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), 2022

CHEMISTRY

THE UNITED REPUBLIC OF TANZANIA

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132 CHEMISTRY

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FOREWORD

This report is based on the Advanced Certificate of Secondary Education Examination (ACSEE) Chemistry paper, which was done in May 2022. The report analyses the responses given by the candidates to each question and the topics in the ACSEE 2022 Chemistry paper. This report also highlights factors that influenced the performance of candidates in Chemistry examination.

The general performance of the candidates who sat for the Chemistry examination in 2022 was good; 97.48 per cent of the candidates passed. This report is intended to give feedback to educational stakeholders such as Chemistry teachers, students, heads of secondary schools as well as educational administrators. The analysis presented in this report will reveal to educational stakeholders the responses that were given by the candidates to help them act appropriately to improve teaching and learning among prospective candidates.

The report has analysed in detail factors that hindered the candidates from responding to the asked questions as required. Such factors include insufficient knowledge of writing chemical equations, lack/shortage of appropriate skills in performing chemical calculations as well as failure to follow the requirements of the questions. The report has also identified factors, which enabled the candidates to perform well in the questions. Such factors include having appropriate competencies in the subject matter and the ability to understand the requirements of questions. The analysis of each question's responses has been supported with extracts from the candidates' scripts.

The feedback and the recommendations given in this report will help to improve performance of prospective candidates in the future examinations administered by the Council.

Lastly, the National Examinations Council of Tanzania thanks the examiners, chemistry examination officers and all other stakeholders who participated in the preparation of this report.

Athumani S. Amasi
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report analyses the responses given by the candidates and their performance in the Chemistry Advanced Certificate of Secondary Education Examination (ACSEE) 2022. The examination tested the candidates in three papers, namely 132/1 Chemistry 1, 132/2 Chemistry 2 and 132/3 Chemistry 3. The latter paper was examined in three equivalent alternative papers (132/3A Chemistry 3A, 132/3B Chemistry 3B and 132/3C Chemistry 3C). The candidates were required to sit for only one alternative paper.

Chemistry 1 consisted of two sections, A and B, with a total of ten (10) questions. Section A comprised seven (7) short answer questions, which weighed 10 marks each. Thus, the total marks in this section were 70. Section B comprised three structured essay questions which weighed 15 marks each. The total marks in this section were 30. The candidates were required to answer all questions in Section A and two questions from Section B. Chemistry 2 consisted of six (6) questions. Each question weighed 20 marks. The candidates were required to answer a total of five (5) questions. Chemistry 3 consisted of three practical questions. The ccandidates were required to answer all three questions.

In this report, the performance on a particular question is categorized based on the percentage of the marks that the candidate scored out of the allocated marks. Thus, the performance is good if the candidate score from 60 to 100 per cent, average if they score from 35 to 59 per cent and weak if they score from 0 to 34 per cent. The weak, average and good levels of performance are denoted by red, yellow and green colors, respectively.

A total of 34,747 candidates sat for the Chemistry examination in the ACSEE 2022. Among them, 33,731 (97,48%) of the candidates passed the examination (They scored 35 marks or above). This indicates that the overall performance was good. In 2021, out of the 34,517 candidates who sat for the Chemistry examination in the ACSEE, 32,541 (94.81%) passed. Thus, the candidates' performance in 2022 has increased by 2.67 per cent.

This report consists of five sections. The first section is the *Introduction*, which highlights the structure and rubric of Chemistry papers. It also introduces the classification/criteria for candidates performance in the ACSEE 2022. It further highlights and compare the overall performance of candidates in 2021/2022 Chemistry examinations.

The second part is *The Analysis of the Candidates Performance on Each Question*. In this part, the candidates responses to each question are analysed. The analysis given is supported with statistical data and samples of blind copies of good and weak answers from the candidates. In this part of the report, the reader will find what the candidates could or could not do with respect to the question demand. It further analyses the common mistakes or misconceptions that were observed in marking the candidates' scripts and suggests possible solutions.

The third part of the report is *The Analysis of the Candidates' Performance on Each Topic*. This part analyses the candidates' performance on each topic included in the Chemistry ACSEE, 2022. The part also compares the performance on the topics of examination in 2022 with those of examination in 2021.

The fourth and fifth parts of this report cover the *Conclusions* and *Recommendations.* Overall observations on the strenghs and weaknesses of the candidates' responses to the examination questions are given in the conclusion part. The appropriate measures to address the observed issues from the candidates' responses to the examination questions have been described in the recommendation part.

2.0 ANALYSIS OF CANDIDATES' PERFORMANCE ON EACH QUESTION

This section analyses the candidates' responses to the question in Chemistry papers 1, 2 and 3. The analysis begins with the requirements of a particular question or the question as it appeared in the examination paper. This is followed by data analysis and a detailed description of the responses given supported with appropriate sample extracts.

2.1 132/1-CHEMISTRY 1

The paper consisted of ten (10) questions. The analysis of each question in this paper is as follows:

2.1.1 Question 1: The Atom

The question asked as follows:

(a) *Energy of an electron in hydrogen atom is given by the expression*

$$E_n = \frac{-1.312 \times 10^6}{n^2} \; J / mol .$$

(i) *Calculate the amount of energy required to promote an electron from the first energy level to the third energy level.*

(ii) *Why an electron in its ground state possesses energy less than zero?*

(b) *(i)* *The elements* ***X****,* ***Y*** *and* ***Z*** *have the following electronic configurations:*

X*:* $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
Y*:* $1s^2\ 2s^2\ 2p^6\ 3s^2$
Z*:* $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

The first ionization energies of the three elements (not in the same order) are 420, 740, and 1500 kJ/mol and the atomic radii are 1.60, 0.94 and 1.97A°. Identify the three elements and match the appropriate ionization energy and atomic radius to each configuration.

(ii) *Excited sodium atoms may emit radiation with the frequency of* 5.09×10^{14}*/s. What is the energy of the photons associated with this radiation?*

(c) *Briefly, differentiate the following terms:*

(i) *Line from continuous spectrum.*

(ii) *Absorption from emission spectrum.*

This question was attempted by all 34,743 candidates. Among them, 6,283 (18.1%) scored from 0 – 3 marks; 12,739 (36.7%) scored from 3.5 – 5.5 marks and 15,721 (45.2%) candidates scored from 6 – 10 marks. The candidates who scored a pass mark or above (≥35 marks) were 28,460 (81.9%). Thus, their overall performance on this question was good. Figure 1 summarizes the candidates' performance on this question.

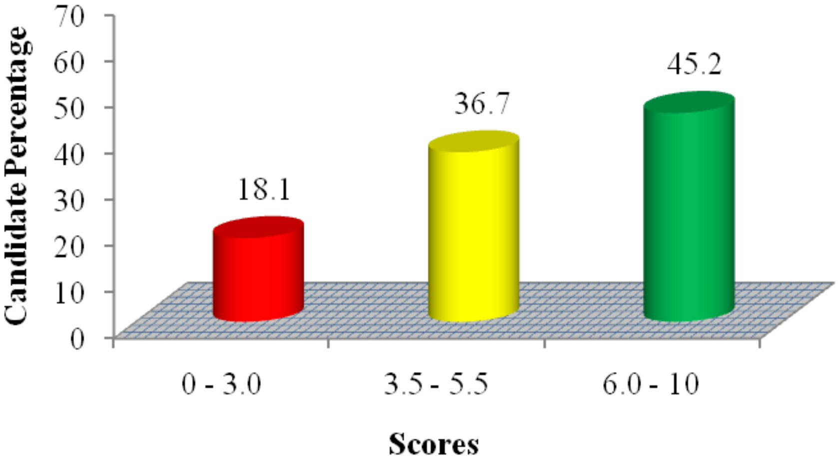
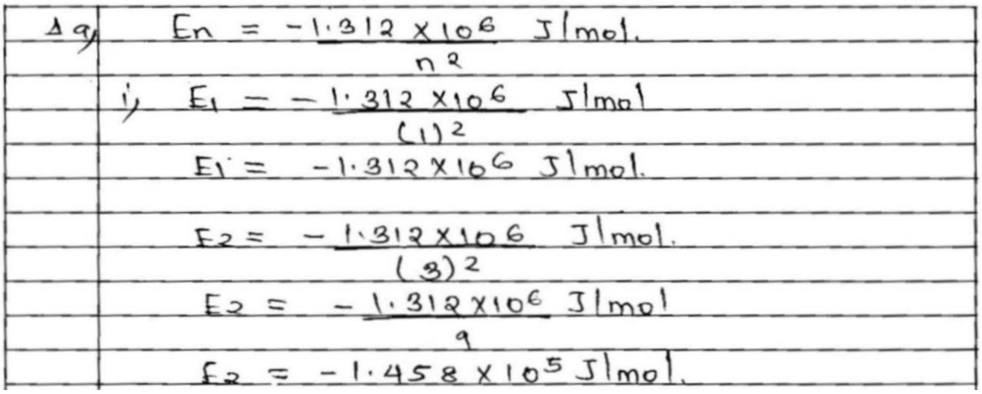


Figure 1: *Candidates' Performance on Question 1*

The candidates who scored high marks on this question were conversant with the concepts of quantum theory. Hence, they correctly performed mathematical manipulations in parts (a) and (b) of the question. They also gave explanation as to why an electron in its ground state possesses energy less than zero, correctly. Furthermore, they correctly applied the rules governing the filling of electrons in atomic orbital. Thus, they managed to relate the values of ionization energy with their appropriate electronic configurations which were designated letters X, Y and Z. In part (c), the candidates with good scores differentiated appropriately pairs of the given terms. This connotes a good understanding of the general concepts pertaining to atomic spectra. Extract 1.1 is a sample of the good responses to part 1(a) of the question.



1 a) $E_n = \frac{-1.312 \times 10^6}{n^2}$ J/mol.

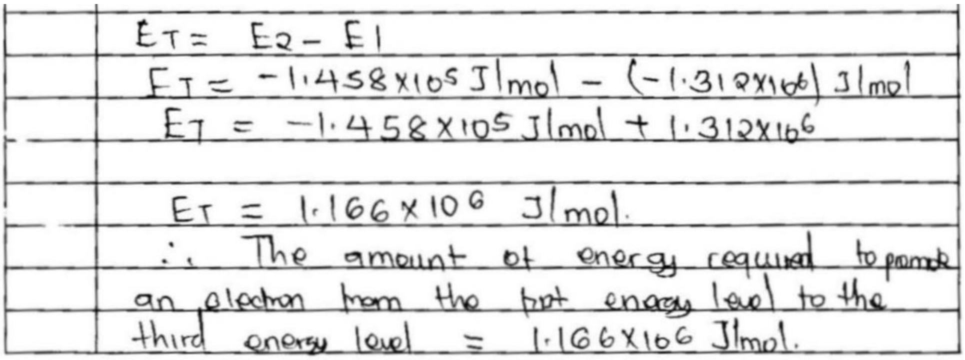
i) $E_1 = -\frac{1.312 \times 10^6}{(1)^2}$ J/mol

$E_1 = -1.312 \times 10^6$ J/mol.

$E_2 = -\frac{1.312 \times 10^6}{(3)^2}$ J/mol.

$E_2 = -\frac{1.312 \times 10^6}{9}$ J/mol

$E_2 = -1.458 \times 10^5$ J/mol.



$E_T = E_2 - E_1$

$E_T = -1.458\times10^5$ J/mol $- (-1.312\times10^6)$ J/mol

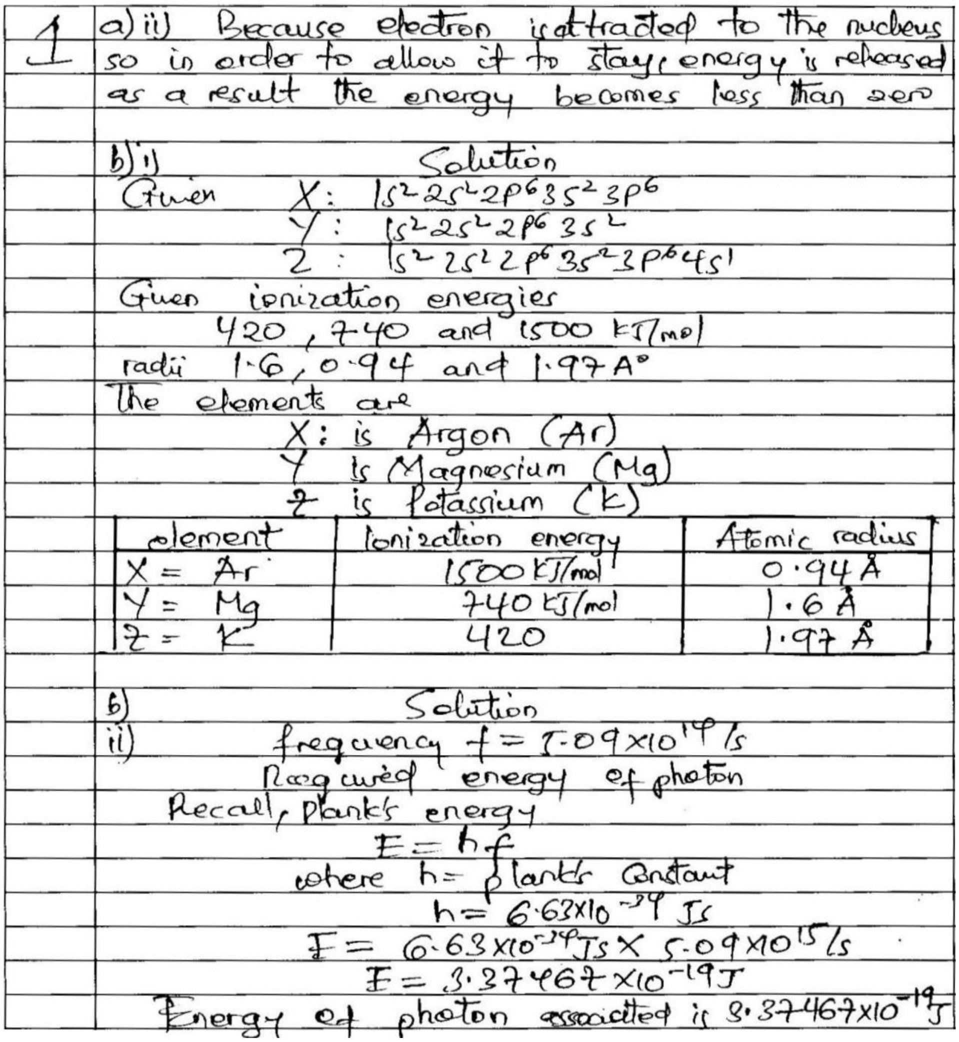
$E_T = -1.458\times10^5$ J/mol $+ 1.312\times10^6$

$E_T = 1.166\times10^6$ J/mol.

∴ The amount of energy required to promote an electron from the first energy level to the third energy level $= 1.166\times10^6$ J/mol.

Extract 1.1: A sample of the good responses to question 1(a)

In Extract 1.1, the candidate correctly calculated the energy (ΔH) required to promote an electron in hydrogen atom.



1 a) ii) Because electron is attracted to the nucleus so in order to allow it to stay, energy is released as a result the energy becomes less than zero

b) i) Solution

Given X: $1s^2 2s^2 2p^6 3s^2 3p^6$

Y: $1s^2 2s^2 2p^6 3s^2$

Z: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

Given ionization energies

420, 740 and 1500 KJ/mol

radii 1.6, 0.94 and 1.97 A°

The elements are

X: is Argon (Ar)

Y is Magnesium (Mg)

Z is Potassium (K)

element	Ionization energy	Atomic radius
X = Ar	1500 KJ/mol	0.94 Å
Y = Mg	740 KJ/mol	1.6 Å
Z = K	420	1.97 Å

b) ii) Solution

frequency $f = 5.09\times10^{14}$ /s

Required energy of photon

Recall, Plank's energy

$E = hf$

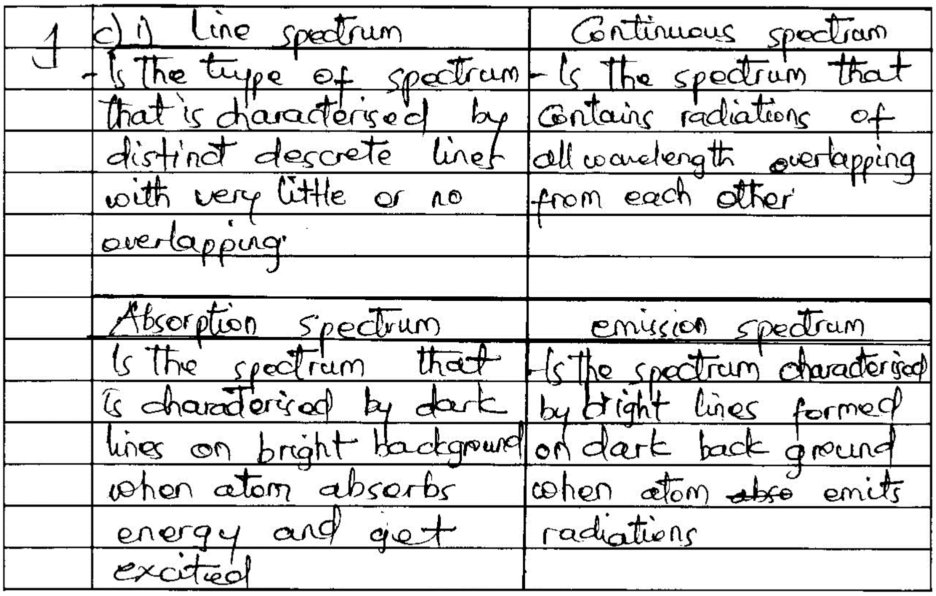
where h = Planck's Constant

$h = 6.63\times10^{-34}$ Js

$E = 6.63\times10^{-34}$ Js $\times 5.09\times10^{15}$ /s

$E = 3.37467\times10^{-19}$ J

Energy of photon associated is 3.37467×10^{-19} J

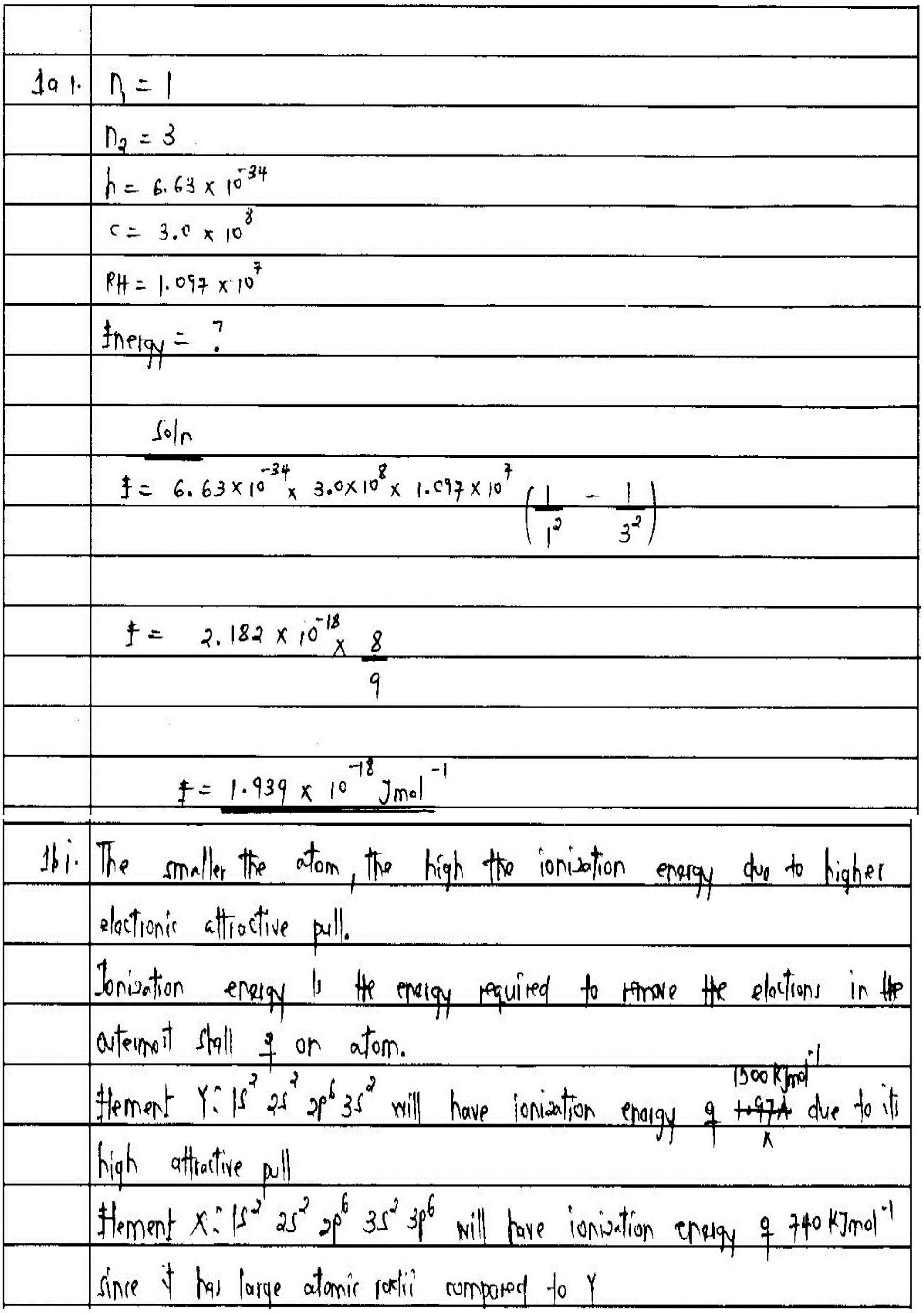


1	c) i) Line spectrum	Continuous spectrum
	- Is The type of spectrum	- Is The spectrum that
	that is characterised by	Contains radiations of
	distinct descrete lines	all wavelength overlapping
	with very little or no	from each other
	overlapping.	
	Absorption spectrum	emission spectrum
	Is The spectrum that	- Is The spectrum characterised
	Is characterised by dark	by bright lines formed
	lines on bright background	on dark back ground
	when atom absorbs	when atom ~~abso~~ emits
	energy and get	radiations
	excited	

Extract 1.2: A sample of the good responses to question 1, parts (a) (ii), (b) and (c)

In Extract 1.2, the candidate used the electronic configurations and atomic radii to identify the required elements. He/she also correctly calculated the energy of photons and differentiated the given terms.

In contrast, 6283 (18.1%) of the candidates failed to answer this question correctly. Hence, they scored below the pass mark. (≤3.0 out of 10 marks). Candidates with weak scores mathematically failed to manipulate the required formulae in parts (a) and (b) of the question. This was caused by their competencies in atomic theory concepts. In part (b) (i), the candidates failed to combine the concepts of electronic configurations and periodic trends to identify the elements given in the question. This was found to be caused by their poor understanding of the concepts of electronic configurations. Moreover, they lacked adequate knowledge of the hydrogen spectrum. Hence, they did not understand why an electron in its ground state possessed energy less than zero. In part (c) of the question, the candidates showed insufficient knowledge of the general concepts of atomic spectrum. They gave wrong differences between the given terms. A sample of the poor answers to this question is shown in Extract 1.3.



1a i. $n = 1$

$n_2 = 3$

$h = 6.63 \times 10^{-34}$

$c = 3.0 \times 10^{8}$

$RH = 1.097 \times 10^{7}$

Energy = ?

Soln

$E = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} \times 1.097 \times 10^{7} \left(\frac{1}{1^2} - \frac{1}{3^2}\right)$

$E = 2.182 \times 10^{-18} \times \frac{8}{9}$

$E = 1.939 \times 10^{-18}\ Jmol^{-1}$

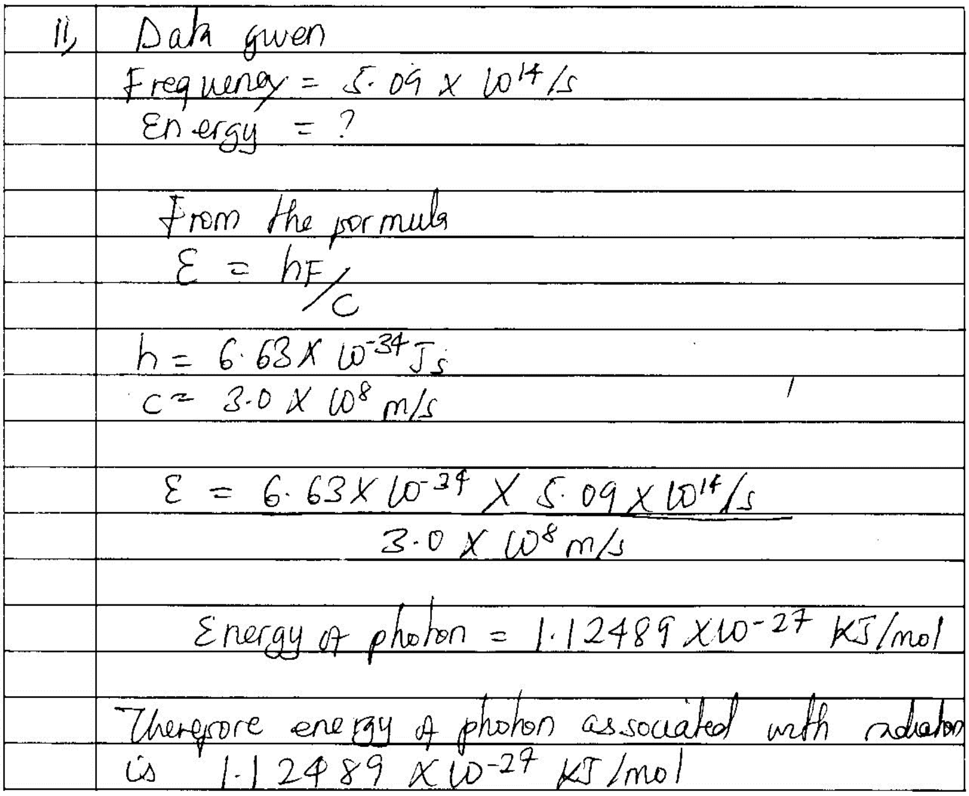
1b i. The smaller the atom, the high the ionization energy due to higher electionic attractive pull.

Ionization energy is the energy required to remove the elections in the outermost shell of an atom.

Element Y: $1s^2\ 2s^2\ 2p^6\ 3s^2$ will have ionization energy of ~~1497A~~ 1500 $KJmol^{-1}$ due to its high attractive pull

Element X: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ will have ionization energy of 740 $KJmol^{-1}$ since it has large atomic radii compared to Y

Extract 1.3: A sample of the weak responses to question 1(a) (i) and 1(b) (i)



ii) Data given

Frequency $= 5.09 \times 10^{14}/s$

Energy $= ?$

From the formula

$$E = \frac{hF}{C}$$

$h = 6.63 \times 10^{-34}\ Js$

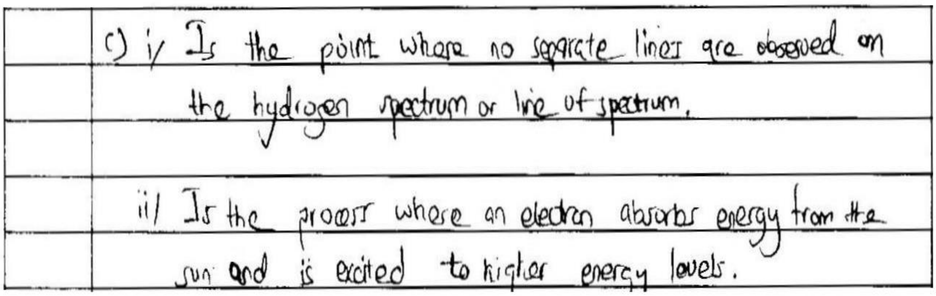
$c = 3.0 \times 10^{8}\ m/s$

$$E = \frac{6.63 \times 10^{-34} \times 5.09 \times 10^{14}/s}{3.0 \times 10^{8}\ m/s}$$

Energy of photon $= 1.12489 \times 10^{-27}$ KJ/mol

Therefore energy of photon associated with radiation is 1.12489×10^{-27} KJ/mol

Extract 1.4: A sample of the weak responses to question 1(b) (ii)



c) i/ Is the point where no separate lines are observed on the hydrogen spectrum or line of spectrum.

ii/ Is the process where an electron absorbs energy from the sun and is excited to higher energy levels.

Extract 1.5: A sample of the weak responses in question 1(c)

In Extract 1.2, the candidate used Rydberg's equation in calculating energy but failed to include Avogadro's constant. As a result, he/she obtained the incorrect value of energy in part (a) (i). In part (b) (i), the candidate gave explanations about ionization energy. Though the explanations were correct, they were contrary to the requirement of the question. Yet, in Extract 1.4, another candidate applied the wrong formula to calculate the value of energy of the photons for the given radiation. Although the candidate knew all the components of the formula, he/she failed to arrange them as required.

Hence, he/she got the value 1.12489 × 10^{-27} kJ/mol instead of 3.3746 × 10^{-19} J/mol or 3.3746 × 10^{-22} kJ/mol. However, the candidates were supposed to use the formula: *Energy of photon (E) = hf, where h = Planck's constant* and *f= frequency of radiation*. In Extract 1.5, the candidate responded by defining line spectrum in part 1(c) (i) and excitation state in part 1(c) (ii) instead of differentiating them.

2.1.2 Question 2: Chemical Equilibrium

The question asked as follows:

(a) *Consider the following reaction that takes place in a fixed volume of a container:*

$H_2(g) + Br_2(g) \rightarrow 2HBr(g) \quad \Delta H^o = -104\ kJ/mol$. *How each of the changes affect the quantity of the reactants, products and equilibrium constant (K_C)? Answer by writing "Increase", "Decrease", or "No change" appropriately, in a tabular form:*

Change	H_2	Br_2	***HBr***	K_C ***Value***
Addition of some H_2				
Removal of some HBr				
Raise in temperature				
Increase in pressure				

(b) *When the reaction* $2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$ *was studied at 25°C, the partial pressures at equilibrium were found to be 1.2 atm for NOCl, 5.0 ×* 10^{-2} *atm for NO and 0.3 atm for Cl. What would be the* K_P *value for this reaction at 25 °C?*

This question was attempted by 34,742 candidates. Out of whom, 4904 (14.1%), 10,680 (30.7%) and 19,158 (55.1%) per cent scored marks from 0 – 3, 3.5 – 5.5 and 6 – 10, respectively. A summary of candidates' performance on this question is shown in Figure 2.

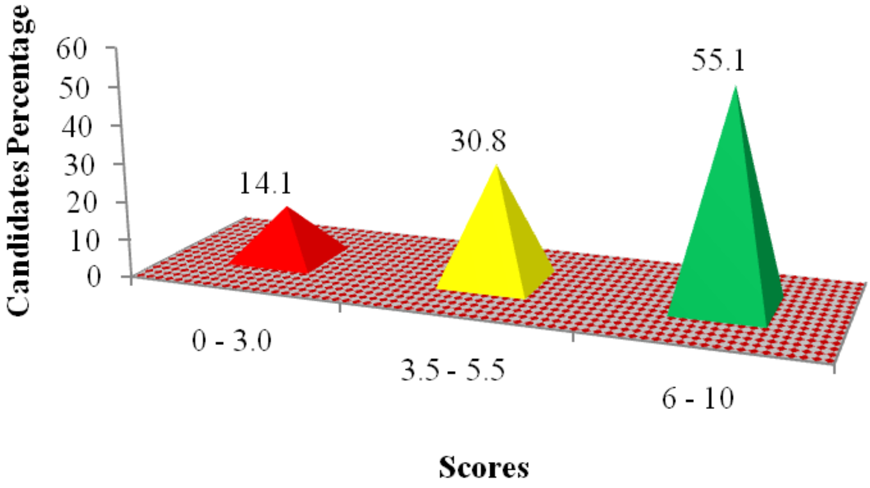
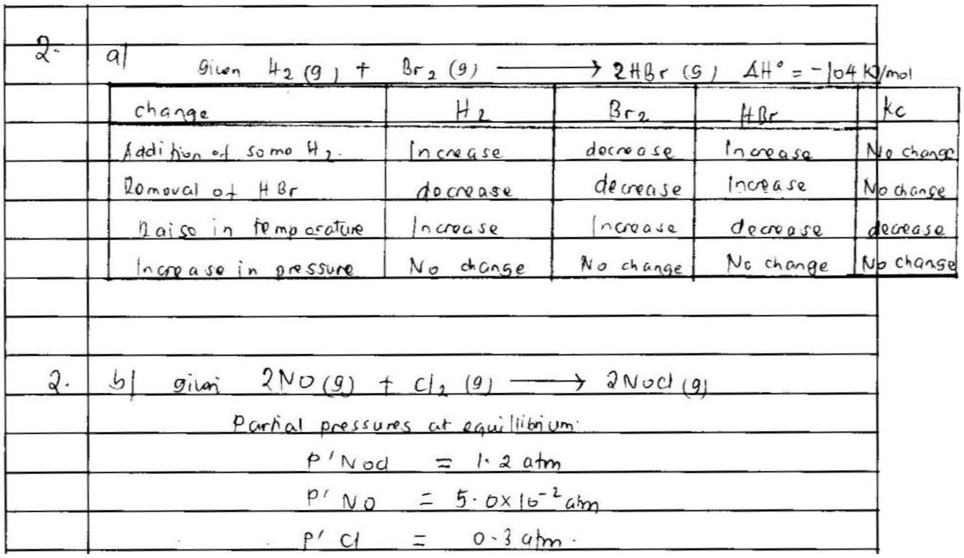


Figure 2: *Candidates' Performance on Question 2*

The general performance on this question was good since 29,838 (85.8%) of the candidates scored 3.5 marks or above. Those who performed well understood the concept of Le-Chatelier's principle and equilibrium constant. Thus, they appropriately predicted all the expected outcomes when changes were introduced to the equilibrium system given in part 2 (a). In part (b), they correctly calculated the value of K_p for the given reaction. Extract 2.1 is a sample of the correct responses to this question.



2. a) Given $H_2(g) + Br_2(g) \longrightarrow 2HBr(g)$ $\Delta H° = -104$ KJ/mol

change	H_2	Br_2	HBr	kc
Addition of somo H_2.	Increase	decrease	Increase	No change
Romoval of HBr	decrease	decrease	Increase	No change
Raiso in temporature	Increase	Increase	decrease	decrease
Increase in pressure	No change	No change	No change	No change

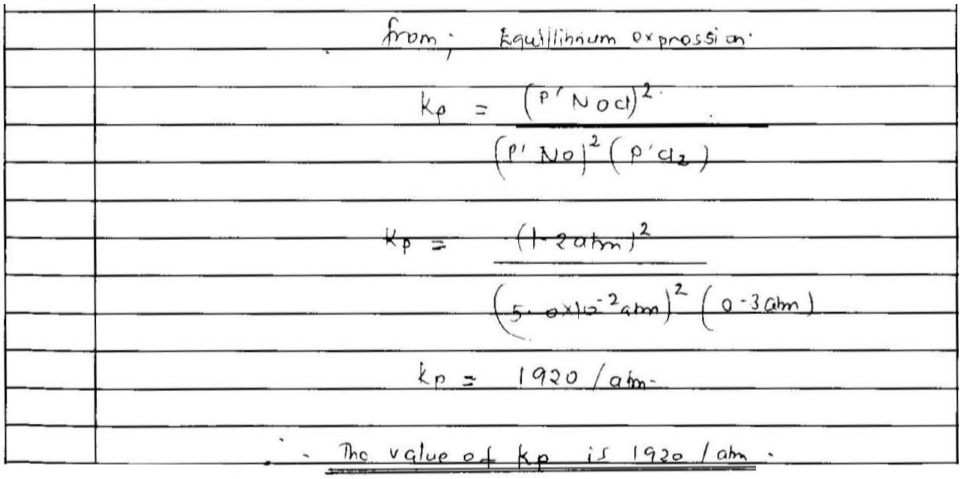
2. b) given $2NO(g) + Cl_2(g) \longrightarrow 2NOCl(g)$

Partial pressures at equilibrium:

$P'_{NOCl} = 1.2$ atm

$P'_{NO} = 5.0 \times 10^{-2}$ atm

$P'_{Cl} = 0.3$ atm.



from; Equillibrium expression:

$$K_p = \frac{(P'NOCl)^2}{(P'NO)^2(P'Cl_2)}$$

$$K_p = \frac{(1.2atm)^2}{(5.0\times10^{-2}atm)^2(0.3atm)}$$

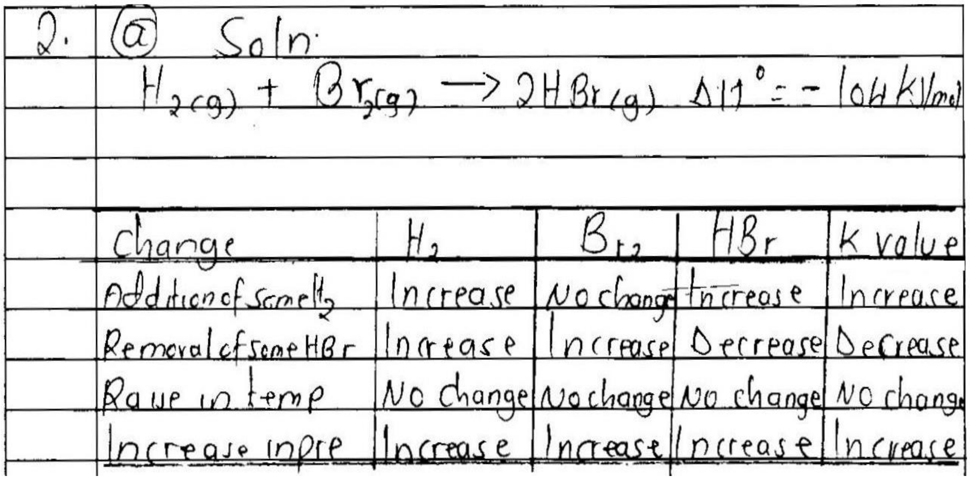
$$K_p = 1920/atm$$

∴ The value of K_p is 1920/atm.

Extract 2.1: A sample of the correct responses to question 2

Extract 2.1 shows responses of a candidate who filled the table with suitable changes basing on Le Chatelier's principle. Moreover, the candidate calculated correctly the numerical value of K_p.

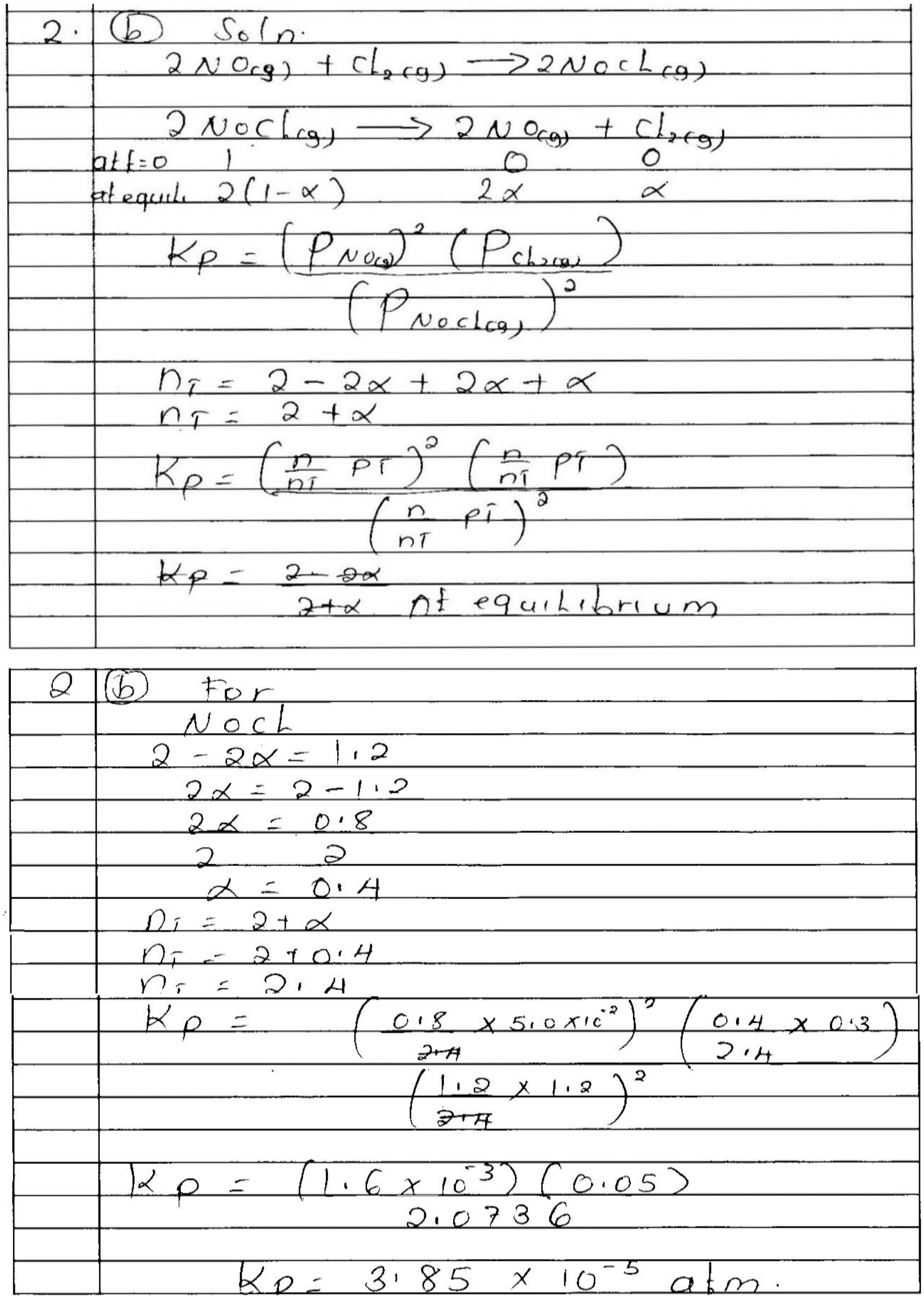
On the other hand, some of the candidates (14.1%), scored low marks in this question. Analysis done on the responses given in their scripts indicated that they predicted what was going to happen to the species that were involved in the given chemical equilibrium wrongly. In part (b) of the question, some of them used wrong formulae while others made incorrect substitution of data in the formula. These observations were caused by insufficient knowledge and skills on the factors affecting a chemical system at equilibrium and lack of competencies on *Equilibrium Constant*. Extract 2.2 shows a sample of incorrect responses from one of the candidates in this question.



2. ⓐ Soln:

$H_{2(g)} + Br_{2(g)} \longrightarrow 2HBr_{(g)}$ $\Delta H^\circ = -104 kJ/mol$

Change	H_2	Br_2	HBr	K value
Addition of some H_2	Increase	No change	Increase	Increase
Removal of some HBr	Increase	Increase	Decrease	Decrease
Raise in temp	No change	No change	No change	No chang
Increase in pre	Increase	Increase	Increase	Increase



2\. (b) Soln.

$2NO_{(g)} + Cl_{2(g)} \longrightarrow 2NOCl_{(g)}$

$2NOCl_{(g)} \longrightarrow 2NO_{(g)} + Cl_{2(g)}$

at t=0 $\quad 1 \quad 0 \quad 0$

at equili. $\quad 2(1-\alpha) \quad 2\alpha \quad \alpha$

$$K_p = \frac{(P_{NO(g)})^2 (P_{Cl_2(g)})}{(P_{NOCl(g)})^2}$$

$n_T = 2 - 2\alpha + 2\alpha + \alpha$

$n_T = 2 + \alpha$

$$K_p = \frac{\left(\frac{n}{n_T} P_T\right)^2 \left(\frac{n}{n_T} P_T\right)}{\left(\frac{n}{n_T} P_T\right)^2}$$

$K_p = \frac{2-2\alpha}{2+\alpha}$ at equilibrium

2 (b) For

NOCl

$2 - 2\alpha = 1.2$

$2\alpha = 2 - 1.2$

$\frac{2\alpha}{2} = \frac{0.8}{2}$

$\alpha = 0.4$

$n_T = 2 + \alpha$

$n_T = 2 + 0.4$

$n_T = 2.4$

$$K_p = \frac{\left(\frac{0.8}{2.4} \times 5.0 \times 10^{-2}\right)^2 \left(\frac{0.4}{2.4} \times 0.3\right)}{\left(\frac{1.2}{2.4} \times 1.2\right)^2}$$

$$K_p = \frac{(1.6 \times 10^{-3})(0.05)}{2.0736}$$

$K_p = 3.85 \times 10^{-5}$ atm.

Extract 2.2: A sample of the incorrect responses to question 2

In Extract 2.2, the candidate filled the table with the wrong changes of the reacting species and products in part (a). The candidate wrongly manipulated the formula for equilibrium constant in terms of partial pressure and made the wrong substitution of data in part (b).

2.1.3 Question 3: Relative Molecular Masses in Solution

The question asked as follows:

(a) *If the vapour pressure of water at 20 °C is 17.5 mm Hg and lowering of vapour pressure of a sugar solution is 0.061 mm Hg, calculate;*

(i) *The relative lowering of vapour pressure.*
(ii) *The vapour pressure of the solution.*
(iii) *The mole fraction of sugar and water.*

(b) *Ethanoic acid had a freezing point of 16.63 °C. When 2.5 g of an organic solute was added to 40 g of the acid, the freezing point was lowered to 14.48 °C. Calculate the relative molecular mass of the solute (Given* K_f *for ethanoic acid = 3.9 °C/m).*

(c) *An aqueous solution freezes at 272.07 K while pure water freezes at 273 K. Calculate the molality and boiling point of this solution (Given* K_f *for water = 1.86 K/m,* K_b *= 0.512 K/m).*

The question was attempted by 34,741 candidates. Out of whom, 29,838 (85.8%) performed well as they scored a pass mark or above (≥3.5 marks). Thus, their overall performance on this question was good as shown in Figure 3.

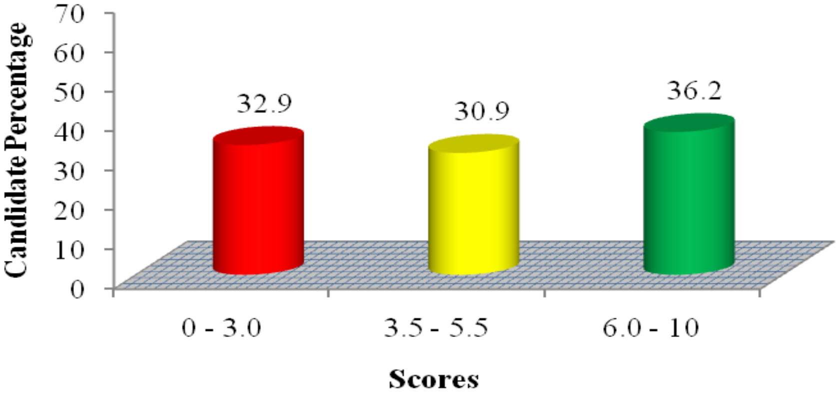
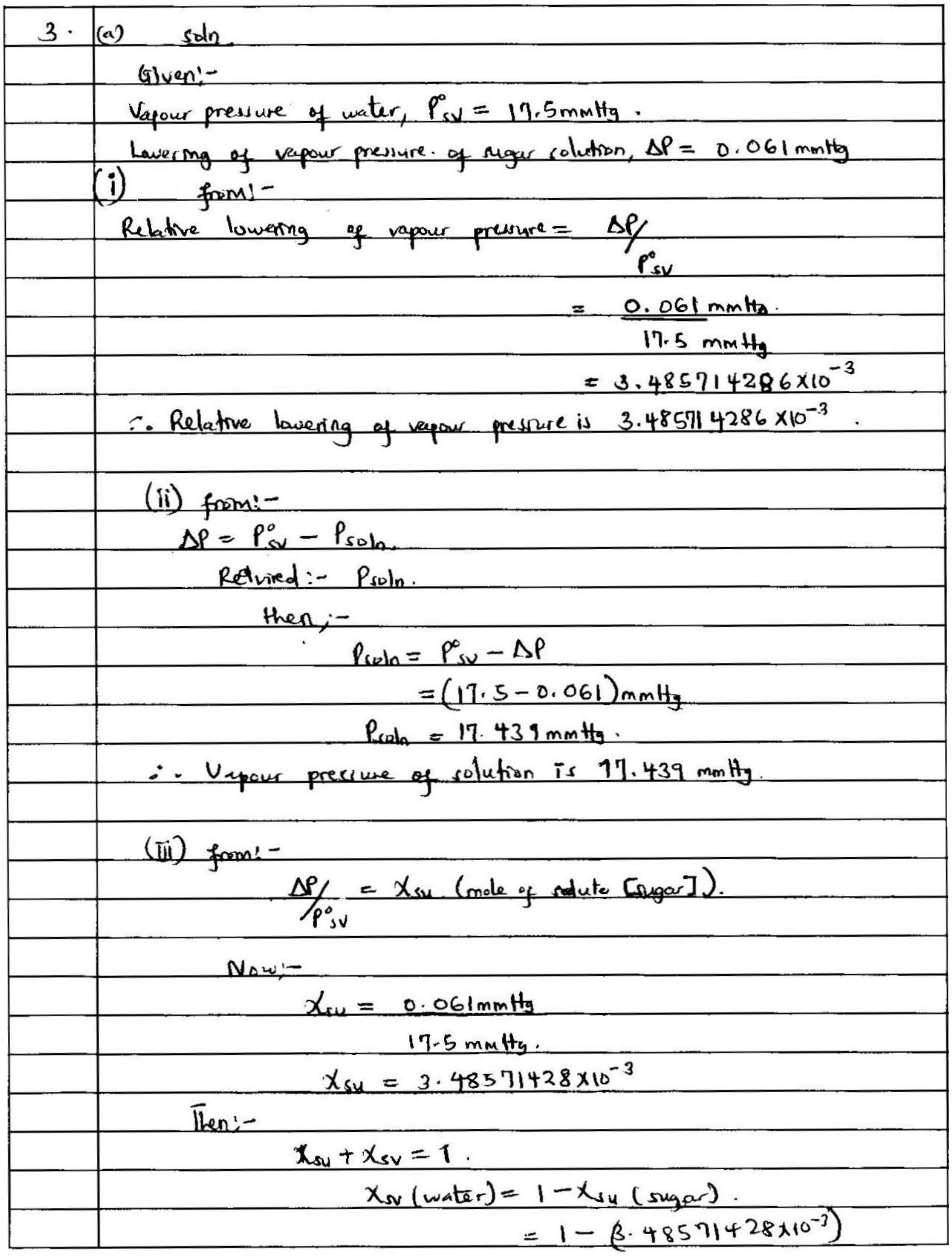


Figure 3: *Candidates' Performance on Question 3*

The candidates who performed well on this question were conversant with the concepts of colligative properties as they apply to different solutions. Hence, they correctly calculated the vapor pressures and mole fraction in part (a) of the question. They also correctly applied the laws governing colligative properties to answer parts (b) and (c). Extract 3.1 is illustrative.



3. (a) soln.

Given:-

Vapour pressure of water, $P^o_{sv} = 17.5 mmHg$.

Lowering of vapour pressure of sugar solution, $\Delta P = 0.061 mmHg$

(i) from:-

Relative lowering of vapour pressure $= \Delta P / P^o_{sv}$

$= \frac{0.061 mmHg}{17.5 mmHg}$

$= 3.485714286 \times 10^{-3}$

∴ Relative lowering of vapour pressure is $3.485714286 \times 10^{-3}$.

(ii) from:-

$\Delta P = P^o_{sv} - P_{soln}$.

Retvired:- P_{soln}.

then;-

$P_{soln} = P^o_{sv} - \Delta P$

$= (17.5 - 0.061) mmHg$

$P_{soln} = 17.439 mmHg$.

∴ Vapour pressure of solution is 17.439 mmHg.

(iii) from:-

$\Delta P / P^o_{sv} = X_{su}$ (mole of solute [sugar]).

Now;-

$X_{su} = \frac{0.061 mmHg}{17.5 mmHg}$.

$X_{su} = 3.48571428 \times 10^{-3}$

Then:-

$X_{su} + X_{sv} = 1$.

X_{sv} (water) $= 1 - X_{su}$ (sugar).

$= 1 - (3.48571428 \times 10^{-3})$

3. (a) (iii) $x_{sv} = 0.996514285$.

∴ Mole fraction of sugar is $3.485714286 \times 10^{-3}$

Mole fraction of water is 0.996514285

(b) Soln.

Given:-

Freezing point of Ethanoic acid, $T_{sv} = 16.63°C$

Freezing point of solution, $T_{soln} = 14.48°C$.

Mass of solute, $M_{su} = 2.5g$.

Mass of acid (solvent), $M_{sv} = 40g/1000 = 0.04kg$

Recall:-

$$\Delta T_f = k_f m.$$

but

$$\Delta T_f = T_{sv} - T_{soln}$$

$$= (16.63 - 14.48)°C$$

$$\Delta T_f = 2.15°C$$

$$k_f = 3.9°C/m$$

then:-

$$m = \Delta T_f / k_f .$$

$$= \frac{2.15°C}{3.9°C/m}$$

molality, $m = 0.551282051\ m$

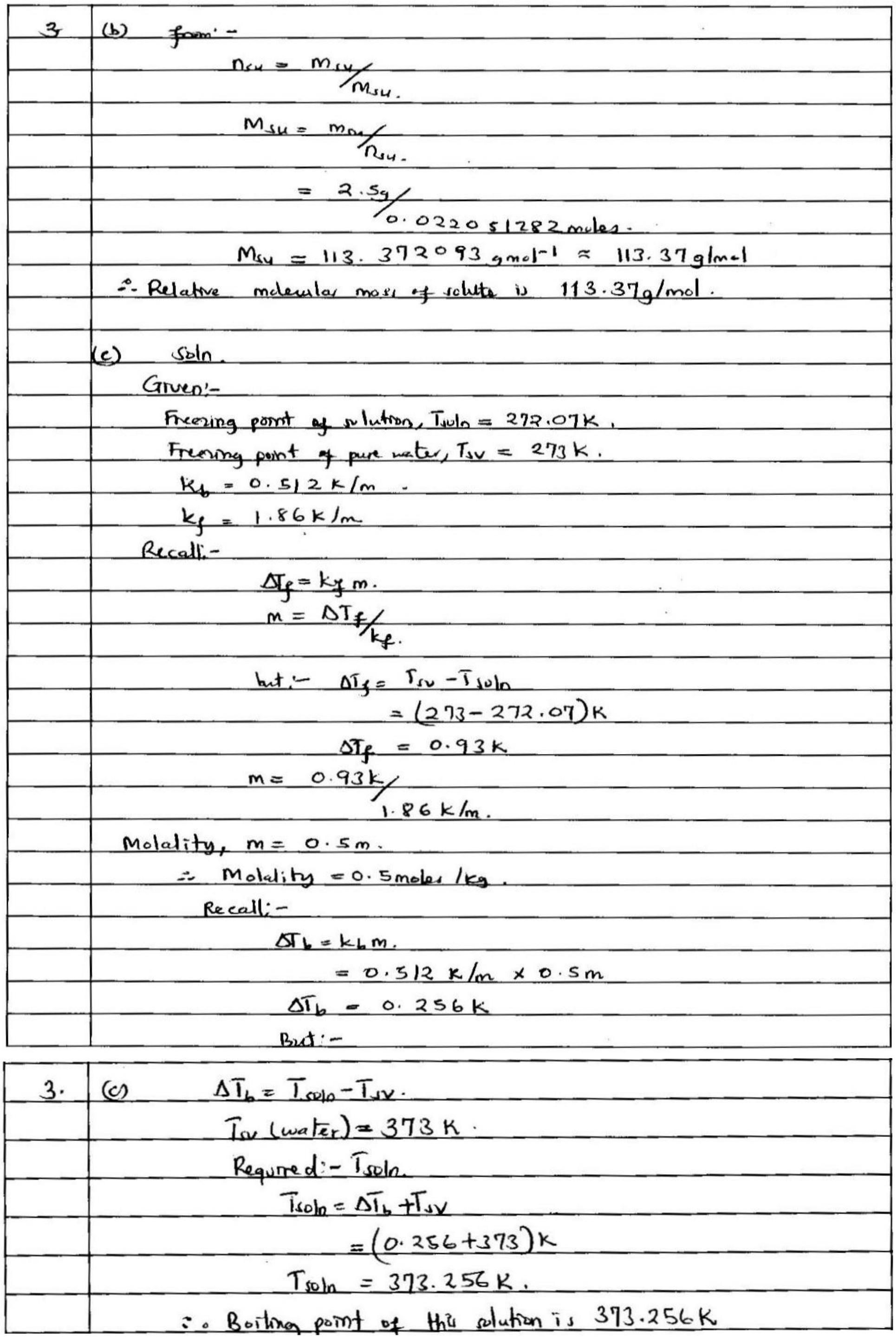
then:-

molality = ~~mass~~ $\frac{\text{number of moles of solute } (n_{su})}{\text{mass of solvent in (kg)}}$ / M_{sv}

$$n_{su} = M_{sv} \times m$$

$$= 0.551282051\ \text{moles/kg} \times 0.04kg$$

$$n_{su} = 0.022051282\ \text{moles}.$$



3 (b) from:-

$n_{su} = m_{su}/M_{su}$.

$M_{su} = m_{su}/n_{su}$.

$= 2.5g / 0.022051282$ moles.

$M_{su} = 113.372093\ gmol^{-1} \approx 113.37\ g/mol$

∴ Relative molecular mass of solute is 113.37g/mol.

(c) Soln.

Given:-

Freezing point of solution, $T_{soln} = 272.07K$.

Freezing point of pure water, $T_{sv} = 273K$.

$K_b = 0.512\ K/m$.

$k_f = 1.86K/m$

Recall:-

$\Delta T_f = k_f m$.

$m = \Delta T_f / k_f$.

but:- $\Delta T_f = T_{sv} - T_{soln}$

$= (273 - 272.07)K$

$\Delta T_f = 0.93K$

$m = 0.93K / 1.86\ K/m$.

Molality, m = 0.5m.

∴ Molality = 0.5moles/kg.

Recall:-

$\Delta T_b = k_b m$.

$= 0.512\ K/m \times 0.5m$

$\Delta T_b = 0.256K$

But:-

3. (c) $\Delta T_b = T_{soln} - T_{sv}$.

T_{sv} (water) = 373 K.

Required:- T_{soln}.

$T_{soln} = \Delta T_b + T_{sv}$

$= (0.256 + 373)K$

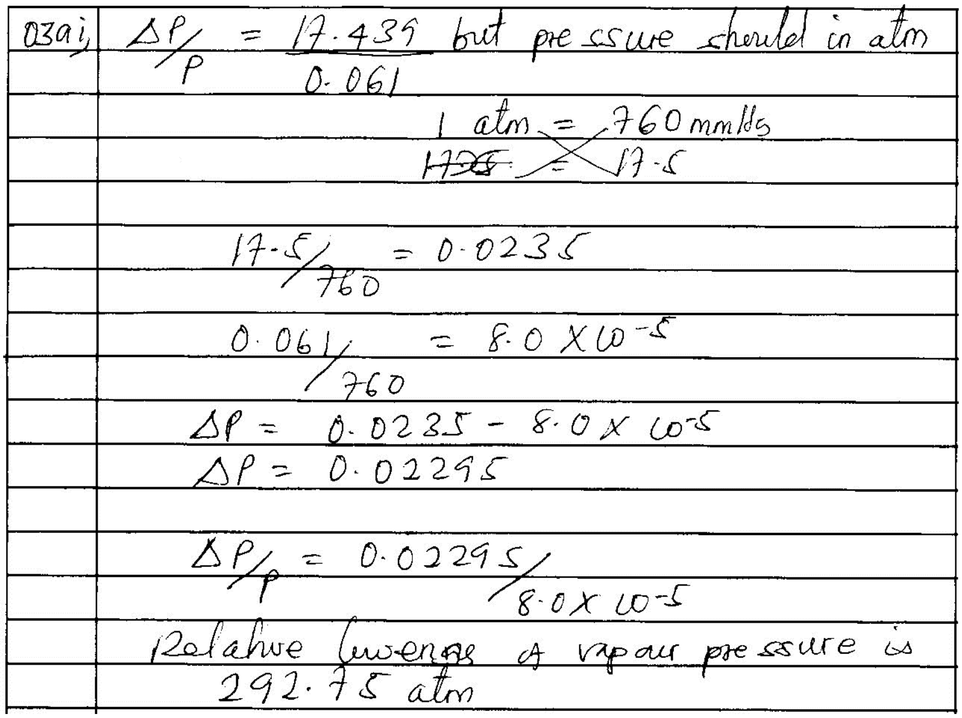
$T_{soln} = 373.256K$.

∴ Boiling point of this solution is 373.256K

Extract 3.1: A sample of the correct responses to question 3

Extract 3.1 shows that the candidate correctly answered all parts of the question. However, the candidate did not include “*mmHg”* as a unit of pressure in his/her answer in 1(a) (i).

Conversely, other candidates did not perform well on this question. Their responses revealed that they used incorrect relationships (formulae) especially in their attempt to determine lowering of vapour pressure, mole fraction, and depression of the freezing point. This indicated insufficient knowledge of the subtopic of *Colligative Properties of Solutions*. A further analysis indicated that they were not competent in applying the laws governing colligative properties to solve the problems given in the question as shown in Extract 3.2.



03ai, $\Delta P/P = \frac{17.439}{0.061}$ but pressure should in atm

1 atm = 760 mmHg
~~[illegible]~~ = 17.5

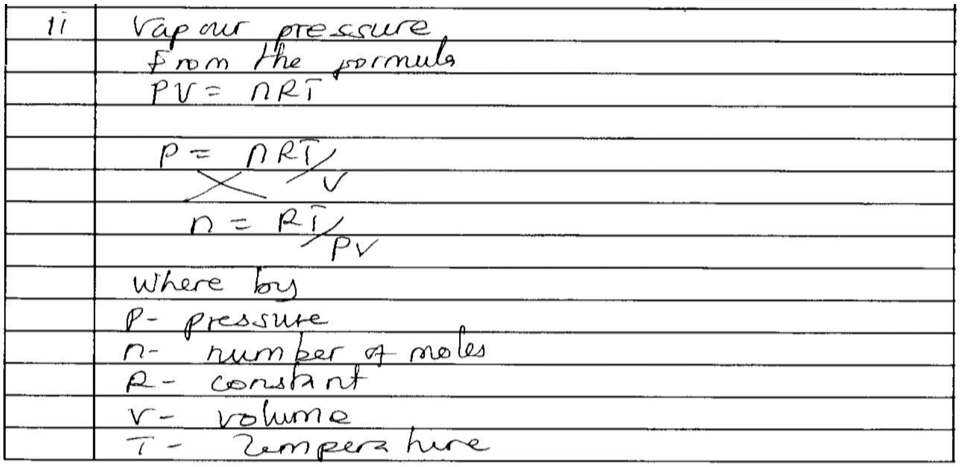
$17.5/760 = 0.0235$

$0.061/760 = 8.0 \times 10^{-5}$

$\Delta P = 0.0235 - 8.0 \times 10^{-5}$
$\Delta P = 0.02295$

$\Delta P/P = 0.02295/8.0 \times 10^{-5}$

Relative lowering of vapour pressure is 292.75 atm

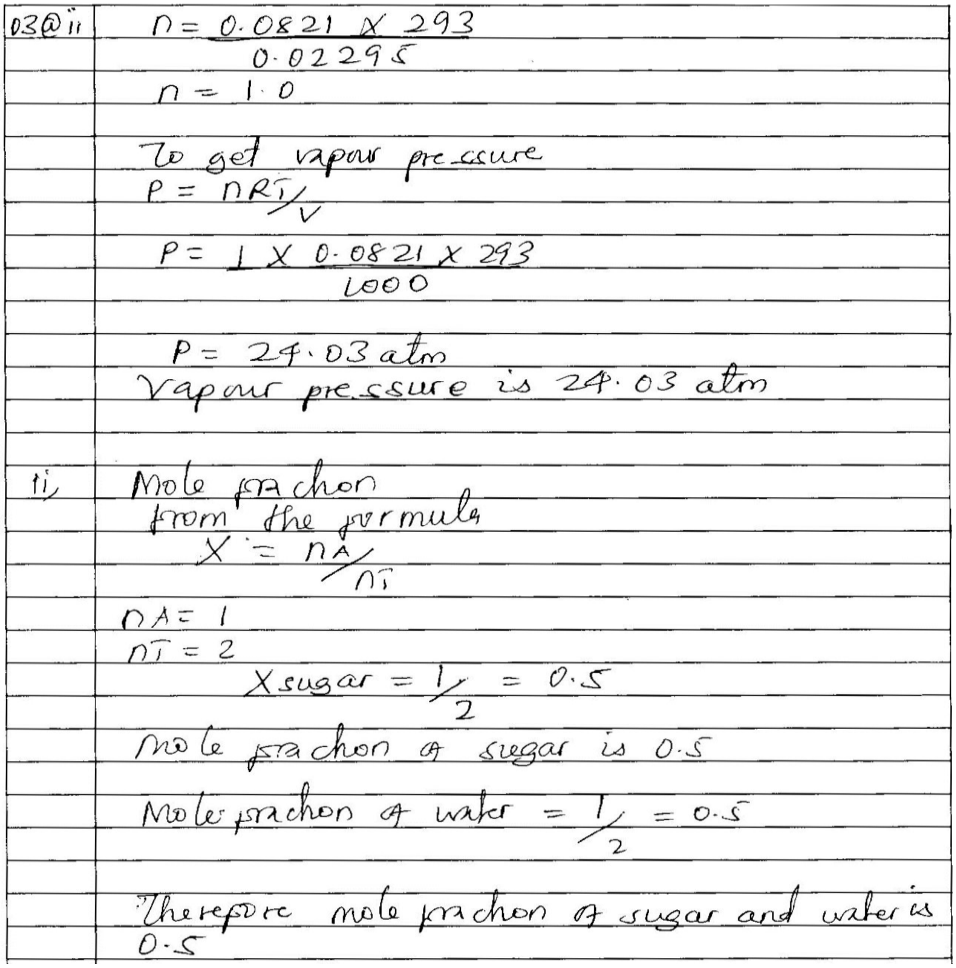


ii Vapour pressure
From the formula
$PV = nRT$

$P = nRT/V$

$n = RT/PV$

Where by
P- pressure
n- number of moles
R- constant
V- volume
T- temperature



03@ii $n = \frac{0.0821 \times 293}{0.02295}$

$n = 1.0$

To get vapour pressure

$P = nRT/V$

$P = \frac{1 \times 0.0821 \times 293}{1000}$

$P = 24.03$ atm

Vapour pressure is 24.03 atm

ii, Mole fraction
from the formula
$X = nA/nT$

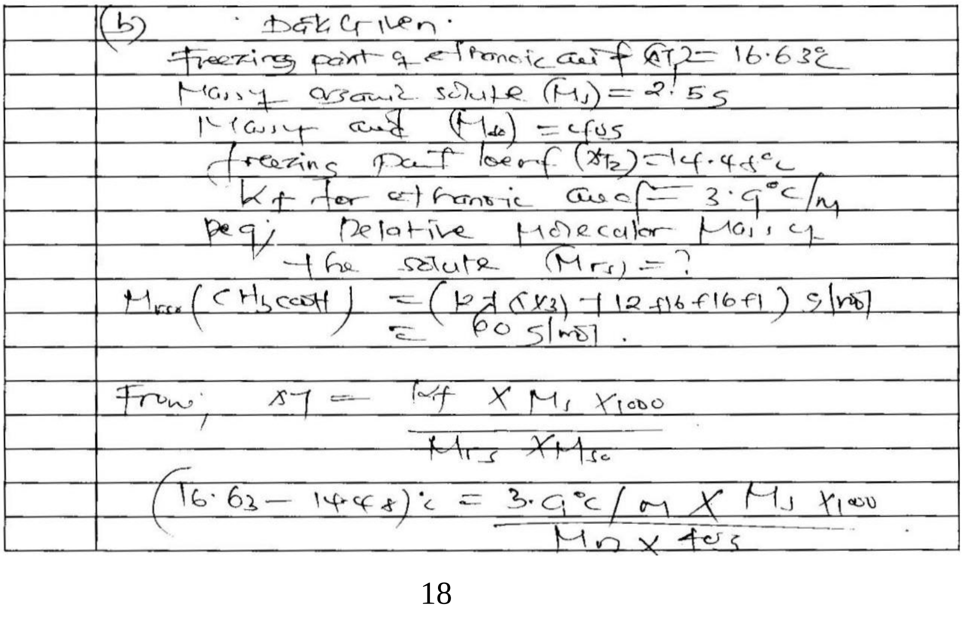
$nA = 1$
$nT = 2$
$X_{sugar} = 1/2 = 0.5$

mole fraction of sugar is 0.5

Mole fraction of water $= 1/2 = 0.5$

Therefore mole fraction of sugar and water is 0.5

Extract 3.2: A sample of the incorrect responses to question 3 (a) (i-ii)

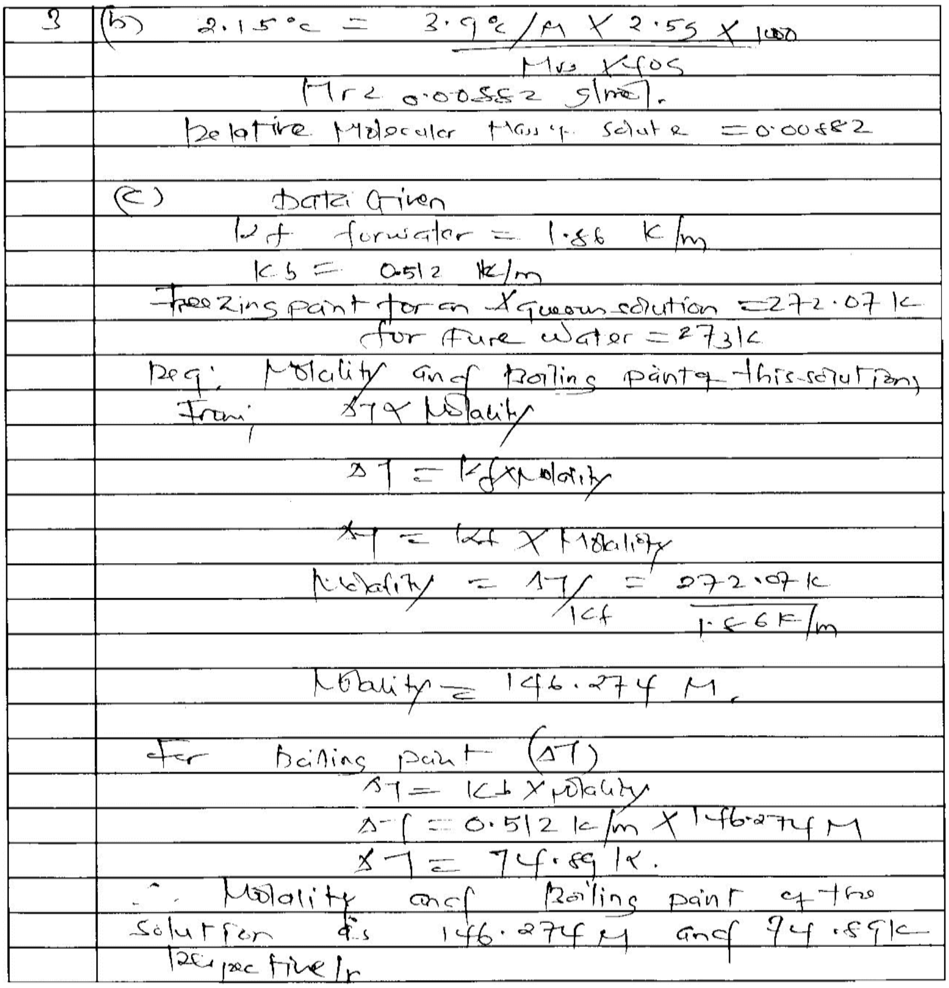


(b) Data Given:
Freezing point of ethanoic acid (T_1) = 16.63°C
Mass of organic solute (M_1) = 2.5 g
Mass of acid (M_{sc}) = 45 g
Freezing point of (T_2) = 14.48°C
Kf for ethanoic acid = 3.9°C/m
Req; Relative molecular Mass of the solute (M_{rs}) = ?

$M_{rcx}(CH_3COOH) = (12 + (1 \times 3) + 12 + 16 + 16 + 1)$ g/mol
= 60 g/mol.

From; $\Delta T = \frac{K_f \times M_1 \times 1000}{M_{rs} \times M_{sc}}$

$(16.63 - 14.48)°C = \frac{3.9°C/m \times M_1 \times 1000}{M_{rs} \times 45g}$



3 (b) $2.15^\circ c = \frac{3.9^\circ c/M \times 2.55 \times 1000}{Mr \times 105}$

Mr = 0.00582 g/mol.

Relative Molecular Mass of solute = 0.00582

(c) Data Given

Kf for water = 1.86 K/m

Kb = 0.512 K/m

Freezing point for an aqueous solution = 272.07 K

for pure water = 273 K

Req: Molality and Boiling point of this solution

From; $\Delta T \propto$ Molality

$\Delta T = K_f \times$ Molality

$\Delta T = K_f \times$ Molality

Molality $= \Delta T / K_f = \frac{272.07\,K}{1.86\,K/m}$

Molality = 146.274 M.

For boiling point (ΔT)

$\Delta T = K_b \times$ Molality

$\Delta T = 0.512\,K/m \times 146.274\,M$

$\Delta T = 74.89\,K$.

∴ Molality and Boiling point of the solution is 146.274 M and 94.89 K respectively

Extract 3.3: A sample of the incorrect responses to question 3 (b) and 3 (c)

Extract 3.2 shows that the candidate divided the values of pure vapour pressure of solvent with that of relative lowering of vapour pressure, instead of its vice versa in 3 (a) (i). In 3 (a) (ii), the candidate used the ideal gas equation to calculate the vapour pressure of the liquid. However, this was not correct. The candidate was supposed to use the formula $\Delta p = p^{o}_{solvent} - p_{solution}$. In 3(a)(iii), the candidate used the incorrect number of moles to calculate the mole fraction of sugar and water. As a result, the candidate arrived to the wrong answer.

Extract 3.3 shows that, although the candidate used the correct formula and made the correct substitution of the data into the formula, he/she failed to get the correct answer in part 3(b). This was caused by poor skills in using the calculator. Hence, he/she missed some marks allocated to the correct answer (113. 372 g/mol). Moreover, in part 3(c), the candidate used the value for the freezing point of solution, which was 272.07 K as the depression of freezing point of solution. This was not correct because the candidate was supposed to subtract the value he/she used from the freezing point of pure water, which was given as 273 K. Thus, the candidate was expected to have 273 K-272.07 K= 0.93 K. Then, this value was supposed to be plugged into the formulae to calculate the molality of the solution and hence its boiling point.

2.1.4 Question 4: Chemical Bonding

The question asked as follows:

(a) (i) Predict whether a chemical bond will be covalent or ionic basing on the charge and the relative size of the cations and anions as follows:

Cation/anion	***Ionic radius (nm)***	***Chemical bond***
C^{4+}	*0.015*	
I^{-}	*0.216*	
Na^{+}	*0.095*	
F^{-}	*0.136*	

(ii) "Intermolecular hydrogen bonding and dative covalent bonding are among the types of bonds exhibited by a number of molecules." Justify this statement by drawing a structure of a molecule for each type of the bonds aforementioned.

(b) Briefly, comment on the following observations:

(i) Fluorine, chlorine and bromine form hydrides, but the hydride of fluorine forms hydrogen bond, whereas those of chlorine and bromine do not.

(ii) When molecules of hydrogen chloride are placed together, they do not show induced dipole interactions but they do so when placed with molecules of argon.

(c) (i) What is the difference between sp^2 and sp hybridization?

(ii) Which bond is stronger than the other in each of the following pairs? Give a reason for your choice.

$C \equiv O$ or C=O; C-N or C-O; C-C or C=C

The question was attempted by 34,743 candidates. Among them, 13,487 (38.8%), 14,564 (41.9%) and 6,692 (19.3%) scored 0–3, 3.5–5.5 and 6.0–10 marks, respectively. These data show that 21,256 (61.2%) passed as they scored 3.5 marks or above out of 10 marks. The overall performance of candidates on this question was good as the majority (61.2%) correctly answered the question. A summary of candidates' performance on this question is shown in Figure 4.

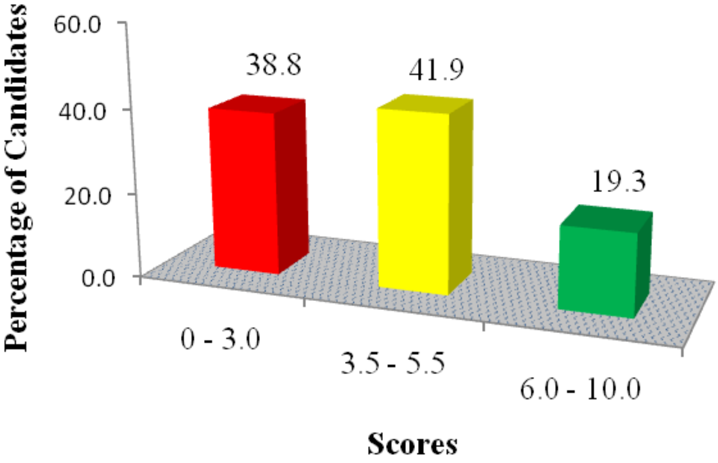


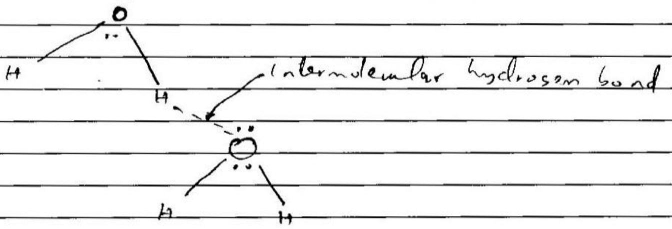
Figure 4: *Candidates Performance on Question 4*

The candidates who scored high marks on this question (19.3%) predicted the type of bonds that were expected to be formed in 3(a) (i) of the question appropriately. They also correctly drew the structures of the molecules for each of the bonds given in 3 (a) (ii). A further analysis of their responses in their scripts indicated that they applied the knowledge of hydrogen bonding formation and induced dipole interactions appropriately in part (b) of the question. In addition, they differentiated sp^2 from sp hybridization and identified the bond which was stronger than the other among the given pairs of bonds correctly. Such good responses from candidates were attributed to their good understanding of the characteristics of chemical bonds and the concept of hybridization of atomic orbital. Extract 4.1 illustrates a good response to this question.

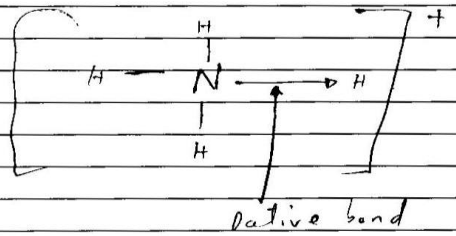
4 (a)(ii)

cation/anion	Ionic radius	Chemical bond
C^{4+}	0.015	Covalent
I^-	0.216	Covalent
Na^+	0.095	Ionic
F^-	0.136	Ionic

(iii) Example of intermolecular hydrogen bonding

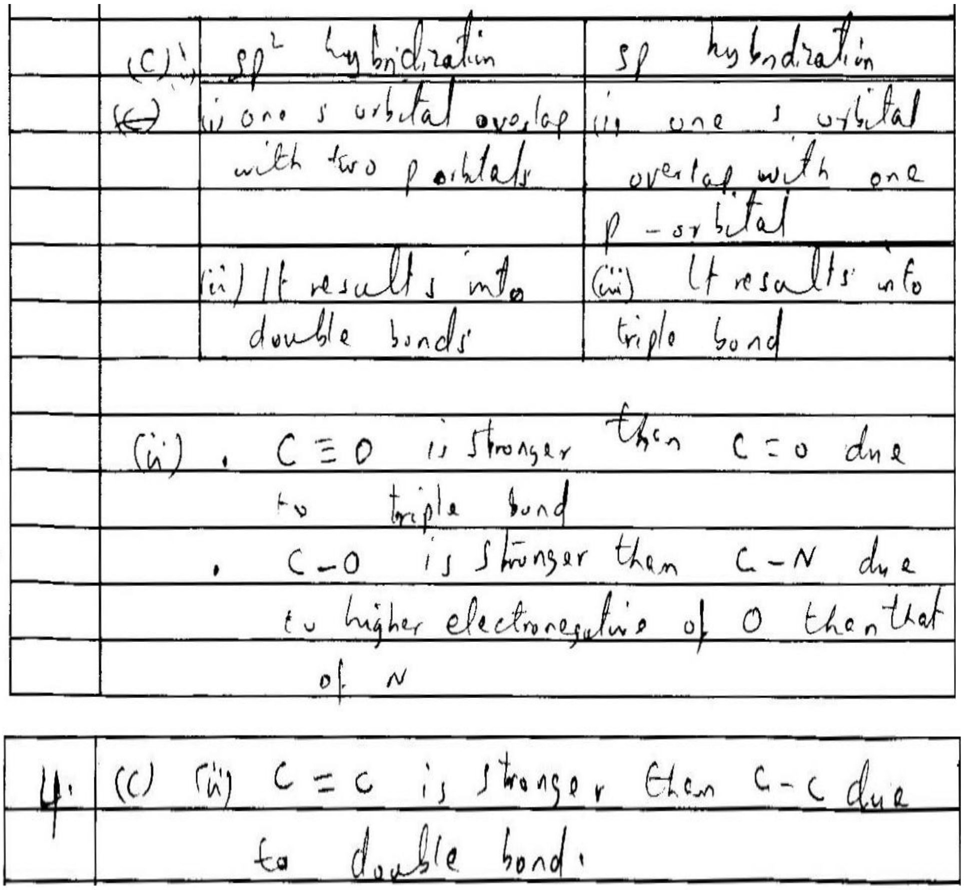


Structure of Dative bond



4 (b) (i) Fluorine is small element and highly electronegative element hence its hydride can form strong hydrogen bondings between its molecules while Chlorine, bromine are large in size hence their hydride cannot form hydrogen bonds between its molecules

(ii) Hydrogen Chloride is polar molecule thus when placed together with another HCl they tend to generate permanent dipoles between hydrogen and chloride ion hence led to dipole dipole interactions instead of induced dipole interaction while when placed with argon form induced dipole interaction because argon is non polar hence HCl induce temporary dipoles to argon.



	sp^2	sp
(c) (i)	sp^2 hybridization	sp hybridration
	(i) one s orbital overlap with two p orbitals	(i) one s orbital overlap with one p - orbital
	(ii) It results into double bonds	(ii) It results into triple bond

(ii) . $C \equiv O$ is stronger than $C = O$ due to triple bond

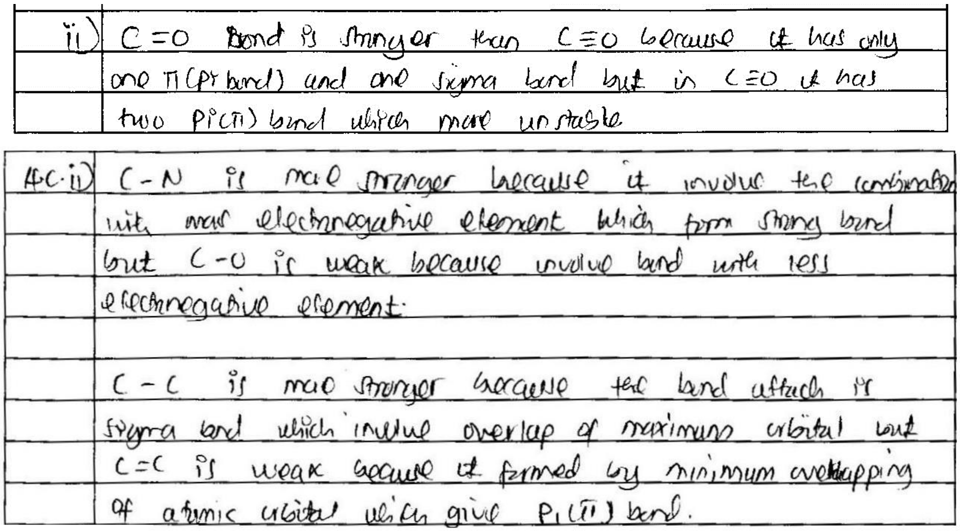
. $C - O$ is stronger than $C - N$ due to higher electronegative of O than that of N

4. (c) (ii) $C = C$ is stronger than $C - C$ due to double bond.

Extract 4.1: A sample of the correct responses to question 4

Extract 4.1 shows that the candidate correctly filled the table and drew the correct structures of molecules to illustrate the concept of hydrogen and dative covalent bonding asked in 4(a). The candidate provided appropriate examples to illustrate the concept of hydrogen bonding while responding to observations expected in 4(b). Finally, the candidate differentiated sp^2 from sp hybridization and identified the strong bond correctly in each of the given pairs.

In contrast, 38.8 per cent of the gave incorrect responses. Some of them even skipped some parts of this question. Hence, they scored low marks. Analysis indicated that they did not understand the concept of bonding and its application. Moreover, they had insufficient knowledge of hybridization as illustrated in Extract 4.2.



ii)	C=O Bond is stronger than C≡O because it has only
	one π (pi bond) and one sigma bond but in C≡O it has
	two pi(π) bond which more unstable

4c.ii)	C-N is more stronger because it involve the combination
	with more electronegative element which form strong bond
	but C-O is weak because involve bond with less
	electronegative element.
	C-C is more stronger because the bond attach is
	sigma bond which involve overlap of maximum orbital but
	C=C is weak because it formed by minimum overlapping
	of atomic orbital which give Pi(π) bond.

Extract 4.2: A sample of the incorrect responses to question 4 (c) (ii)

In Extract 4.2, the candidate identified weak bonds among the given pairs of bonds and explained them as strong ones. This was contrary to the requirement of the question; hence, he/she lost the marks allotted to this part.

2.1.5 Question 5: Aliphatic Hydrocarbons

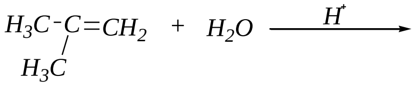
The question asked as follows:

(a) *A certain chemical industry in Tanzania got an order to supply some reagents for research purposes. However, the requested reagents were not in the stock at that moment though enough starting materials shown in each case were present. What synthetic route(s) will you device in each case to meet the order required? Confine your reactions in not more than four steps.*

- *(i) Propan – 1, 2-diol from propene*
- *(ii) Acetone from 2-methyl propene*
- *(iii) Ethanol from propane*
- *(iv) Ethyne from calcium carbide*

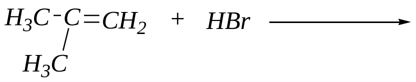
(b) *Use Markovnikov's rule to predict the products of the following Reactions:*

(i)



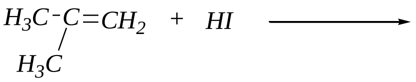
$$H_3C-\underset{\displaystyle H_3C}{C}=CH_2 + H_2O \xrightarrow{H^+}$$

(ii)



$$H_3C\text{-}\underset{H_3C}{C}=CH_2 \;+\; HBr \longrightarrow$$

(iii)



$$H_3C\text{-}\underset{H_3C}{C}=CH_2 \;+\; HI \longrightarrow$$

(c) *"Wurtz synthesis is not suitable for preparation of an asymmetrical alkane." Briefly, justify this statement while supporting your answer with a chemical equation.*

The question was attempted by 34,740 candidates. The analysis of statistical data indicates that 20,201 (58.1%) scored 0–3, 6,589 (19%) scored 3.5–5.5 and 7,950 (22.9%) scored 6–10 marks (Figure 5). A further analysis of data indicates that 14,539 (41.9%) scored from 3.5–10 marks. Therefore, the overall performance of candidates on this question was average.

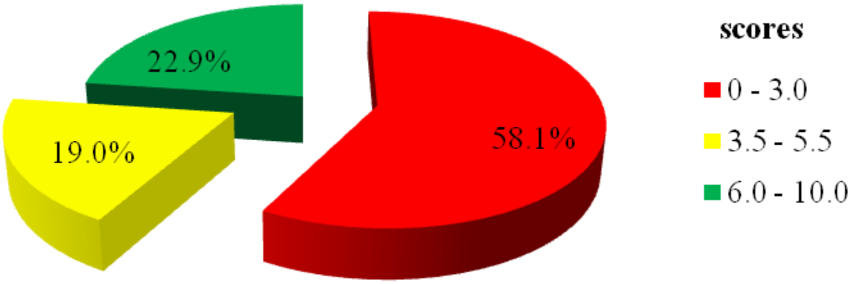


Figure 5: *Candidates' Performance on Question 5*

Analysis indicated that the 22.9 per cent who scored from 6 to 10 marks were conversant with the different types of functional group inter-conversions. They understood the reactions involving hydrocarbons, alcohols, carbonyls and alkyhalides. They were also familiar with electrophilic addition reactions. Hence, they understood properly the Wurtz reaction and its implications in synthesizing various organic reagents.

Some candidates only responded well to some parts of the question. This was because of their partial knowledge of organic reactions and reaction mechanisms. Consequently, they scored averagely marks from 3.5–5.5 marks. Extract 5.1 is a sample responses by a candidate who correctly responded to this question.

Qn. 5 (a) i)

$\cdot\ CH_3-CH=CH_2 \xrightarrow[H_2O,\ OH^-]{KMnO_4} CH_3-\overset{OH}{\overset{|}{C}H}-CH_2OH$

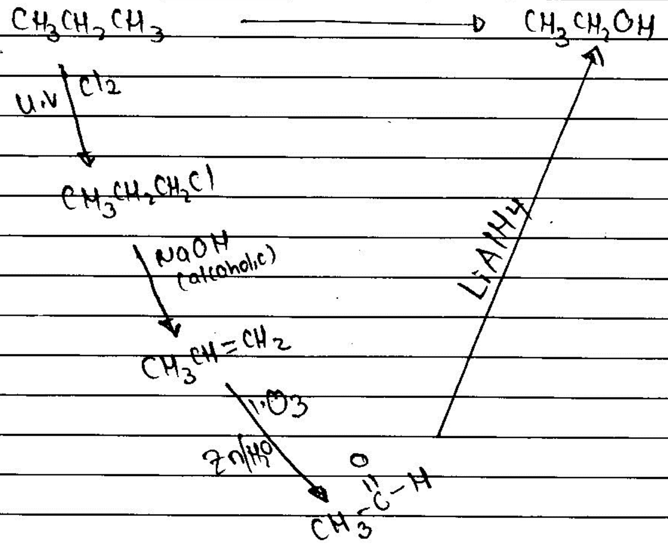
ii) $CH_3-\overset{O}{\overset{\|}{C}}-CH_3$ from $CH_3-\underset{CH_3}{\underset{|}{C}}=CH_3$

$CH_3-\underset{CH_3}{\underset{|}{C}}=CH_3 \xrightarrow[2\cdot Zn/H_2O]{1\cdot O_3} CH_3-\overset{O}{\overset{\|}{C}}-CH_3$

$\cdot$ Acetone

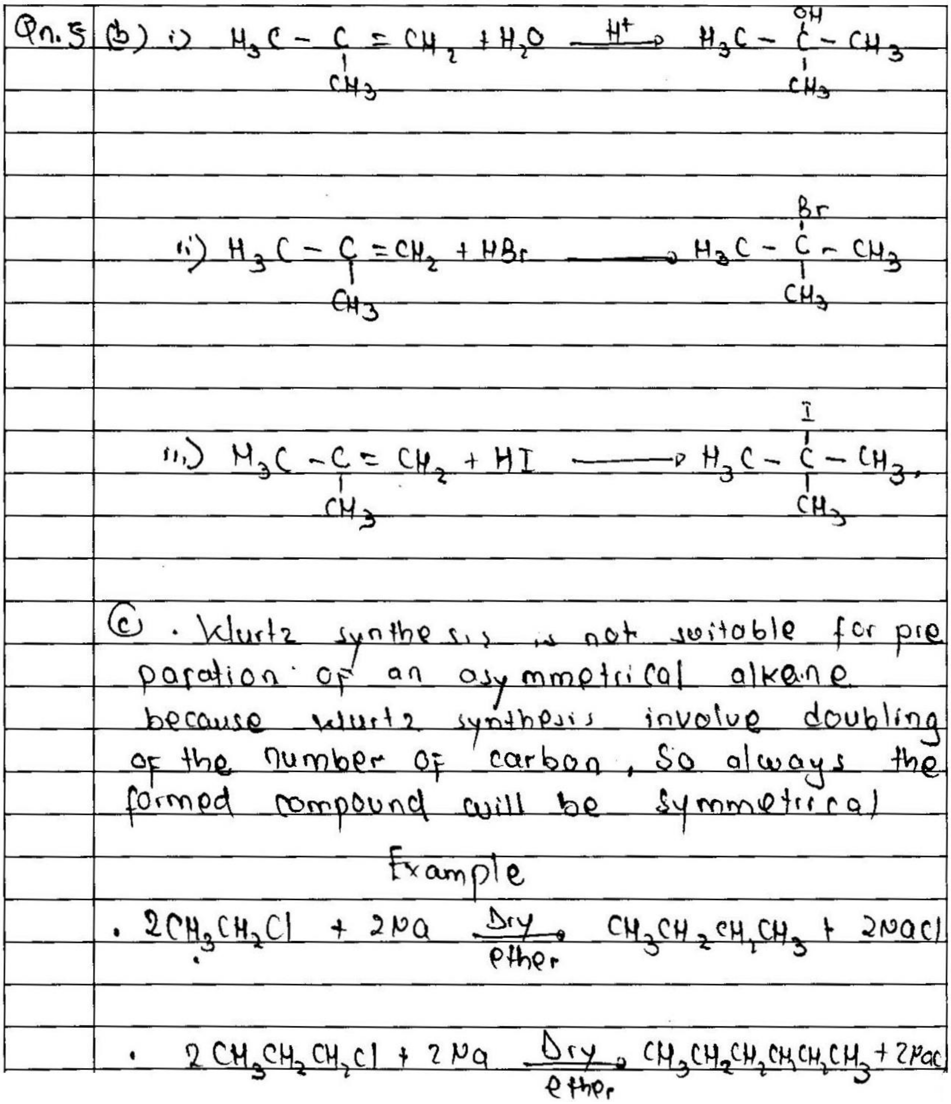
$+HCOH$

iii) Ethanol from propane



(iv)

$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$.



Qn.5 (b) i) $H_3C-\underset{CH_3}{C}=CH_2 + H_2O \xrightarrow{H^+} H_3C-\overset{OH}{\underset{CH_3}{C}}-CH_3$

ii) $H_3C-\underset{CH_3}{C}=CH_2 + HBr \longrightarrow H_3C-\overset{Br}{\underset{CH_3}{C}}-CH_3$

iii) $H_3C-\underset{CH_3}{C}=CH_2 + HI \longrightarrow H_3C-\overset{I}{\underset{CH_3}{C}}-CH_3.$

(c) • Wurtz synthesis is not suitable for preparation of an asymmetrical alkane because wurtz synthesis involve doubling of the number of carbon, So always the formed compound will be symmetrical

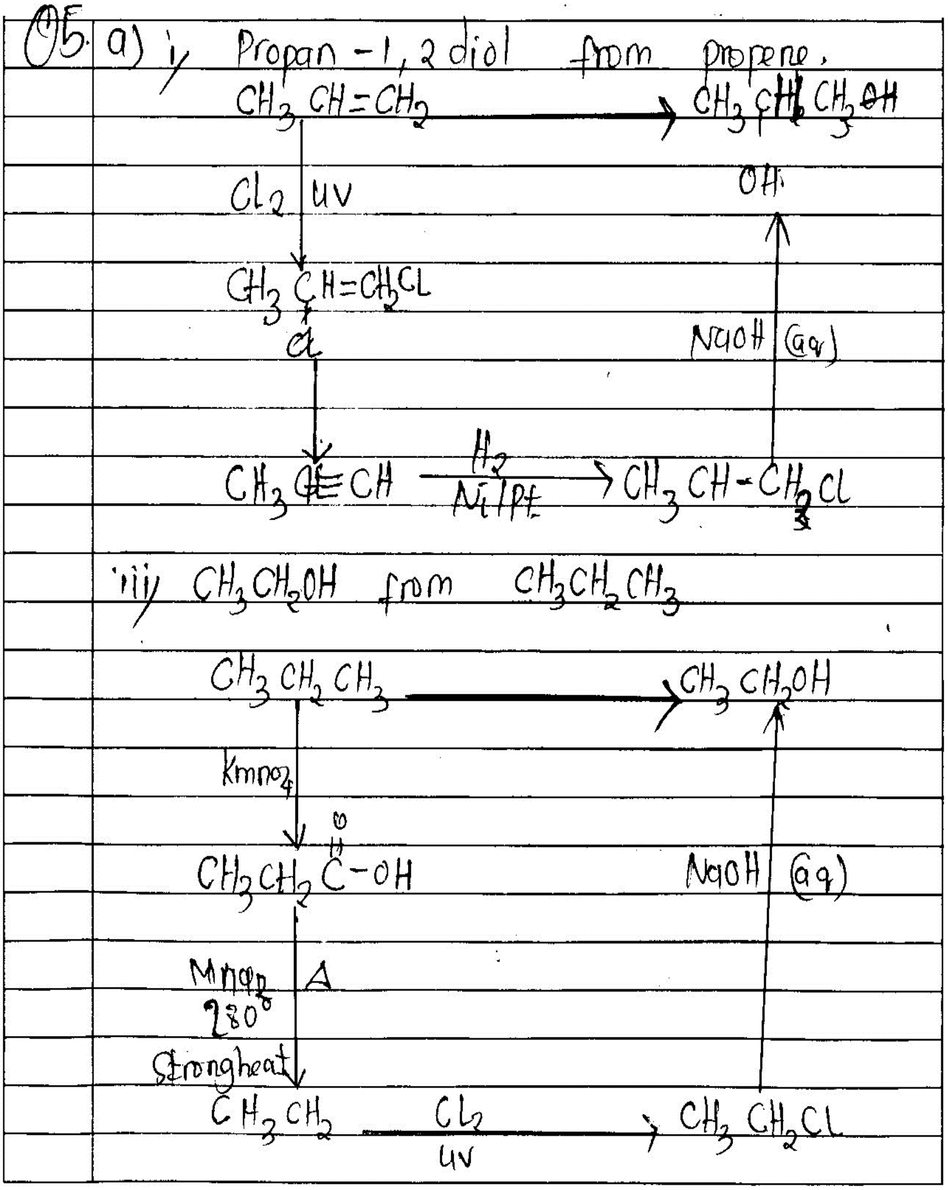
Example

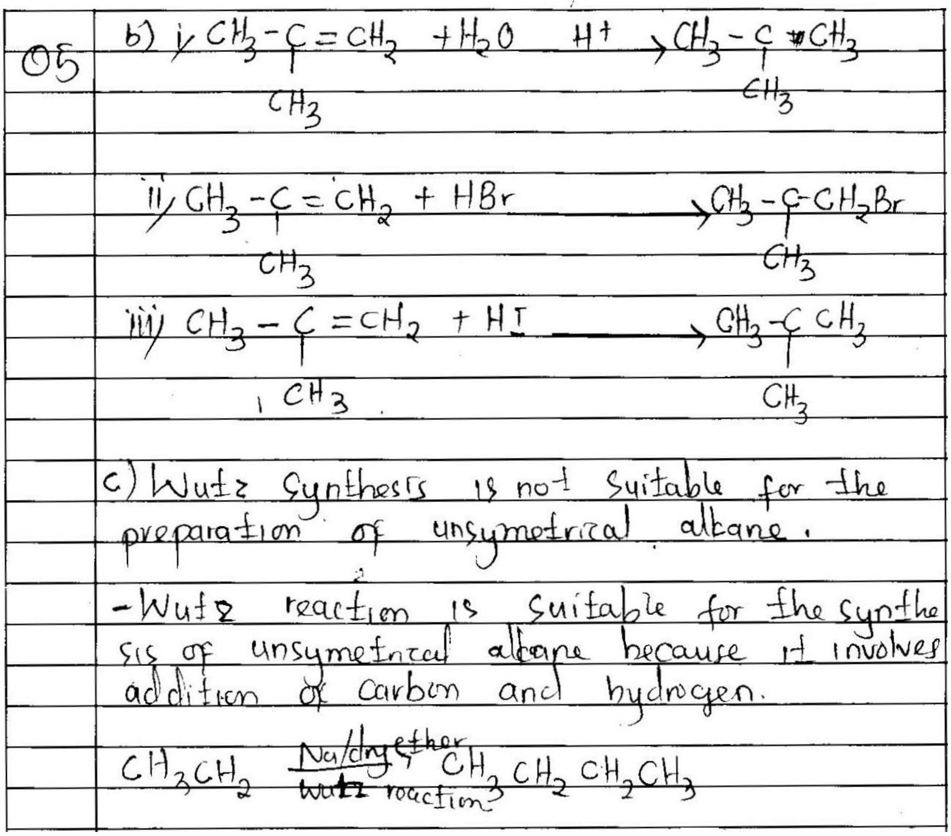
- $2CH_3CH_2Cl + 2Na \xrightarrow[ether]{Dry} CH_3CH_2CH_2CH_3 + 2NaCl$
- $2CH_3CH_2CH_2Cl + 2Na \xrightarrow[ether]{Dry} CH_3CH_2CH_2CH_2CH_2CH_3 + 2NaC$

Extract 5.1: A sample of the correct responses to question 5

In Extract 5.1, the candidate performed functional group inter-conversion correctly in parts (a) and (b). Moreover, he/she provided plausible responses to the subsequent parts of the question.

However, 58.1 per cent of the candidates failed to address this question. Their responses indicated that they used wrong chemical structures for the asked organic compounds. Most of them gave incorrect explanations on the Wurtz reaction. Hence, they failed to convert one organic reagent into another. They were supposed to understand the varieties of functional groups such as hydrocarbons, alcohols, alkyhalides and carbonyls to perform well. Moreover, they were supposed to be conversant with the basic reaction mechanism which, in this case, would have enabled them achieve suitable products. This is important because organic reactions cut across all (sub) topics under organic chemistry as stipulated in the syllabus. Extract 5.2 shows responses from a candidate who did not answer correctly.





05 b) i) $CH_3-\underset{CH_3}{\underset{|}{C}}=CH_2 + H_2O \xrightarrow{H^+} CH_3-\underset{CH_3}{\underset{|}{C}}\#CH_3$

ii) $CH_3-\underset{CH_3}{\underset{|}{C}}=CH_2 + HBr \longrightarrow CH_3-\underset{CH_3}{\underset{|}{C}}-CH_2Br$

iii) $CH_3-\underset{CH_3}{\underset{|}{C}}=CH_2 + HI \longrightarrow CH_3-\underset{CH_3}{\underset{|}{C}}\,CH_3$

c) Wutz synthesis is not suitable for the preparation of unsymetrical alkane.

-Wutz reaction is suitable for the synthesis of unsymetrical alkane because it involves addition of carbon and hydrogen.

$CH_3CH_2 \xrightarrow[\text{wutz reaction}]{\text{Na/dry ether}} CH_3CH_2CH_2CH_3$

Extract 5.1: A sample of the incorrect responses to question 5

In Extract 5.2, the candidate gave the wrong conversions in 5(a) and gave incorrect reaction products in 5(b). He/she also gave a reason in part 5(c) which did not address the requirement of the question. The candidate supported his/her reason with wrong chemical reaction.

2.1.6 Question 6: Energetics

The question asked as follows:

(a) (i) Given that, the heat of formation of $CO_2(g)$, $CO(g)$ and $H_2O(g)$ are –393.5, –121.31 and –241.8 kJ/mol, respectively. Calculate the enthalpy change (ΔH^o) for the reaction $CO_2(g) + H_2(g) \longrightarrow CO(g) + H_2O(g)$.

(ii) What are the four factors affecting the quantity of heat evolved or absorbed during a physical or chemical transformation?

(b) Determine the heat of formation of ethyne basing on the following information given by the reactions ***A-D****.*

A: $C(s) + O_2(g) \rightarrow CO_2(g) \;\; \Delta H_f = -393 \; kJ \; mol^{-1}$

B: $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) \;\; \Delta H_f = -286 \; kJ \; mol^{-1}$

C: $6C(s) + 3H_2(g) \rightarrow C_6H_6(g) \;\; \Delta H_f = +50.2 \; kJ \; mol^{-1}$

D: $C_2H_2(g) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l) \; \Delta H_f = -1323 kJ \; mol^{-1}$

The question was attempted by all 34,743 candidates. Their performance was as follows: 11,541 (33.2%) candidates scored from 0–3; 12,185 (35.1%) scored from 3.5–5.5 and 11,017 (31.7%) scored 6–10 marks (Figure 6). The candidates who passed this question were 23,202 (66.8%). They scored from 3.5 to 10 marks (i.e. from average to good marks). Such performance on this question was generally good.

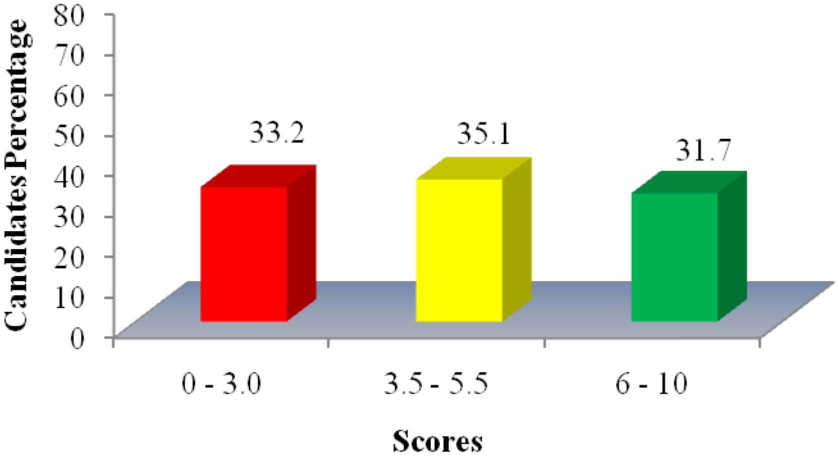
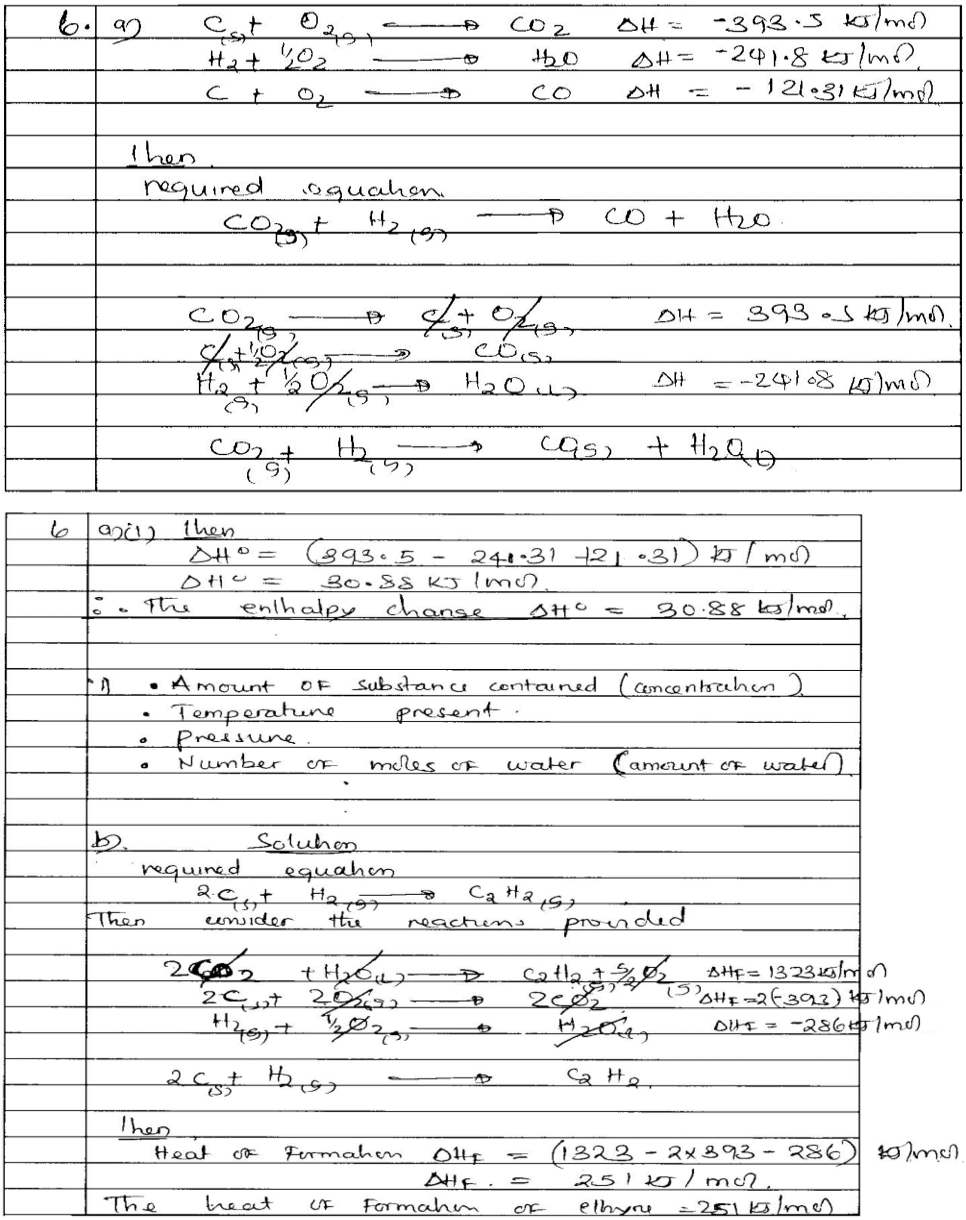


Figure 6: *Candidates' Performance on Question 6*

The candidates (31.7%) who performed well on this question correctly applied Hess's law to calculate heat changes associated with given reactions in parts 6 (a) and (b). These candidates had sufficient knowledge of the concepts of heat of reaction and their pathways (Hess's Law). Extract 6.1 shows a sample of the correct responses to this question.



6. a) $C_{(s)} + O_{2(g)} \longrightarrow CO_2$ $\Delta H = -393.5$ kJ/mol

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$ $\Delta H = -241.8$ kJ/mol.

$C + O_2 \longrightarrow CO$ $\Delta H = -121.31$ kJ/mol

Then.

required equation.

$CO_{2(g)} + H_{2(g)} \longrightarrow CO + H_2O$.

$CO_{2(g)} \longrightarrow \cancel{C_{(s)}} + \cancel{O_{2(g)}}$ $\Delta H = 393.5$ kJ/mol.

$\cancel{C_{(s)}} + \frac{1}{2}\cancel{O_{2(g)}} \longrightarrow CO_{(s)}$

$H_{2(g)} + \frac{1}{2}\cancel{O_{2(g)}} \longrightarrow H_2O_{(l)}$ $\Delta H = -241.8$ kJ/mol

$CO_{2(g)} + H_{2(g)} \longrightarrow CO_{(s)} + H_2O_{(l)}$

6 a)(i) Then

$\Delta H^\circ = (393.5 - 241.31 - 121.31)$ kJ/mol

$\Delta H^\circ = 30.88$ kJ/mol.

∴ The enthalpy change $\Delta H^\circ = 30.88$ kJ/mol.

ii) • Amount of substance contained (concentration)

• Temperature present.

• Pressure.

• Number of moles of water (amount of water).

b). Solution

required equation

$2C_{(s)} + H_{2(g)} \longrightarrow C_2H_{2(g)}$.

Then consider the reactions provided

$2\cancel{CO_2} + \cancel{H_2O_{(l)}} \longrightarrow C_2H_{2(g)} + \frac{5}{2}\cancel{O_{2(g)}}$ $\Delta H_f = 1323$ kJ/mol

$2C_{(s)} + 2\cancel{O_{2(g)}} \longrightarrow 2\cancel{CO_2}$ $\Delta H_f = 2(-393)$ kJ/mol

$H_{2(g)} + \frac{1}{2}\cancel{O_{2(g)}} \longrightarrow \cancel{H_2O_{(l)}}$ $\Delta H_f = -286$ kJ/mol

$2C_{(s)} + H_{2(g)} \longrightarrow C_2H_2$.

Then

Heat of Formation $\Delta H_f = (1323 - 2 \times 393 - 286)$ kJ/mol

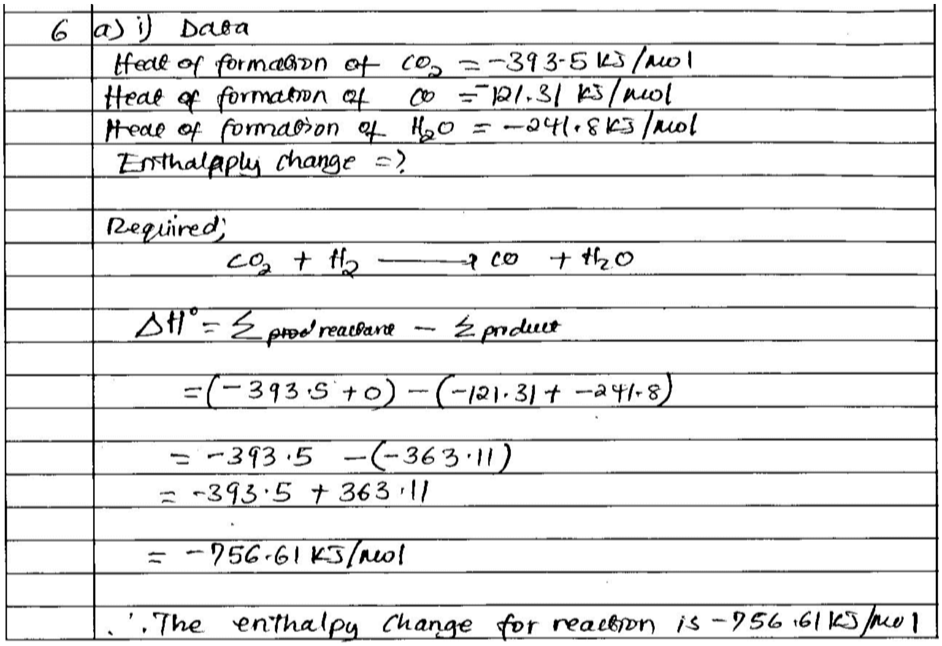
$\Delta H_f = 251$ kJ/mol.

The heat of Formation of ethyne $= 251$ kJ/mol

Extract 6.1: A sample of the correct responses to question 6

In Extract 6.1, the candidate used one of the correct approaches to calculate the heat of formation for the reaction given in part 6(a) and the heat of formation of ethyne in part 6 (b). However, the candidate used -241.3 kJmol^{-1} as the value for the enthalpy of formation of water instead of using 241.8 kJmol^{-1}. The candidate also forgot to include state symbols for the required equations in part 6(a) and (b); hence, he/she could not score full marks.

In contrast, 11,541 (33.2%) of the candidates failed to address this question; they scored below 3.5 out of 10 marks. They did the wrong calculations of heat changes that accompanied the given chemical reactions. This was caused by their insufficient knowledge of and skills in applying Hess’s law in parts (a) and (b) of the question. Moreover, some of them gave partial answers when giving factors that affect the quantity of heat evolved/absorbed during chemical transformation. These were attributed to their insufficient knowledge of the subtopics of the *Heat of Reaction* and *Hess’s Law*. Extract 6.2 is illustrative.



6 a) i) Data

Heat of formation of CO_2 = −393.5 KJ/mol

Heat of formation of CO = −121.31 KJ/mol

Heat of formation of H_2O = −241.8 KJ/mol

Enthalpply change = ?

Required;

$CO_2 + H_2 \longrightarrow CO + H_2O$

$\Delta H^\circ = \Sigma$ ~~prod~~ reactant − Σ product

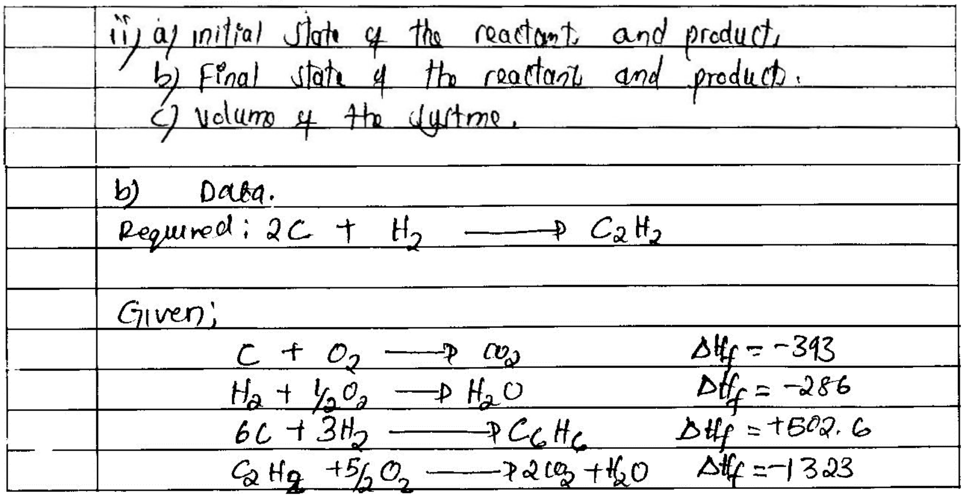
$=(-393.5 + 0) - (-121.31 + -241.8)$

$= -393.5 - (-363.11)$

$= -393.5 + 363.11$

$= -756.61$ KJ/mol

∴ The enthalpy change for reaction is −756.61 KJ/mol



ii) a) initial state of the reactant and product,

b) Final state of the reactant and product.

c) volume of the systme.

b) Data.

Required: $2C + H_2 \longrightarrow C_2H_2$

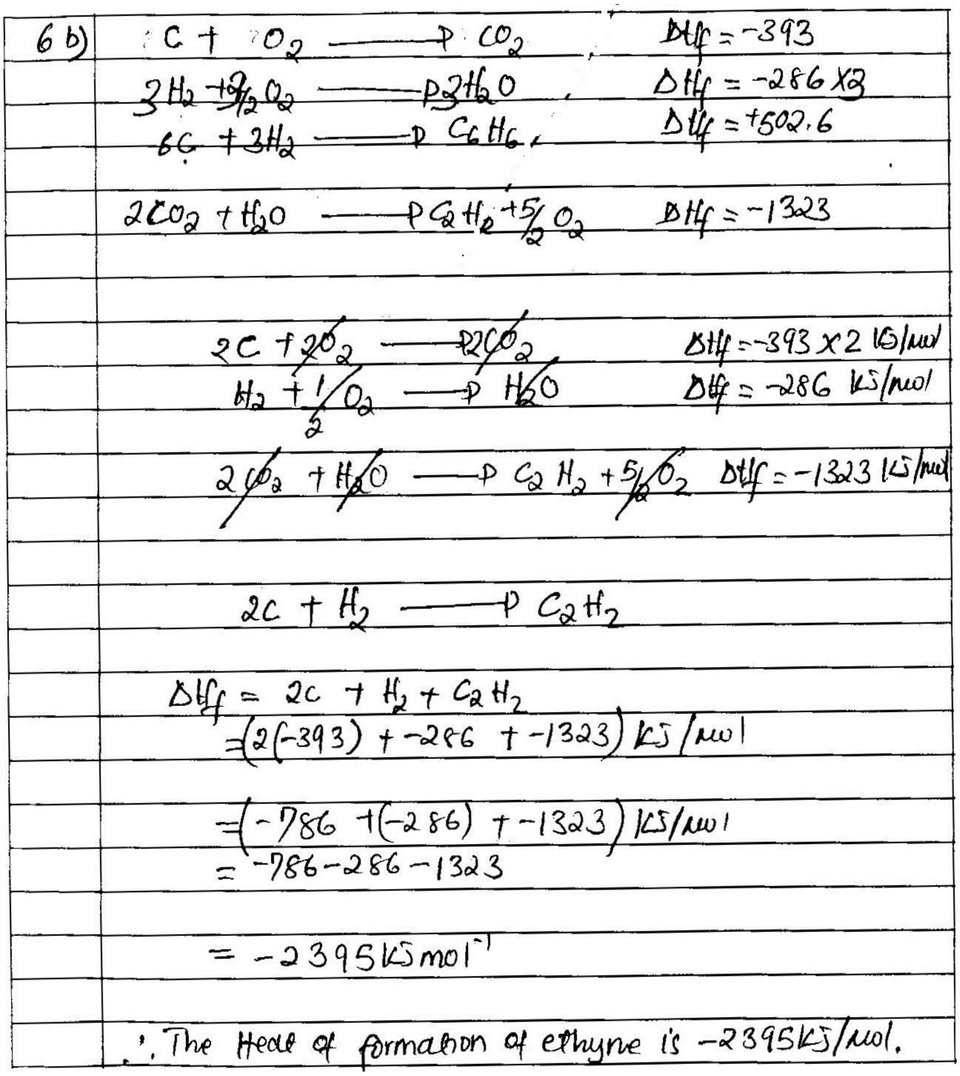
Given;

$C + O_2 \longrightarrow CO_2$ $\Delta H_f = -393$

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$ $\Delta H_f = -286$

$6C + 3H_2 \longrightarrow C_6H_6$ $\Delta H_f = +502.6$

$C_2H_2 + \frac{5}{2}O_2 \longrightarrow 2CO_2 + H_2O$ $\Delta H_f = -1323$



6 b) $C + O_2 \longrightarrow CO_2$, $\Delta H_f = -393$

$3H_2 + 9/2\, O_2 \longrightarrow 3H_2O$, $\Delta H_f = -286 \times 3$

$6C + 3H_2 \longrightarrow C_6H_6$, $\Delta H_f = +502.6$

$2CO_2 + H_2O \longrightarrow C_2H_2 + 5/2\, O_2$ $\Delta H_f = -1323$

$2C + 2\cancel{O_2} \longrightarrow 2\cancel{CO_2}$ $\Delta H_f = -393 \times 2$ kJ/mol

$H_2 + \frac{1}{2}\cancel{O_2} \longrightarrow \cancel{H_2O}$ $\Delta H_f = -286$ kJ/mol

$2\cancel{CO_2} + \cancel{H_2O} \longrightarrow C_2H_2 + 5/\cancel{2}\, \cancel{O_2}$ $\Delta H_f = -1323$ kJ/mol

$2C + H_2 \longrightarrow C_2H_2$

$\Delta H_f = 2C + H_2 + C_2H_2$
$= (2(-393) + -286 + -1323)$ kJ/mol

$= (-786 + (-286) + -1323)$ kJ/mol
$= -786 - 286 - 1323$

$= -2395\ \text{kJmol}^{-1}$

∴ The Heat of formation of ethyne is -2395 kJ/mol.

Extract 6.2: A sample of the incorrect responses to question 6

In Extract 6.2, the candidate wrongly used the formula $\Delta H_r = \sum \Delta H_f\,(\text{reactants}) - \sum \Delta H_f\,(\text{products})$, instead of $\Delta H_r = \sum \Delta H_f\,(\text{products}) - \sum \Delta H_f\,(\text{Reactants})$. Accordingly, he/she got the incorrect answer in part 6(a) (i). In the subsequent parts of the question, the candidate used the chemical equations without reversing them. Furthermore, the candidate made a summation of enthalpies without multiplying them by stoichiometric coefficients. Hence, their responses were weak, and they scored low marks.

2.1.7 Question 7: Environmental Chemistry

The question asked as follows:

(a) *Suppose you are employed by the National Environment Management Council (NEMC), an institution which has a mandate to oversee the environmental management issue in Tanzania; what are the four possible intervention measures of environmental degradation you can address to the community.*

(b) *"Most of the greenhouse gases are produced from anthropogenic activities." Justify this statement by giving two reasons while supporting your answer with appropriate chemical equation in each case.*

(c) *Acid rain is formed as a result of excessive dissolution of gases in the atmosphere to produce acids with pH less than 5.6. What are the four chemical reactions that take place during the formation of an acidic rain?*

All 34,743 candidates attempted this question and scored as follows: 11,423 (32.9%) scored 0–3; 17,520 (50.4%) scored 3.5-5.5 and 5800 (16.7%) scored 6-10 marks (Figure 7). A further analysis indicates that 23,320 (67.1%) of the candidates scored from 3.5 to 10 marks. Thus, their overall performance on this question was good.

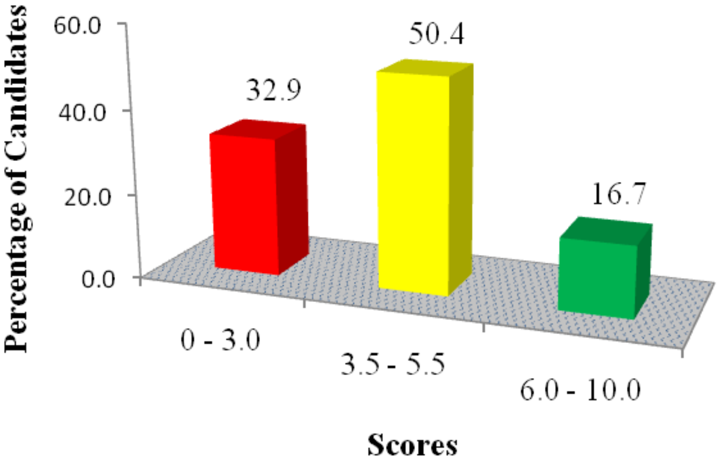
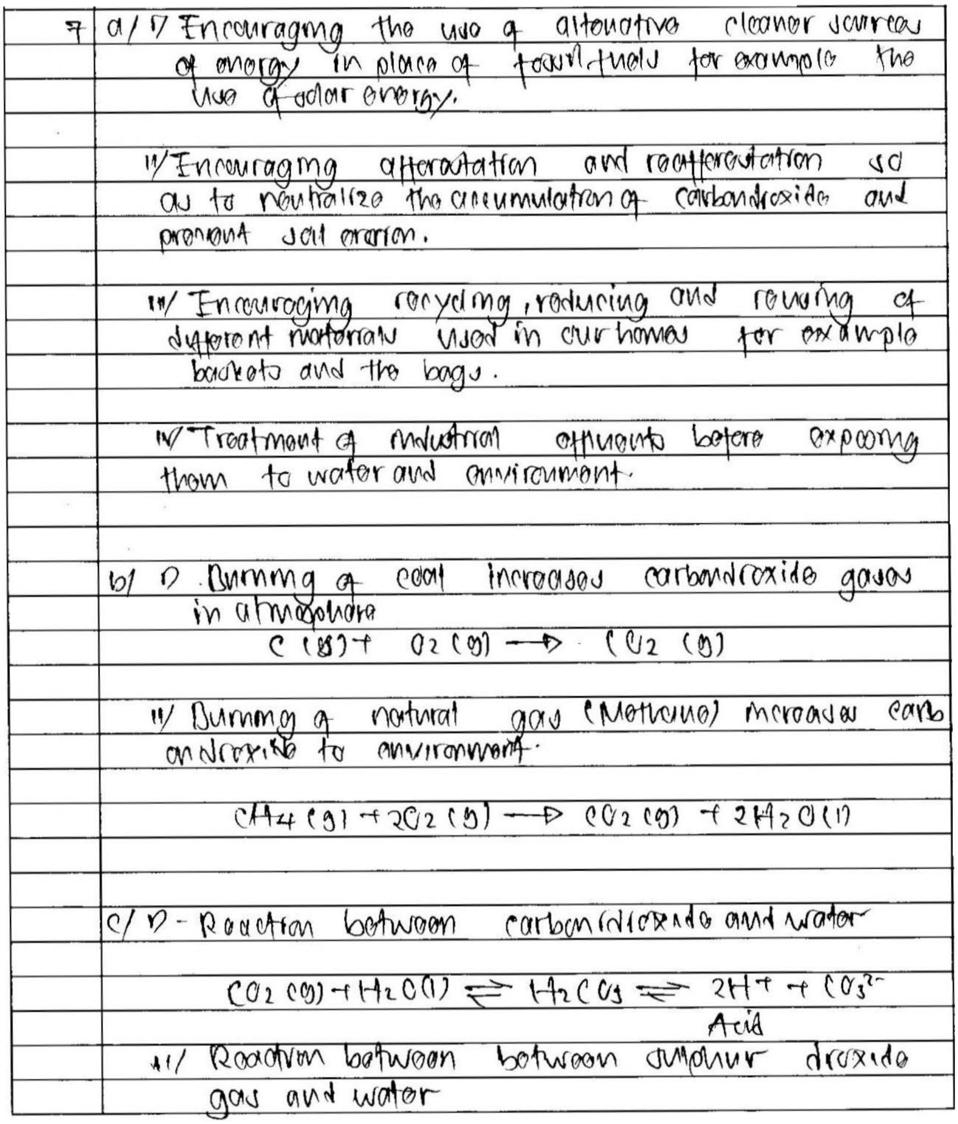


Figure 7: *Candidates' Performance on Question 7*

The candidates who performed well on this question provided appropriate measures to address the current environmental degradation. They also wrote the correct chemical equations as required in parts (b) and (c). They demonstrated a good mastery of the contents from the (sub) topics of *Conservation* and *Pollution* in the topic of *Environmental Chemistry*. These candidates were conversant with the current environmental issues. The candidates with average scores responded partially to some parts of the question. Extract 7.1 is a sample of the correct responses to this question.



7 a/ i/ Encouraging the use of alternative cleaner sources of energy in place of fossil fuels for example the use of solar energy.

ii/ Encouraging afforestation and reafforestation so as to neutralize the accumulation of carbondioxide and prevent soil erosion.

iii/ Encouraging recycling, reducing and reusing of different materials used in our homes for example baskets and the bags.

iv/ Treatment of industrial effluents before exposing them to water and environment.

b/ i/ Burning of coal increases carbondioxide gases in atmosphere

$C(s) + O_2(g) \rightarrow CO_2(g)$

ii/ Burning of natural gas (Methane) increases carbondioxide to environment.

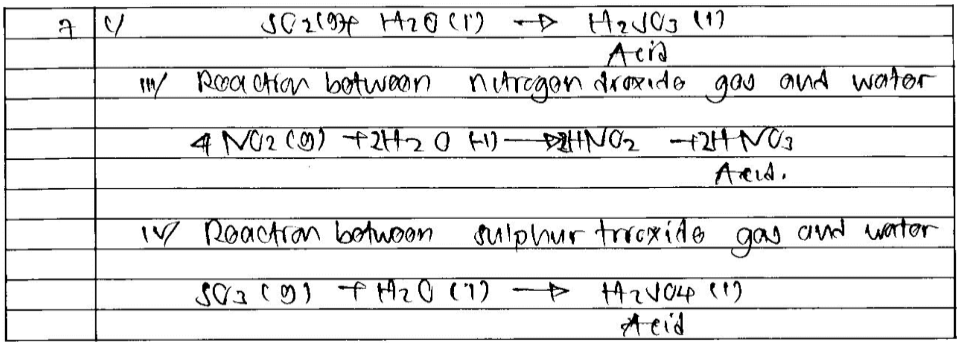
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

c/ i/ - Reaction between carbondioxide and water

$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3 \rightleftharpoons 2H^+ + CO_3^{2-}$

Acid

ii/ Reaction between between sulphur dioxide gas and water



7 i/ $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(l)$

Acid

iii/ Reaction between nitrogen dioxide gas and water

$4NO_2(g) + 2H_2O(l) \rightarrow 2HNO_2 + 2HNO_3$

Acid.

iv/ Reaction between sulphur trioxide gas and water

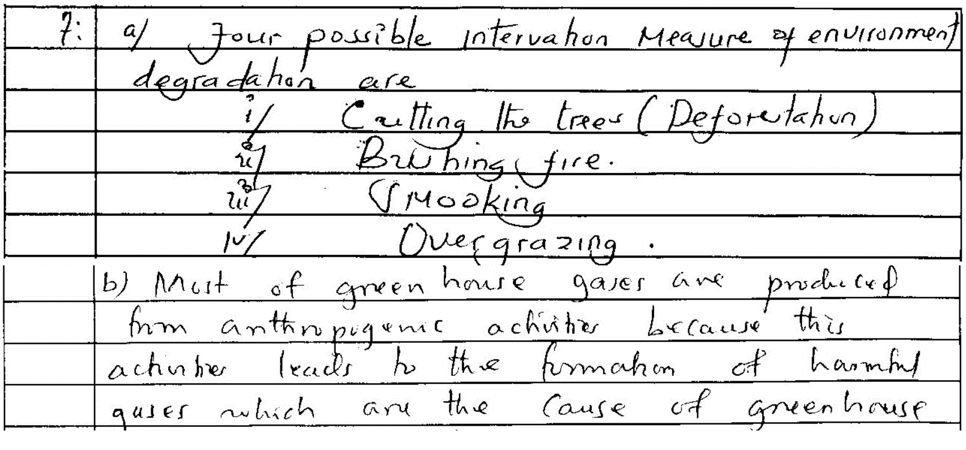
$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$

Acid

Extract 7.1: A sample of the correct responses to question 7

In Extract 7.1, the candidate, assuming roles of a NEMC officer, encouraged the community to use four appropriate intervention measures to combat environmental degradation in part 7(a). The candidate justified the given statement and supported his/her answer with the correct chemical equations in part 7(b). Moreover, in the last part of the question, the candidate gave chemical reactions with their correct corresponding equations for the formation of acidic rain.

In contrast, 11,423 (32.9%) of the candidates responded incorrectly to most parts of the question. Hence, they scored below the pass mark (i.e. below 3.5 out of 10). Some of them did not understand the key words "*environmental degradation*" and "*anthropogenic activities*" that were used in parts (a) and (b). Hence, they responded wrongly. They also wrote incorrect chemical reactions to illustrate the formation of acidic rain in 7(c), as shown in Extract 7.2.



7: a/ Four possible intervation Measure of environment degradation are

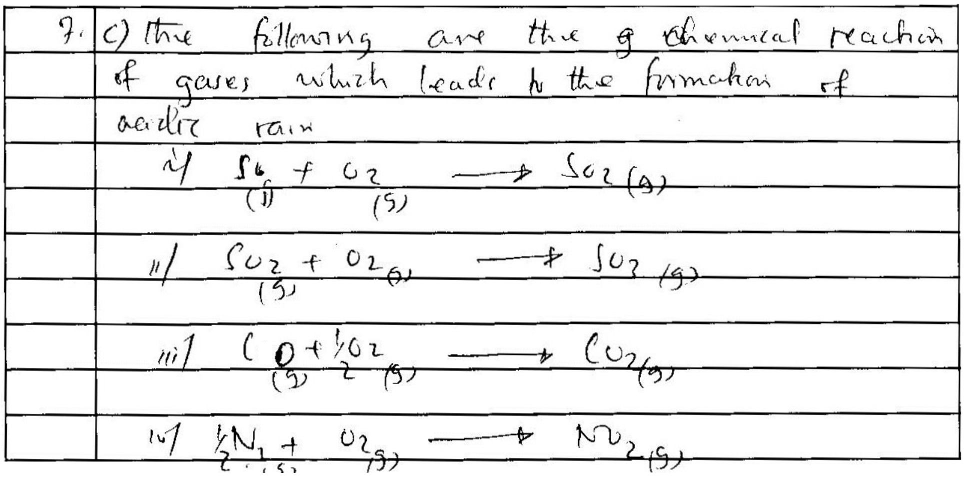
i/ Cutting the trees (Deforetation)

ii/ Burning fire.

iii/ Smooking

iv/ Overgrazing.

b) Must of green house gases are produced from anthropogenic activities because this activities leads to the formation of harmful gases which are the cause of green house



7. c) the following are the ~~g~~ chemical reaction of gases which leads to the formation of acidic rain

i/ $S_{6(l)} + O_{2(g)} \longrightarrow SO_{2(g)}$

ii/ $SO_{2(g)} + O_{2(g)} \longrightarrow SO_{3(g)}$

iii/ $CO_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{2(g)}$

iv/ $\frac{1}{2}N_{2(g)} + O_{2(g)} \longrightarrow NO_{2(g)}$

Extract 7.2: A sample of the incorrect responses to question 7

In Extract 7.2, the candidate gave the causes of environmental degradation, instead of intervention measures. The candidate gave partial reason without justification in part 7 (b). In part 7 (c), the candidate gave reactions for the formation of gases without reacting them with water, which is a pre-requisite for the formation of the acidic rain.

2.1.8 Question 8: Gases

The question was asked in Section B and carried 15 marks. Candidates were considered to have passed the question if they had scored from 5.5 to 15 marks. Candidates were asked as follows:

(a) (i) *While pumping air into a ball, the volume as well as the pressure increase. Does the Boyles's law applicable here? Briefly, explain.*

(ii) *Hot air balloons are being used in the Serengeti National Park by tourists. Why hot air is more preferred in filling these balloons than cold air? Briefly, explain.*

(iii) *It is said that "Dalton's law of partial pressure cannot hold true for a mixture of SO_2 and O_2 gases. Briefly, explain the truth of this argument.*

(iv) *What would have happened to the gas pressure if the molecular collisions were not elastic?*

(b) *The density of a gas at 27 °C and 1520 mmHg pressure was found to be 5.46×10^{-3} g/cm^3. What will be its density in g/dm^3 at* ***s.t.p.****?*

(c) (i) *Relative densities of carbon dioxide and oxygen are 22 and 16, respectively. If 25 cm^3 of carbon dioxide diffuses in 75 seconds, what volume of oxygen gas will diffuse in 96 seconds under similar conditions?*

(ii) *What are the two significances of Graham's law of diffusion in our daily life?*

The question was attempted by 31,163 (89.7%) out of the 34,743 candidates since it was an optional question in Section B. The statistical data (Figure 8) show that 13,220 (42.4%) of the candidates scored from 0–5; 9,030 (29%) scored from 5.5–8.5 and 8,913 (28.6%) scored from 9–15 marks. Overall, data analysis indicates that 17,943 (56.7%) of the candidates scored from 5.5 to 15 marks. The general performance of candidates on this question was average.

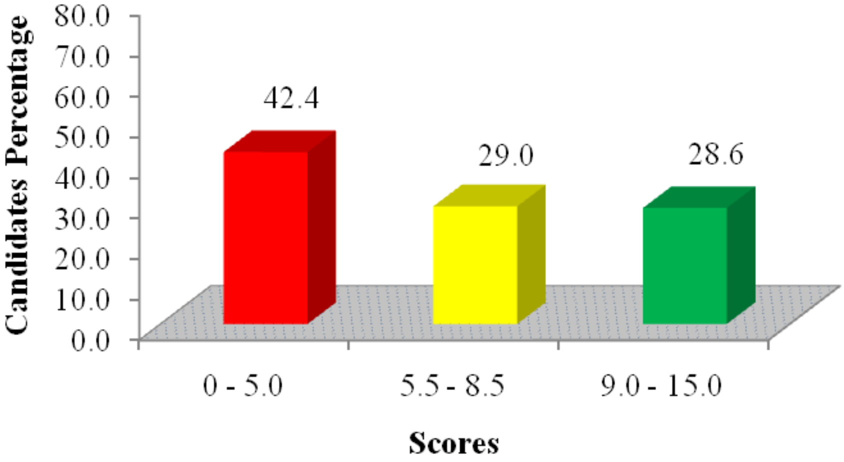


Figure 8: *Candidates Performance on Question 8*

The candidates who performed well (28.6%) gave the correct responses to most parts of the question. This indicated that they were knowledgeable about the concept of gas laws, especially Boyle's law, Charles' law, Dalton's law of partial pressure and Graham's law. They were also competent in applying the kinetic molecular theory of gases and the ideal gas equation. The 29.0 per cent of the candidates who scored averagely responded partially to some parts of the question and skipped others. Extract 8.1 is a sample of the to question 8.

8. (a) (i)

No, Boyle's law is not applicable there
BECAUSE, Boyle's law is applicable for a Constant mass of a gas, but when pumping air into a ball, mass of air change
Boyle's law states that, "Volume of a fixed mass of a gas Is inversely proportional to it's pressure at Constant temperature"

(ii) Hot air is prefferred in filling balloons then cold air
BECAUSE; Hot air has high temperature and so, air expand (charle's law) in doing so density of air decreases and therefore thrust in produced due to low density of air

(iii) Yes, In a mixture of O_2 and SO_2, Dalton's law ~~Can~~ of partial pressure can not hold true
BECAUSE; Oxygen gas react with sulphur dioxide in a mixture

$$O_2 + SO_2 \longrightarrow SO_3$$

Dalton's law is applicable only in a mixture of gases which Can not react to each other

Dalton's law states that, "In a mixture of gases which can not react to each other, total pressure of a gases Is equal to the sum of partial pressure of each gas",

(iv) If molecular collisions were not elastic,
– Gas pressure would decrease untill became zero, (0)
BECAUSE, energy of gases molecule will decrease Continously untill energy became zero and therefore no more energy possessed by gases molecules required to make them move and collide again, since gas pressure is produced by collision of molecules, then even pressure of a gas will be zero (0) after decreasing Continously.

8 (b) Initially

Data given; Temperature, $T_1 = 27°C + 273K$.
$= 300K$

Pressure, $P_1 = 1520mmHg$

Density, $\rho = \frac{m}{V} = \frac{5.46\times10^{-3}g}{1cm^3}$.

Volume ~~x~~, $V_1 = 1cm^3$ (in $5.46\times10^{-3}g$ y a gas)

at s.t.p

Temperature, $T_2 =$ ~~760mmHg~~ 273K.

Pressure, $P_2 = 760mmHg$

Volume, $V_2 = ?$

General gas equation; $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$

$= \frac{1520mmHg \times 1cm^3}{300k} \times \frac{273K}{760mmHg}$

$V_2 = 1.82cm^3$

at s.T.P, gas will have $V = 1.82cm^3$

mass remain constant, $m = 5.46\times10^{-3}g$

Density, $\rho = \frac{m}{V} = \frac{5.46\times10^{-3}g}{1.82cm^3} = 3\times10^{-3}gcm^{-3}$.

$\therefore$ Density y a gas will be $= 3\times10^{-3}gcm^{-3}$

8. (c) (i)

Data given; ~~RA~~ Density y CO_2, $\rho_{CO_2} = 22$

R.Density y O_2, $\rho_{O_2} = 16$

Volume y CO_2, $V_{CO_2} = 25cm^3$, time, $t_{CO_2} = 75s$

Volume y O_2, $V_{O_2} = ?$ $t_{O_2} = 96s$.

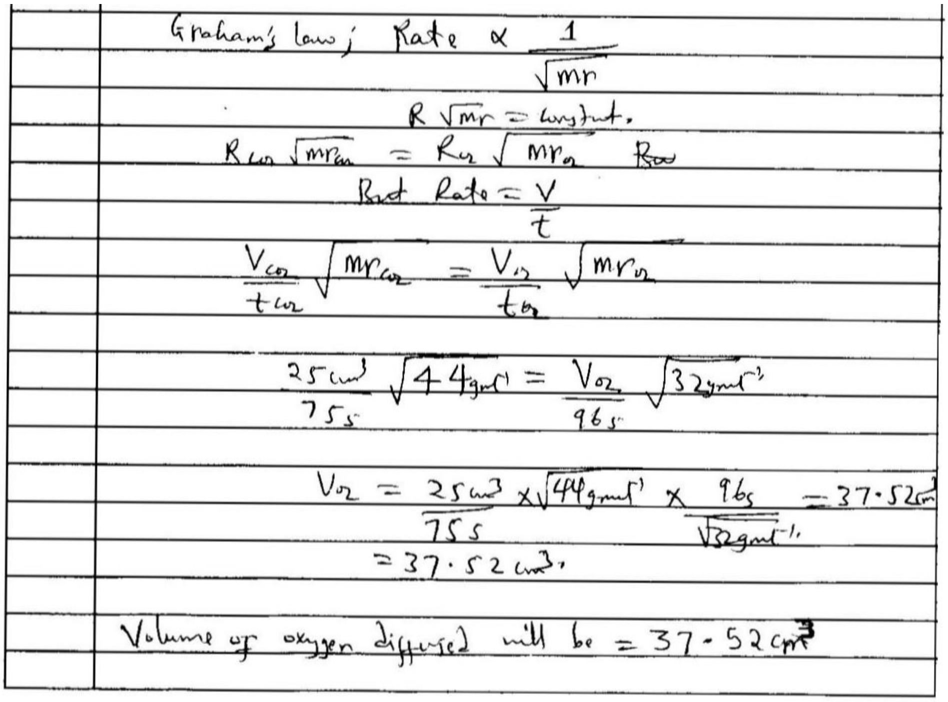
Molar mass of CO_2 $= 2\times$ Relative density

$= 2\times22$

$Mr_{CO_2} = 44gmol^{-1}$.

Molar mass y $O_2 = 2\times16$

$Mr_{O_2} = 32gmol^{-1}$.



Graham's law; Rate $\propto \frac{1}{\sqrt{mr}}$

$R\sqrt{mr}$ = constant.

$R_{co_2}\sqrt{mr_{co_2}} = R_{o_2}\sqrt{mr_{o_2}}$ ~~Roo~~

But Rate $= \frac{V}{t}$

$\frac{V_{co_2}}{t_{co_2}}\sqrt{mr_{co_2}} = \frac{V_{o_2}}{t_{o_2}}\sqrt{mr_{o_2}}$

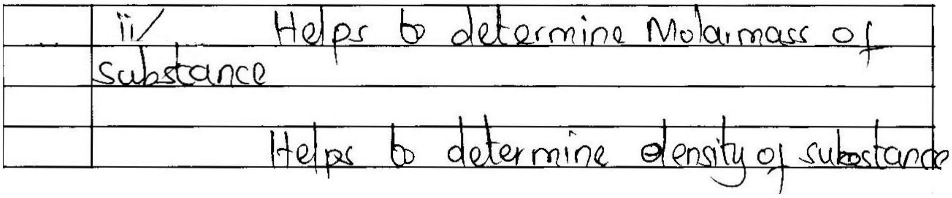
$\frac{25cm^3}{75s}\sqrt{44gmol^{-1}} = \frac{V_{o_2}}{96s}\sqrt{32gmol^{-1}}$

$V_{o_2} = \frac{25cm^3}{75s} \times \sqrt{44gmol^{-1}} \times \frac{96s}{\sqrt{32gmol^{-1}}} = 37.52cm^3$

$= 37.52\,cm^3$.

Volume of oxygen diffused will be $= 37.52cm^3$

Extract 8.1: A sample of the correct responses to question 8



ii/ Helps to determine Molarmass of substance

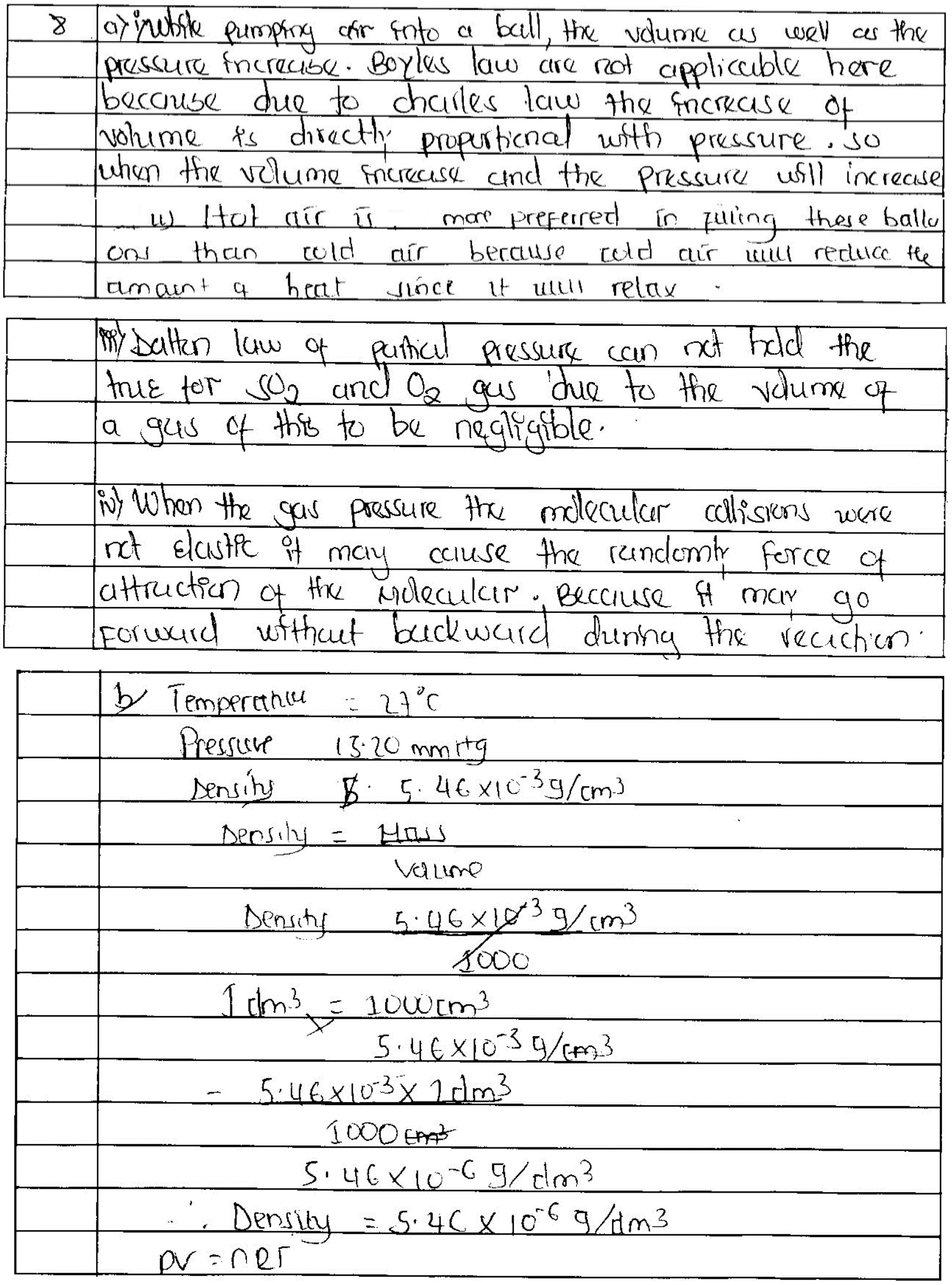
Helps to determine density of substance

Extract 8.2: A sample of the correct responses to question 8

In Extract 8.1, the candidate correctly applied the general concept of gas laws in answering parts (a) and (b). However, the candidate did not give density in g/dm^3; hence, he/she lost some marks. The candidate was supposed to multiply the value of the density he/she obtained by 1000 as it was in g/cm^3. Extract 8.2 shows a response from a candidate appropriately applied the Graham's law.

Despite the good and average responses given by such candidates, 42.4 per cent of the candidates who attempted this question gave incorrect responses. Hence, scored marks below the pass mark (i.e. they scored marks below 5.5). These candidates incorrectly related the variables for the states of gases in part 8(a) (i-iii). They also gave the wrong reasons in part 8(a) (iv) and used the wrong formula or substitution while responding to part 8(b).

Moreover, some of them wrongly converted Graham’s law of diffusion of gases to its mathematical expression. Hence, they did not address part 8(c) of the question. The responses given by these candidates indicated inadequate knowledge about the subtopics of *The Gas Laws*, *Kinetic Theory of Gases* and *Relative Molecular Masses and Densities of Gases*. Extract 8.3 is illustrative.



8 a) i) while pumping air into a ball, the volume as well as the pressure increase. Boyles law are not applicable here because due to charles law the increase of volume is directly proportional with pressure. so when the volume increase and the pressure will increase

ii) Hot air is more preferred in filling these balloons than cold air because cold air will reduce the amount of heat since it will relax.

iii) Dalton law of partical pressure can not hold the true for SO_2 and O_2 gas due to the volume of a gas of this to be negligible.

iv) When the gas pressure the molecular collisions were not elastic it may cause the randomly force of attraction of the molecular. Because it may go forward without backward during the reaction.

b) Temperature = 27°C

Pressure 13.20 mmHg

Density ~~B~~ $5.46 \times 10^{-3}\ g/cm^3$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Density} \quad \frac{5.46 \times 10^{-3}\ g/cm^3}{1000}$$

$1\ dm^3 = 1000\ cm^3$

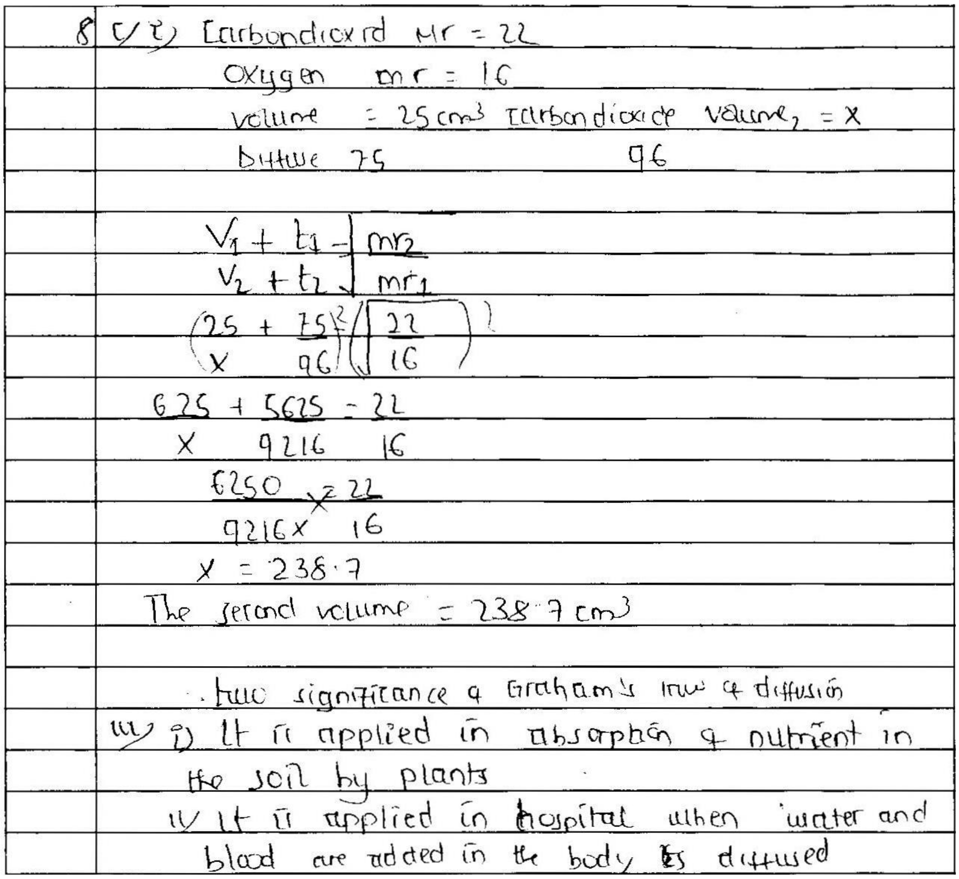
$5.46 \times 10^{-3}\ g/cm^3$

$$= \frac{5.46 \times 10^{-3} \times 1\ dm^3}{1000\ \cancel{cm^3}}$$

$5.46 \times 10^{-6}\ g/dm^3$

$\therefore$ Density $= 5.46 \times 10^{-6}\ g/dm^3$

$pv = nRT$



8 (c) (i) Carbondioxid Mr = 22

Oxygen mr = 16

volume = 25 cm³ Carbondioxide volume₂ = X

Diffuse 75 96

$$\frac{V_1 + t_1}{V_2 + t_2} = \sqrt{\frac{mr_2}{mr_1}}$$

$$\left(\frac{25}{X} + \frac{75}{96}\right)^2 \left(\sqrt{\frac{22}{16}}\right)^2$$

$$\frac{625}{X} + \frac{5625}{9216} = \frac{22}{16}$$

$$\frac{6250}{9216X} = \frac{22}{16}$$

$$X = 238.7$$

The second volume = 238.7 cm³

. two significance of Graham's law of diffusion

(ii) i) It is applied in absorption of nutrient in the soil by plants

ii) It is applied in hospital when water and blood are added in the body is diffused

Extract 8.3: A sample of the incorrect responses to question 8

In Extract 8.3, the candidate gave inappropriate responses to all parts of the question and missed all marks alloted to this question.

2.1.9 Question 9: Selected Compounds of Metals

The question was asked in Section B and carried 15 marks. Candidates were considered to have passed the question if they scored from 5.5 to 15 marks. The question asked as follows:

(a) *Briefly, explain five uses of metal oxides in daily life.*

(b) *When a dilute nitric acid was added to a green solid* ***P****, a blue solution* ***Q*** *was formed and a gas* ***R*** *that formed a white precipitate with lime water was evolved. When the blue solution was evaporated to dryness by heating it in a crucible, a black solid* ***S****, brown fumes of gas* ***T*** *and a gas that relighted a glowing splint were formed.*

  (i) *Identify solids* ***P*** *and* ***S****, and gases* ***R*** *and* ***T****.*

(ii) Write an equation for the reaction between solid ***P*** *and dilute nitric acid.*

(c) What is the importance of the following metal compounds in everyday life?

(i) Lime stone

(ii) Plaster of Paris

The question was attempted by 27,353 (78.7%) out of the 34,743 candidates who sat for the Chemistry examination in the ACSEE, 2022. The candidates' performance (Figure 9) on this question was as follows: 10,722 (39.2%) scored from 0–5; 8,236 (30.1%) scored from 5.5–8.5 and 8,395 (30.7%) scored from 9–15 marks. A further statistical analysis indicates that 16,631 (60.8%) of the candidates who attempted this question passed; they scored 5.5 marks or above. Thus, the candidates' general performance on this question was good.

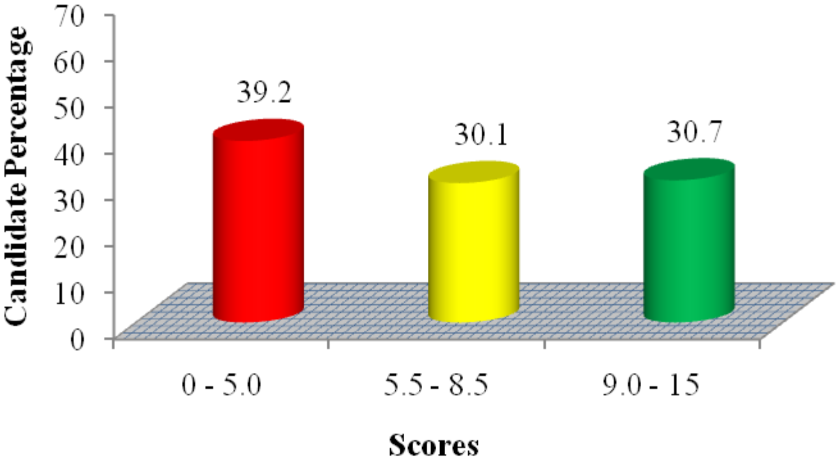


Figure 9: *Candidates' Performance on Question 9*

The 30.7 per cent who scored good marks on this question gave appropriate uses and chemical reactions in part (a), identified the solids and gases asked in part (b) and suggested the uses of metal compounds in part (c) appropriately. Their good responses were attributed to sufficient knowledge of the subtopics of *Oxides*, *Carbonates and Hydrogen Carbonates*, *Sulphates* and *Nitrates*. Extract 9.1 is a sample of the correct responses to this question.

Uses of metal oxides.

(i) They are used in making building materials.

-> Metal oxides can be used in the manufacturing of cement, Limestone and mortar but it can also be used in the making of bricks and different building materials. e.g. CaO and MgO_2 can be used in making $CaCO_3$, $CaHCO_3$ and $MgCO_3$.

ii. They are used in Pharmacentical industries.

Metal oxides are used in the production of tooth pastes, cosmetics, dental cleaners and they are used in the neutralization of other medical reactions such as ulcers and bee stings.

iii. Nanotechnology

They are used in agricultural production of chemicals, pesticides and the production of materials used in the neutralization of soil pH and soil colloids.

iv. Used in production of other chemicals.

Metal oxides are used in the production of other chemicals like Ammonia (NH_3), Zinc and other inorganic chemicals and this includes compounds like CaO used as a drying agent.

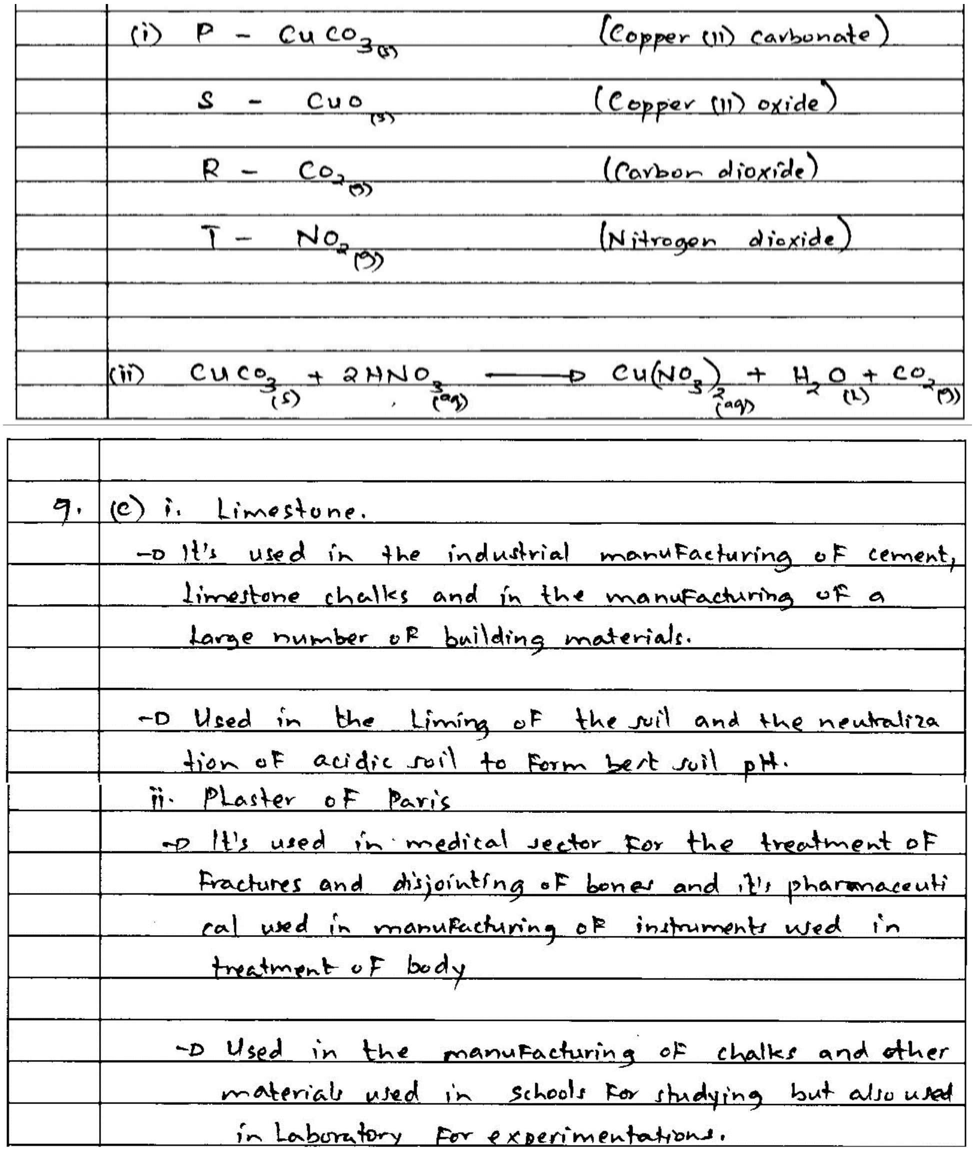
9. (v) They are used in agricultural activities.

Metal oxides can be used in the production of pesticides and agro chemicals added to the soil but they can also be used in soil treatments and adding plant nutrients e.g. Na_2O_2 and MgO_2

(b) i. $$CuCO_{3(s)} + 2HNO_3 \longrightarrow \overset{Q}{Cu(NO_3)_2} + \overset{R}{CO_2} + H_2O$$

$$\Big\downarrow \Delta$$

$$\underset{\text{black solid}}{\overset{S}{CuO}} + \underset{\text{brown Fumes}}{\overset{T}{NO_2}} + O_2$$



(i) P – $CuCO_{3(s)}$ (Copper (II) carbonate)

S – $CuO_{(s)}$ (Copper (II) oxide)

R – $CO_{2(g)}$ (Carbon dioxide)

T – $NO_{2(g)}$ (Nitrogen dioxide)

(ii) $CuCO_{3(s)} + 2HNO_{3(aq)} \longrightarrow Cu(NO_3)_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

9. (c) i. Limestone.

→ It's used in the industrial manufacturing of cement, limestone chalks and in the manufacturing of a large number of building materials.

→ Used in the Liming of the soil and the neutralization of acidic soil to form best soil pH.

ii. PLaster of Paris

→ It's used in medical sector for the treatment of fractures and disjointing of bones and it's pharmaceutical used in manufacturing of instruments used in treatment of body

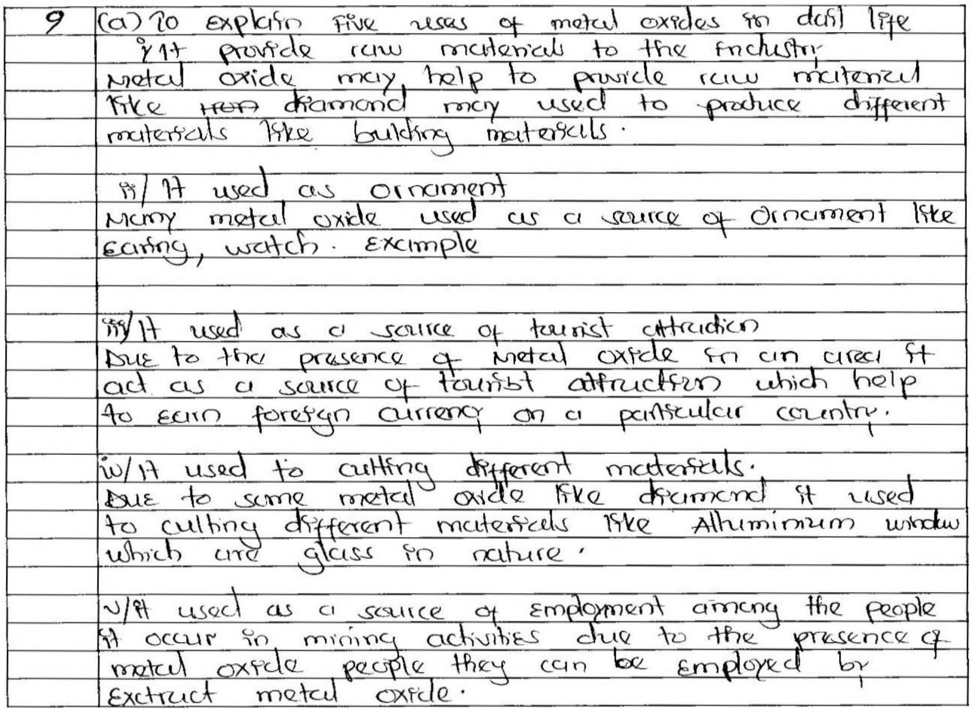
→ Used in the manufacturing of chalks and other materials used in schools for studying but also used in Laboratory for experimentations.

Extract 9.1: A sample of the correct responses to question 9

In Extract 9.1, the candidate provided the correct answers to most parts of the question and scored good marks. However, while responding to part 9(a) of the question, in the first use of metal oxide, the candidate wrote $CaHCO_3$ instead of $Ca(HCO_3)$.

Conversely, other candidates provided partial answers or failed to correctly respond to any part of the question. These failed to understand the key terms used in the question. Such terms include metal oxides, green solid, white precipitate, black solid, brown fumes, limestone, and Plaster of Paris (POP). Understanding these common terms in the topic of *Selected Compounds of*

Metals could have helped them to respond appropriately to the question. Extracts 9.2, 9.3 and 9.4 show samples of the incorrect responses to this question.



9 (a) To explain five uses of metal oxides in daily life

i/ It provide raw materials to the industry

Metal oxide may help to provide raw material like ~~iron~~ diamond may used to produce different materials like building materials.

ii/ It used as ornament

Many metal oxide used as a source of ornament like earing, watch. Example

iii/ It used as a source of tourist attraction

Due to the presence of metal oxide in an area it act as a source of tourist attraction which help to earn foreign currency on a particular country.

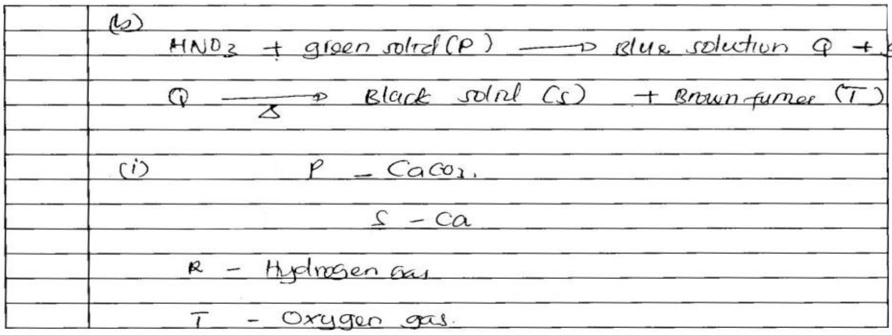
iv/ It used to cutting different materials.

Due to some metal oxide like diamond it used to cutting different materials like Alhuminium window which are glass in nature.

v/ It used as a source of employment among the people

It occur in mining activities due to the presence of metal oxide people they can be employed by Extract metal oxide.

Extract 9.2: A sample of the incorrect responses to question 9 (a)



(b)

$HNO_3 + \text{green solid (P)} \longrightarrow \text{blue solution Q} + \text{gas R}$

$Q \xrightarrow{\Delta} \text{Black solid (S)} + \text{Brown fumes (T)}$

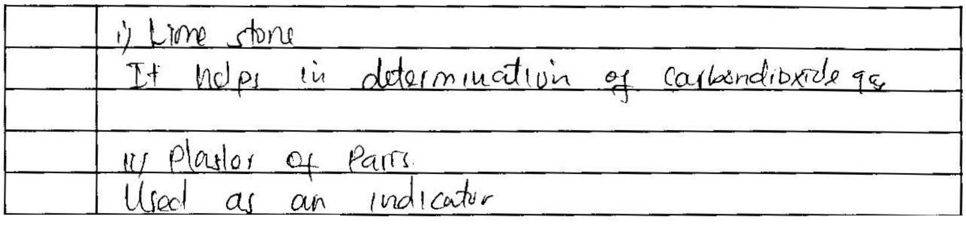
(i) P – $CaCO_3$.

S – Ca

R – Hydrogen gas

T – Oxygen gas.

Extract 9.3: A sample of the incorrect responses to question 9 (b)



i) Lime stone

It helps in determination of carbondioxide gas

ii/ Plastor of Paris

Used as an indicator

Extract 9.4: A sample of the incorrect responses to question 9 (c)

In Extract 9.2, the candidate wrongly explained, in general terms, the uses of metal oxides. In Extract 9.3, the candidate gave only initial steps while trying to identify the asked solids and gases. In Extract 9.4, the candidate gave incorrect uses of the Plaster of Paris.

2.1.10 Question 10: Aliphatic Hydrocarbons, Aromatic Hydrocarbons and Halogen Derivatives of Hydrocarbons

The question was asked in Section B as one of the three optional questions. It carried 15 marks. The candidates were considered to have passed the question if they scored from 5.5 to 15 marks. The question asked as follows:

(a) *Briefly explain the following concepts:*
  (i) *Concentrated sulphuric acid is necessary for nitration of benzene.*
  (ii) *Bromination of benzene takes place in the presence of Lewis acid, while that of hydroxybenzene does not require the presence of Lewis acid.*
  (iii) *Despite chlorine atom being an electron withdrawing group, it directs an incoming group to the ortho or para positions in electrophilic aromatic substitution reactions.*

(b) *During one of the practical sessions in a school, a student wanted to differentiate a set of reagents. Briefly, advise the student on how to differentiate the given sets of reagents while supporting your answer with a chemical equation:*
  (i) *Benzene and ethane*
  (ii) *3-chloro-2-methylpent-2-ene and 1-chloropropane*
  (iii) *Bromobenzene and bromomethane*

(c) *Briefly explain the following concepts:*
  (i) *$(CH_3)_2CHBr$ undergoes SN_1 mechanism, while $CH_3CH_2CH_2Br$ undergoes SN_2 mechanism when they react with aqueous alkalis.*
  (ii) *Haloalkanes undergo nucleophilic substitution reactions, while halobenzenes undergo electrophilic substitution reactions.*

(d) *Two isomeric hydrocarbons **K** and **L** have the molecular formula C_9H_{12}. On oxidation, **K** gives a monocarboxylic acid which when*

> *heated with excess soda lime yields benzene. When* ***L*** *is oxidized, it gives tricarboxylic acid, which can undergo nitration to give a mono-derivative. What are the structural formulae of* ***K*** *and* ***L****?*

The question was attempted by 10,968 (31.6%) out of the 34,743 candidates who sat for the Chemistry examination in the ACSEE, 2022. Their performance on this question was as follows: 8572 (78.2%) scored from 0–5; 1,668 (15.2%) scored from 5.5–8.5 and 728 (6.6%) scored from 9–15 marks (Figure 10). The candidates' overall performance on this question was poor since the majority (8,572, 78.2%) scored below the pass mark (i.e. they scored from 0–5 marks). In addition, statistical data indicate that this question was the least chosen by the candidates in Section B.

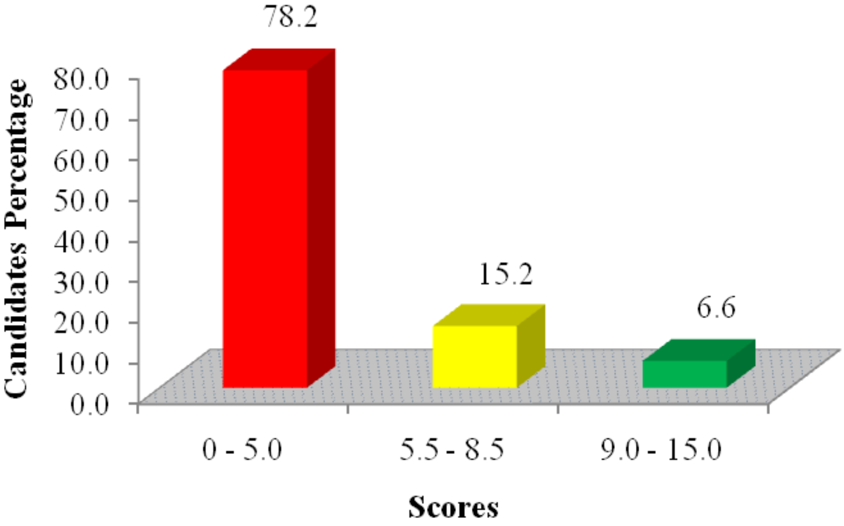
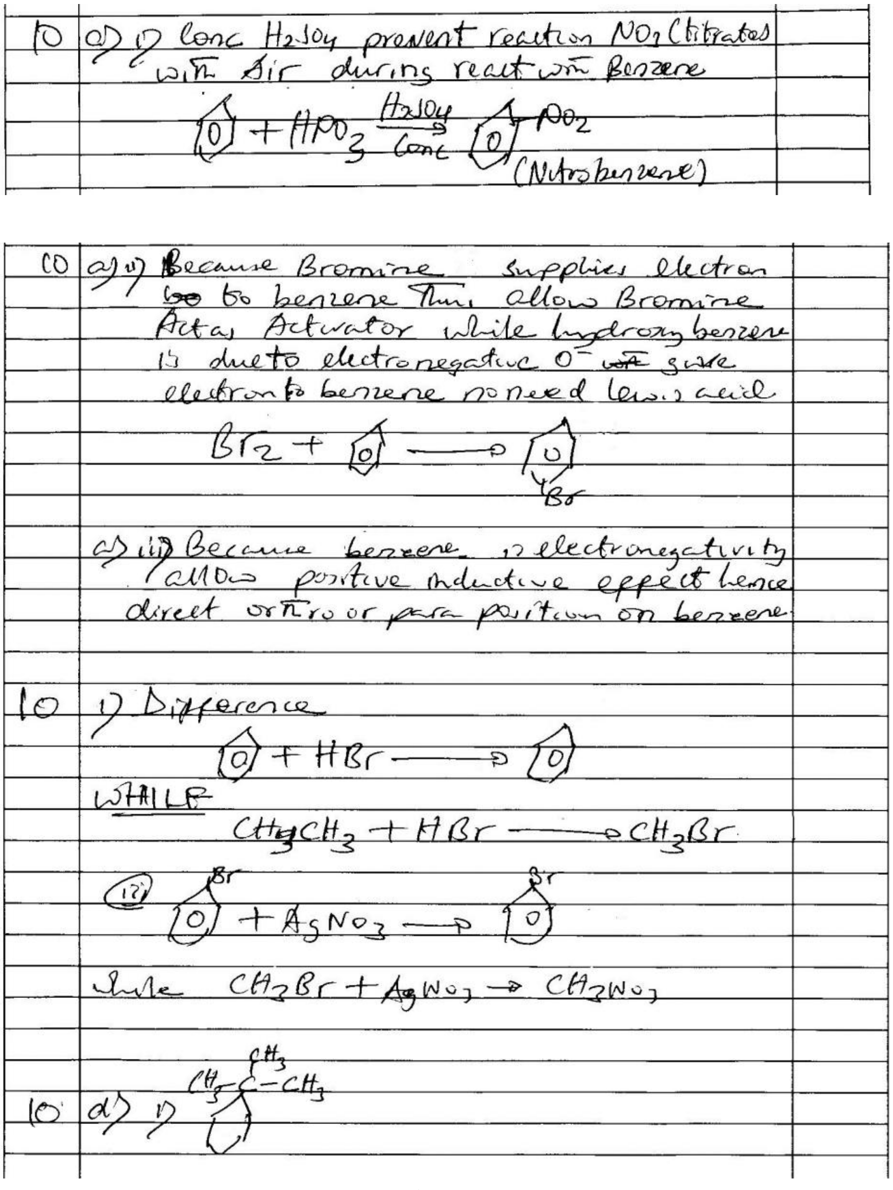


Figure 10: *Candidates' Performance on Question 10*

The candidates who performed poorly on this question provided the wrong answers to most parts of the question. Their responses indicated that the candidates had insufficient knowledge about the delocalization of the benzene π system as well as its ring and outside the ring chemical reactions. They also lacked knowledge of the chemical properties of hydrocarbons and haloalkanes. Hence, they were not knowledgeable about the function of concentrated sulphuric acid in the nitration of benzene in parts (a) (i). Moreover, they failed to understand the role of Lewis acid on Bromine molecule as well as the impact posed by the OH group on the resonance of benzene. Besides, they lacked knowledge of the effect of lone pairs present in chlorine atom in directing the incoming group to the benzene ring in part (a). The candidates failed to give the correct identification of compounds in parts (b) and (d). They gave inappropriate explanations for nucleophilic substitution reactions asked in part (c). Extract 10.1 is an example of the poor to the question.



10 a) i) Conc H_2SO_4 prevent reaction NO_2 (Nitrates) with Air during react with Benzene

$+ HNO_3 \xrightarrow[Conc]{H_2SO_4}$ NO_2 (Nitrobenzene)

10 a) ii) Because Bromine supplies electron ~~bo~~ to benzene Thus allow Bromine Act as Activator while hydroxy benzene is due to electronegative O^- ~~wt~~ give electron to benzene no need lewis acid

$Br_2 +$ ⟶ Br

a) iii) Because benzene is electronegativity allow positive inductive effect hence direct ortho or para position on benzene

10 i) Difference

$+ HBr \longrightarrow$

WHILE

$CH_3CH_3 + HBr \longrightarrow CH_3Br$

(ii) Br $+ AgNO_3 \longrightarrow$ Br

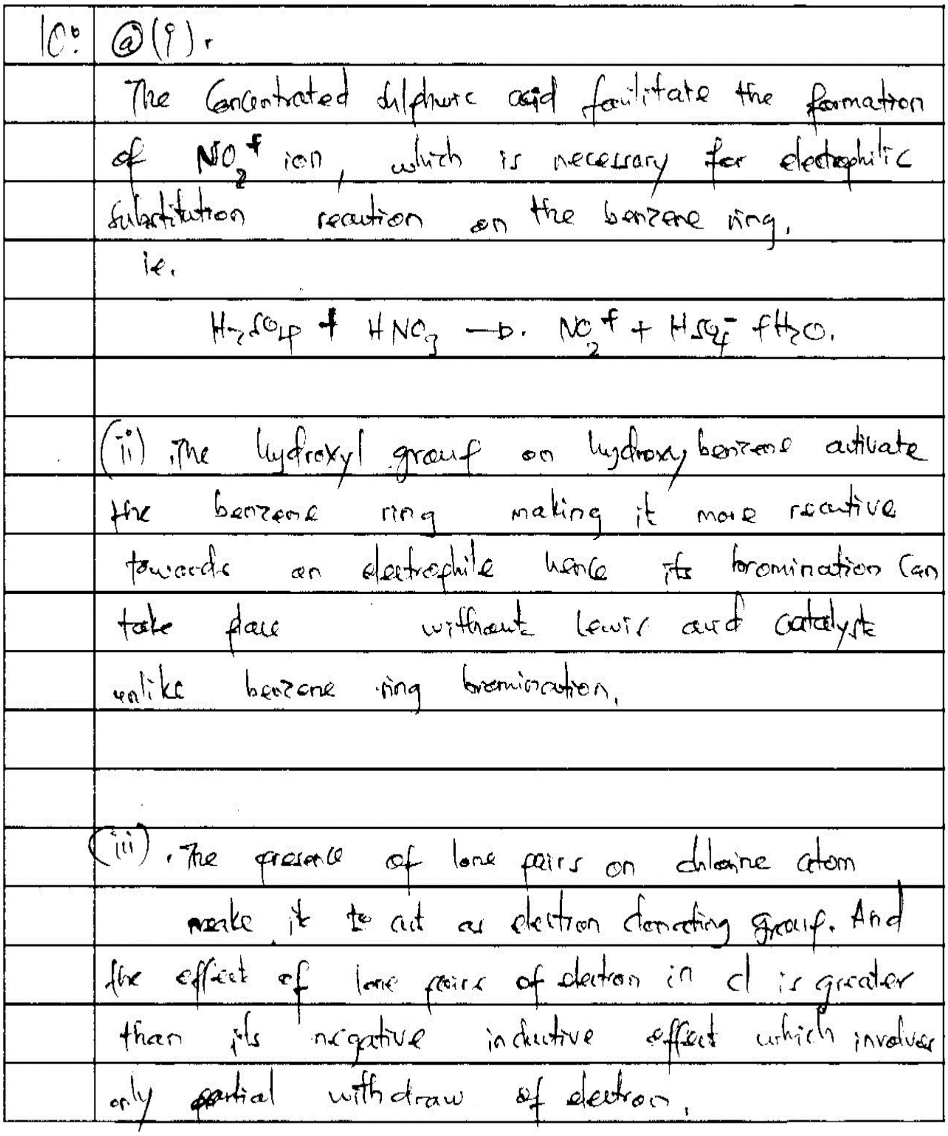
while $CH_3Br + AgNO_3 \rightarrow CH_3NO_3$

10 d) i) CH_3 CH_3-C-CH_3

Extract 10.1: A sample of incorrect responses in question 10

In Extract 10.1, although the candidate wrote the correct equation for bromination of benzene, he/she did not explain the role of concentrated sulphuric acid in that process as per requirement of part 10(a)(i). The candidate gave the wrong explanations and equations on the subsequent parts of the question.

A few candidates (728, 6.6%) chose this question. They responded well and scored good marks. Their responses showed that they gave the correct explanations for the concepts required in part (a). They also correctly differentiated the given sets of chemicals in part (b). They also explained the nucleophilic substitution reactions in part (c) and correctly deduced the structural formula of the unknown isomeric hydrocarbons in the last part of the question correctly. In general, the good performance was due to the candidates' sufficient knowledge of the chemical properties of aliphatic, aromatic and halogen derivatives of hydrocarbons. Extract 10.2 shows an example of the correct responses to the question.



10: ⓐ(i).

The Concentrated sulphuric acid facilitate the formation of NO_2^+ ion, which is necessary for electrophilic substitution reaction on the benzene ring.

ie.

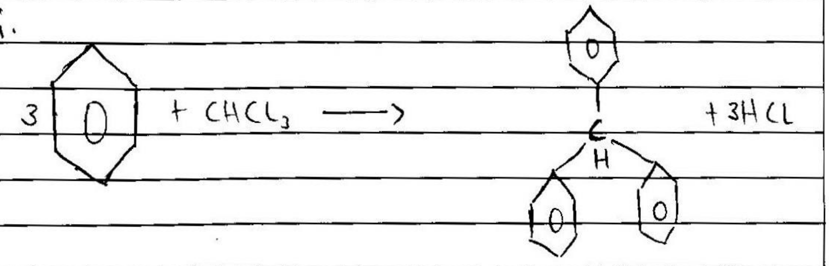
$$H_2SO_4 + HNO_3 \longrightarrow NO_2^+ + HSO_4^- + H_2O.$$

(ii) The hydroxyl group on hydroxybenzene activate the benzene ring making it more reactive towards an electrophile hence its bromination can take place without Lewis acid catalyst unlike benzene ring bromination.

(iii) The presence of lone pairs on chlorine atom make it to act as electron donating group. And the effect of lone pairs of electron in Cl is greater than its negative inductive effect which involves only partial withdraw of electron.

b i: Benzene will react with trichloromethane to give a bright coloured dye whereas ethane does not react with trichloromethane

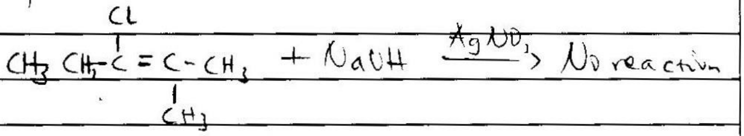
10 b i.



Bright colored dye

$CH_3CH_3 + CHCl_3 \longrightarrow$ No reaction

ii. 3-chloro-2-methylpent-2-ene does not react with sodium hydroxide in presence of silver nitrate whereas 1-chloropropane reacts with sodium hydroxide in presence of silver nitrate to form white precipitate of silver chloride.



$$CH_3CH_2-\overset{Cl}{\overset{|}{C}}=\underset{\underset{CH_3}{|}}{C}-CH_3 + NaOH \xrightarrow{AgNO_3} \text{No reaction}$$

$$CH_3CH_2CH_2Cl + NaOH \xrightarrow{AgNO_3} AgCl_{(s)}$$

White precipitate

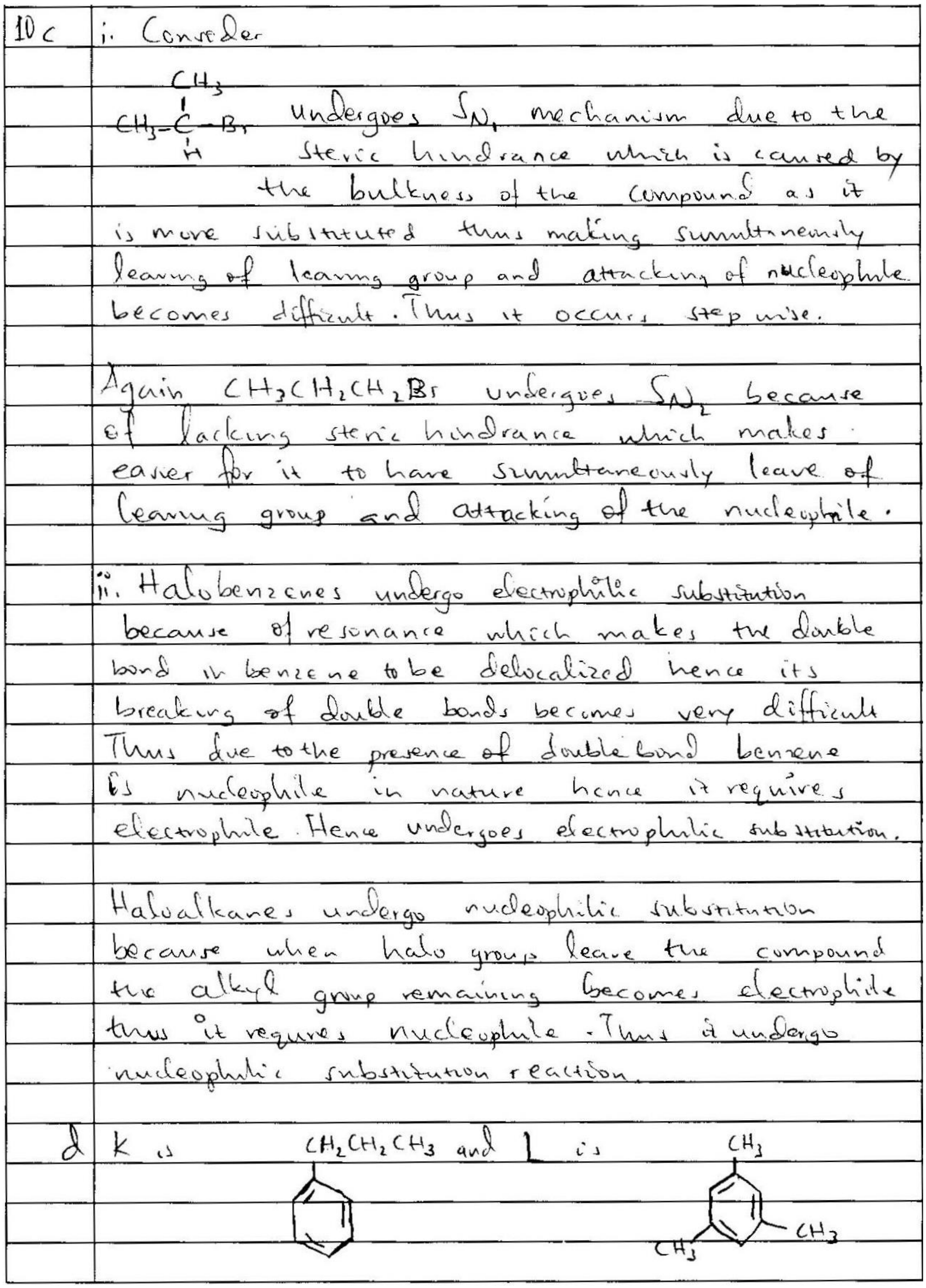
(iii). KOH followed by $AgNO_3$ test.

- on treating bromomethane with KOH followed by $AgNO_3$ it gives positive test by precipitating yellow precipitate of AgBr.

ie.

$CH_3Br + KOH + AgNO_3 \longrightarrow CH_3OH + AgBr + KNO_3$.

Precipitate.



10 c i. Consider

$CH_3-\overset{CH_3}{\underset{H}{C}}-Br$ undergoes S_{N_1} mechanism due to the steric hindrance which is caused by the bulkness of the compound as it is more substituted thus making simultaneously leaving of leaving group and attacking of nucleophile becomes difficult. Thus it occurs step wise.

Again $CH_3CH_2CH_2Br$ undergoes S_{N_2} because of lacking steric hindrance which makes easier for it to have simultaneously leave of leaving group and attacking of the nucleophile.

ii. Halobenzenes undergo electrophilic substitution because of resonance which makes the double bond in benzene to be delocalized hence its breaking of double bonds becomes very difficult. Thus due to the presence of double bond benzene is nucleophile in nature hence it requires electrophile. Hence undergoes electrophilic substitution.

Haloalkanes undergo nucleophilic substitution because when halo group leave the compound the alkyl group remaining becomes electrophile thus it requires nucleophile. Thus it undergo nucleophilic substitution reaction.

d K is $CH_2CH_2CH_3$ and L is CH_3

Extract 10.2: A sample of the correct responses to question 10

In Extract 10.2, the candidate correctly explained the concepts asked in part 10 (a). He/she made correct choices of reagents/conditions and differentiated the given pairs of organic compounds correctly. Lastly, he/she gave the correct structural formulae for K and L.

2.2 132/2-CHEMISTRY 2

Chemistry 2 was a theory paper and consisted of six (6) questions. Each question carried 20 marks. It required the candidates to answer five (5) questions. The candidates were considered to have passed the question if they scored 7 or above out of 20 marks.

2.2.1 Question 1: Two Component Liquid Systems

The question asked as follows:

*(a) (i) A solid **Y** is added to a mixture of benzene and water. After shaking well and allowing the mixture to equilibrate, 10 cm^3 of the benzene layer was found to contain 0.13 g of **Y** while 100 cm^3 of the aqueous layer contained 0.22 g of **Y**. Calculate the value of the distribution coefficient of **Y** between benzene and water.*

*(ii) Comment on the solubility of **Y** in benzene and water with respect to the distribution coefficient you have obtained in 1 (a) (i).*

(b) (i) What are the two applications of fractional distillation? Explain briefly.

(ii) Calculate the percentage by mass of bromobenzene (C_6H_5Br) in the distillate when a mixture of bromobenzene and water distills in steam at 95 °C. The vapour pressures of bromobenzene and water at 95 °C are 1.59×10^4 and 8.50×10^4 N m^{-2} respectively.

(c) Heptane (C_7H_{16}) and octane (C_8H_{18}) form an ideal solution. At 373 K, the vapour pressures of pure heptane and octane were 105.2 kPa and 46.8 kPa respectively. Calculate the vapour pressure of the mixture of 26.0 g of heptane and 35.0 g of octane.

This question was selected by 34,087 (98.1%) of the candidates. Among them, 5,251 (15.4%), 11,134 (32.7%) and 17,702 (51.9%) scored 0–6.5, 7–11 and 12–20 marks, respectively (Figure 11). Moreover, the analysis of statistical data indicates that 28,836 (84.6%) of the candidates scored the pass mark or above (i.e. scored ≥7 out of the 20 marks). Thus, the overall performance of the candidates on this question was good.

The candidates who passed this question (51.9%) correctly applied the distribution law to calculate the value for distribution coefficient. They also managed to provide their views on the solubility of Y with respect to the

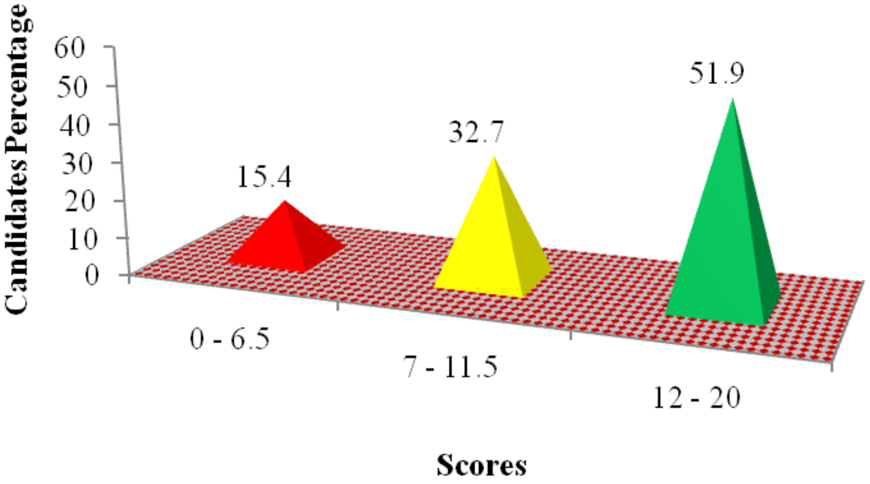
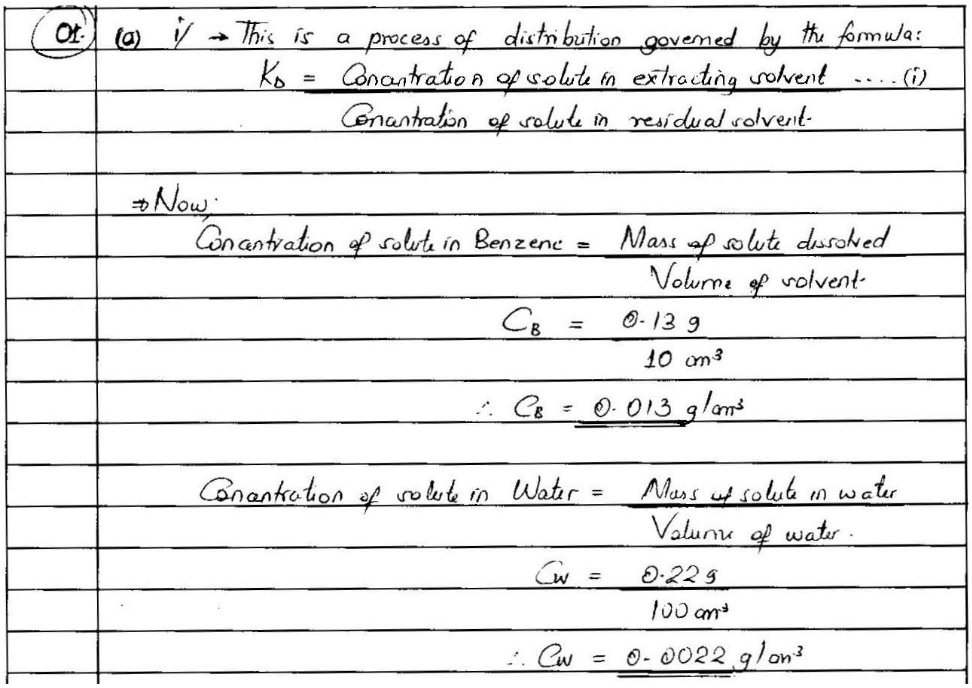


Figure 11: *Performance of the candidates in question 1*

distribution coefficient observed in the preceding part. In addition, candidates who scored good marks correctly calculated the partial pressures of heptane and octane, the total pressure of the mixture, and the percentage by mass of bromobenzene. Their correct responses were attributed to the ability to apply theoretical knowledge. Moreover, the candidates' ability to solve numerical problems and manipulate units contributed significantly to their good performance observed. Extract 11.1 shows a sample of the correct responses to this question.



Q1. (a) i/ → This is a process of distribution governed by the formula:

$$K_D = \frac{\text{Concentration of solute in extracting solvent}}{\text{Concentration of solute in residual solvent}} \quad \dots(i)$$

⇒ Now:

$$\text{Concentration of solute in Benzene} = \frac{\text{Mass of solute dissolved}}{\text{Volume of solvent}}$$

$$C_B = \frac{0.13\ g}{10\ cm^3}$$

$$\therefore C_B = \underline{0.013\ g/cm^3}$$

$$\text{Concentration of solute in Water} = \frac{\text{Mass of solute in water}}{\text{Volume of water}}.$$

$$C_W = \frac{0.22\ g}{100\ cm^3}$$

$$\therefore C_W = \underline{0.0022\ g/cm^3}$$

→ Now, from eqn (i):

$$K_D = \frac{C_B}{C_W}$$ (Between Benzene and Water)

$$K_D = \frac{0.013\ g/cm^3}{0.0022\ g/cm^3}$$

$$K_D = \underline{5.91}$$

∴ The Value of the Distribution Coefficient of Y between Benzene and Water is <u>5.91</u>.

(ii) → Now, distribution coefficient can be expressed in terms of solubility as follows;

$$K_D = \frac{\text{Solubility of solute in Benzene}}{\text{Solubility of solute in aqueous layer}}$$

∴ Thus, we can say that the solute is 5.91 times soluble in Benzene as compared to water.

Q1 (b) i) → Fractional distillation is used in:-

- Separation of constituents in crude oil

— This is a common application since crude oil is a raw material for many products such as petrol, diesel, kerosene, naphtha and many others in the process of crude oil refinery at different temperatures.

- Purification of alcohols:

— This is a useful application in industries where alcohol is passed through different stages of temperature until finally, the pure alcohol is obtained as product and ready for other processes of manufacturing.

ii/ → From:

$$P_T = P_A^\circ X_A + P_B^\circ X_B + P_C^\circ X_C + P_D^\circ X_D + \dots + P_N^\circ X_N$$

→ For N constituents in the mixture:

→ Now:

Number of moles of Bromobenzene = n_b

Number of moles of Water = n_w

→ For Steam distillation, the liquids are immiscible, hence:

$$\frac{P_B^\circ V}{P_W^\circ V} = \frac{n_B RT}{n_W RT}$$

$$\frac{P_B^\circ}{P_W^\circ} = \frac{n_B}{n_W}$$

→ But $n_B = \frac{m_B}{M_{rB}}$ and $n_W = \frac{m_W}{M_{rW}}$

Q1 (b) ii)

$$\frac{P^{\circ}_B}{P^{\circ}_W} = \frac{m_B/Mr_B}{m_W/Mr_W}$$

$$\frac{m_B}{m_W} = \frac{P^{\circ}_B}{P^{\circ}_W} \times \frac{Mr_B}{Mr_W}$$

→ Perantage by mass $= \frac{m_B}{m_W + m_B} \times 100\%$

$$\frac{m_B}{m_W} \times 100\% = \left(\frac{P^{\circ}_B}{P^{\circ}_W} \times \frac{Mr_B}{Mr_W}\right) \times 100\%$$

$$= \frac{1.59 \times 10^4}{8.50 \times 10^4} \times \frac{157}{18} \times 100\%$$

$$= 1.632 \times 100\%$$

Hence;-

$$m_B = 1.632\ m_W$$

From .

$$\frac{m_B}{m_T} = \frac{m_B}{m_B + m_W}$$

$$\%\text{ by mass} = \frac{1.632\ m_W}{1.632 m_W + m_W} \times 100\%$$

$$\%\text{ by mass} = \frac{1.632\ m_W}{2.632\ m_W} \times 100\%$$

$$\%\text{ by mass} = 62\%$$

∴ The Percantage by mass is 62%

Q1. (c) Number of moles of Heptane $= \frac{26g}{100 g/mol}$

$\therefore n_H = 0.26$ moles

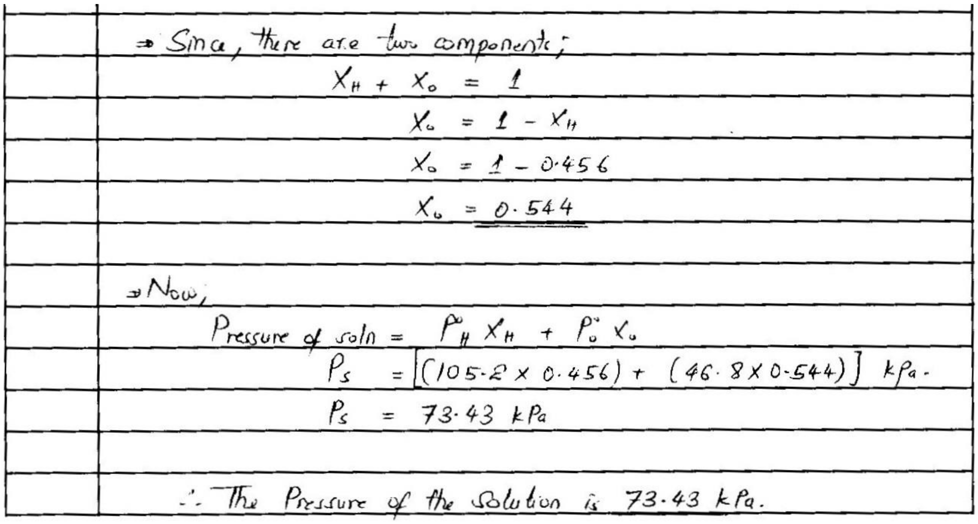
Number of moles of Octane $= \frac{35g}{114 g/mol}$

$n_o = 0.31$ moles

→ Mole fraction of Heptane $= \frac{n_H}{n_H + n_o}$

$$X_H = \frac{0.26}{0.26 + 0.31}$$

$$X_H = 0.456$$



⇒ Since, there are two components;

$X_H + X_o = 1$

$X_o = 1 - X_H$

$X_o = 1 - 0.456$

$X_o = \underline{0.544}$

⇒ Now,

Pressure of soln = $P^o_H X_H + P^o_o X_o$

$P_s = [(105.2 \times 0.456) + (46.8 \times 0.544)]$ kPa.

$P_s = 73.43$ kPa

∴ The Pressure of the Solution is 73.43 kPa.

Extract 11.1 A sample of the correct responses to question 1

Extract 11.1 shows that the candidate correctly related the distribution coefficient and the amount of solute dissolved between the two solvents. Moreover, in part (b), the candidate manipulated the units to obtain the correct value for the percentage composition of the distillate. Lastly, the candidate correctly computed the pressure of the mixture between heptane and octane using Raoult's law.

However, 15.4 per cent of the candidates who attempted this question did not address it accordingly. Their responses indicated that they wrongly calculated the distribution coefficient and provided the wrong comments on the solubility of **Y** in benzene and water in part (a). This was attributed to the insufficient knowledge about the subtopics of *Immiscible Liquids,* and *The Distribution Law*. Likewise, the candidates who scored low failed to calculate the percentage values by the mass of bromobenzene and the vapour pressure of the mixture of heptane and octane in 1 (b) and 1 (c), respectively. They were not knowledgeable about the subtopic of *Immiscible Liquids* (determination of molar mass of a high boiling liquid using steam distillation) and *Completely Miscible Liquids* (application of Raoult's law). Extracts 11.2 and 11.3 shows samples of the incorrect responses to the question.

Q1 (a) (i) Solution

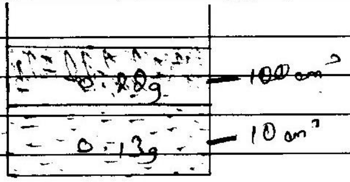
Given 0.13g of Y present in 10cm³ of benzene
0.22g of Y presents in 100cm³ of aques
kd = ?

from:

Distribution Coefficient, $kd = \frac{\text{Upper Concentratio}}{\text{Lower Concentrat}}$

$$kd = \frac{\text{Upper Concentration}}{\text{Lower Concentration}}$$

Consider



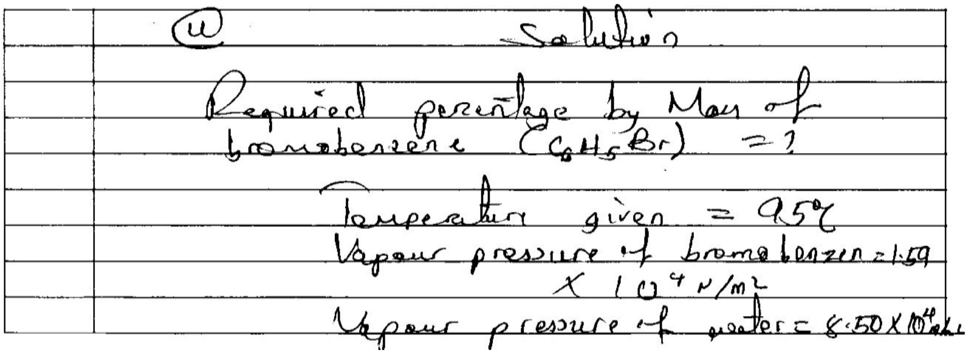
$$kd = \frac{0.22g/100cm^3}{0.13g/10cm^3}$$

$$kd = \frac{0.22g}{100cm^3} \times \frac{10cm^3}{0.13g}$$

$$kd = 0.17$$

∴ The distribution Coffuent of Y = 0.17

Q1 (a) (ii) The Solubility of Y in benzene and water is high Compared to the distribu Coeffiuent present on the Nature of benzene and water



ⓘ Solution

Required percentage by Mass of bromobenzene (C_6H_5Br) = ?

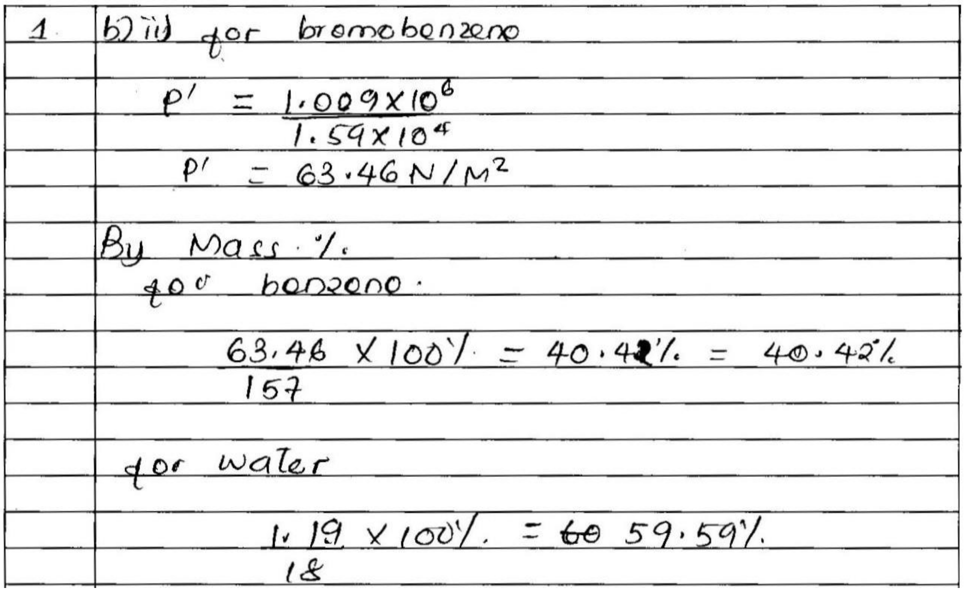
Temperature given = 95°C

Vapour pressure of bromobenzen = 1.59×10^{4} N/m²

Vapour pressure of water = 8.50×10^{4}

Extract 11.2: A sample of the incorrect responses to question 1

In Extract 11.2, the candidate divided the concentration of water with that of benzene in part (a) (i) and obtained the value for distribution coefficient (Kd) as 0.17. However, this was not correct. The candidate was supposed to put the concentration of **Y** in benzene on top and divide it by the concentration of **Y** in water to get Kd = 5.9. The candidate gave an irrelevant statement about the solubility of **Y** between the two layers in part 1 (ii). Besides, the candidate wrote the data given in the question paper without calculating the percentage by the mass of bromobenzene that was asked in 1 (b) (ii).



1. b) ii) for bromobenzeno

$$P' = \frac{1.009 \times 10^{6}}{1.59 \times 10^{4}}$$

$$P' = 63.46\ N/M^{2}$$

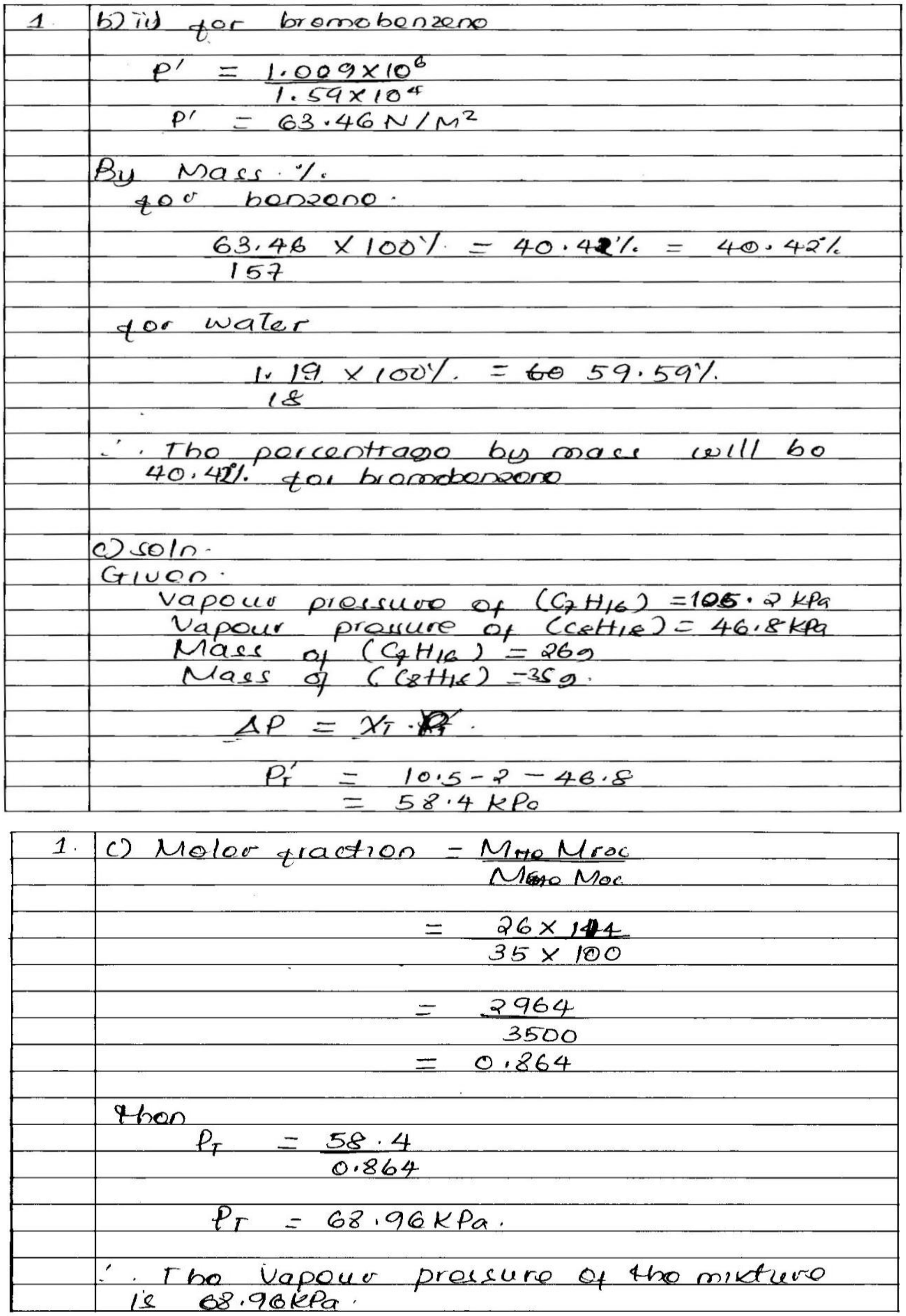
By Mass %

for benzeno.

$$\frac{63.46}{157} \times 100\% = 40.42\% = 40.42\%$$

for water

$$\frac{1.19}{18} \times 100\% = \cancel{60}\ 59.59\%$$



1 b) ii) for bromobenzene

$P' = \frac{1.009\times10^{6}}{1.59\times10^{4}}$

$P' = 63.46\,N/M^2$

By Mass %

for benzene.

$\frac{63.46}{157} \times 100\% = 40.42\% = 40.42\%$

for water

$\frac{1.19}{18} \times 100\% = \cancel{60}\ 59.59\%$

∴ Tho porcentrago by mace will bo 40.42%. for bromobenzene

c) soln.

Given.

Vapour pressure of $(C_7H_{16}) = 105.2$ kPa

Vapour pressure of $(C_8H_{18}) = 46.8$ kPa

Mass of $(C_7H_{16}) = 26g$

Mass of $(C_8H_{18}) = 35g$.

$\Delta P = X_T \cdot \cancel{P}$.

$P_T' = 10.5 - 2 - 46.8$

$= 58.4$ kPa

1. c) Molor fraction $= \frac{M_{H_2O}\,M_{roc}}{M_{H_2O}\,M_{oc}}$

$= \frac{26\times114}{35\times100}$

$= \frac{2964}{3500}$

$= 0.864$

Then

$P_T = \frac{58.4}{0.864}$

$P_T = 68.96$ KPa.

∴ The Vapour pressure of the mixture is 68.96kPa.

Extract 11.3: A sample of the incorrect responses to question 1

Extract 11.3 shows that the candidate wrongly calculated the percentage by the mass of bromobenzene in 1(b) (ii). The candidate also used the wrong formulae to calculate the vapour pressure of the mixture of heptane and octane in the last part of the question.

2.2.2 Question 2: Solubility/Solubility Product and Ionic Product/Acids, Bases and Salts

The question asked as follows:

(a) *Calculate the pH of a sample of pure water at 25 °C. Given* $K_W = 10^{-14}$ *mol*^{2}*/dm*^{6} *at 25 °C.*

(b) *A 500 cm*^{3} *of 0.1 M aqueous solution of* CH_3COOH *(acetic acid) were mixed with 500 cm*^{3} *of 0.1 M HCl solution. If 3 g of NaOH are added to the mixture, calculate the pH of the mixture before and after addition of NaOH, assuming that no change in volume occurs on mixing.*

(c) *(i)* *Although lead(II) chloride is sparingly soluble in pure water, it is soluble in concentrated hydrochloric acid. Explain briefly.*

(ii) *A chemist wanted to separate* Al^{3+} *and* Zn^{2+} *using fractional precipitation method. In the first experiment,* NH_4OH *was added and both* Al^{3+} *and* Zn^{2+} *precipitated. In the second experiment,* NH_4OH *was added followed by addition of* NH_4Cl *and only* Al^{3+} *precipitated. Comment briefly on the results obtained in the second experiment.*

(d) *Equal volumes of 0.025 mol/dm*^{3} *barium nitrate and 0.010 mol/dm*^{3} *sodium fluoride were mixed together. Show whether the solution is saturated, super saturated or unsaturated (*K_{sp} *value of* BaF_2 *is* 1.7×10^{-6} *mol*^{3}*/dm*^{9}*).*

The question was chosen by 31,185 (89.8%) of the candidates. Among them, 23,211 (74.4%) scored from 0–6.5; 7,110 (22.8%) scored from 7–11.5 and 864 (2.8%) scored from 12–20 marks (Figure 12). Statistical data show that 7,974 (25.6%) candidates scored a pass mark or above (i.e. they scored 6.5 or above out of the 20 marks). The candidates’ overall performance on this question was weak since majority (74.4%) scored below the pass mark.

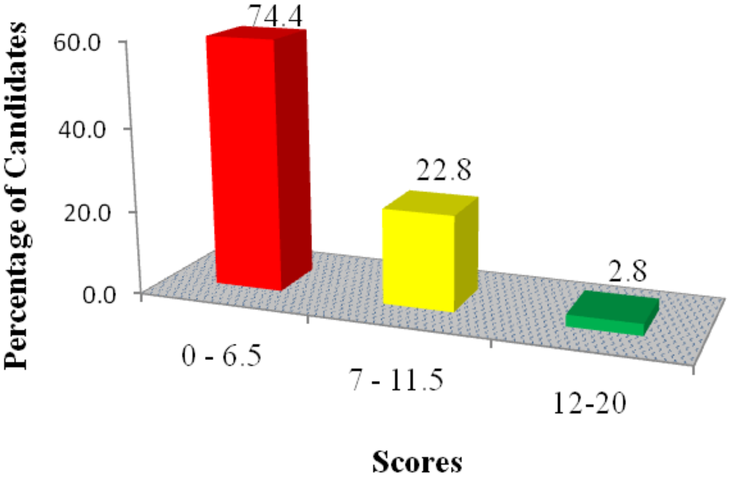
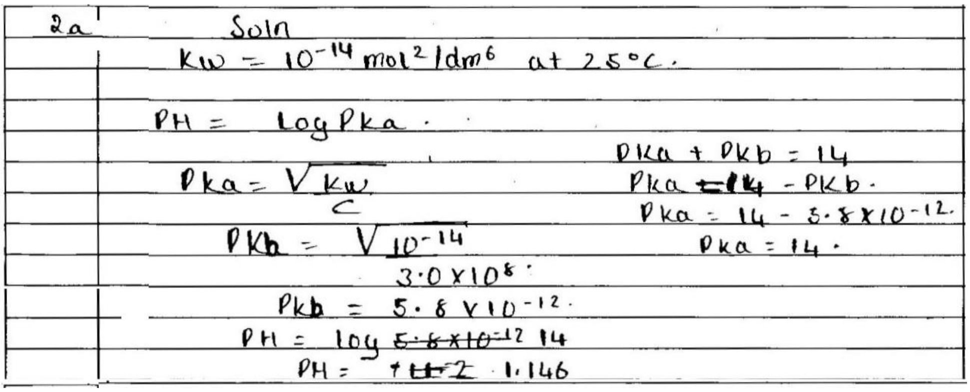


Figure 12: *Candidates' Performance on Question 2*

The candidates who scored low marks on this question failed to calculate the pH of pure water. They had insufficient knowledge about the ionic product of water (K_W). They also failed to assume that the concentrations of hydrogen ions and hydroxide ions are equal at 1 atm and 25 ^{0}C in 2 (a). The candidates failed to compute the pH of the mixture between acetic acid and hydrochloric acid in 2 (b). This was attributed to the lack of knowledge about dilution and electrolytes. In part (c), the candidates explained the effect of the formation of complex compound and common ion on the solubility of sparingly soluble salts incorrectly. Moreover, they predicted wrongly the preferential precipitation of ions. They seemed to have no idea about how ionic product (Q_{SP}) and solubility product (K_{SP}) could have been used to predict/determine the preferential precipitation of ions. Extract 12.1 is an example of the incorrect responses to the question.



2a Soln

$Kw = 10^{-14} mol^2/dm^6$ at 25°C.

$PH = Log Pka$.

$Pka = \sqrt{\frac{Kw}{C}}$

$PKb = \sqrt{\frac{10^{-14}}{3{\cdot}0 \times 10^8}}$

$Pkb = 5{\cdot}8 \times 10^{-12}$.

$PH = \log$ ~~$5{\cdot}8\times10^{-12}$~~ 14

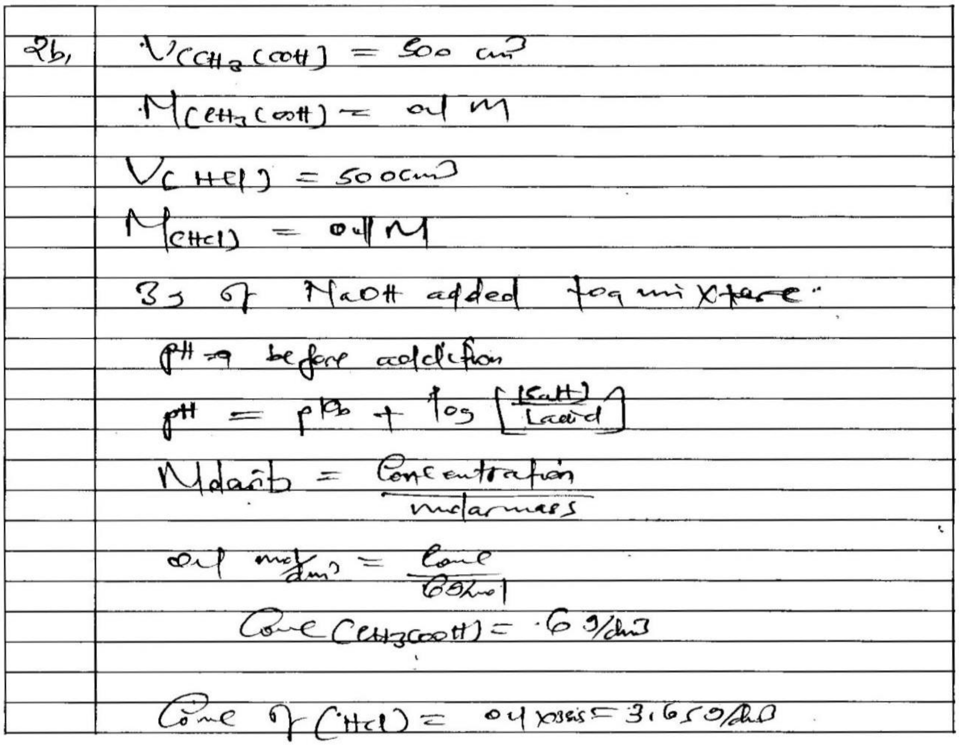
$PH =$ ~~1 11 2~~ 1.146

$Pka + Pkb = 14$

$Pka = 14 - PKb$.

$Pka = 14 - 5{\cdot}8\times10^{-12}$.

$Pka = 14$.



2b,

$V_{(CH_3COOH)} = 500\ cm^3$

$M_{(CH_3COOH)} = 0.1\ M$

$V_{(HCl)} = 500 cm^3$

$M_{(HCl)} = 0.1\ M$

3g of NaOH added to a mixture.

pH = 9 before addition

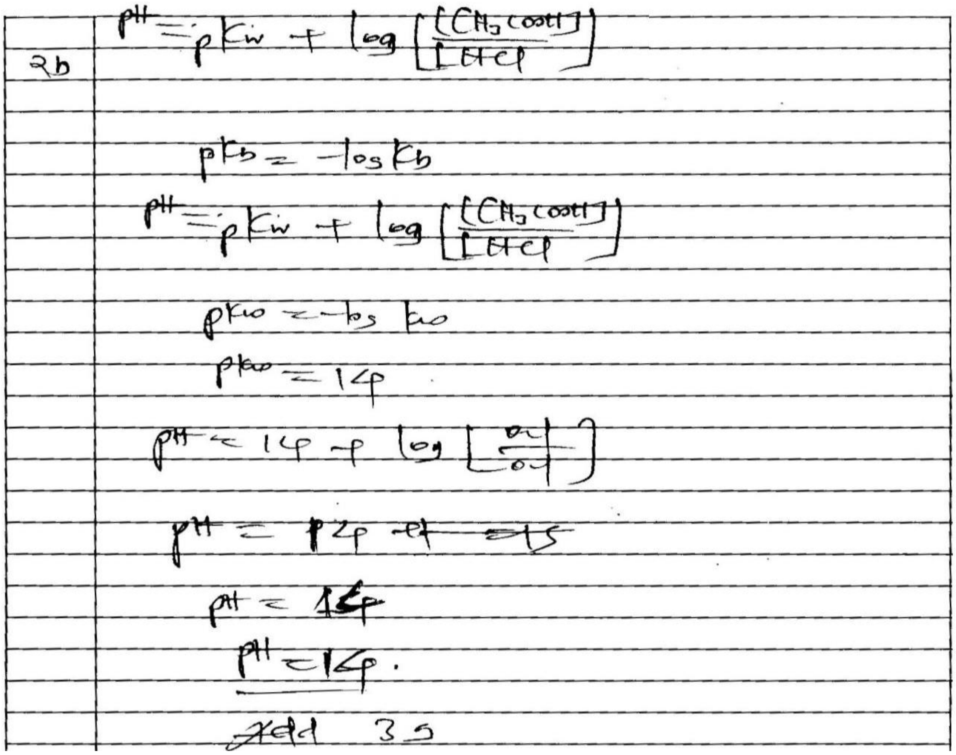
$pH = pKb + \log\left[\frac{[salt]}{[acid]}\right]$

$Molarity = \frac{Concentration}{molar mass}$

$0.1\ mol/dm^3 = \frac{Conc}{60g/mol}$

$Conc\ (CH_3COOH) = .6\ g/dm^3$

$Conc\ of\ (HCl) = 0.1 \times 36.5 = 3.65\ g/dm^3$



2b

$pH = pKw + \log\left[\frac{[CH_3COOH]}{[HCl]}\right]$

$pKb = -\log Kb$

$pH = pKw + \log\left[\frac{[CH_3COOH]}{[HCl]}\right]$

$pKw = -\log Kw$

$pKw = 14$

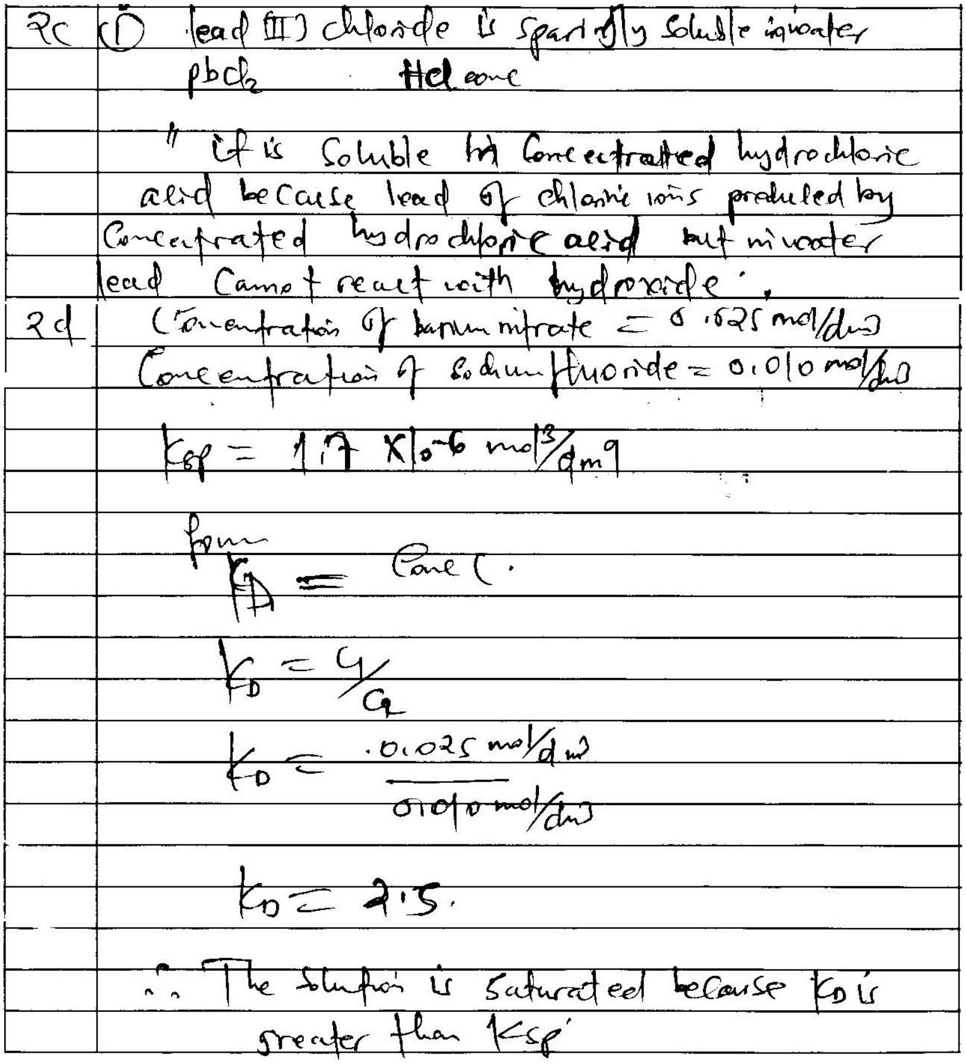
$pH = 14 + \log\left[\frac{0.1}{0.1}\right]$

pH = 14 ~~+1 = 15~~

pH = 14

pH = 14.

~~Add~~ 3g



2c (i) lead (II) chloride is sparingly soluble in water

pbcl₂ HCl conc

" it is soluble in concentrated hydrochloric acid because lead of chlorine ions produced by concentrated hydrochloric acid but in water lead cannot react with hydroxide.

2d Concentration of barium nitrate = 0.025 mol/dm3

Concentration of sodium fluoride = 0.010 mol/dm3

$K_{sp} = 1.7 \times 10^{-6}$ mol³/dm9

from

K_D = Conc (.

$K_D = C_1/C_2$

$K_D = \frac{0.025 \text{ mol/dm3}}{0.010 \text{ mol/dm3}}$

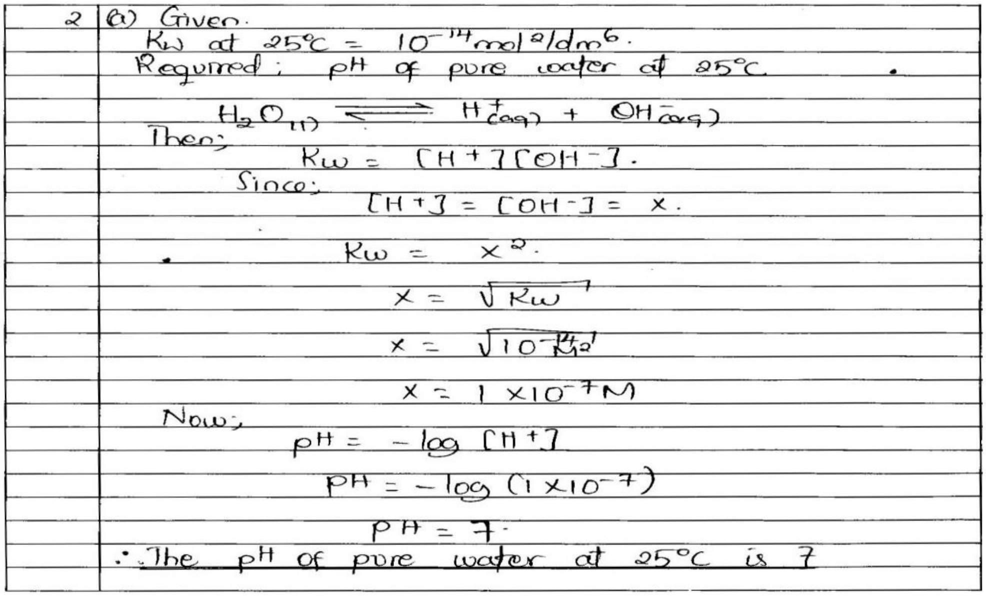
$K_D = 2.5$.

∴ The solution is saturated because K_D is greater than Ksp

Extract 12.1: A sample of the incorrect responses to question 2

In Extract 12.1, the candidate used the incorrect formula to calculate the pH of pure water. The candidate responded incorrectly in the subsequent parts of the question.

In contrast, 864 candidates (2.8%) performed well on this question. They calculated the pH of water in 2 (a) and that of the mixture of acetic, hydrochloric acid and sodium hydroxide in 2 (b). This was possible for them because they had sufficient knowledge about the concept of the ionic product of water (K_W) and pH. They understood that the concentration of hydrogen and hydroxide ions were equal; hence, they calculated the required pH correctly. The candidates also explained the effects of common ion effect and the formation of complex compound in 2 (c). This was because they had sufficient knowledge about the subtopic of *Solubility*. In the last part of the question, the candidates calculated and interpreted the values of ionic product and solubility product to predict the status of solubility of the given sparingly soluble substances. This was associated with their good understanding of the subtopic of *Ionic Product*. As a result, candidates managed to explain the effects of common ion effect and the formation of complex compounds, which increased the solubility of the given sparingly soluble salts. Extracts 12.2–12.4 show sample responses from candidates who performed well on this question.



2 (a) Given.

K_w at 25°C = $10^{-14} mol^2/dm^6$.

Required; pH of pure water at 25°C.

$H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$

Then;

$K_w = [H^+][OH^-]$.

Since;

$[H^+] = [OH^-] = x$.

$K_w = x^2$.

$x = \sqrt{K_w}$

$x = \sqrt{10^{-14}}$

$x = 1 \times 10^{-7} M$

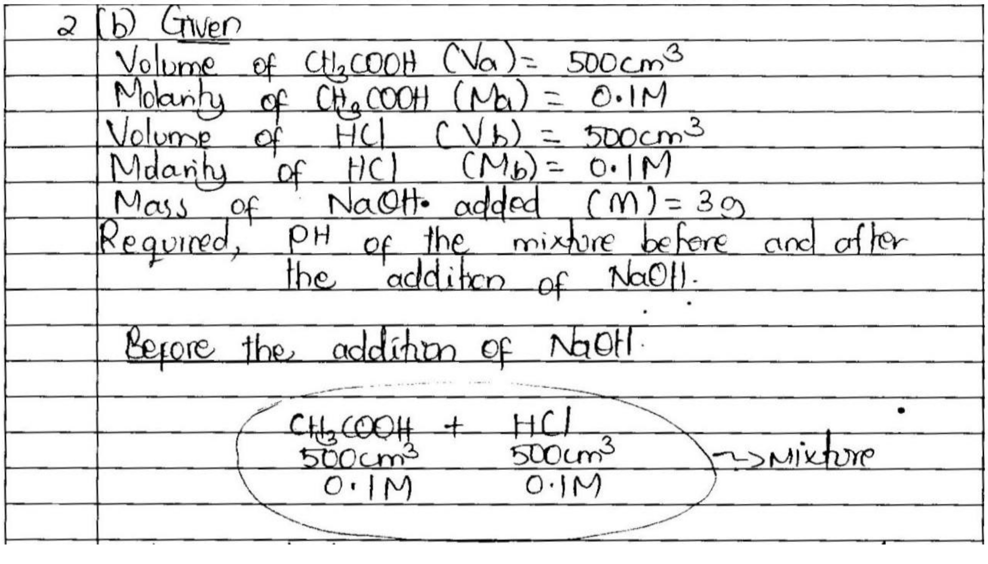
Now;

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

$pH = -\log(1 \times 10^{-7})$

$pH = 7$.

∴ The pH of pure water at 25°C is 7



2 (b) Given

Volume of CH_3COOH (Va) = 500cm³

Molarity of CH_3COOH (Ma) = 0.1M

Volume of HCl (Vb) = 500cm³

Molarity of HCl (Mb) = 0.1M

Mass of NaOH added (M) = 3g

Required, pH of the mixture before and after the addition of NaOH.

Before the addition of NaOH.

$CH_3COOH + HCl$

500cm³ 500cm³ → Mixture

0.1M 0.1M

New molarity of each component in the mixture

For CH_3COOH

$$M_cV_c = M_dV_d.$$

$$M_aV_a = M_dV_d$$

$$M_d = \frac{M_aV_a}{V_d}$$

$$M_d = \frac{0.1M \times 500cm^3}{1000\,cm^3}$$

$$M_d = 0.05M$$

For HCl

$$M_cV_c = M_dV_d$$

$$M_bV_b = M_dV_d$$

$$M_d = \frac{M_bV_b}{V_d}$$

$$M_d = \frac{0.1\,M \times 500cm^3}{1000\,cm^3}$$

2 b) $M_d = 0.05M.$

Then;

$$HCl_{(aq)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

Since CH_3COOH is only a weak acid and it dissociates partially, the hydrogen ions (H^+) in the mixture are mainly due to HCl

Then;

$$\begin{array}{cccc} HCl_{(aq)} & \longrightarrow & H^+_{(aq)} & + & Cl^-_{(aq)} \\ 0.05M & & 0.05M & & 0.05M \end{array}$$

From;

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

$$pH = -\log(0.05)$$

$$pH = 1.3.$$

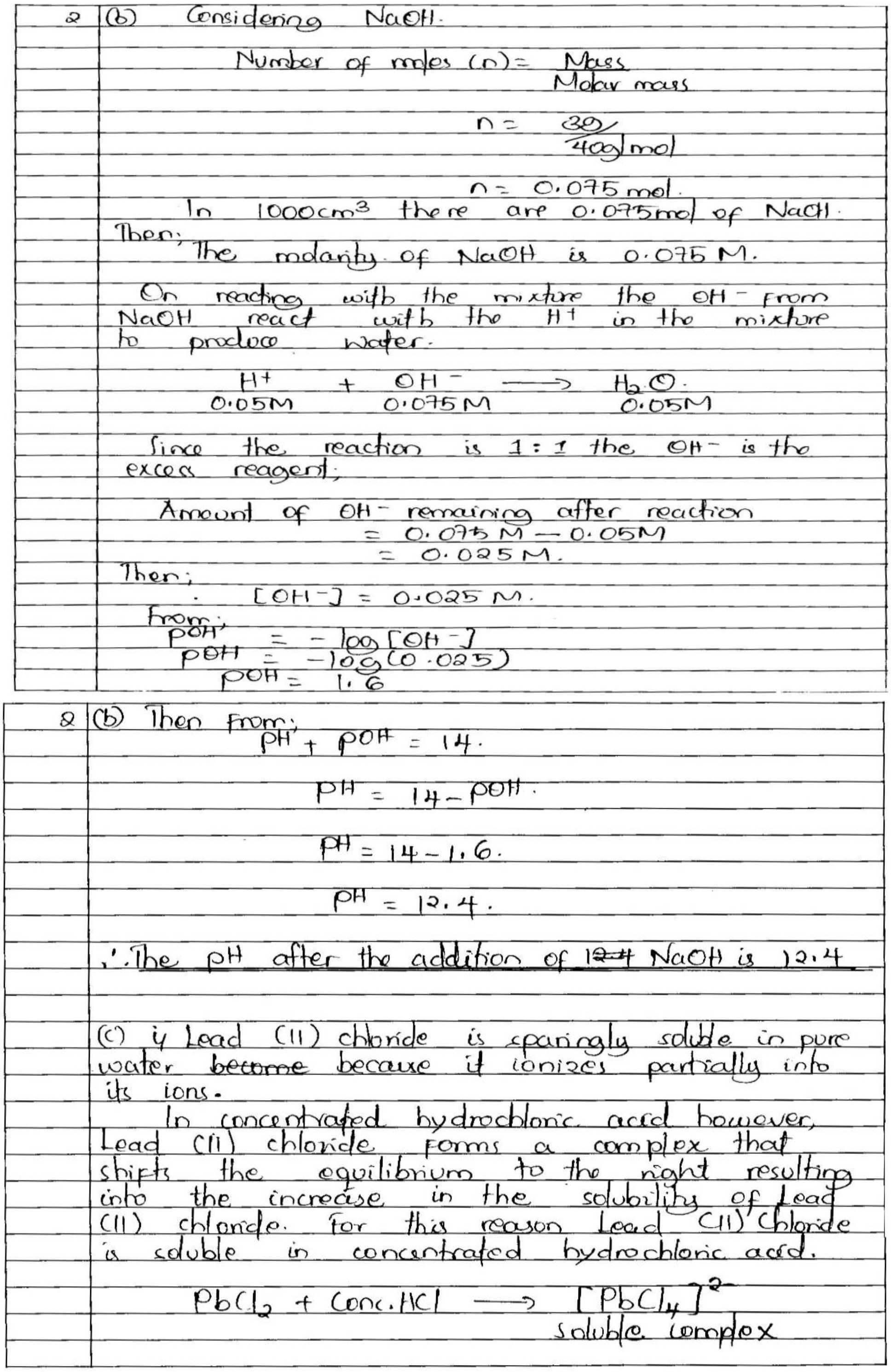
∴ The pH before the addition of NaOH is 1.3

After the addition of NaOH

$$\boxed{\begin{array}{c} CH_3COOH. \\ HCl \end{array} + NaOH} \rightarrow \text{Mixture}$$

$$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O.$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$



2 (b) Considering NaOH.

Number of moles (n) = $\frac{\text{Mass}}{\text{Molar mass}}$

$n = \frac{3g}{40g/mol}$

$n = 0.075$ mol.

In 1000cm^3 there are 0.075mol of NaOH.

Then; The molarity of NaOH is 0.075 M.

On reacting with the mixture the OH$^-$ from NaOH react with the H$^+$ in the mixture to produce water.

$$\underset{0.05M}{H^+} + \underset{0.075M}{OH^-} \longrightarrow \underset{0.05M}{H_2O}.$$

Since the reaction is 1 : 1 the OH$^-$ is the excess reagent;

Amount of OH$^-$ remaining after reaction
= 0.075 M − 0.05M
= 0.025 M.

Then;
$[OH^-] = 0.025$ M.

From;
pOH = −log[OH$^-$]
pOH = −log(0.025)
pOH = 1.6

2 (b) Then from;
pH + pOH = 14.

pH = 14 − pOH.

pH = 14 − 1.6.

pH = 12.4.

∴ The pH after the addition of ~~12.4~~ NaOH is 12.4

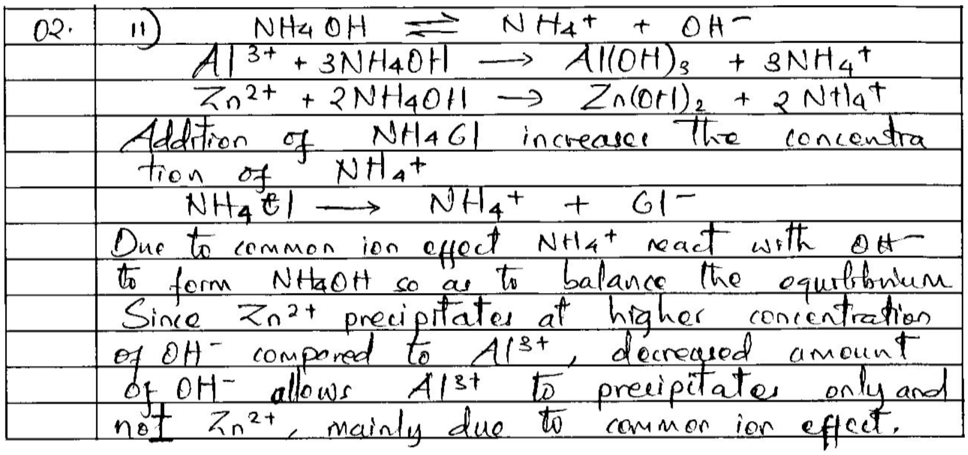
(c) i) Lead (II) chloride is sparingly soluble in pure water ~~become~~ because it ionizes partially into its ions.

In concentrated hydrochloric acid however, Lead (II) chloride forms a complex that shifts the equilibrium to the right resulting into the increase in the solubility of Lead (II) chloride. For this reason Lead (II) Chloride is soluble in concentrated hydrochloric acid.

$$PbCl_2 + Conc.HCl \longrightarrow \underset{\text{soluble complex}}{[PbCl_4]^{2-}}$$

Extract 12.2: A sample of the correct responses to question 2 (a), 2 (b) and 2 (c) (i)

In Extract 12.2, the candidate correctly wrote the mathematical expressions for the ionic product of water (K_w); he/she managed to apply the dilution law, substituted the data, and correctly manipulated the units in parts 2 (a) and 2 (b). Furthermore, the candidate correctly explained the solubility of lead (II) chloride in 2 (c) (i).



02. ii) $NH_4OH \rightleftharpoons NH_4^+ + OH^-$

$Al^{3+} + 3NH_4OH \longrightarrow Al(OH)_3 + 3NH_4^+$

$Zn^{2+} + 2NH_4OH \longrightarrow Zn(OH)_2 + 2NH_4^+$

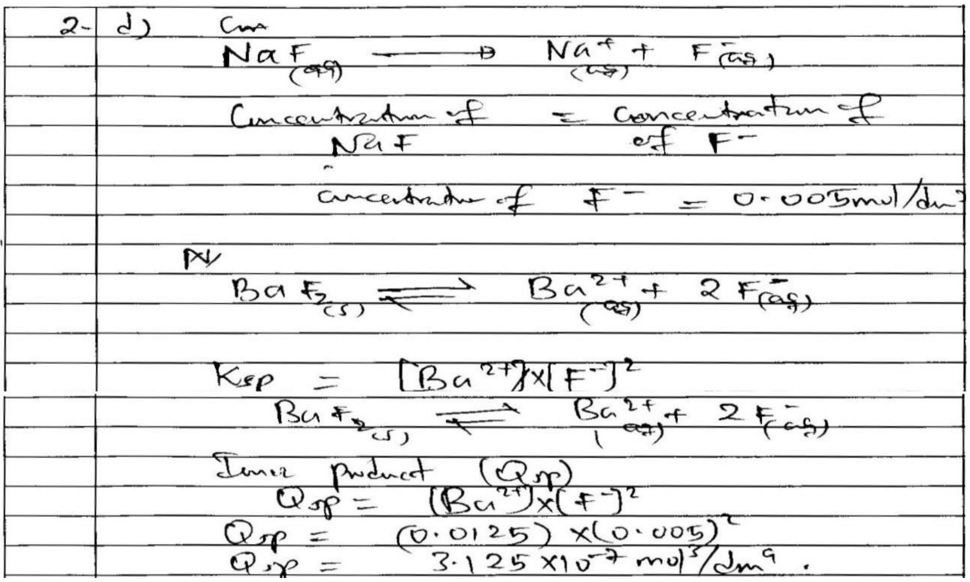
Addition of NH_4Cl increases the concentration of NH_4^+

$NH_4Cl \longrightarrow NH_4^+ + Cl^-$

Due to common ion effect NH_4^+ react with OH^- to form NH_4OH so as to balance the equilibrium. Since Zn^{2+} precipitates at higher concentration of OH^- compared to Al^{3+}, decreased amount of OH^- allows Al^{3+} to precipitates only and not Zn^{2+}, mainly due to common ion effect.

Extract 12.3: A sample of the correct responses to question 2 (c) (ii)

In Extract 12.3, the candidate correctly deduced and explained the solubility of the ionic species given by associating the observation made with the concept of common ion effect.



2- d)

$NaF_{(aq)} \longrightarrow Na^+_{(aq)} + F^-_{(aq)}$

Concentration of NaF = Concentration of F^-

concentration of F^- = 0.005 mol/dm³

$BaF_{2(s)} \rightleftharpoons Ba^{2+}_{(aq)} + 2F^-_{(aq)}$

$Ksp = [Ba^{2+}] \times [F^-]^2$

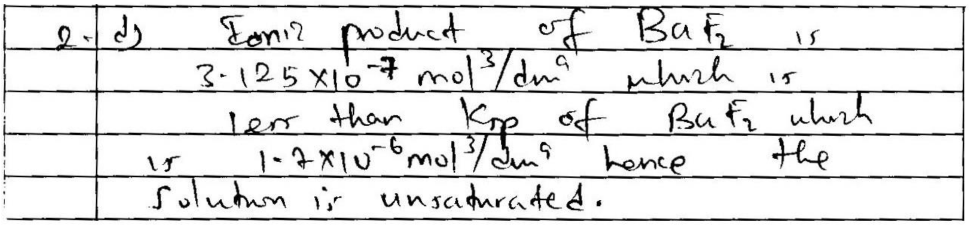
$BaF_{2(s)} \rightleftharpoons Ba^{2+}_{(aq)} + 2F^-_{(aq)}$

Ionic product (Qsp)

$Qsp = [Ba^{2+}] \times [F^-]^2$

$Qsp = (0.0125) \times (0.005)^2$

$Qsp = 3.125 \times 10^{-7}\ mol^3/dm^9$.



2. d) Ionic product of BaF_2 is 3.125×10^{-7} mol^3/dm^9 which is less than Ksp of BaF_2 which is 1.7×10^{-6} mol^3/dm^9 hence the solution is unsaturated.

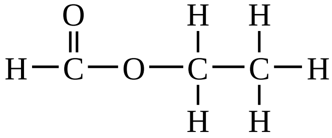
Extract 12.4: A sample of the correct responses to question 2

In Extract 12.4, the candidate correctly calculated the value of the ionic product. He/she made an appropriate conclusion after comparing the value of the calculated ionic product and the given Ksp.

2.2.3 Question 3: Carboxylic Acids and Derivatives/Amines

The question was set from two topics, namely *Carboxylic Acids and Derivatives* and *Amines*. It asked the candidates as follows:

(a) *Compound* ***Q*** *is commonly added to foods to give them rum flavour. It has the following structural formula:*



$HCOOCH_2CH_3$

(i) *To which class of organic compounds does the compound* ***Q*** *belong?*

(ii) *How would you synthesize compound* ***Q*** *from ethanol and methanol and any other suitable inorganic reagent?*

(iii) *What is the IUPAC name of compoun**d Q?***

(iv) *Compoun**d Q** can react with NaOH in presence of heat. How can you represent this reaction using a chemical equatio**n?***

Briefly, comment on the following observations:

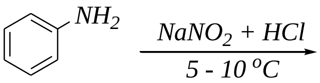
(i) *The boiling point of ethanoic acid is higher than that of ethanol.*

(ii) *Methylamine is a stronger base than ammonia.*

(iii) *Trimethylamine and n-propylamine have the same molecular mass but the former boils at a lower temperature (276 K) than the later (322 K).*

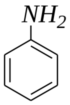
(c) Complete the following organic reactions:

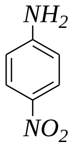
(i)

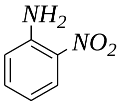


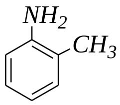
(ii) $CH_3CH_2NH_2 + CHCl_3 + KOH \xrightarrow{alcohol}$

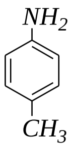
(d) Arrange the following organic compounds in order of increasing their basic strength.











The question was choosen by 23,063 (66.4%) out of the 34,744 candidates who sat for the Chemistry ACSEE 2022. The candidates' performance on this question was as follows: 14,654 (63.5%) scored from 0–6.5, 4,540 (19.7%) scored from 7–11.5 and 3,869 (16.8%) scored from 12–20 marks (Figure 13). These data indicate that 8,409 (36.5%) of the candidates effectively addressed this question as they scored from 7 to 20 marks. Thus, the candidates' overall performance on this question was average in the lower margin.

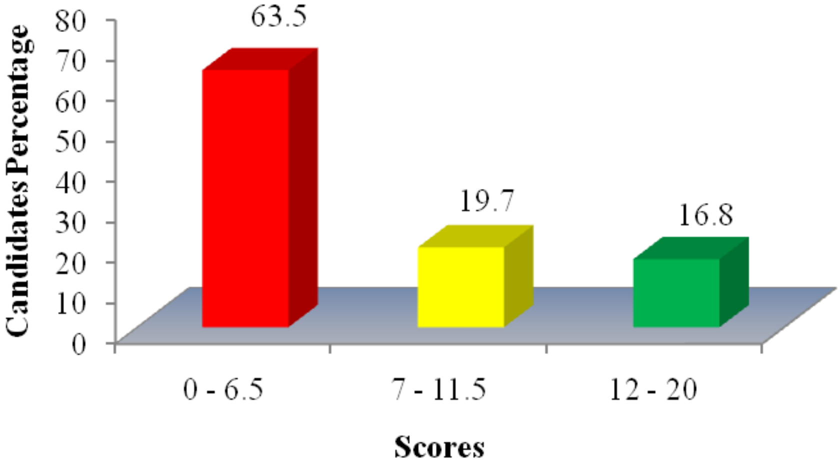
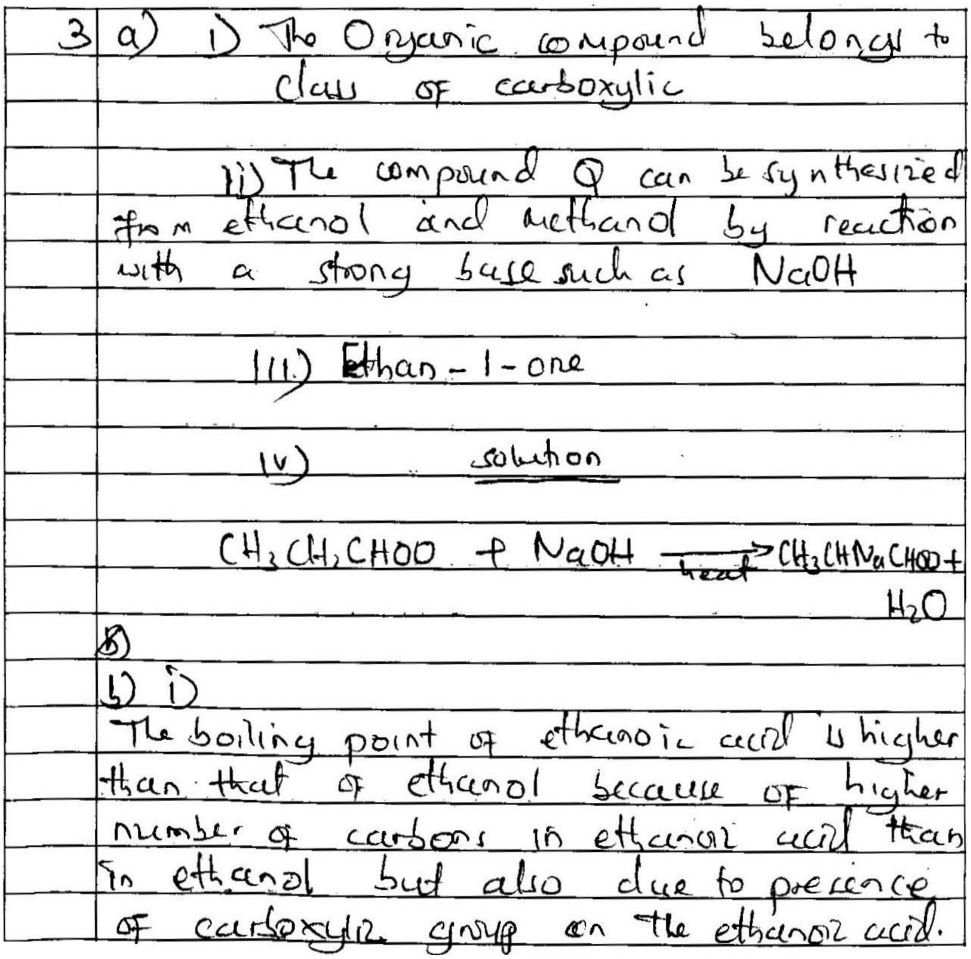


Figure 13: *Candidates' Performance on question 3*

The majority of candidates who failed part 3 (a) of the question (63.5%), mentioned other classes/functionalities of organic compounds such as carbonyl group and ethers, which were not correct. They were supposed to identify the functionality of ester, which was presented in the given compound **Q**. These candidates identified the class of the given organic compound **Q**; hence, failed in part 3 (a) (ii-iv). Their weak performance on part (a) of the question was attributed to insufficient knowledge about the subtopics of *Carboxylic Acids* and *Esters*, which comprise the Topic of *Carboxylic Acids and Derivatives*. In part 3 (b), the candidates who scored low marks gave comments which did not address the requirement of the question. This was because they did not understand the concept and effects of hydrogen bonding on organic acids and amines. Thus, they failed to give appropriate comments on the observations presented in 3(b) (i-iii). Moreover, the candidates with low scores gave incorrect products for the reactions and the arrangement of organic compounds in 3(c) and (d), respectively. A sample of such incorrect responses is given in Extract 13.1.



3 a) i) The Organic compound belongs to class of carboxylic

ii) The compound Q can be synthesized from ethanol and methanol by reaction with a strong base such as NaOH

iii) Ethan-1-one

iv) solution

$CH_3CH_2CHOO + NaOH \xrightarrow[heat]{} CH_3CHNaCHOO + H_2O$

B)

b) i)

The boiling point of ethanoic acid is higher than that of ethanol because of higher number of carbons in ethanoic acid than in ethanol but also due to presence of carboxylic group on the ethanoic acid.

3 b)

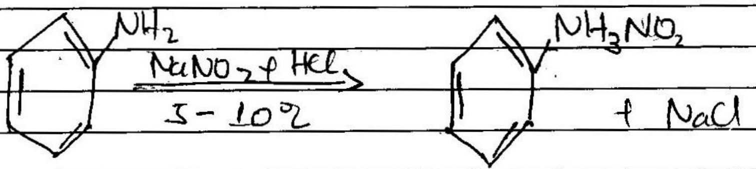
(i)

Methylamine is stronger base than Ammonia because Ammonia contain a lone pair but methylamine do not have it but also Methylamine have high electronegativity than ammonia.

(ii) This is because Trimethylamine contains few number of amines than n-propylamine and this despite they have the same molecular Mass but they differ in boiling points.

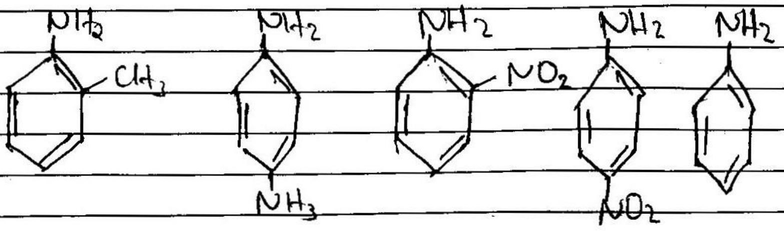
c)

i)



ii) $CH_3CH_2NH_2 + CHCl_3 + KOH \xrightarrow{alcohol} CH_3CH_2NH_3 + KCl + H_2O$

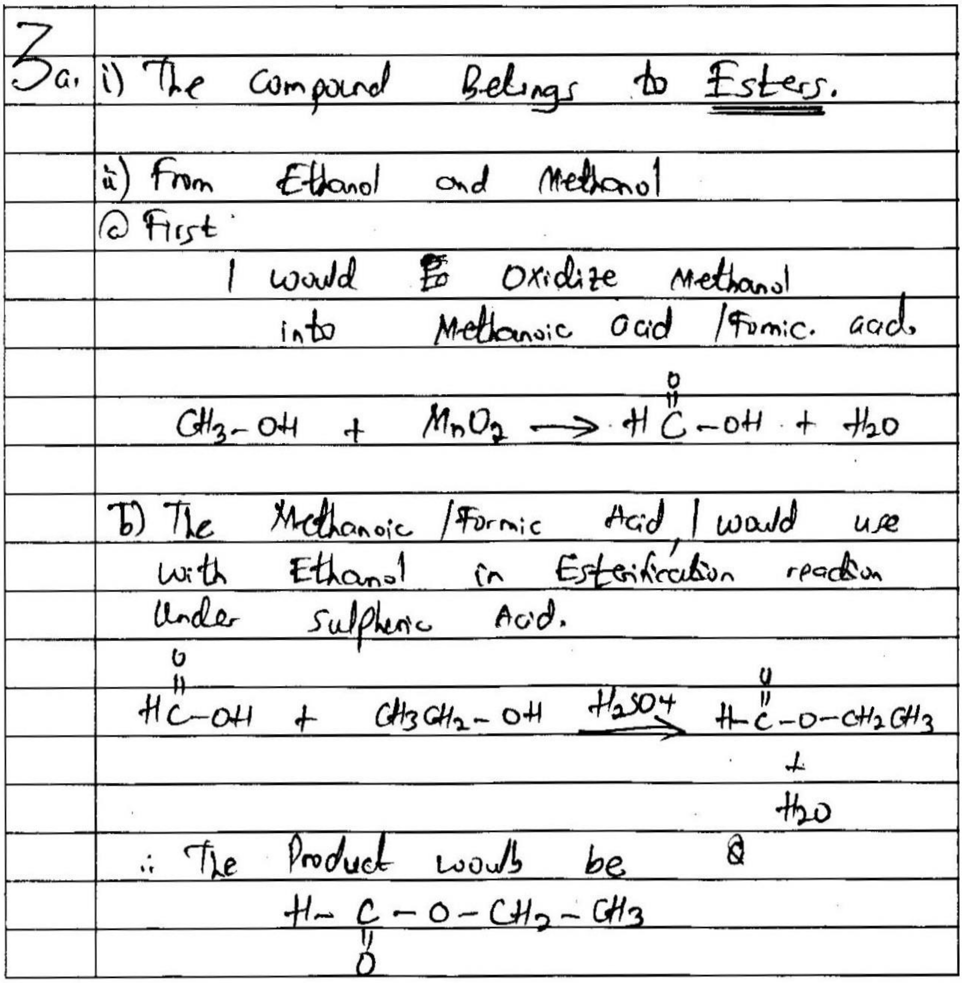
d)



Extract 13.1: A sample of the incorrect responses to question 3

In Extract 13.1, the candidate gave carboxylic acid in 3 (a) (i) as a class to which compound **Q** belongs instead of an ester. The candidate responded by repeating the requirement of the question in 3 (a) (ii) and named compound **Q** incorrectly in 3(a) (iii). Moreover, the candidate gave an incorrect chemical reaction in 3 (a) (iv). The candidate gave incorrect answers in the subsequent parts of the question.

Despite the weak responses to this question by the majority of candidates, 3,869 (16.8%) responded well and scored good marks. These candidates correctly identified the class to which compound **Q** belonged and used ethanol and methanol appropriately to devise the synthesis of compound **Q**. Besides, they named compound **Q** as ethyl methanoate, which was the correct name according to IUPAC rules. Such good responses to this part of the question indicated good mastery of the subtopics of *Carboxylic Acids* and *Esters*. They also managed to associate the concept of hydrogen bonding with the observations given in 3(b). In the last part of the question, they gave correct reaction products and the arrangement of organic bases as per the requirement of the question. Such performance on this part was contributed by adequate knowledge about the subtopic of *Preparation, Properties and Uses of Amines* as shown in Extract 13.2.



3a. i) The Compound Belings to Esters.

ii) From Ethanol and Methanol

(a) First

I would Oxidize Methanol into Methanoic acid /Fomic. acid.

$CH_3-OH + MnO_2 \longrightarrow H\overset{O}{\overset{\|}{C}}-OH + H_2O$

b) The Methanoic /Formic Acid I would use with Ethanol in Esterification reaction Under sulpheric Acid.

$H\overset{O}{\overset{\|}{C}}-OH + CH_3CH_2-OH \xrightarrow{H_2SO_4} H-\overset{O}{\overset{\|}{C}}-O-CH_2CH_3 + H_2O$

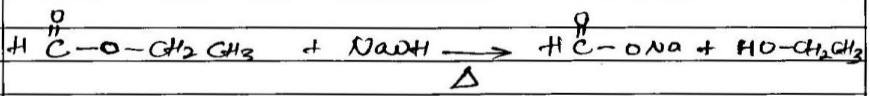
∴ The Product would be Q

$H-\underset{\overset{\|}{O}}{C}-O-CH_2-CH_3$

3a iii) IUPAC name of Q

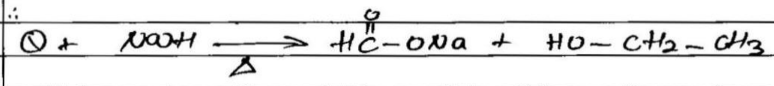
Ethylmethanoate.

3a iv)



$$H\overset{O}{\overset{\|}{C}}-O-CH_2CH_3 + NaOH \xrightarrow[\Delta]{} H\overset{O}{\overset{\|}{C}}-ONa + HO-CH_2CH_3$$

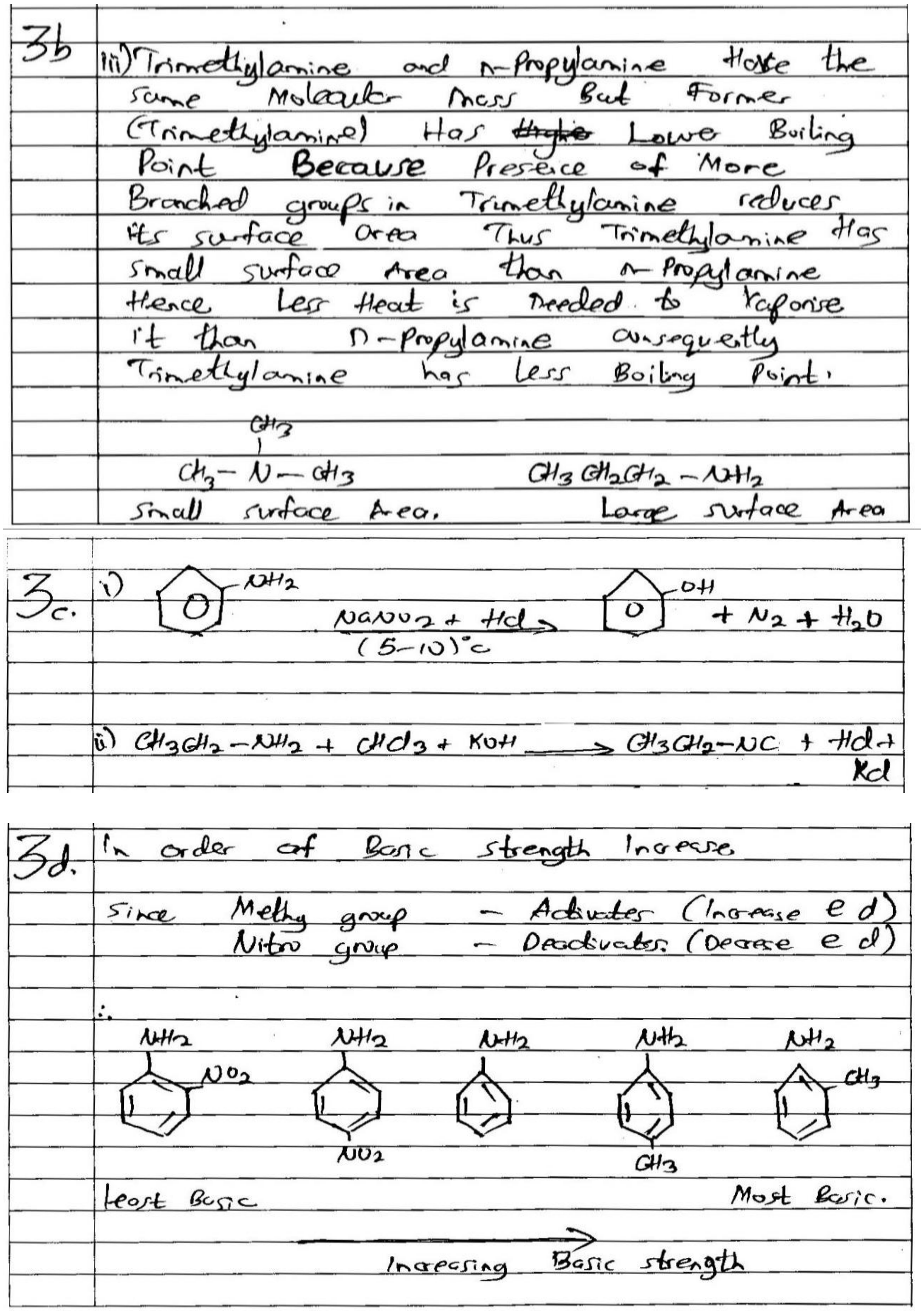
∴



$$Q + NaOH \xrightarrow[\Delta]{} H\overset{O}{\overset{\|}{C}}-ONa + HO-CH_2-CH_3$$

3b. i) Boiling point of ethanoic acid is Higher than that of Ethanol Because Ethanoic Has Greater Hydrogen Bonds Forming ability than Ethanol this is due to presence of double sites of Hydrogen formation is Ethanoic acid as contains $\underset{\overset{\|}{O}}{C}-OH$ group thus two oxygens are possibly used Unlike Ethanol Hence Hydrogen Bonds in ~~A~~ Ethanoic Acids accounts for its greater Boiling point than Methanol with one oxygen Hence less Hydrogen bond forming ability

3b ii) Methylamine is a stronger Base than Ammonia Because Methylamine contains the Methyl group (CH_3-) which is an Activating group that is Supply electrons to the functional group while Ammonia Does not cointain such a group Thus Both Nitrogen in Methyl Amine and Ammonia contains Lone electron Pair However there is More electrons density in Methylamine than Ammonia due to Added electron from Methyl group Hence Methylamine Easily donates its electron Pair than Ammonia Hence More ~~Basing~~ Basic.



3b iii) Trimethylamine and n-Propylamine Have the same Molecular Mass But Former (Trimethylamine) Has ~~Higher~~ Lowe Boiling Point Because Presence of More Branched groups in Trimethylamine reduces its surface area Thus Trimethylamine Has small surface Area than n-Propylamine Hence Less Heat is needed to Vaporise it than n-Propylamine consequently Trimethylamine has less Boiling Point.

$$CH_3-\overset{\overset{\displaystyle CH_3}{|}}{N}-CH_3 \qquad CH_3CH_2CH_2-NH_2$$

Small surface Area. Large surface Area

3c. i) $\xrightarrow[(5-10)^\circ C]{NaNO_2 + HCl}$ $+ N_2 + H_2O$

ii) $CH_3CH_2-NH_2 + CHCl_3 + KOH \longrightarrow CH_3CH_2-NC + HCl + KCl$

3d. In order of Basic strength Increase

Since Methy group – Activates (Increase e d)
Nitro group – Deactivates (Decrese e d)

∴

Least Basic Most Basic.

Increasing Basic strength

Extract 13.2: A sample of correct responses in question 3

In Extract 13.2, the candidate responded very well to the requirement of the question. He/she gave the correct explanation and supported it with appropriate chemical equations. Thus, the candidate scored full marks.

2.2.4 Qustion 4: Electrochemistry

The question was as follows:

(a) *During a tour to one of the emerging local industries in Tanzania, it was noticed that some of the machine parts made up of iron were corroding. What do you think would be the factors affecting the extent of corrosion? Briefly, explain three factors only.*

(b) *By using half-reaction method, balance the following redox reaction if it takes place in an acidic medium:* $Cr_2O_7^{2-}(aq) + HNO_2(aq) \rightarrow Cr^{3+} + NO_3^-(aq)$.

(c) *Ethanedioc acid crystal,* $H_2C_2O_4.\ 2H_2O$, *weighing 0.95 g was dissolved in a 0.25* dm^3 *of distilled water. A 25.0* cm^3 *of the resulting solution required 33.0* cm^3 *of potassium permanganate(VII) solution for complete reaction during a titration experiment. Calculate the concentration of potassium permanganate(VII) solution.*

(d) *With a reason, predict if the reaction will occur when iodine and bromine are added to a solution containing ions of iodide and bromide both maintained at 1 M. The electrode potential for the reactions are given as follows:*

$$I_2 + 2e \rightarrow I^- \quad E° = +0.54V$$

$$Br_2 + 2e^- \rightarrow 2Br^-,\ E° = +1.08V$$

This question was attempted by 32,446 (93.3%) of the 34,744 candidates who sat for the Chemistry ACSEE, 2022. The candidates' performance (also summarized in Figure 14) was as follows: 19,550 (60.3%) scored from 0–6.5; 9,360 (28.8%) scored from 7–11.5 and 3,536 (10.9%) scored from 12–20 marks.

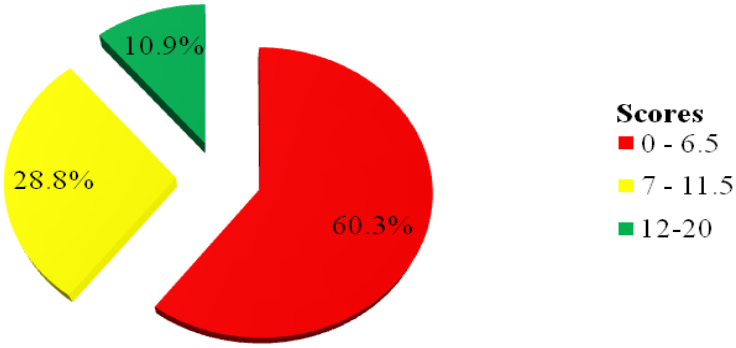
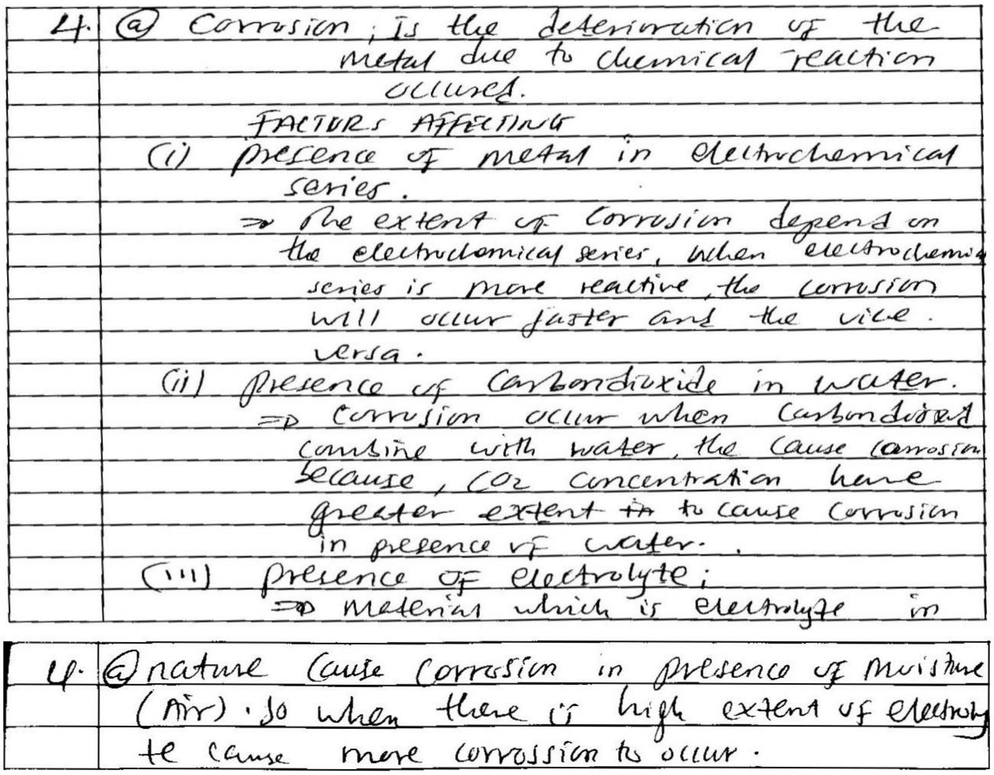


Figure 14: *Candidates' Performance on question 4*

The candidates' overall performance on this question was average as 12,896 (39.7%) candidates who answered this question passed (i.e. they scored 7 marks or above). Though their overall performance was average, a few of them (3,536, 10.9%) answered most parts of the question correctly. They explained the factors affecting the extent of corrosion and correctly balanced the given chemical equation in 4 (a) and 4 (b). Such good responses to these parts were attributed to their sufficient knowledge of oxidation and reduction reactions as well balancing half reactions. Moreover, the candidates correctly calculated the molarity of potassium permanganate(VII) and observed manipulation of units. In the last part of the question, the candidates managed to predict the occurrence of a reaction using the values of given electrode potentials. The appropriate responses observed from the candidates' scripts in part 4 (c) and 4 (d) were attributed to their competencies in performing redox titrations and applying standard electrode potentials. Examples of the correct responses are shown in Extracts 14.1 and 14.2.



4. ⓐ Corrosion; Is the deterioration of the
metal due to chemical reaction
occured.
FACTORS AFFECTING
(i) presence of metal in electrochemical
series.
⇒ The extent of corrosion depend on
the electrochemical series, when electrochemical
series is more reactive, the corrosion
will occur faster and the vice.
versa.
(ii) presence of Carbondioxide in water.
⇒ Corrosion occur when Carbondioxide
combine with water, the cause corrosion
because, CO_2 concentration have
greater extent ~~in~~ to cause corrosion
in presence of water.
(iii) presence of electrolyte;
⇒ Material which is electrolyte in

4. ⓐ nature cause corrosion in presence of moisture
(Air). So when there is high extent of electroly
te cause more corrossion to occur.

Extract 14.1: A sample of the correct responses to question 4 (a)

In extract 14.1, the candidate appropriately explained the factors that could affect the extent of corrosion in our emerging local industries.

(b) Given

$$Cr_2O_7^{2-}(aq) + HNO_2(aq) \longrightarrow Cr^{3+} + NO_3^-(aq)$$

Half-reduction equation

$$Cr_2O_7^{2-}(aq) \longrightarrow Cr^{3+}(aq)$$

$$Cr_2O_7^{2-}(aq) \longrightarrow 2Cr^{3+}(aq)$$

$$Cr_2O_7^{2-}(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O$$

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O$$

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6\bar{e} \longrightarrow 2Cr^{3+}(aq) + 7H_2O$$

4 (b) Half-oxidation equation.

$$HNO_2(aq) \longrightarrow NO_3^-(aq)$$

$$HNO_2(aq) + H_2O(l) \longrightarrow NO_3^-(aq)$$

$$HNO_2(aq) + H_2O(l) \longrightarrow NO_3^-(aq) + 3H^+(aq)$$

$$HNO_2(aq) + H_2O(l) \longrightarrow NO_3^-(aq) + 3H^+(aq) + 2\bar{e}$$

Overall equation.

$$\begin{array}{l} 3 \\ 1 \end{array}\left\{\begin{array}{l} HNO_2(aq) + H_2O(l) \longrightarrow NO_3^-(aq) + 3H^+(aq) + 2\bar{e} \\ Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6\bar{e} \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l) \end{array}\right.$$

$$+\left\{\begin{array}{l} 3HNO_2(aq) + 3H_2O(l) \longrightarrow 3NO_3^-(aq) + 9H^+(aq) + 6\bar{e} \\ Cr_2O_7^{2-}(aq) + 14H^+ + 6\bar{e} \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l) \end{array}\right.$$

$$3HNO_2(aq) + Cr_2O_7^{2-}(aq) + 5H^+ \longrightarrow 2Cr^{3+}(aq) + 3NO_3^-(aq) + 4H_2O(l)$$

The overall balanced redox reaction is as follows

$$3HNO_2(aq) + Cr_2O_7^{2-}(aq) + 5H^+ \longrightarrow 2Cr^{3+}(aq) + 3NO_3^-(aq) + 4H_2O(l)$$

4 (C) Given

Mass of $H_2C_2O_4 \cdot 2H_2O$ = 0·95g
Volume of water = ~~26~~ 0·25dm^3
Volume of $H_2C_2O_4 \cdot 2H_2O$ used = 25cm^3
Volume of $KMnO_4$ used = 33cm^3
Required; Concentration of $KMnO_4$.

Consider the reaction

$$C_2O_4^{2-}(aq) + MnO_4^- \longrightarrow Mn^{2+} + CO_2$$

Then;

$$MnO_4^-(aq) \longrightarrow Mn^{2+}(aq)$$
$$MnO_4^-(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$$
$$MnO_4^-(aq) + 8H^+(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$$
$$MnO_4^-(aq) + 8H^+(aq) + 5\bar{e} \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$$

↳ Half – reduction equation.

Also;

$$C_2O_4^{2-}(aq) \longrightarrow CO_2.$$
$$C_2O_4^{2-}(aq) \longrightarrow 2CO_2$$
$$C_2O_4^{2-}(aq) \longrightarrow 2CO_2 + 2\bar{e}$$

↳ Half – oxidation equation

Overall equation.

$$2\{MnO_4^-(aq) + 8H^+(aq) + 5\bar{e} \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$$
$$5\{C_2O_4^{2-}(aq) \longrightarrow 2CO_2(g) + 2\bar{e}$$

$$+\begin{cases} 2MnO_4^-(aq) + 16H^+ + 10\bar{e} \longrightarrow 2Mn^{2+} + 8H_2O(l) \\ 5C_2O_4^{2-}(aq) \longrightarrow 10CO_2 + 10\bar{e} \end{cases}$$

$$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 10CO_2 + 8H_2O(l)$$

4 (C) From the balanced equation:

$$n_{MnO_4^-} = 2$$
$$n_{C_2O_4^-} = 5.$$

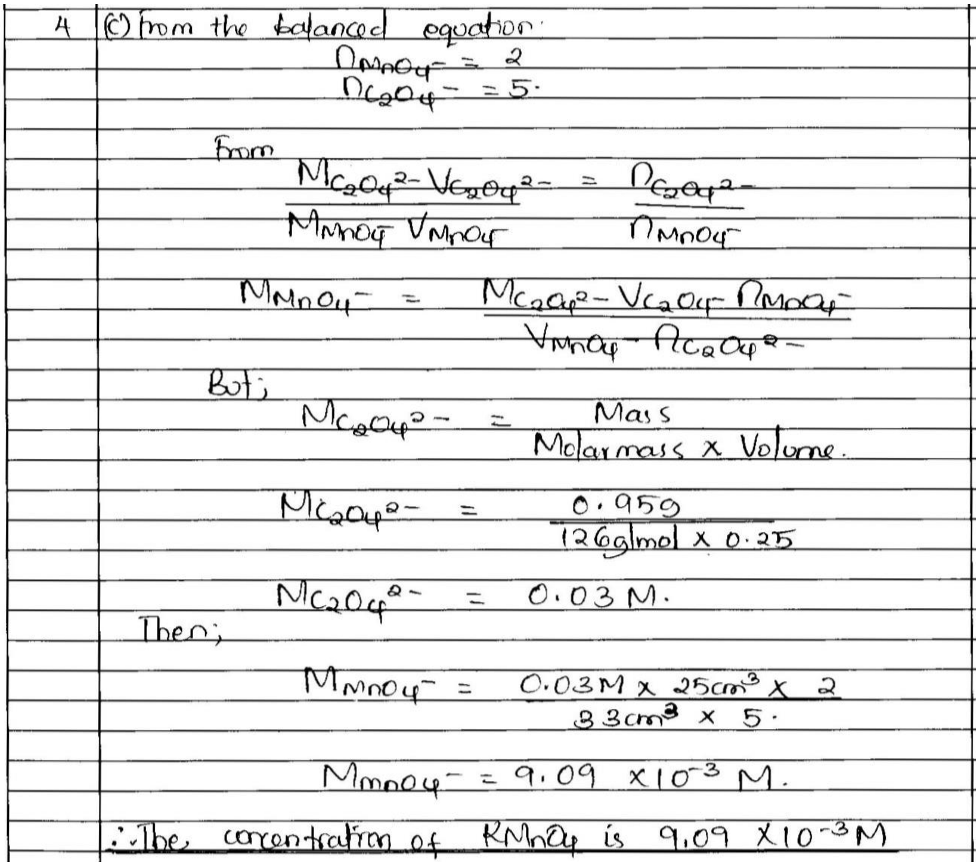
From

$$\frac{M_{C_2O_4^{2-}}V_{C_2O_4^{2-}}}{M_{MnO_4^-}V_{MnO_4^-}} = \frac{n_{C_2O_4^{2-}}}{n_{MnO_4^-}}$$

$$M_{MnO_4^-} = \frac{M_{C_2O_4^{2-}}V_{C_2O_4^-}n_{MnO_4^-}}{V_{MnO_4^-}n_{C_2O_4^{2-}}}$$

But;

$$M_{C_2O_4^{2-}} = \frac{\text{Mass}}{\text{Molarmass} \times \text{Volume}}.$$



4 (c) From the balanced equation.

$n_{MnO_4^-} = 2$

$n_{C_2O_4^-} = 5$.

From

$$\frac{M_{C_2O_4^{2-}} V_{C_2O_4^{2-}}}{M_{MnO_4^-} V_{MnO_4^-}} = \frac{n_{C_2O_4^{2-}}}{n_{MnO_4^-}}$$

$$M_{MnO_4^-} = \frac{M_{C_2O_4^{2-}} V_{C_2O_4^-} n_{MnO_4^-}}{V_{MnO_4^-} n_{C_2O_4^{2-}}}$$

But;

$$M_{C_2O_4^{2-}} = \frac{Mass}{Molar\ mass \times Volume}.$$

$$M_{C_2O_4^{2-}} = \frac{0.95g}{126g/mol \times 0.25}$$

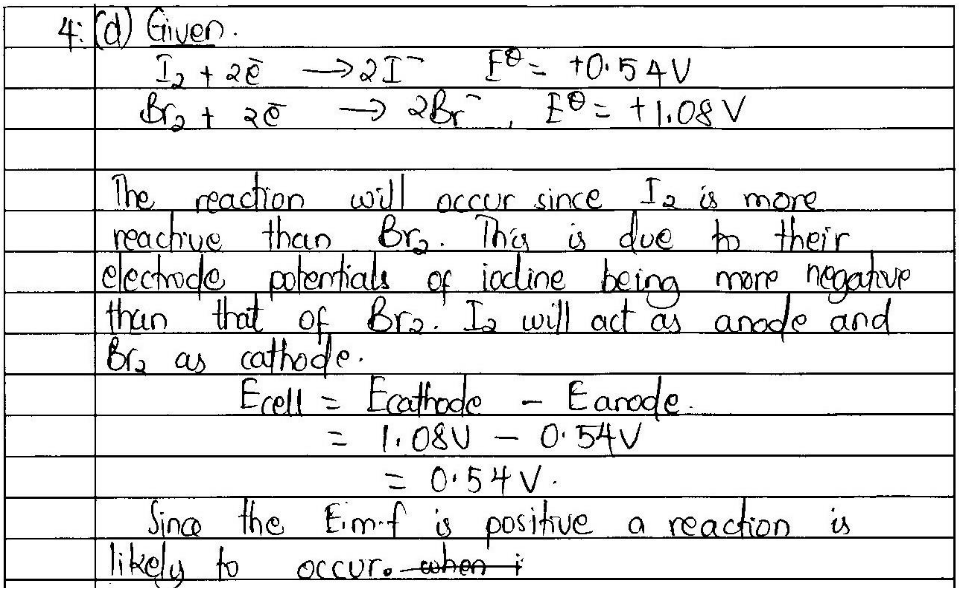
$$M_{C_2O_4^{2-}} = 0.03\ M.$$

Then;

$$M_{MnO_4^-} = \frac{0.03M \times 25cm^3 \times 2}{33cm^3 \times 5}.$$

$$M_{MnO_4^-} = 9.09 \times 10^{-3}\ M.$$

∴ The concentration of $KMnO_4$ is 9.09×10^{-3} M



4: (d) Given.

$I_2 + 2\bar{e} \rightarrow 2I^-$ $E^\theta = +0.54V$

$Br_2 + 2\bar{e} \rightarrow 2Br^-$, $E^\theta = +1.08V$

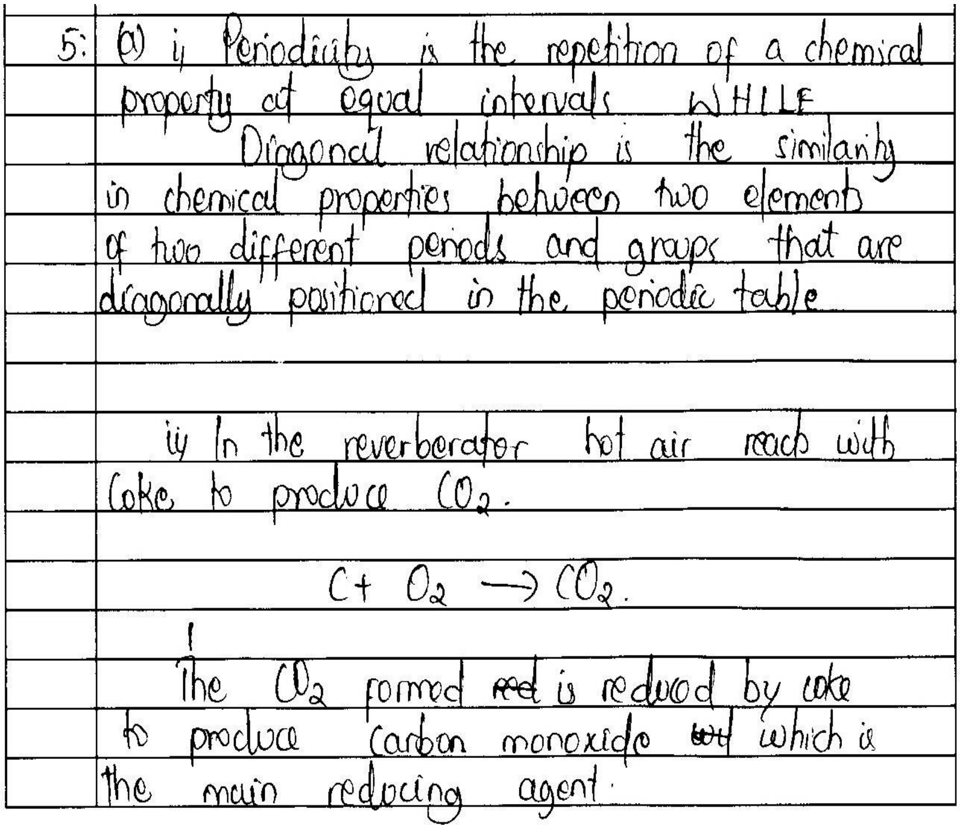
The reaction will occur since I_2 is more reactive than Br_2. This is due to their electrode potentials of iodine being more negative than that of Br_2. I_2 will act as anode and Br_2 as cathode.

$$E_{cell} = E_{cathode} - E_{anode}.$$

$$= 1.08V - 0.54V$$

$$= 0.54V.$$

Since the E.m.f is positive a reaction is likely to occur. ~~when i~~



5: (a) i) Periodicity is the repetition of a chemical property at equal intervals WHILE

Diagonal relationship is the similarity in chemical properties between two elements of two different periods and groups that are diagonally positioned in the periodic table

ii) In the reverberator hot air reach with Coke to produce CO_2.

$$C + O_2 \longrightarrow CO_2.$$

The CO_2 formed ~~red~~ is reduced by coke to produce carbon monoxide ~~wt~~ which is the main reducing agent.

Extract 14.2: A sample of the correct responses to question 4 (b-d)

In Extracts 14.1 and 14.2, the candidates correctly addressed the asked questions and scored good marks.

Conversely, 60.3 per cent of the candidates did not perform well on this question. Their responses indicated that they had insufficient knowledge of the factors affecting the extent of corrosion asked in part 5 (a). Likewise, in parts (b) and (c), the candidates were not knowledgeable about how to balance redox reactions in acidic medium. Hence, they failed to calculate the molarity of potassium permanganate solution. In part (d), the candidates were knowledgeable about how to use the value of electrode potential in calculating the cell potential. Hence, they failed to predict the feasibility of the redox reaction between bromine and iodide ions. Extract 14.3 is an example of the incorrect responses to question 4.

4. a). - Presence of water.

Through the presence of water in iron ~~corr~~ Iron can easily erode away its surface since Iron and water will react and form rust.

- Availability of Oxygen gas.

In any Iron metal which is not prevented either by the method rusting will take place since oxygen have the tendency of forming rust when reacted with irone.

$$Fe + O_2 \rightarrow FeO.$$

- Pressence of moisture.

In Iron surface when there is some sort of moisture it is easly for the iron to be eroded and carried or weared away since when moisture is exposed in iron surface form rust.

b). Soln.

given equation

$$Cr_2O_7^{2-}{}_{(aq)} + HNO_{2(aq)} \longrightarrow Cr^{3+} + NO_3^-{}_{(ag)}.$$

Reduction.

$$Cr_2O_7^{2-} \longrightarrow Cr^{3+}$$

$$Cr_2O_7^{2-} \longrightarrow Cr^{3+} + 7H_2O_{(l)}$$

$$14H^+ + Cr_2O_7^{2-} \longrightarrow Cr^{3+} + 7H_2O$$

$$14H + Cr_2O_7^{2-} \longrightarrow Cr^{3} + 7H_2O_{(l)} + \bar{e}$$

4 b. Oxidation. half-reaction,

$HNO_2 \longrightarrow NO_3^-$

$H_2O_{(l)} + HNO_{2(aq)} \longrightarrow NO_3^-$

$H_2O + HNO_{2(aq)} \longrightarrow 3H + NO_3^- + \bar{e}$

$H_2O_{(l)} + HN_{2(aq)} \longrightarrow 3H + NO_3^- + \bar{e}$

Adding two half reaction to get net. equation,

$14H + Cr_2O_{7(aq)}^{2-} \longrightarrow Cr^{3+} + 7H_2O + \bar{e}$

$H_2O + \cancel{HNO}_{2(aq)} \longrightarrow 3H + NO_3^- + \bar{e}$

net equation

$11H + Cr_2O_7^{2-} + HNO_2 \longrightarrow Cr^{3+} + 6H_2O + NO_3^-$

c. Data given.

mass of Ethanedioec acid = 0·95g.

Volume of distilled water = 0·25 dm^3

Volume of solution ~~or~~ 25·0 cm.

volume of Potassium proman(VI) 33·0 cm^3

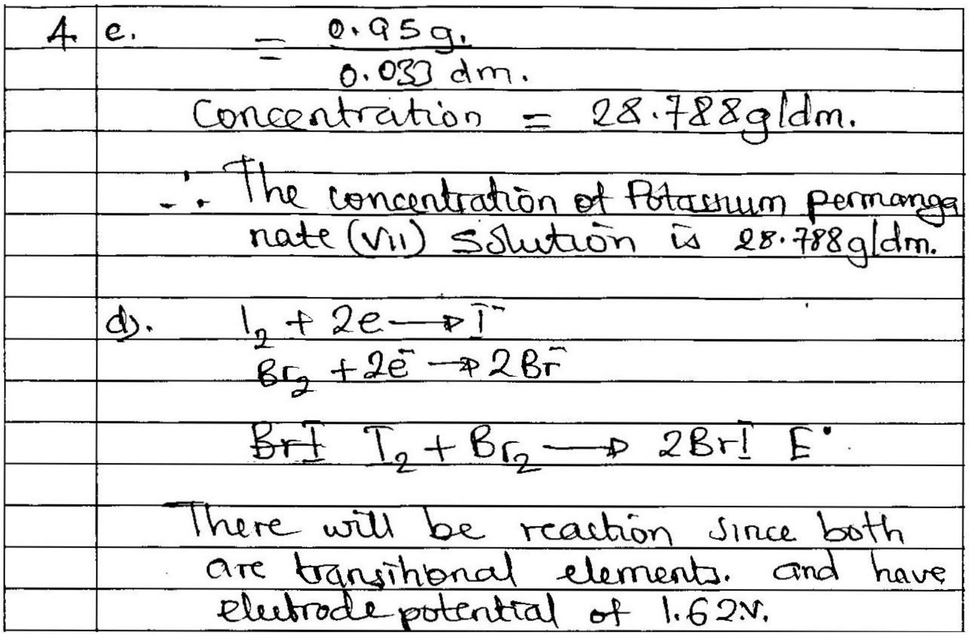
Required

To Calculate concentration of potassium permanganate (VII). solution

From.

$$\text{Concentration g/dm} = \frac{\text{mass in g.}}{\text{volume }(dm^3)}$$

$$= \frac{0{\cdot}95g}{33{\cdot}\overset{5}{\ast}1000}$$



4\. e. $= \frac{0.95g.}{0.033\ dm.}$

Concentration = 28.788g/dm.

∴ The concentration of Potassium permanganate (VII) solution is 28.788g/dm.

d). $I_2 + 2e \rightarrow I^-$

$Br_2 + 2e^- \rightarrow 2Br^-$

~~BrI~~ $I_2 + Br_2 \rightarrow 2BrI$ E°

There will be reaction since both are transitional elements. and have eletrode potential of 1.62V.

Extract 14.3: A sample of the incorrect responses to question 4

In part (a) of Extract 14.3 (a), the candidate confused the concept of conditions for corrosion and the factors affecting the extent of corrosion as a redox reaction. Furthermore, in parts (b) and (c), the candidate failed to calculate the molarity of potassium permanganate solution. In part (d), the candidate failed to use the value of electrode potential to calculate the value of cell potential. Hence, he/she failed to predict the feasibility of the redox reaction given.

2.2.5 Question 5: Periodic Classification / Extraction of Metal

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

5. (a) (i) What is the difference between periodicity and diagonal relationship?

(ii) How is tin reduced by thermal method in the reverberator furnace? Explain briefly while supporting your answer with appropriate chemical equations.

(b) "Lithium and magnesium relate diagonally in a periodic table of elements." By giving three reasons, briefly justify this statement.

(c) *The metallic characters of the elements change across the period. Illustrate this concept with reference to chlorides and hydrides of the elements of period 3.*

This question was attempted by 29,498 (84.9%) candidates; out of whom, 19,237 (65.2%) scored from 0–6.5 marks, 8,895 (30.2%) scored from 7.0–11.0 marks and 1,366 (4.6%) scored from 12.0–20.0 marks. Figure 15 summarizes the performance of the candidates on this question.

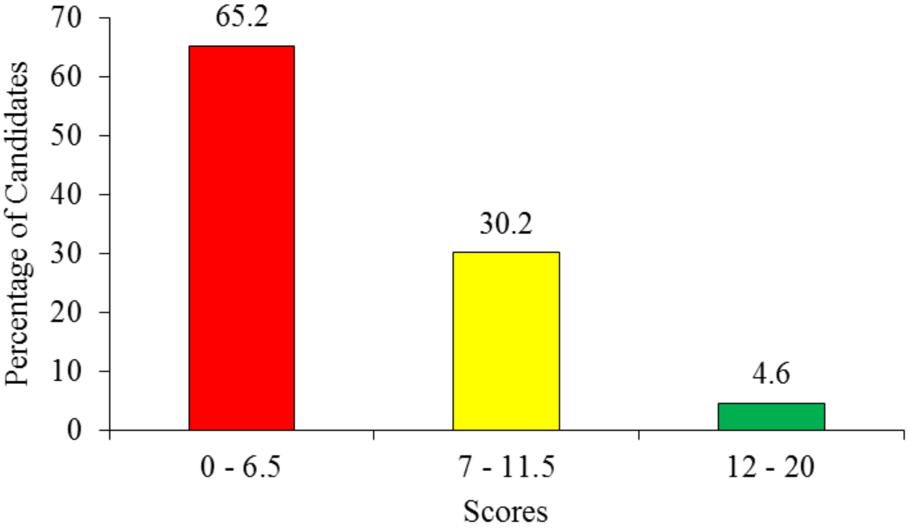
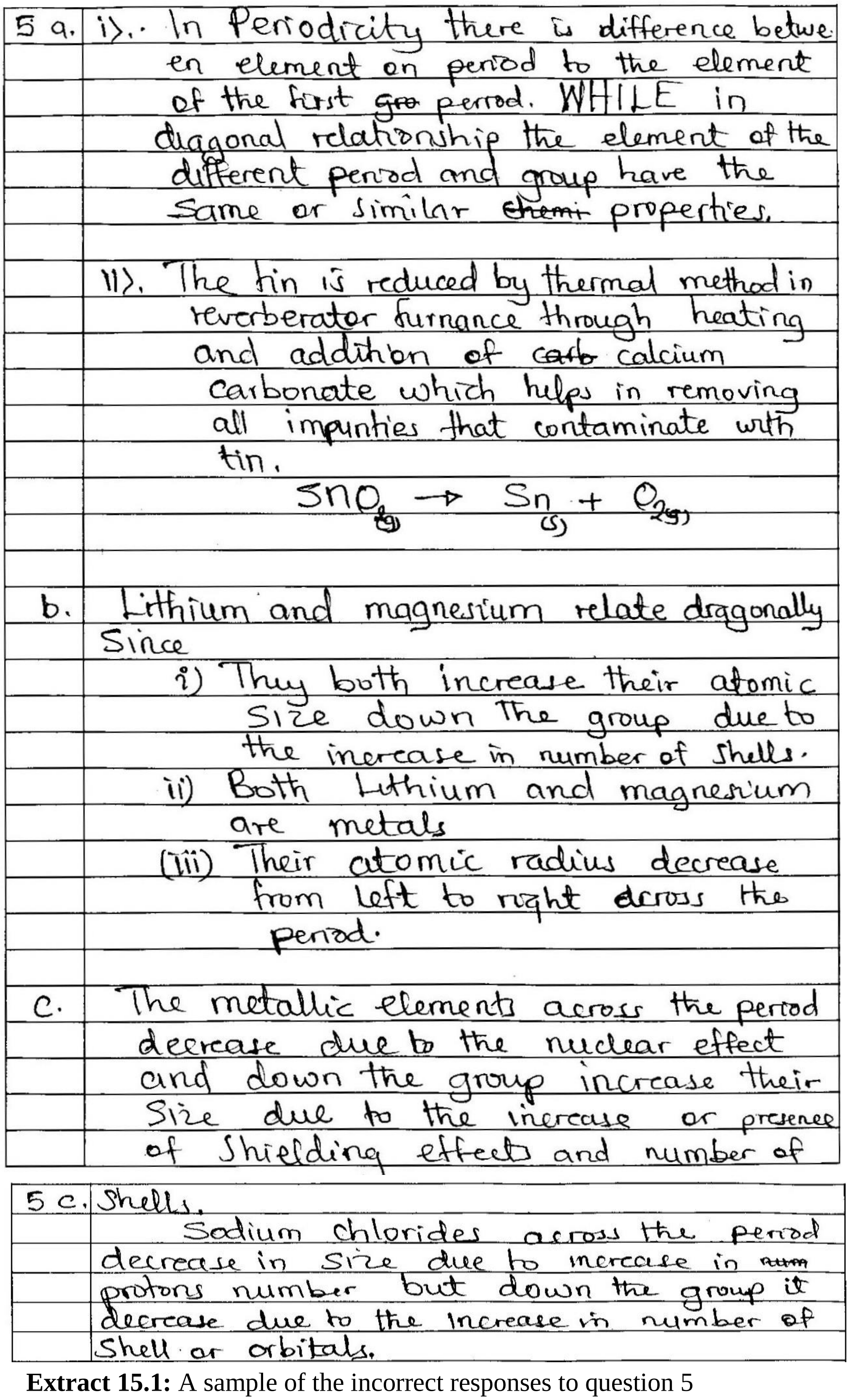


Figure 15: *Candidates' Performance on question 5*

The general performance on this question was weak since majority of candidates (19,237, 65.2%) scored below 7.0 marks.

The analysis of the candidates' responses to this question revealed that those who scored weak marks failed to comprehend the concepts of reduction based on the reactivity of metals. This caused them to fail to use the common reducing agents such as carbon and carbon monoxide to reduce cassiterite ore (stannic oxide) in part (a) (ii). In part (b), the candidates were not knowledgeable about the causes of the diagonal relationship within the periodic table; hence, they gave incorrect responses about the physical and chemical properties of lithium and magnesium. In part (c), they lacked knowledge of how atomic size influences the trend of metallic characteristics in period 3. Extract 15.1 is illustrative.



5 a. i).. In Periodicity there is difference between element on period to the element of the first ~~gro~~ period. WHILE in diagonal relationship the element of the different period and group have the Same or similar ~~chemi~~ properties.

ii). The tin is reduced by thermal method in reverberator furnance through heating and addition of ~~carb~~ calcium carbonate which helps in removing all impurities that contaminate with tin.

$SnO_{2(g)} \rightarrow Sn_{(s)} + O_{2(g)}$

b. Lithium and magnesium relate diagonally Since

i) They both increase their atomic Size down The group due to the increase in number of Shells.

ii) Both Lithium and magnesium are metals

(iii) Their atomic radius decrease from left to right across the period.

c. The metallic elements across the period decrease due to the nuclear effect and down the group increase their Size due to the increase or presence of Shielding effects and number of

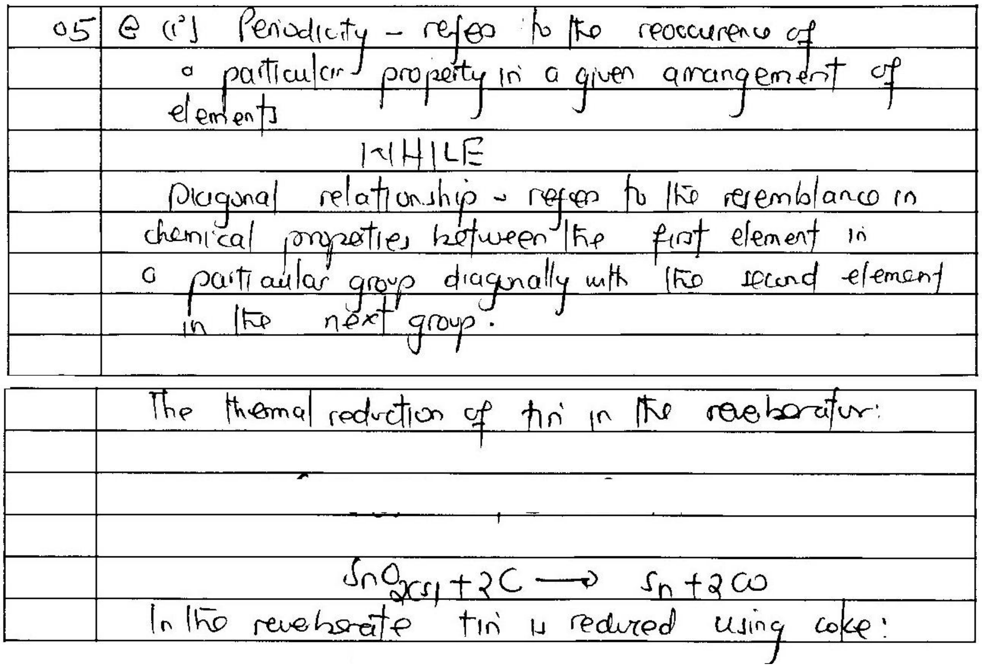
5 c. Shells.

Sodium chlorides across the period decrease in size due to increase in ~~num~~ protons number but down the group it decrease due to the increase in number of Shell or orbitals.

Extract 15.1: A sample of the incorrect responses to question 5

In Extract 15.1, the candidate wrote about the decomposition of stannic oxide in the presence of calcium carbonate instead of using carbon / carbon dioxide for the reduction of stannic oxide (cassiterite ore). Moreover, the candidate confused the concept of diagonal relationship with periodic trends such as atomic size, ionisation energy, metallic character and electron affinity. Furthermore, he/she candidate failed to illustrate the influence of atomic sizes on metallic characters of the chlorides and hydrides of the elements of period 3.

However, a few (4.6%) candidates who scored high marks on this question were knowledgeable about the extraction of metals, periodicity and periodic trends. Henceforth, they correctly explained the thermal reduction of tin and the diagonal relationship between lithium and magnesium. Moreover, they managed to illustrate the metallic characteristics of elements across period 3 in terms of the chemical properties of their chlorides and hydrides. Extract 15.2 is a response from one of the candidates with high scores on this question.



05 (e) (i) Periodicity - refers to the reoccurence of a particular property in a given arrangement of elements

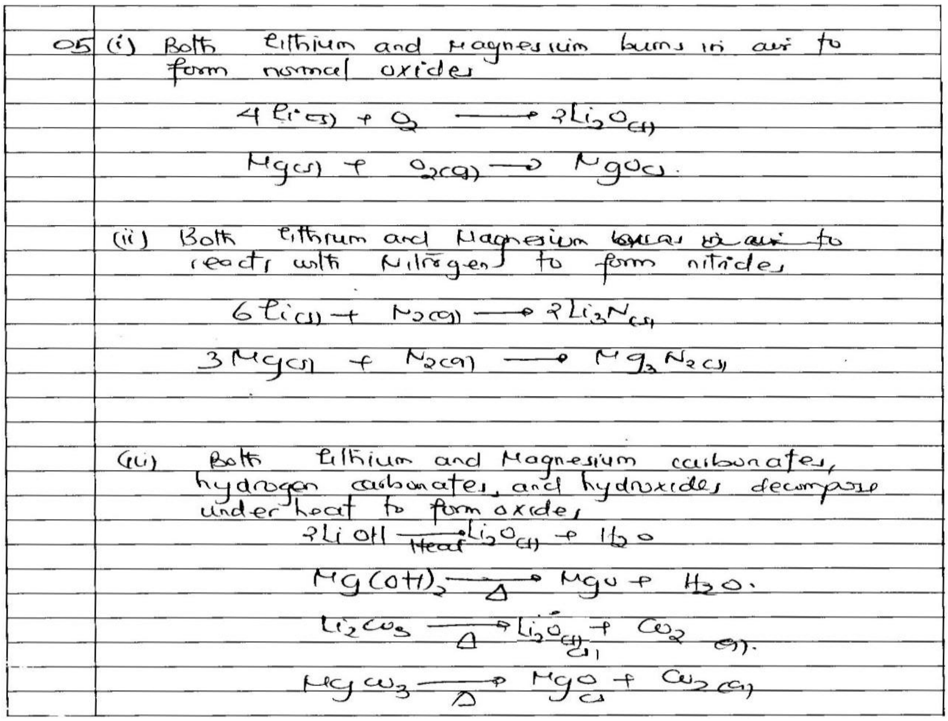
WHILE

Diagonal relationship - refers to the resemblance in chemical properties between the first element in a particular group diagonally with the second element in the next group.

The thermal reduction of tin in the reverberator:

$SnO_{2(s)} + 2C \longrightarrow Sn + 2CO$

In the reverberate tin is reduced using coke:



05 (i) Both Lithium and Magnesium burns in air to form normal oxides

$$4Li_{(s)} + O_2 \longrightarrow 2Li_2O_{(s)}$$

$$Mg_{(s)} + O_{2(g)} \longrightarrow MgO_{(s)}.$$

(ii) Both Lithium and Magnesium ~~[illegible]~~ to react with Nitrogen to form nitrides

$$6Li_{(s)} + N_{2(g)} \longrightarrow 2Li_3N_{(s)}$$

$$3Mg_{(s)} + N_{2(g)} \longrightarrow Mg_3N_{2(s)}$$

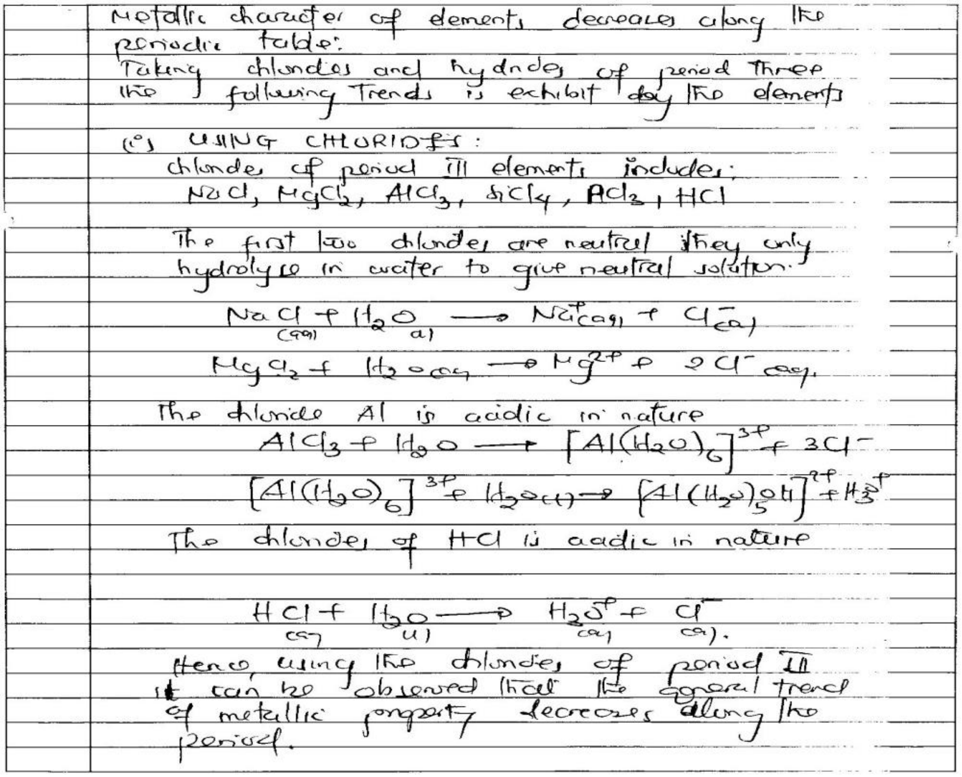
(iii) Both Lithium and Magnesium carbonates, hydrogen carbonates, and hydroxides decompose under heat to form oxides

$$2LiOH \xrightarrow[Heat]{} Li_2O_{(s)} + H_2O$$

$$Mg(OH)_2 \xrightarrow[\Delta]{} MgO + H_2O.$$

$$Li_2CO_3 \xrightarrow[\Delta]{} Li_2O_{(s)} + CO_{2(g)}.$$

$$MgCO_3 \xrightarrow[\Delta]{} MgO_{(s)} + CO_{2(g)}$$



Metallic character of elements decreases along the periodic table:
Taking chlorides and hydrides of period Three the following Trends is exhibit by the elements

(i) USING CHLORIDES:
chlorides of period III elements includes:
NaCl, $MgCl_2$, $AlCl_3$, $SiCl_4$, PCl_3, HCl

The first two chlorides are neutral they only hydrolyse in water to give neutral solution.

$$NaCl_{(aq)} + H_2O_{(l)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$$

$$MgCl_2 + H_2O_{(aq)} \longrightarrow Mg^{2+} + 2Cl^-_{(aq)}.$$

The chloride Al is acidic in nature

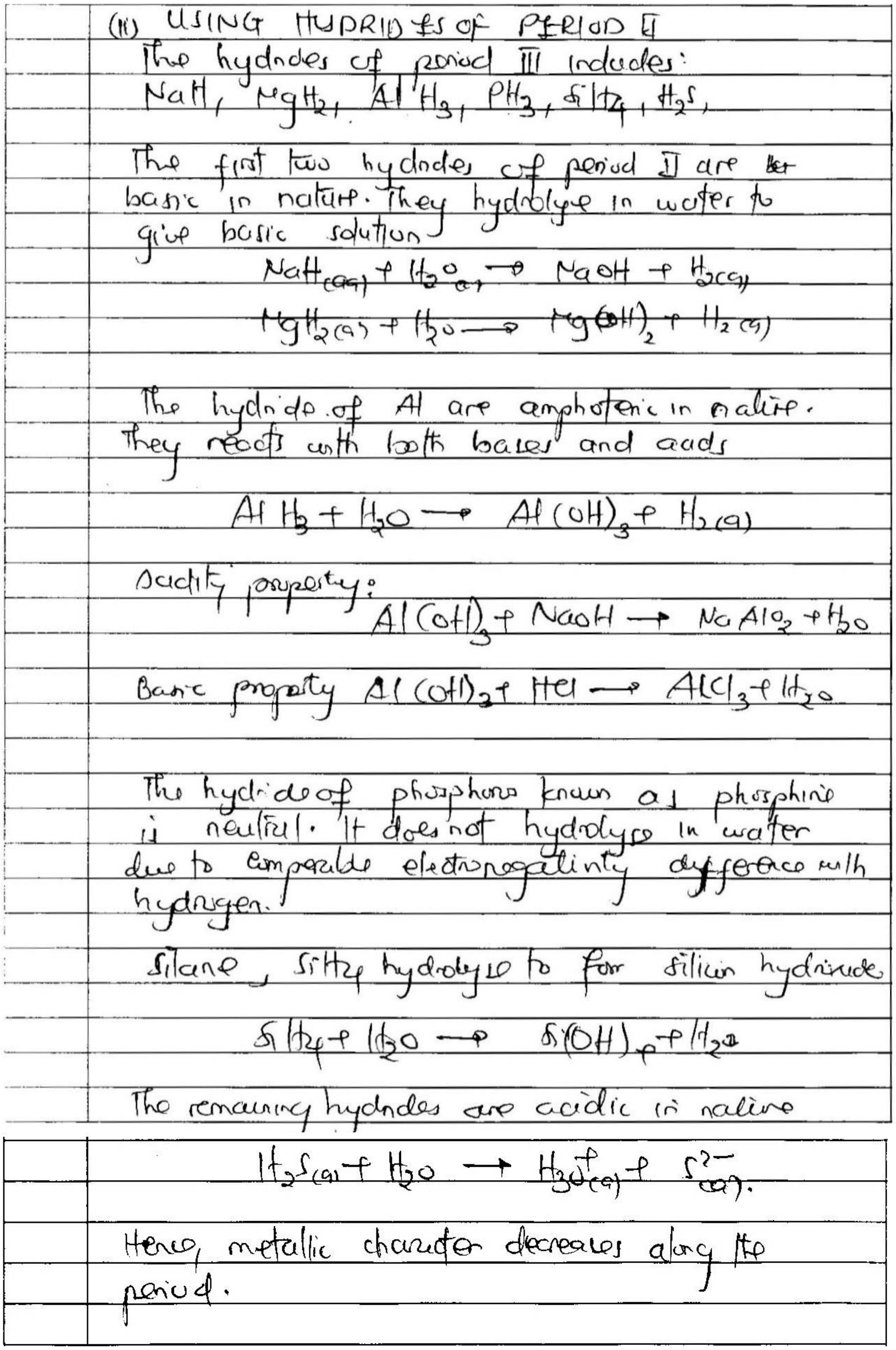
$$AlCl_3 + H_2O \longrightarrow [Al(H_2O)_6]^{3+} + 3Cl^-$$

$$[Al(H_2O)_6]^{3+} + H_2O_{(l)} \longrightarrow [Al(H_2O)_5OH]^{2+} + H_3O^+$$

The chlorides of HCl is acidic in nature

$$HCl_{(aq)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}.$$

Hence, using the chlorides of period III it can be observed that the general trend of metallic property decreases along the period.



(ii) USING HYDRIDES OF PERIOD III

The hydrides of period III includes:

NaH, MgH_2, AlH_3, PH_3, SiH_4, H_2S,

The first two hydrides of period III are ~~ba~~ basic in nature. They hydrolyse in water to give basic solution

$$NaH_{(aq)} + H_2O_{(l)} \rightarrow NaOH + H_{2(g)}$$

$$MgH_{2(s)} + H_2O \rightarrow Mg(OH)_2 + H_{2(g)}$$

The hydride of Al are amphoteric in nature. They reacts with both bases and acids

$$AlH_3 + H_2O \rightarrow Al(OH)_3 + H_{2(g)}$$

Acidity property: $Al(OH)_3 + NaOH \rightarrow NaAlO_2 + H_2O$

Basic property $Al(OH)_3 + HCl \rightarrow AlCl_3 + H_2O$

The hydride of phosphorus known as phosphine is neutral. It does not hydrolyse in water due to comparable electronegativity difference with hydrogen.

Silane, SiH_4 hydrolyse to form silicon hydroxide

$$SiH_4 + H_2O \rightarrow Si(OH)_4 + H_2$$

The remaining hydrides are acidic in nature

$$H_2S_{(g)} + H_2O \rightarrow H_3O^+_{(aq)} + S^{2-}_{(aq)}.$$

Hence, metallic character decreases along the period.

Extract 15.2: A sample of the correct responses to question 5

In Extract 15.2, the candidate managed to write the thermal reduction equation between the reducing agent (carbon monoxide and carbon) and stannic oxide ore correctly. In addition, he/she gave correct explanation and equations showing how lithium and magnesium are diagonally related. Likewise, he/she wrote the correct chemical reactions of the hydrides and chlorides of period 3 elements with water based on the trend of atomic size across the period.

2.2.6 Question 6: Polymer / Transition Elements

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

6. (a) *By giving a reason, arrange the following complex compounds in order of increasing their magnetic properties.*

$$[MnCl_4]^{2-};[FeF_6]^{4-};[Fe(CN)_6]^{4-}$$

(b) *Briefly explain the following:*

(i) *A concentrated aqueous copper(II) chloride solution is bright green in colour but changes to light blue when diluted with water.*

(ii) *The d orbitals for both zinc and copper contain paired electrons, but copper is considered a transition element while zinc is not.*

(c) *You have been employed as a chemist in a chemical industry which plan to use transition elements as catalysts in their production. Briefly, explain four applications/uses of transition elements as catalysts. Support your answer with one chemical equation in each case.*

(d) (i) *With an example in each case, explain two types of polymers based on physical properties.*

(ii) *Why Tanzania government banned the use of polymers obtained from ethylene monomers? Briefly, explain.*

(iii) *How does the structural differences of High Density Polythene (HDP) and Low Density Polythene (LDP) account for their differences in behaviour and nature?*

This question was attempted by 23,435 (67.5%) of the candidates. Out of whom, 15,619 (66.7%) scored from 0–6.5 marks, 5,962 (25.4%) scored from 7–11.5 marks and 1,854 (7.9%) scored from 12.0–20.0 marks. Figure 16 summarizes the candidates' performance on this question.

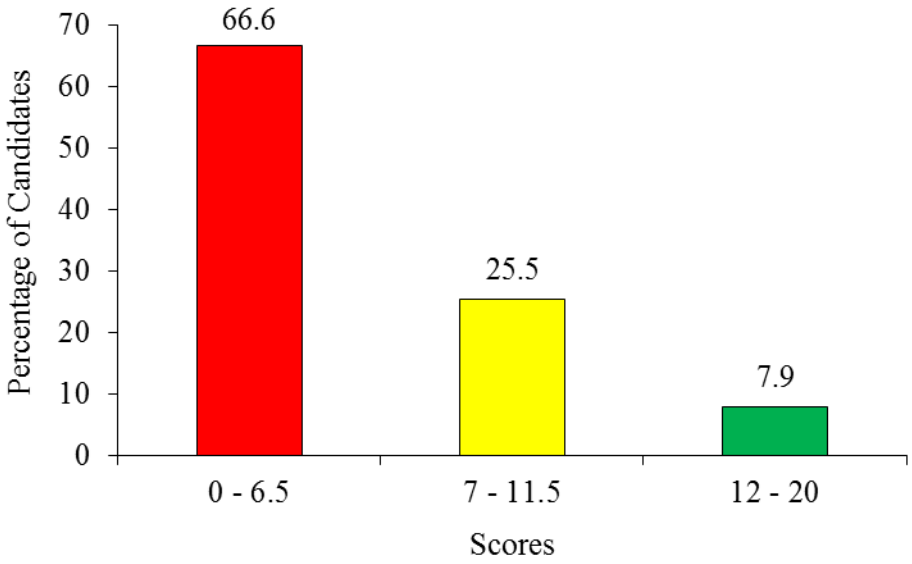
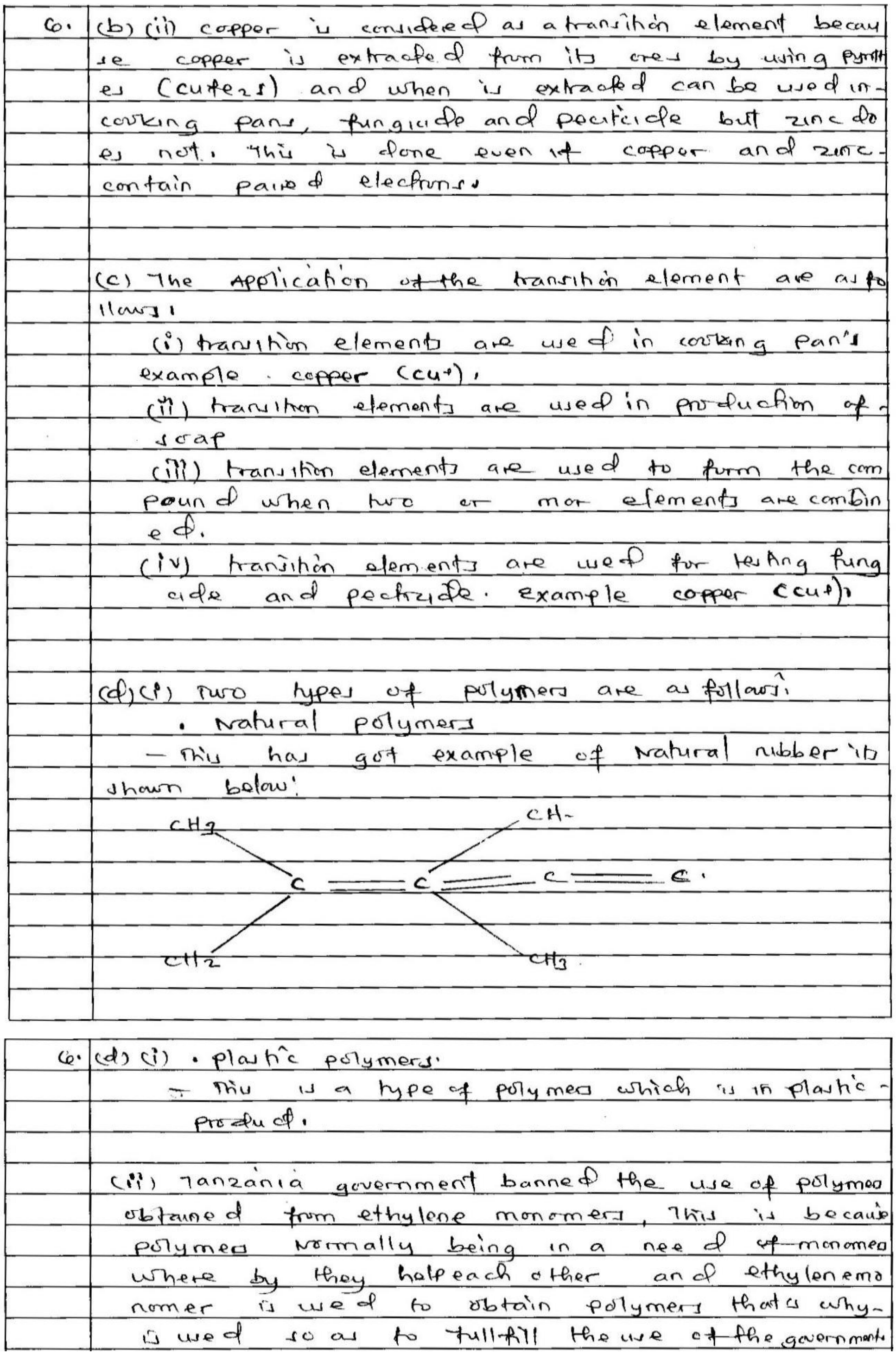


Figure 16: *Candidates' Performance on Question 6*

Figure 16 shows that the general performance on this question was weak; the majority of the candidates who attempted the question (66.7%) scored below the pass mark (<7 marks).

Their responses show that candidates lacked the required competencies in understanding the topic of *Polymer* and *Transition Elements*. For example, in part (a), they were not knowledgeable about the oxidation number of central metal atoms. This resulted in the failure to correlate the number of unpaired electrons present in the *d* orbital in relation to the strength of the ligand bonded to the central metal atom. In part (b), the candidates lacked knowledge about the excitation of electrons in relation to colour formation in transition elements. In part (c), they demonstrated inadequate knowledge about the conditions that favour transition elements to exhibit catalytic property. In part (d), they showed insufficient knowledge of how the structures of different polymers affect the strength of Van der Waal's forces, which differentiate the behaviour and nature of different polymers as shown in Extract 16.



6. (b) (ii) copper is considered as a transition element because copper is extracted from its ores by using pyrithes (cufe₂s) and when is extracted can be used in cooking pans, fungicide and pecticide but zinc does not. This is done even if copper and zinc contain paired electrons.

(c) The application of the transition element are as follows:

(i) transition elements are used in cooking pan's example. copper (cu+),

(ii) transition elements are used in production of soap

(iii) transition elements are used to form the compound when two or mor elements are combined.

(iv) transition elements are used for testing fungicide and pectricide. example copper (cu+),

(d) (i) Two types of polymers are as follows.

- Natural polymers

— This has got example of Natural rubber its shown below:

6. (d) (i) • plastic polymers.

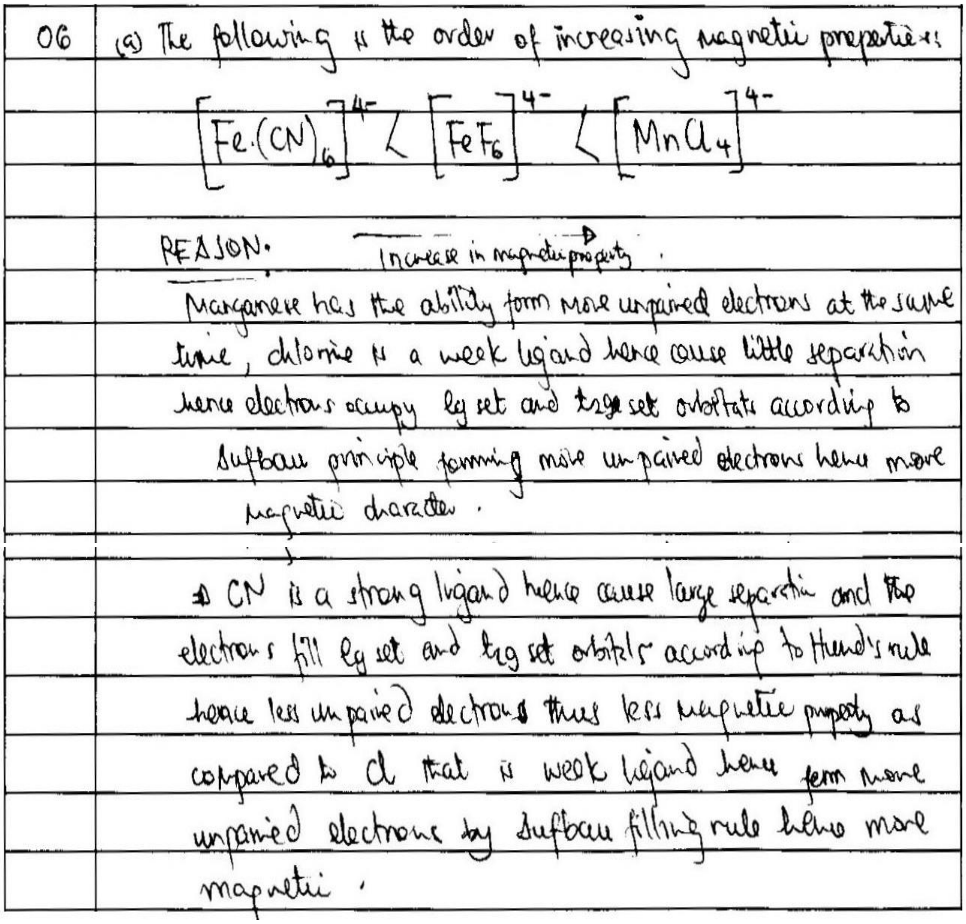
— This is a type of polymeo which is in plastic product.

(ii) Tanzania government banned the use of polymeo obtained from ethylene monomers, This is because polymeo normally being in a need of monomeo where by they help each other and ethylene monomer is used to obtain polymers that is why is used so as to fullfill the use of the governments

Extract 16.1: A sample of the incorrect responses to question 6

In part (a) of the Extract 16.2, the candidate gave the reason for the observed sequence of increasing magnetic properties of complex compounds being "ions" instead of connecting the concept of oxidation state of the central metal atom with the number of unpaired electrons in the *d* orbital. In part (b), the candidate presented issues related to the extraction of metals instead of integrating the concept of *d-d* transition of electron to account for the colour formation in the transition elements. In Part (c), the candidate lacked knowledge about the conditions that favour transition elements to exhibit catalytic property. In part (d), the candidate presented issues that do not address the demand of the question. He/she was supposed to associate the explanations with the structures of polymer and the strength of van der Waal's forces that give different behaviour and nature of polymers.

In contrast, the candidates who scored high marks in this question were conversant with the concepts of the types of polymer based on their physical properties as well as their side effects on the environment. Furthermore, they showed knowledge about the formation of colour, magnetic and catalytic properties of transition elements as shown in Extract 16.2.



06 (a) The following is the order of increasing magnetic properties:

$$[Fe.(CN)_6]^{4-} < [FeF_6]^{4-} < [MnCl_4]^{4-}$$

REASON. $\xrightarrow{\text{Increase in magnetic property}}$

Manganese has the ability form more unpaired electrons at the same time, chlorine is a week ligand hence cause little separation hence electrons occupy e_g set and t_{2g} set orbitals according to Aufbau principle forming more unpaired electrons hence more magnetic character.

CN is a strong ligand hence cause large separation and the electrons fill e_g set and t_{2g} set orbitals according to Hund's rule hence less unpaired electrons thus less magnetic property as compared to Cl that is week ligand hence form more unpaired electrons by Aufbau filling rule hence more magnetic.

06 (b) (i) Addition of water to conc $CuCl_2$ solution makes $CuCl_2$ become hydrated to form the complex compound that make it turn to light blue solution from green colour.

(ii) Zinc is not a transition element because the d-orbital is still filled during ionization but as for copper the d-orbital still contain the unpaired orbitals when excited by supply of energy.

(c) The following are applications of transition elements as catalyst

- Nickel is used in catalytic hydrogenation of unsaturated organic compounds; This results to formation of saturated compounds (alkane).

Example; $CH_2 = CH_2 + H_{2(g)} \xrightarrow[200°C]{Ni} CH_3CH_3$.

- Iron is used in Haber process

- In this reaction Iron fillings catalyse the formation of ammonia from Hydrogen and Nitrogen gases.

Example; $N_{2(g)} + 3H_{2(g)} \overset{Fe}{\rightleftharpoons} 2NH_{3(g)}$ $\Delta H = -x\ KJmol^{-1}$.

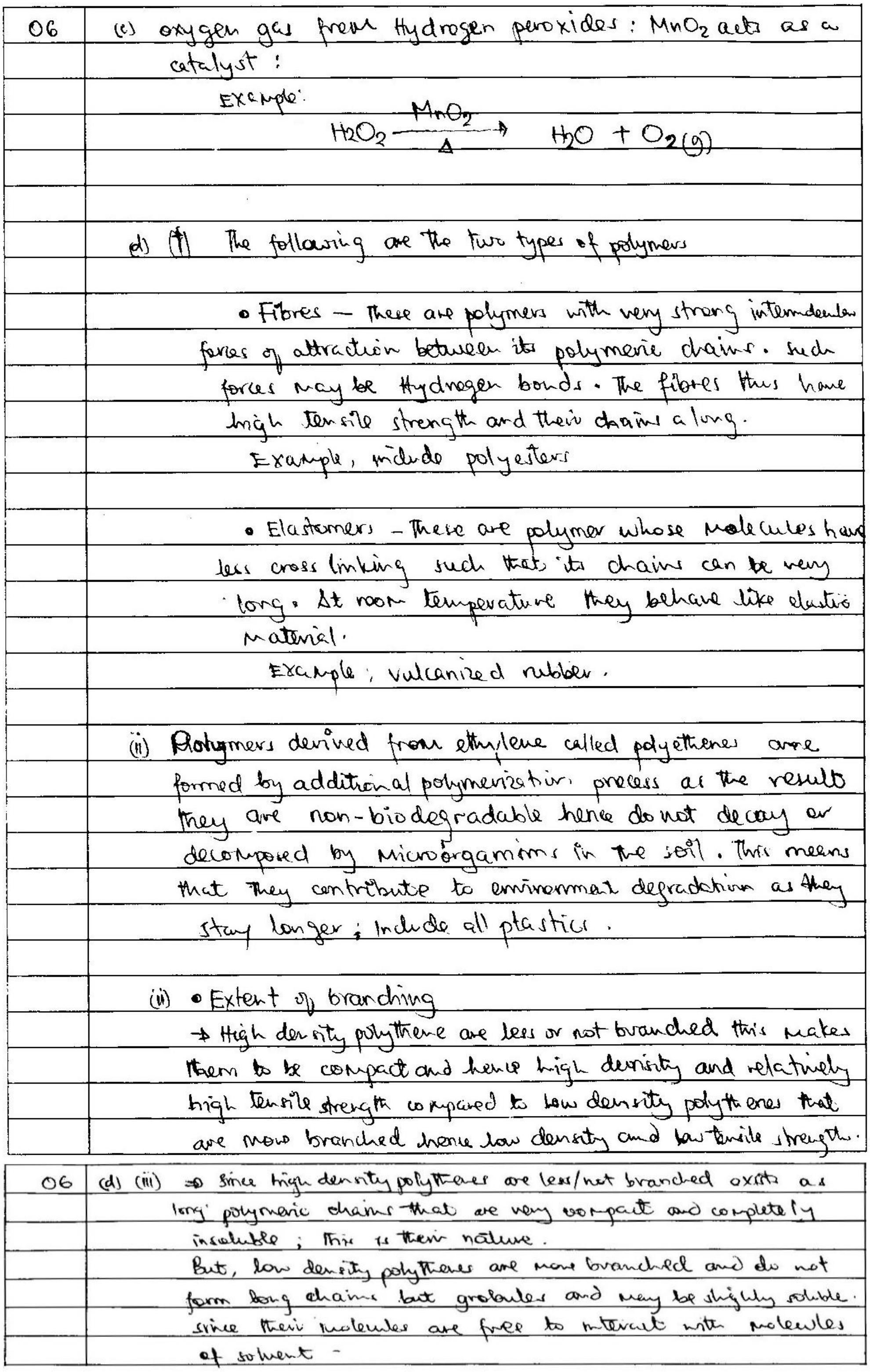
- Vanadium pentaoxide (Vn_2O_5) is used in contact process,

- In this reaction oxygen gas reacts with SO_2 to form SO_3 which then dissolves in water to form H_2SO_4

Example

$$O_{2(g)} + SO_{2(g)} \xrightarrow{Vn_2O_5} SO_{3(g)} + H_2O \longrightarrow H_2SO_4.$$

- Manganese oxide is used in the laboratory to prepare



06 (c) oxygen gas from Hydrogen peroxides : MnO_2 acts as a catalyst :

Example:

$$H_2O_2 \xrightarrow[\Delta]{MnO_2} H_2O + O_{2(g)}$$

d) (i) The following are the two types of polymers

- Fibres — These are polymers with very strong intermolecular forces of attraction between its polymeric chains. such forces may be Hydrogen bonds. The fibres thus have high tensile strength and their chains a long.
  Example, include polyesters

- Elastomers — These are polymer whose molecules have less cross linking such that its chains can be very long. At room temperature they behave like elastic material.
  Example ; vulcanized rubber.

(ii) ~~P~~olymers derived from ethylene called polyethenes are formed by additional polymerization process as the result they are non-biodegradable hence do not decay or decomposed by microorganisms in the soil. This means that they contribute to environment degradation as they stay longer ; include all plastics.

(iii) • Extent of branching
⇒ High density polythene are less or not branched this makes them to be compact and hence high density and relatively high tensile strength compared to low density polythenes that are more branched hence low density and low tensile strength.

06 (d) (iii) ⇒ Since high density polythenes are less/not branched exists as long polymeric chains that are very compact and completely insoluble ; this is their nature.
But, low density polythenes are more branched and do not form long chains but globules and may be slightly soluble. since their molecules are free to interact with molecules of solvent -

Extract 16.2: A sample of the correct responses to question 6

In Extract 16.2, the candidate correctly presented the effects of the strength of ligands (weak ligand/strong ligand) on the arrangement of electrons in the *d* orbital. She/he also explained well the oxidation state of central metal atoms in relations to the magnetic property of the given complex compounds. Furthermore, the candidate wrote the correct answer on the disadvantages of polyethylene based on their polarity when they are exposed or disposed to the environment.

2.3 132/3-CHEMISTRY 3

This was an 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 questions which carried a total of 50 marks. Question one weighed 20 marks, while questions 2 and 3 carried 15 marks each. The candidates were examined in the topic of *Chemical Analysis* in all of the three alternative papers. The questions were set from the subtopics of *Volumetric Analysis*, *Physical Chemistry Analysis* and *Qualitative Analysis* for question 1, 2 and 3, respectively. The candidates were required to answer all questions. The pass mark for question 1 was 7.0 while for questions 2 and 3 was 5.5.

Results shows that the overall performance was good; most candidates (80.95%) scored average marks or above. The overall performance in the practical examination was the average of the candidates' performance on questions 1, 2 and 3. The analysis of each question in the practical papers is as follows:

2.3.1 Question 1: Volumetric Analysis
Chemistry 3A, 3B and 3C

Question 1 of 132/3A Chemistry 3A was as follows:

"You are provided with the following solutions:

***A**: 2.96 g of a mixture of sodium carbonate and sodium bicarbonate in a 500 cm^3 of an aqueous solution;*

***B**: 1.46 g of a pure hydrochloric acid in a 0.4 dm^3 of an aqueous solution;*

***MO**: Methyl orange indicator.*

***POP**: Phenolphthalein indicator;*

Procedure

*(i) Pipette 20 or 25 cm^3 of **A** into a 250 cm^3 titration flask.*

*(ii) Add two drops of **POP**.*

*(iii) Titrate this solution against **B** until a colour change is observed.*

(iv) Record the first titre value.

*(v) Add **MO** to the same solution.*

(vi) Continue titrating until a second colour change is observed.

(vii) Record the second titre value.

(viii) Repeat the titration procedures (i) to (vii) three times and record your results in a tabular form.

Summary

*__________ cm^3 of solution **A** required __________ cm^3 of solution **B** when **POP** was used and __________ cm^3 of solution **B** when **MO** was used.*

Questions

(a) Based on the indicator used, state the colour changes during the titrations.

*(b) Calculate the concentration of solution **A** in moles per litre when;*

  *(i) **POP** was used.*

  *(ii) **MO** was used.*

*(c) Calculate the percentage of sodium carbonate in solution **A**."*

Question 1 of 132/3B Chemistry 3B was as follows:

"You are provided with the following:

***AA**: A solution of sodium oxalate, $Na_2C_2O_4$ made by dissolving 3.35 g of the salt in a 0.5 dm^3 solution;*

***BB**: A solution of potassium permanganate, $KMnO_4$;*

***CC**: A solution of hydrated iron(II) ammonium sulphate, $FeSO_4(NH_4)_2SO_4.XH_2O$ made by dissolving 33.3 g of the salt in distilled water to form 1 dm^3 of an aqueous solution;*

***DD**: Dilute sulphuric acid;*

Thermometer.

Theory

Standardization of ***BB*** *solution is done by titrating it against the standard solution of* ***AA*** *in an acidic medium. The resulting reaction equation is as follows:* $2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 10CO_2$.

The standardized $KMnO_4$ *is then titrated against* ***CC*** *whose number of molecules of water of crystallization can then be calculated. The resulting equation is as follows:* $MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$.

Procedure

Part I

(i) *Measure 10* cm^3 *of solution* ***AA*** *into a titration flask and then add 10* cm^3 *of solution* ***DD****.*

(ii) *Heat the contents near boiling (about* $80\,°C$*).*

(iii) *Titrate this hot mixture against solution* ***BB*** *from the burette until there is a colour change.*

(iv) *Repeat the steps (i) to (iii) to obtain three more readings and record the results in a tabular form.*

Summary

____________ *cm^3 of solution* ***AA*** *required* **___________** *cm^3 of solution* ***BB*** *for a complete reaction.*

Part II

(i) *Measure 10* cm^3 *of solution* ***CC*** *into a titration flask and then add 10* cm^3 *of solution* ***DD****.*

(ii) *Titrate the reaction mixture against solution* ***BB*** *from the burette until there is a colour change.*

(iii) *Repeat the steps (i) and (ii) to obtain three more readings and record the titration results in a tabular form.*

Questions

(a) *Calculate the;*

(i) molarity of potassium permanganate.

(ii) concentration of potassium permanganate in gdm^{-3}.

(iii)molarity of iron(II) salt.

(iv) concentration of anhydrous iron(II) salt in gdm^{-3}.

(b) *Find the value of X in the formula* $FeSO_4(NH_4)_2SO_4.XH_2O$*."*

Question 1 of 132/3C Chemistry 3C was as follows:

"You are provided with the following:

K: *A solution of 7.45 g of an impure hydrated sodium carbonate in a 500 cm^3 of an aqueous solution;*

L: *1.825 g of hydrochloric acid in a 500 cm^3 of an aqueous solution.*

POP: *Phenolphthalein indicator;*

MO: *Methyl orange indicator.*

Procedure

(i) Pipette 20 or 25 cm^3 of a solution ***K*** *and put it in a clean conical flask.*

(ii) Add two drops of ***POP****.*

(iii) Put solution ***L*** *into the burette.*

(iv) Titrate solution ***L*** *against* ***K*** *using* ***POP*** *until the colour change is observed.*

(v) Add two drops of ***MO*** *and continue to titrate until further colour change is observed.*

(vi) Repeat the procedures (i) - (v) three times and record the results in a tabular form.

Questions

(a) Calculate the average titre value when:

  (i) ***POP*** *was used.*
  (ii) ***MO*** *was used.*

(b) Write a balanced chemical equation when;

  (i) ***POP*** *was used.*
  (ii) ***MO*** *was used*

(c) Calculate the total overall average volume of the solution ***L*** *used for complete reaction with the solution* ***K****.*

(d) Write the overall reaction equation of the ***L*** *and* ***K****.*

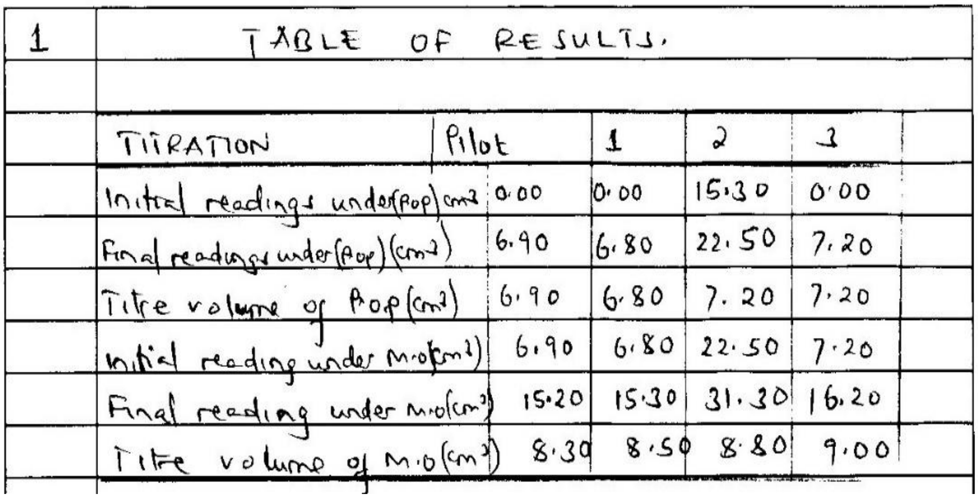
(e) Calculate the percentage purity of the hydrated sodium carbonate.

Question 1 was attempted by all 34,735 candidates. Their performance on question 1 is summarized in Table 1.

Table 1: Candidates’ Performance on Question 1

S/n	Scores	Number of Candidates	Percentage of Candidates
1	0.0 – 6.5	2,164	6.2
2	7.0 - 11.5	10,135	29.2
3	12.0 – 20.0	22,436	64.6

Their overall performance on this question was good. A total of 32,571 candidates (93.8%) scored an average mark or above (Table 1). The candidates (64.6%) who scored high marks on this question had adequate skills in volumetric standardization. In alternative A, the candidates managed to standardize the mixture of sodium carbonate and sodium bicarbonate using hydrochloric acid. In alternative B, they managed to standardize acidified potassium permanganate by using sodium oxalate. Hydrated iron(II) ammonium sulphate with an unknown number of molecules of water of crystallization, **X** was titrated by using standardized potassium permanganate. In alternative C, the candidates managed to standardize impure hydrated sodium carbonate using hydrochloric acid. Extracts 17.1, 17.2 and 17.3 are samples of the correct responses to question 1 in alternative A, B, and C, respectively.



1	TABLE OF RESULTS.				
	TITRATION	Pilot	1	2	3
	Initial readings under(Pop)cm^3	0.00	0.00	15.30	0.00
	Final readings under(Pop)(cm^3)	6.90	6.80	22.50	7.20
	Titre volume of Pop(cm^3)	6.90	6.80	7.20	7.20
	Initial reading under M.o(cm^3)	6.90	6.80	22.50	7.20
	Final reading under M.o(cm^3)	15.20	15.30	31.30	16.20
	Titre volume of M.o(cm^3)	8.30	8.50	8.80	9.00

Average volume when (M.O) was used

$$V = \frac{V_1 + V_2 + V_3}{3}$$

$$V = \frac{8.5 + 8.8 + 9.0}{3} (cm^3)$$

$$V = 8.80 cm^3$$

Average volume when (P.O.P) was used.

$$V = \frac{6.80 + 7.20 + 7.20}{3} (cm^3)$$

$$V = 7.10 cm^3.$$

---

1 Summary.

20 cm^3 of solution A required 7.10 cm^3 of solution B when P.O.P was used and 8.80 cm^3 of solution B when MO was used

- The pipette used was 20 cm^3
- The burette used was 50 cm^3,

(a) - When P.O.P was used the colour changed from pink to colourless.

- When M.O was used the colour changed from yellow to red,

(b) Solution

Required: concentration of solution A in moles per litre when

(i) P.O.P was used

$$Na_2CO_{3(aq)} + HCl_{(aq)} \xrightarrow{P.O.P} NaHCO_{3(aq)} + NaCl_{(aq)}$$

$$\text{Molarity } (M_a) = \frac{\text{concentration}}{\text{molar mass}}$$

$$\text{concentration of acid} = \frac{\text{mass}}{\text{volume}}$$

$$= \frac{1.46 g}{0.4 dm^3}$$

1 (b) (1) concentration $= \frac{1·46 (g)}{0·4 (dm^3)}$

$= 3·65\ g/dm^3$

Molarity (Ma) $= \frac{3·65 g/dm^3}{36·5 g/mol}$

Molarity (Ma) $= 0·1\ mol/dm^3$.

Molarity of base (Mb) = ? required

V(a) = 7·1 cm³.

na = 1

nb = 1

from

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

$$\frac{0·1 \times 7·1}{M_b \times 20} = \frac{1}{1}$$

$$M_b = \frac{7·1 \times 0·1}{20}$$

$M_b = 0·0355\ mol/dm^3$

∴ concentration of solution A is when p.o.p was used is 0·0355 mol/dm³

1(b)(ii) When M.O was used

~~$V_{P.O.P} + V_{NaHCO_3}$~~ =

$NaHCO_{3(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

$\frac{M_aV_a}{M_bV_b} = \frac{n_a}{n_b}.$

$NaHCO_{3(aq)} + HCl_{(aq)} \xrightarrow{M.O} NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

$\frac{0.1 \times 8.80}{M_b \times 20} = \frac{1}{1}$

$M_b = 0.044 \text{ mol/dm}^3$

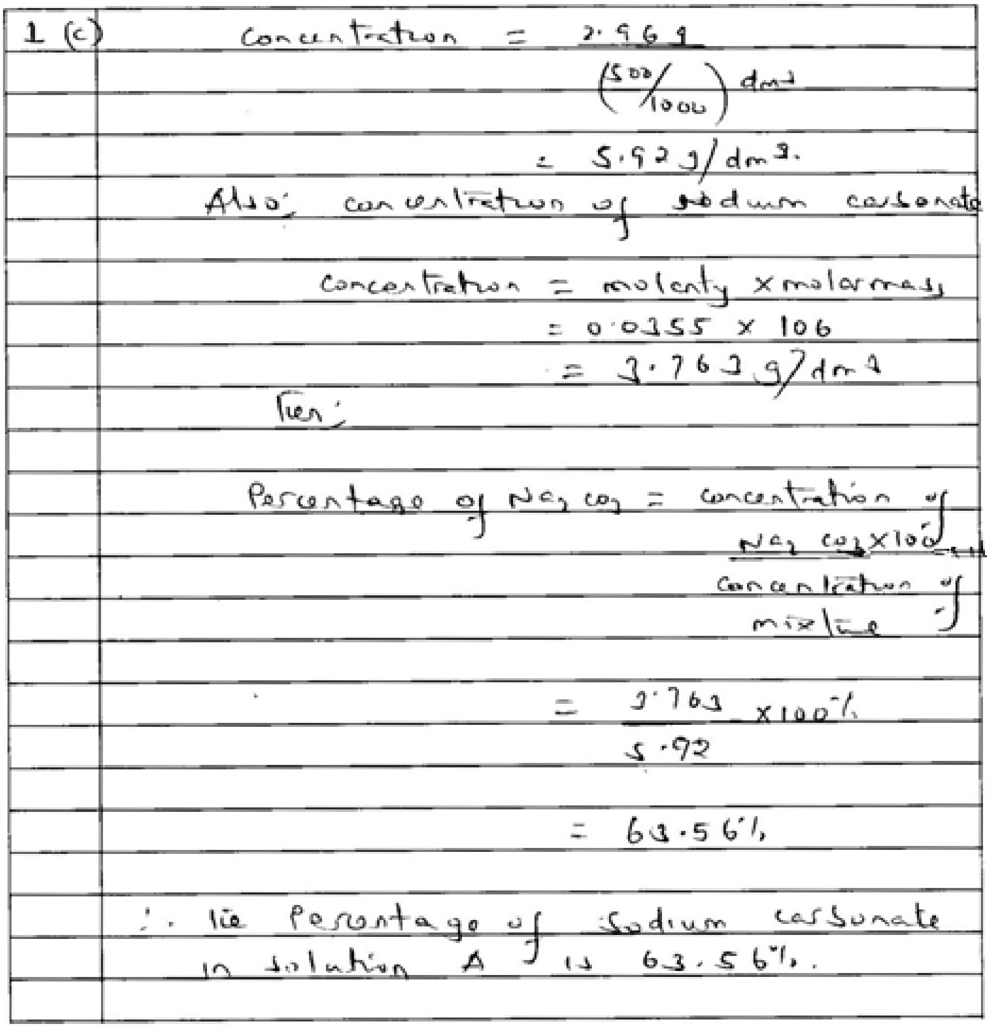
∴ The concentration of solution A when M.O was used is 0.044 mol/dm³

(c) solution

Required; The percentage of sodium carbonate in solution A

from concentration of the mixture

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



1 (c) Concentration $= \dfrac{2.96\,g}{\left(\frac{500}{1000}\right) dm^3}$

$= 5.92\ g/dm^3.$

Also: concentration of sodium carbonate

Concentration = molarity × molar mass

$= 0.0355 \times 106$

$= 3.763\ g/dm^3$

Then:

Percentage of Na_2CO_3 $= \dfrac{\text{concentration of } Na_2CO_3 \times 100}{\text{concentration of mixture}}$

$= \dfrac{3.763}{5.92} \times 100\%$

$= 63.56\%$

∴ The percentage of sodium carbonate in solution A is 63.56%.

Extract 17.1: A sample of the correct responses to question 1 in Alternative Practical A

In Extract 17.1, the candidate filled appropriately the table of results by observing the required two decimal places. The candidate correctly calculated the titre value which was within the acceptable range in comparison to the expected value (i.e., ± 0.5 cm^3). The candidate gave the correct chemical reaction between the given bases and acid; besides he/she correctly identified the colour changes during titration. Thereafter, he/she correctly performed all the required calculations to identify the percentage of sodium carbonate in the solution.

01. **Part I**

Pilot

	Pilot	1	2	3
Final Volume(cm³)	9.70	9.60	9.50	9.70
Initial volume	0.00	0.00	0.00	0.00
Titre Volume(cm³)	9.70	9.60	9.50	9.70

Average Titre volume $= \frac{9.60cm^3 + 9.50cm^3 + 9.70cm^3}{3}$

$= \frac{28.8cm^3}{3}$

$= 9.60cm^3$

Summary:
10cm³ of solution AA required 9.60cm³ of solution BB for a complete reaction

Part II.

	Pilot	1	2	3
Final volume(cm³)	8.60	8.50	8.60	8.40
Initial Volume(cm³)	0.00	0.00	0.00	0.00
Titre Volume(cm³)	8.60	8.50	8.60	8.40

Average titre volume $= \frac{8\cdot6 \cdot 8.50cm^3 + 8.60cm^3 + 8.40cm^3}{3}$

$= 25.5cm^3/3 = 8.50cm^3$

Summary:

$10cm^3$ of solution CC required $8.50cm^3$ of Solution BB for a complete reaction.

Questions

Required

1a(i) Molarity of Potassium Permanganate in gdm^{-3}.

from the reaction given

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

$$n_{MnO_4^-} : n_{C_2O_4^{2-}} = 2:5$$

from

$$\frac{M_{MnO_4^-} V_{MnO_4^-}}{M_{C_2O_4^{2-}} V_{C_2O_4^{2-}}} = \frac{n_{MnO_4^-}}{n_{C_2O_4^{2-}}}$$

But

$$M_{C_2O_4^{2-}} = \frac{\text{Concentration}}{\text{Molar mass}}$$

$$\text{Conc} = \frac{3.35g}{0.5dm^3} = 6.7\,g\,dm^{-3}$$

then

$$M_{C_2O_4^{2-}} = \frac{6.7gdm^{-3}}{[(23\times2)+(12\times2)+(16\times4)]gmol^{-1}}$$

$$= \frac{6.7gdM^{-3}}{134gmol^{-1}} = 0.05M$$

Since $M_{C_2O_4^{2-}} = 0.05M$

Then

$$M_{MnO_4^-} = \frac{M_{C_2O_4^{2-}} \times V_{C_2O_4^{2-}} \times n_{MnO_4^-}}{V_{MnO_4^{2-}} \times n_{C_2O_4^{2-}}}$$

$$= \frac{0.05M \times 10cm^3 \times 2}{9.60cm^3 \times 5}$$

$\underline{\text{Molarity } KMnO_4 = 0.02M}$

1a(ii) so Molarity of potasium permanganate in g/dm^{-3} (concentration).

$= \text{Molarity } (mol\,L^{-1}) \times \text{Molar mass}$

But molar mass of $KMnO_4$

$= [39+55+(16\times4)]\ gmol^{-1}$

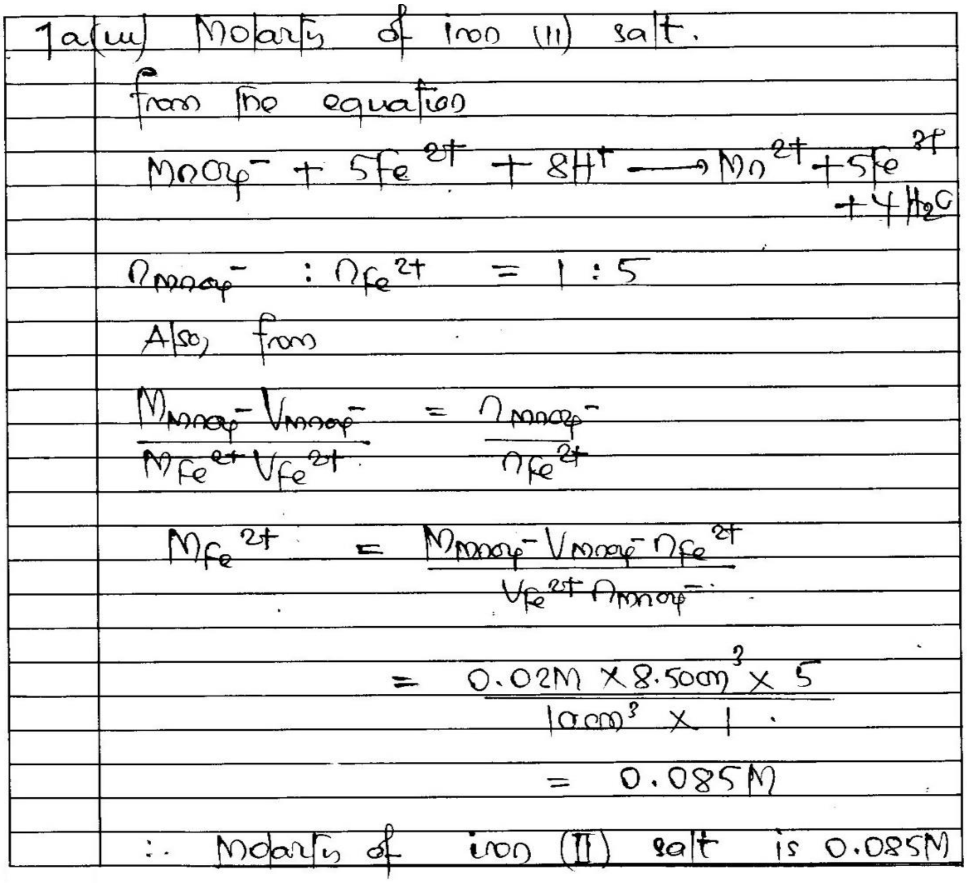
$= 158gmol^{-1}$.

Then

Concentration $= 0.02M \times 158gmol^{-1}$

$= 3.16g/dm^3$

$\underline{\therefore \text{ concentration of } KMnO_4 \text{ is } 3.16gdm^{-3}}$



1a(iii) Molarity of iron (II) salt.

from the equation

$MnO_4^- + 5Fe^{2+} + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

$n_{MnO_4^-} : n_{Fe^{2+}} = 1 : 5$

Also, from

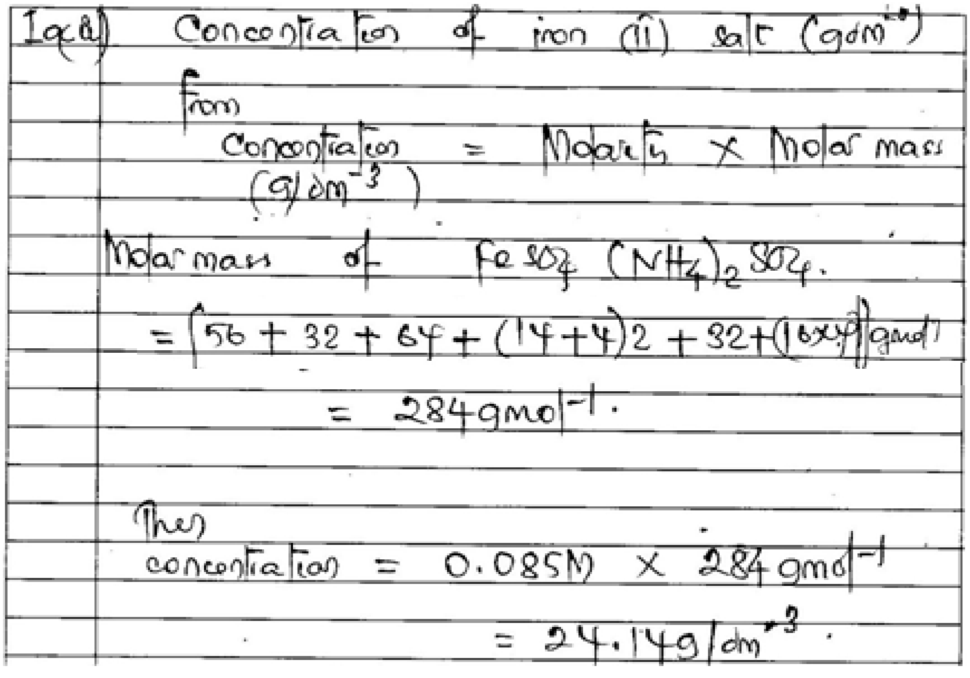
$$\frac{M_{MnO_4^-} V_{MnO_4^-}}{M_{Fe^{2+}} V_{Fe^{2+}}} = \frac{n_{MnO_4^-}}{n_{Fe^{2+}}}$$

$$M_{Fe^{2+}} = \frac{M_{MnO_4^-} V_{MnO_4^-} n_{Fe^{2+}}}{V_{Fe^{2+}} n_{MnO_4^-}}$$

$$= \frac{0.02M \times 8.50cm^3 \times 5}{10cm^3 \times 1}$$

$$= 0.085M$$

∴ Molarity of iron (II) salt is 0.085M



1a(iv) Concentration of iron (II) salt (gdm^{-3})

from

Concentration (g/dm^{-3}) = Molarity × Molar mass

Molar mass of $FeSO_4(NH_4)_2SO_4$.

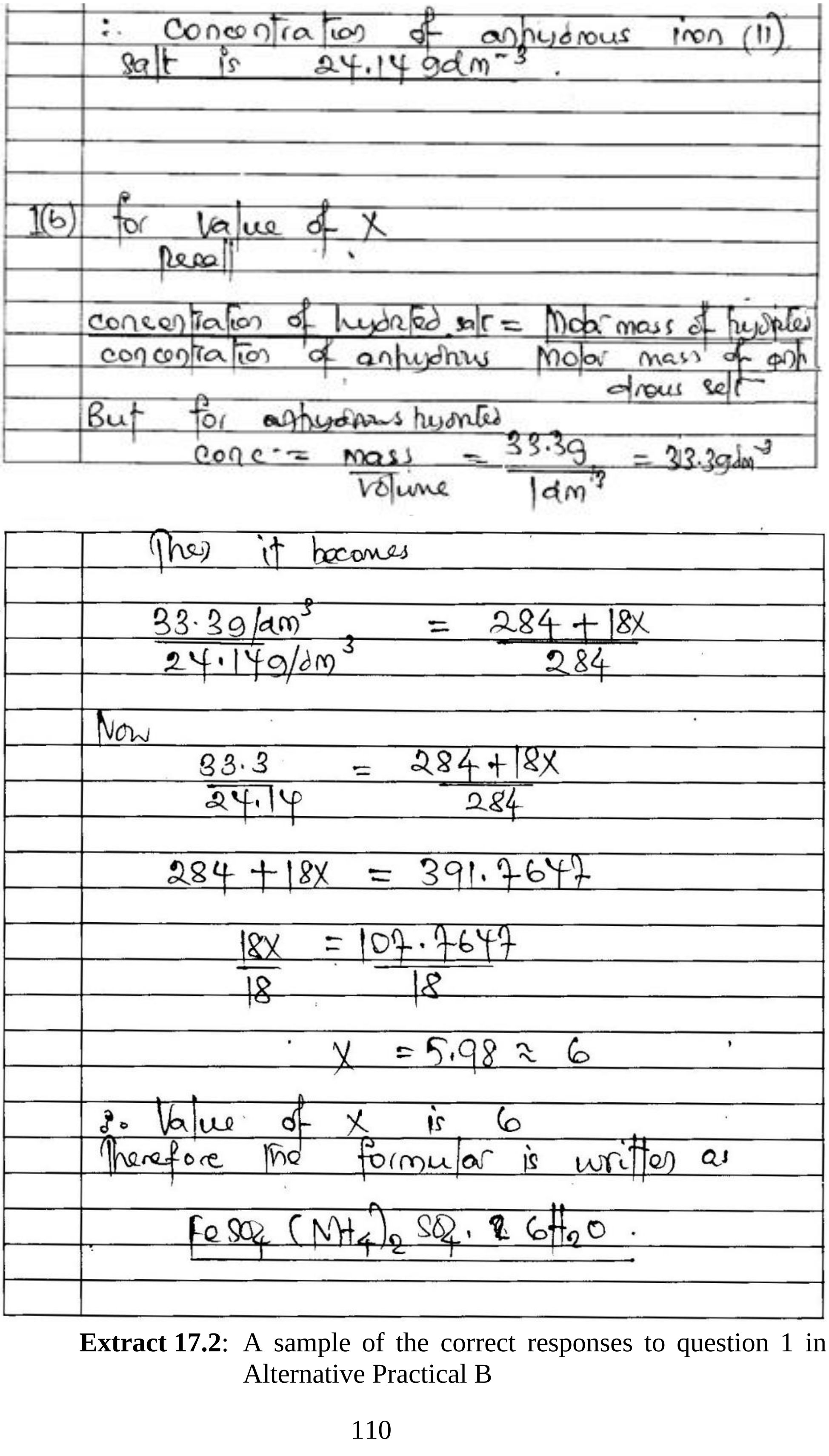
$= [56 + 32 + 64 + (14+4)2 + 32 + (16\times4)] gmol^{-1}$

$= 284 gmol^{-1}$.

Then

concentration $= 0.085M \times 284 gmol^{-1}$

$= 24.14 g/dm^{-3}$.



∴ Concentration of anhydrous iron (II) salt is 24.14 gdm^{-3} .

1(b) for value of X

Recall:

$$\frac{\text{concentration of hydrated salt}}{\text{concentration of anhydrous}} = \frac{\text{Molar mass of hydrated}}{\text{Molar mass of anhydrous salt}}$$

But for anhydrous hydrated

$$\text{conc} = \frac{\text{mass}}{\text{volume}} = \frac{33.3g}{1dm^3} = 33.3gdm^{-3}$$

Then it becomes

$$\frac{33.3g/dm^3}{24.14g/dm^3} = \frac{284+18X}{284}$$

Now

$$\frac{33.3}{24.14} = \frac{284+18X}{284}$$

$$284 + 18X = 391.7647$$

$$\frac{18X}{18} = \frac{107.7647}{18}$$

$$X = 5.98 \approx 6$$

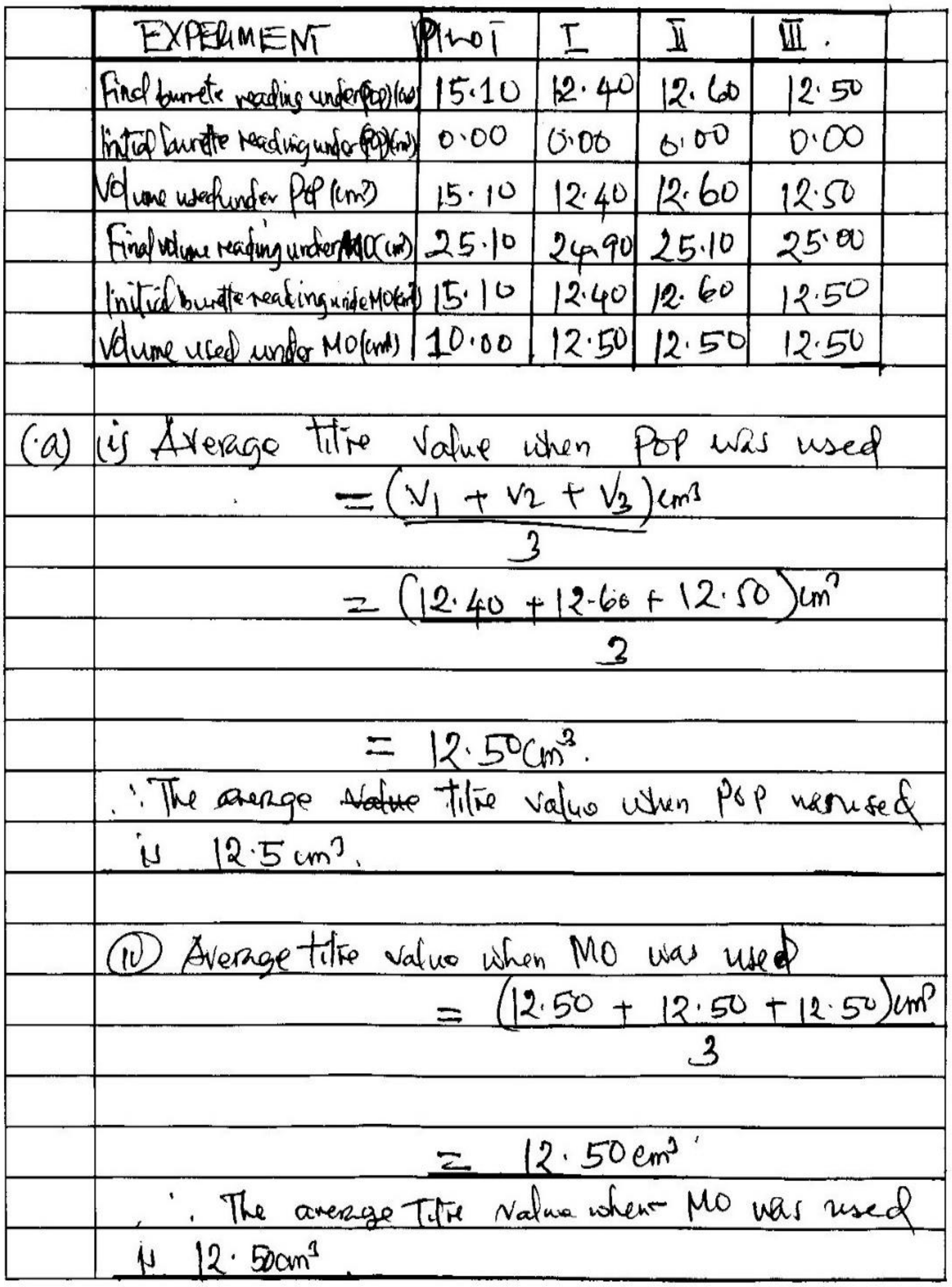
∴ Value of X is 6

Therefore the formular is written as

$FeSO_4 (NH_4)_2 SO_4 \cdot 6H_2O$.

Extract 17.2: A sample of the correct responses to question 1 in Alternative Practical B

In Extract 17.2, the candidate managed to record experimental results in the table and gave the volumes in two decimal places as required. He/she arrived to the correct titre value, which was within the expected range (i.e., ±0.5 cm^3). The candidate managed to calculate the number of molecules of water of crystallization.



EXPERIMENT	PILOT	I	II	III.
Final burette reading under(POP)(cm³)	15.10	12.40	12.60	12.50
Initial burette reading under (POP)(cm³)	0.00	0.00	0.00	0.00
Volume used under POP (cm³)	15.10	12.40	12.60	12.50
Final volume reading under MO (cm³)	25.10	24.90	25.10	25.00
Initial burette reading under MO (cm³)	15.10	12.40	12.60	12.50
Volume used under MO (cm³)	10.00	12.50	12.50	12.50

(a) (i) Average titre value when POP was used

$$= \frac{(V_1 + V_2 + V_3)\,cm^3}{3}$$

$$= \frac{(12.40 + 12.60 + 12.50)\,cm^3}{3}$$

$$= 12.50\,cm^3.$$

∴ The average ~~Value~~ titre value when POP was used is 12.5 cm^3.

(ii) Average titre value when MO was used

$$= \frac{(12.50 + 12.50 + 12.50)\,cm^3}{3}$$

$$= 12.50\,cm^3$$

∴ The average Titre Value when MO was used is 12.50 cm^3.

I (b) (i) Chemical equation when POP was used is

$$Na_2CO_{3(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + NaHCO_{3(aq)}$$

(ii) Chemical equation when MO was used is

$$NaHCO_{3(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

(c) ~~(i)~~ Total overall average volume of the solution L used for complete reaction with solution K is given by,

Titre Value under (POP) + Titre value under MO.

$= 12.50cm^3 + 12.50cm^3$

$= 25.00cm^3$.

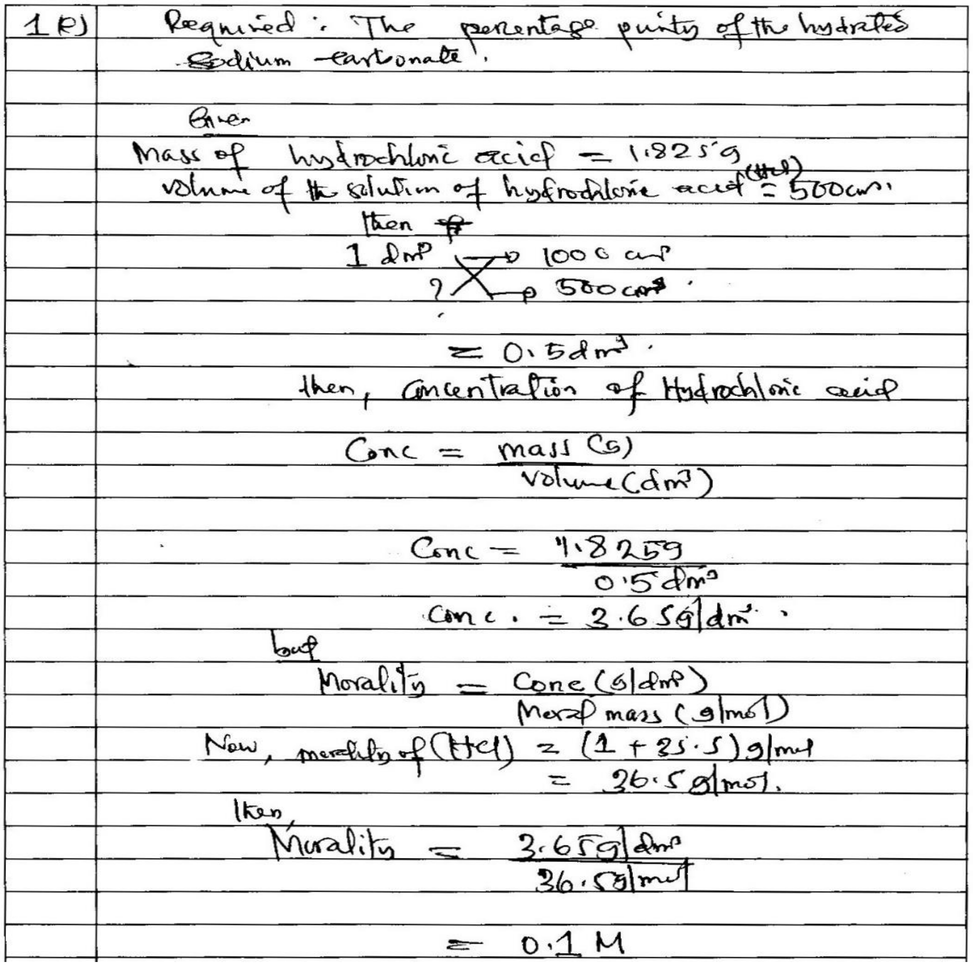
∴ The total overall average volume of the solution L used is $25.00cm^3$.

(d) Overall reaction between L and K.

$$+\left|\begin{array}{l} Na_2CO_{3(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + \cancel{NaHCO_{3(aq)}} \\ \cancel{NaHCO_{3(aq)}} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)} \end{array}\right.$$

$$\Rightarrow Na_2CO_{3(aq)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

∴ The above equation is an overall equation between L and K



1(e) Required : The percentage purity of the hydrated Sodium carbonate.

Given

Mass of hydrochloric acid = 1.825 g

volume of the solution of hydrochloric acid (HCl) = 500 cm³.

then ~~of~~

$1\ dm^3 \rightarrow 1000\ cm^3$

$? \rightarrow 500\ cm^3$.

$= 0.5\ dm^3$.

then, concentration of Hydrochloric acid

$$\text{Conc} = \frac{\text{mass (g)}}{\text{volume} (dm^3)}$$

$$\text{Conc} = \frac{1.825\ g}{0.5\ dm^3}$$

$\text{Conc.} = 3.65\ g/dm^3$.

but

$$\text{Morality} = \frac{\text{Conc} (g/dm^3)}{\text{Mozal mass} (g/mol)}$$

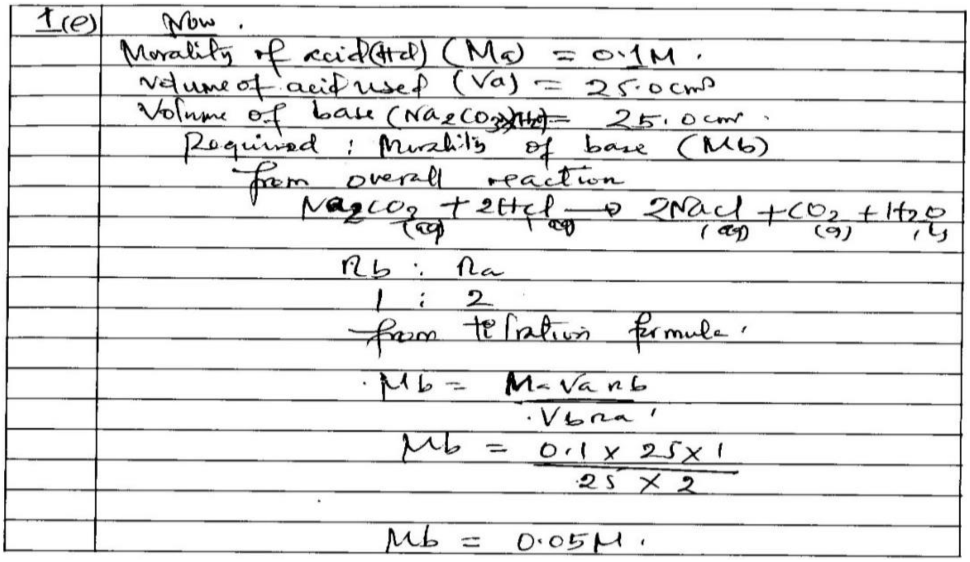
Now, morality of (HCl) $= (1 + 35.5)\ g/mol$

$= 36.5\ g/mol$.

then,

$$\text{Morality} = \frac{3.65\ g/dm^3}{36.5\ g/mol}$$

$= 0.1\ M$



1(e) Now.

Morality of acid (HCl) (Ma) = 0.1 M.

volume of acid used (Va) = 25.0 cm³

Volume of base (Na_2CO_3 ~~H₂O~~) = 25.0 cm³.

Required : Morality of base (Mb)

from overall reaction

$$Na_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

nb : na

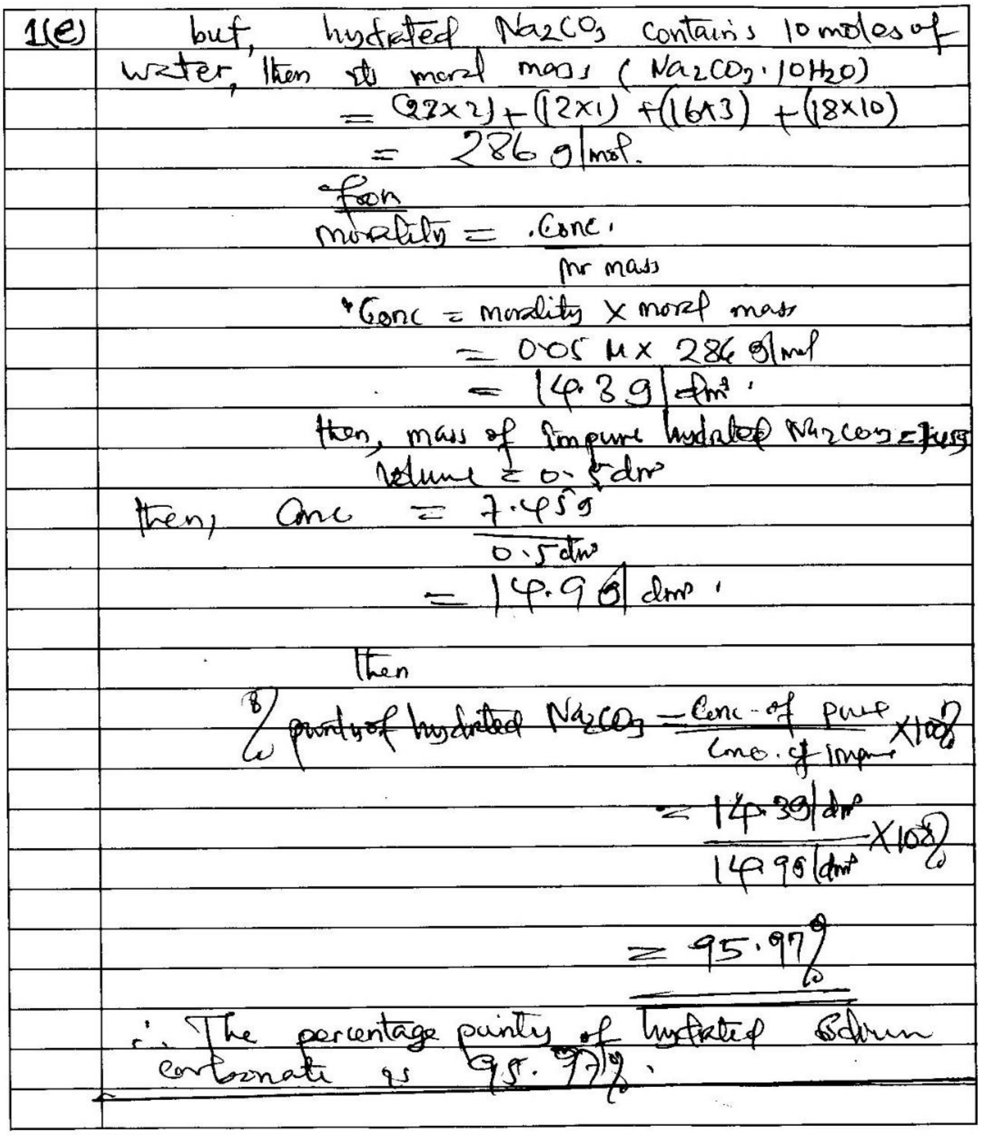
1 : 2

from titration formula.

$$Mb = \frac{Ma\,Va\,nb}{Vb\,na}$$

$$Mb = \frac{0.1 \times 25 \times 1}{25 \times 2}$$

$Mb = 0.05\ M$.



1(e) but, hydrated Na_2CO_3 contains 10 moles of water, then its moral mass ($Na_2CO_3 \cdot 10H_2O$)

$= (23 \times 2) + (12 \times 1) + (16 \times 3) + (18 \times 10)$

$= 286$ g/mol.

from

$\text{morality} = \dfrac{\text{Conc.}}{\text{Mr mass}}$

*Conc = morality x moral mass

$= 0.05\ M \times 286$ g/mol

$= 14.3$ g/dm³.

then, mass of impure hydrated Na_2CO_3 = 7.45g

volume = 0.5 dm³

then, $\text{Conc} = \dfrac{7.45g}{0.5dm^3}$

$= 14.9$ g/dm³.

then

$\%$ purity of hydrated $Na_2CO_3 = \dfrac{\text{Conc. of pure}}{\text{Conc. of impure}} \times 100\%$

$= \dfrac{14.3g/dm^3}{14.9g/dm^3} \times 100\%$

$= 95.97\%$

∴ The percentage purity of hydrated Sodium carbonate is 95.97%.

Extract 17.3: A sample of correct responses in question 1 of the alternative practical C

In Extract 17.3, the candidate correctly recorded the results in the table by observing the required two decimal places. The candidate calculated the titre value correctly which was within the acceptable range in comparison to the expected value (i.e ± 0.5 cm^3). The candidate wrote the correct chemical reaction between the given hydrated sodium carbonate and hydrochloric acid. Thereafter, he/she performed all the required calculations to identify the percentage purity of the hydrated sodium carbonate.

However, a few candidates (2,164 6.2%) scored low marks, from 0–6.5 in question 1 (Table 1). Their responses show that they had insufficient knowledge of the topic of *Chemical Analysis*, specifically of *Volumetric Analysis,* although it was also studied in the topic of *Volumetric Analysis and Related Calculations* in Form Three. Generally, mistakes such as failing to record and manipulate experimental data according to the requirements of the question were observed. Some of the candidates recorded titration data by using one decimal place instead of two. They also lacked accuracy in performing the titration experiment. This led to titre values which fell outside the expected value. Additionally, some of the candidates used indicators **MO** and **POP** interchangeably; as result, they observed irrelevant colours.

Additionally, some of the candidates who scored low marks used the wrong chemical equations in relation to the indicator used. For example, in alternative paper A, one of the candidates wrote the reactions that took place when MO and POP as

$$"HCl(aq) + Na_2CO_3\text{(aq)} \xrightarrow{MO} NaHCO_3\text{(aq)} + \text{NaCl(aq)}$$

$$HCl(aq) + NaHCO_3(aq) \xrightarrow{POP} H_2O\text{(l)} + CO_2(aq) + NaCl(aq)"$$

Though the chemical equations were correct and balanced, the candidate used the indicator interchangeably. He/she was supposed to be familiar with the concept of choosing suitable indicators. Thus, he/she would have realized that the MO indicator is suitable for titration(s) involving strong acid against a strong base and POP is a suitable indicator for titration(s) involving weak acid and strong base. Thus, the correct reactions were supposed to be as follows:

$$"HCl(aq) + Na_2CO_3\text{(aq)} \xrightarrow{POP} NaHCO_3\text{(aq)} + \text{NaCl(aq)}$$

$$HCl(aq) + NaHCO_3(aq) \xrightarrow{MO} H_2O\text{(l)} + CO_2(aq) + NaCl(aq)"$$

Extracts 17.4, 17.5 and 17.6 show sample responses to question 1 of the alternative papers A, B and C, respectively.

01 Solution

Table of Results.

Experiment	pilot	1	2	3
Initial volume under pop	0.00	0.00	15.00	0.00
Final volume under p.o.p	8.90	9.00	23.8	8.70
Inihal reading volume under m.o	9:00	0.00	0.00	0.00
Final reading volume under m.o	24.5	15.00	15.00	14.8
First reading titte under p.op	8.90	9.00	8.8	8.7
Second reading titte under m.o	15.5	15.00	15.00	14.8

Avarage volume in(cm³) used under p.o.p =

$$\text{Experiment } \frac{1+2+3}{3}$$

$$\frac{9+8.8+8.7}{3} = \frac{26.5}{3} = 8.83$$

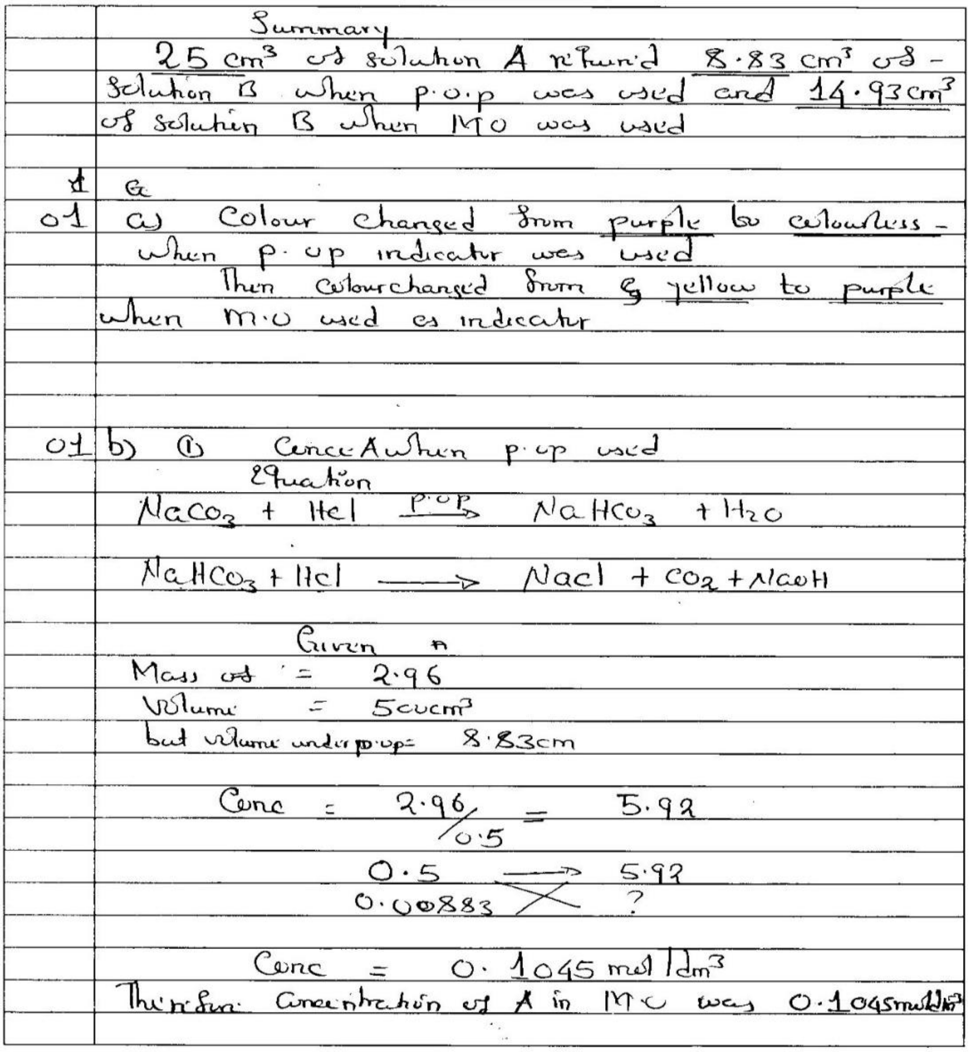
Therefore average volumed used under p.o.p is 8.83 cm³

Avarage volumed used under M.O

$$= \text{Experiment } \frac{1+2+3}{3}$$

$$\frac{15+15+14.8}{3} = \frac{44.8}{3} = 14.93$$

Therefore average volume used under m.o is 14.93cm³



Summary
25 cm^3 of solution A returned 8.83 cm^3 of -
solution B when p.o.p was used and 14.93 cm^3
of solution B when MO was used

1 G
01 a) Colour changed from purple to colourless -
when p.op indicator was used
Then colourchanged from ~~g~~ yellow to purple
when M.O used as indicator

01 b) ① Conc A when p.op used
Equation
$NaCO_3 + Hcl \xrightarrow{P.O.P} NaHCO_3 + H_2O$

$NaHCO_3 + Hcl \longrightarrow Nacl + CO_2 + NaoH$

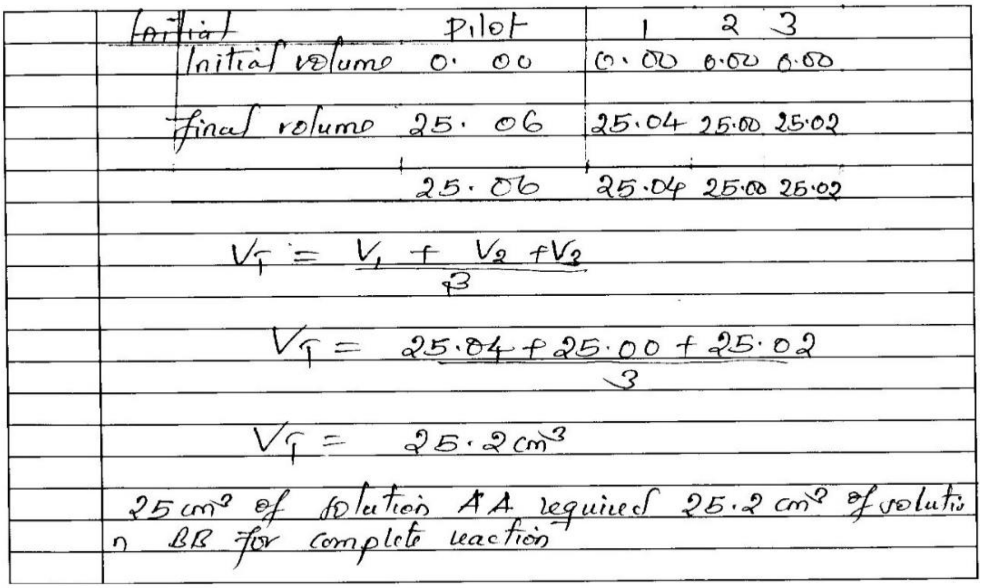
Given A
Mass of = 2.96
Volume = 500cm^3
but volume under p.op = 8.83cm

Conc = $2.96/0.5$ = 5.92
$0.5 \longrightarrow 5.92$
$0.00883 \quad ?$

Conc = 0.1045 mol/dm^3
Therefore Concentration of A in MO was 0.1045mol/dm^3

Extract1 7.4: A sample of the incorrect responses to question 1 in Alternative Practical A

In Extract 17.4, although the candidate recorded the results in tabular form, some of the data are in one decimal place, instead of two. In part (a) (i) and (ii), the candidates failed to recognize the actual colour change. He/she wrote purple to colourless and yellow to purple, instead of pink to colourless and yellow to orange/red, respectively. In addition, in part (b) (i), he/she wrote incorrect balanced chemical equations. This is indicates a lack of knowledge about communicating through chemical symbols and equation.



~~Initial~~	Pilot	1	2	3
Initial volume	0. 00	0.00	0.00	0.00
final volume	25. 06	25.04	25.00	25.02
	25. 06	25.04	25.00	25.02

$$V_T = \frac{V_1 + V_2 + V_3}{3}$$

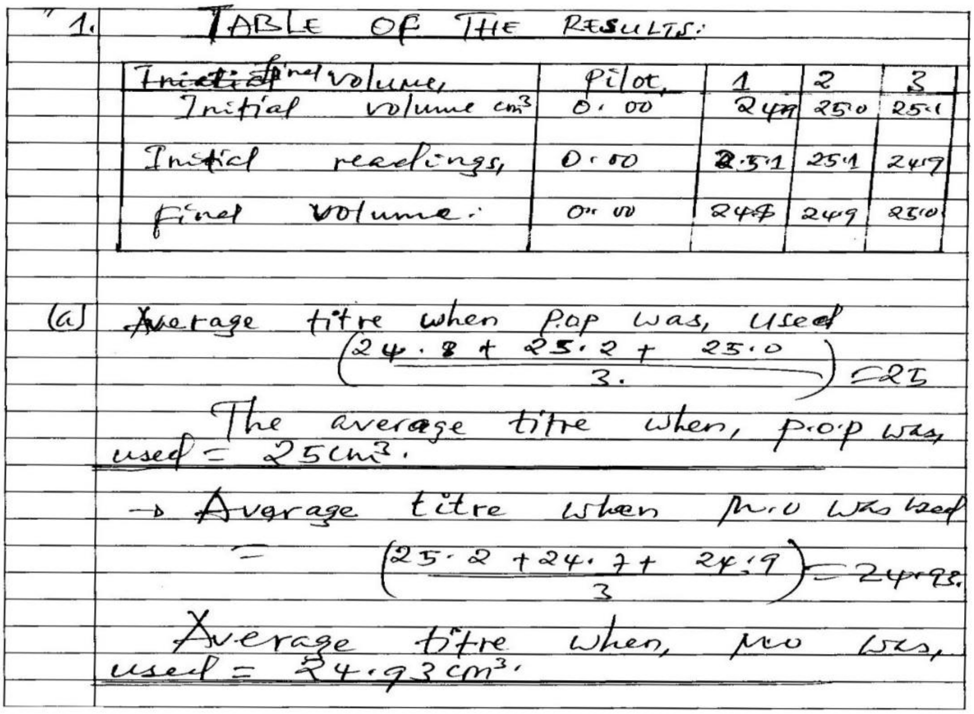
$$V_T = \frac{25.04 + 25.00 + 25.02}{3}$$

$$V_T = 25.2\,cm^3$$

25 cm³ of solution AA required 25.2 cm³ of solution BB for complete reaction

Extract 17.5: A sample of the incorrect responses to question 1 in Alternative Practical B

In Extract 17.5, the candidate presented the data which were out of range. Hence, he/she obtained the titre value which fell out of range. This indicates that the candidate lacked knowledge of volumetric analysis procedures.



1. TABLE OF THE RESULTS:

~~Initial~~ final volume,	Pilot,	1	2	3
Initial volume cm³	0. 00	247	25.0	25.1
Initial readings,	0. 00	25.1	25.1	24.9
final volume.	0. 00	24.8	249	25.0

(a) Average titre when P.O.P was, used

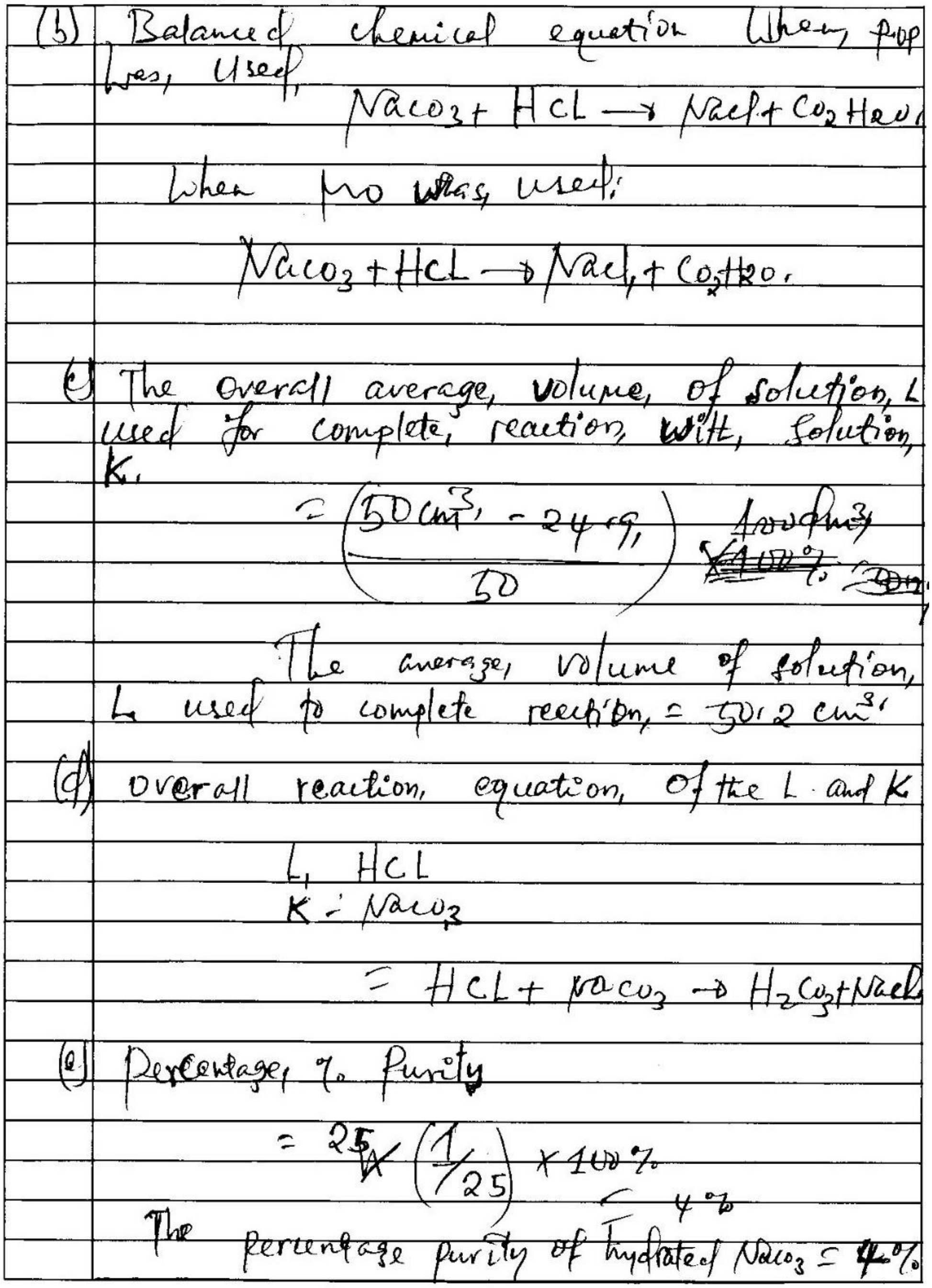
$$\left(\frac{24.8 + 25.2 + 25.0}{3.}\right) = 25$$

The average titre when, P.O.P was, used = 25 cm³.

→ Average titre when M.O was used

$$= \left(\frac{25.2 + 24.7 + 24.9}{3}\right) = 24.93.$$

Average titre when, M.O was, used = 24.93 cm³.



(b) Balanced chemical equation When pop was, used,

$Naco_3 + HCL \rightarrow Nacl + Co_2 H_2O,$

When pro was, used;

$Naco_3 + HCL \rightarrow Nacl, + Co_2 H_2O.$

(c) The overall average, volume, of solution, L used for complete, reaction, with, solution, K,

$= \left(\frac{50 cm^3, - 24.9,}{50}\right)$ 100 cm³ ~~×100%~~ ~~30~~

The average, volume of solution, L used to complete reaction, = 50.2 cm³.

(d) overall reaction, equation, Of the L . and K

L, HCL
K - $Naco_3$

$= HCL + Naco_3 \rightarrow H_2Co_3 + Nacl$

(e) Percentage, % Purity

$= 25 \times \left(\frac{1}{25}\right) \times 100\%$
$= 4\%$

The percentage purity of hydrated $Naco_3$ = 4%.

Extract 17.6: A sample of the incorrect responses to question 1 in Alternative Practical C

In Extract 17.6, the candidate presented incorrect data in the table of result; he/she gave initial volumes without showing the indicator responsible. Furthermore, in parts (b), (c), (d) and (e), the candidate gave incorrect chemical equations, formulae and calculations as required by the questions. This was contributed by the lack of knowledge about the basic principles of volumetric analysis.

2.3.2 Question 2: Physical Chemistry Analysis
Chemistry 3A, 3B and 3C

Question 2 of 132/3A Chemistry 3A was as follows:

"*You are provided with the following:*

***K1**: 0.1 M sodium hydroxide;*

***K2**: Butanedioic acid of unknown concentration;*

***K3**: Isobutyl alcohol;*

***POP**: Phenolphthalein indicator;*

Distilled water.

Theory

Butanedioic acid $(CH_2COOH)_2$ *dissolves in both water and isobutyl alcohol at constant ratio of concentration and temperature.*

Procedure 1

*(i) Pipette 20 or 25 cm^3 of a solution **K2** into a conical flask. Add 2 or 3 drops of **POP**.*

*(ii) Put **K1** in a burette.*

*(iii) Titrate **K2** against **K1** in the presence of **POP** until a colour change is observed.*

*(iv) Record the volume of the pipette and the volume of **K1**used as well as the room temperature.*

Procedure 2

*(i) Put 50 cm^3 of **K3** into a separating funnel. Add to it 50 cm^3 of distilled water.*

*(ii) Measure 50 cm^3 of **K2** and put it into a separating funnel in (i). Shake the mixture well.*

(iii) Run off the lower aqueous layer into a clean beaker.

(iv) Using a measuring cylinder, measure 25 cm^3 of the aqueous layer into a clean conical flask.

*(v) Titrate this aliquot against **K1** using **POP** (only one titration is enough).*

Summary 2

*Volume of **K1** used was _____________*

Questions

(a) Write a balanced chemical equation representing the reaction taking place in the titration.

(b) Calculate the;

  *(i) initial concentration of **K2** in water.*
  *(ii) final concentration of **K2** in the aqueous layer.*
  (iii) acid concentration in the organic layer.
  *(iv) partition coefficient of **K2** between water and isobutyl alcohol".*

Question 2 of 132/3B Chemistry 3B was as follows:

"*You are provided with the following:*

***JJ**: 0.05 M sulphuric acid;*
***MM**: 0.035 M potassium iodide;*
***KK**: 0.035 M sodium thiosulphate;*
***LL**: 0.9 M hydrogen peroxide;*
***HH**: Starch solution;*
Stop watch.

Theory

Hydrogen peroxide reacts with iodide ions in the presence of hydrogen ions in an aqueous solution as follows: $H_2O_2 + 2I^- + 2H^+ \longrightarrow 2H_2O + I_2$*. The iodine produced immediately reacts with thiosulphate ions as follows:* $I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$*. When all the thiosulphate ions have reacted, iodine begins to accumulate in the solution and its presence can be detected by starch.*

Procedure

*(i) Using a measuring cylinder, put 100 cm^3 of solution **JJ** into a conical flask and then 10 cm^3 of solution **MM** into the same flask, followed by 10 cm^3 of solution **HH**.*

(ii) Swirl the contents of the flask to ensure proper mixing.

*(iii) Fill the burette with the solution **KK** and adjust the level to zero mark. Run 2.0 cm^3 of the solution **KK** into the mixture and again swirl the contents.*

(iv) *Using a measuring cylinder, add 10 cm^3 of solution **LL** into the mixture and immediately start the stop watch. Shake well the flask when the solution **LL** is running into it.*

(v) *Note the time when suddenly the mixture turns blue. Without stopping the stop watch, add further 2.0 cm^3 of solution **KK** and shake well the flask. Again note the time when the blue colour reappear.*

(vi) *Continue this way until you have added 12 cm^3 of the solution **KK**.*

(vii) *Record all your readings as indicated in Table 1.*

(viii) *Repeat procedure (i) to (vii) using fresh portions of the solutions, but this time use 10 cm^3 of diluted solution **LL**. Dilute solution **LL** as follows; measure 10 cm^3 of solution **LL** into a beaker and then add 10 cm^3 of distilled water. Swirl the contents.*

Results

Table 1: Undiluted LL

*Volume of **KK** added (cm^3)*	*2*	*4*	*6*	*8*	*10*	*12*
Time in seconds						

Table 2: Diluted LL

*Volume of **KK** added (cm^3)*	*2*	*4*	*6*	*8*	*10*	*12*
Time in seconds						

Questions

(a) *On the same axes, plot a graph showing the volume of sodium thiosulphate solution, **KK** against time for each experiment.*

(b) *Comment on the shapes of your graphs and explain what is expected to the graph if you continue adding **KK** for a longer period of time.*

(c) *Calculate the slope of each curve and deduce the order of the reaction with respect to hydrogen peroxide.*

(d) *How is the amount of iodine liberated related to the amount of hydrogen peroxide consumed?"*

Question 2 of 132/3C Chemistry 3C was as follows:

"*You are provided with the following:*

***M**:* *A solution of 0.05 M sodium thiosulphate;*

***N**:* *A solution of 0.1 M nitric acid;*

Stop watch;
Thermometer.

Theory

Dilute nitric acid reacts with sodium thiosulphate to form a white precipitate of sulphur according to the following equation: $S_2O_3^{2-}(aq)+2H_3O^+(\text{aq})\longrightarrow 3H_2O(l)+SO_2(g)+S^-(s)$

The precipitate of sulphur causes the solution to become opaque. From this phenomenon, the rate of formation of sulphur precipitate can be measured.

Procedure

- *(i)* *Draw a letter X on a sheet of white paper and place a 100 cm^3 beaker on top of the letter.*
- *(ii)* *Pour about 200 cm^3 of a clean water into a 250 or 300 cm^3 beaker and heat gently. Use this as your water bath.*
- *(iii)* *Measure exactly 10 cm^3 of* ***M*** *and 10 cm^3 of* ***N*** *into separate two boiling tubes. Put the two tubes in the water bath and warm the contents to about 50 °C.*
- *(iv)* *Immediately, pour the hot solutions* ***M*** *and* ***N*** *into a 100 cm^3 beaker in (i) and simultaneously start the stop watch.*
- *(v)* *Swirl the mixture in (iv) and record the time taken for the letter X to disappear completely.*
- *(vi)* *Repeat the steps (i) - (v) using temperature 60 °C, 70 °C and 80 °C.*
- *(vii)* *Record your results in a tabular form.*

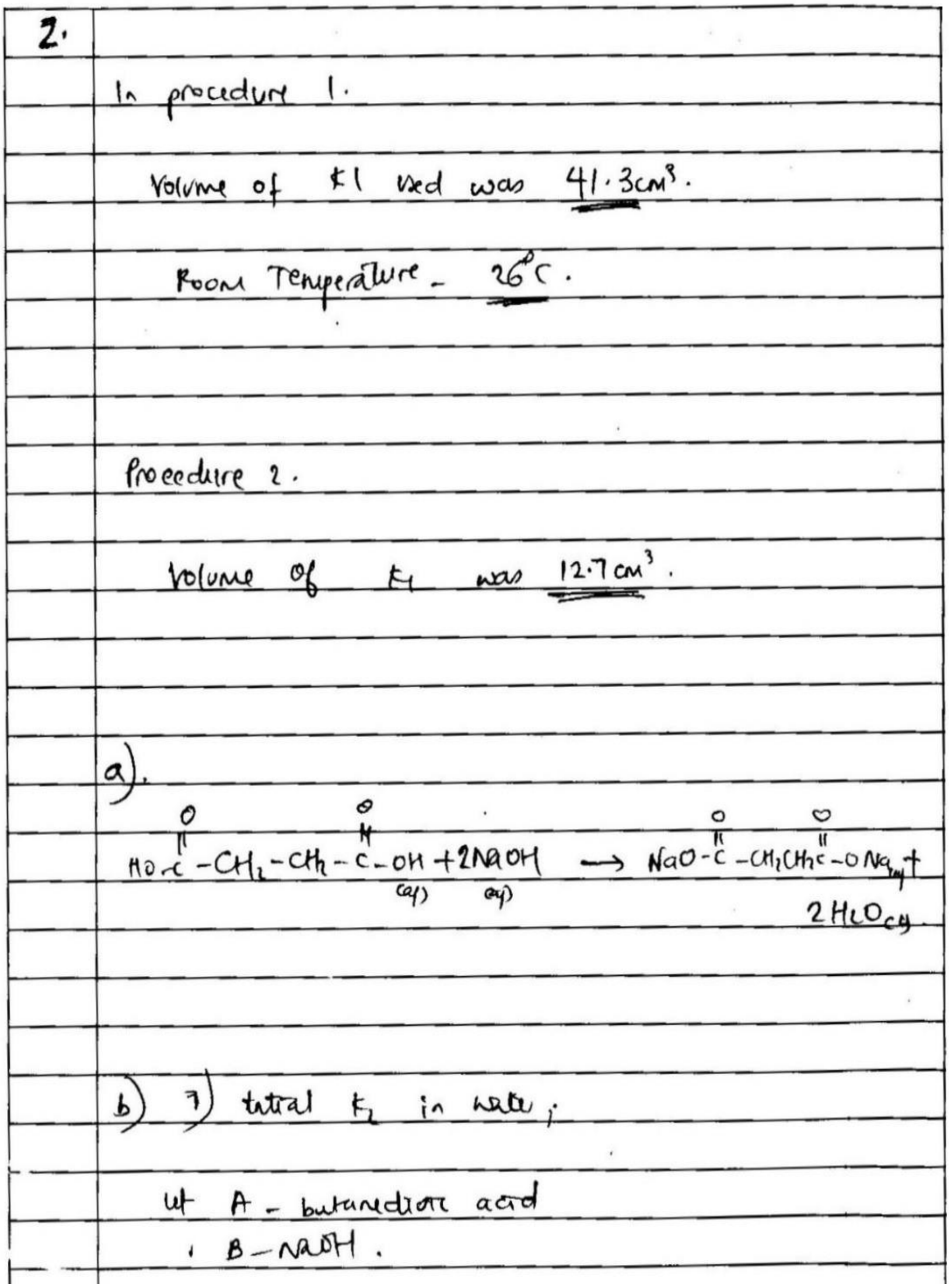
Questions

- *(a)* *Plot a graph of* $\log\frac{1}{t}(\sec^{-1})$ *against* $\frac{1}{T}(K^{-1})$.
- *(b)* *Determine the slope of the graph.*
- *(c)* *Using Arrhenius equation, determine the activation energy of the reaction".*

The question was attempted by 34,735 candidates. Among them, 7,125 (20.5%) scored from 9.0–15 marks, indicating good scores. Further, 10,620 (30.6%) scored from 5.5–8.5 marks, indicating average scores and 16,990 (48.9%) scored from 0–5.0 marks, indicating weak scores.

The candidates' overall performance on the question was average; the majority (51.1%) of the candidates scored a pass mark or above (≥5.5 marks). The candidates who performed well had mastered the subtopic of

Physical Chemistry Analysis. These candidates managed to determine partition coefficient in alternative paper A, the order of reaction in alternative paper B as well as the effect of temperature on the rate of a chemical reaction in alternative C correctly. Extracts 18.1, 18.2 and 18.3 show samples of the correct responses to question 2 in alternative A, B, and C, respectively.



2.

In procedure 1.

Volume of KI used was $41.3cm^3$.

Room Temperature - 26°C.

Procedure 2.

Volume of KI was $12.7cm^3$.

a).

$$HO-\overset{\overset{O}{||}}{C}-CH_2-CH_2-\overset{\overset{O}{||}}{C}-OH_{(aq)} + 2NaOH_{(aq)} \longrightarrow NaO-\overset{\overset{O}{||}}{C}-CH_2CH_2\overset{\overset{O}{||}}{C}-ONa_{(aq)} + 2H_2O_{(aq)}$$

b) i) titral K_2 in wate;

let A - butanedioic acid

, B - NaOH.

2.

b)

i) From.

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

$M_B = 0.1M$ ~~M_A~~

$V_B = 41.3cm^3$

$M_A = ?$

$V_A = 25cm^3$

$n_A = 1$

$n_B = 2$

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

$$M_A = \frac{0.1M \times 41.3cm^3 \times 1}{25cm^3 \times 2}$$

$$M_A = 0.0826M$$

∴ Initial conc. of K_2 in water is $\underline{0.0826M}$.

ii) Since $50cm^3$ were added.

$$V_2 = 50 + 50 = 100cm^3$$

$$M_1 V_1 = M_2 V_2$$

$$0.0826 \times 50cm^3 = M_2 \times 100cm^3$$

$M_2 = \underline{0.0413M}$. in ageous layer.

2. b)

ii) Now,

$M_B = 0.1M$

$V_B = 12.7cm^3$

$n_B = 2$

$n_A = 1$

$M_A = ?$

$V_A = 25cm^3$

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

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

$M_A = \frac{0.1M \times 12.7cm^3 \times 1}{25cm^3 \times 2}$

$M_A = \underline{0.0254M}$. in ageous layer.

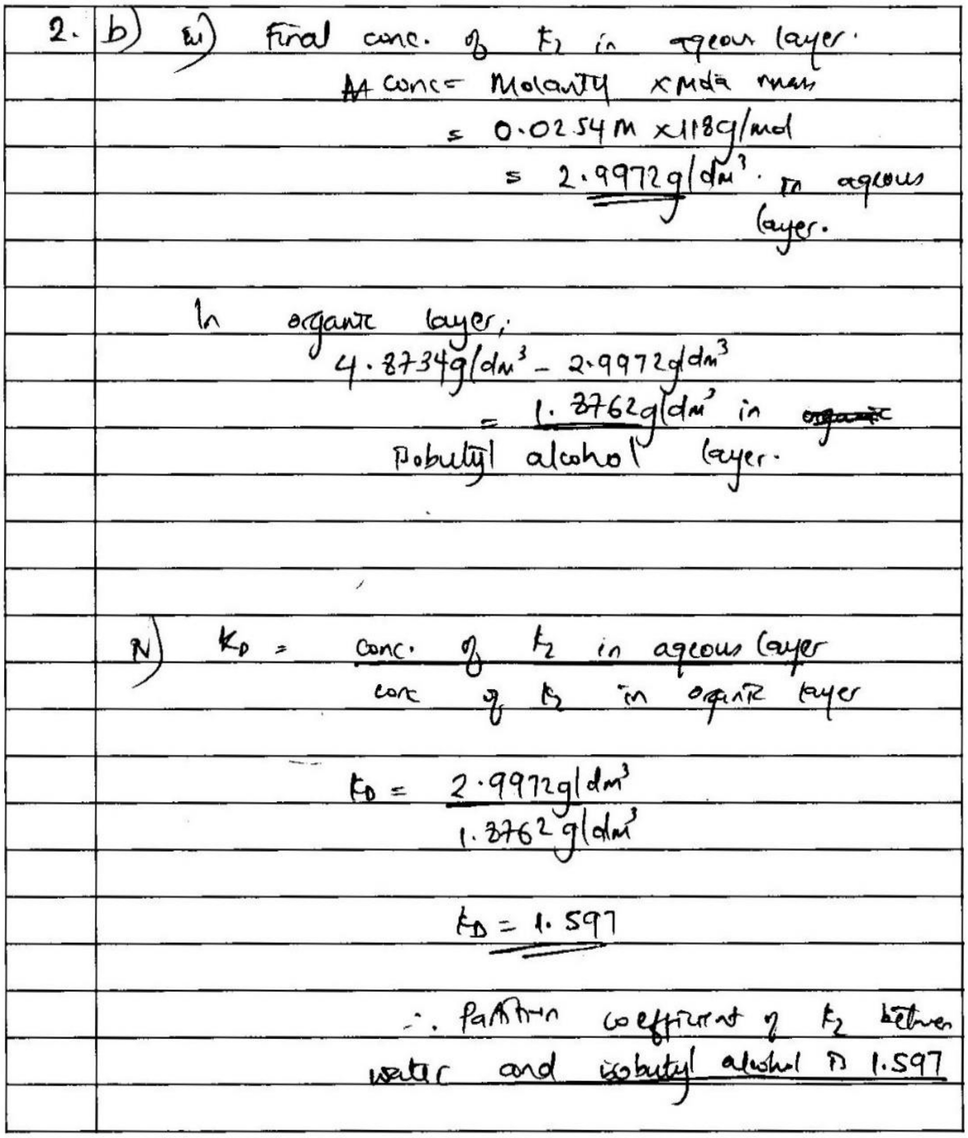
iii) Initial conc = 0.0413M

molarity = $\frac{\text{conc (g/dm}^3)}{M_r}$

Molar mass of butanedioic acid is 118g/mol

Conc = Molarity × Molar mass

Conc = $\underline{4.8734}$ g/dm^3 initially in the ageous layer.



2. b) ii) Final conc. of I_2 in aqeous layer.

~~A4~~ conc = Molarity x Molar mass

= 0.0254M x 118g/mol

= 2.9972g/dm³ in aqeous layer.

In organic layer,

4.8734g/dm³ − 2.9972g/dm³

= 1.8762g/dm³ in ~~organic~~ isobutyl alcohol layer.

iii) $K_D = \frac{\text{conc. of } I_2 \text{ in aqeous layer}}{\text{conc of } I_2 \text{ in organic layer}}$

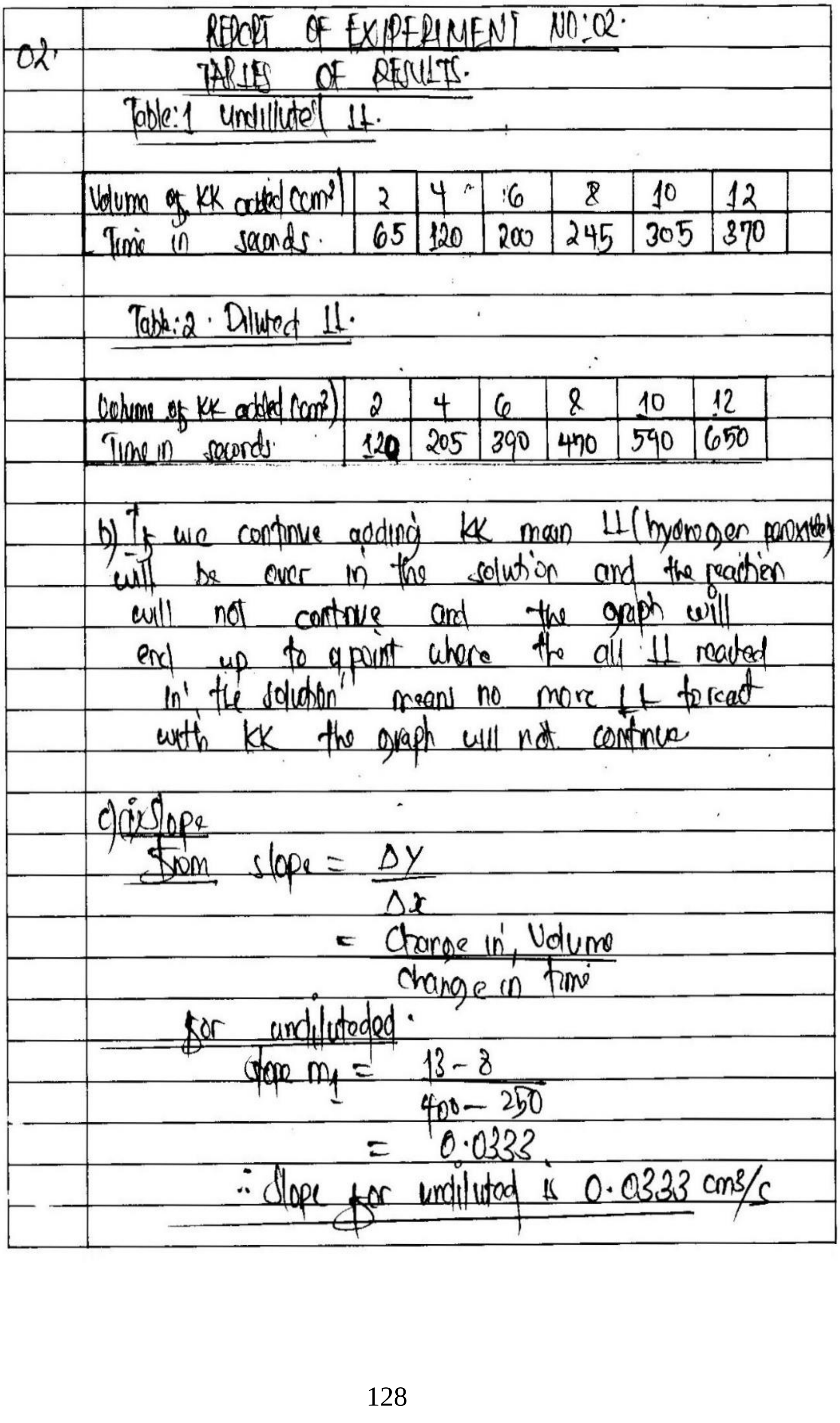
$K_D = \frac{2.9972 g/dm^3}{1.8762 g/dm^3}$

$K_D = 1.597$

∴ Partition coefficient of I_2 between water and isobutyl alcohol is 1.597

Extract 18.1: A sample of the correct responses to question 2 in Alternative Practical A

In Extract 18.1, the candidate correctly measured the volume of the solution and titrated it to obtain the titre value. He/she also correctly calculated the partition coefficient.



02.

REPORT OF EXIPERIMENT NO:02.

TABLES OF RESULTS.

Table:1 undillutedl LL.

Volume of KK added (cm³)	2	4	6	8	10	12
Time in seconds.	65	120	200	245	305	370

Table:2 · Diluted LL.

Volume of KK added (cm³)	2	4	6	8	10	12
Time in seconds	120	205	390	470	590	650

b) If we continue adding KK mean LL (hydrogen paroxide) will be over in the solution and the reaction will not continue and the graph will end up to a point where the all LL reacted in the solution means no more LL to react with KK the graph will not continue

c) (i) Slope

From slope $= \frac{\Delta Y}{\Delta x}$

$= \frac{\text{Charge in, Volume}}{\text{change in time}}$

for undilutoded.

slope $m_1 = \frac{13-8}{400-250}$

$= 0.0333$.

∴ slope for undilutod is 0.0333 cm³/c

Q2 for dilluted

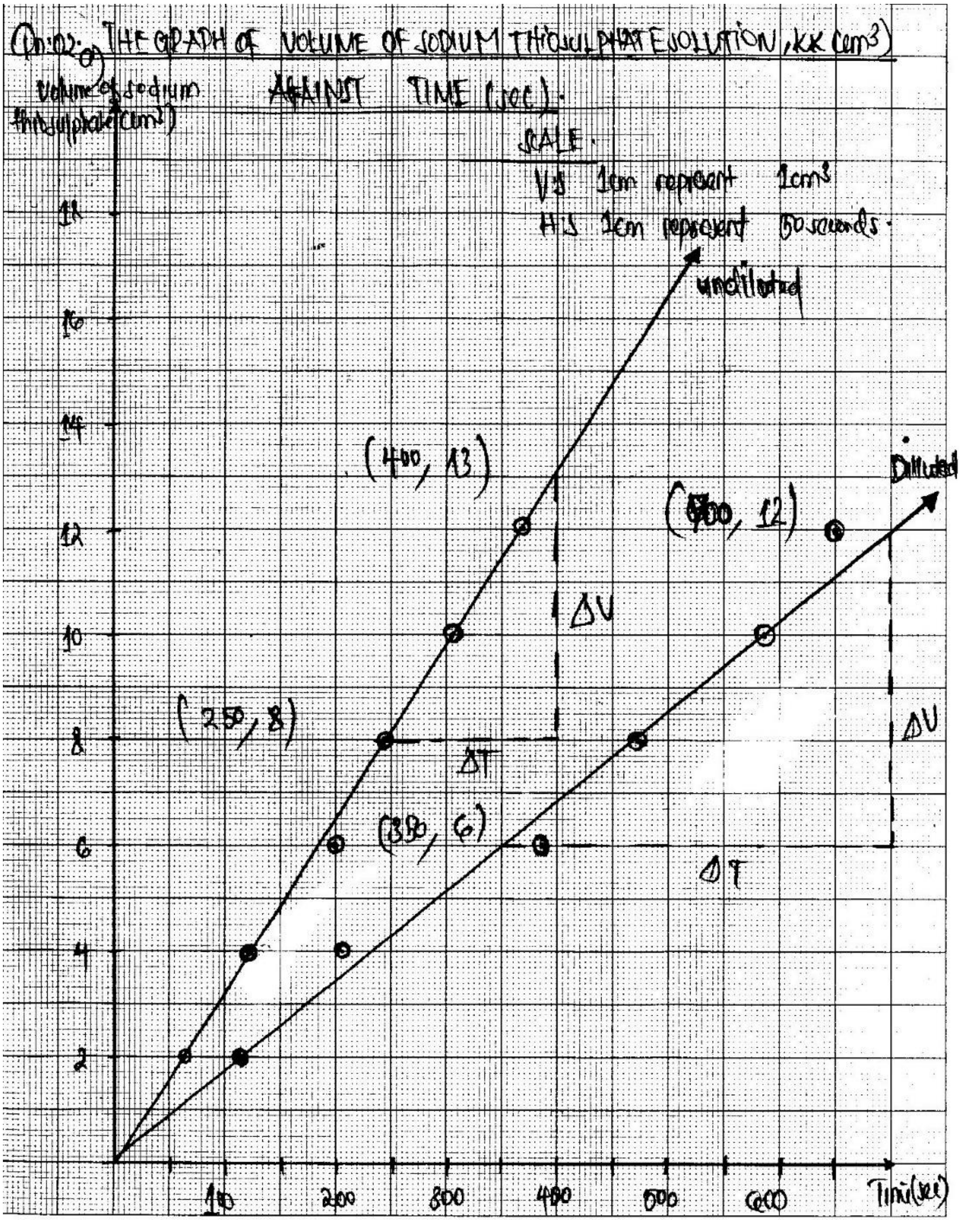
$$\text{slope } m_2 = \frac{12-0}{700-350}$$

$$= 0.0171 \text{ cm}^3/\text{s}$$

slope, m_2 is $0.0171 \text{ cm}^3/\text{s}$

(iii) The order of the reaction is first (1st) order of reaction since volume of KK (Sodium thiosulphate) is directly proportional to the time t (in second) which indicated that the reaction is first order.

d) The more the consumption of hydrogen peroxide the more the production and liberation of Iodine ∴ If the large amount of hydrogen peroxide is consumed also the large amount of iodine will be liberated and vice versa If small amount of hydrogen peroxide is consumed also small amount of iodine will be liberated.



Extract 18.2*:* A sample of the correct responses to question 2 in Alternative Practical B

In Extract 18.2, the candidate managed to fill experimental result in the table. The candidate also correctly plotted the graph of the volume of sodium thiosulphate solution against time, analyzed the data, and performed the required calculations in all parts of the question.

2. Soln.

(vi) TABLE OF RESULTS

°C	Temp (θ°K)	$\frac{1}{T}$ (K^{-1})	Time (t)	$\frac{1}{t}$ (sec^{-1})	log ($\frac{1}{t}$)	
	~~323~~	~~3.1×10^{-3}~~				
50	323	3.1×10^{-3}	65.25	0.0153	-1.82	
60	333	3×10^{-3}	45.05	0.0222	-1.65	
70	343	2.9×10^{-3}	32.95	0.0303	-1.52	
80	353	2.8×10^{-3}	20.05	0.0500	-1.30	

(b) Soln

Slope of the graph => Recall

$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{\Delta \log(1/t)\ (sec^{-1})}{\Delta (1/T)\ (K^{-1})}$$

$$\text{Slope} = \frac{-1.82 - (-0.3)}{3.1 \times 10^{-3} - 2.1 \times 10^{-3}} \frac{(sec^{-1})}{(K^{-1})}$$

$$\text{Slope} = -2960\ sec^{-1}\ K^{-1}$$

$$\text{Slope} = -2960\ sec^{-1}\ K^{-1}$$

2 (c) soln.

From $k = Ae^{\frac{Ea}{RT}}$.

Apply ln both sides

~~$\ln k = \ln A - \frac{Ea}{RT}$~~.

~~$\ln k =$~~

$\ln k = \ln A + -\frac{Ea}{RT}\ln e$

$\ln k = -\frac{Ea}{RT}\ln e + \ln A$.

$\log k = -\frac{Ea}{RT}\log e + \log A$.

Then,

from $y = mx + c$.

$\log k = -\frac{Ea}{RT}\log e + \log A$

$y = m x + c$

$m = -\frac{Ea \log e}{R}$.

$+2960 = +\frac{Ea \times \log e}{R}$.

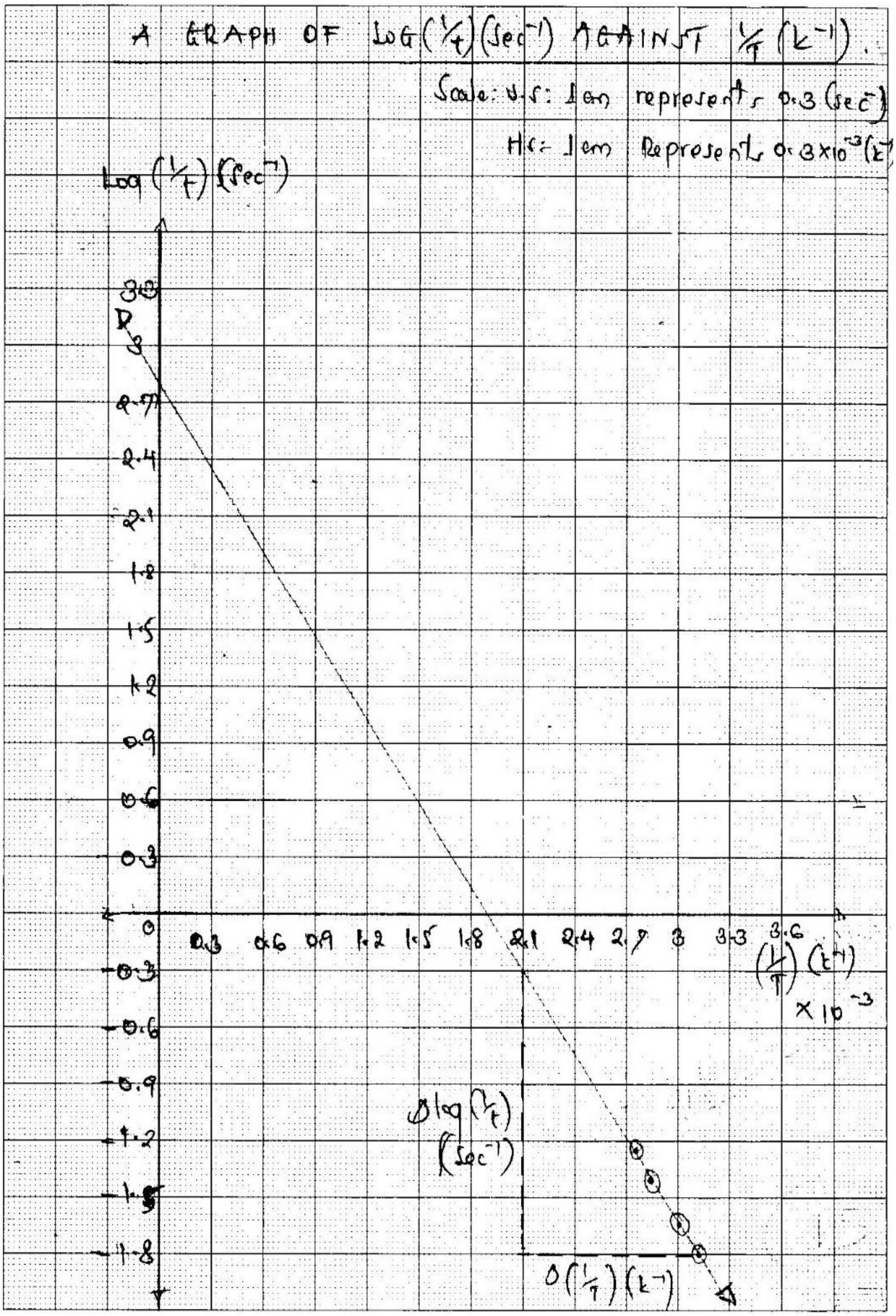
$Ea = \frac{+2960 \times 8.314}{\log e}$.

$Ea = 56,665.33\ J/$~~mol~~

Activation Energy = 56,665.33 Joules

or 56.67 kJoules

2(a)



Extract 18.3: A sample of the correct responses to question 2 in Alternative Practical C

In Extract 18.3, the candidate correctly recorded the required experimental data and plotted the graph of $\log \frac{1}{t}(\sec^{-1})$ against $\frac{1}{T}(K^{-1})$. In addition, the candidate correctly determined the activation energy of the reaction by using the Arrhenius equation.

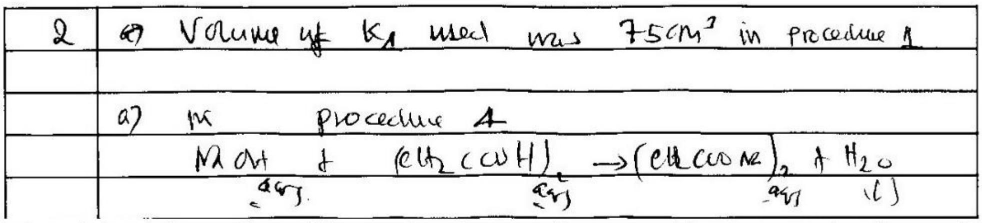
In contrast, the candidates who scored low marks on this question (48.9%) had insufficient skills in calculating the partition coefficient in alternative A. This was contributed by their incompetence in using different glassware in measurements. Nevertheless, some of them wrote unbalanced chemical equations and incorrect chemical formula in part (a). Hence, they failed to proceed to the subsequent parts of the question. In part (b) (i) and (ii), the candidates were required to use

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

where; n_a = moles of acid, n_b = moles of base, V_a = volume of acid, V_b = volume of base, M_a = molarity of acid and M_b = molarity of base, but they failed to use it and hence, failed to obtain the correct concentration.

Besides, in part (b) (iii), some failed to use the dilution law in calculating the initial concentration of butanedioic acid while in part (c), others used incorrect formulae to calculate the partition coefficient (K_D).

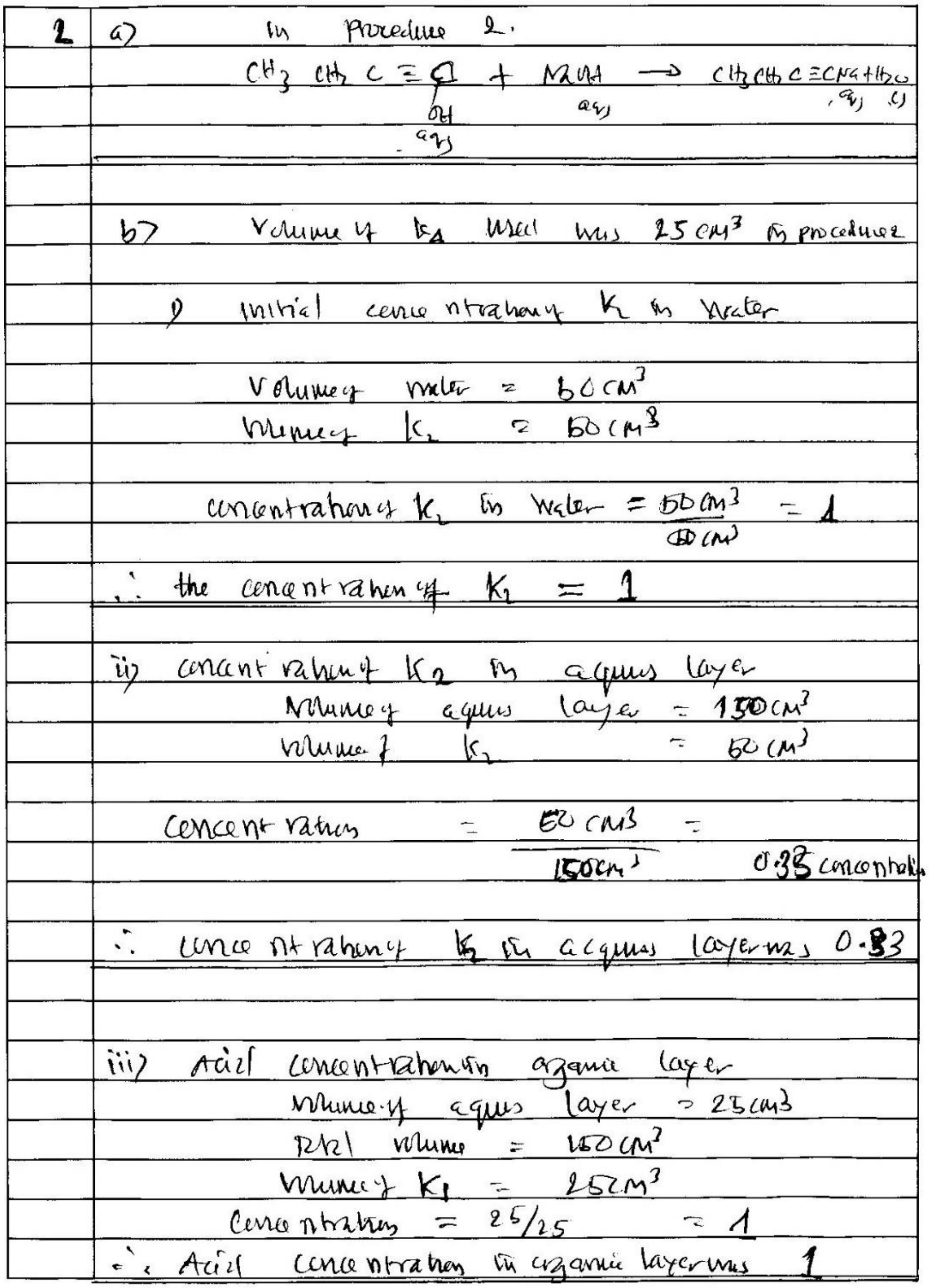
A further analysis of the responses given by the candidates with low scores in alternative B and C indicates that they lacked graphing techniques. For example, in part (a) of the alternative B, some did not include a title of the graph; labels of axis and the choice of scale was poor. They failed to understand that each coordinate axis of a graph should be labeled with the word or symbol for the variable plotted. Every graph should have a title that clearly states which variables appear on the plot. The scales should also be chosen to ensure that the data are easy to plot and read. The candidates overlooked these important aspects. Extracts 18.4, 18.5 and 18.6 show samples of the incorrect responses to question 2 in alternative A, B and C, respectively.



2 a) Volume of K_1 used was 75 cm^3 in procedure 1

a) in procedure 1

$NaOH_{(aq)} + (CH_3COOH)_{2(aq)} \rightarrow (CH_3COONa)_{2(aq)} + H_2O_{(l)}$



2 a) In Procedure 2.

$CH_3CH_2C \equiv C(OH)_{(aq)} + NaOH_{(aq)} \rightarrow CH_3CH_2C \equiv CNa_{(aq)} + H_2O_{(l)}$

b) Volume of K_1 used was 25 cm^3 in procedure 2

i) initial concentration of K_2 in water

Volume of water = 60 cm^3

Volume of K_2 = 50 cm^3

concentration of K_2 in Water = $\frac{50\ cm^3}{50\ cm^3}$ = 1

∴ the concentration of K_2 = 1

ii) concentration of K_2 in aqueous layer

Volume of aqueous layer = 150 cm^3

Volume of K_2 = 50 cm^3

Concentration = $\frac{50\ cm^3}{150\ cm^3}$ = 0.33 concentration

∴ concentration of K_2 in aqueous layer was 0.33

iii) Acid concentration in organic layer

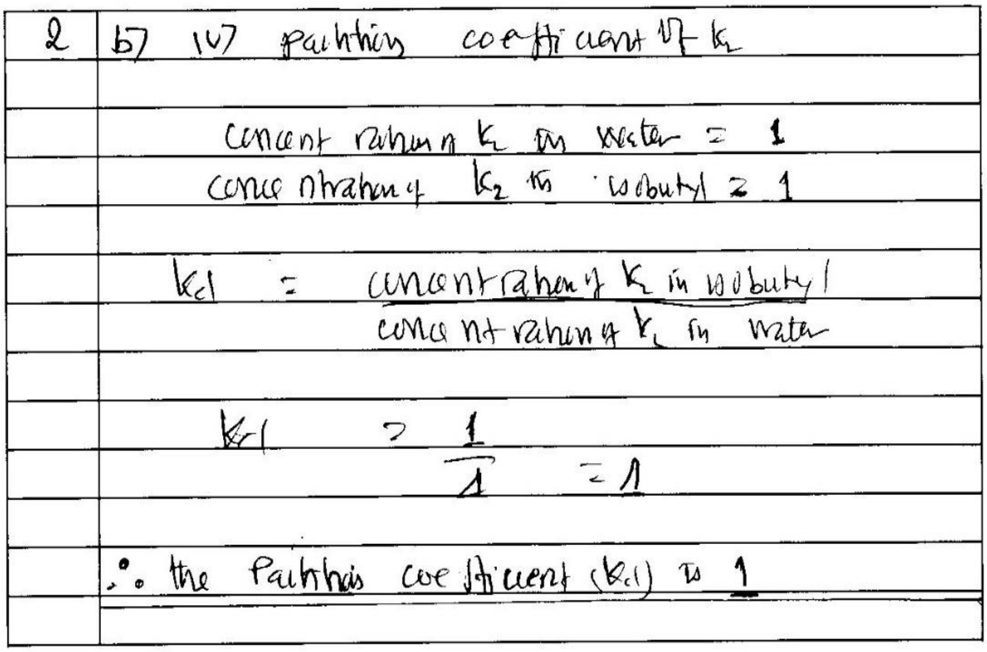
Volume of aqueous layer = 25 cm^3

Total volume = 150 cm^3

Volume of K_1 = 25 cm^3

Concentration = 25/25 = 1

∴ Acid concentration in organic layer was 1



2 b) iv) partition coefficient of K_2

concentration K_2 in water = 1

concentration of K_2 in isobutyl = 1

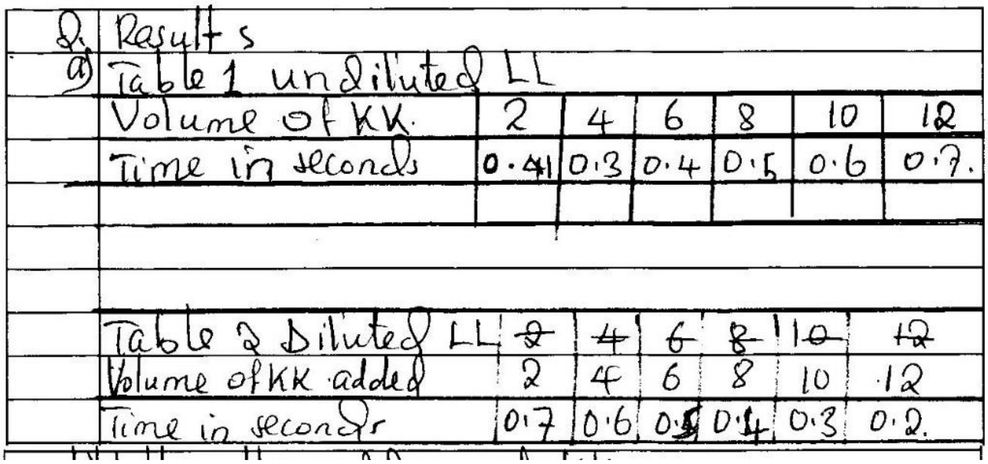
K_d = concentration of K_2 in isobutyl / concentration of K_2 in water

$K_d = \frac{1}{1} = 1$

∴ the Partition coefficient (K_d) is 1

Extract 18.4*:* A sample of the incorrect responses to question 2 in Alternative Practical A

In Extract 18.4, the candidate failed to obtain the correct titre value in the experiment procedure 1 and 2. He/she wrote 75 cm^3 and 25 cm^3, which were very far from the expected range. The candidate also used an incorrect formula in doing the calculations, leading led to an incorrect value of the partition coefficient.



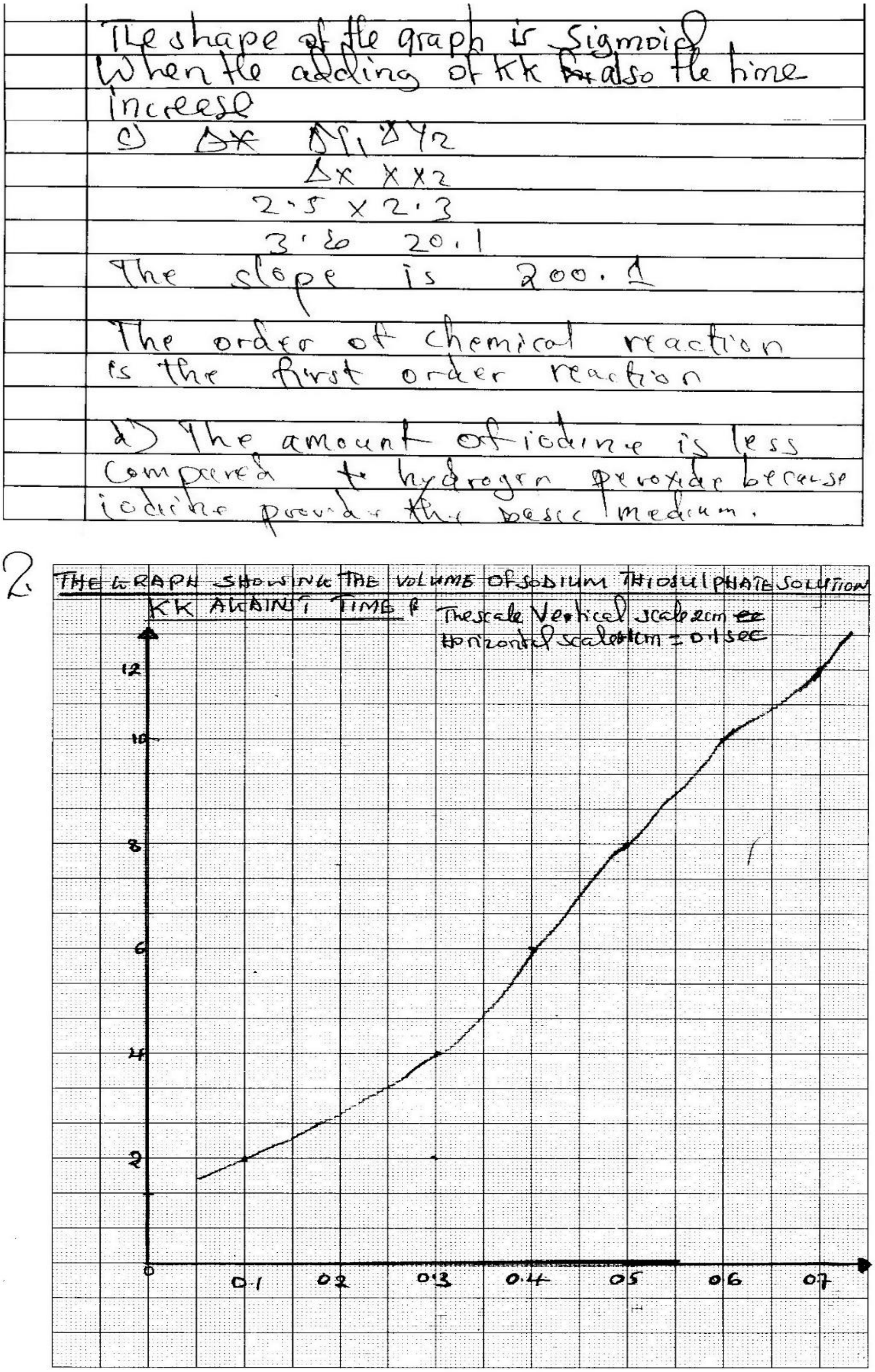
2. Results

a) Table 1 undiluted LL

Volume of KK	2	4	6	8	10	12
Time in seconds	0.41	0.3	0.4	0.5	0.6	0.7.

Table 2 Diluted LL ~~2~~ ~~4~~ ~~6~~ ~~8~~ ~~10~~ ~~12~~

Volume of KK added	2	4	6	8	10	12
Time in seconds	0.7	0.6	0.5	0.4	0.3	0.2.



The shape of the graph is Sigmoid
When the adding of KK ~~fr~~ also the time
increase
c) Δx $\delta y_1 \delta y_2$
Δx $x x_2$
2·5 x 2·3
3·6 20.1
The slope is 200.1

The order of chemical reaction
is the first order reaction

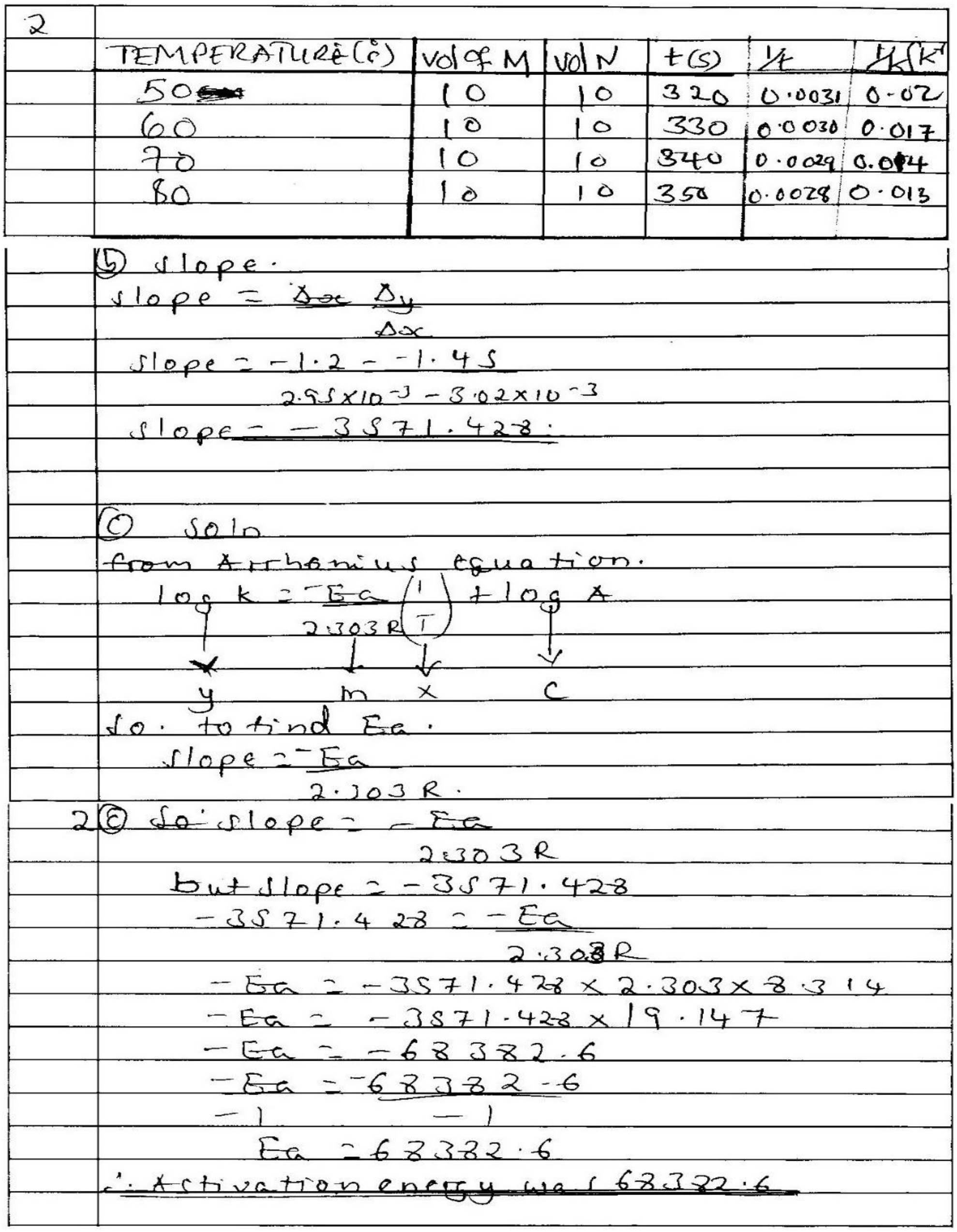
d) The amount of iodine is less
compared to hydrogen peroxide because
iodine provide the basic medium.

2. THE GRAPH SHOWING THE VOLUME OF SODIUM THIOSULPHATE SOLUTION KK AGAINST TIME

The scale Vertical scale 2cm ~~ee~~
Horizontal scale 1cm = 0.1 sec

Extract 18.5*:* A sample of the incorrect responses to question 2 in Alternative Practical B

In Extract 18.5, the candidate recorded the time incorrectly in both tables of diluted and undiluted **LL**. Also, in the table of diluted **LL**, the time recorded was decreasing as the volume of **KK** added, instead of increasing. Hence, the plotted graph was incorrect and the followed calculations and conclusions were incorrect. Again, he/she used a free hand to obtain the sigmoid curve instead of a straight line.



2

TEMPERATURE (°c)	vol of M	vol N	t(S)	1/t	1/T (K⁻¹)
50	10	10	320	0.0031	0.02
60	10	10	330	0.0030	0.017
70	10	10	340	0.0029	0.014
80	10	10	350	0.0028	0.013

ⓑ slope.

slope = ~~Δx~~ $\frac{\Delta y}{\Delta x}$

slope = $\frac{-1.2 - -1.45}{2.95\times10^{-3} - 3.02\times10^{-3}}$

slope = −3571.428.

ⓒ Soln

from Arrhenius equation.

$\log k = \frac{-Ea}{2.303R}\left(\frac{1}{T}\right) + \log A$

$\downarrow$ y $\quad\downarrow$ m $\quad\downarrow$ x $\quad\downarrow$ c

So. to find Ea.

slope = $\frac{-Ea}{2.303R}$.

2ⓒ So: slope = $\frac{-Ea}{2.303R}$

but slope = −3571.428

$-3571.428 = \frac{-Ea}{2.303R}$

$-Ea = -3571.428 \times 2.303 \times 8.314$

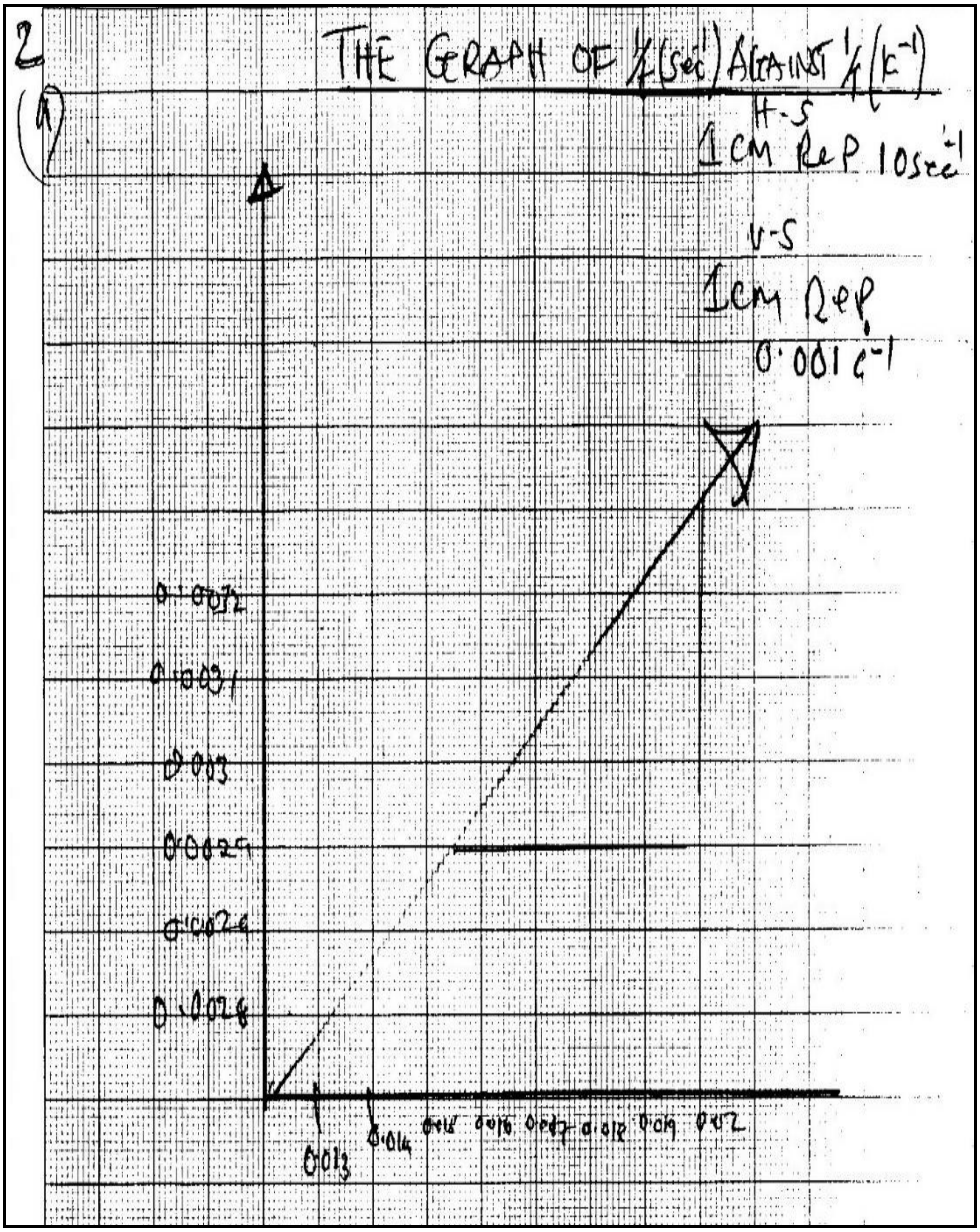
$-Ea = -3571.428 \times 19.147$

$-Ea = -68382.6$

$\frac{-Ea}{-1} = \frac{-68382.6}{-1}$

Ea = 68382.6

∴ Activation energy was 68382.6



Extract 18.6*:* A sample of the incorrect responses to question 2 in Alternative Practical C

In Extract 18.6, the candidate obtained incorrect results. He/she presented the time of the reaction, which increase as the temperature increases. In this experiment, the time was supposed to decrease as the temperature increases. Thus, he/she failed to plot the correct graph and incorrectly calculated the activation energy.

2.3.3 Question 3: Qualitative Analysis Chemistry 3A, 3B and 3C

In 132/3A Chemistry 3A, the question was as follows:

"*Substance **H** contains **two cations** and **one anion**. Use the information given in the experiments column of the experimental Table to complete the observations and inferences columns. Hence, identify the two cations and an anion in **H**.*

S/n	***Experiments***	***Observations***	***Inferences***
(a)	*Appearance of the sample **H**.*		
(b)	*Heat a small portion of the sample in a dry test tube.*		
(c)	*Perform a flame test.*		
(d)	*Add concentrated sulphuric acid to the small portion of the sample.*		
(e)	*To the small portion of the prepared solution, 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 ferrocyanide(II).		
	(ii) Dissolve the residue in aqua regia and then add excess 50% ammonia solution.		
(g)	*To the small portion of the solution, 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?

In alternative B, the question was as follows:

"*Substance **T** contains **two cations** and **one anion**. Use the information given in the experiments column of the Table 3 to complete the observations and inferences columns. Hence, identify the two cations and an anion.*

S/n	***Experiments***	***Observations***	***Inferences***
(a)	*Appearance of the sample.*		
(b)	*Heat a small portion of the sample in a dry test tube.*		
(c)	*Add concentrated sulphuric acid to the small portion of the sample.*		
(d)	*Perform a flame test.*		
(e)	*To a small portion of a sample solution, add sodium hydroxide solution.*		
(f)	*To a small portion of a sample solution add nitric acid followed by silver nitrate solution, then aqueous ammonia.*		
(g)	*To the small portion of the solution, pass hydrogen sulphide gas or ammonium sulphide solution in presence of hydrochloric acid. Filter the precipitates to obtain filtrate and residue.*		
	(i) To the filtrate, add barium chloride solution.		
	(ii) Dissolve the residue, add aquea regia and then excess 50% ammonia solution.		

Questions

(i) *Write the molecular formulas for the sample.*

(ii) *What are the cations and an anion in the sample?*

In alternative C, the question asked as follows:

"*Substance **H** contains **two cations** and **one anion**. Use the information given in the experiments column of the experimental Table to complete the observations and inferences columns. Hence, identify the two cations and an anion.*

S/n	***Experiments***	***Observations***	***Inferences***
(a)	*Appearance of the sample.*		
(b)	*Heat a 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 dilute HCl followed by barium chloride solution.*		
(f)	*To the small portion of the prepared solution, add excess ammonia solution and then add ammonia sulphide solution or pass hydrogen sulphide slowly for one minute.*		
(g)	*Perform confirmatory test for cations present in the sample.*		

Questions

(i) *Write the molecular formula for the sample.*

(ii) *What are the cations and anion in the sample?"*

The question was attempted by 34,735 candidates. Their performance on this question was good; 34,036 (89.3%) of the candidates scored 8.5 marks or above. In contrast, only a few candidates (699, 2%) scored from 0–5 marks. Their performance on this question is shown in Figure 17.

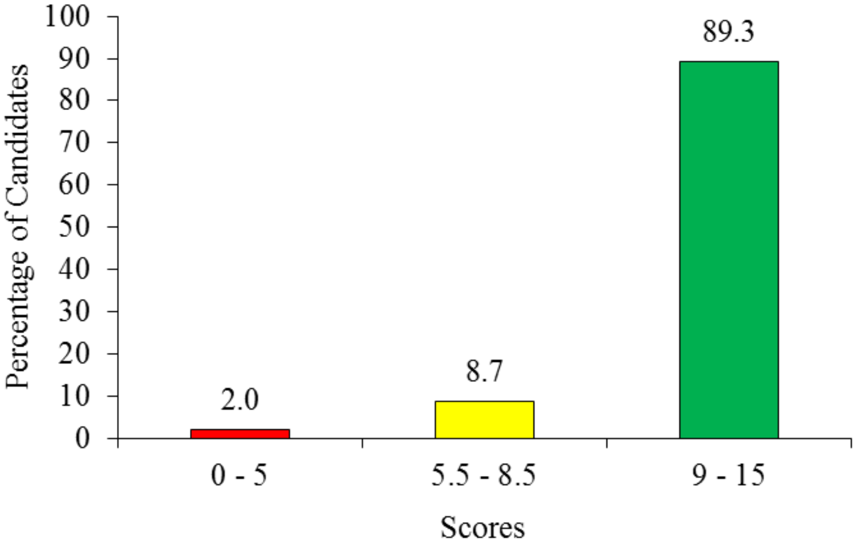
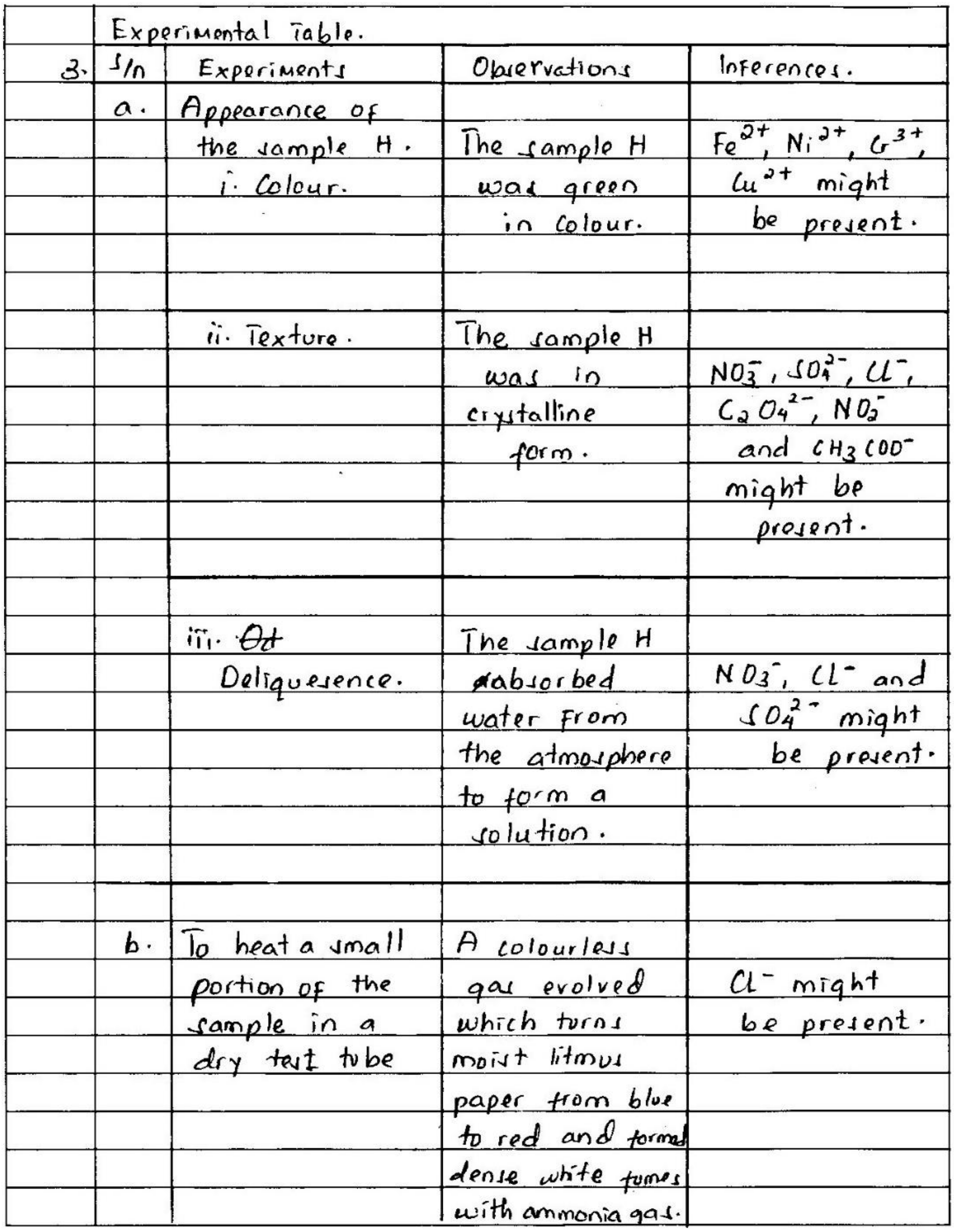


Figure 17: *Candidates' Performance on Question 3*

Figure 17 shows that 98.0% per cent of the candidates scored 5.5 marks or above, making the question to be one of the well performed questions.

The candidates with good performance on the question had adequate knowledge about the concept of salt analysis in all three alternatives (A, B and C). 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.

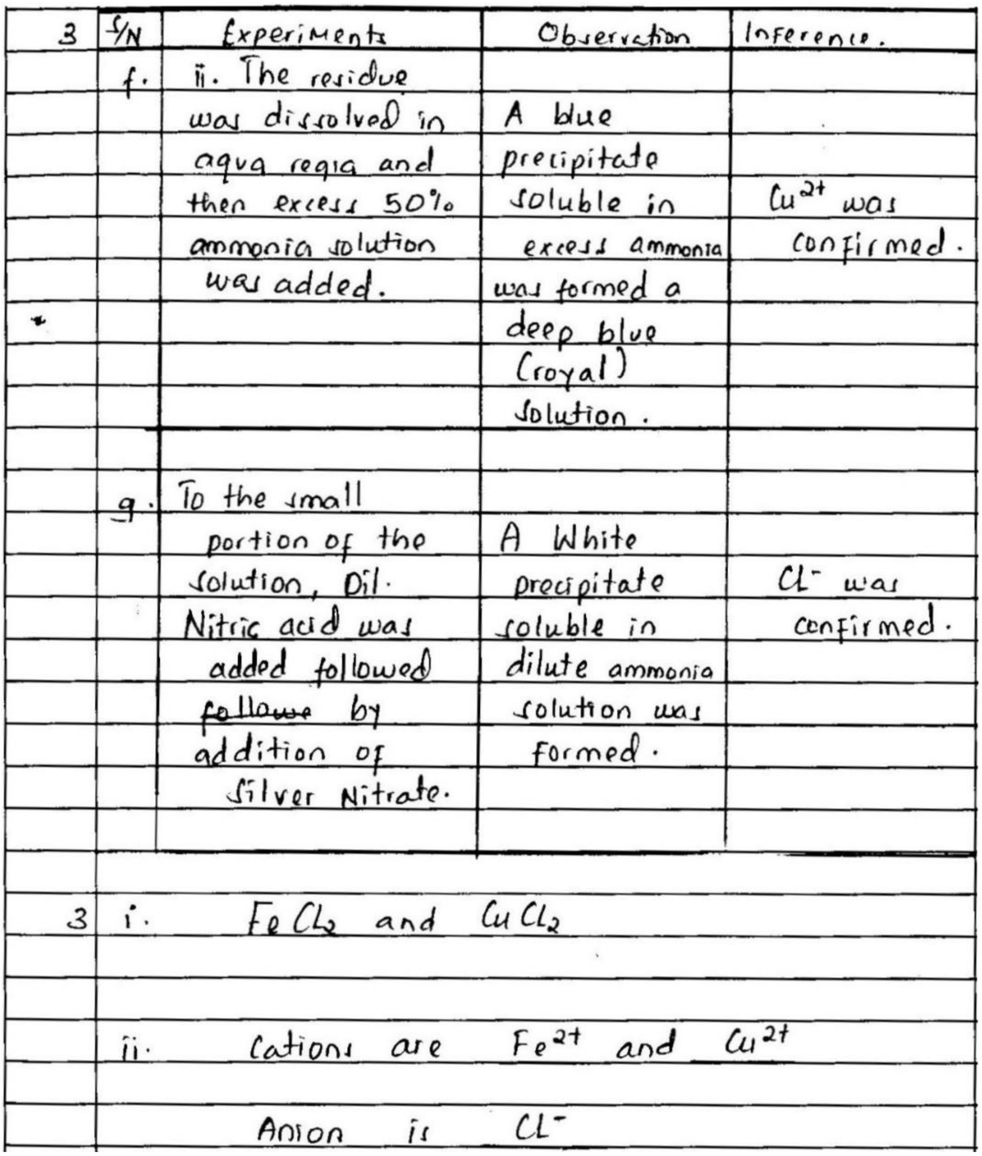


Experimental Table.

3.	S/n	Experiments	Observations	Inferences.
	a.	Appearance of the sample H. i. Colour.	The sample H was green in colour.	Fe^{2+}, Ni^{2+}, Cr^{3+}, Cu^{2+} might be present.
		ii. Texture.	The sample H was in crystalline form.	NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, NO_2^- and CH_3COO^- might be present.
		iii. ~~Od~~ Deliquesence.	The sample H ~~d~~absorbed water from the atmosphere to form a solution.	NO_3^-, Cl^- and SO_4^{2-} might be present.
	b.	To heat a small portion of the sample in a dry test tube	A colourless gas evolved which turns moist litmus paper from blue to red and formed dense white fumes with ammonia gas.	Cl^- might be present.

3	S/N	Experiments	Observations	Inferences.
	b.		A black residue was formed.	Cu^{2+} might be present.
	c.	To perform a flame test.	A blue-green colour was observed from sample H.	Cu^{2+} Might be present.
			Yellow sparks were observed	Fe^{2+}, Fe^{3+} Might be present.
	d.	To add a concentrated sulphuric acid to the small portion of the sample.	A colourless gas with irritating smell evolved which turns moist litmus paper from blue to red and formed dense white fumes with ammonia gas.	CL^- might be present.

3.	S/N	Experiments	Observations	Inferences.
	e.	To the small portion of the prepared solution, Dilute Sodium Hydroxide was added.	Dirty green precipitate was observed which turns brown on exposure to air.	Fe^{2+} might be present.
			On addition of excess NaOH, insoluble precipitate was formed	
	f.	To the small portion of the solution, Dil. HCL. was added followed by hydrogen sulphide. Then the precipitates were filtrated to obtain the filtrate and residue.	A black precipitate was formed.	Cu^{2+} might be present.
		i. To the filtrate, Potassium ferro-cyanide (III) added.	A dark blue precipitate was formed.	Fe^{2+} was confirmed.



3	S/N	Experiments	Observation	Inference.
	f.	ii. The residue was dissolved in aqua regia and then excess 50% ammonia solution was added.	A blue precipitate soluble in excess ammonia was formed a deep blue (royal) solution.	Cu^{2+} was confirmed.
	g.	To the small portion of the solution, Dil. Nitric acid was added followed ~~followe~~ by addition of Silver Nitrate.	A White precipitate soluble in dilute ammonia solution was formed.	Cl^- was confirmed.

3 i. $FeCl_2$ and $CuCl_2$

ii. Cations are Fe^{2+} and Cu^{2+}

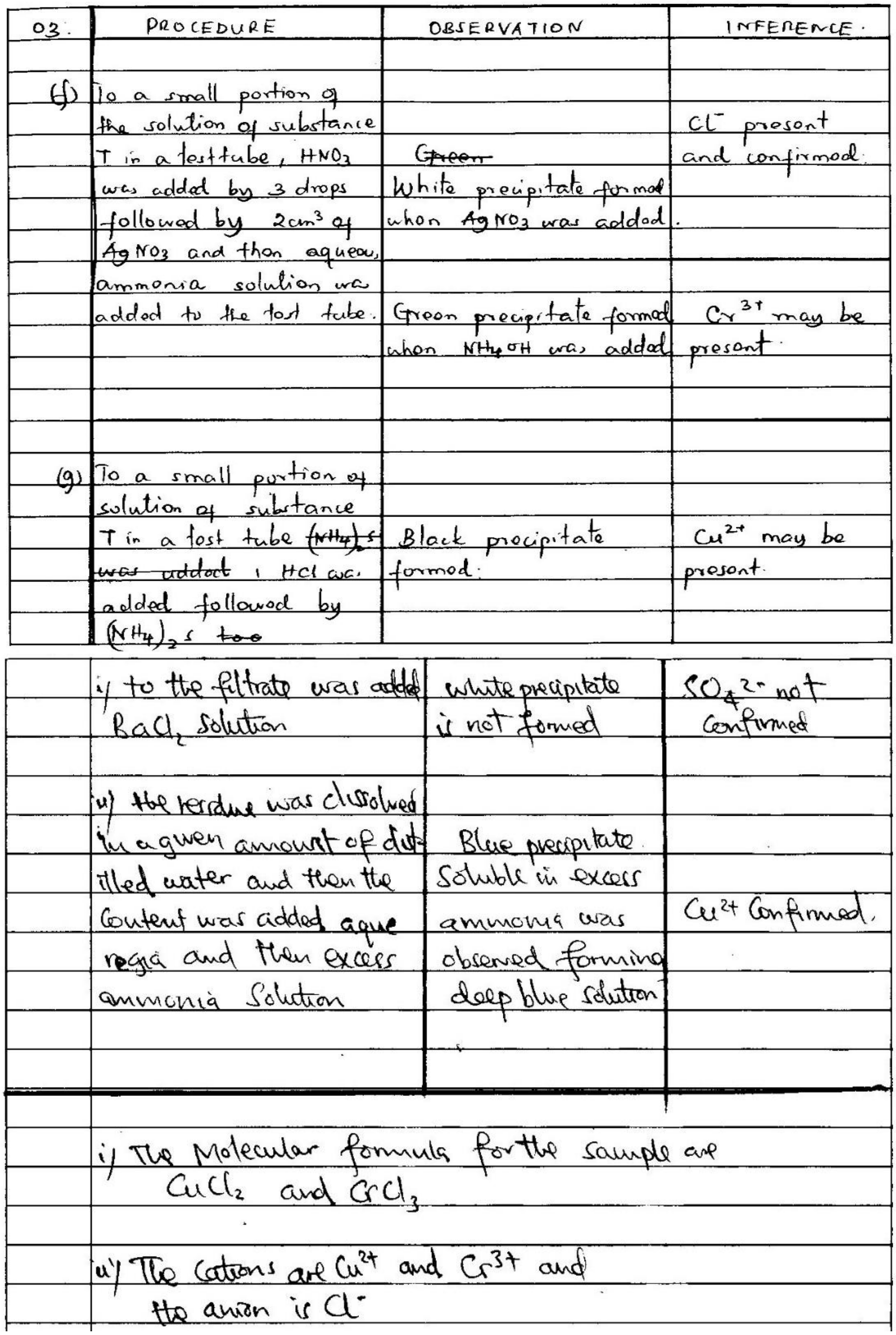
Anion is Cl^-

Extract 19.1: A sample of the correct responses in question 3 of Alternative Practical A

In Extract 19.1, the candidate properly followed the procedures given. Therefore, he/she identified the two cations (Fe^{2+} and Cu^{2+}) and one anion, Cl^- correctly. The candidate also correctly wrote the molecular formulas for samples $FeCl_2$ and $CuCl_2$.

	PROCEDURE	OBSERVATION	INFERENCE.
(a)	Appearance of the sample.	Green salt.	Fe^{2+}, Ni^{2+}, Cr^{3+} Cu^{2+} may be present
		Crystalline salt.	NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^-, CH_2COO^-, $Cr_2O_7^{2-}$ may be present.
(b)	0.5 g of substance T was put in a clean and dry test tube and then heated.	Colourless gas which turn wet blue litmus paper to red. evolved and forms white dense fumes with ammonia gas.	Cl^- may be present.
		Black residue formed	Cu^{2+} may be present.

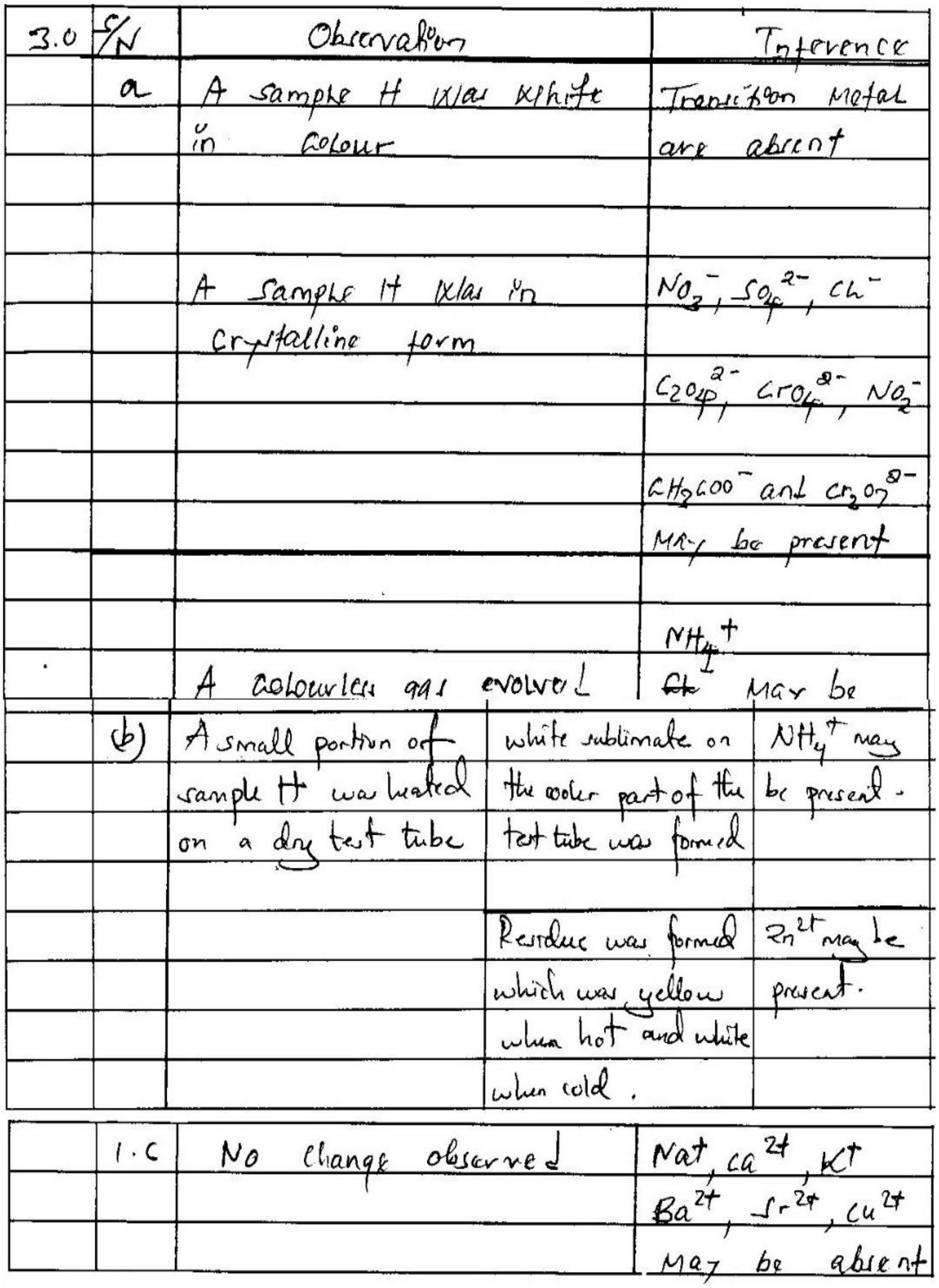
	PROCEDURE	OBSERVATION	INFERENCE.
(c)	0'5g of substance T was put in a clean and dry test tube and then $2cm^3$ of concentrated sulphuric acid was added into the test tube.	A colourless gas evolved which turns wet litmus paper from blue to red and form white fumes with ammonia gas.	Cl^- may be present.
(d)	Flame test.	Blue green flame	Cu^{2+} may be present.
~~(e)~~	0.5g of substance T was dissolved in enough amount of water.	Green solution ~~was~~ formed.	Fe^{2+}, Ni^{2+}, Cu^{2+}, Cr^{3+} may be present.
(e)	To a small portion of the solution of substance T, ~~NaOH~~ ~~was~~ ~~ad~~ in a test tube, NaOH was added.	Pale blue precipitate formed	Cu^{2+} may be present.



03.	PROCEDURE	OBSERVATION	INFERENCE.
(f)	To a small portion of the solution of substance T in a test tube, HNO_3 was added by 3 drops followed by $2 cm^3$ of $AgNO_3$ and then aqueous ammonia solution was added to the test tube.	~~Green~~ White precipitate formed when $AgNO_3$ was added. Green precipitate formed when NH_4OH was added	Cl^- present and confirmed. Cr^{3+} may be present.
(g)	To a small portion of solution of substance T in a test tube ~~$(NH_4)_2S$~~ ~~was added~~ , HCl was added followed by $(NH_4)_2S$ ~~too~~	Black precipitate formed.	Cu^{2+} may be present.
	i) to the filtrate was added $BaCl_2$ Solution	white precipitate is not formed	SO_4^{2-} not Confirmed
	ii) the residue was dissolved in a given amount of distilled water and then the Content was added aque regia and then excess ammonia Solution	Blue precipitate. Soluble in excess ammonia was observed forming deep blue solution	Cu^{2+} Confirmed.
	i) The Molecular formula for the sample are $CuCl_2$ and $CrCl_3$		
	ii) The Cations are Cu^{2+} and Cr^{3+} and the anion is Cl^-		

Extract 19.2: A sample of the correct responses to question 3 in Alternative Practical B

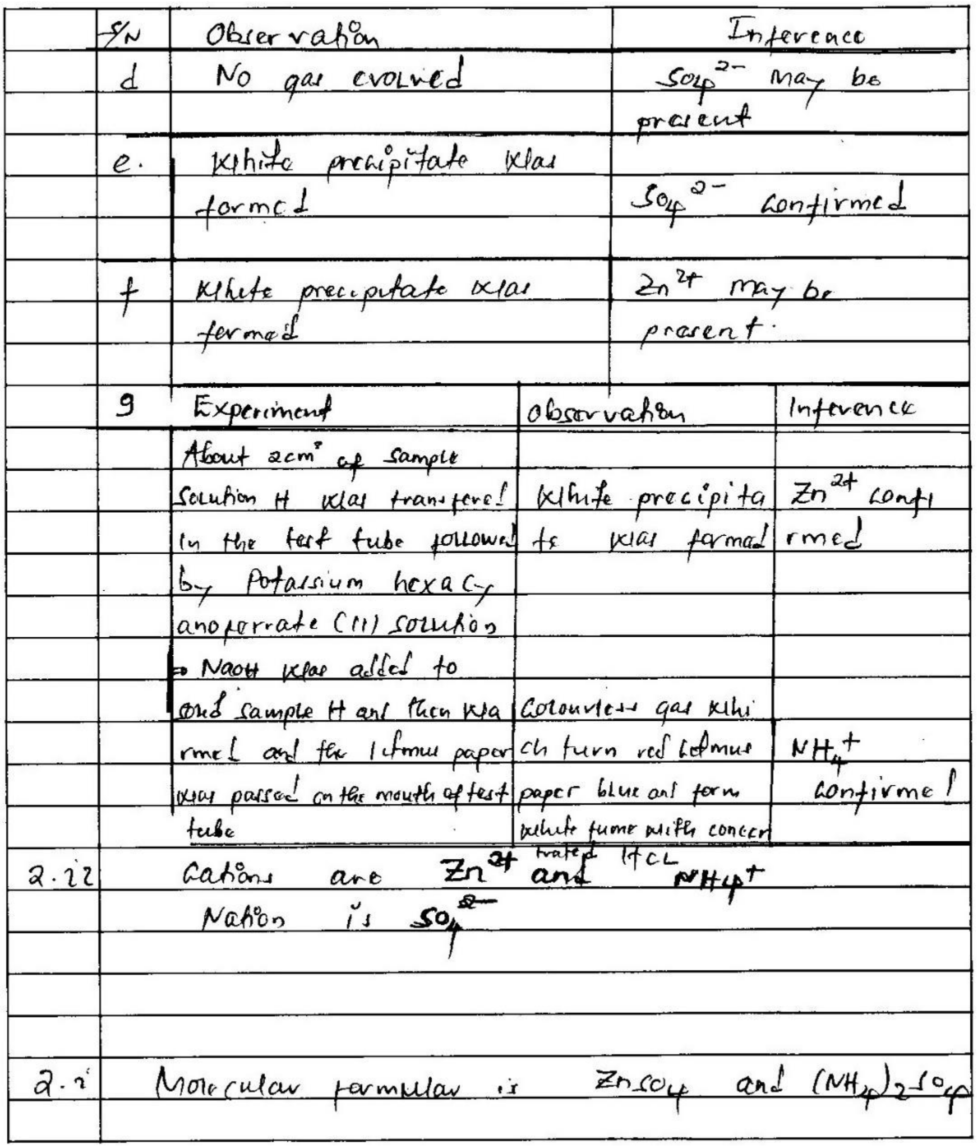
In Extract 19.2, the candidate correctly followed the procedures given and identified the presence of two cations $(Cu^{2+}$ and $Cr^{3+})$ and one anion Cl^-. The candidate also wrote the correct molecular formulae for the samples $(CuCl_2$ and $CrCl_3)$.



3.0	S/N	Observation	Inference
	a	A sample H was white in colour	Transition Metal are absent
		A sample H was in crystalline form	NO_3^-, SO_4^{2-}, Cl^- $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^- CH_3COO^- and $Cr_2O_7^{2-}$ May be present
		A colourless gas evolved	NH_4^+ ~~Cl~~ May be

(b)	A small portion of sample H was heated on a dry test tube	white sublimate on the cooler part of the test tube was formed	NH_4^+ may be present.
		Residue was formed which was yellow when hot and white when cold.	Zn^{2+} may be present.

	1.C	No change observed	Na^+, Ca^{2+}, K^+ Ba^{2+}, Sr^{2+}, Cu^{2+} May be absent



S/N	Observation	Inference
d	No gas evolved	SO_4^{2-} may be present
e.	White precipitate was formed	SO_4^{2-} confirmed
f	White precipitate was formed	Zn^{2+} may be present.

g	Experiment	Observation	Inference
	About 2cm³ of sample solution H was transfered in the test tube followed by Potassium hexacyanoferrate (II) solution	White precipitate was formed	Zn^{2+} confirmed
	NaOH was added to and sample H and then warmed and the litmus paper was passed on the mouth of test tube	Colourless gas which turn red litmus paper blue and form white fume with concentrated HCL	NH_4^+ confirmed

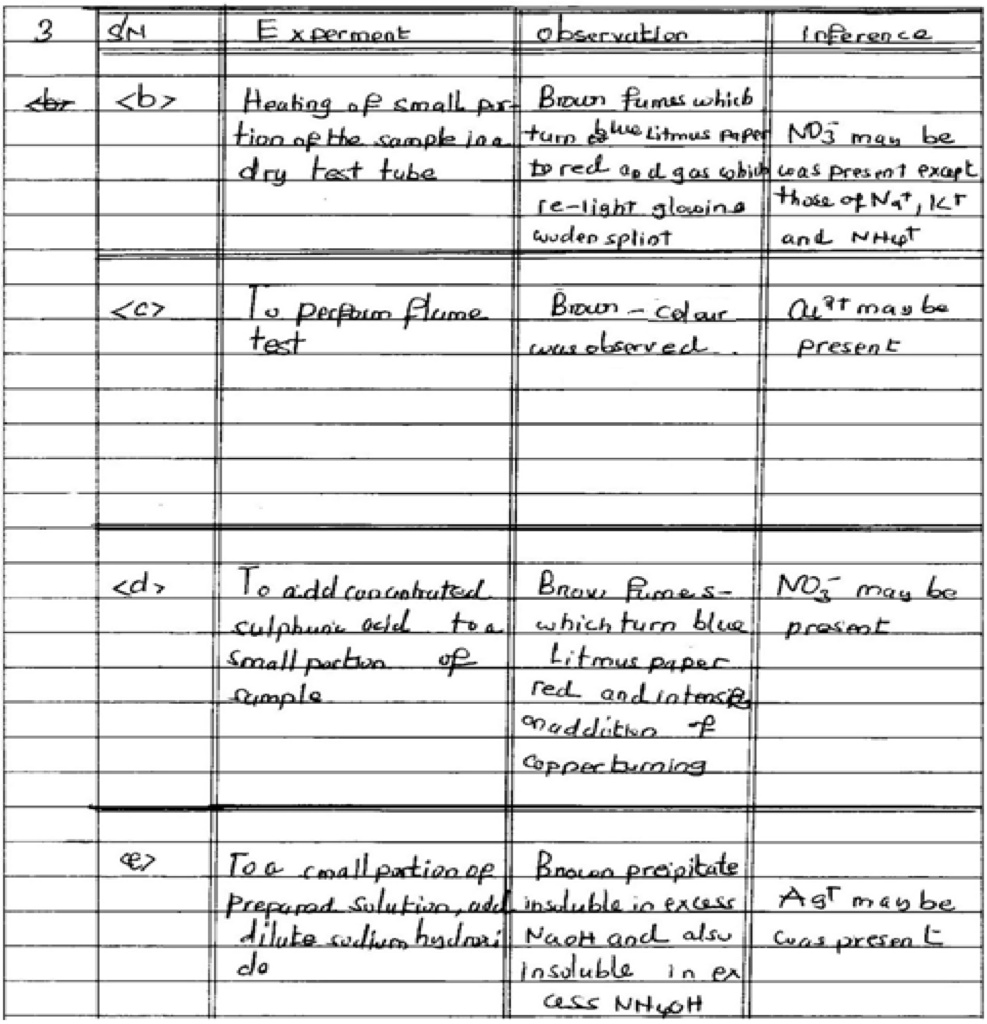
2.22 Cations are Zn^{2+} and NH_4^+
Nation is SO_4^{2-}

2.2 Molecular formular is $ZnSO_4$ and $(NH_4)_2SO_4$

Extract 19.3: A sample of the correct responses to question 3 in the Alternative Practical C

In Extract 19.3, the candidate performed the given tests properly and identified the two cations (Zn^{2+}, NH_4^+) and one anion (SO_4^{2-}) present in the given salt sample **H**. Moreover, the candidate wrote correctly the molecular formulae for the sample **H**, which are $(ZnSO_4)$ and $(NH_4)_2SO_4$.

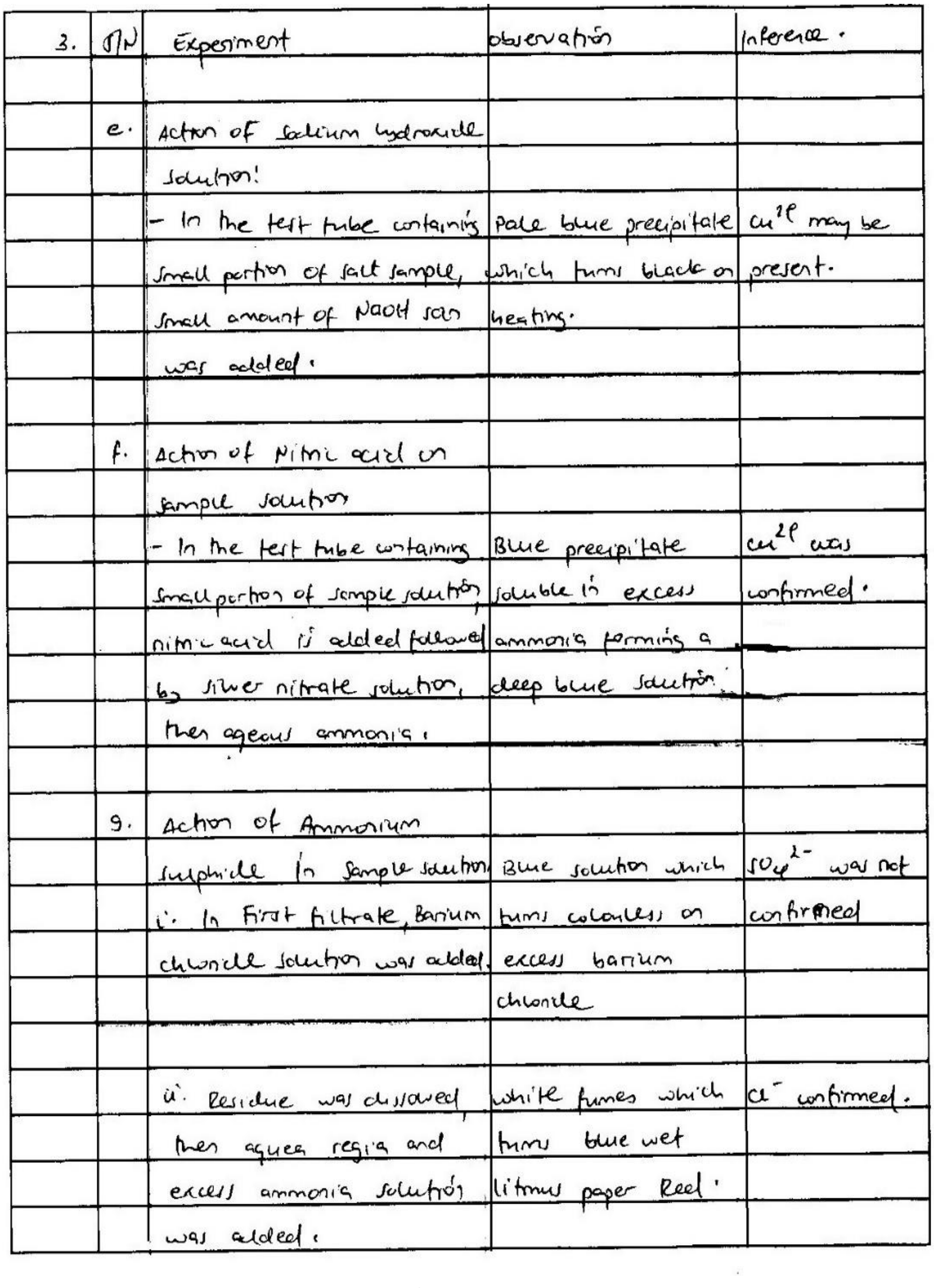
In contrast, the candidates who scored low marks in the question (2.0%) reported incorrect observations and inferences in the first experiment which involved the physical properties of salt; hence, they failed to get the correct conclusion. Those candidates failed to understand that, making correct initial observations of the physical properties of the salt was the crucial step in identifying the salts. It was also observed that, other candidates failed to adhere to the instructions given on the tests given. This signifies a lack of basic knowledge about salt analysis. Extracts 19.4, 19.5 and 19.6 show samples of the incorrect responses to question 3 in Alternative Practical A, B, and C, respectively.



3	S/N	Experment	observation	Inference
~~<b>~~	<b>	Heating of small portion of the sample in a dry test tube	Brown fumes which turn blue Litmus paper to red and gas which re-light glowing wuden spliot	NO_3^- may be was present exept those of Na^+, K^+ and NH_4^+
	<c>	To perform flume test	Brown - colour was observed .	Cu^{2+} may be present
	<d>	To add concentrated sulphuric acid to a small portion of sample	Brown fumes - which turn blue Litmus paper red and intense on addition of copper turning	NO_3^- may be present
	<e>	To a small portion of prepared solution, add dilute sodium hydroxido	Brown precipitate insoluble in excess NaOH and also insoluble in excess NH_4OH	Ag^+ may be was present

Extract 19.4: A sample of the incorrect responses to question 3 in Alternative Practical A

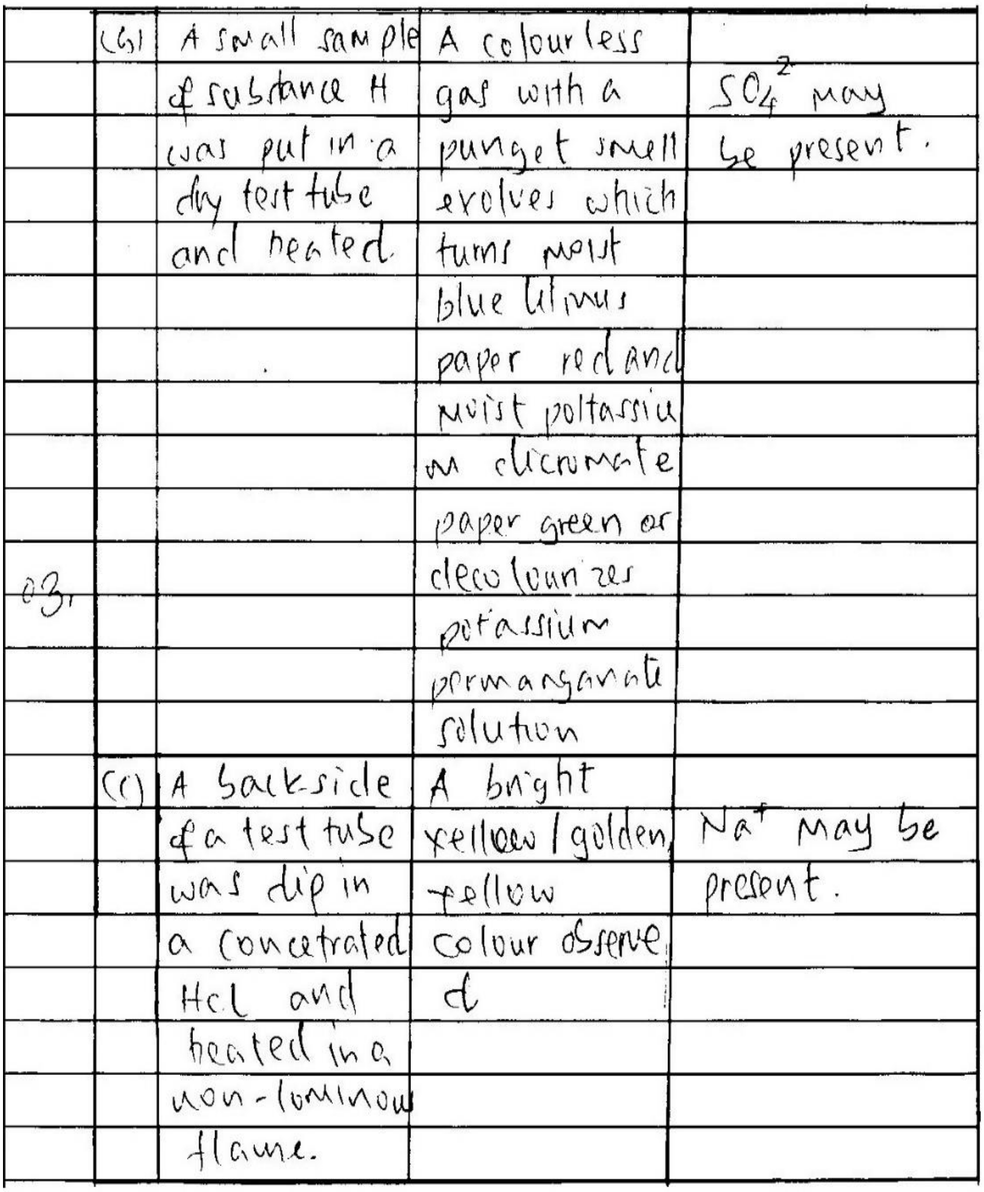
In Extract 19.4, the observations and inferences given by the candidate contradict each other. For example, in part (c), the brown colour observed in the flame test does not infer the presence of Cu^{2+} ions. The same applies to parts (d) and (e). The candidate wrote brown fumes instead of colourless gas and brown precipitates instead dirty green precipitates, respectively.



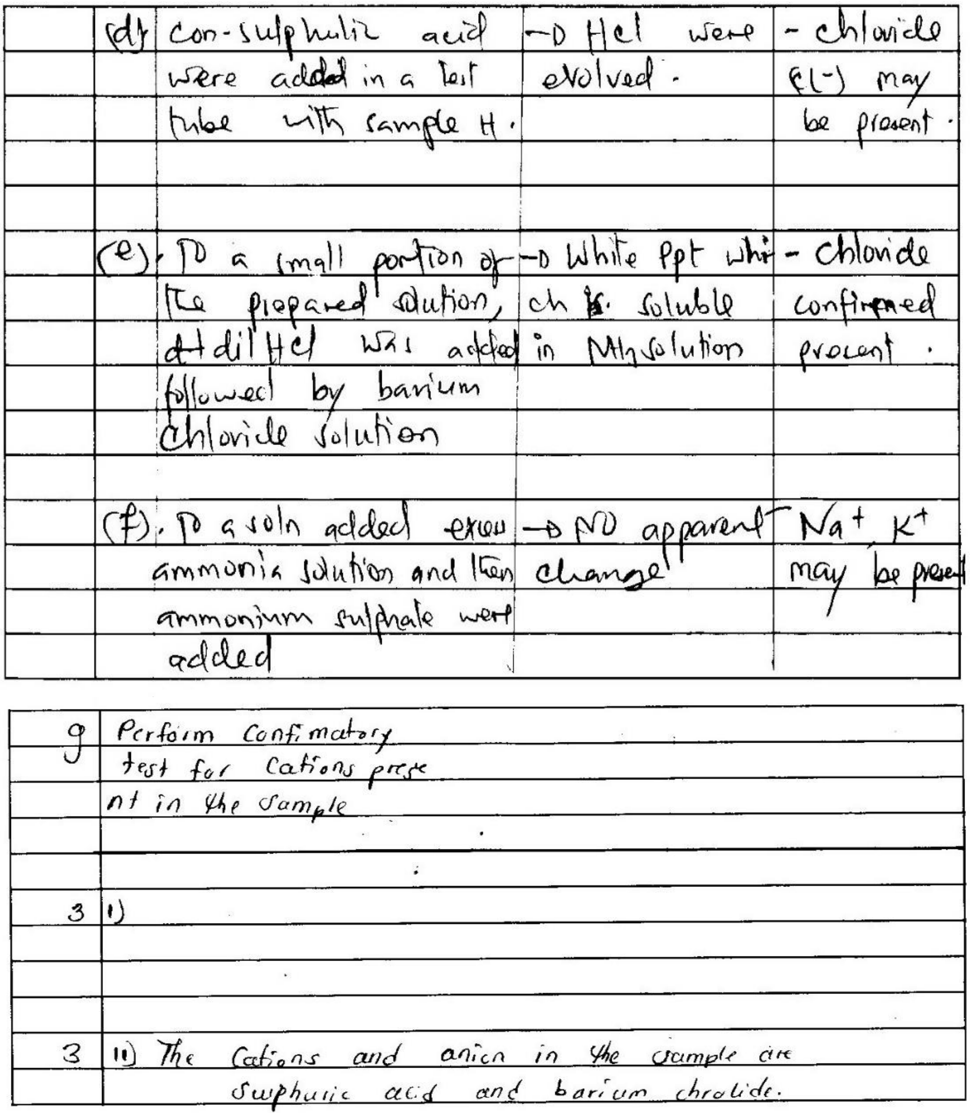
3.	S/N	Experiment	observation	Inference.
	e.	Action of Sodium hydroxide solution!		
		– In the test tube containing small portion of salt sample, small amount of NaOH soln was added.	Pale blue precipitate which turns black on heating.	cu^{2+} may be present.
	f.	Action of Nitric acid on sample solution		
		– In the test tube containing small portion of sample solution, nitric acid is added followed by silver nitrate solution, then ageous ammonia.	Blue precipitate soluble in excess ammonia forming a deep blue solution.	cu^{2+} was confirmed.
	9.	Action of Ammonium sulphide in sample solution		
		i. In First filtrate, Barium chloride solution was added.	Blue solution which turns colourless on excess barium chloride	SO_4^{2-} was not confirmed
		ii. Residue was dissolved, then aquea regia and excess ammonia solution was added.	white fumes which turns blue wet litmus paper Red.	cl^- confirmed.

Extract 19.5: A sample of the incorrect responses to question 3 in Alternative Practical B

In Extract 19.5, the candidate presented incorrect inferences as deep blue precipitates in part (f) instead of white precipitates. This implies that the candidate did not use silver nitrate solution $(AgNO_3)$ as instructed. The candidate also gave incorrect observations and inferences in parts (g) (i) and (ii) of the question.



03,	(g)	A small sample of substance H was put in a dry test tube and heated.	A colourless gas with a punget smell evolves which turns moist blue litmus paper red and moist poltassium dicromate paper green or decolourizes potassium permanganate solution	SO_4^{2} may be present.
	(c)	A backside of a test tube was dip in a concetrated Hcl and heated in a non-luminou flame.	A bright yellow/golden yellow colour observed	Na^+ may be present.



	(d)	con-sulphulic acid were added in a test tube with sample H.	→ HCl were evolved.	- chloride Cl^{-} may be present.
	(e)	To a small portion of the prepared solution, dil HCl was added followed by barium chloride solution	→ White ppt which is soluble in NH_3 solution	- Chloride confirmed procent.
	(f)	To a soln added exess ammonia solution and then ammonium sulphate were added	→ NO apparent change	Na^+, K^+ may be present

g	Perform confimatory test for cations present in the sample
3	i)
3	ii) The cations and anion in the sample are suphuric acid and barium chrolide.

Extract 19.6: A sample of the incorrect responses to question 3 in Alternative Practical C

In Extract 19.6, the candidate failed to identify the characteristics of the evolved gas in part (b) which could have helped him/her to obtain some clue for the cations present in the sample. The proposed incorrect characteristics of the evolved gas led to the wrong inferences. In part (c), the candidate wrote the flame test as yellow/golden yellow colour instead of writing no defined colour was observed. The candidate made wrong observations and inferences in the subsequent parts of the question.

3.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE ON EACH TOPIC

The ACSEE 132 Chemistry examination in 2022 consisted 22 topics. Among them, 12 topics (*The Atom*; *Chemical Equilibrium; Relative Molecular Masses in Solution*; Chemical Bonding; Aliphatic *Hydrocarbons; Energetics; Environmental Chemistry; Gases; Selected Compounds of Metals; Aliphatic Hydrocarbons; Aromatic Hydrocarbons* and *Halogen Derivatives of Hydrocarbons*.) were included in Chemistry Paper 1. In Chemistry paper 2, ten topics (*Two component Liquid Systems* ; *Acids, bases and salts; Solubility, Solubility Product and Ionic Product*; *Carboxylic Acids and its Derivative*; Amines; *Electrochemistry; Periodic Classification; Extraction of Metals; Polymers* and *Transition Elements*) were included. Chemistry practicals consisted of three subtopics *Volumetric Analysis*, *Physical Chemistry Analysis* and *Qualitative Analysis* which were derived from the topic of *Chemical Analysis*.

Among the topics included in Chemistry theory (Paper 1 and 2), the topic of *Chemical Equilibrium* which was covered in Question 2 was the best performed topic by the candidates (as 85.88 per cent of the candidates scored average or above average marks). Other topics on which they had good performance were *The Atom (81.92); Environmental Chemistry (67.12%); Relative Molecular Masses in Solution (67.07%); Energetics (66.78%); Chemical Bonding (61.18%) and Selected Compounds of Metals (60.80%).* The candidates' performance on the topic of *Chemical Analysis* was good, as the majority (80.95%) of the candidates who sat for one of the alternative practical papers scored average marks or above. The performance of the candidates on the topic of *Chemical Analysis* was average on the subtopics *Qualitative Analysis* (98.0%), *Volumetric Analysis* (93.8%) and *Physical Chemistry Analysis* (51.1%) in questions 1, 2 and 3, respectively. The candidates who performed well understood the requirements of the questions. They showed appropriate competencies in the topics tested.

A further analysis indicates that the candidates had average performance on the topics of *Gases (*57.6%); *Aliphatic Hydrocarbons (41.9%); Electrochemistry (39.8%), Carboxylic Acids and its Derivative; Amines (36.7%); Periodic Classification* and *Extraction of metals (34.8%).* Although some of the candidates had adequate knowledge of the tested topics, they provided partial answers and were not keen on understanding requirements of the questions. Thus, they performed averagely on most of the tested topics.

However, some of the candidates performed weakly in the topics of *Polymer; Transition Element* (33.35%); *Acids, bases and salts; Solubility, Solubility Product and Ionic Product (25.57%)* and *Aliphatic Hydrocarbons; Aromatic Hydrocarbons* and *Halogen Derivatives of Hydrocarbons (21.85%).*

A further analysis of data indicates that the performance of the candidates in the topic of *Selected Compounds of Metals (60.80%) and Aliphatic Hydrocarbons (41.9%)* improved compared to the candidates' performance on the topic in 2021 (14.2%) and (32.3%), respectively. The analysis of responses given by the candidates with weak scores on these topics indicates that they had insufficient knowledge of the subject matter. Hence, they gave wrong formulae, chemical equations and followed incorrect approaches to performing calculations. A summary of the candidates' performance on different topics of theoretical and practical examinations is presented in Appendices A and B, respectively.

4.0 CONCLUSIONS

The general performance of the candidates who sat for the Chemistry examination in 2022 was good; 97.48 per cent passed. The analysis of the candidates' responses to each question from the theory and practical papers indicates that the majority of the candidates were conversant with the tested concepts. The performance in the practicals was a bit higher than in the theory paper because, as a rule of thumb, when a candidate involves more sense organs in learning, he/she builds a long term memory and remembers with ease. Therefore, teachers are advised to be more creative in integrating theory into practical work and utilize locally available materials whenever is possible. Responses from the candidates who performed weakly indicate that the candidates lacked or had insufficient knowledge of the subject matter tested.

5.0 RECOMMENDATIONS

The weak and average performance observed in the tested topics can be improved through collaborative efforts of teachers and prospective candidates during teaching and learning. Based on the analysis of the responses given by the candidates, as discussed in this report, the following measures are hereby recommended to improve candidates' future performance in the examination:

a) Teachers and students should participate in designing and building organic compounds models during the teaching and learning of *Aliphatic Hydrocarbons* and *Hydroxyl Compounds.* This can help not only to raise learners' interest in the subject matter, but also to build a long term memory of students of structural and chemical formulae.

b) Teachers should guide students through discussing various types of chemical reactions and their inferences using wall charts. This will help learners to grasp many concepts and build their long term memory, especially in relation to the topic of *Selected Compounds of Metals.*

c) Teachers should guide learners through forming small groups and perform practical tasks on chemical reactions; involving the identification of *oxides, hydroxides, carbonates, hydrogen carbonates, sulphates*, *chlorides* and *nitrates*. Thereafter, the students should present their findings written on flipcharts/manila cards, to other groups, followed by the plenary discussion.

d) Teachers should facilitate small group discussions on different types of manures and fertilizers, the importance of liming and the chemical reactions taking place in the soil; followed by the plenary discussion. This will help learners to acquire appropriate competencies in the topic of *Soil Chemistry*.

e) During the teaching and learning processes, teachers are encouraged to use examples drawn from real life situations and to encourage learners to do the same. This will help in integrating scientific concepts into applications. As a result, teaching and learning will be more meaningful.

Appendix A: The Summary of the Performance of the Candidates Topic-wise in Theory Papers

S/n	**Topic**	**2021**			**2022**		
		Number of Question	**The Percentage of the Candidates who Scored an average of 35 or Above**	**Remarks**	**Number of Question**	**The Percentage of the Candidates who Scored an Average of 35 or Above**	**Remarks**
1	Chemical Equilibrium	1	81.5	Good	1	85.9	Good
2	Two Component Liquid Systems	1	69.0	Good	1	84.6	Good
3	The Atom	1	66.4	Good	1	81.9	Good
4	Environmental Chemistry				1	67.1	Good
5	Relative Molecular Masses in Solution	1	53.9	Good	1	67.1	Good
6	Energetics	1	60.5	Good	1	66.8	Good
7	Chemical Bonding	1	74.5	Good	1	61.2	Good
8	Selected Compounds of Metals	1	14.2	Weak	1	60.8	Good
9	Gases	1	62.8	Good	1	57.6	Average
10	Aliphatic Hydrocarbons	1	32.4	Weak	1	41.9	Average
11	Electrochemistry	1	46.9	Average	1	39.8	Average
12	Carboxylic Acids and its Derivative/ Amines	1	48.8	Average	1	36.5	Average
13	Periodic Classification/and Extraction of metals				1	34.8	Average
14	Polymer/ and Transition Element				1	33.4	Weak
15	Acids, bases and salts/ Solubility, Solubility Product and Ionic Product				1	25.6	Weak
16	Solubility, Solubility Product and Ionic Product	1	44.3	Average			
17	Aromatic Hydrocarbons/ Halogen Derivatives of Hydrocarbons.	1	51.9	Average			
18	Aliphatic hydrocarbons/Aromatic Hydrocarbons/ Halogen Derivatives of Hydrocarbons.				1	21.9	Weak
19	Soil Chemistry	1	33.9	Weak			
20	Hydroxyl Compounds	1	26.6	Weak			

Appendix B: The Summary of the Performance of the Candidates Topic-wise in Practical Paper

S/n	Subtopic	2021			2022		
		Number of Question	The Percentage of the Candidates who Scored an average of 35 or Above	Remarks	Number of Question	The Percentage of the Candidates who Scored an Average of 35 or Above	Remarks
1	Qualitative Analysis	1	94.5	Good	1	98.0	Good
2	Volumetric Analysis	1	89.5	Good	1	93.8	Good
3	Physical Chemistry Analysis	1	86.2	Good	1	51.1	Average