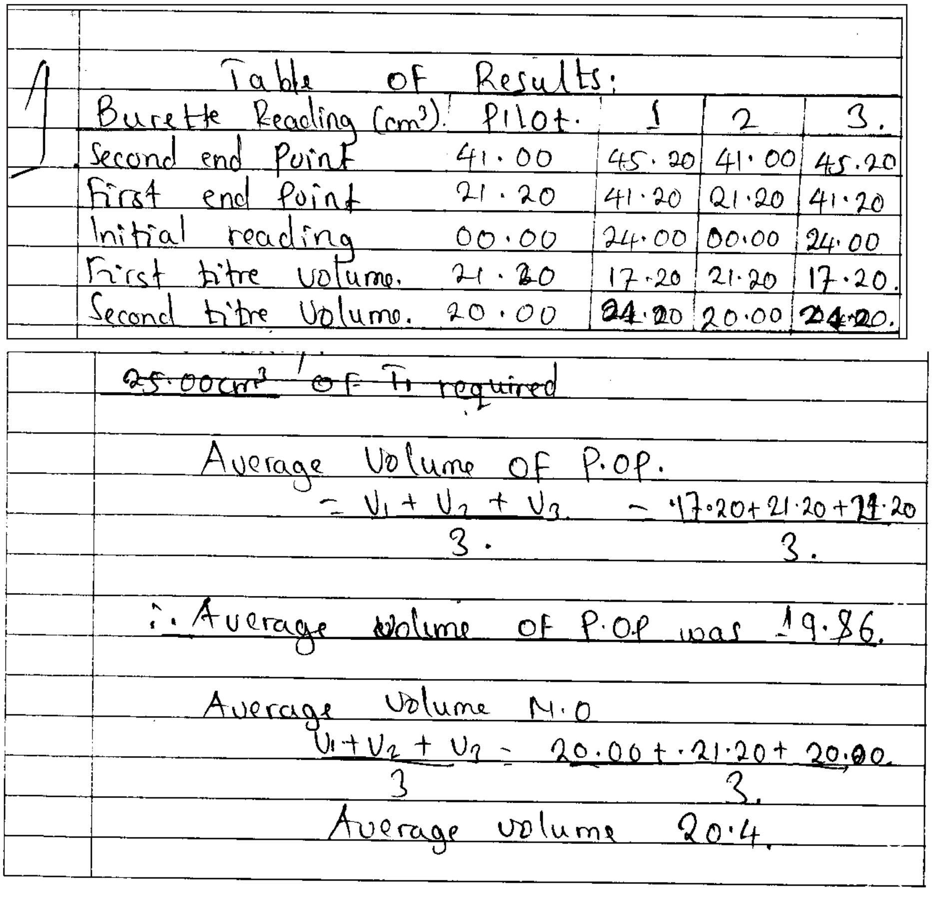
Extract 17.3: A sample of correct responses to Question 1 of the alternative practical 3C

In Extract 17.3, the candidate successfully performed all the necessary calculations and identified the concentration of the original solution of hydrogen peroxide.

In the other hand, the candidates who scored low marks failed to fill the table of results correctly. Some of them got incorrect volumes of the acid solution used. Similarly, they neglected to account for the two decimal places while others left some gaps in the table of results. Moreover, some of them did not indicate the volume of pipette used. Likewise, in alternative 3A, the candidates failed to write well balanced chemical equations involved in double indicator and redox titration. As a result, the candidates obtained incorrect mole ratio of acid to base. In addition, others used wrong formulae in the successive calculations in an attempt to determine the percentage purity of sodium carbonate and sodium hydroxide in the solution. Generally, the candidates in this category had insufficient knowledge about the concept of volumetric analysis technique.

However, in alternative 3B the candidates who scored low marks mistakenly wrote, the function of **M** (starch) was to provide an acidic medium contrary to the fact it is an external indicator during titration in part (a). Similarly, in part (b), some candidates wrote the main purpose of **L** (KI) was to react with sodium thiosulphate contrary to its primary role of facilitating the liberation of iodine. Principally, potassium iodide (KI) ionizes to produce iodide ions, which are then oxidized by potassium permanganate, leading to the formation of iodine. Generally, the candidates falling under this category lacked adequate knowledge about the chemical equation, mole concept, and volumetric analysis.

Moreover, in alternative 3C, the candidates who scored low marks failed to attempt most parts of the question. For instance, some of them failed to write the overall ionic equation for the redox reaction. In other case, some candidates provided partial responses, while others left the field blank. This suggests that the candidates lacked adequate knowledge about balancing redox reactions to derive the overall ionic equation. Extracts 17.6, 17.7 and 17.8 show samples of the incorrect responses to question 1 in Alternative Practical A, B, and C, respectively.



1

Table of Results:

Burette Reading (cm³).	Pilot.	1	2	3.
Second end Point	41.00	45.20	41.00	45.20
First end Point	21.20	41.20	21.20	41.20
Initial reading	00.00	24.00	00.00	24.00
First titre volume.	21.20	17.20	21.20	17.20.
Second titre Volume.	20.00	24.20	20.00	24.20.

~~25.00cm³ of T₁ required~~

Average Volume of P.OP.

$$= \frac{V_1 + V_2 + V_3}{3.} = \frac{17.20 + 21.20 + 24.20}{3.}$$

∴ Average volume of P.OP was 19.86.

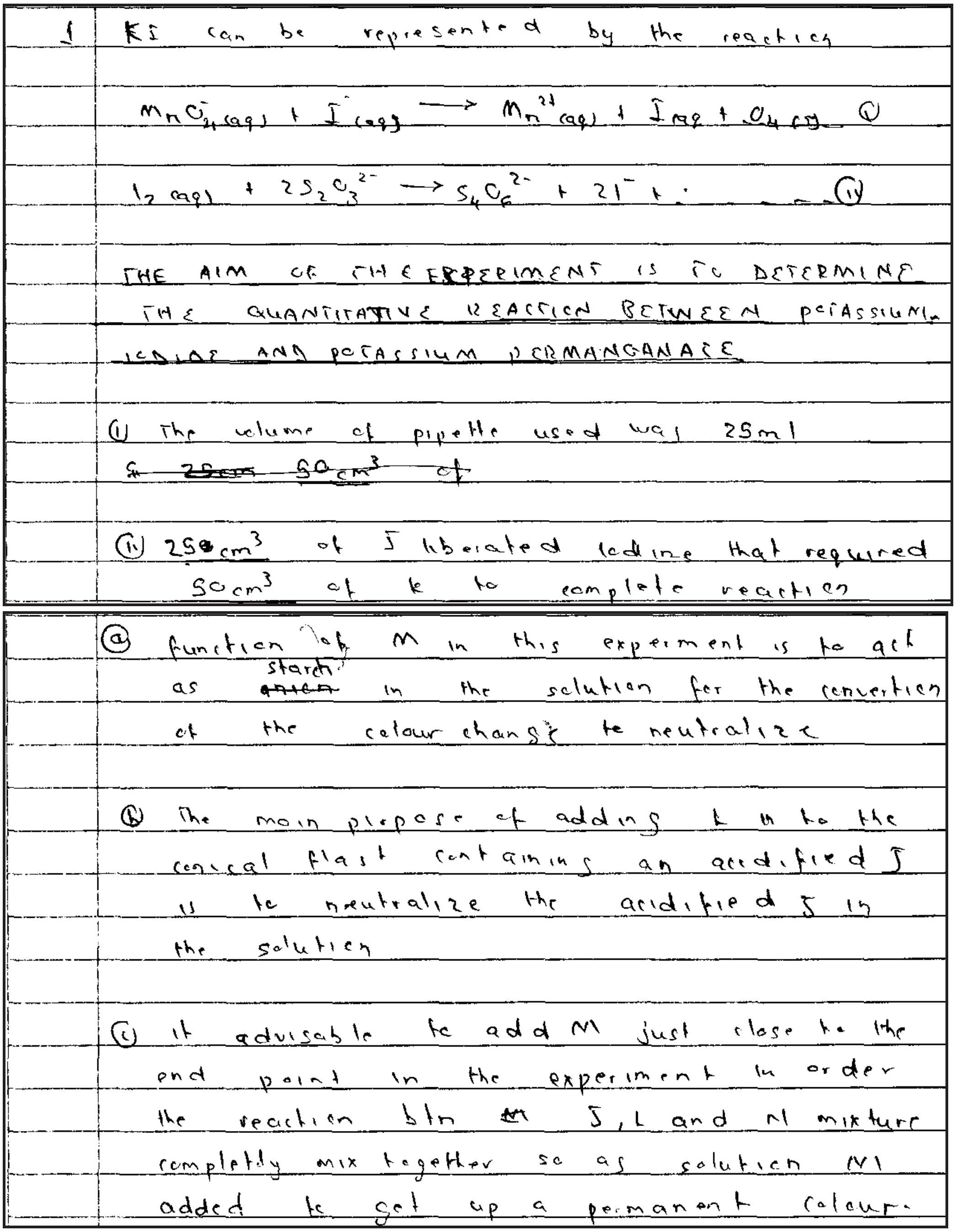
Average Volume M.O

$$\frac{V_1 + V_2 + V_3}{3} = \frac{20.00 + 21.20 + 20.00}{3.}$$

Average volume 20.4.

Extract1 7.6: A sample of incorrect responses to Question 1 in Alternative Practical 3A

In Extract 17.6, the candidate recorded inaccurate data that deviated negatively by 2.10 cm^3.



1 KI can be represented by the reaction

$MnO_{4(aq)}^{-} + I^{-}_{(aq)} \longrightarrow Mn^{2+}_{(aq)} + I_{aq} + O_{4(g)}$ (i)

$I_{2\,(aq)} + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2I^- + \cdot$ (ii)

THE AIM OF THE EXPERIMENT IS TO DETERMINE THE QUANTITATIVE REACTION BETWEEN POTASSIUM IODIDE AND POTASSIUM PERMANGANATE

(i) The volume of pipette used was 25ml
~~S 25cm 50 cm^3 of~~

(ii) 25cm^3 of J liberated Iodine that required 50cm^3 of K to complete reaction

(a) function of M in this experment is to act as ~~anion~~ starch in the solution for the convertion of the colour change to neutralize

(b) The main plopose of adding L in to the conical flask containing an accidified J is to neutralize the acidified J in the solution

(c) it advisable to add M just close to the end point in the experiment in order the reaction btn ~~M~~ J, L and M mixture completly mix together so as solution M added to get up a permanent colour.

ⓓ overall equations

Given

$2MnO_{4(aq)} + 2I_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + I_2 + 2O_2$

~~K~~ $2MnO_{4(aq)} + 2I_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + I_2 + 2O_{2(g)} + K_{(s)}$

Given

$I_{2(aq)} + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2I +$

$KMnO_4 + KI + H_2SO_4 \longrightarrow K + Mn + 2O + H_2O + SO$

$KMnO_{4(aq)} + KI_{(aq)} + H_2SO_{4(l)} \longrightarrow K_{(s)} + Mn_{(s)} + 2O_{(g)} + H_2O_{(g)} + SO_2$

ⓔ from

Concentration = ?

from

$\text{Concentration} = \frac{\text{Molar mass}}{\text{molarity}}$

$KMnO_4 = 39 + 55 + (16 \times 4)$

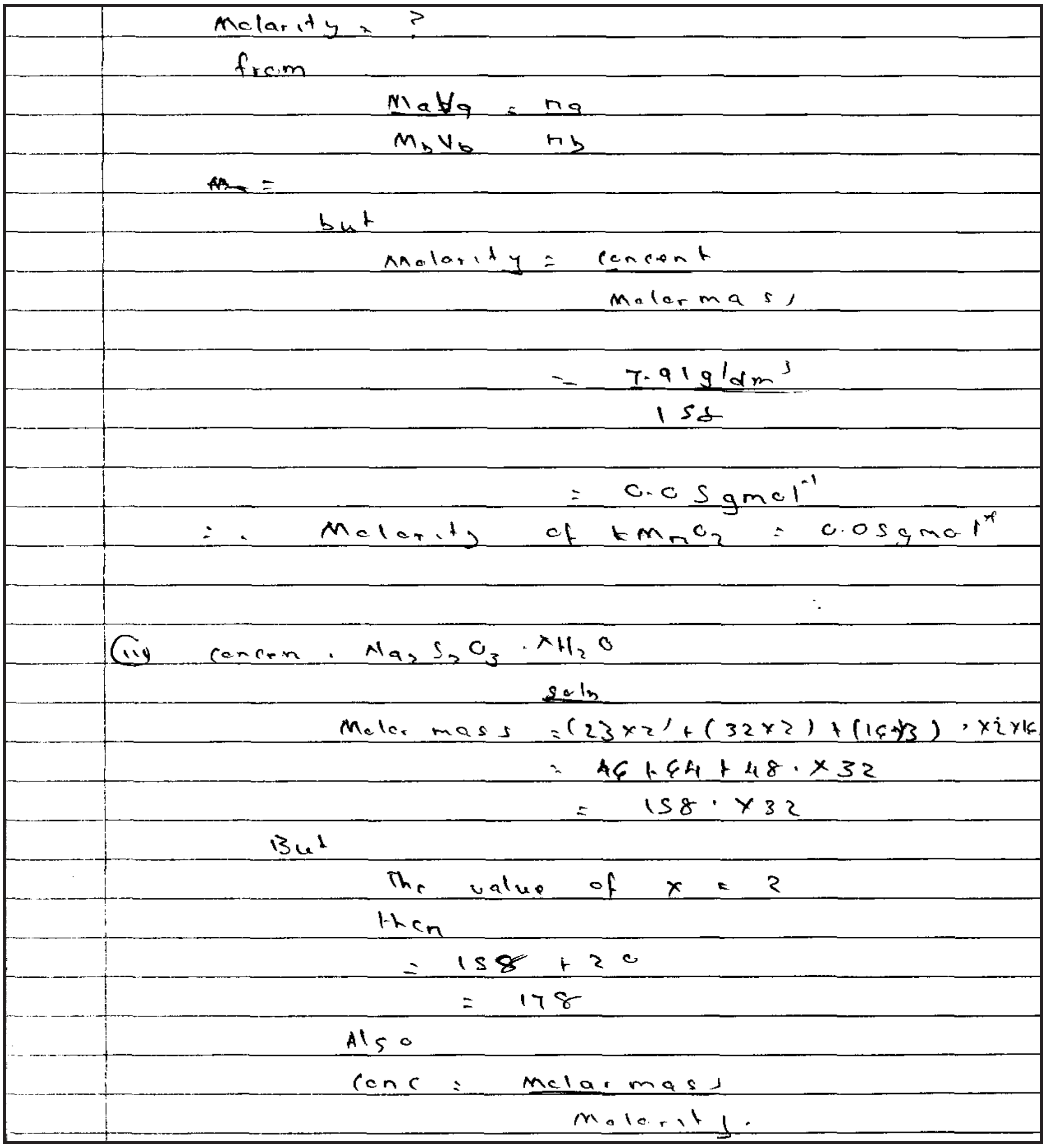
$= 39 + 55 \; 1 \; 64$

$= 158$

Then

$\text{Conc. } KMnO_4 = \frac{0.01}{158}$

$= 6.33 \times 10^{-5} g/dm^3$



Molarity = ?

from

$\frac{M_aV_a}{M_bV_b} = \frac{n_a}{n_b}$

~~Ma~~ =

but

Molarity = $\frac{\text{concent}}{\text{Molar mass}}$

= $\frac{7.91 g/dm^3}{158}$

= 0.05 $gmol^{-1}$

∴ Molarity of $KMnO_2$ = 0.05 $gmol^{-1}$

(iii) concen. $Na_2S_2O_3 . XH_2O$

soln

Molar mass = (23×2) + (32×2) + (16×3) . X2×16

= 46 + 64 + 48 . X32

= 158 . X32

But

The value of X = 2

then

= 158 + 20

= 178

Also

conc = $\frac{\text{Molar mass}}{\text{Molarity}}$.

Extract 17.7: A sample of incorrect responses to Question 1 in Alternative Practical 3B

In Extract 17.7, the candidate wrote incorrect redox chemical equations and failed to explain the role of starch during the titration. Hence failed to get the correct value of X in $Na_2S_2O_3.XH_2O$.

1. Summary

(i) The volume of pipette used was 20 cm³

~~(ii) The volume~~

(ii) 20 cm³ of solution B1 required 20 cm³ of B2 for complete reaction

Questions

@ Solution

$KMnO_4^-$

$MnO_4^- \longrightarrow Mn^{2+}$

$H_2O_2 \longrightarrow \cancel{H_2O_2}\ \underset{(0)}{O_2}$

S/n	EXP	Pilot	1	2	3
1	Initial volume (cm³)	00.00	00.00	00.00	00.00
2	Final volume (cm³)	21.00	19.90	20.40	20.20
3	Volume used (cm³)	21.00	19.90	20.40	20.20

Volume used

$$\text{Average volume} = \frac{19.90 + 20.40 + 20.20}{3}$$

$$= 20.2 \approx 20\,cm^3$$

1. (c) $\text{Molarity (M)} = \dfrac{\text{concentration (conc)}}{\text{Molar mass (Mr)}}$

$M = \dfrac{\text{Conc}}{Mr}$

but $\text{conc} = \dfrac{\text{Mass}}{\text{volume}}$

$= \dfrac{0.79g}{1.00cm^3 \times 1000}$

$= \dfrac{0.79g}{1000dm^3}$

Concentration $= 0.00079g\,dm^3$

Where
Volume of $H_2O_2 = 1.00cm^3$
volume of soln $= 250cm^3$
Mass of solution of $KMnO_4 = 0.79g$

Then

Concentration $= \dfrac{\text{Mass}}{\text{volume in}(dm^3)}$

$= \dfrac{0.79g}{1000\,dm^3}$

Conc $= 7.9 \times 10^{-4}$

∴ Concentration of original solution of hydrogen peroxide in g/dm^3 is $7.9 \times 10^{-4}g/dm^3$

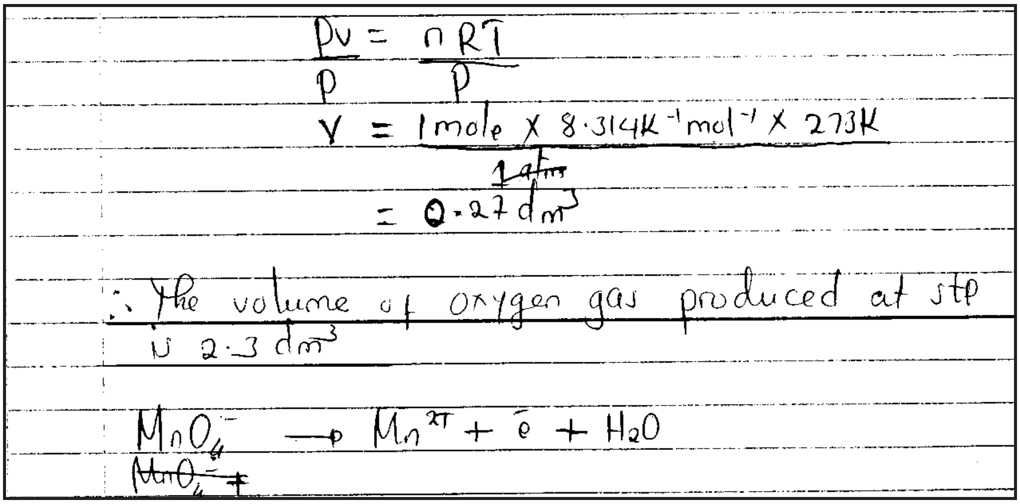
volume

(d) $M = \dfrac{\text{conc}}{Mr}$

$M_a = \dfrac{7.9 \times 10^{-4}g/dm^3}{34g/mol}$

$M = 2.32 \times 10^{-5}$

Then
volume From ideal gas eqn



$$\frac{PV}{P} = \frac{nRT}{P}$$

$$V = \frac{1\,mole \times 8{\cdot}314K^{-1}mol^{-1} \times 273K}{1atm}$$

$$= 0{\cdot}27\,dm^3$$

∴ The volume of oxygen gas produced at stp is $2{\cdot}3\ dm^3$

$MnO_4^- \longrightarrow Mn^{2+} + \bar{e} + H_2O$

~~MnO_4^-~~ +

Extract 17.8: A sample of incorrect responses to Question 1 in Alternative Practical 3C

In Extract 17.8, the candidate provided incorrect data in the table of results. Similarly, her/his responses to parts (a), (b), (c), and (d), including chemical equations, formulae, and calculations were incorrect.

2.3.2 Question 2: Physical Chemistry Analysis

2.3.2.1 Alternative 3A

The question was as follows:
You are provided with the following:

***P1**: A solution containing 49.6 g/dm^3 of $Na_2S_2O_3.5H_2O$;*

***P2**: Dilute HCl;*

Distilled water.

*A white plain paper marked **X**;*

Stop watch/clock.

Procedure

You are required to investigate the effect of concentration of sodium thiosulphate on the rate of the reaction between sodium thiosulphate and hydrochloric acid using the following steps:

(i) *Place a 50 cm^3 beaker on top of the mark **X** in such a way that the mark is clearly seen through the bottom of the beaker.*

(ii) *Measure 10 cm^3 of solution **P1** and pour it into a beaker in (i). Then add 5 cm^3 of **P2** and immediately start the stop watch. Stir the mixture gently and record the time taken for disappearance of the mark **X**.*

(iii) *Repeat the procedure (ii) using:*

- *8 cm^3 of **P1**, 2cm^3 of water and 5 cm^3 of **P2**.*
- *6 cm^3 of **P1**, 4cm^3 of water and 5 cm^3 of **P2**.*
- *4 cm^3 of **P1**, 6cm^3 of water and 5 cm^3 of **P2**.*

(iv) *Record your results in a tabular form as follows:*

Volume of P1 (cm^3)	***Volume of Distilled Water (cm^3)***	***Volume of P2 (cm^3)***	$[\mathrm{P1}]$ ***(mol/mol/dm^3)***	***T(sec***	***1/t(sec^{-1})***	$[\mathrm{P1}]\times t$ ***(mol/dm^{-3}sec)***

Questions

(a) *Plot a graph **[P1]** (mol/dm^3) against time, t (sec).*

(b) *Plot a graph of 1/t (sec^{-1}) against **[P1]** (mol/dm^3).*

(c) *Study the results and the graphs then answer the following questions:*

  (i) *What is the effect of concentration of sodium thiosulphate on the rate of chemical reaction?*

  (ii) *What is the order of reaction with respect to $Na_2S_2O_3$?*

  (iii) *How did you reach your conclusion in (c) (ii)?*

(d) *Comment on the value of the product of concentration and time; that is $[\mathrm{P1}]\times t$.*

2.3.2.2 Alternative 3B

The question was as follows:

You are provided with the following:

***A**: A solution of 0.02 M potassium permanganate;*

***C**: A solution of 0.05 M oxalic acid in 0.5 M of sulphuric acid;*

A thermometer (0 - 100°C);

Stop watch/clock.

Theory

In acidic medium, oxalic acid is oxidized by potassium permanganate. Completion of the reaction is indicated by the disappearance of the purple colour of the permanganate ions as shown by the following chemical equation:

$$2MnO_4^{-}(aq) + 5C_2O_4^{2-}(aq) + 6H^{+}(aq) \longrightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

Procedure

(i) *Put about 200 cm³ of water into a 250 cm³ or 300 cm³ beaker. Heat the beaker containing water. Use it as water bath.*

(ii) *Measure 10 cm³ of solution **A** and 10 cm³ of **C**; put them into two separate boiling test tubes.*

(iii) *Take the test tubes containing **A** and **C** and put them into the water bath; allow the contents to warm to 50°C.*

(iv) *Pour both solutions **A** and **C** into a 50 cm³ beaker. Immediately, start a stop watch/ clock and record the time taken for the purple colour to disappear.*

(v) *Repeat the procedures (ii) to (iv) using temperatures 60°C, 70°C, 80°C, 90°C. Record your results as indicated in Table 1:*

Table 1: Experimental Table.

Temperature, T (°C)	***Temperature, T (K)***	***Time for reaction, t (Sec)***	$\frac{1}{T}$ ***(K⁻¹)***	***Log (t) (sec)***
50				
60				
70				
80				
90				

Questions

(a) *Write ionic redox half equations for this experiment.*

(b) *Plot a graph of log (t) against* $\frac{1}{T}$ *(K⁻¹).*

(c) *Calculate the activation energy (Ea) of the reaction for the experiment.*

2.3.2.3 Alternative 3C

The question was as follows:

You are provided with the following:

***S**:* *A solution of 0.5 M sodium thiosulphate;*

***T**:* *A solution of 0.1 M nitric acid;*

A stop watch/clock;

*A white plain paper marked **N**;*

A thermometer (0 – 100°C);

Theory

A yellow precipitate of amorphous Sulphur can be obtained by the action of the dilute acid on sodium thiosulphate ($Na_2S_2O_3$) according to the equation;

$$S_2O_3^{2-}(aq) + 2H_3O^+(aq) \longrightarrow 3H_2O(l) + SO_2(g) + S(s).$$

The precipitated Sulphur causes the solution to become opaque. From this phenomenon, you can assess the rate of Sulphur precipitation by measuring the time taken for the solution to become totally opaque due to Sulphur.

Procedure

(i) *Place a 50 cm^3 beaker on top of a white plain paper marked **N** in such a way that, the mark is clearly seen through the bottom of the beaker.*

(ii) *Put about $\frac{3}{4}$ full of water into a 250 or 300 cm^3 beaker and use it as your water bath.*

(iii) *Measure 10 cm^3 of solution **S** and 10 cm^3 of **T** into two separate boiling test tubes.*

(iv) *Put the two boiling test tubes containing **S** and **T** into the water bath and warm the contents to about 50°C.*

(v) *Immediately pour the hot solutions of **S** and **T** into a 50 cm^3 beaker placed on top of letter **N** in step (i), and immediately start a stop watch/ clock.*

(vi) *Using a glass rod, stir the reaction mixture in (v) and record the time taken in seconds, for letter **N** to disappear completely.*

(vii) *Repeat the procedures (iii) to (vi) at temperatures 60°C, 70°C and 80°C and tabulate your results as indicated in Table 1:*

Table 1: Experimental Table.

Temperature of the Reaction Mixture		***Time for reaction, t (sec)***	$\frac{1}{T}$ ***(K⁻¹)***	$\frac{1}{t}(\text{sec}^{-1})$	***log*** $\frac{1}{t}(\text{sec}^{-1})$
°C	***T (K)***				
50					
60					
70					
80					

Questions

(a) *Plot a graph of* $\log \frac{1}{t}(\sec^{-1})$ *against* $\frac{1}{T}(K^{-1})$.

(b) *Determine the slope of the graph in part (a).*

(c) *Using the equation,* $K = Ae^{\frac{-Ea}{RT}}$, *which gives the relation describing the dependence of the rate constant on temperature, determine the value of activation energy in a given equation.*

The question was attempted by 37,798 candidates (100%). Among them, 35,334 (68.23%) scored from 9–15 marks, 1,924 (26.11%) from 5.5–8.5 marks, while 540 (5.65%) scored from 0–5.0 marks. The performance distribution is shown in Figure 18.

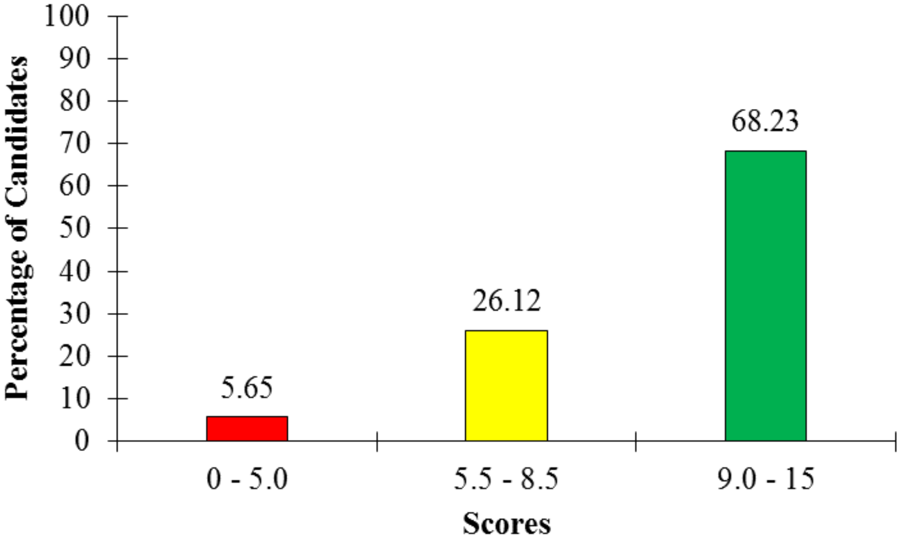
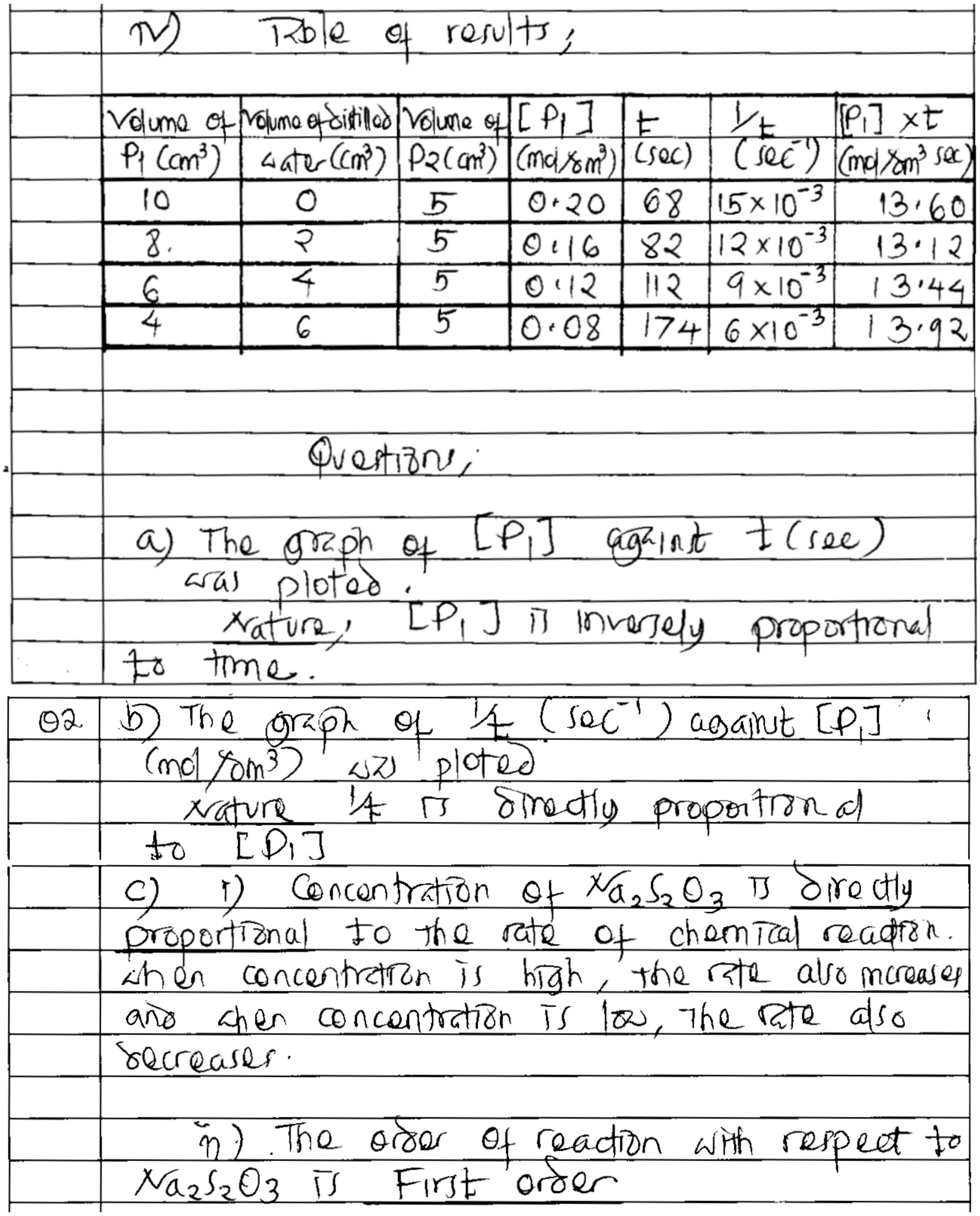


Figure 18: *Candidates' Performance in Question 2 Paper 3*

The candidates who performed well demonstrated mastery on Physical Chemistry Analysis. They displayed proficiency in recording data, analyzing data, and plotting graphs (to obtain the best-fit line).

In alternative 3A, the candidates appropriately pointed out that, the effect of concentration of $Na_2S_2O_3$ shows that, the rate of reaction is directly proportion to the concentration. In addition, they determined the order of reaction experimentally using both the graphical method and initial rate method. In addition, they commented that, the values of the product are constant. In alternative 3B, the candidates accurately determined the activation energy as demanded by the question. In addition, they demonstrated proficiency across multiple skills, including balance chemical equation, and effectively apply the Arrhenius equation to determine the value of activation energy in a given equation in alternative 3C. Extracts 18.1, 18.2 and 18.3 show samples of the correct responses to question 2 in Alternative Practical A, B, and C, respectively.



IV) Table of results;

Volume of P_1 (cm^3)	Volume of distilled water (cm^3)	Volume of P_2 (cm^3)	[P_1] (mol/dm^3)	t (sec)	1/t (sec^{-1})	[P_1] x t (mol/dm^3 sec)
10	0	5	0·20	68	15×10^{-3}	13·60
8.	2	5	0·16	82	12×10^{-3}	13·12
6	4	5	0·12	112	9×10^{-3}	13·44
4	6	5	0·08	174	6×10^{-3}	13·92

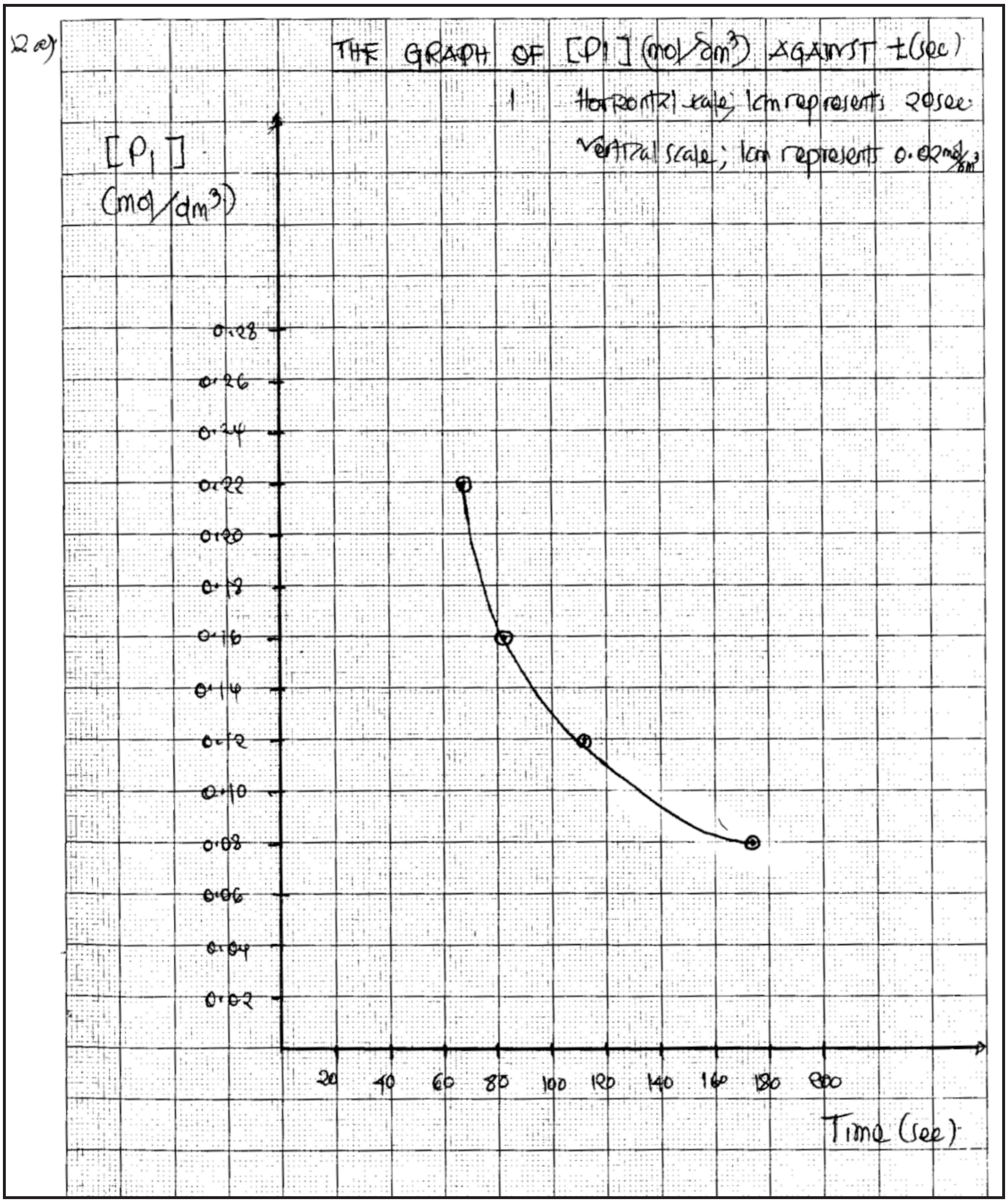
Questions;

a) The graph of [P_1] against t (sec) was ploted.
Nature; [P_1] is inversely proportional to time.

Q2 b) The graph of 1/t (sec^{-1}) against [P_1] (mol/dm^3) was ploted
Nature 1/t is directly proportional to [P_1]

c) i) Concentration of $Na_2S_2O_3$ is directly proportional to the rate of chemical reaction. when concentration is high, the rate also increases and when concentration is low, the rate also decreases.

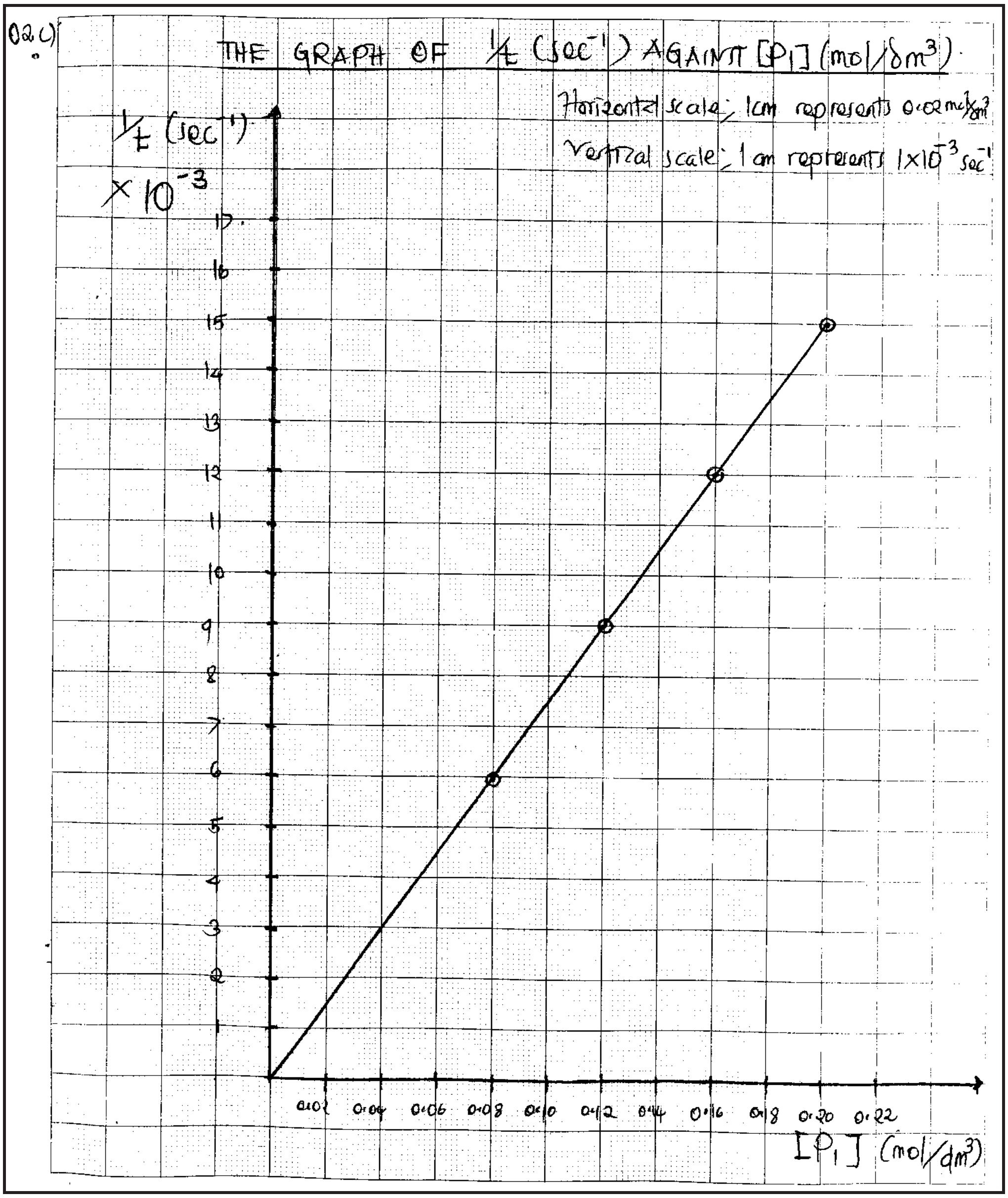
ii) The order of reaction with respect to $Na_2S_2O_3$ is First order



12 a) THE GRAPH OF $[P_1]$ (mol/dm^3) AGAINST t(sec)

Horizontal scale; 1cm represents 20sec

Vertical scale; 1cm represent 0.02mol/dm^3



Extract 18.1: A sample of correct responses to Question 2 in Alternative Practical 3A

In Extract 18.1, the candidate successfully tabulated the experimental data and appropriately plotted the graph and determined the order of the reaction graphically. This implies that the candidate was competent in all aspects of the question including experimental data handling, manipulation of data and drawing the graph.

2.

Temperature T(°c)	Temperature T (K)	Time t(sec)	$1/T$ (K^{-1})	log t.
50	323	63.00	3.096×10^{-3}	1.799
60	333	39.00	3×10^{-3}	1.591
70	343	17.00	2.915×10^{-3}	1.230
80	353	8.10	2.833×10^{-3}	0.903
90	363	2.5	2.755×10^{-3}	0.3408

a) First half equation (reduction)

$MnO_4^- \longrightarrow Mn^{2+}$

$MnO_4^- \longrightarrow Mn^{2+} + 4H_2O$

$8H^+ + MnO_4^- \longrightarrow Mn^{2+} + 4H_2O$.

$\underline{8H^+_{(aq)} + MnO^-_{4(aq)} + 5e^-_{(aq)} \longrightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)}}$

Oxidation eqn;

$C_2O_4^{2-} \longrightarrow 2CO_{2(g)}$

$\underline{C_2O^{2-}_{4(aq)} \longrightarrow 2CO_{2(g)} + 2e^-_{(aq)}}$

2c) From;

$$\text{Slope} = \frac{Ea}{2.303\,R}$$

from the eqn;

$$\text{But slope} = \frac{\Delta \log t}{\Delta \frac{1}{T}}.$$

$$\text{Slope} = \frac{1.5 - 0.6 \text{ sec}}{(2.75\times10^{-3}) - (2.36\times10^{-3}) \ /K.}$$

$$\underline{\text{Slope} = 2,307.692 \text{ Ksec}}$$

$$Ea = \text{Slope} \times 2.303 \times R.$$

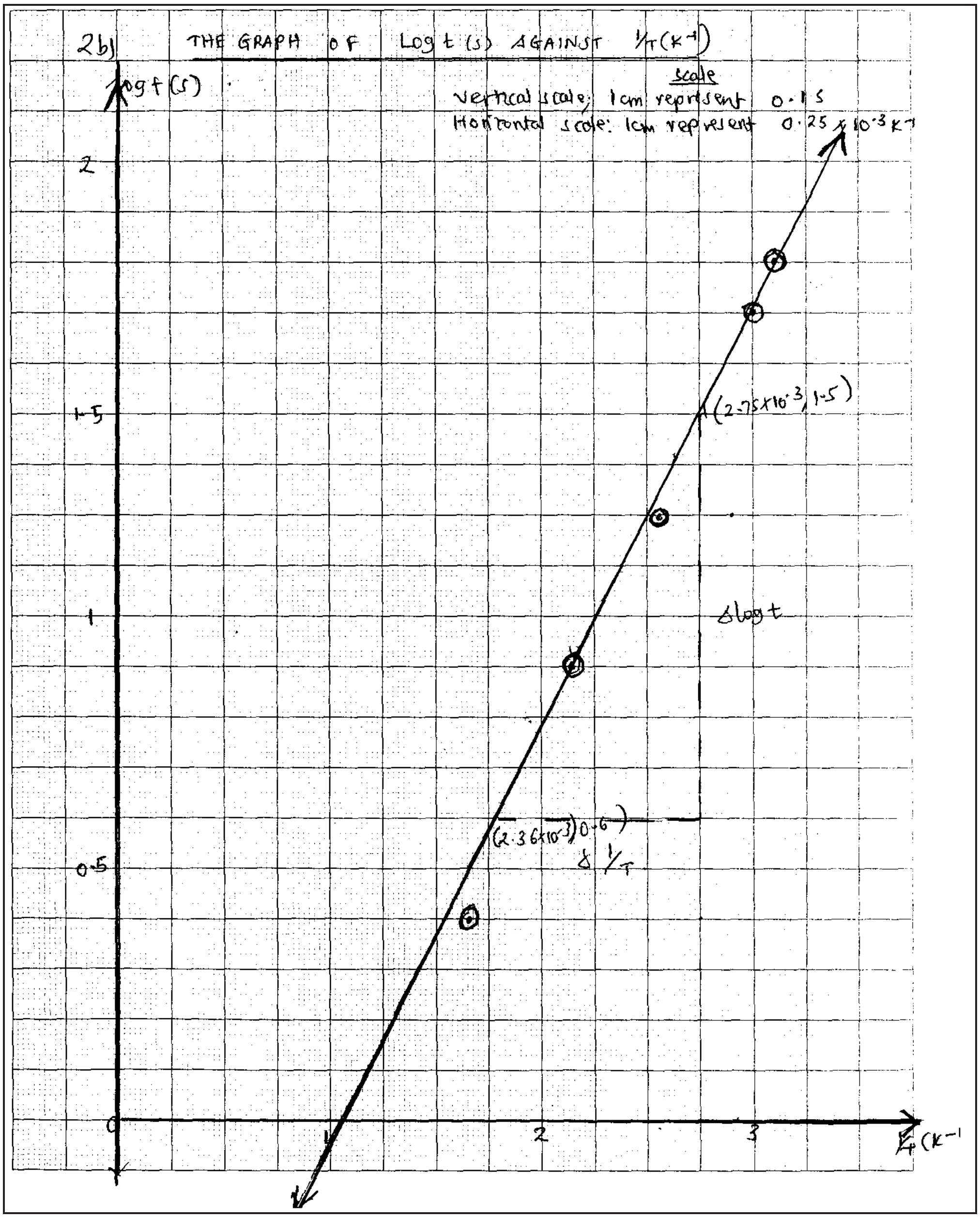
$$Ea = 2,307.692 \times 2.303 \times 8.314$$

$$Ea = 44,185.71 \text{ J/mol}.$$

In KJ/mol

$$Ea = 44.1857 \text{ KJ/mol}$$

∴ The activation energy of the reaction was <u>44.1857 KJ/mol</u>



Extract 18.2: A sample of correct responses to Question 2 in Alternative Practical 3A

In Extract 18.2, the candidate successfully tabulated the experimental data. In part (a) and (b), he/she appropriately plotted the graph and determined the activation energy by relating slope from the graph and Arrhenius equation. This implies that the candidate was competent and excelled in all aspects of the question from experimental data handling, manipulation of data and drawing the graph.

02.

EXPERIMENTAL RESULTS.

TEMPERATURE OF THE MIXTURE		Time of reaction;	$\frac{1}{T}$ (K^{-1})	$1/t$ (sec^{-1})	log $1/t$ (se
°C	T (K)	t (sec)			
50	323	3.5	3.096×10^{-3}	0.286	-0.5436
60	333	2.38	3.003×10^{-3}	0.420	-0.3767
70	343	1.84	2.915×10^{-3}	0.543	-0.2652
80	353	0.86	2.832×10^{-3}	1.162	0.0652

(b) From a graph.

Slope; $m = \frac{\Delta \log 1/t \ (sec^{-1})}{\Delta \ 1/T \ (K^{-1})}$

$m = \frac{(-0.5436 - -0.2652) sec^{-1}}{(2.915 \times 10^{-3} - 3.096 \times 10^{-3}) K^{-1}}$

$m = -2.190189 \times 10^{3} K sec^{-1}$

$\therefore$ Slope; $m = -2.190189 \times 10^{3}$ K sec^{-1}

(c) From ;

Equation ;

$k = Ae^{\frac{-Ea}{RT}}$

Ist multiplying by natural logarithm both sides.

$\ln k = \ln\left(Ae^{\frac{Ea}{RT}}\right)$

$\ln k = \frac{-Ea}{RT} + \ln A$

$$\ln k = -\frac{Ea}{R}\left(\frac{1}{T}\right) + \ln A$$

$$Y = m x + c.$$

Thus; $m = \frac{-Ea}{R\cancel{T}}.$

$-Ea = m \times R\cancel{T}$ But $R = 8.314$

$- Ea = - 2.190189 \times 10^{3} \times R$

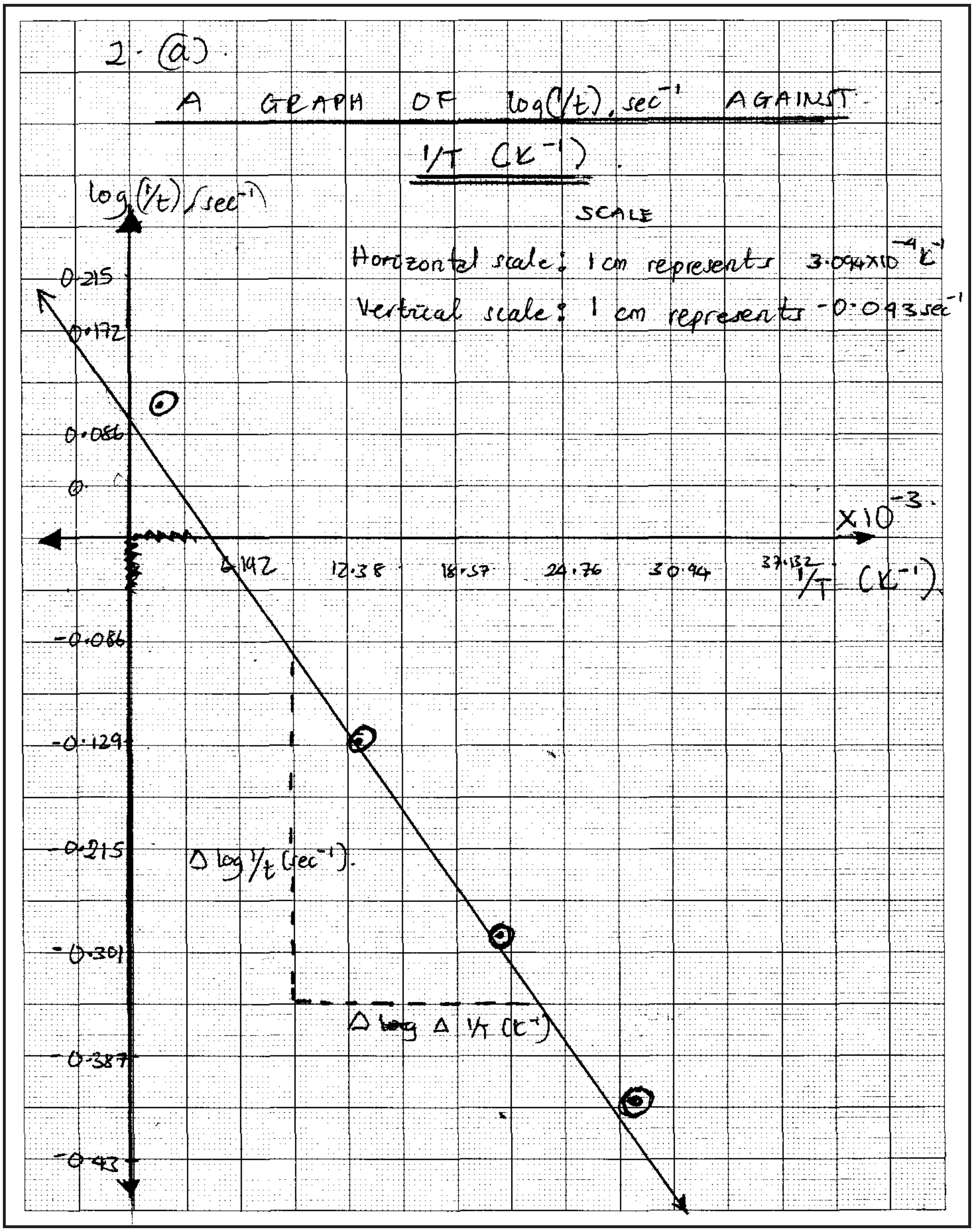
But $R = 8.314 \ J K^{-1} mol^{-1}$

$+Ea = + 2.190189 \times 10^{3} \times 8.314$

$Ea = 18.20923 \times 10^{3} \ KJ mol^{-1}.$

∴ The value of $Ea = 18.20923 \ KJmol^{-1}$

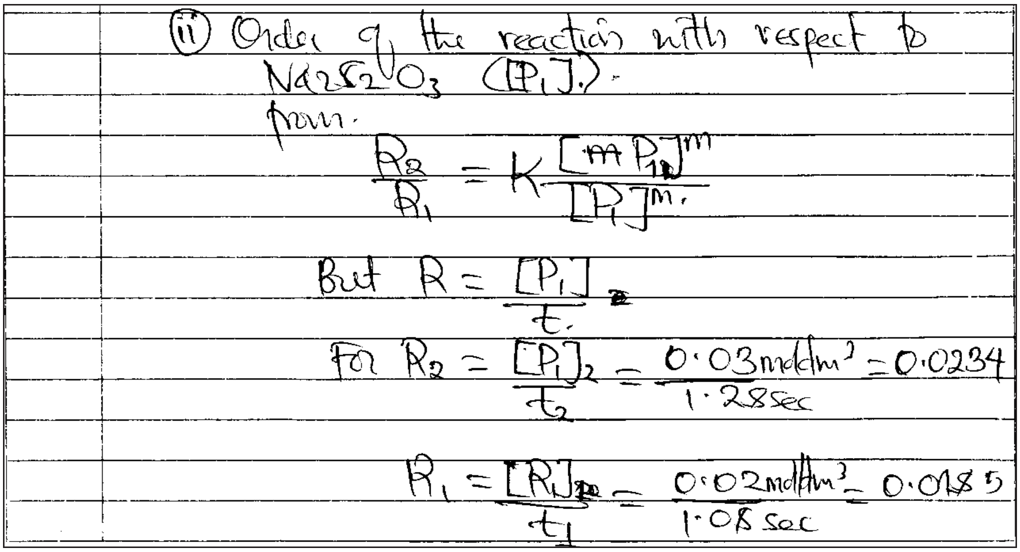
∴ $Ea = 18.20923 \ KJ mol^{-1}$



Extract 18:3 A sample of correct responses to Question 2 in Alternative Practical 3C

In Extract 18.3, the candidate correctly plotted the graph in part (a) and determined the slope of the graph in part (b). He/she finally calculate the activation energy by manipulating the Arrhenius equation.

On other hand, the candidates who scored low marks failed to complete the table of results correctly. Some of them recorded time which deviated much from the expected range, implying that they lacked skills of timing the stop watch. There were also some candidates who recorded similar values of both time and 1/t, indicating failure in recognizing the relationship between the two dimensions. In other case, the candidates did not indicate the reciprocal of time as the rate of the reaction. Similarly, some of the candidates plotted the graph without labeling the axes, while others did not indicate the title of the graph. Moreover, in sketching the graph, some candidates used inappropriate vertical and horizontal scales. Some even sketched curves instead of linear graphs. This sequence of errors ultimately resulted in an inaccurate determination of the order of reaction and activation energy. These findings indicate that the candidates possessed insufficient knowledge regarding chemical kinetics. Extracts 18.4, 18.5 and 18.6 show samples of the incorrect responses to question 2 in Alternative Practical A, B, and C, respectively.



(ii) Order of the reaction with respect to $Na_2S_2O_3$ ($[P_1]$).
from.

$$\frac{R_2}{R_1} = K\frac{[P_1]^m}{[P_1]^m}.$$

$$\text{But } R = \frac{[P_1]}{t}.$$

$$\text{For } R_2 = \frac{[P_1]_2}{t_2} = \frac{0.03\,mol\,dm^{3}}{1.28\,sec} = 0.0234$$

$$R_1 = \frac{[P_1]}{t_1} = \frac{0.02\,mol\,dm^{3}}{1.08\,sec} = 0.0185$$

2. (c) (ii) then,

$$\frac{R_2}{R_1} = \frac{[P_1]_2^m}{[P_1]_1^m}$$

$$\frac{0.0234}{0.0185} = \left(\frac{0.03}{0.02}\right)^m$$

$$1.26 = 1.5^m$$

$$m = 1$$

∴ The order of the reaction with respect to $Na_2S_2O_3$ is First order reaction.

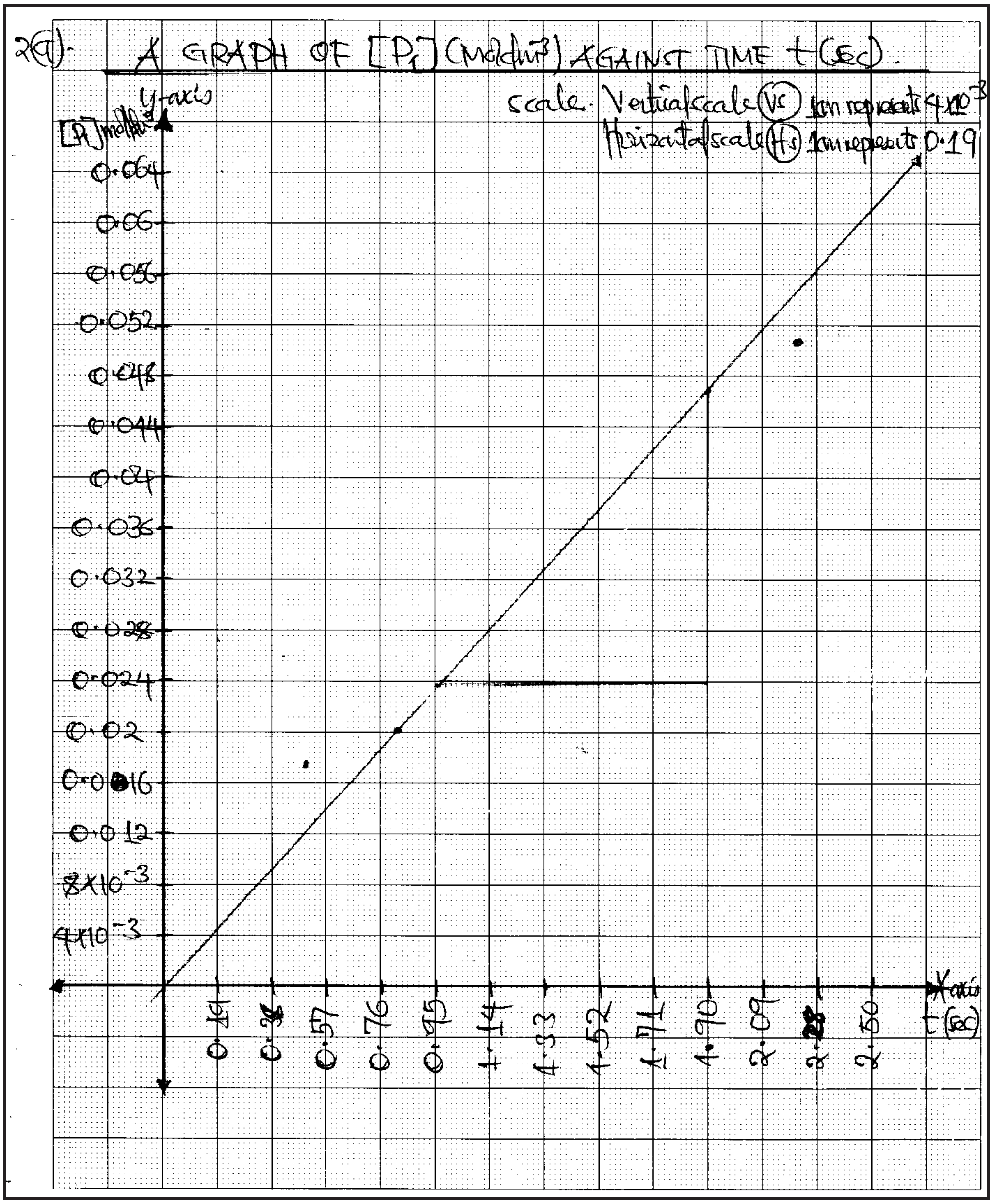
(iii) I reached the conclusion through the Mathematic law of exponent that any number raised to a exponent zero is equal to 1.
i.e:

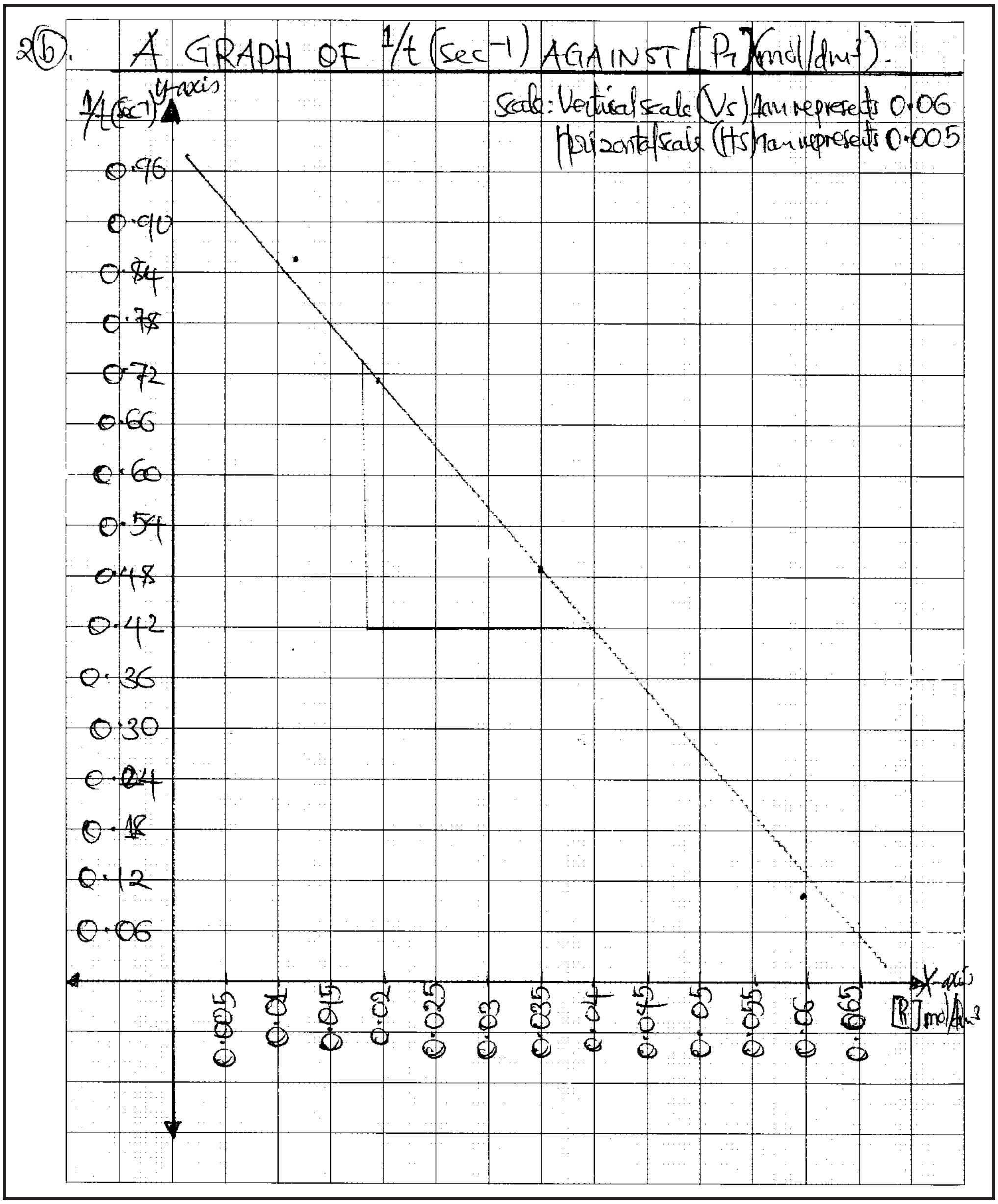
$$1.26 = 1.5^m$$

then $1.26^0 = 1$.

therefore the order of reaction is 1st order.

(d) The value of product of $[P_1]$ and time ($[P_1] \times t$) increased as the rate of the reaction increased. This was because both $[P_1]$ and time increased leading to increase of their product.


2(a).
A GRAPH OF [P1] (mol dm-3) AGAINST TIME t (sec).
scale. Vertical scale (Vs) 1cm represents 4×10-3
Horizontal scale (Hs) 1cm represents 0.19
y-axis
[P1] mol dm-3
0.064
0.06
0.056
0.052
0.048
0.044
0.04
0.036
0.032
0.028
0.024
0.02
0.016
0.012
8×10-3
4×10-3
0.19
0.38
0.57
0.76
0.95
1.14
1.33
1.52
1.71
1.90
2.09
2.28
2.50
X-axis
t (sec)



Extract 18.4: A sample of incorrect responses to Question 2 in Alternative Practical 3A

In Extract 18.4, the candidate recorded the data incorrectly for both concentration and the product of concentration and time. Furthermore, he/she failed to utilize the graphical and initial rate methods to determine the order of the reaction, and gave a wrong comment on the value of the product of concentration and time.

2 THE AIM OF THE EXPERIMENT IS TO DETERMINE THE CONCENTRATION OF POTASSIUM PERMANGANATE

Experimental Table

Temperature, T (°c)	Temperature, T (K)	Time for Reaction, t(sec)	$\frac{1}{T}$ (K^{-1})	log t
50	513	240	1.95×10^{-3}	2.38
60	393	120	2.54×10^{-3}	2.08
70	333	60	3.00×10^{-3}	1.78
80	303	30	3.00×10^{-3}	1.48
90	288	15	2.47×10^{-3}	1.18

ⓐ Ionic redox half equation

Given

$2MnO_4^-{}_{(aq)} + 5C_2O_4^{2-}{}_{(aq)} + 6H^+_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + 10CO_{2(g)}$
$+ 8H_2O_{(l)}$

$2MnO_4\ 6H^+ \longrightarrow 2Mn + 10CO_2 + 8H_2O$

$MnO_4^- + 9C_2O_4^{2-} \longrightarrow Mn^{2+} + 4CO_2$

$OH^-_{(aq)} + MnO_{(aq)} \longrightarrow H_2O_{(l)} + 2Mn^{2+} + 2e$

2nd Ionic redox half equation

$CO_{2(g)}^{2+} \longrightarrow CO_2^{2+}{}_{(g)}$

$CO_{2(s)}^{2+} \longrightarrow 2CO_{2(g)}$

$CO_{2(g)}^{2-} \longrightarrow 2CO_{2(g)} + 2e$

ⓒ Activation energy = ?

from

$Ea = \cancel{Ea}$

$\ln k = \frac{Ea}{RT} + \ln A$

Given

~~ln k~~

~~$Ea = RT(\ln k - \ln A)$~~

~~$Ea = 2T f$~~

from

$$\ln k = \frac{Ea}{RT} + \ln A$$

$$\downarrow \qquad \downarrow \qquad \downarrow$$

$$y = mx + c$$

Then

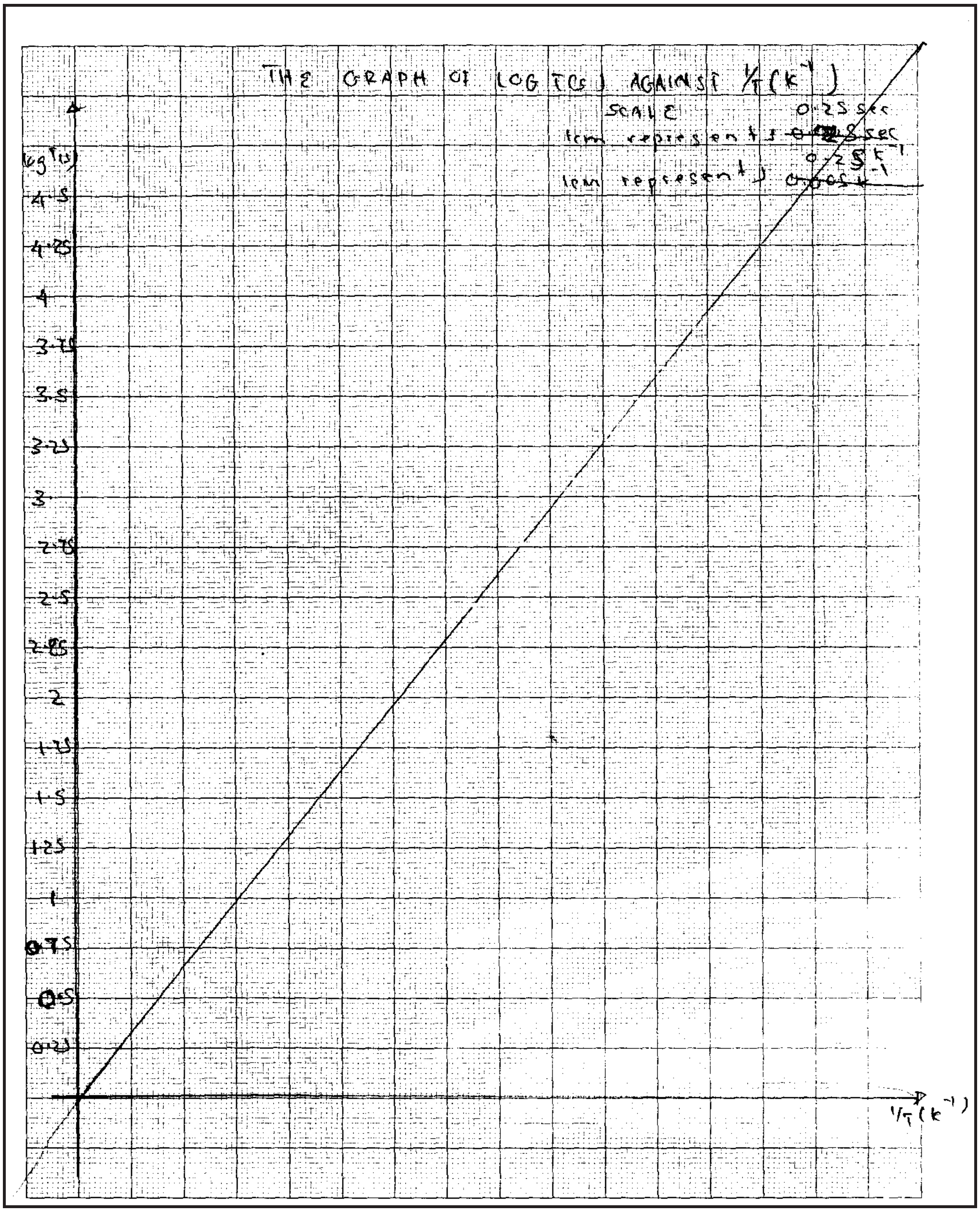
Slope = $\underline{Ea}$

$Ea = (1714.2857 \times 3.303 \times 8.14)$

$= 32823.672 \ J mol^{-1}$

$\therefore Ea = 32.824 \ kJ mol^{-1}$

Activation energy of the reaction is 32.824 kJmol



Extract 18.5: A sample of incorrect responses to Question 2 in Alternative Practical 3B

In Extract 18.5, the candidate recorded the time incorrectly, leading to inaccurate data representation and errors in the subsequent calculations or graphing. Additionally, the candidate failed to insert data on both the y-axis and x-axis, resulting in an incorrect value of the slope. Furthermore, the candidate wrote an incorrect half redox ionic equation and determining the activation energy using incorrect formula and gas constant.

2. TABLE OF RESULTS.

Volume of P_1 (cm³)	Volume of water (cm³)	Volume of P_2 (cm³)	$[P_1]$ mol/dm³	t (sec)	1/t (sec⁻¹)	$[P_1] \times t$ mol/dm³ sec.
10	00	05	0.02	1.08	0.926	0.0216
8	02	05	0.03	1.28	0.781.	0.0384
6	04	05	0.04	1.48	0.677	0.0592
4	06	05	0.06.	2.50	0.4	0.15.

(c). (i) The effect of concentration of $Na_2S_2O_3$ on the rate of the reaction, as the ~~Conc~~ concentration increased also the rate of the reaction increased, therefore the increase in concentration is direct proportional to the rate of the chemical reaction.

(ii) Order of the reaction with respect to $Na_2S_2O_3$ ($[P_1]$).

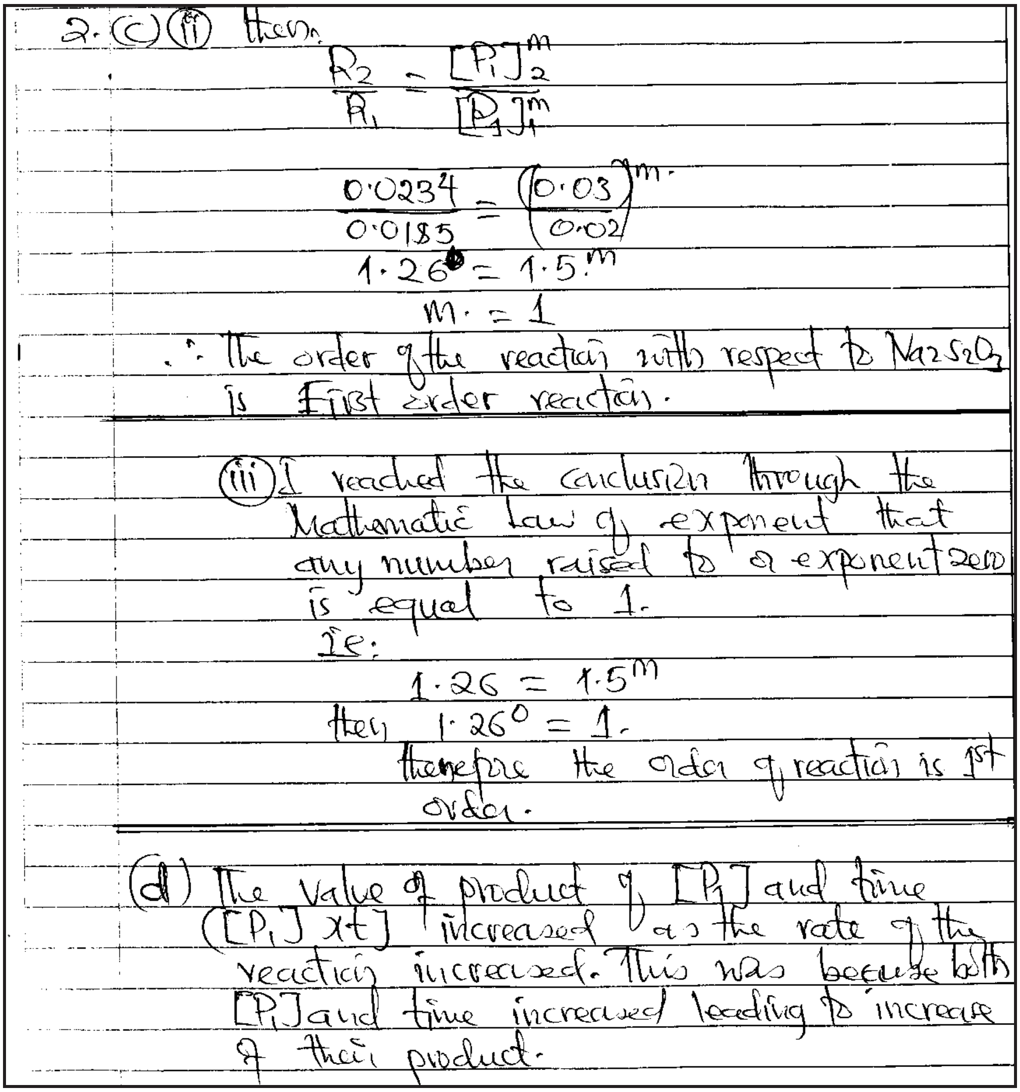
from.

$$\frac{R_2}{R_1} = K\frac{[P_1]^m}{[P_1]^m.}$$

But $R = \frac{[P_1]}{t.}$

For $R_2 = \frac{[P_1]_2}{t_2} = \frac{0.03 \text{mol/dm}^3}{1.28 \text{sec}} = 0.0234$

$R_1 = \frac{[P_1]_1}{t_1} = \frac{0.02 \text{mol/dm}^3}{1.08 \text{sec}} = 0.0185$



2. (c) (ii) then,

$$\frac{R_2}{R_1} = \frac{[P_1]_2^m}{[P_1]_1^m}$$

$$\frac{0.0234}{0.0185} = \left(\frac{0.03}{0.02}\right)^m.$$

$$1.26 = 1.5^m$$

$$m. = 1$$

∴ The order of the reaction with respect to $Na_2S_2O_3$ is First order reaction.

(iii) I reached the conclusion through the Mathematic law of exponent that any number raised to a exponent zero is equal to 1.

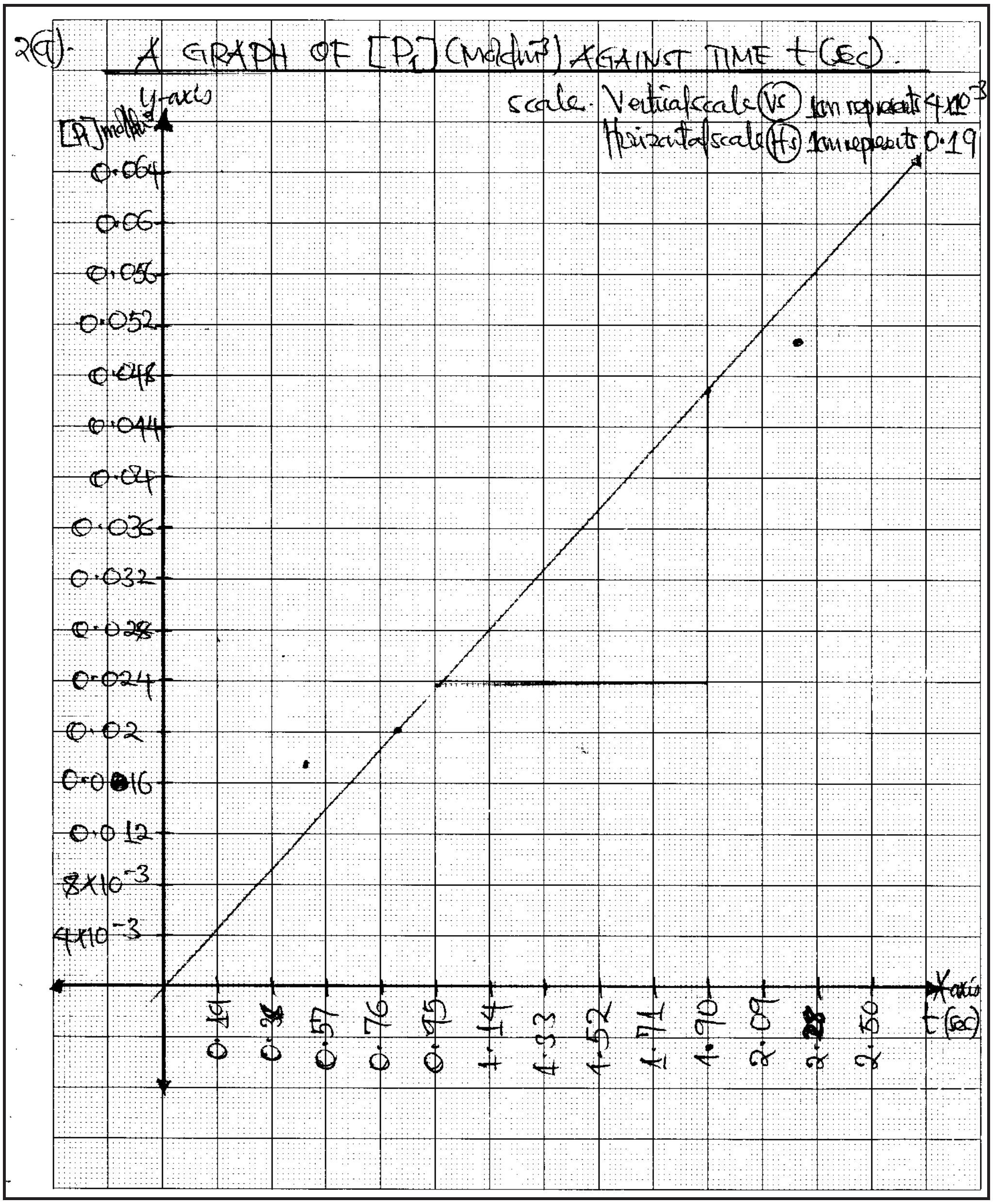
ie:

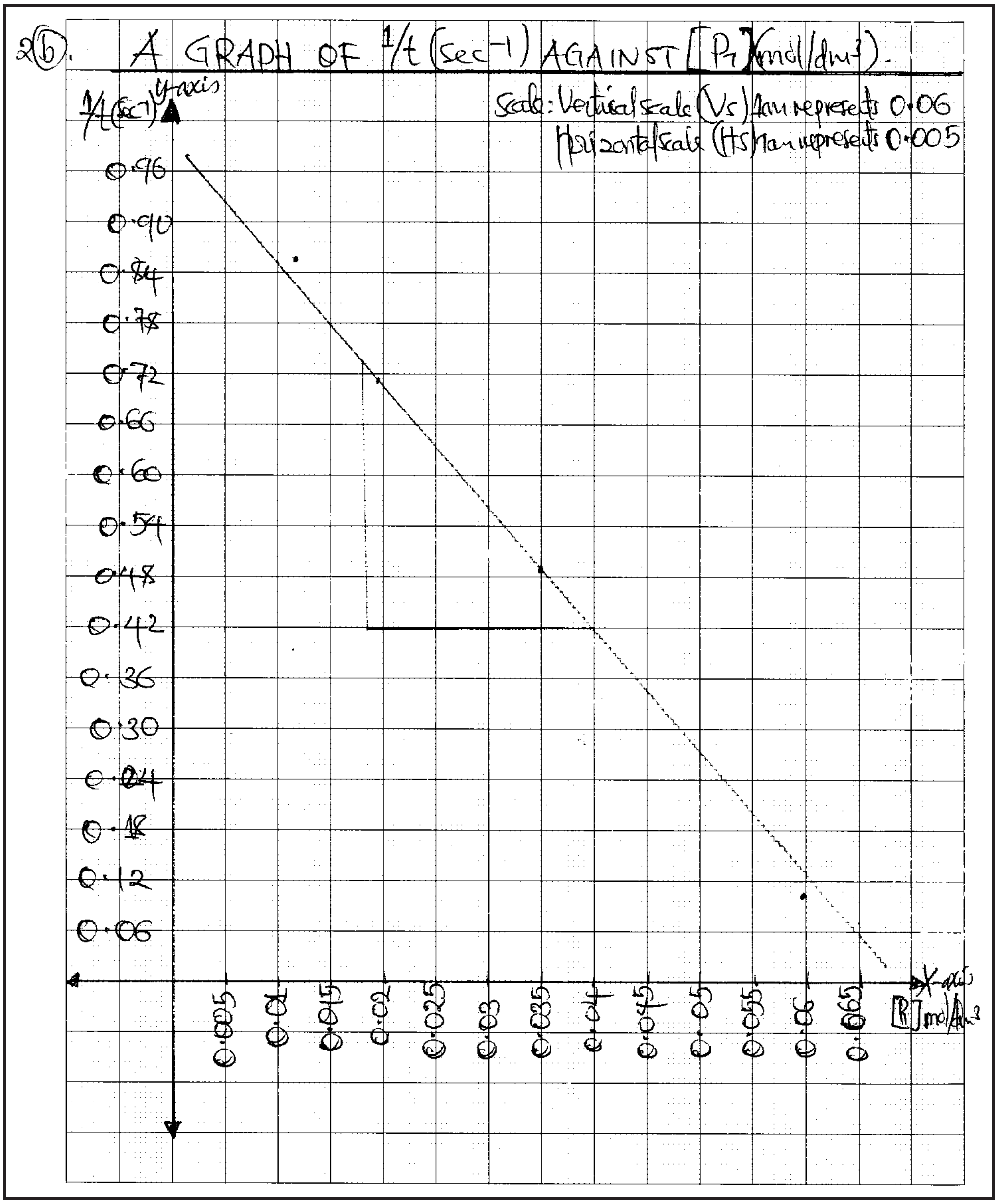
$$1.26 = 1.5^m$$

then $1.26^0 = 1$.

therefore the order of reaction is 1st order.

(d) The value of product of $[P_1]$ and time ($[P_1] \times t$) increased as the rate of the reaction increased. This was because both $[P_1]$ and time increased leading to increase of their product.


2(a). A GRAPH OF [P1] (Moldm-3) AGAINST TIME t (sec).
scale. Vertical scale (Vs) 1cm represents 4x10-3
Horizontal scale (Hs) 1cm represents 0.19
y-axis
[P1] moldm-3
0.064
0.06
0.056
0.052
0.048
0.044
0.04
0.036
0.032
0.028
0.024
0.02
0.016
0.012
8x10-3
4x10-3
x-axis
0.19
0.38
0.57
0.76
0.95
1.14
1.33
1.52
1.71
1.90
2.09
2.28
2.50
t (sec)



Extract 18.6*:* A sample of incorrect responses to Question 2 in Alternative Practical 3C

In Extract 18.6, the candidate recorded the data incorrectly for both concentration and the product of concentration and time. Furthermore, he/she failed to utilize the graphical and initial rate methods to determine the order of the reaction, and gave incorrect comment on the value of the product of concentration and time.

2.3.3 Question 3: Qualitative Analysis

2.3.3.1 Alternative 3A

The question was as follows:

*You are provided with sample **U** containing **two cations** and **one anion**. Perform the experiments given in Table 2 and record the observations. Make appropriate inferences and hence identify the two cations and anion.*

Table 2: Experimental Table

S/n	*Experiments*	*Observations*	*Inferences*
(a)	*Observe sample **U**.*		
(b)	*Heat a small portion of the sample in a dry test tube.*		
(c)	*Perform a flame test.*		
(d)	*Add concentrated sulphuric acid to a small portion of the sample.*		
(e)	*To the small portion of solution, of the sample, add dilute sodium hydroxide.*		
(f)	*To the small portion of the solution, add dilute HCl followed by hydrogen sulphide. Filter the precipitates to obtain filtrate and residue then proceed as follows:*		
	(i) To the filtrate, add potassium Hexacyanoferrate (II).		
	(ii) Dissolve the residue in aqua regia and then add excess ammonia solution.		
(g)	*To the small portion of the solution of the sample, add dilute nitric acid followed by silver nitrate.*		

Questions

(i) *Write the molecular formula for the sample.*

(ii) *What are the cations and anion in the sample?*

2.3.3.2 Alternative 3B

The question was as follows:

*Sample **B** contains **two cations** and **one anion**. Perform the experiments given in Table 2 and record the observations and make appropriate inferences. Hence, identify the two cations and an anion.*

Table 2: Experimental Table

S/n	***Experiment***	***Observations***	***Inferences***
(a)	*Observe sample **B**.*		
(b)	*Heat a small portion of the sample in a dry test tube.*		
(c)	*Add concentrated sulphuric acid to a small portion of the sample.*		
(d)	*Perform a flame test.*		
(e)	*To a small portion of the sample solution, add NaOH solution.*		
(f)	*To a small portion of the sample solution, add dilute nitric acid followed by silver nitrate solution, then ammonia solution.*		
(g)	*To the small portion of the sample solution, pass hydrogen sulphide gas or ammonium sulphide solution in the presence of hydrochloric acid. Filter the precipitates to obtain filtrate and residue.*		
	(i) To the filtrate add dilute acetic acid followed by a few drops of lead acetate.		
	(ii) Dissolve the residue, add aqua regia and then excess ammonia solution.		

Questions

(i) Write the molecular formula for the sample.

(ii) What are the cations and anion in the sample?

2.3.3.3 Alternative 3C

The questions was as follows:

*Sample **Z** contains **two cations** and **one anion**. Perform the experiments given in the Table 2 and record the observations. Make appropriate inferences and hence, identify the two cations and anion.*

Table 2: Experimental Table

S/n	***Experiment***	***Observations***	***Inferences***
(a)	*Observe sample* ***Z****.*		
(b)	*Heat small portion of the sample in a dry test tube.*		
(c)	*Perform a flame test.*		
(d)	*Add concentrated sulphuric acid to the dry sample.*		
(e)	*To the small portion of the prepared solution, add HCl followed by barium chloride solution.*		
(f)	*To the small portion of the prepared solution, add excess ammonia solution and then pass hydrogen sulphide gas slowly for one minute.*		
(g)	*Perform confirmatory tests for cations present in the sample.*		

Questions

(i) *Write the molecular formulas for the samples.*

(ii) *What are the cations and anion in the sample?*

The question was attempted by a total of 37,798 candidates. The statistics show that 30,533 (80.78%) candidates scored from 9.0–15 marks while 5,251 (13.89%) scored from 5.5–8.5 marks. However, 2,014 (5.33%) candidates scored from 0–5 marks. This question attained good performance in which 94.67% candidates scored 5.5 marks or above. The summary of the performance is shown in Figure 19.

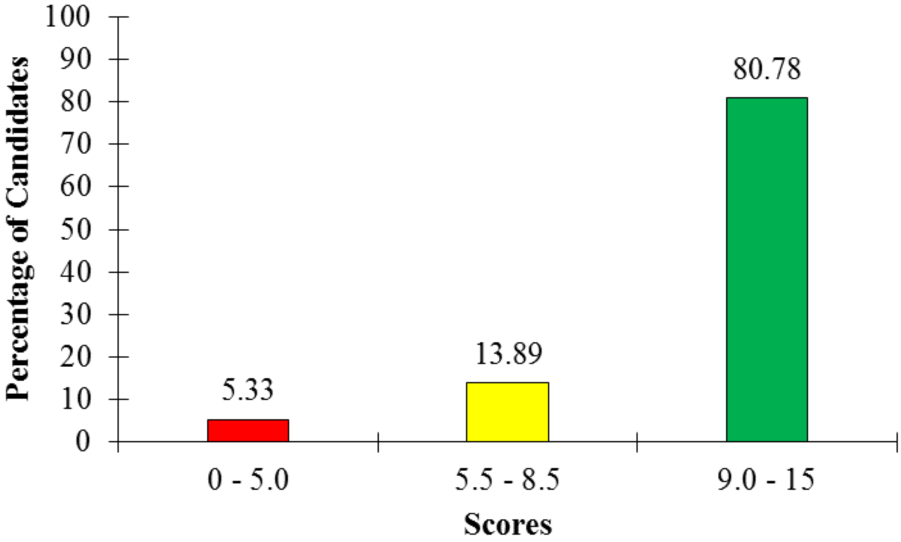
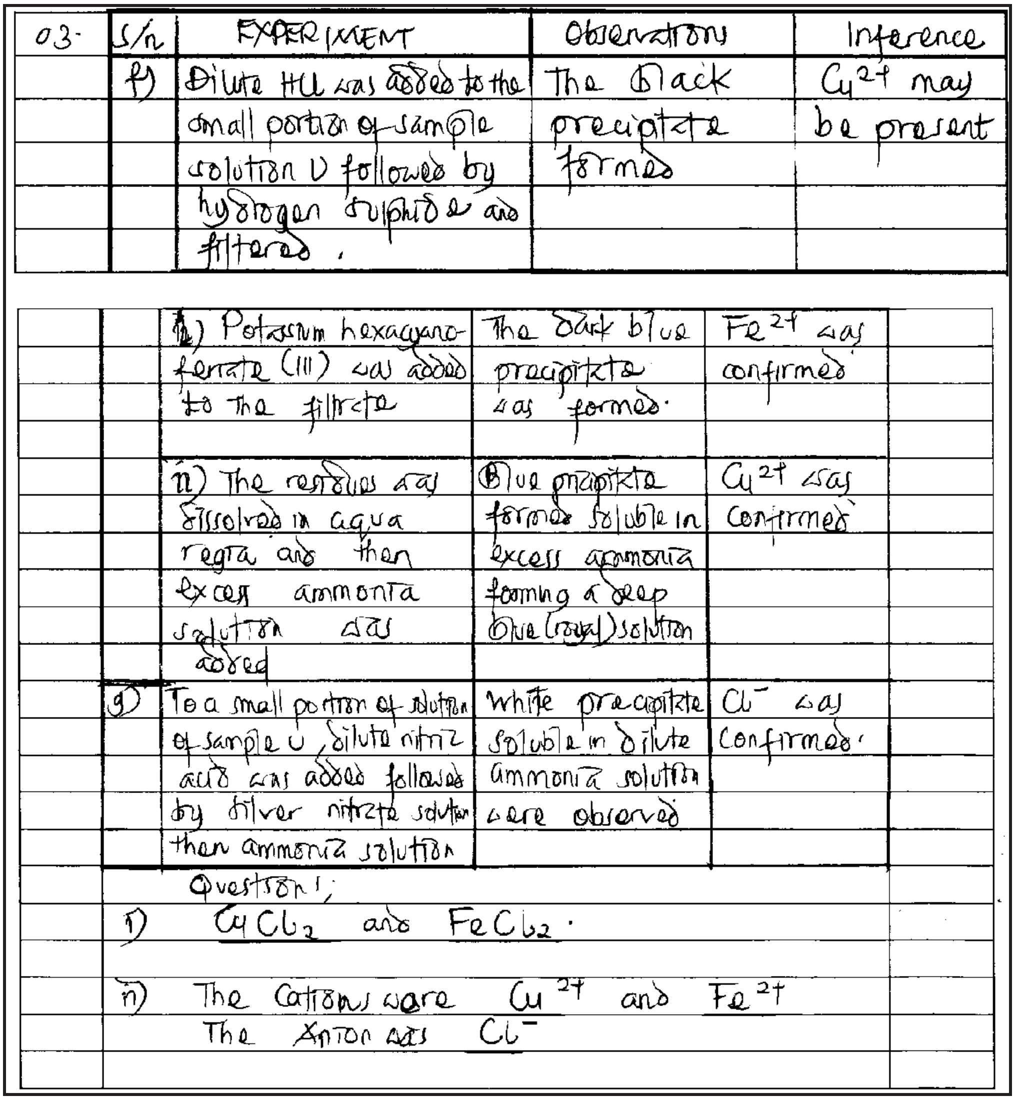


Figure 19: *Candidates' Performance in Question 3*

The candidates who performed well in this question exhibited sufficient knowledge of laboratory techniques, sound understanding of chemical reactions, and effective analytical skills. They displayed keen and precise observation skills and accurately noted the color of the sample, and other visual cues during the experiment. The candidates also correctly followed the experimental procedures, used appropriate reagents in the right proportions, and ensured proper mixing and handling of solutions. Moreover, they applied the fundamental concepts, including solubility rules, ion reactions, and acid-base behavior. This strong conceptual foundation enabled them to anticipate reactions, predict outcomes, and make informed conclusions based on their observations. In addition, they effectively communicated their findings in a clear and organized manner. Their written descriptions of observations, inferences, and conclusions were concise yet comprehensive, making it easy for assessors to follow their analytical thought process. In addition, their ability to discern various color and appearance allowed them to accurately identify the presence of ions. Extracts 19.1, 19.2 and 19.3 show samples of the correct responses to question 3 in Alternative Practical A, B, and C, respectively.

Q2	S/n	Experiments	Observations	Inferences.
	a)	Sample U was observed on the watch glass.	Sample U was a green crystalline and deliquescent sample	Fe^{2+}, Ni^{2+}, Cr^{3+}, Cu^{2+} of NO_3^-, Cl^- and SO_4^{2-} may be present
	b)	A small sample U was transferred in a clean and dry test tube then it was heated gently then strongly.	The colourless gas evolved which turned blue litmus paper to red.	Cl^- may be present
			The reddish brown residue were observed	Fe^{2+} may be present
	c)	The back of test tube was dip in concentrated HCl then to the sample followed by heating it on a flame	The blue green flame was observed	Cu^{2+} may be present
			Yellow sparks were observed	Fe^{2+} may be present
	d)	A small sample U was transfered in a clean and dry test tube followed by addition of concentrated H_2SO_4.	Colourless gas with misting small evolved which turned moist litmus paper from blue to red.	Cl^- may be present
	e)	Dilute sodium hydroxide was added to the small portion of the solution of sample U.	The dirty green precipitate which turned brown on exposure to air were observed	Fe^{2+} may be present



03.	S/n	EXPERIMENT	Observation	Inference
	f)	Dilute HCl was added to the small portion of sample solution U followed by hydrogen sulphide and filtered.	The black precipitate formed	Cu^{2+} may be present
	i)	Potassium hexacyanoferrate (III) was added to the filtrate	The dark blue precipitate was formed.	Fe^{2+} was confirmed
	ii)	The residue was dissolved in aqua regia and then excess ammonia solution was added	Blue precipitate formed soluble in excess ammonia forming a deep blue (royal) solution	Cu^{2+} was confirmed
	g)	To a small portion of solution of sample U, dilute nitric acid was added followed by silver nitrate solution then ammonia solution	White precipitate soluble in dilute ammonia solution were observed	Cl^- was confirmed.

Question 1;

i) $CuCl_2$ and $FeCl_2$.

ii) The Cations were Cu^{2+} and Fe^{2+}

The Anion was Cl^-

Extract 19.1: A sample of correct responses to Question 3 of Alternative Practical 3A

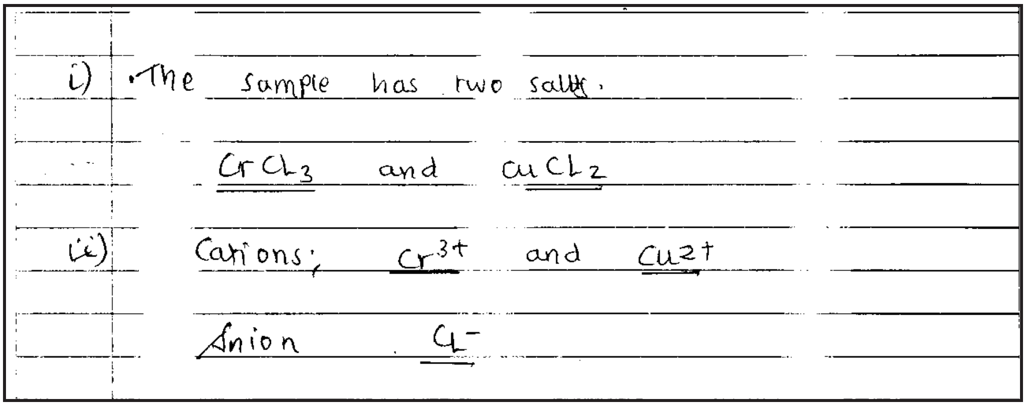
In Extract 19.1, the candidate gave correct observations and inferences thus he/she identified the cations (Fe^{2+} and Cu^{2+}) and the anion (Cl^-).

3.	S/n	Experiment	observation	Inferences
	a)	Appearance of		
		sample B	A green crystalline	Fe^{2+}, Ni^{2+},
			Salt was observe d.	Cr^{3+}, Cu^{+} may
				be present.
				NO_3^-, SO_4^{2-},
				Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}
				NO_2^- may be
				present.
	b)	Action of heat.		
		A small amount of	Colourles gas evolved	
		sample was placed	which turned wet	Cl^- may be
		in a clean and	blue litmus paper red	present
		dry test tube then	and formed dense	
		heated gently and	white fumes with	
		then strongly.	ammonia gas.	
			Black residue was	Cu^{2+} may be
			observed	present
	c)	Action of concentrated	Colourless gas with	
		sulphuric acid.	irritating smell evolved	Cl^- may be
		A small amount of	which turned moist	present.
		sample was transfered	litmus paper from blue	
		in a clean and dry	to red and formed	
		test tube and	dense white fumes	
		small amount of concent-	with ammonia gas.	
		rated sulphuric acid was		
		added.		

3.	S/n	Experiment	Observation	Inferences.
	d)	flame test.		
		The backside of the	A blue-green flame	Cu^{2+} may be
		test tube was dipped	was observed	present.
		into concentrated		
		HCl then picked up		
		a small amount of		
		sample and was		
		heated directly to		
		the flame.		

	e)	Action of NaOH soln. To a small portion of the sample solution NaOH solution was added.	Pale blue precipitate was formed which turned black on heating.	Cu^{2+} may be present.
	f)	To a small portion of the sample solution, dilute nitric acid was added followed by silver nitrate and then ammonia solution.	white precipitate soluble in dilute ammonia solution was formed	Cl^- confirmed

3.	S/n	Experiment	observation	Inference.
	g)	To small portion of sample, H_2S gas was passed through in presence of hydrochloric acid.	A black precipitate was observed	Cu^{2+} may be present.
	i)	To the filtrate, dilute acetic acid was added followed by a few drops of Lead acetate	A yellow precipitate was formed	Cr^{3+} confirmed
	ii)	The residue was dissolved and aqua regia was added followed by excess ammonia solution.	A blue precipitate soluble in excess ammonia forming a deep blue solution was formed	Cu^{2+} confimed



i) •The sample has two salts.

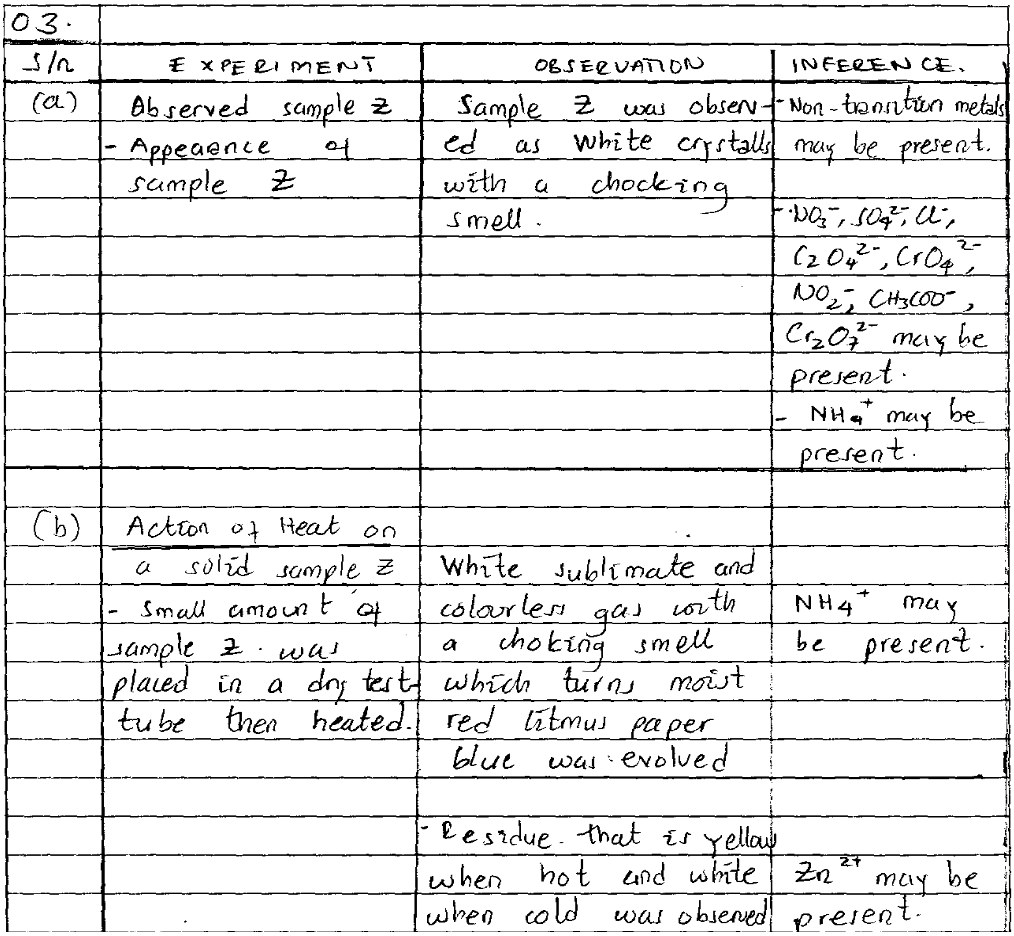
$CrCl_3$ and $CuCl_2$

ii) Cations; Cr^{3+} and Cu^{2+}

Anion Cl^-

Extract 19.2: A sample of correct responses to Question 3 of Alternative Practical 3B

In Extract 19.2, the candidate appropriately interpreted the observations, gave precise inferences and identified the ions as Cr^{3+}, Cu^{2+} and Cl^-.



03.

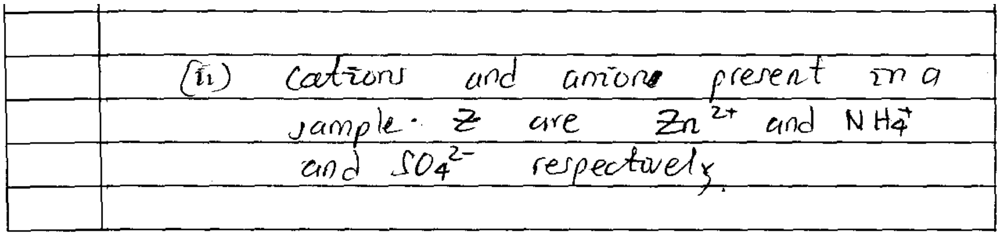
S/n	EXPERIMENT	OBSERVATION	INFERENCE.
(a)	Observed sample Z - Appeaence of sample Z	Sample Z was observed as white crystalls with a chocking smell.	- Non-transition metals may be present. - NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^-, CH_3COO^-, $Cr_2O_7^{2-}$ may be present. - NH_4^+ may be present.
(b)	Action of Heat on a solid sample Z - Small amount of sample Z was placed in a dry test-tube then heated.	White sublimate and colourless gas with a choking smell which turns moist red litmus paper blue was evolved	NH_4^+ may be present.
		- Residue that is yellow when hot and white when cold was observed	Zn^{2+} may be present.

(c)	Flame test.		
	Test tube was dipped in a concentrated HCL in watch glass then heated in a non-luminous flame	No flame test	Zn^{+} may be present

S/N			
3			
S/N	EXPERIMENT	OBSERVATION	INFERENCE
(d)	Action of concentrated H_2SO_4 on a solid sample Z. - Small amount of sample Z was transferred in a clean dry test tube and followed by addition of small amount of of H_2SO_4 (concentrated).	No gas was evolved	SO_4^{2-} may be present.
(e)	Small amount of sample Z solution in a test tube was added by dilute HCL then followed by Barium chloride solution.	White precipitate was formed. which are insoluble in dilute HCL and HNO_3	SO_4^{2-} confirmed

S/N	EXPERIMENT	OBSERVATION	INFERENCE
(f)	A small portion of solution of sample Z in a clean test tube was added by excess ammonia solution and then passed to hydrogen sulphide gas slowly for one minutes.	Precipitate dissolved in a solution mixture	Zn^{2+} may be present.
(g)	CONFIMATORY TESTS FOR CATIONS.		
	(i) To a solution sample Z dilute NaOH/NH_4OH solution was added until in excess.	White precipitates soluble in excess was observed	Zn^{2+} confirmed.
	(ii) A small amount of solid sample Z in a test tube was added by dilute NaOH and warmed. Then moist litmus paper passed to the mouth of the test tube containing the mixture. Also Dipped glass rod in concentrated HCl and passed to the mouth of test tube containing the mixture.	Colourless gas which turned a moist red litmus paper blue and white fumes with concentrated HCl evolved was observed.	NH_4^+ confirmed

	Conclusion.
	• Cations presents are NH_4^+ and Zn^{2+}.
	• Anion presents is SO_4^{2-}.
3	(a) (i) Molecular formula of the samples.
	$ZnSO_4$ and $(NH_4)_2SO_4$.



(ii) cations and anions present in a sample. Z are Zn^{2+} and NH_4^+ and SO_4^{2-} respectively.

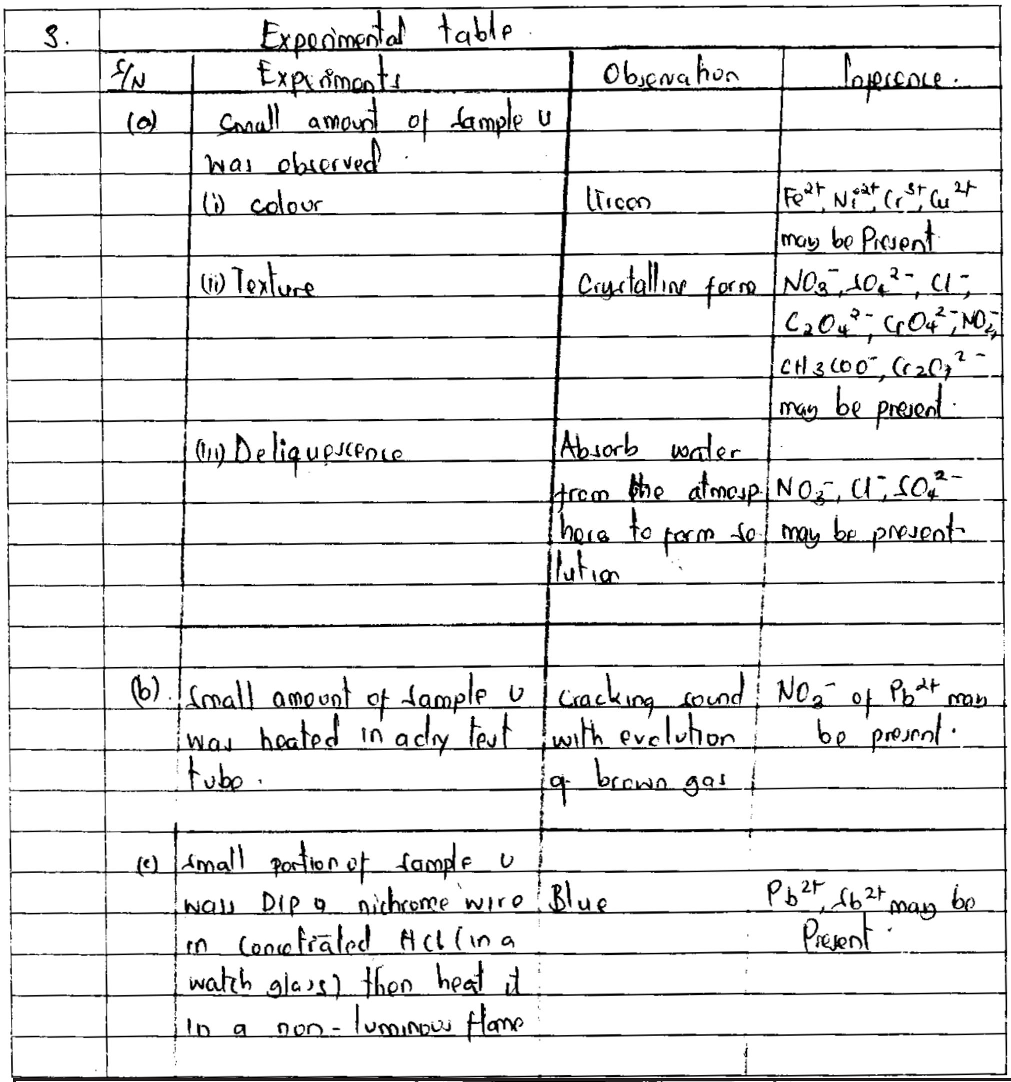
Extract 19.3: A sample of correct responses to Question 3 in the Alternative Practical 3C

In Extract 19.3, the candidate correctly identified the cations and anion. He/she precisely gave the molecular formulas for the samples $ZnSO_4$ and $(NH_4)_2SO_4$.

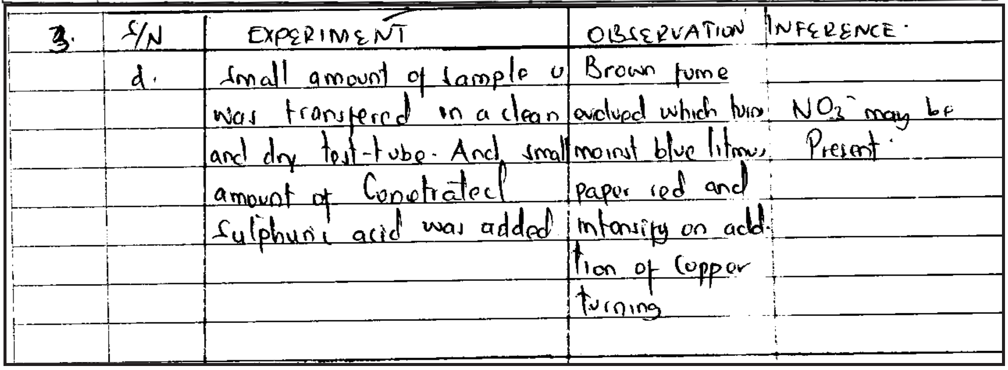
The candidates who performed poorly in this question exhibited a various challenges in their approach, execution, and interpretation of the experiment. Most of them struggled with accurate observation of color changes. They failed to distinguish between similar colors, or misinterpreted the appearance of the samples. This hindered them to identify and differentiate the presence of ions in the mixture. Not only that, a significant portion of the candidates displayed inadequate laboratory technique. Improper use of reagents, incorrect dilutions, and insufficient mixing of solutions led to unreliable or inconclusive results. This compromised the candidates' ability to perform precise and reliable tests, impacting their overall analysis. In other cases, other candidates struggled with making accurate inferences from their observations. They often misidentified the ions responsible for specific reactions, leading to incorrect conclusions. For instance, some candidates incorrectly attributed reactions to Cr^{3+} ions when they were actually caused by Cu^{2+} ions, and vice versa in alternative 3B. A significant portion of the candidates exhibited a lack of understanding of fundamental chemical concepts related to complex ion reactions and solubility rules. This hindered their ability to predict and interpret the outcomes of different reactions, contributing to their overall poor analysis. Candidates also faced challenges in effectively communicating their findings. Inadequate descriptions of observations, poorly written inferences, and disorganized presentation of results made it difficult for assessors to follow their thought process and evaluate their performance accurately.

Further analysis shows that, some candidates struggled with time management, spending excessive time on certain steps of the analysis and rushing through others, this was observed through incomplete experiments. As a results it affected the thoroughness of their observations, the accuracy of their interpretations, and the overall quality of their analysis.

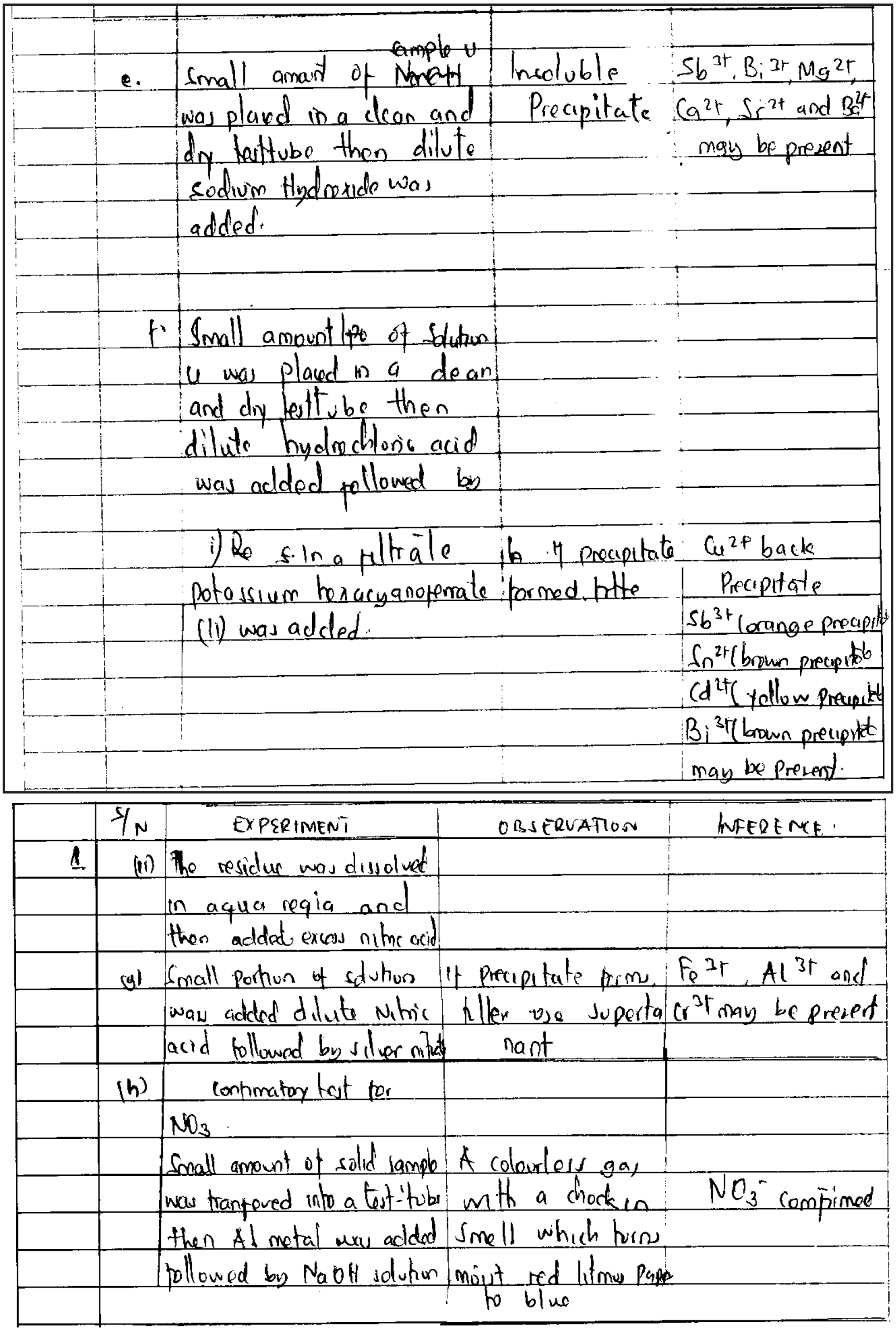
To address these shortcomings and improve the future candidates' performance in qualitative analysis, it is recommended that they receive additional training and practice in laboratory techniques, observation skills, and fundamental chemical concepts. Hands-on practice, interactive learning, and guided experiments can help candidates develop a stronger foundation in qualitative analysis and enhance their ability to accurately identify and interpret chemical reactions. Moreover, emphasizing the importance of systematic observation, precise measurements, and clear communication of findings can contribute to a more robust and effective analysis process. Extracts 19.4 provide sample of incorrect responses in alternatives 3B. Extracts 19.1, 19.2 and 19.3 show samples of the incorrect responses to question 3 in Alternative Practical A, B, and C, respectively.



3.	Experimental table			
	S/N	Experiments	Observation	Inference.
	(a)	Small amount of sample U was observed.		
		(i) colour	Green	Fe^{2+}, Ni^{2+}, Cr^{3+}, Cu^{2+} may be Present.
		(ii) Texture	Crystalline form	NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^-, CH_3COO^-, $Cr_2O_7^{2-}$ may be present.
		(iii) Deliquescence	Absorb water from the atmosphere to form solution	NO_3^-, Cl^-, SO_4^{2-} may be present.
	(b)	Small amount of sample U was heated in a dry test tube.	Cracking sound with evolution of brown gas	NO_3^- of Pb^{2+} may be present.
	(c)	Small portion of sample U was DIP a nichrome wire in Concetrated HCl (in a watch glass) then heat it in a non-luminous flame	Blue	Pb^{2+}, Sb^{2+} may be Present.



3.	S/N	EXPERIMENT	OBSERVATION	INFERENCE.
	d.	Small amount of sample U was transferred in a clean and dry test-tube. And small amount of Concetrated Sulphuric acid was added	Brown fume evolved which turn moist blue litmus paper red and intensify on addition of Copper turning	NO_3^- may be Present.

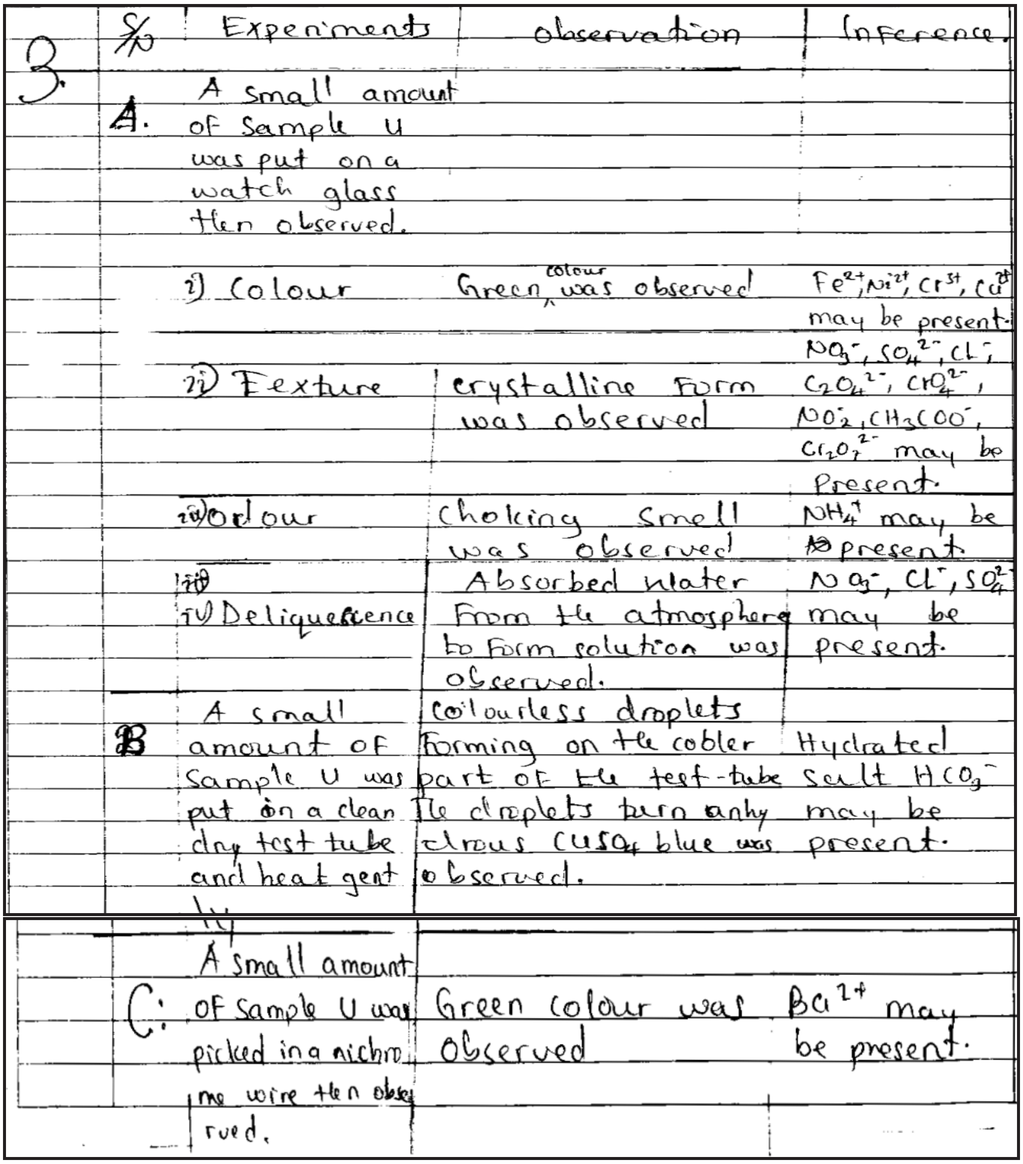


	e.	Small amount of ~~NaOH~~ sample U was placed in a clean and dry testtube then dilute sodium Hydroxide was added.	Insoluble Precipitate	Sb^{3+}, Bi^{3+}, Mg^{2+}, Ca^{2+}, Sr^{2+} and Ba^{2+} may be present
	f.	Small amount ~~lpo~~ of Solution U was placed in a clean and dry testtube then dilute hydrochloric acid was added followed by		
		i) ~~Re~~ f. In a filtrate potassium hexacyanoferrate (II) was added.	~~ih~~ A precipitate formed. ~~blte~~	Cu^{2+} back Precipitate Sb^{3+} (orange precipitate Sn^{2+} (brown precipitate Cd^{2+} (yellow precipitate Bi^{3+} (brown precipitate may be Present.

	S/N	EXPERIMENT	OBSERVATION	INFERENCE.
4	(ii)	The residue was dissolved in aqua regia and then added excess nitric acid		
	(g)	Small portion of solution was added dilute Nitric acid followed by silver nitrate	If precipitate form, filter use supernatant	Fe^{2+}, Al^{3+} and Cr^{3+} may be present
	(h)	Confirmatory test for NO_3. Small amount of solid sample was transferred into a test-tube then Al metal was added followed by NaOH solution	A colourless gas with a chock in Smell which turns moist red litmus Paper to blue	NO_3^- comfirmed

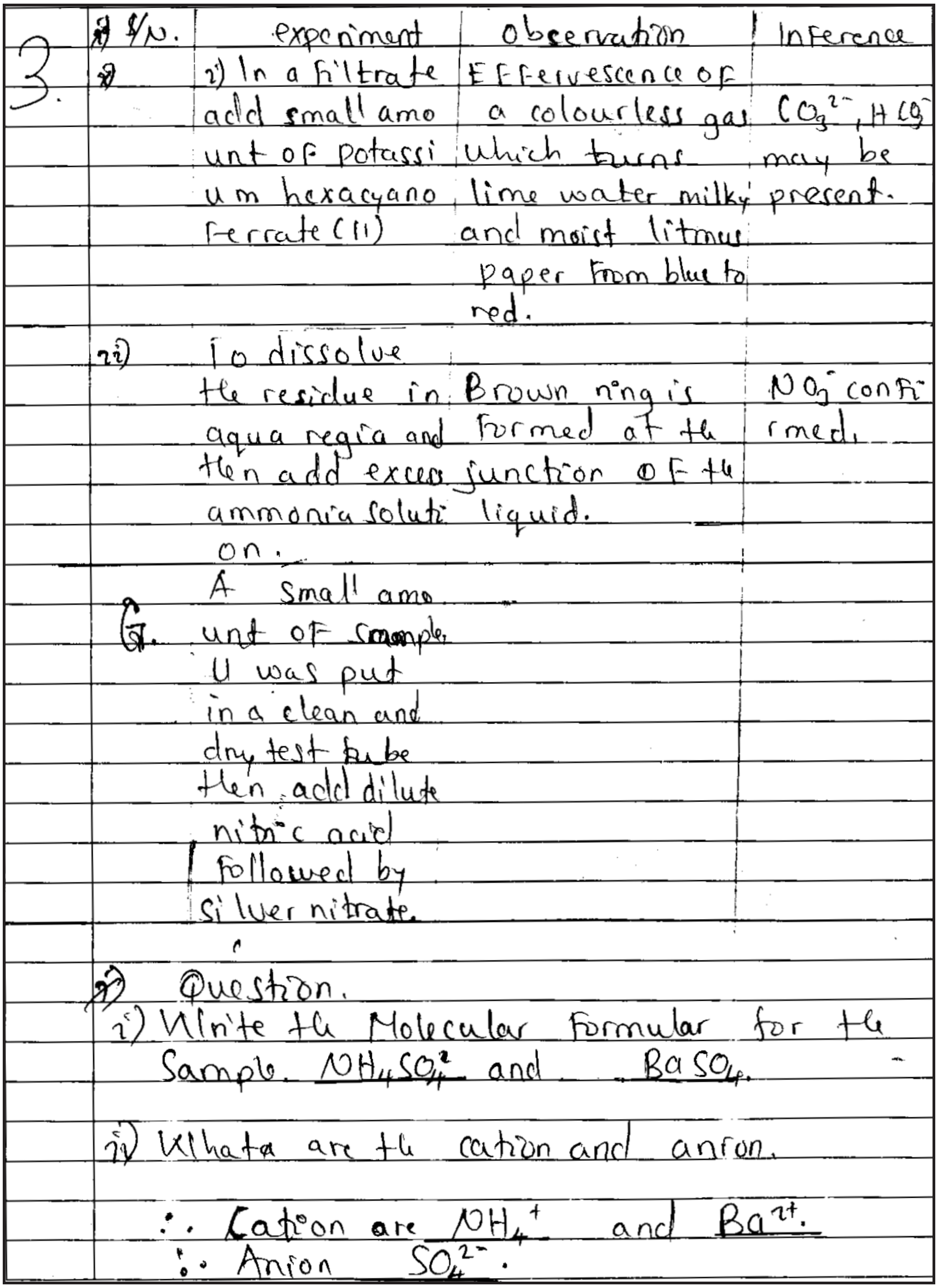
Extract 19.4: A sample of incorrect responses to Question 3 in Alternative Practical 3A

In Extract 19.4, the candidate gave inappropriate observations and inferences. For instance, in part (c), the candidate mentioned the observation of a brown color in the flame test, which does not infer the presence of Zn^{2+} ions. Similarly, in part (d), the candidate incorrectly wrote *brown fumes* instead of *colorless gas*. Additionally, in part (e), the candidate mistakenly referred to *insoluble salts* instead of *soluble salts*. These discrepancies imply that the candidate had poor skills in observation and interpretation.



	S/N	Experiments	observation	Inference.
3.	A.	A small amount of Sample U was put on a watch glass then observed.		
		i) Colour	Green colour was observed	Fe^{2+}, Ni^{2+}, Cr^{3+}, Cu^{2+} may be present.
		ii) Texture	crystalline Form was observed	NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^-, CH_3COO^-, $Cr_2O_7^{2-}$ may be Present.
		iii) Odour	Choking smell was observed	NH_4^+ may be present.
		iv) Deliquescence	Absorbed water From the atmosphere to Form solution was observed.	NO_3^-, Cl^-, SO_4^{2-} may be present.
	B	A small amount of Sample U was put on a clean dry test tube and heat gently	colourless droplets Forming on the cobler part of the test-tube The droplets turn anhydrous $CuSO_4$ blue was observed.	Hydrated salt HCO_3^- may be present.
	C.	A small amount of sample U was picked in a nichrome wire then observed.	Green colour was Observed	Ba^{2+} may be present.

	S/N	Experiments	observation	Inference.
3.	D.	A small amount of sample U was put in a clean and dry test-tube then add small amount of Sulphuric acid	No gas evolves was observed	SO_4^{2-} may be present.
	E!	A small amount of sample U was put in a dry clean test tube then add small amount of dilute ~~hydro~~ Sodium hydroxide	Ammonia gas evolves on Warming	NH_4^+ may be present
	F.	A small amount of sample U was put in a clean dry test tube then add small amount of dilute HCl Followed by hydrogen Sulphide Filtre the precipitates to obtain Filtrate and residue then poceed as Follow		



3.

S/N.	experiment	observation	Inference
i)	In a filtrate add small amount of potassium hexacyano ferrate (II)	Effervescence of a colourless gas which turns lime water milky and moist litmus paper from blue to red.	CO_3^{2-}, HCO_3^- may be present.
ii)	To dissolve the residue in aqua regia and then add excess ammonia solution.	Brown ring is formed at the junction of the liquid.	NO_3^- confirmed.
(g).	A small amount of sample U was put in a clean and dry test tube then add dilute nitric acid followed by silver nitrate.		

(h) Question.

i) Write the Molecular Formular for the Sample. $NH_4SO_4^{2}$ and $BaSO_4$.

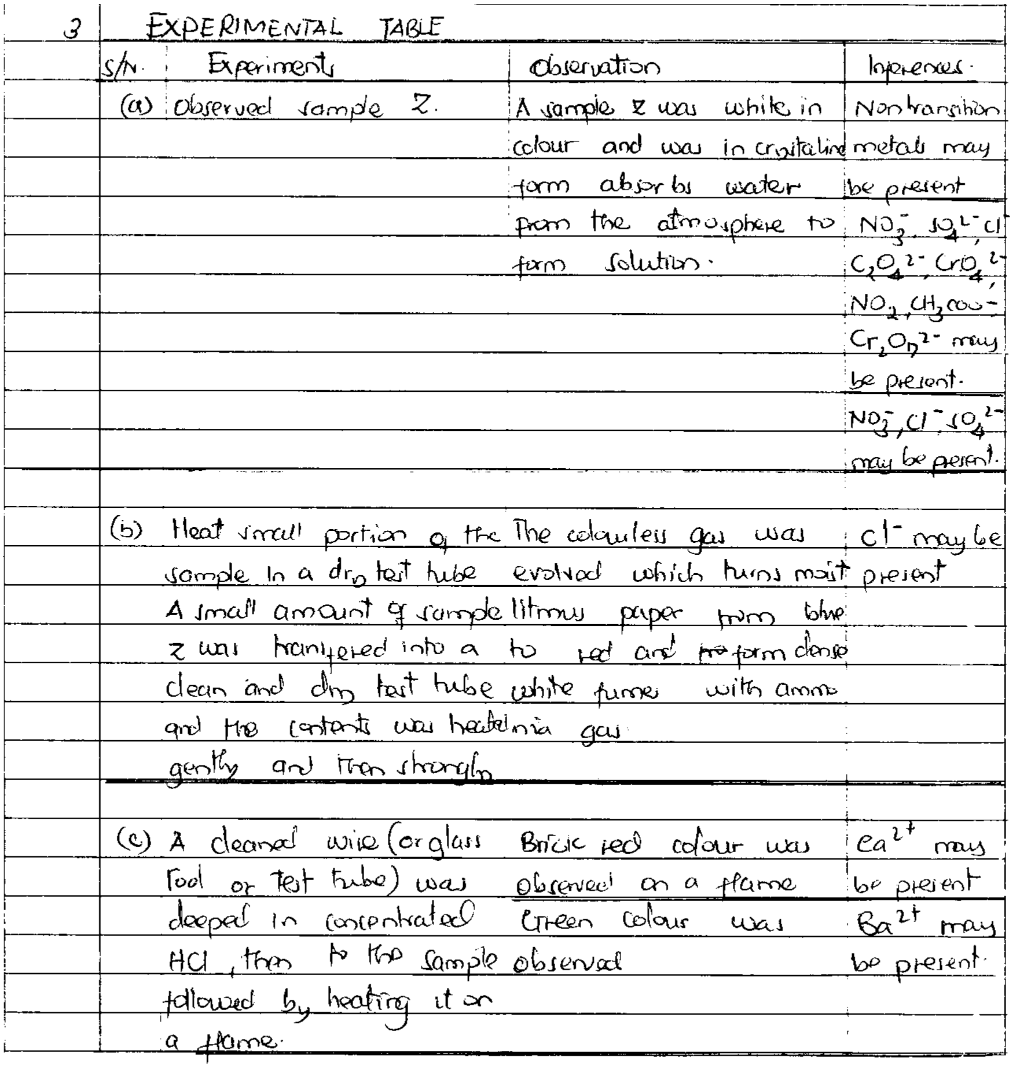
ii) Whata are the cation and anion.

∴ Cation are NH_4^+ and Ba^{2+}.

∴ Anion SO_4^{2-}.

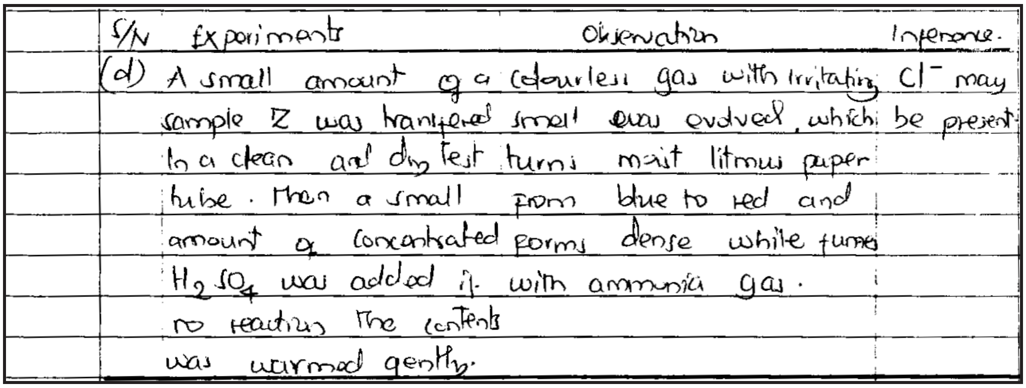
Extract 19.5: A sample of incorrect responses to Question 3 in Alternative Practical 3B

In Extract 19.5, the candidate gave incorrect observations and inferences. For instance, in part (d), he/she failed to identify the gas evolved. Similarly, in part (e), the candidate failed to recognize the formation of precipitate. Finally, the candidate made inappropriate confirmations regarding the cations and the anion.



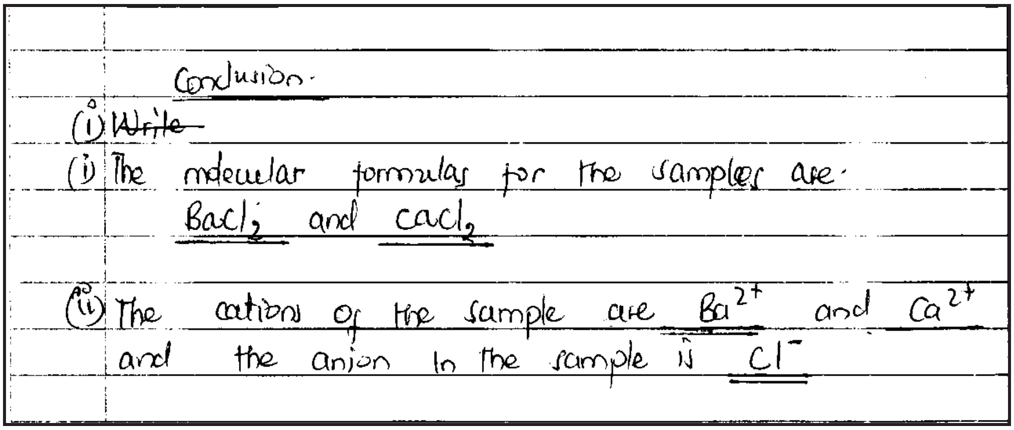
3 EXPERIMENTAL TABLE

S/N.	Experiments	Observation	Inferences.
(a)	Observed sample Z.	A sample Z was white in colour and was in crystaline form absorbs water from the atmosphere to form solution.	Non transition metals may be present NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2, CH_3COO^- $Cr_2O_7^{2-}$ may be present. NO_3^-, Cl^-, SO_4^{2-} may be present.
(b)	Heat small portion of the sample In a dry test tube A small amount of sample Z was transfered into a clean and dry test tube and the contents was heated gently and then strongly	The colourless gas was evolved which turns moist litmus paper from blue to red and ~~pro~~ form dense white fume with ammonia gas	Cl^- may be present
(c)	A cleaned wire (or glass rood or Test tube) was deeped in concentrated HCl, then to the sample followed by heating it on a flame.	Brick red colour was observed on a flame Green colour was observed	Ca^{2+} may be present Ba^{2+} may be present.



S/N	Experiments	Observation	Inference.
(d)	A small amount of sample Z was transfered In a clean and dry test tube. Then a small amount of concentrated H_2SO_4 was added it. no reaction The contents was warmed gently.	a colourless gas with irritating smell was evolved, which turns moist litmus paper from blue to red and forms dense white fumes with ammonia gas.	Cl^- may be present.

S/N	Experiment	observation	Inference
(e)	To the small portion of the prepared solution ~~add~~ dilute HCl was added followed by barrium chloride solution	white solution was formed	Cl^- may be present
(f)	To the small portion of the prepared solution was transfered in a clean and dry test tube then excess ammonia solution was added then pass hydrogen sulphide gas slowly for one minute.	No precipitate was formed	Ca^{2+}, Sr^{2+}, Ba^{2+} may be present
(g)	Confrimatory test of cation. Ba^{2+} A cleaned wire (or glass rod or test tube) was deeped in concentrated HCl then to the sample followed by heating it on a flame.	~~Brick red~~ Green ~~colour~~ flame was observed	Ba^{2+} Confirmed
	Confirmatory test of Ca^{2+} A cleaned wire (or glass rod or test tube) was deeped in a concentrated HCl then to the sample followed by heating it on a flame.	Brick red flame was observed	Ca^{2+} Confirmed



Conclusion·

(i) ~~Write~~

(i) The molecular formulas for the samples are·
$BaCl_2$ and $CaCl_2$

(ii) The cations of the sample are Ba^{2+} and Ca^{2+}
and the anion in the sample is Cl^-

Extract 19.6: A sample of incorrect responses to Question 3 in Alternative Practical 3C

In Extract 19.6, the candidate gave incorrect observations about flame test in part (c). In part (d), he/she reported of gas evolution, while the procedure was not accompanied with evolution of gas. Similarly, in part (f), the candidate failed to recognize the residue formed from reacting Zn^{2+} (aq) with S^{2-}(aq).

3.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE IN EACH TOPIC

The 2023 ACSEE Chemistry examination comprised 23 topics, spread into three papers. Chemistry Paper 1 covered 10 topics, including *The Atom, Chemical Bonding, Relative Molecular Masses in Solution, Chemical Equilibrium, Gases, Energetics, Aliphatic Hydrocarbons, Soil Chemistry, Selected Compounds of Metals,* and *Aromatic Hydrocarbons*. Chemistry Paper 2 covered 10 topics, namely; *Acids, Bases and Salts, Chemical Kinetics, Carbonyl Compounds, Amines, Carboxylic Acids and its Derivatives, Transition Elements, Polymers, Periodic Classification, Extraction of Metals,* and *Two Component Liquid Systems*. In the practical paper the candidates were tested on *Volumetric Analysis, Physical Chemistry Analysis*, and *Qualitative Analysis* which are subtopics under the topic of *Chemical Analysis*.

Chemical Analysis was the highest-performed topic, with 93.03 per cent of the candidates scoring average marks or above. Other topics which attained high performances were *The Atom (91.10%), Energetics (75.09%), Soil Chemistry (74.25%), Relative Molecular Masses in Solution (72.08%), Chemical Bonding (67.70%), Gases (63.11%),* and *Two Component Liquid Systems (75.66%).*

The candidates who achieved high in these topics demonstrated sufficient knowledge of the questions' requirements and exhibited appropriate competencies in the tested concepts. Their good performance reflects the grasp of the underlying concepts and ability to apply the acquired skills effectively.

However, the analysis reveals that the candidates had average performance on the following topics: *Elements and Polymers (43.61%)*, *Chemical Equilibrium (42.19%)*, *Aromatic Hydrocarbons (40.89%)*, *Carbonyl Compounds, Amines, Carboxylic Acids, and its Derivatives (39.81%)* and *Aliphatic Hydrocarbons (38.42%)*. The candidates provided partially correct responses to the questions from these topics.

On the other hand, the candidates performed weakly in the topics of *Chemical Kinetics (34.67%)*, *Acids, Bases, and Salts (26.73%)*, *Selected Compounds of Metals (21.75%)* and *Periodic Classification and Extraction of Metals (18.01%)*. Analysis of responses from the candidates who scored weakly in these topics indicate insufficient knowledge of the subject matter, leading to errors in formulas, chemical equations, and calculation approaches.

Additionally, when comparing the 2023 performance to that of 2022, there have been improvements in the topic of *Aromatic Hydrocarbons*. However, there were declines in performance in the topics of *Chemical Equilibrium*, *Selected Compounds of Metals*, and *Periodic Classification and Extraction of Metals*. A comprehensive summary of candidates' performance in various topics tested in the theoretical paper and topics tested in the practical paper is provided in Appendices A and B, respectively.

4.0 CONCLUSIONS

The general performance of the candidates who sat for the Chemistry examination in 2023 was good, with a pass rate of 97.48%. The analysis of the candidates' responses to each question indicated that the majority of the candidates demonstrated a good understanding of the tested concepts. The performance in the practical paper was better than in the theory papers, which can be attributed to the saying, "when I do I remember and understand." Engaging in practical sessions allowed the candidates to acquire more competences and achieve higher scores.

Given these findings, teachers are advised to incorporate more practical sessions into the curriculum implementation and make use of locally available materials whenever possible. This will enhance students' understanding and eventually improve the overall performance in the subject.

On the other hand, the responses from the candidates who performed weakly suggested that they lacked sufficient knowledge of the subject matter that was tested. To address this, educators should focus on reinforcing fundamental concepts and offering additional support to weak students. Overall, this analysis provides valuable insights into the strengths and weaknesses of the candidates, which can guide future teaching strategies and help students excel in the subject.

5.0 RECOMMENDATIONS

The weak and average performance observed in the tested topics can be improved through collaborative efforts between teachers and prospective candidates during teaching and learning. Based on the analysis of the candidates' responses, the following measures are recommended to enhance the candidates' future performance in the examination:

(a) Practical Sessions:

  (i) Students should be provided with more practical exercises to improve their knowledge and competence in data collection.
  (ii) Teachers should guide students to increase accuracy in recording data, emphasising the importance of recording data to two decimal places.
  (iii) Key concepts such as the mole concept in relation to stoichiometry, oxidation states, and balancing of redox reactions should be emphasised. This will help students in mathematical manipulations based on these concepts.

(b) Periodic Table:
Students should be encouraged to focus more on learning periodic classification practically to become familiar with the properties and reactivity of elements in the Periodic Table.

(c) Use of Atomic Models:
Teachers should use atomic models as a suitable teaching aid, especially in the topics like chemical bonding, to help students develop interest and understanding, ultimately enhancing their memory retention.

(d) Real-Life Examples:
During teaching and learning processes, teachers are encouraged to use real-life situations as examples to help students understand and apply scientific concepts more effectively. This approach will make teaching and learning more meaningful.

(e) Chemistry Club:
Chemistry clubs should be integrated within schools to engage more students in discussions about challenging topics such as Chemical Kinetics. This will improve students' understanding of the subject and foster a sense of confidence among learners.

Appendix A: Summary of the Candidates' Performance in the Theory Papers 2023 and 2022

S/n	Topic	2022			2023		
		Number of Question	The Percentage of the Candidates who Scored 35% or Above	Remarks	Number of Question	The Percentage of the Candidates who Scored 35% or Above	Remarks
1.	The Atom	1	81.90	Good	1	91.09	Good
2.	Two Component Liquid systems	1	84.60	Good	1	75.66	Good
3.	Energetics	1	66.80	Good	1	75.09	Good
4.	Soil Chemistry				1	74.22	Good
5.	Relative Molecular Masses in Solution	1	67.10	Good	1	72.08	Good
6.	Chemical Bonding	1	61.20	Good	1	67.69	Good
7.	Gases	1	57.60	Average	1	63.11	Good
8.	Transition Elements and Polymers				1	43.62	Average
9.	Chemical Equilibrium	1	85.90	Good	1	42.19	Average
10.	Aromatic Hydrocarbons	1	21.90		1	40.85	Average
11.	Carbonyl Compounds; Amines; Carboxylic Acids and its Derivatives	1	36.50	Average	1	39.80	Average
12.	Aliphatic Hydrocarbons	1	41.90	Average	1	38.40	Average
13.	Chemical Kinetics				1	34.68	Weak
14.	Acids, Bases and Salts				1	26.72	Weak
15.	Selected Compounds of Metals	1	60.80	Good	1	21.74	Weak
16.	Periodic Classification and Extraction of Metals	1	34.80	Weak	1	18.03	Weak
17.	Polymer and Transition Element	1	33.40	Weak			
18.	Acids, Bases and Salts/ Solubility, Solubility Product and Ionic Product	1	25.60	Weak			
19.	Electrochemistry	1	39.80	Average			
20.	Environmental Chemistry	1	67.10	Good			
21.	Aliphatic hydrocarbons/Aromatic Hydrocarbons/ Halogen Derivatives of Hydrocarbons.	1	21.9	Weak			

Appendix B: Summary of the Candidates' Performance in the Practical Papers 2023 and 2022

S/n	Subtopic	2022			2023		
		Number of Question	The Percentage of the Candidates who Scored 35% or Above	Remarks	Number of Question	The Percentage of the Candidates who Scored 35% or Above	Remarks
1.	Qualitative Analysis	1	98.00	Good	1	94.67	Good
2.	Physical Chemistry Analysis	1	51.10	Average	1	94.35	Good
3.	Volumetric Analysis	1	93.80	Good	1	90.05	Good