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), 2021

CHEMISTRY

THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

CANDIDATES' ITEM RESPONSE ANALYSIS REPORT ON THE ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (ACSEE) 2021

132 CHEMISTRY

Published by:

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

TABLE OF CONTENTS

FOREWORD

This report is based on Advanced Certificate of Secondary Education Examination (ACSEE) Chemistry subject which was attempted in May 2021. Following the analysis of the responses given by the candidates, NECTA has prepared the report on factors that influenced the performance in Chemistry examination. It is worth mentioning here that the report also presents a comprehensive analysis of the candidates' items responses in Chemistry practicals.

The general performance of the candidates who sat for Chemistry examination in 2021 was good; as 94.81 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 and college principals as well as educational administrators, to mention a few. The analysis presented in this report will serve the purpose of revealing to educational stakeholders the responses that were given by the candidates, to help them take appropriate measures to improve the teaching and learning to the prospective candidates.

The report has analysed in details factors that hindered the candidates to respond to the asked questions as required such factors include insufficient knowledge of writing chemical equations, lack/shortage of appropriate skills to perform chemical calculations as well as the failure to follow the requirements of questions. On the other hand, the report has identified factors which enabled the candidates to perform well in the tested questions such as having appropriate competencies in the subject matter and ability to comprehend the requirements of questions properly. The analysis done for each question has been supplemented with extracts from candidates' scripts.

In lieu of the above account, it is expected that the feedback and the recommendations given in this report will help, to a great extent, to improve the performance of the prospective candidates in future examinations administered by the Council.

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

Dr. Charles E. Msonde
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report analyses responses given by candidates and their performance in Chemistry examination on the Advanced Certificate of Secondary Education Examination (ACSEE) 2021. The Chemistry examination tested candidates in three papers namely 132/1 Chemistry 1, 132/2 Chemistry 2 and 132/3 Chemistry 3. The later paper was examined in three equivalent alternative papers (132/3A Chemistry 3A, 132/3B Chemistry 3B and 132/3C Chemistry 3C), whereby candidates were expected to sit for one of the alternative papers.

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

Candidates' performance in a particular question/topic is categorized basing on the percentage of the marks that a particular candidate was able to score out of the allocated marks. Thus, the performance is good if the candidate scored from 60 to 100 percent, average if they scored from 35 to 59 percent and is regarded weak if they scored from 0 to 34 percent. The weak, average and good performances are denoted by red, yellow and green colours, respectively.

A total of 34,517 candidates sat for Chemistry examination (ACSEE) in 2021. The examination results indicate that 94.81 per cent of the candidates passed. This indicates that the overall performance was good. Despite the good performance shown by the candidates in 2021, it was lower by 0.01 percent compared to the performance of candidates in this subject in the year 2020, which was 94.82 per cent.

This report consists of five parts, namely Introduction, The Analysis of the Candidates' Performance in Each Question, the Analysis of the Candidates Performance in Each Topic, Conclusions and Recommendations.

2.0 THE ANALYSIS OF THE CANDIDATES' PERFORMANCE IN EACH QUESTION

This section analyses the responses of the candidates in each of the question tested. For each of the question, the analysis starts by giving the requirements of that particular question, data analysis and detailed discussion of responses given by the candidates, supplemented with appropriate sample extracts from the candidate(s).

2.1 132/1-CHEMISTRY 1

The paper consisted of sections A and B. Section A had a total of seven (7) short answer questions which carried 10 marks each. Candidates were required to answer all questions from this section. Section B consisted of three (3) structured-essay questions and candidates were required to answer two questions. Each question in this section weighed 15 marks. In total, candidates were required to answer nine questions in this paper.

2.1.1 Question 1: The Atom

The question comprised of three parts, namely (a), (b) and (c). In part (a), candidates were required to differentiate (i) isotopy from isotopes, (ii) atomic spectrum from photon and (iii) continuous spectrum from line spectrum. In part (b), the questions required candidates to calculate the frequency of a wave in a visible region that formed following the emission of energy by an electron falling from energy level n = 4 to the ground level. Part (c) of the question required candidates to list two uses of mass spectrometer.

This question was attempted by 34,392 (99.6%) candidates out of which 10,680 (31.1%) scored from 6.0 – 10 marks, 12,159 (35.3%) scored from 3.5 – 5.5 marks and 11,553 (33.6%) candidates scored weakly (from 0 – 3.0 marks). The overall performance of the candidates in this question was good. This is because the majority (66.4%) of the candidates scored the pass mark or above (3.5 – 10 marks). Figure 1 summarizes the candidates' performance in this question.

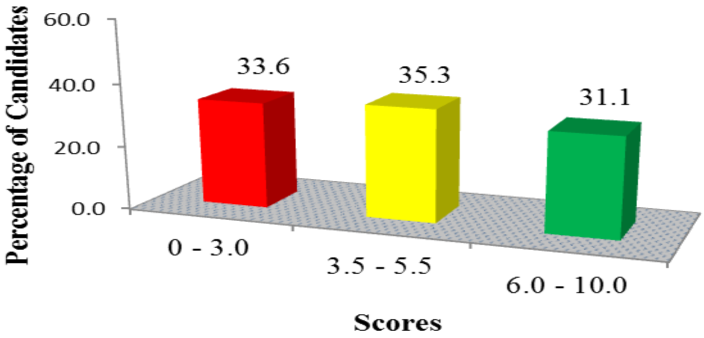
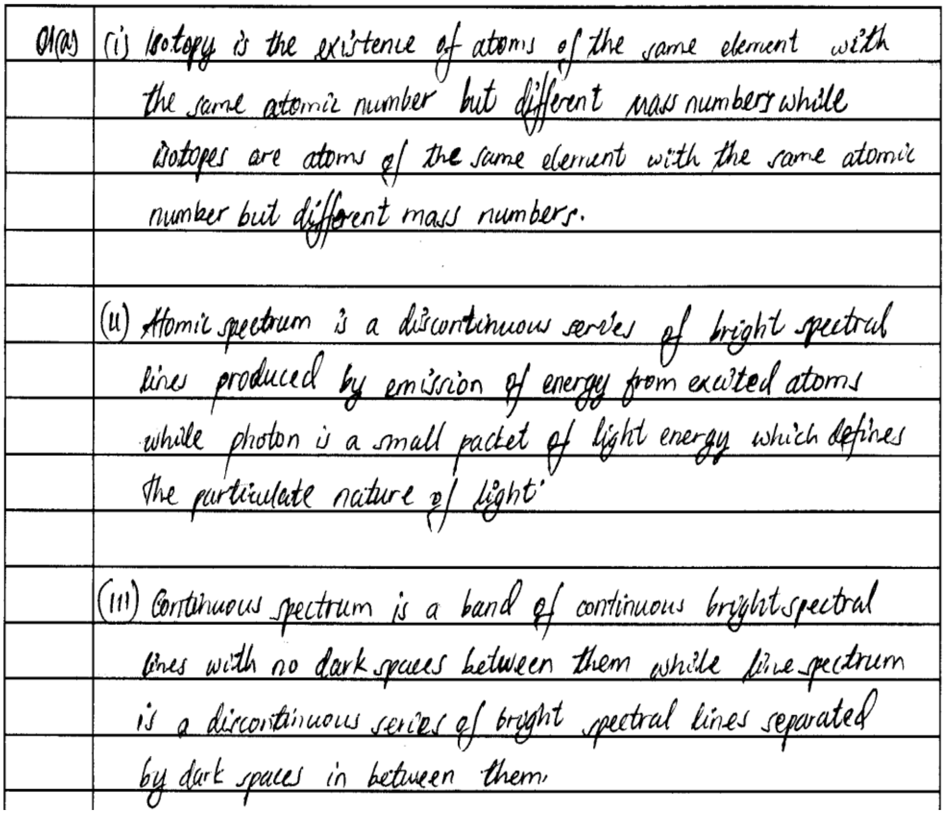


Figure 1: *Performance of the candidates in question 1*

The candidates who scored high marks in this question were those who were able to differentiate the given terms correctly. They managed to write the Rydberg's equation and correctly calculated the frequency of a wave developed when the given electron fall from n = 4 to 2. Extract 1.1 is a sample response from one of the candidates with good scores in question 1.



01(a)	(i) Isotopy is the existence of atoms of the same element with the same atomic number but different mass numbers while isotopes are atoms of the same element with the same atomic number but different mass numbers.
	(ii) Atomic spectrum is a discontinuous series of bright spectral lines produced by emission of energy from excited atoms while photon is a small packet of light energy which defines the particulate nature of light.
	(iii) Continuous spectrum is a band of continuous bright spectral lines with no dark spaces between them while line spectrum is a discontinuous series of bright spectral lines separated by dark spaces in between them.

(b)	Soln:
	Data given:
	Initial energy level $(n_2) = 4$
	Ground energy level $(n_1) = 2$
	Req: frequency of wave emitted (f)
	from,
	Rydberg's equation
	$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$
	$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{4^2} \right)$
	$\frac{1}{\lambda} = R_H \times 0.1875$
	but $R_H = 1.09678 \times 10^7 m^{-1}$
	$\frac{1}{\lambda} = 1.09678 \times 10^7 m^{-1} \times 0.1875$
	$\lambda = 4.863 \times 10^{-7} m$

01(b)	but from:
	$c = f\lambda$.
	$f = \frac{c}{\lambda}$
	Now, $c = 3 \times 10^8 m/s$
	$f = \frac{3 \times 10^8 m/s}{4.863 \times 10^{-7} m}$
	$= 6.17 \times 10^{14} Hz$
	∴ The frequency of the wave emitted is $6.17 \times 10^{14} Hz$.
(c)	→ Finding the relative atomic masses of elements
	→ Determining the number of isotopes and relative abundances
	of isotopes an element has.

Extract 1.1: A sample of good responses in question 1

Extract 1.1 displays responses of a candidate who differentiated the terms asked in part (a) properly. The candidate correctly applied the Rydberg equation to calculate the frequency of a wave when an electron fall from n = 4 to 2. Moreover, the candidate gave appropriate applications of the mass spectrometer.

However, some of the candidates scored weakly in part (a) because they used the terms 'element' and 'atom' interchangeably while differentiating isotopy from isotopes. In part (b), some of the candidates failed to interpret the ground level of the visible region as $n_1 = 2$; instead, they used levels which were not correct and thus ended up with wrong value of frequency. Besides, some of the candidates showed inadequate competence in mathematical manipulations. As a result, they failed to relate and combine the Rydberg's and Planck's equations to get the resultant equation required to calculate the frequency required for the given electron transition. In part (c), some of the candidates showed the lack of basic knowledge of the mass spectrometer, hence gave inappropriate application of the instrument.

10 (a) (i)	Isotopy is the existance of an element having the same neutrone number but different mass number
	While
	Isotopes is the ability of an element having the same mass number but different neutrone number
(ii)	Atomic spectrum are the wavelength which indicate the direction and quantity of an atom to its quantum number
	While
	Photon are the element which indicate the number of proton, electron and neutrone in the same quantum number
(iii)	Continuous spectrum is the type of atomic spectrum which impact the colour of an compound or element from the ground state to the excited state.
	While
	Line spectrum is the type of atomic spectrum which does not impact any colour change from the ground state to the excited state.
(b)	Solution
	From the formula
	$\lambda = RH\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$
	but
	$\lambda = c/v$
	$E = hv$
	$= 6.63 \times 10^{-34} \times 3.0 \times 10^{8}$
	$E = 1.999 \times 10^{-23}$ J

1(a) (i)	Isotopy is the existance of an element having the same neutrone number but different mass number
	While
	Isotopes is the ability of an element having the same mass number but different neutrone number
(ii)	Atomic spectrum are the wavelength which indicate the direction and quantity of an atom to its quantum number
	While
	Photon are the element which indicate the number of proton, electron and neutrone in the same quantum number
(iii)	Continuous spectrum is the type of atomic spectrum which impact the colour of an compound or element from the ground state to the excited state.
	While
	Line spectrum is the type of atomic spectrum which does not impact any colour change from the ground state to the excited state.
(b)	Solution
	From the formula
	$\lambda = RH\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$
	but
	$\lambda = c/v$
	$E = hv$
	$= 6.63 \times 10^{-34} \times 3.0 \times 10^{8}$
	$E = 1.999 \times 10^{-23}$ J

1b	$n_1 = 4$
	$n_2 = 3$
	$RH = 1.09678 \times 10^{-7} m^{-1}$
	$\lambda = RH\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$
	$\lambda = 1.09678 \times 10^{-7}\left[\frac{1}{4^2} - \frac{1}{3^2}\right]$
	$= 1.09678 \times 10^{-7}\left[\frac{1}{16} - \frac{1}{9}\right]$
	$= 1.09678 \times 10^{-7} \times -7/144$
	$\lambda = 5.33157 \times 10^{-9}$ ms
	$\therefore$ Frequency $= 5.33157 \times 10^{-9}$ ms
c)	(i) To impact the colour change of an element during excitation state
	(ii) To calculate the mass, frequency and wavelength of a certain energy.

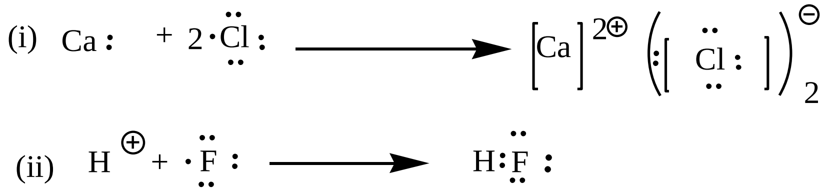
Extract 1.2: A sample of incorrect responses in question 1

In part (a), as shown in Extract 1.2, the candidate defined the terms incorrectly and applied inappropriate formulae to calculate the value of frequency asked. The candidate wrongly assumed that the electron transited from Paschen ($n_2 = 3$) to Brackett series ($n_1 = 4$) instead of transition from

Brackett (n_2 = 4) to Balmer series (n_1 = 2). Thus, he/she got a wrong value for the wavelength with a negative sign. Finally, the candidate wrote part of the mode of action of mass spectrometer instead of its uses.

2.1.2 Question 2: Chemical Bonding

This question had three parts, namely (a), (b) and (c). In part (a), candidates were required to identify the energetically stable compounds among the following pairs: (a) (i) NaBr and $NaBr_2$, (ii) ClO_4 and ClO_4^- (iii) OF_4 and SeF_4 and (iv) SO_4 and XeO_4. In part (b), candidates were given the statement that "*Although the Valency Shell Electron Pair Repulsion Theory (VSEPR) predicts correctly the CH_4 and NH_3 molecular geometries (or shapes), it does not account for the differences in (H-C-H) and (H-N-H) bonds whose angles are 109.5^o and 107.3^o, respectively*." Then, candidates were required to give reasons for such deviations. In part (c), candidates were required to classify the type of bond involved in each of the following chemical equations.



This question was attempted by a total of 32,871 (95.2%) candidates, out of which 52.1, 22.4 and 25.5 per cent scored from 6.0 – 10, 3.5 – 5.5 and 0 – 3.0 marks, respectively. Figure 2 presents the summary of the candidates' performance in question 2.

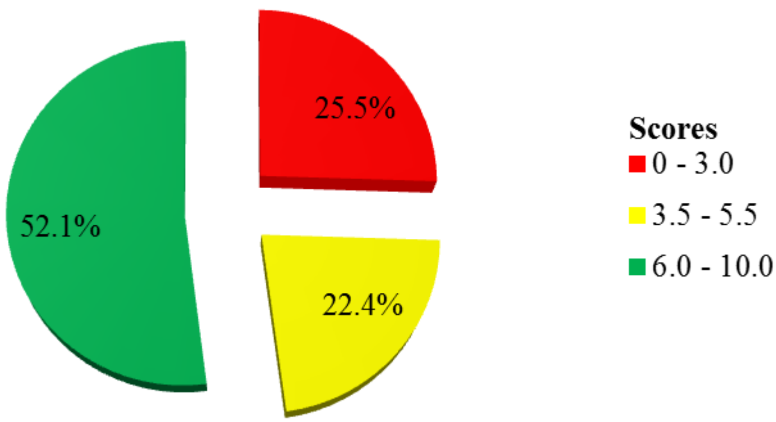
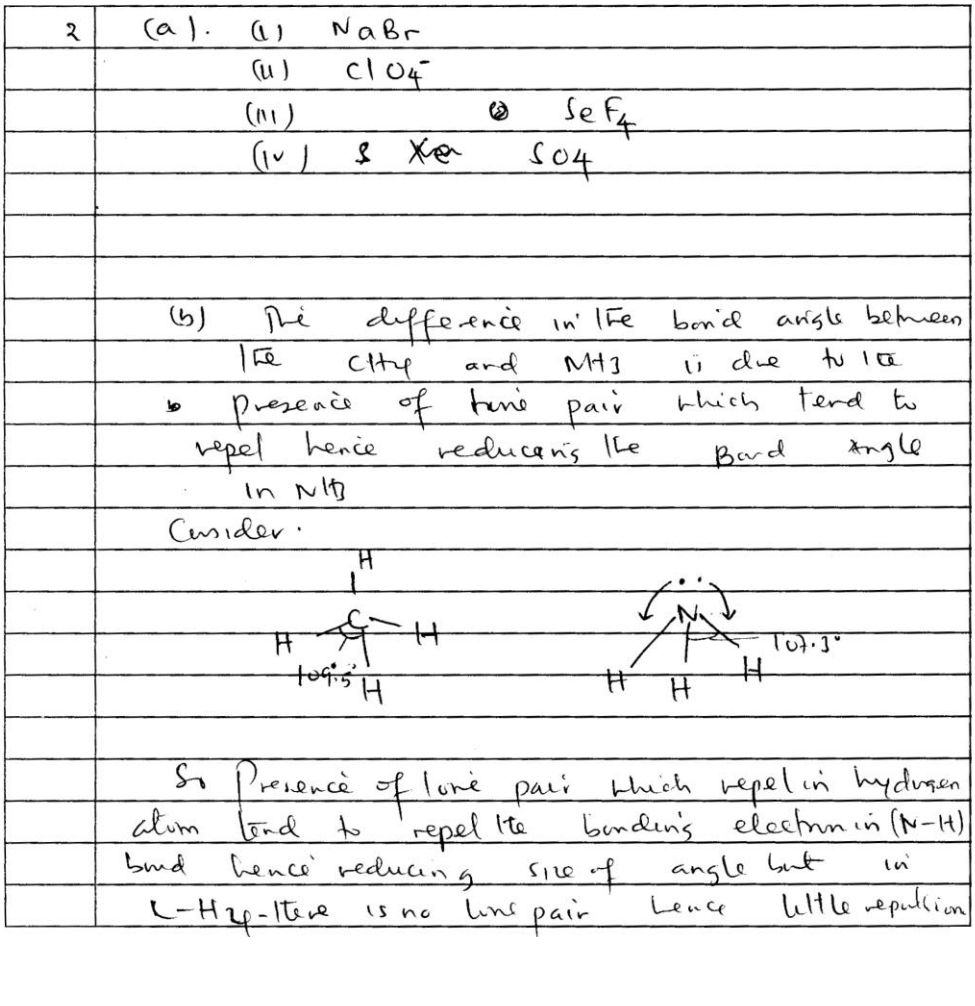


Figure 2: *Performance of the candidates in question 2*

The statistics shows that the general performance in this question was good, as a total of 24,499 (74.5%) candidates scored 3.5 marks or above.

The candidates who performed well (74.5%) demonstrated proper competencies in arranging electrons in a compound. These candidates managed to relate the concept of electron arrangement to the bond strength and stability of compounds. Thus, they managed to identify the most energetically stable compound among the given pairs. In part (b), they were able to relate the extent of repulsion of electron pairs (lone pair and bonded pair) to the bond angles while giving the geometrical shapes. Good performers in part (c) were able to relate the arrangement of valence electrons according to Lewis structure and the nature of bond formed. Extract 2.1 is a sample of correct responses from one of the candidates.


2 (a). (i) NaBr
(ii) ClO_4^-
(iii) SeF_4
(iv) SO_4

(b) The difference in the bond angle between the CH_4 and NH_3 is due to the presence of lone pair which tend to repel hence reducing the Bond angle in NH_3
Consider:

So Presence of lone pair which repel in hydrogen atom tend to repel the bonding electron in (N–H) bond hence reducing size of angle but in CH_4 there is no lone pair hence little repulsion

2 (c)

(i) The Ionic bond; because there is transfer of electron from Ca to Cl_2 creating the opposite charge Ion which attract each other

(ii) Covalent bond since there is the sharing of the electron. one from H^+ and one from F.

Extract 2.1: A sample of correct responses in question 2

In Extract 2.1, the candidate correctly identified the more energetically stable compound than the other in each of the pairs. The candidate used the idea of the effect of lone pairs (non-bonding electron pairs) to comment correctly on the deviation of bond angles observed.

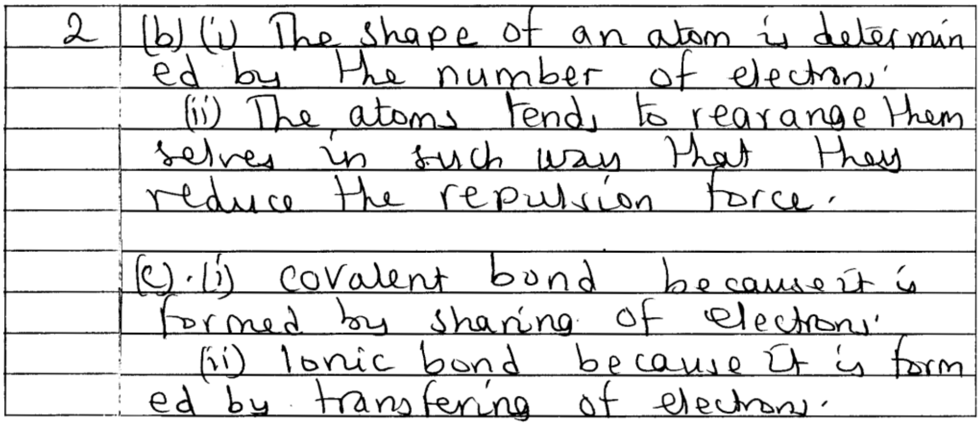
On the other hand, some of the candidates (25.5%) lacked appropriate knowledge of electron arrangement within a compound, the concept which would help them to determine the bond strength and stability of the compound. Thus, they wrongly picked the energetically stable compounds from the given pairs. In part (b), some of the candidates commented on the deviation of bond angles incorrectly. The candidates who scored low marks in part (c) failed to relate the arrangement of valence electrons according to Lewis structure and the types of bonds formed in terms of electron transfer or sharing. Extract 2.2 shows a sample of weak responses from one of the candidates in this question.

2 (a)(i) The more energetic and stable compound is $NaBr_2$.

(ii) The more energetic and stable compound is ClO_4.

(iii) The more energetic and stable compound is OF_4.

(iv) The more energetic and stable compound is XeO_4.



2 (b) (i) The shape of an atom is determin ed by the number of electrons.
(ii) The atoms tends to rearange them selves in such way that they reduce the repulsion force.

(c). (i) covalent bond because it is formed by sharing of electrons.
(ii) Ionic bond because It is form ed by transfering of electrons.

Extract 2.2: A sample of incorrect responses in question 2

In Extract 2.2, the candidate identified less stable compounds in terms of energy, instead of the most energetically stable compounds. The candidate though had some ideas about VSEPR, failed to establish the base for the difference in bond angles that was asked in part 2 (b). Moreover, the candidate interchanged the type of bond in part 2 (c) (i) and 2 (c) (i).

2.1.3 Question 3: Relative Molecular Masses in Solution

This question had three parts. Part (a) required candidates to determine the partial pressure of water in a mixture containing 36 g of water and 32 g of methanol at 298 K. Candidates were given 3.2 kPa as the vapour pressure of pure water at 298 K. Part (b) required candidates to calculate the vapour pressure of a solution made by dissolving 10 g of non-volatile candle wax ($C_{22}H_{46}$) in 40 g of carbon tetrachloride at 23 °C. Candidates were given 100 mm Hg as the vapour pressure of carbon tetrachloride at 23 °C. Part (c) required candidates to comment on the observation that, "*further dilution of 0.1 M KCl solution causes the observed molecular mass to approach the theoretical value of 37.3.*"

The question was attempted by 32,725 (94.8%) candidates. Figure 3 summarizes the candidates' performance in the question.

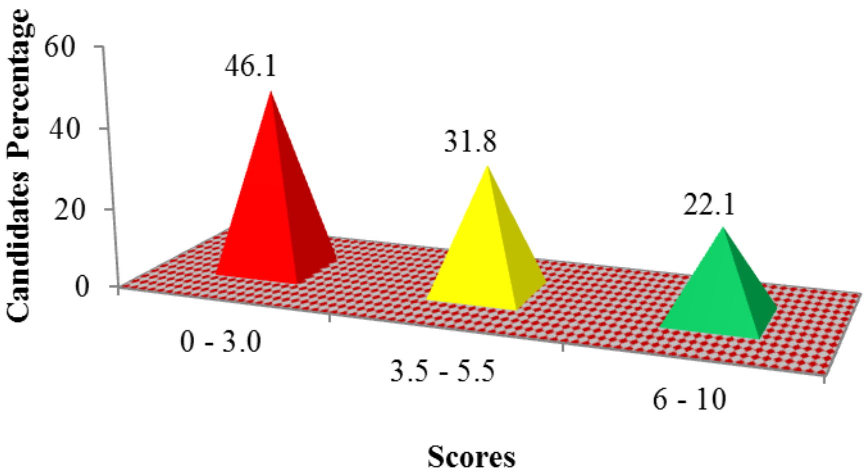


Figure 3: *Performance of the candidates in question 3*

Figure 3 shows that the overall performance in the question was good, as 53.9 per cent of the candidates who attempted the question scored 3.5 marks or above.

The analysis of responses shows that the candidates who performed well in the question exhibited appropriate mathematical skills as well as correct manipulation of the units. Hence, they scored in most parts of the question. They managed to derive the relationship between the mole fractions and vapour pressure of pure solvent properly. Moreover, the candidates had enough knowledge regarding the effect of dissociation of solute on its molecular weight. Extract 3.1 shows responses from one of the candidates with good scores in question 3.

3.	(a) Given that
	Mass of water (m_{H_2O}) = 36g
	Mass of methanol (mM) = 32g
	Number of moles of water
	n_{H_2O} = mass of water / molar mass of water
	~~nH_2O~~ = $n_{H_2O} = \frac{m_{H_2O}}{M_r}$
	$n_{H_2O} = \frac{36g}{18g/mol} = 2mol$
	$H_2O = (2+16)g/mol = 18g/mol$
	$n_{H_2O} = 2mol$
	Number of moles of methanol nM
	n_M = mass of methanol / Molar mass of methanol

methanol (CH_3OH) = (12 + 3 + 16 + 1) g/mol = 32g/mol

$n_M = \frac{32g}{32g/mol} = 1 mol$

$n_M = 1 mol$

mole fraction of water $X_{H_2O} = \frac{n_{H_2O}}{n_{H_2O} + n_M}$

$X_{H_2O} = \frac{2 mol}{(2+1) mol} = \frac{2}{3} = 0.67$

$X_{H_2O} = 0.67$

partial pressure of water = $X_{H_2O} \cdot P_{H_2O}$

$P'_{H_2O} = X_{H_2O} \cdot P_{H_2O}$

$P'_{H_2O} = 0.67 \times 3.2 kPa$

$P'_{H_2O} = 2.144 kPa$

∴ Partial vapour pressure of water is 2.144kPa

(b) Given that

Mass of wax (mw) = 10g

Mass of carbon Tetrachloride (mc) = 40g

3. Vapour pressure of carbon tetrachloride = 100mmHg

From the Formular $\Delta P = X_{su} \cdot P^o_{sv}$

Number of moles of wax (n_w) = $\frac{mass (mw)}{molarmass}$

Molar mass of $C_{22}H_{46}$ = (22×12 + 46) g/mol = 310g/mol

M_r of $C_{22}H_{46}$ = 310g/mol

Number of moles $n_w = \frac{10g}{310g/mol} = 0.032mol$

Number of moles of carbon tetrachloride

$n_c = \frac{mass (mc)}{Molar mass (M_r)}$

Molar mass of CCl_4 = (12 + 35.5×4) g/mol

M_r of CCl_4 = 154g/mol

Number of moles $n_c = \frac{40g}{154g/mol} = 0.26mol$

$n_c = 0.26 mol$

mole fraction of solute

$X_{su} = \frac{n_w}{n_w + n_c}$

$X_{su} = \frac{0.032 mol}{(0.032 + 0.26) mol}$

$X_{su} = 0.1$

$\Delta P = X_{su} \cdot P^o_{sv}$

$\Delta P = 0.1 \times 100mmHg = 10mmHg$

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

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

$P_{soln} = 100 mmHg - 10 mmHg$

$P_{soln} = 90mmHg$

∴ The vapour pressure of the solution is 90mmHg

3. From the dilution law CV = constant since there is further dilution the dissociation of the KCl solution assumed to be 1. (it totally dissociate)

From equation $KCl_{(aq)} \rightarrow K^+_{(aq)} + Cl^-_{(aq)}$

$n = 2$

since $\alpha = 1$. Recall $\alpha = \frac{i-1}{n-1}$

$\alpha = i - 1$

$i = \alpha + 1 = 1 + 1 = 2$

$i = 2$

But $i = \frac{\text{Expected Molar mass}}{\text{observed molar mass}}$

∴ observed molar mass = $\frac{\text{Expected}}{i}$

Expected Molar mass KCl = (39 + 35.5) g/mol

Mr of KCl = 74.5 g/mol

observed Molar mass = $\frac{74.5 \text{ g/mol}}{2}$ = 37.3

∴ Observed Molar mass be 37.3 g/mol

Extract 3.1: A sample of correct responses in question 3

In Extract 3.1, the candidate was able to perform all the required calculations while manipulating the units correctly. The candidate managed to relate the effect of dissociation of solute to its molecular weight. Hence, commented in part 3 (c) of the question appropriately.

Besides, some of the candidates amounting to 46.1 per cent scored weakly in this question. These candidates failed to manipulate the units while performing the required calculations. Moreover, they provided a wrong relationship between the effect of dissociation of solute and the relative molecular mass of the solute. Extract 3.2 is an example of responses with weak scores from one of the candidates.

3\. (a) $P^{o}_{solv} = 3.2$ KPa

Mass of solvent = 36g

mass of solute = 32g

ΔP^{o} = ?

Temp = 298K.

$$\frac{\Delta P}{P^{o}_{sv}} = \frac{n_{su}}{n_{sv}}$$

$$\frac{\Delta P}{P^{o}_{sv}} = \frac{m_{su} \times mr_{sv}}{m_{sv} \times mr_{su}}$$

$$\frac{\Delta P}{3.2} = \frac{32 \times 18}{32 \times 36}$$

$$\frac{\Delta P}{3.2} = \frac{576}{1152}$$

$$\frac{1152\,\Delta P}{1152} = \frac{1843.2}{1152}$$

$\Delta P = 1.6$ KPa.

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

$1.6 = P_{soln} - 3.2$

$P_{soln} = 1.6 + 3.2$

$P_{soln} = 4.8$ KPa.

∴ The partial vapour pressure of water in solution = 4.8KPa.

$\frac{\Delta P^o}{100} = \frac{10 \times 154}{310 \times 40}$

$\frac{12400 \Delta P^o}{12400} = \frac{154000}{12400}$

$\Delta P^o = 12.419\ mmHg$

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

$12.419 = P^o_{soln} - 100$

$100 + 12.419 = P^o_{soln}$

$P^o_{soln} = 112.419\ mmHg$

∴ ~~Par~~ Vapour pressure of the solution = 112.419 mmHg

(C) Expected mr = 74.5 $gmol^{-1}$

observed mr = 37.3 $gmol^{-1}$

~~When~~ This is because when the dilution of the KCl increased the solution tends to ~~dicr~~ decrease its bond energy the ~~free~~ decrease of bond energy hence cause the molar mass of KCl to decrease at 0.1 m to 37.3

Extract 3.2: A sample of incorrect responses in question 3

In Extract 3.2, the candidate not only used inappropriate formulae, but also manipulated the units wrongly in performing the required calculations. Moreover, the candidate incorrectly commented in the last part of the question; as he/she did not understand how to derive the theoretical value of the molar mass (37.3).

2.1.4 Question 4: Energetics

The question had two parts, namely (a) and (b). Part (a) of the question asked candidates "*Using the following chemical equations and values provided for each, calculate the enthalpy of formation of Ca(OH)₂.*

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) \quad \Delta H = -68.3\ kCal$

$Ca(s) + H_2O(l) \rightarrow Ca(OH)_2(s) \quad \Delta H = -15.3\ kCal$

$Ca(s) + \frac{1}{2}O(g) \rightarrow CaO(s) \quad \Delta H = -151.8\ kCal$."

Part (b) required candidates to calculate the heat change for the synthesis of diborane (B_2H_6) from its elements according to the equation $2B(s)+3H_2(g) \rightarrow B_2H_6(g)$. Candidates were supplied with the following information:

S/N	Reaction	ΔH kJ
1	$2B(s)+\frac{3}{2}O_2(g) \rightarrow B_2O_3(s)$	-1273
2	$B_2H_6(s) + 3O_2(g) \rightarrow B_2O_3(s) + 3H_2O(g)$	-2035
3	$H_2(g) + \frac{1}{2}O_2(g) \rightarrow 3H_2O(l)$	-286
4	$H_2O(g) \rightarrow H_2O(l)$	44

The question was attempted by 26,705 candidates, corresponding to 77.4 per cent, out of which, 42.8 percent scored high marks (6.0 - 10), 17.7 per cent scored average marks (3.5 – 5.5) and 39.5 percent scored from 0 – 3.0 marks. The summary of the candidates' performance in this question is summarized in Figure 4.

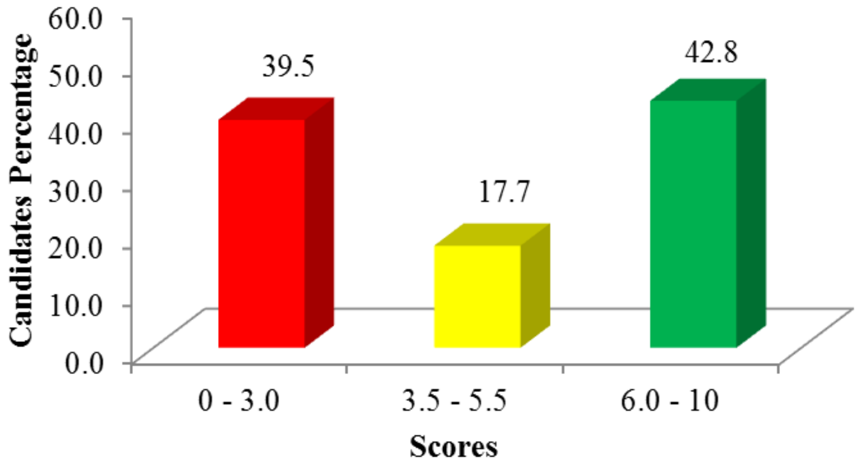


Figure 4: *Performance of the candidates in question 4*

The overall performance in this question was good, as 60.5 per cent of the candidates scored 3.5 marks or above. The candidates who scored high marks managed to manipulate the thermochemical equations given and got correct answers appropriately. Extract 4.1 presents a section of correct responses from one of the candidates.

4 (b) Heat change for the synthesis in eqn (iii) is not balance.

$3H_{2(g)} + \frac{3}{2}O_{2(g)} \rightarrow 3H_2O_{(l)}$ ΔH° -286.

Add eqn (iii) with reverse of eqn (iv x3)

$3H_{2(g)} + \frac{3}{2}O_{2(g)} \rightarrow 3H_2O_{(l)}$ -286

$3H_2O_{(l)} \rightarrow 3H_2O_{(g)}$ -132

$3H_{2(g)} + \frac{3}{2}O_{2(g)} \rightarrow 3H_2O_{(g)}$ -418 kJ —(v)

Add eqn (v) with eqn (i)

$2B_{(s)} + \frac{3}{2}O_2 \rightarrow B_2O_{3(s)}$ -1273 kJ

$3H_{2(g)} + \frac{3}{2}O_2 \rightarrow 3H_2O_{(g)}$ -418 kJ.

$2B_{(s)} + 3H_{2(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(g)}$ $= -1691$ kJ.

followed by reverse of eqn (ii)

$2B_{(s)} + 3H_{2(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(g)}$ -1691 kJ

$+$ $B_2O_3 + 3H_2O_{(g)} \rightarrow B_2H_{6(g)} + 3O_{2(g)}$ 2035 kJ.

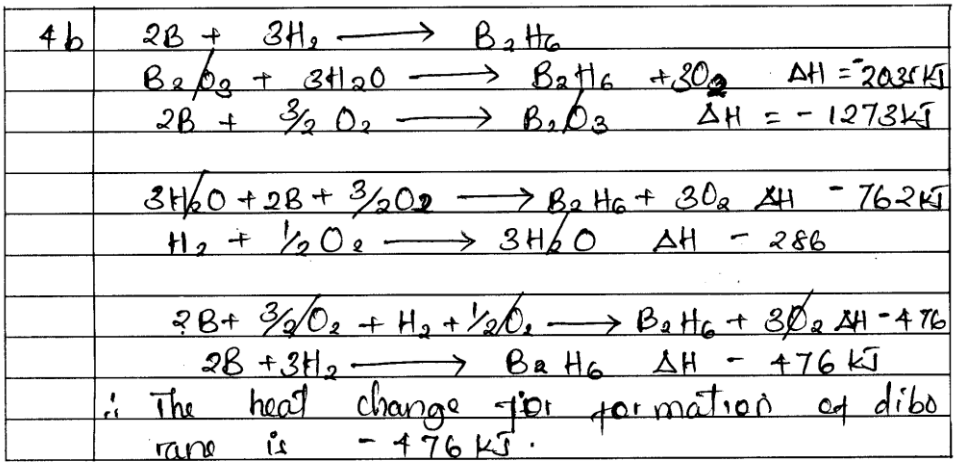
$2B_{(s)} + 3H_{2(g)} \rightarrow B_2H_{6(g)}$ 344 kJ.

∴ Heat change for synthesis of diborane is 344 kJ

Extract 4.1: A sample of good responses in question 4

In Extract 4.1, the candidate managed to balance all the thermochemical equations correctly and reversed equations 2 and 4. The candidate calculated the enthalpy of formation of diborane (B_2H_6) correctly.

On the other hand, (39.5%) candidates who got weak scores in this question showed lack of knowledge of manipulating thermochemical equations. Hence, they did not arrive at the expected chemical equations and their associated enthalpies. Extract 4.2 from one of the candidates is an example of weak responses.


4b 2B + 3H₂ ⟶ B₂H₆

$B_2O_3 + 3H_2O \longrightarrow B_2H_6 + 3O_2$ ΔH = 2035 kJ

$2B + \frac{3}{2}O_2 \longrightarrow B_2O_3$ ΔH = −1273 kJ

$3H_2O + 2B + \frac{3}{2}O_2 \longrightarrow B_2H_6 + 3O_2$ ΔH − 762 kJ

$H_2 + \frac{1}{2}O_2 \longrightarrow 3H_2O$ ΔH − 286

$2B + \frac{3}{2}O_2 + H_2 + \frac{1}{2}O_2 \longrightarrow B_2H_6 + 3O_2$ ΔH − 476

$2B + 3H_2 \longrightarrow B_2H_6$ ΔH − 476 kJ

∴ The heat change for formation of diborane is − 476 kJ.

Extract 4.2: A sample of incorrect responses in question 4

In Extract 4.2, the candidate failed to balance the equations and failed to reverse equations 2 and 4 which resulted in an incorrect calculation.

2.1.5 Question 5: Soil Chemistry

The question comprised of two parts, namely (a) and (b). Part (a) required candidates to justify the following facts: "*(i) Ion exchange in the soil system is a reversible process (ii) All calcium or magnesium compounds can be used as liming materials (iii) Aluminum contributes to soil acidity*." In part (b), candidates were asked as follow: "*Rungwe high school farm soil requires 100 kg of nitrogen to fulfill the plant requirement of nitrogen per hectare. If the farm has 60 hectares, calculate the number of bags of ammonium sulphate,* $(NH_4)_2SO_4$ *fertilizer required to meet this demand. (One bag of fertilizer weighs 25 kg).*"

A total of 31,331 candidates equivalent to 90.8 per cent attempted the question, out of which 66.1 per cent scored from 0 – 3.0 marks, 26.0 per cent scored from 3.5 – 5.5 marks and 7.9 per cent scored from 6.0 – 10 marks. Figure 5 shows a graphical distribution of the candidates' scores in question 5.

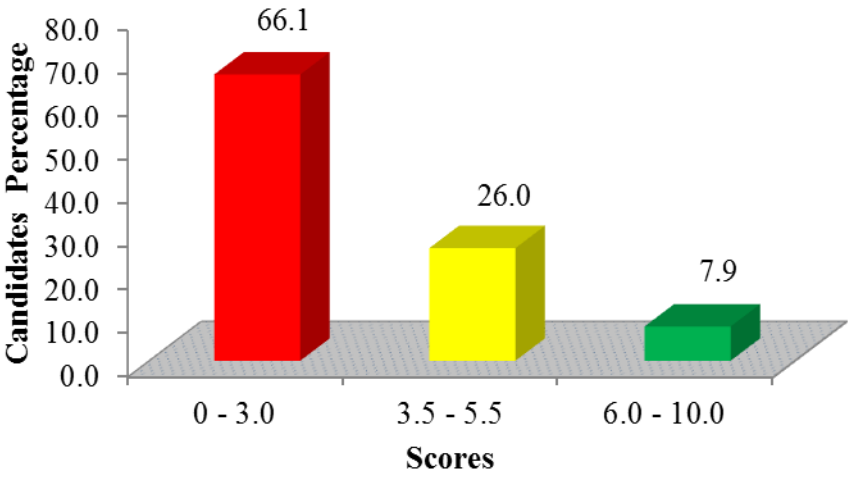
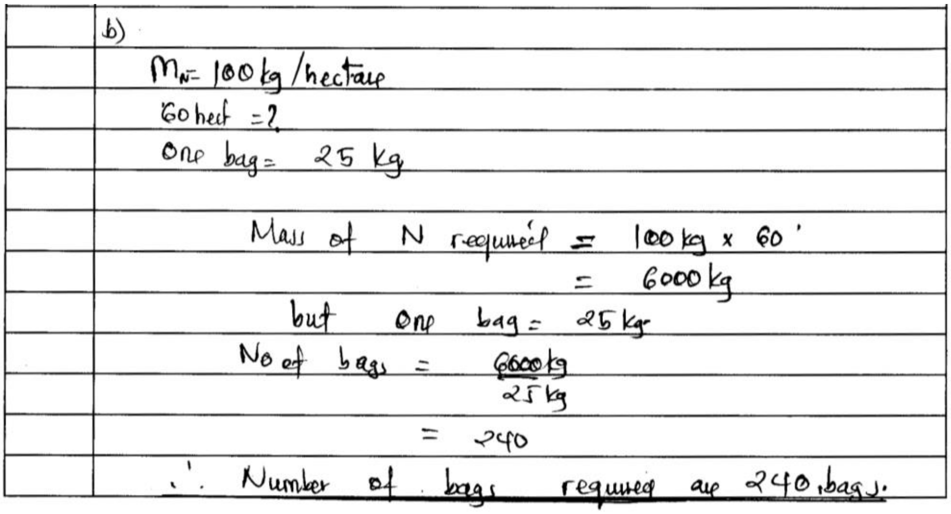


Figure 5: *Performance of the candidates in question 5*

The overall performance in this question was weak, as 66.1 per cent of the candidates scored below the pass mark (<3.5 marks), as Figure 5 shows. The statistical data shows that only 33.9 per cent of the candidates were able to score an average mark or above (from 3.0 – 10 marks).

The analysis of responses given by the candidates in this question revealed that the candidates (66.1%) who scored weak marks were not knowledgeable of the concept of ion exchange within the soil (soil colloids and soil solution regrading reversible change of ions), and had no knowledge of the basic-acidic character of the resulting solutions obtained when metals hydrolyze in the soil water. Moreover, some of them showed to have weak language skills hence could not understand the meaning of the term justify. For instance, in attempting part (a) (i) of the question, one of the candidates responded "*calcium and magnesium can be used in the laboratories in the experimental processes such as magnesium ribbon and* $CaCl_2$ *which may be used in qualitative analysis experiment*" contrary to the requirement of the question. The candidate was supposed to defend or substantiate or validate or endorse or rationalize the use of Ca and Mg compounds in liming process. The candidate was expected to point out that hydrolysis of Mg and Ca compounds (particularly the oxides and carbonates) leads to the formation of strong basic solutions which can neutralize the amount of acid in the soil during the process of liming. Extract 5.2 is a sample of incorrect responses given by one of the candidates in part 5 (b).



b)

m_N = 100 kg/hectare

60 hect = ?

One bag = 25 kg

Mass of N required = 100 kg x 60

= 6000 kg

but one bag = 25 kg

No of bags = $\frac{6000\text{ kg}}{25\text{ kg}}$

= 240

∴ Number of bags required are 240 bags.

Extract 5.2: A sample of incorrect responses in question 5

In Extract 5.2, the candidate presented partial data in an attempt to calculate the number of fertilizer bags that were required. His/her approach to divide the total amount of nitrogen required (6000 kg) by the mass of one fertilizer bag (25 kg) to get the number of bags required (240), was not correct. The candidate was also supposed to determine the nitrogen content in ammonium sulphate fertilizer and perform appropriate mathematical operations to get 1132 bags of fertilizers.

On the other hand, 33.9 per cent of the candidates were able to perform in this question well. These candidates showed to have acquired appropriate competencies in ion exchange processes taking place in the soil. They also demonstrated good mathematical skills. In part (a) of the question, the candidates managed to explain the concept of reversibility of ions within the soil and used the concept of acid–base character of metal in contact with soil water to explain how soil acidity and soil basicity can be controlled. In part (b), the candidates who got full marks in the question mastered mathematical skills about stoichiometry. Extract 5.1 displays an example of good responses from a candidate who scored high marks in this question.

5. a) i) This is because, ions can be exchanged between soil colloid and soil solution, in either direction. This means that ions can move either from soil colloid to soil solution or from soil solution to soil colloid

for example

$$\text{(Soil colloid)}\begin{matrix}-H\\-H\end{matrix} + Ca^{2+} \rightleftharpoons \text{(Soil colloid)}-Ca + 2H^+$$

ii) - No, Not all compounds of calcium and magnesium can be used in liming. Only oxides, hydroxides, carbonates and silicates of calcium and magnesium are used in liming.

- This is because, these compounds are naturally base and they therefore will rise the soil pH

iii) - This is because aluminium while in soil, tends to form complex with aqua ligand. The formed complex tends to release hydrogen protons,

5. a) iii) which contributes to soil acidity

equation

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

b) Data given

Requirements of nitrogen per hectare = 100kg

number of hectares = 60

fertilizer required = $(NH_4)_2SO_4$

weight of one bag = 25kg

Required = number of bags

~~From~~

Solution

one hectare = 100kg

60 hectares = x

then

$$x = \frac{60\,\text{hectares} \times 100\text{kg}}{1\ \text{hectare}}$$

x = 6000kg = 6000,000g

where x is number of killograms (Mass) of nitrogen required in 60 hectares

then

Total Molecular Mass of $(NH_4)_2SO_4$ is

$= (((14 + 4\times1)\times2) + 32 + (16\times4))$ g/mol

= 132 g/mol

then

in $(NH_4)_2SO_4$, there are (14×2)g/mol of nitrogen

then

132 g of $(NH_4)_2SO_4$ ≡ 28g of N

x ≡ 6000×10^3g

5.	b) $X = \frac{6000,000\,g \times 132\,g}{28\,g}$
	$= 28,285,714.29\,g. = 28,285.71429\,kg$
	where X is Mass of $(NH_4)_2SO_4$ that contain
	6000kg of Nitrogen
	then
	then
	Since 1 bag = 25kg.
	X = 28,285.71429kg
	$X = \frac{1bag \times 28,285.71429kg}{25kg}$
	= 1131.43 bags
	X = 1132 bags.
	Where X is number of bags containing 28,285.71429kg
	of $(NH_4)_2SO_4$
	∴ 1132 bags of $(NH_4)_2SO_4$ are required to
	suit the requirements of 60 hectares
	at Rungwe secondary school.

Extract 5.1: A sample of correct responses in question 5

Extract 5.1 shows responses of a candidate who explained the concept of soil colloids and soil solution well. Moreover, the candidate highlighted the concept of metal hydrolysis in the soil correctly. Lastly, He/she performed the required calculations correctly.

2.1.6 Question 6: Selected Compounds of Metals

This question had two parts, namely (a) and (b). In part (a), candidates were given the following information: "*When dilute hydrochloric acid is added to a yellow solution of potassium chromate, an orange solution of dichromate is produced.*" Then, they were required to provide a brief explanation of what could be observed if the following were done: "*6 (a) (i) adding more hydrochloric acid (ii) addition of dilute solution of sodium hydroxide (iii) addition of anhydrous calcium chloride.*" Part (b) required candidates to give brief explanation of "*(i) Hydrogen gas is evolved when magnesium is introduced into a beaker containing aqueous solution of ammonium chloride. (ii) $AlCl_3$ reacts chemically with water while NaCl does not.*"

The question was attempted by a total of 26,705 (77.4%) candidates. Statistical data shows that 22,903 (85.8%), 2464 (9.2%) and 1338 (5%) candidates scored from 0 – 3.0, 3.5 – 5.5 and 6.0 – 10 marks, respectively. Figure 6 shows the distribution of the candidates' scores in question 6.

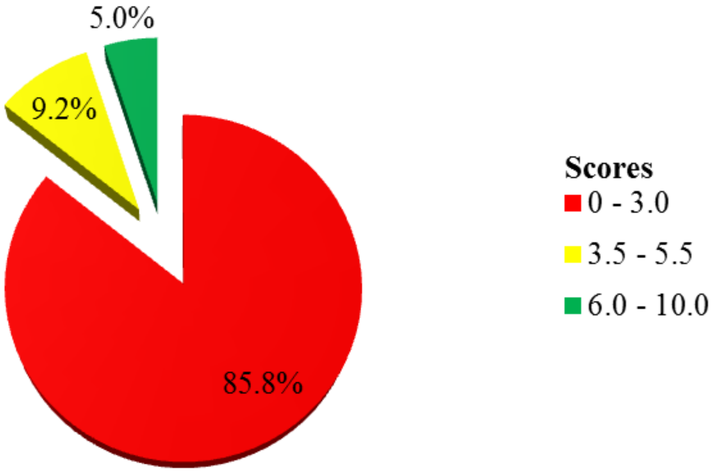


Figure 6: *Performance of the candidates in question 6*

The general performance in this question was weak, as 22,903 (85.8%) of the total candidates (26,705; 77.4%) who attempted the question scored marks below the pass mark (<3.5).

The analysis of responses given by the candidates with low scores (85.8%) revealed that they had insufficient knowledge of the topic of *Selected Compounds of Metals*. These candidates failed to comprehend the situation that could be taking place in the reaction mixture following an addition of the given reagents. For instance, one of the candidates while attempting part 6 (a) (i) of the question wrote, "*On addition of more HCl will not change the colour of the solution*" contrary to the correct answer. The candidates were supposed to understand that upon adding more HCl, the reaction lies more to the right hand side (products side). Thus, the orange colour is observed due to the formation of dichromate.

Besides, some of the candidates with low scores repeated the requirement of the question. For example, one of the candidates in responding to part 6 (b) (i) wrote, "*So from the reaction above show that when magnesium is introduced into a beaker containing aqueous solution of ammonium* *chloride we can see that hydrogen gas is evolved*" which is contrary to the requirement of the question. In this part of the question, the candidate was expected to understand and respond that when magnesium is introduced into a beaker containing aqueous solution of ammonium chloride, it reacts with ammonium chloride to produce magnesium chloride and ammonium (strong acidic radical). Thereafter, the ammonium ions produced reacts with water to produce ammonium hydroxide and hydrogen ions. Magnesium reduces the hydrogen ions to form hydrogen gas. Extract 6.1 is a sample of incorrect responses given by one of the candidates in question 6.

6. (a)

$HCl_{(aq)} + K_2CrO_{2(aq)} \longrightarrow Cr_2O_4^{-} + 2KCl_{(aq)} + H_{2(g)}$

Yellow → orange

i) When adding more hydrochloric acid the dichromate formed will form a complex compound. (ppt)

ii) When adding dilute NaOH soln the reaction will reverse to it's acidic medium since NaOH used to provide the acid medium of dichromate

iii) When adding anhydrous calcium chloride the compound formed is calcium dichromate and with reduce $H_{2(g)}$ in product side.

(b) i) $2NH_3Cl_{(aq)} + Mg_{(s)} \longrightarrow MgCl_{2(aq)} + H_{2(g)} + 2NH_{2(g)}$

Hydrogen obtained as mg introduced in NH_3Cl since it gives $MgCl_2$ and gases as $NH_{2(g)}$ and $H_{2(g)}$

ii) The electronegativity between Na–Cl is approximately the same as the result it does not break to provide loop for chemical reaction.

Extract 6.1: A sample of incorrect responses in question 6

In Extract 6.1, the candidate gave incorrect equation to represent the equilibrium between chromate and dichromate ions under acidic medium in part 6 (a) (i), instead of explaining the expected observation. The candidate was supposed to understand that there is an equilibrium existing between chromate (yellow in colour) and dichromate ions (orange in colour) under acidic medium.

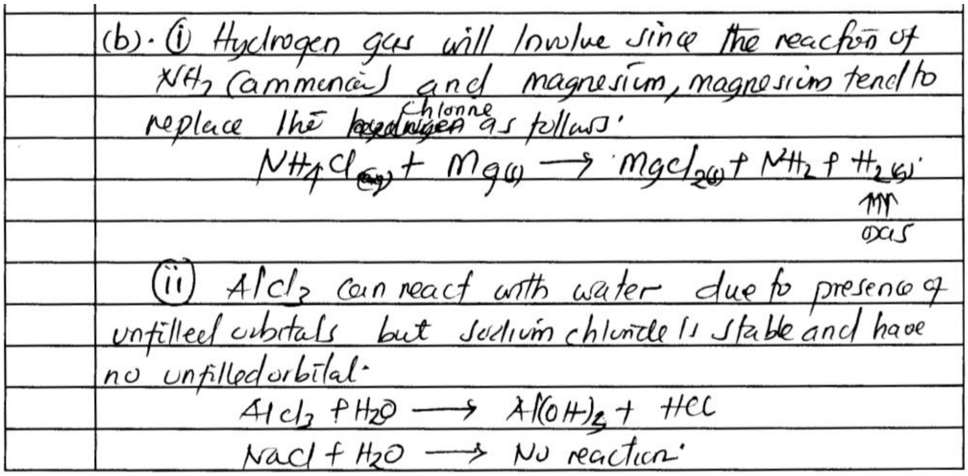
The candidate also gave incorrect observation in the subsequent parts of 6 (a). In part 6 (a) (ii), the candidate was supposed to understand and respond that, when NaOH is added to the equilibrium which was in acidic condition, neutralization occurs and the equilibrium moves to the left hand side hence producing yellow chromate. In part 6 (a) (iii), the candidate was expected to understand that, when anhydrous calcium chloride is added to the equilibrium it absorbs water and hence the system shifts to the right hand side producing more orange dichromate. Lastly, the candidate gave incorrect equation and explanation in 6 (b) (i) and 6 (b) (ii), respectively. The candidate was supposed respond to this part as described in the preceding paragraph.

Despite the fact that the majority of the candidates scored weakly in this question, some of the candidates (5.0%) scored high marks. These candidates showed appropriate competencies required in this topic. They applied Le Chatelier's principle to explain the equilibrium position upon an addition of given reagents. They also managed to apply the knowledge of properties of metal compounds in giving explanations in part 6 (b) of the question. Extract 6.2 shows a sample of responses from one of the candidates who performed well in this question.

(i) If more hydrochloric acid is added the forward reaction will be favoured hence the the colour of the solution will be more orange to show the presence of dichromate.

(ii) If adding dil. sodium hydroxide solution the backward reaction will be favoured hence the yellow colouration will be observed

(iii) Anhydrous Calcium chloride the reaction will be proceed in forward due to Increase of chloride solution hence favour orange colouration.


(b). (i) Hydrogen gas will Involve since the reaction of NH_3 (ammonia) and magnesium, magnesium tend to replace the chlorine as follows.

$NH_4Cl_{(aq)} + Mg_{(s)} \rightarrow MgCl_{2(s)} + NH_3 + H_{2(g)}\uparrow$ gas

(ii) $AlCl_3$ can react with water due to presence of unfilled orbitals but sodium chloride is stable and have no unfilled orbital.

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

$NaCl + H_2O \rightarrow$ No reaction.

Extract 6.2: A sample of appropriate responses in question 6

In Extract 6.2, the candidate gave correct observations in all parts of 6 (a). The candidate also managed to respond to the remaining parts of the question correctly.

2.1.7 Question 7: Aliphatic Hydrocarbons

This question had two parts, namely (a) and (b). Part (a) (i) required candidates to give two properties that make organic compounds a suitable source of fuel. Part (a) (ii) was as follows: "*Compressed natural gas methane, (CH_4) is a fossil fuel found in large quantities in our country, Tanzania. Due to its several advantages, compressed natural gas is considered the most promising vehicles' fuel and thus it should be promoted as the main fuel in our country. State four benefits offered by the compressed natural gas over conventional fuel like gasoline and diesel.*" Part (b) required candidates to suggest a suitable chemical test to distinguish between the following pairs of organic compounds: *(i) Butane and 1-butene (ii) Propyne and propene (iii) Pent-1-yne and pent-2-yne (iv) Propane and 1-bromopropane.*

The question was attempted by 31,489 (91.2%) candidates, out of which, 67.6 per cent scored marks ranging from 0 – 3.0. Meanwhile, 21.7 and 10.7 per cent of the candidates scored from 3.5 – 5.5 marks and from 6.0 – 10 marks, respectively. The summary of the candidates' performance in this question is shown in Figure 7.

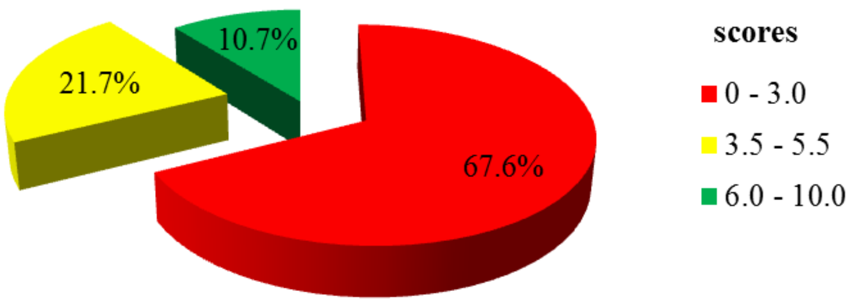
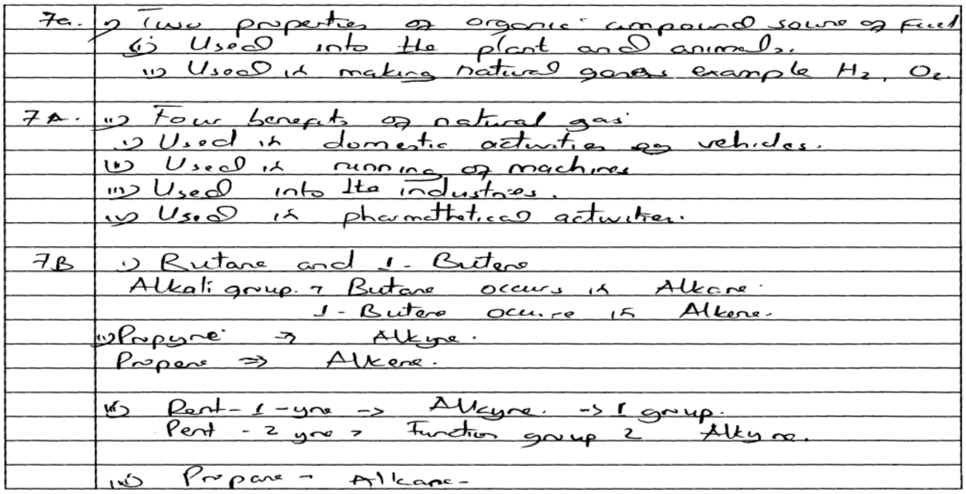


Figure 7: *Performance of the candidates in question 7*

Figure 7 shows that the general performance in this question was weak, as the majority of the candidates (67.6%) who attempted the question scored below the pass mark (<3.5).

The responses of the candidates who scored weakly in this question (67.6%) shows that they lacked the required competencies in understanding the nature of alkanes as fuels. Moreover, responses from these candidates indicate that they lacked basic knowledge of the chemical properties of hydrocarbons. Most of these candidates failed to answer part (b) of the question. This is attributed to insufficient knowledge of the chemical properties of functional groups. As a result, candidates failed to choose suitable reagents which would give observable changes to distinguish between the given compounds. Extract 7.1 presents a sample of incorrect responses given by one of the candidates in this question.


7a. i) Two properties of organic compound source of Fuel
(i) Used into the plant and animals.
ii) Used in making natural gases example H_2, O_2.

7A. ii) Four benefits of natural gas
i) Used in domestic activities as vehicles.
ii) Used in running of machines
iii) Used into the industries.
iv) Used in pharmatheticas activities.

7B i) Butane and 1- Butene
Alkali group. 7 Butane occurs in Alkane.
1 - Butene occure in Alkene.
ii) Propyne → Alkyne.
Propene ⇒ Alkene.

iii) Pent-1-yne → Alkyne. → 1 group.
Pent - 2 yne → Function group 2 Alkyne.

iv) Propane → Alkane.

Extract 7.1: A sample of incorrect responses in question 7

In Extract.7.1, the candidate gave incorrect properties in part (a) (i). In (a) (ii), the candidate gave the uses of natural gas instead of giving reasons that make natural gas superior over conventional fuel. Lastly, the candidate differentiated the given pair of organic compounds in terms of their origin contrary to the requirement of the question.

However, 10.7 per cent of the candidates managed to score high marks in the question. The analysis of responses of such candidates showed that, apart from having appropriate competencies in the topic of *Aliphatic Hydrocarbons*, they properly understood the requirements of the question and scored correctly in most parts of the question. Extract 7.2 is a sample of responses from one of the candidates who performed well in the question.

7a

i) Properties of fuel.

i) The Organic Compounds ~~must~~ have a very high energy Value. This means that the Combustion of the Compound ~~should~~ yields a reasonable amount of energy.

ii) Organic Compounds are easily Stored, transported ~~dont~~ and they are affordable Since they are available in plenty.

ii) Benefits offered by Compressed natural gas.

i) It is environmentally friendly fuel and doesnot pollute the environment as Compared to other fuels like diesel.

ii) Natural gas has a Very high energy Value as Compared to the other Conventional fuels like diesel.

iii) Natural gas is easily Stored and transported as Compared to diesel and gasoline that are hard to transport

iv) Natural gas is affordable as Compared to other Conventional fuels that a Very expensive

7b.

i) Butane and 1-Butene.

By using Bromine water, 1-Butene reacts with Bromine water and decolourizes it but Butane doesnt react with Bromine water.

$$CH_2 = CHCH_2CH_3 + Br_2 \xrightarrow{H_2O} CH_2BrCH(OH)CH_2CH_3$$

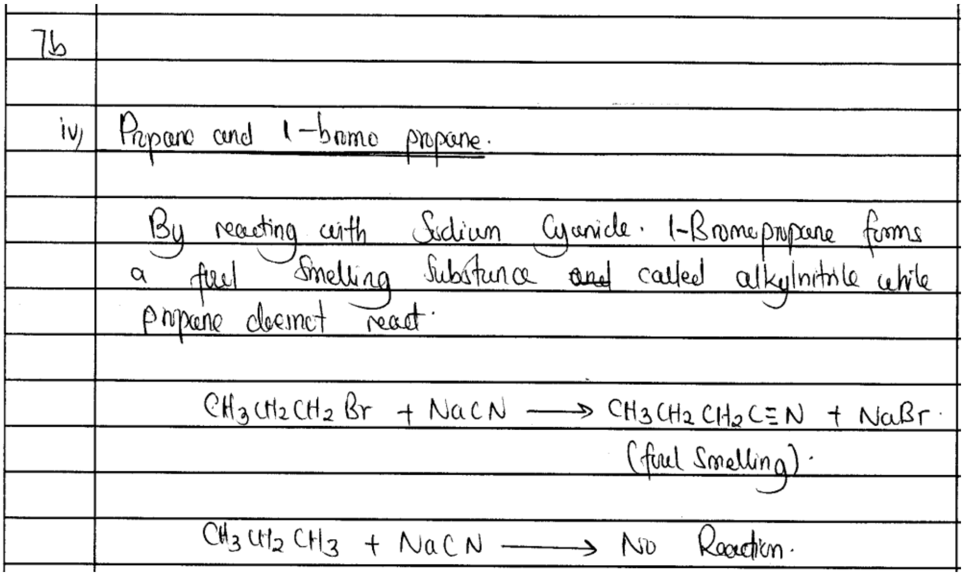
$$CH_3 - CH_2CH_2CH_3 + Br_2 \xrightarrow{H_2O} \text{No Reaction.}$$

ii) Propyne and propene.

By reacting with Ammoniacal Silver nitrate Solution. Propyne forms white precipitates with Ammoniacal Silver nitrate but propene doesnt react with Ammoniacal Silver nitrate..

iii) Pent-1-yne from pent 2 yne.

By reacting with Ammoniacal Silver nitrate. Pent-1-yne forms precipitates Since it has a terminal ~~methyl group but~~ alkyne group but Pent-2-yne doesnt form precipitates Since it lacks a terminal alkyne group



7b

iv) Propane and 1-bromo propane.

By reacting with Sodium Cyanide. 1-Bromopropane forms a foul smelling substance ~~and~~ called alkylnitrile while propane doesnot react.

$CH_3CH_2CH_2Br + NaCN \longrightarrow CH_3CH_2CH_2C\equiv N + NaBr$.
(foul smelling).

$CH_3CH_2CH_3 + NaCN \longrightarrow$ No Reaction.

Extract 7.2: A sample of correct responses in question 7

In Extract 7.2, the candidate gave correct properties that make organic compounds suitable for fuels. The candidate also gave appropriate benefits of compressed natural gas over conventional fuels. Furthermore, he/she managed to distinguish the given organic compounds correctly.

2.1.8 Question 8: Chemical Equilibrium

This question had four parts, namely (a), (b), (c) and (d). In part (a), candidates were required to (i) state Le Chatelier's principle (ii) differentiate homogeneous equilibrium from heterogeneous equilibrium as applied in chemistry. In part (b), candidates were required to predict by giving one reason in each case, the direction of the net reaction when the pressure of the system is doubled at constant temperature. They were given the following equilibrium reactions:

$(i)\ 2Pb(s) + 3O_2\,(g) \rightleftharpoons 2PbO(s) + 2O_2\,(g)$

$(ii)\ PCl_5(\text{g}) \rightleftharpoons PCl_3(\text{g}) + Cl_2\,(g)$

$(\text{iii})\ H_2(g) + CO_2\,(g) \rightleftharpoons H_2O(\text{g}) + CO\,(g)$

In part (c), candidates were asked as follows; "*Hydrogen iodide gas was synthesized from hydrogen gas and iodine vapour at 450 °C in a 2.0 Litre vessel. The value of the equilibrium constant, K_C for the reaction was found to be 50.5. If 1.0 x 10 $^{-2}$ moles of hydrogen gas, 3.0 x 10 $^{-2}$ moles of iodine vapour and 2.0 x 10 $^{-2}$ moles of hydrogen iodide were placed in a vessel at the stated temperature; (i) write a balanced equilibrium reaction equation* *for the synthesis of hydrogen iodide gas. (ii) calculate the reaction quotient (Q) for the reaction. (iii) state whether the reaction will proceed to the right or left of the equation. Give a reason (iv) with a reason, comment on a possible effect regarding the equilibrium position, if the pressure of the reaction system is increased.*" Part (d) of the question asked candidates to calculate the equilibrium constant in terms of partial pressure, *Kp* for the reaction $K_2 + N_2 \rightleftharpoons 2KN \Delta H = -20\, jmol^{-1}$ which had the K_C value of 10 at 25 °C.

Question 8 was among the three optional questions (Questions 8 – 10). In this section, candidates were required to answer only two questions. The statistical data show that this question was attempted by 32,451 (94.0%) out of 34,517 candidates making it the most chosen question in Section B. Statistical data further indicates that this question was the most well performed by the candidates in ACSEE 2021 Chemistry theory paper. That is, 26,434 (81.5%) candidates who attempted it scored a pass mark or above (≥5.5 marks). The distribution of the candidates' scores in this question is as follows: 19,503 (60.1%), 6,931 (21.4%) and 6,017 (18.5%) candidates scored marks ranging from 9.0 – 15, 5.5 – 8.5 and from 0 – 5.5, respectively. Figure 8 summarizes the candidates' performance in this question.

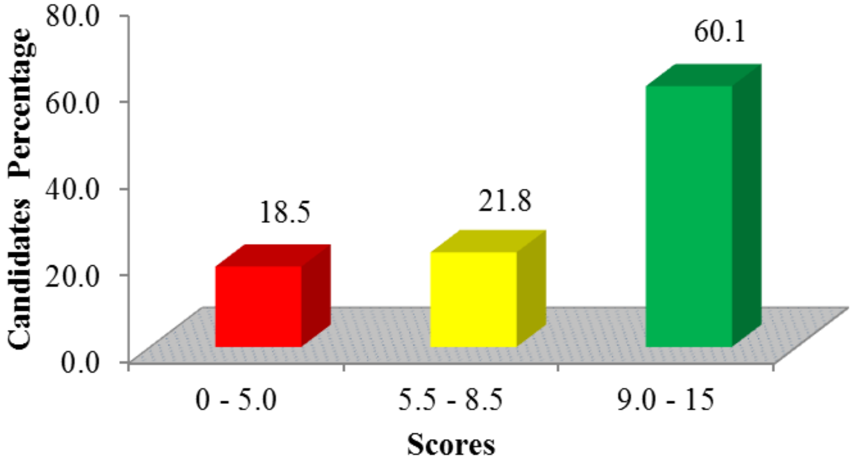


Figure 8: *Performance of the candidates in question 8*

The candidates who passed this question (60.1%) responded to the most parts of the question correctly. The analysis of responses given by the candidates in this question indicates that they had acquired appropriate competencies in the topic of *Chemical Equilibrium*. Thus, these candidates managed to apply Le Chateliers principle appropriately to attempt part (a) (i) and (b) (i – iii). Moreover, they were familiar with the concept of equilibrium constant. As a result, they responded to part (c) and (d) of the question correctly. Extract 8.1 is a sample of correct responses given by one of the candidates in question 8.

8. a) i/ Le chatelier's principle states that "If the reaction is in equillibrium and one of the factor is altered ~~the equil~~ to one side the equillibrium will shift to other side in order to counterate the changes."

ii/ Homogeneous equillibrium - is the type of equillibrium in which all reagents / species are involved in chemical reaction are in the same phase.

while

Heterogeneous equillibrium - is the type of equillibrium where by ~~all~~ reagents / species involved in reaction are in different phase.

b) i/ The equillibrium reaction will be more forward i.e toward product side because there are large number of molecules in reactants side than product side in gaseous species.

ii/ There is no changes i.e equillibrium reaction will as normal because there is same number of moles to both sides in gaseous species.

iii/ There is no changes i.e equillibrium reaction will be as it is because there is the same number of moles to both sides of the equation.

8 c)

i) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

ii)

$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

$\frac{1.0\times10^{-2}}{2.0}$ $\frac{3.0\times10^{-2}}{2.0}$ $\frac{2.0\times10^{-2}}{2.0}$

$5\times10^{-3}M$ $0.015M$ $0.01M$

Required; RQ

$Q = \frac{[2HI]^2}{[H_2]\times[I_2]}$

$Q = \frac{(0.01)^2}{(5\times10^{-3})(0.015)}$

$Q = 1.333$

∴ Reaction quotient, Q is 1.333.

iii) Since $K_c > Q$ the reaction will proceed to Right of the reaction until it will reach a point where $K_c = Q$ (at equilibrium).

iv) If the pressure is increased the equilibrium will ~~Shift to~~ remain as normal i.e there is no changes because there is the same number of moles in both sides of the equation.

8 d) Given:

$K_2 + N_2 \rightleftharpoons 2KN \quad \Delta H = -20Jmol^{-1}$

$kc = 10$ at $25°C = 293k$

$kp = ?$

from

$kp = kc(RT)^{m-n}$

m = no of moles of products

n = no of moles of reactant

$m - n = 2 - 2 = 0$

so

$kp = kc(RT)^0 \quad (RT)^0 = 1$

$kp = kc(1)$

$kp = kc$

$kc = 10$

so $kp = 10$

∴ $kp = 10$.

Extract 8.1: A sample of correct responses in question 8

Extract 8.1 shows responses of a candidate who gave a correct statement on the Le Chateliers principle and differentiated the two types of equilibria given correctly. The candidate manipulated the equations given and calculated the value of reaction quotient and the equilibrium constant correctly.

However, some of the candidates scored low marks in this question (18.5%) because they were unfamiliar with the practical application of Le Chateliers principle despite the fact that it was one of the topics in ordinary level Chemistry. Most of such candidates failed to write the balanced chemical equation for reaction at equilibrium hence got an incorrect K_P/K_C expression. In addition, some of them did not include the stoichiometric coefficient in the expressions for reaction quotient and equilibrium constant. Thus, they got incorrect values of Q and K_P. Extract 8.2 is a sample of poor responses given by one of the candidates in question 8.

8. (a) (i) State that at the low Concentration of mass and molecular of Constant temperature is Uterlized In a low way.

(ii) Homogenecus equilibrum is a balanced mixture of two liquids while heterogenecus is the one which have Single liquid.

8 (b) (i) Yes the Reaction is Double at Constant temperature

ii) The Reaction is well balanced and is at Constant temperature

iii) Yes the Reaction is Double at a Constant temperature.

8 (c) (i) $H_{2(g)} + OH_{(g)} \rightarrow H_2O_{(l)}$

(ii) $\frac{8.0 \times 10^{-2}}{2.0 \times 10^{-2}} = 1.5$

$450/2.0$

$= Q = 226.5$

8 (c)	III) The Reaction will Proceed to the left because the Reaction is at con Stant Temperature.
	IV) the Pressure Of the Reaction will Proceed and Increase the Pressure of the Reaction and the effect will be that the equation will be well balanced and It will be In a Constant temperature and Pressure.
8(d)	$K_2 + N_2 \rightleftharpoons 2KN \quad \Delta H = {}^{-}20J mol^{-1}$
	$= -20/10$
	$= {}^{-}2 \times 25$
	$= {}^{-}50$
	KC is equal to $^{-}50$

Extract 8.2: A sample of incorrect responses in question 8

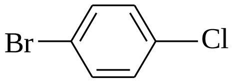
In Extract 8.2, the candidate gave a statement without proper meaning in 8 (a) (i), and attempted to give the differences between homogenous and heterogeneous mixture instead of heterogeneous and homogenous equilibrium. In part (b), the candidate did not understand the requirement of the question, and thus gave irrelevant statements. In part (c) (i), the candidate wrote a wrong equation for calculating the reaction quotient. The candidate just divided the enthalpy accompanying the given chemical reaction by the value of equilibrium constant, instead of using the expression $K_P = K_C[RT]^{n-m}$. Thus, the candidate got a wrong answer in this part of the question.

2.1.9 Question 9: Aromatic Hydrocarbons and Halogen Derivatives of Hydrocarbons

This question consisted of six parts, namely (a), (b), (c), (d), (e), and (f). In Part (a), candidates were required to write the IUPAC names of the following organic compounds:

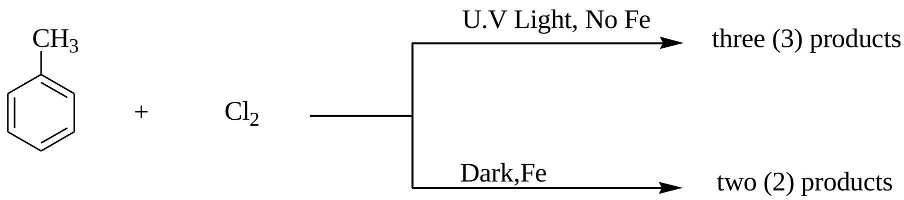
(i) CCl_3CH_3

(ii) $CHCl_2CCl_2CHCl_2$

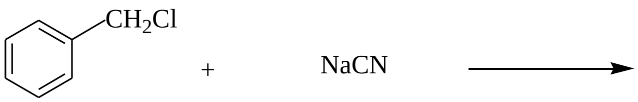
(iii) 

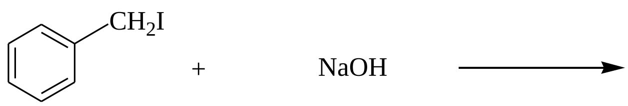
(iv) $CCl_3CH_2CCl_3$

In part (b), candidates were asked as follows: "*With the aid of a chemical equation (no reaction mechanism is needed), give a reason for the position occupied by bromide atom when bromine reacts with: (i) phenol (ii) benzene carbaldehyde.*" In part (c), candidates were required to write the structures and provide names for the five products in the reaction;

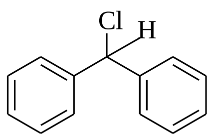


In part (d), the candidates were required to write the product of each of the following nucleophilic substitution reactions:

(i) 

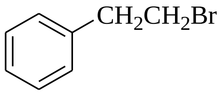
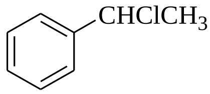
(ii) 

In part (e), candidates were required to distinguish the following chemical compounds:

(i) Bromobenzene from 

(i) Vinyl bromide from *p*-chlorobenzene.

In part (f), candidates were required to show step-wise conversion of 2-phenol into each of the following organic compounds.

(i)  (ii) 

The question was attempted by 9,189 (26.6%) candidates, out of which, 16.2 per cent scored from 9.0 – 15 marks, 35.7 per cent scored from 5.5 – 8.5 marks, while 48.1 per cent scored marks ranging from 0 – 5.0. The summary of the candidates' performance in this question is shown in Figure 9.

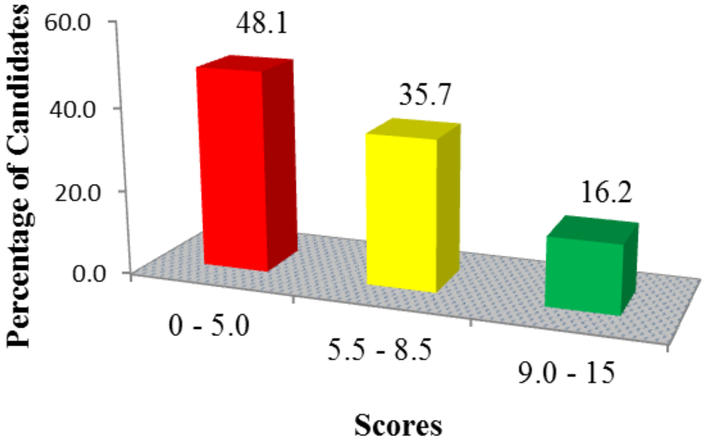
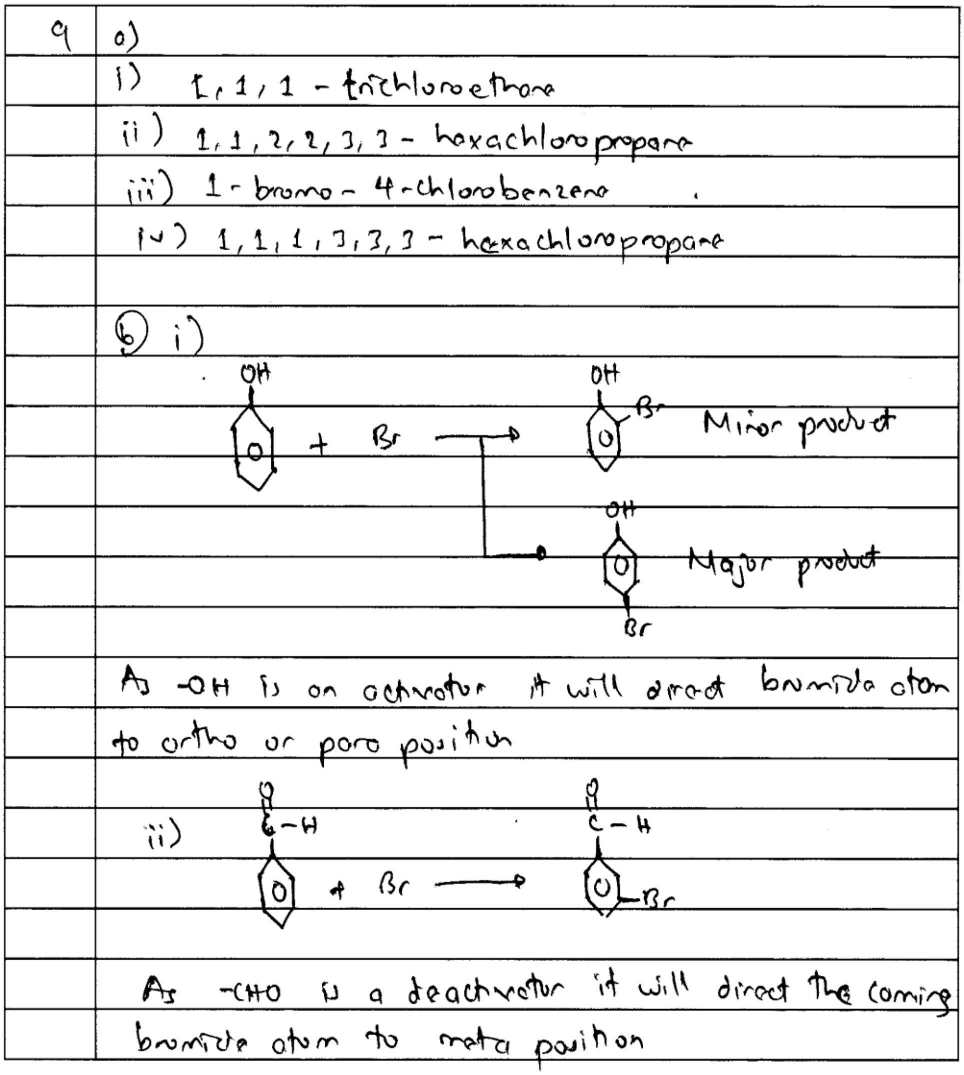


Figure 9: *Performance of the candidates in question 9*

Figure 9 indicates that the overall performance in this question was average, as the majority of the candidates (51.9%) scored average marks or above (≥5.5). The analysis of the candidates' responses shows that a few candidates who scored high marks (9.0 - 15) understood concepts in both topics of *Aromatic Hydrocarbons* and *Halogen Derivatives of Hydrocarbons* well. Hence, they managed to answer all parts of the question correctly. The analysis also shows that 35.7 per cent of the candidates were partially competent in *Aromatic Hydrocarbons* and *Halogen Derivatives of Hydrocarbons*. Hence, they provided partial answers in most parts of the question and scored average marks. For example, despite that one of the candidates scored in part (a) (i-iii), he/she failed in part (a) (iii), as she/he named the given compound as "*1-trichloro-3-trichloropropane*" instead of 1,1,1,3,3,3-hexachloropropane which was the answer. This indicates that the candidate possessed partial knowledge of naming organic compounds; given that she/he succeeded in some rules but failed in naming the substituents groups correctly.

In another case, one of the candidates with average score in the question responded to part (b) (ii) as follows: "*carbaldehyde is deactivator so it direct the electron toward para and ortho position*", which was incorrect. The candidate was expected to understand that deactivators such as carbaldehyde direct the incoming group to *meta* position. Such incorrect responses indicated that the candidates were not competent enough in *Resonance Theory*. However, some of the candidates performed well in the question. Extract 9.1 shows an example of correct responses given by one of the candidates in the question.



9 a)

i) 1, 1, 1 - trichloroethane

ii) 1, 1, 2, 2, 3, 3 - hexachloropropane

iii) 1 - bromo - 4 - chlorobenzene

iv) 1, 1, 1, 3, 3, 3 - hexachloropropane

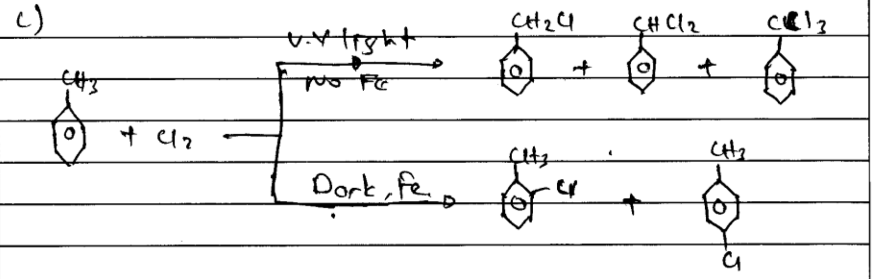
b) i)

As -OH is an activator it will direct bromide atom to ortho or para position

ii)

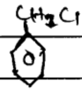
As -CHO is a deactivator it will direct the coming bromide atom to meta position

9 c)

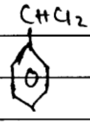


Name of products

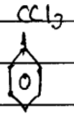
• Under U.V light, No Fe



Benzylchloride / 1-chloro-1-phenyl methane

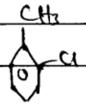


1,1-dichloro-1-phenylmethane

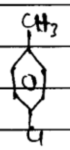


1,1,1-trichloro-1-phenylmethane

• Under Dark, Fe



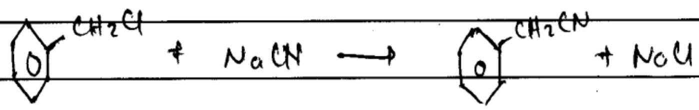
2-chloro-1-methylbenzene



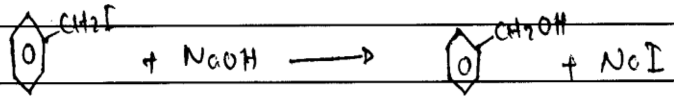
4-chloro-1-methylbenzene.

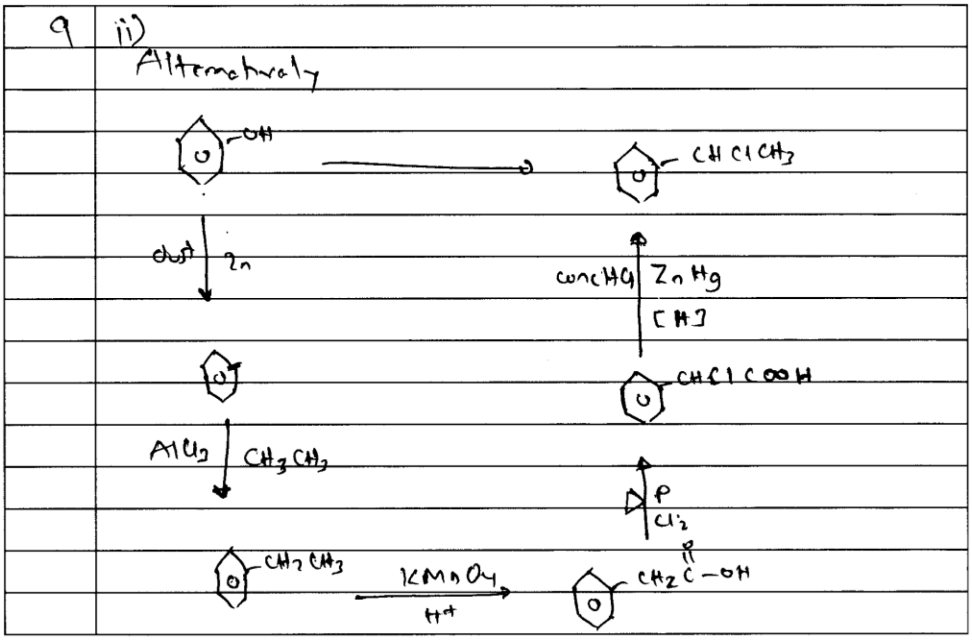
9 d)

i)



ii)



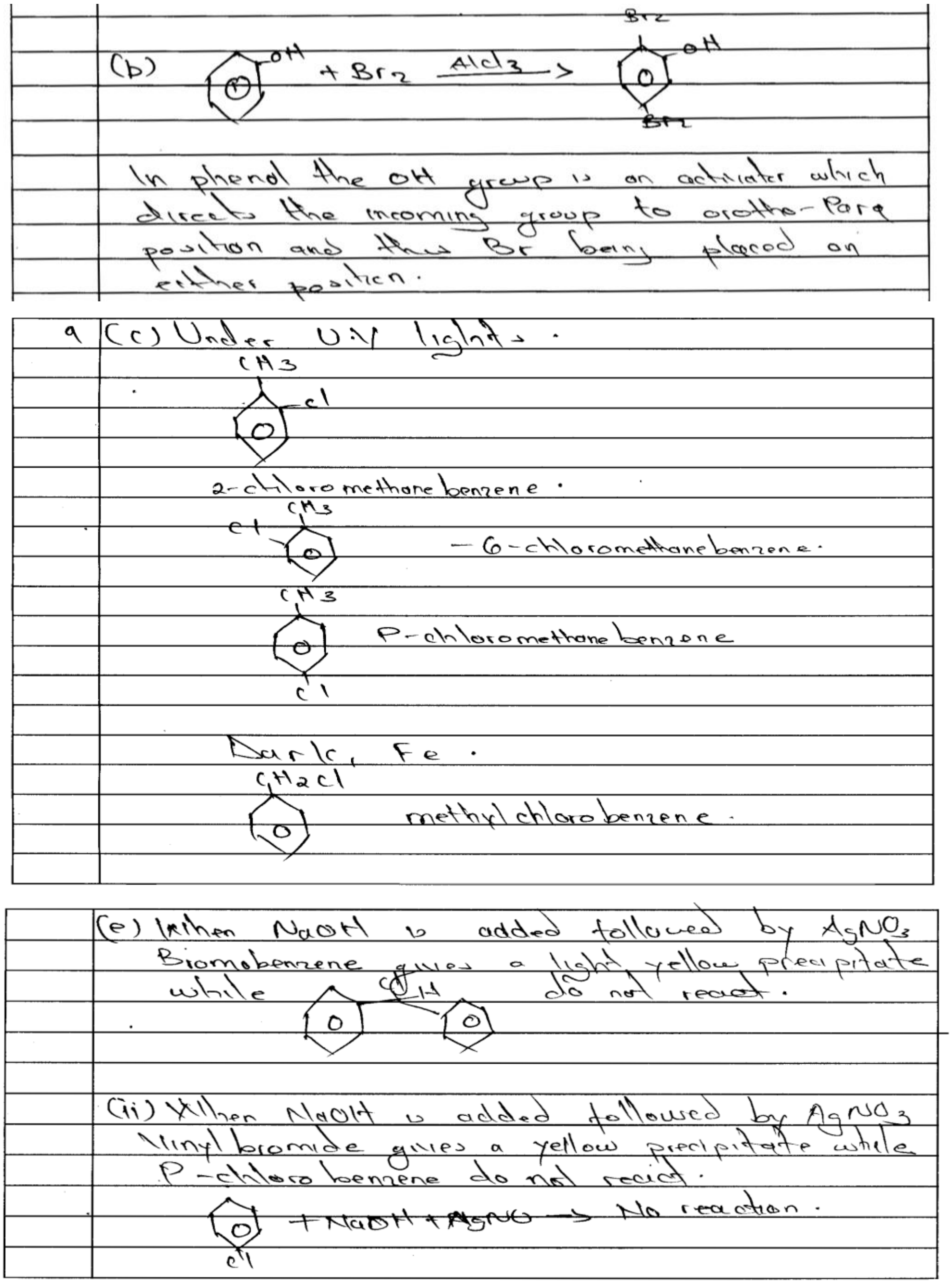


Extract 9.1: A sample of appropriate responses in question 9

Extract 9.1 shows the responses of a candidate who was able to name organic compounds according to IUPAC system. The candidate also gave correct products in subsequent parts of the question.

Nonetheless, 48.1 per cent of the candidates scored weakly in this question. Analysis of the responses given by these candidates indicates that they had insufficient knowledge of the properties and reactions of aromatic hydrocarbons and halogen derivatives of hydrocarbons. The candidates showed to have experienced difficulties in naming organic compounds according to IUPAC system. Extract 9.2 shows a sample of poor responses from one of the candidates in question 9.

9	(a) (i) trichloroethane.
	(ii) 1,1-dichloro-2,2-dichloro-3,3dichloro pentane.
	(iii) 1-chloro-3-bromobenzene.
	(iv) 1,1,1-trichloro-3,3,3 trichloro pentane.


(b) + Br2 —AlCl3→

In phenol the OH group is an activator which directs the incoming group to ortho-Para position and thus Br being placed on either position.

9 (c) Under U.V light.

2-chloromethanebenzene.

— 6-chloromethanebenzene.

P-chloromethanebenzene

Dark, Fe.

methylchlorobenzene.

(e) When NaOH is added followed by AgNO3 Bromobenzene gives a light yellow precipitate while do not react.

(ii) When NaOH is added followed by AgNO3 Vinyl bromide gives a yellow precipitate while P-chlorobenzene do not react.

+ NaOH + AgNO3 → No reaction.

Extract 9.2: A sample of incorrect responses in question 9

In extract 9.2, the candidate named the given organic compounds without observing the IUPAC rules, particularly, when naming substituent groups in part (a) of the question. In part (b), the candidate wrongly introduced the bromide group into *meta* position. Moreover, he/she gave incorrect answers to the subsequent parts of the question.

2.1.10 Question 10: Gases

This question consisted of five parts, namely (a), (b), (c), (d) and (e). In Part (a), candidates were required to show how Boyle's and Charle's laws are special cases of the ideal gas law. In part (b), candidates were asked as follows: "*(b) (i) Theoretically, ideal gases cooled to a temperature of -273.15 °C will occupy zero (0) volume. With reason(s) comment on whether gases practically occupy zero volume at such temperature.* "*(b) (ii) Molecule A is twice as heavy as molecule B. Which of these has higher kinetic energy at any temperature? Give a reason."* Part (c) required candidates to explain the following phenomena: *(i) Liquid ammonia bottle is cooled before opening the seal (ii) The tyre of an automobile is inflated to a slightly lower pressure in summer than in winter.* In part (d), candidates were given the following information: *"A 1.0 litre sample of dry air at $25^{\circ}C$ and 786 mmHg contains 0.925 g of nitrogen gas (N_2) and other gases."* Candidates were required to assume the dry air was ideal and calculate (d) (i) mole fraction of N_2 in the gas sample while (d) (ii) required them to calculate the partial pressure of N_2 in the gas sample in mmHg. In part (e), the candidates were asked as follows: "*The volume of 200 cm^3 of oxygen gas required 250 seconds to diffuse through a porous membrane. Under the identical conditions, 200 cm^3 of gas 'Z' is diffused in 177 seconds. Calculate the relative molecular mass of gas 'Z'.*"

The question was attempted by 26,492 candidates, equivalent to 76.8 per cent. Statistical data show that 22.7 per cent of the candidates scored from 9.0 – 15 marks, 40.1 per cent scored from 5.5 – 8.5 marks, while 37.2 per cent scored from 0 – 5.0 marks. The summary of the candidates' performance in this question is shown in Figure 10.

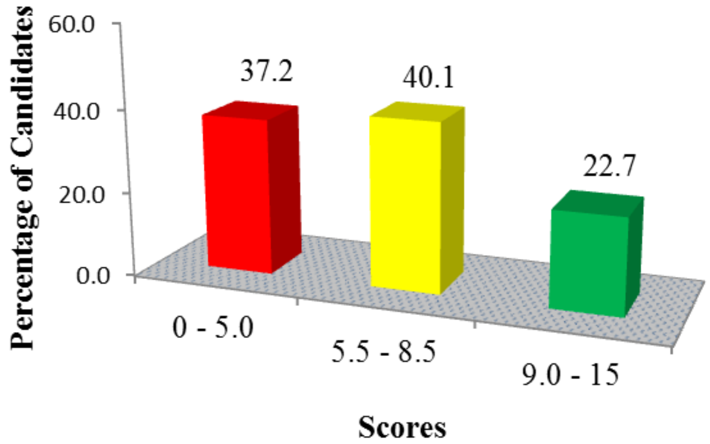


Figure 10: *Performance of the candidates in question 10*

The general performance in this question was good, as 62.8 per cent of the candidates scored marks from 5.5 – 15. The candidates who performed well in this question were able to show how Boyle's and Charles's laws are special cases of ideal gas equation. They were able to give precise explanation of the effect of temperature on kinetic energy. Moreover, these candidates properly explained the application of Boyle's and Charles law in daily life. In addition, this group of candidates showed to have appropriate mathematical skills, given that they calculated the mole fraction, partial pressure and relative molecular mass of the gas correctly. Extract 10.1 shows an example of good responses from one of the candidates in question 10.

10(a) Required to show that: Boyle's law and charles' Law are special cases of ideal gas law.

Mathematical expression of Boyle's law.

$$V \propto \frac{1}{P} \text{ ——— (i)}$$

Mathematical expression of charles' Law

$$V \propto T \text{ ——— (ii)}$$

On combining expression (i) and (ii)

$$V \propto \frac{T}{P}$$

$$PV \propto T$$

$$PV = KT$$

K is determined experimentally and it is Universal gas constant, R.

$$PV = RT$$

For n moles of a gas.

$$PV = nRT$$

Hence boyle's and charles' law are special cases of ideal gas law.

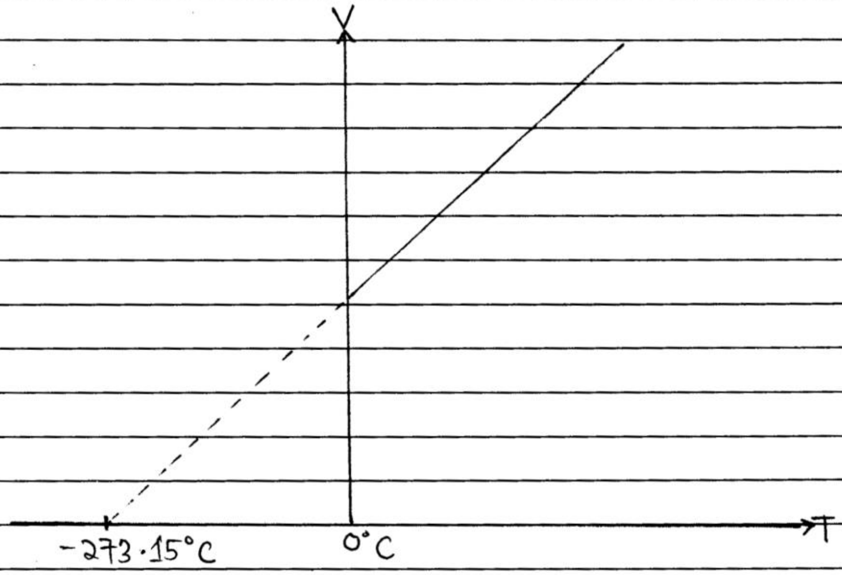
10(b) (i) Theoritically when ideal gas is cooled to a temperature of −273.15°C will occupy zero volume because

- Ideal gas obey charles law, charles law state that volume is directly proportional to absolute temperature. So when it is cooled below zero, means that volume decreases to zero

- And also at −273.15°C, pressure is low thus intermolecular forces of attraction are also low, and hence the particle / molecules of gas are far a-part hence zero volume.

Consider the graph below

GRAPH OF VOLUME AGAINST TEMPERATURE OF IDEAL GAS.



10(b) (ii) K.E ∝ T

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

Hence both molecules have the same energy at any temperature because kinetic energy depends on T and not mass.

10(c) (i) Liquid Ammonia bottle is cooled before opening the seal, because at room temperature the vapour pressure of ammonia is high, so when the bottle is opened, it is likely that explosion will occur. So it is cooled in order to decrease vapour pressure.

(ii) The tyre of an automobile is inflated to a lower pressure in summer than winter because, when large pressure is applied, the temperature of gas molecules increases and so collision and the tyre might burst.

10(d)

$$PV = nRT$$

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

$$P = \frac{786}{760} \text{ atm}$$

V = 1.0 litre

T = 298 K , T = t + 273 = 25 + 273

T = 298 K

1c(d)

$$n_T = \frac{\left(\frac{786}{760}\right) \times 1}{0.0821 \times 298}$$

$n_T = 0.0423 mol.$

$$n_{Nitrogen} = \frac{mass}{molar\ mass}$$

$$= \frac{0.925}{28}$$

$n_{N_2} = 0.033 mol$

(i) mole fraction

$$X_{N_2} = \frac{n_{N_2}}{n_T}$$

$$= \frac{0.033}{0.0423}$$

$$= 0.78$$

(ii) $P_T V = n_T R T$

$P_{N_2} V = n_{N_2} R T$

$$\frac{P_T}{P_{N_2}} = \frac{n_T}{n_{N_2}}.$$

$$P_{N_2} = \frac{n_{N_2}}{n_T} \times P_T$$

$P_{N_2} = 0.78 \times 786$

$P_{N_2} = 613.08 mmHg$

10 (d) from Grahams law of diffusion

$$\text{rate} = \frac{1}{\sqrt{\text{density}}}$$

density, $\rho \propto Mr$

$$\text{Rate} = \frac{1}{\sqrt{Mr}}$$

$$\text{Rate of } O_2 = \frac{\text{volume of } O_2}{\text{Time taken}}$$

$$R_{O_2} = \frac{200}{250}$$

$$\text{Rate of gas } Z = \frac{\text{volume of } Z}{\text{Time taken}}$$

$$= \frac{200}{177}$$

$$\frac{R_{O_2}}{R_Z} = \sqrt{\frac{M_Z}{M_{O_2}}}$$

$$\frac{200}{250} \div \frac{200}{177} = \sqrt{\frac{Mr_Z}{32 g/mol}}$$

$$Mr_Z = 16.04 g/mol$$

∴ The Relative molecular mass of gas Z is 16.04.

Extract 10.1: A sample of good responses in question 10

In Extract 10.1, the candidate managed to combine Boyle's and Charle's law correctly to give ideal gas equation. The candidate calculated the mole fraction, partial pressure and relative molecular mass of the gas Z correctly.

However, 37.2 per cent of the candidates got low scores in this question. These candidates failed to derive the ideal gas equation from Boyle's and Charles's law. Moreover, they failed to explain the effect of temperature on kinetic energy as well as the application of Boyle's and Charles law in daily life. Extract 10.2 is a sample of incorrect responses given by one of the candidates in question 10.

10 Boyle's law

$P_1V_1 = P_2V_2$

But Ideal gas = PV = nRT

Charles law = $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\frac{P_1V}{T_1} = \frac{P_2V_2}{T_2}$

10. b) Yeap because it is the Standard Value of temperature

ii) Soln

Molecule A×2

2A

Molecule B

∵ Molecule A has higher kinetic energy because it has a great Value Compared to molecule B

c) i) Liquid ammonia bottle is Cooled before opening the seal because ammonia is a Very sensitive chemical that can burn your skin hence thus why it is Coold first.

ii) So as to Increase surface area of the tyre to be able to pass in winter days

d) Soln

Data Given

Volume = 1.0L

Temperature = ~~786mmHg~~ 25°C

Pressure = 786 mmHg

Mass = 0.925g

mole fraction = ?.

From $\frac{PV}{RT} = \frac{nRT}{RT}$

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

$n = \frac{786 \times 1}{0.0821 \times 298}$

$n = 32.126$

mole fraction $= \frac{n_A}{n_B}$

$n = \frac{0.925}{14}$

$= 0.067$

$X = \frac{0.067}{32.125 + 0.067}$

$X = 2 \times 10^{-3}$

ii/ Partial pressure $= P^{\circ}X_A$

$= 786 \times 2 \times 10^{-3}$

$= 1.6359$

e/ soln

Data Given

$V_1 = 200cm^3$

$V_2 = 200cm^3$

$t_1 = 250sec$

$t_2 = 177sec$

$\frac{t_1}{t_2} = \frac{V_1}{V_2}$

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

$Rate = \frac{200}{250}$

$= 0.8$

Extract 10.2: A sample of incorrect responses in question 10

In Extract 10.2, the candidate derived the general gas equation instead of the ideal gas equation. The candidate gave wrong explanation and failed to deduce with a reason a molecule that was heavier than the other. Lastly, the candidate used a wrong approach in performing the required calculations in part (d) and (e) and got incorrect answers.

2.2 132/2-CHEMISTRY 2

This paper was a theory paper and consisted of a total of six (6) questions. All questions in this paper were short answers and each question carried 20 marks. Candidates were required to answer 5 questions. The pass mark in each question was 7.0 marks.

2.2.1 Question 1: Electrochemistry

This question had four parts, namely (a), (b), (c) and (d). Part (a) (i) required candidates to distinguish between an electrolytic cell and a galvanic cell. Part (a) (ii) asked as follows: "*Lead rods are placed in each of the following solutions: $AgNO_3$, $CuSO_4$, $FeSO_4$ and $ZnSO_4$. In which solution would you expect a coating of one metal on lead rod?Give a reason.*" Candidates were given: $\mathcal{E}°$ Zn^{2+}/Zn = - 0.76 V, .$\mathcal{E}°$ Pb^{2+}/Pb = - 0.13 V, $\mathcal{E}°$ Cu^{2+}/Cu = + 0.34 V, $\mathcal{E}°$ Ag^{+}/Ag = + 0.81 V and $\mathcal{E}°$ Fe^{2+}/Fe = - 0.44 V. In part (b), candidates were required to give a brief explanation on why the Kohlrausch's law of independent migration of ions applies at infinite dilution of electrolyte. In part (c), candidates were required to show that the cell potential for the cell reaction $Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$ with different cell concentration at temperature of 298K could be given by $\varepsilon° = \varepsilon°\text{cell} - 0.0295\log\frac{[Zn^{2+}(aq)]}{[Cu^{2+}(aq)]}$ In part (d), candidates were given a galvanic cell which consisted of metallic plates of zinc and lead immersed in 0.1 M $Zn(NO_3)_2$ and 0.02 M $Pb(NO_3)_2$ solution, they were then required to (i) write the chemical equations for the electrode reactions (ii) write the cell notation for the reaction and (iii) calculate the e.m.f of the cell.

This question was attempted by 32,082 (93.0%) candidates out of which 3,988 (12.4%) scored from 12.0 – 20, 11,057 (34.5%) scored from 7.0 – 11.5 and 17,043 (53.1%) scored from 0 – 6.5 marks, respectively. The summary of the performance of the candidates in this question is shown in Figure 11.

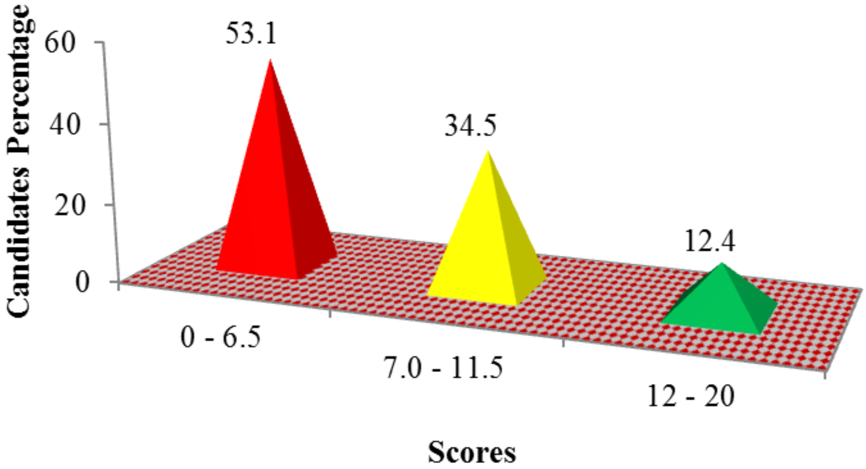


Figure 11: *Performance of the candidates in question 1*

The general performance in this question was average, as 15,039 (46.9%) candidates scored the pass mark or above. The candidates who scored high marks showed proper understanding of the concept of oxidation–reduction. As a result, they managed to differentiate electrolytic cell from galvanic cell and derived the expression for cell potential from the cell reaction equation. Moreover, they correctly applied the Nernst equation in calculating the e.m.f of the given cell. The candidates who scored average marks responded correctly to some parts of the question and missed some. For example, one of the candidates attempted part (d) (iii) as follows:

$$\text{“}\varepsilon^{\circ} = \varepsilon^{\circ}_{cell} - 0.0295\log\frac{[Zn^{2+}(aq)]}{[Pb^{2+}(aq)]}$$

$$\varepsilon^{\circ}_{cell} = \varepsilon^{\circ}_{reduction} - \varepsilon^{\circ}_{oxidation}$$

$$But\,\varepsilon^{\circ} = 0$$

$$But\,\varepsilon^{\circ} = 0$$

$$\varepsilon^{\circ} = 0 - 0.0295 lo\,g\frac{0.1}{0.02}$$

$$\varepsilon^{\circ}_{cell} = 0.02V\text{”}$$

Although this candidate wrote the correct formulae and scored some of the marks, he/she plugged in the wrong ($\varepsilon^{\circ} = 0$) value for the standard electrode potential of the cell and, thus, got incorrect answer. The candidate was supposed to proceed as follows:

$$\varepsilon^{\circ} = \varepsilon^{\circ}_{cell} - 0.0295\log\frac{[Zn^{2+}(aq)]}{[Pb^{2+}(aq)]}$$

$$\varepsilon^{\circ}_{cell} = \varepsilon^{\circ}_{reduction} - \varepsilon^{\circ}_{oxidation}$$

$$\varepsilon^{\circ}_{cell} = \text{-}0.13V + 0.76V = 0.63\,V$$

substituting

$$\varepsilon^{\circ} = 0.63\text{-}\,0.0295\log\frac{0.1}{0.02} = 0.609\ V\ .$$

Extract 11.1 shows a sample of correct responses given by one of the candidates in question 1.

1a) i) Electrolytic cell is a cell which uses electricity for accurance of spontaneous chemical reaction while galvanic cell is a cell which uses chemical reactions to produce electricity

1b) This is because at infinite dilution, there is higher molar conductivity of the electrolyte due to ions of the metal electrode being comparably higher than those of the solution in which the metal electrode is contained, thus easily migration of ions due to its high molar conductivity.

1c) Soln.

Consider the cell Reaction

$Zn_{(s)} + Cu^{2+}{}_{(aq)} \longrightarrow Zn^{2+}{}_{(aq)} + Cu_{(s)}$

From Gibb's Free energy

$\Delta G = -\frac{nF}{n}$

$\Delta G = -\frac{RT}{nF} \log RQ$ ——— (i)

Where;

ΔG is Gibb's free energy

T is Temperature at 25°C ≈ 298K

n is Number of moles transferred in chemical reaction

F is Faradays Constant

RQ is Reaction Quotient.

But:

$\Delta G = E_{cell} - E^{\circ}_{cell}$ ——— (ii)

Substitute eqn (ii) into (i)

So;

$E_{cell} - E^{\circ}_{cell} = -\frac{RT}{nF} \log RQ$ ——— (iii)

But;

$RQ = \frac{[Oxidation]}{[Reduction]}$

So,

$RQ = \frac{[Zn^{2+}{}_{(aq)}]}{[Cu^{2+}{}_{(aq)}]}$ ——— (iv)

1(c) Substitute (iv) into (iii)

So,

$$E_{cell} - E^\circ_{cell} = \frac{-RT}{nF} \log \frac{[Zn^{2+}_{(aq)}]}{[Cu^{2+}_{(aq)}]}$$

So,

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \log \frac{[Zn^{2+}_{(aq)}]}{[Cu^{2+}_{(aq)}]}$$

But, $R = 8.31 J/mol K$

$F = 96500 C/mol$.

$T = 298 K$

So,

$$E_{cell} = E^\circ_{cell} - \frac{8.31 \times 298}{n \times 96500} \log \frac{[Zn^{2+}_{(aq)}]}{[Cu^{2+}_{(aq)}]}$$

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n} \log \frac{[Zn^{2+}_{(aq)}]}{[Cu^{2+}_{(aq)}]} \quad \text{— (v)}$$

But, From cell Reaction,

Oxidation Half Reaction

$$Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2\bar{e}$$

Also

Reduction Half Reaction

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

Overall equation

$$+\begin{cases} Zn_{(s)} \longrightarrow Zn^{2+} + 2\bar{e} \\ Cu^{2+} + 2\bar{e} \longrightarrow Cu_{(s)} \end{cases}$$

$$Zn_{(s)} + Cu^{2+} \longrightarrow Zn^{2+} + Cu_{(s)}$$

1c	So,
	n = 2
	So, From eqn (v) substitute the value of n
	So,
	$E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{2} \log \frac{[Zn^{2+}_{(aq)}]}{[Cu^{2+}_{(aq)}]}$
	$E_{cell} = E^{\circ}_{cell} - 0.0295 \log \frac{[Zn^{2+}_{(aq)}]}{[Cu^{2+}_{(aq)}]}$
	$\therefore E_{cell} = E^{\circ}_{cell} - 0.0295 \log \frac{[Zn^{2+}_{(aq)}]}{[Cu^{2+}_{(aq)}]}$ ← Hence shown
d)	i) Soln.
	Given,
	$[Zn^{2+}] = 0.1\,M$ Also $E^{\circ}\,Zn^{2+}/Zn = -0.76V$
	$[Pb^{2+}] = 0.02M$ $E^{\circ}\,Pb^{2+}/Pb = -0.13V$
	For chemical equations:
	Cathodic (Reduction) half cell Reaction.
	$Pb^{2+}_{(aq)} + 2e^- \longrightarrow Pb_{(s)}$
	Also,
	Oxidation (Anode) half cell Reaction
	$Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2e^-$

1 d i) The Overall Cell equation

$$\begin{cases} Pb^{2+} + 2\bar{e} \longrightarrow Pb_{(s)} \\ Zn_{(s)} \longrightarrow Zn^{2+} + 2\bar{e} \end{cases}$$

$$Pb^{2+} + Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + Pb_{(s)}$$

ii) The Cell notation for the reaction is

$\Rightarrow$ $Zn_{(s)} / Zn^{2+}_{(aq)} (0.1M) // Pb^{2+}_{(aq)} (0.02M) / Pb_{(s)}$

iii) Soln

Required: Emf of the Cell.

From Given data,

$[Zn^{2+}] = 0.1M$

$[Pb^{2+}] = 0.02M$

$E^{\circ} Zn^{2+}/Zn = -0.76\ V$

$E^{\circ} Pb^{2+}/Pb = -0.13V$

$E\ cell$ = Required

From Formula;

$$E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{n} \log \frac{[Oxidation]}{[Reduction]}$$

But,

$E^{\circ}cell = E^{\circ}cathode - E^{\circ}anode.$

$= (-0.13 - -0.76)V$

$= 0.63V$

$E^{\circ}cell = 0.63V$

1(d)(ii) Also,

From Chemical Reaction in d(i)

$Pb^{2+} + 2e^- \longrightarrow Pb_{(s)}$

$Zn_{(s)} \longrightarrow Zn^{2+} + 2e^-$

$Pb^{2+} + Zn_{(s)} \longrightarrow Pb_{(s)} + Zn^{2+}$

Thus,

$n = 2$

Also, [Oxidation] = $[Zn^{2+}]$ = 0.1 M

[Reduction] = $[Pb^{2+}]$ = 0.02 M

So, Recall from formula..

Ecell = ~~0.9~~

$$E_{cell} = 0.63 - \frac{0.0591}{2} \log\left(\frac{(0.1)}{(0.02)}\right)$$

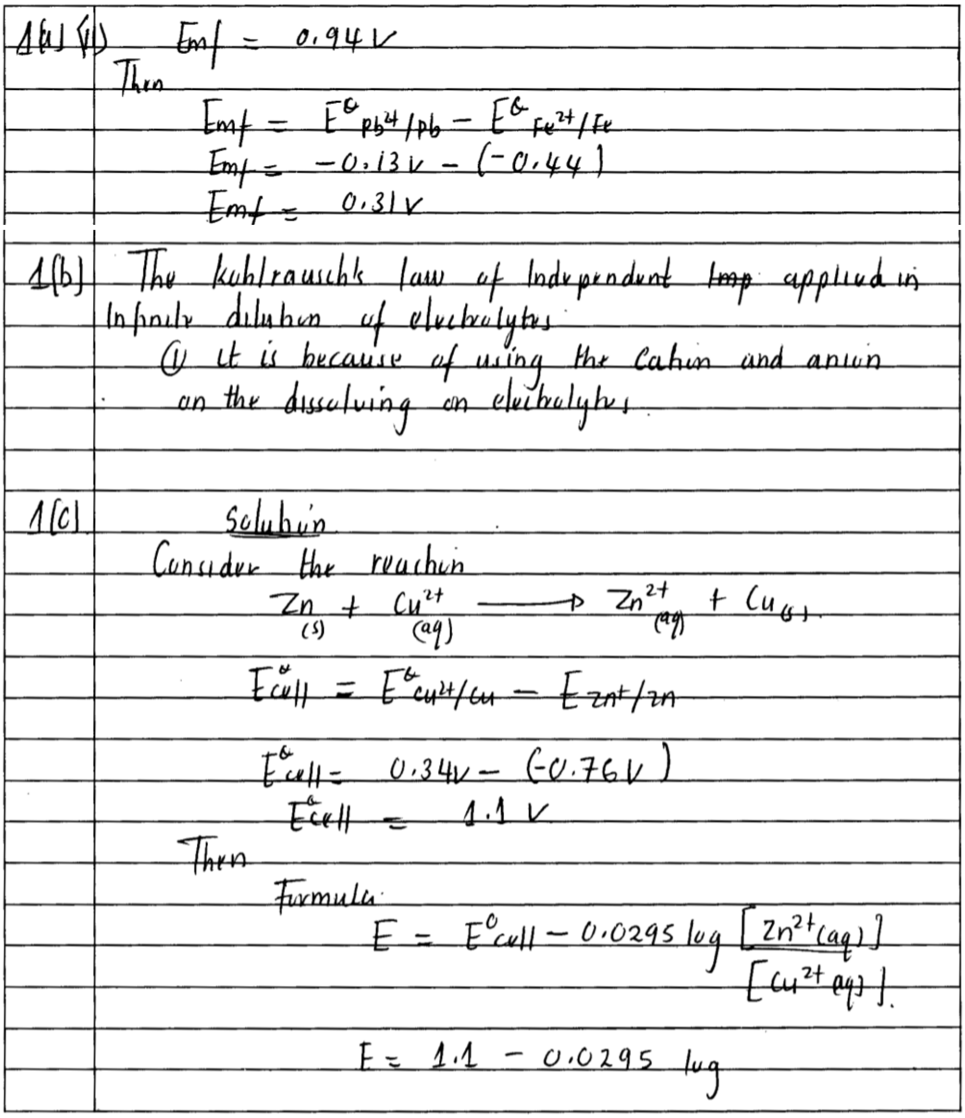
Ecell = 0.609V ~~0.61~~

∴ Emf of the cell = 0.609V

Extract 11.1 A sample of correct responses in question 1

In Extract 11.1, the candidate correctly distinguished between galvanic cell and electrolytic cell. The candidate gave half-reaction equations and derived the expression for the cell potential correctly. He/she also used an appropriate formula to calculate the e.m.f of the cell.

On the contrary, some of the candidates got unsatisfactory performance in the question. They gave wrong responses in all parts of the question. This was attributed to the misunderstanding of the requirement of the question. The candidates did not also master the concept of oxidation-reduction. Hence, they wrote half-reaction equations incorrectly. Moreover, they failed to derive the expression for the cell potential. Extract 11.2 shows a sample of incorrect responses given by one of the candidates' in question 1.



1(a)(i) Emf = 0.94V
Then
Emf = $E^{\theta}_{Pb^{4}/Pb} - E^{\theta}_{Fe^{2+}/Fe}$
Emf = −0.13V − (−0.44)
Emf = 0.31V

1(b) The kohlrauschh law of Independent ~~Ion~~ applied in Infinity dilution of electrolytes
(i) it is because of using the Cation and anion on the dissolving on electrolytes.

1(c) Solution
Consider the reaction
$Zn_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$.
$E^{\theta}_{cell} = E^{\theta}_{Cu^{2+}/Cu} - E_{Zn^{+}/Zn}$
$E^{\theta}_{cell} = 0.34V - (-0.76V)$
$E^{\theta}_{cell} = 1.1V$
Then
Formula:
$E = E^{0}_{cell} - 0.0295 \log \frac{[Zn^{2+}(aq)]}{[Cu^{2+}aq]}$.
E = 1.1 − 0.0295 log

Extract 11.2: A sample of incorrect responses in question 1

In Extract 11.2, the candidate calculated the e.m.f of a cell in part (a); contrary to the requirement of the question. The candidate gave a wrong reason regarding the application of the Kohlrauschs' law. In part (c), the candidate failed to derive the required expression.

2.2.2 Question 2: Two Component Liquid Systems

This question had four parts, namely (a), (b), (c) and (d). Part (a) required candidates to write the mathematical expression for distribution law. Part (b) asked candidates as follows: *"Compound **P** has a partition coefficient of 4.00 between ethoxyethane and water. Given that 2.0 g of **P** is obtained in* *solution, in 50cm^3 of water, calculate the mass of **P** that can extracted from the aqueous solution by (i) 50cm^3 of ethoxyethane (ii) two successive extractions of 25 cm^3 of ethoxyethane each.*" Part (c) required candidates to comment on the variation of the amount extracted in (b) (i) and (ii). Part (d) of the question asked as follows: "*When 500 cm^3 of an aqueous solution containing 4 g of solute **G** per litre was shaken with 100 cm^3 of pentan-1-ol, 1.5 g of the solute **G** was extracted. Assuming a molecular state of the solute remains the same in both solvents, calculate* (i) *The partition coefficient of the solute **G** between pentan-1-ol and water (ii) Mass of the solute **G** which will remain in the aqueous solution after a further shaking with 100 cm^3 of pentan-1-ol.*"

This question was attempted by 33,310 (96.5%) candidates out of which, 29.0 per cent scored from 12 – 20 marks, 40.0 per cent scored from 7.0 – 11.5 marks and 31.0 per cent scored from 0 – 6.5 marks. The candidates' performance is summarized in Figure 12.

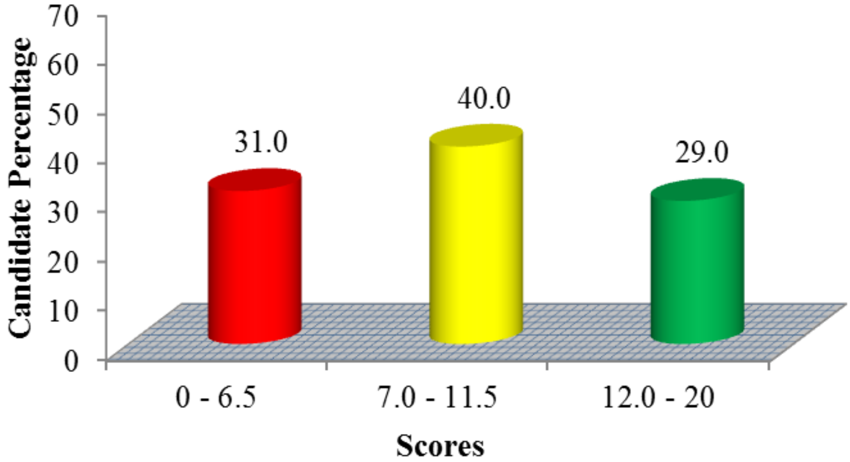


Figure 12: *Performance of the candidates in question 2*

The data in Figure 12 show that the majority of the candidates (69.0%) passed the question, as they managed to score marks from 7.0 – 20. The candidates with good scores were able to write the correct formula for the partition coefficient. The candidates transposed the formula for calculating partition coefficient according to the requirement of the question. Moreover, they were knowledgeable of the concept of solvent extraction and scored in all parts of the question. Extract 12.1 shows responses from one of the candidates who performed well in this question.

2. (a). Mathematical expression is:-

$$Kd = \frac{\text{Concentration of solute in the upper layer}}{\text{Concentration of solute in the lower layer.}}$$

where:

Kd = Partition Coefficient

(b)(i) Solution:

Given:

Kd = 4.

$$Kd = \frac{[P \text{ in ethoxy ethane}]}{[P \text{ in water}]}.$$

X = 2.0g.

V_w = 50cm³.

X_1 = ?

V_E = 50cm³.

F = ?

From

$$Kd = \frac{[P \text{ in ethoxy ethane}]}{[P \text{ in water}]}.$$

$$Kd = \frac{\text{mass concentration of P in ethoxy ethane}}{\text{mass concentration of P in water.}}$$

$$Kd = \frac{F/V_E}{X-F/V_W}.$$

2. (b)(i).

$$Kd = \frac{F/V_E}{X-F/V_w}$$

$$4 = \frac{F/50cm^3}{2g-F/50cm^3}$$

$$4 = \frac{F}{2g-F}$$

$$8g - 4F = F$$

$$5F = 8g$$

$$F = 1.6g$$

The mass of P extracted from aqueous solution by 50cm³ of ethoxyethane is 1.6 g.

(ii). solution:
From the first extraction.

$$Kd = \frac{F/V_E}{2g-F/V_w}$$

$$4 = \frac{F/25cm^3}{2g-F/50cm^3}$$

$$4 = \frac{F}{2g-F} \times \frac{50cm^3}{25cm^3}$$

2. (b) (ii). 4

$$4 = \frac{2F}{2g - F}$$

$$8g - 4F = 2F$$

$$6F = 8g$$

$$F = 1.33\,g$$

∴ For the first extraction mass of P extracted is 1.33 g.

For the second extraction

$$K_D = \frac{F_1/V_E}{M - F_1/V_W}$$

But $m = 2g - 1.33g = 0.67g$.

$$4 = \frac{F_1/25cm^3}{0.67g - F_1/50cm^3}$$

$$4 = \frac{F_1}{0.67g - F_1} \times \frac{50cm^3}{25cm^3}$$

$$4 = \frac{2F_1}{0.67g - F_1}$$

$$2.68g - 4F_1 = 2F_1$$

$$6F_1 = 2.68g.$$

2. (b) (ii) $F_1 = 0.45\,g$.

∴ Mass of P extracted for the second extraction is 0.45g.

Total mass extracted $(F_T) = F + F_1$

$F_T = 1.33g + 0.45g$.

$F_T = 1.78g$.

∴ For two successive extractions of $25cm^3$ of ethoxyethane each, the amount of P extracted is 1.78g

(c). - The amount extracted in (b) (ii) is higher (1.78g) than that extracted in (b) (i) which is (1.6g).

This shows that one dividing the extractive solvent into small volume and using for many successive extractions will yield much amount of salt extracted compared to with using the whole volume for only one extractions. Hence two successive extraction is much efficient than single extraction.

(d) (i). Solution.

From.

since there is 4g of G in 1 litre.

x of G would present in $500cm^3$

Q. (d)(i).

$$x = \frac{4g \text{ of } G \times 500cm^3}{1 \text{ litre}}$$

But 1 litre = 1000 cm³.

$$\therefore x = \frac{4g \text{ of } G \times 500cm^3}{1000 cm^3}$$

$$x = 2g \text{ of } G.$$

∴ Mass of solute G present in 500cm³ of aqueous solution is 2g.

From.

$$Kd = \frac{\text{Mass concentration of G in Pentan-1-ol}}{\text{Mass concentration of G in water}}$$

$$Kd = \frac{1.5g/100cm^3}{\frac{2g - 1.5g}{500cm^3}}$$

$$Kd = \frac{1.5g}{2g - 1.5g} \times \frac{500 cm^3}{100 cm^3}$$

$$Kd = 15$$

∴ Partition Coefficient of solute G between Pentan-1-01 and water is 15.

2. (d) (ii) Solution.

From.

$$Kd = \frac{\text{Concentration of G in pentan-1-ol}}{\text{Concentration of G in water}}$$

$$15 = \frac{F/100\,cm^3}{m-F/500\,cm^3}$$

But $m = 2g - 1.5g = 0.5$

$$15 = \frac{F}{0.5g - F} \times \frac{500\,cm^3}{100\,cm^3}$$

$$15 = \frac{5F}{0.5g - F}$$

$7.5g - 15F = 5F$

$20F = 7.5g$

$F = 0.375g$

Total solute extracted $F_T = 1.5g + 0.375g$

$F_T = 1.875g$

Mass of solute G remains $(M_r) = 2g - 1.875g$

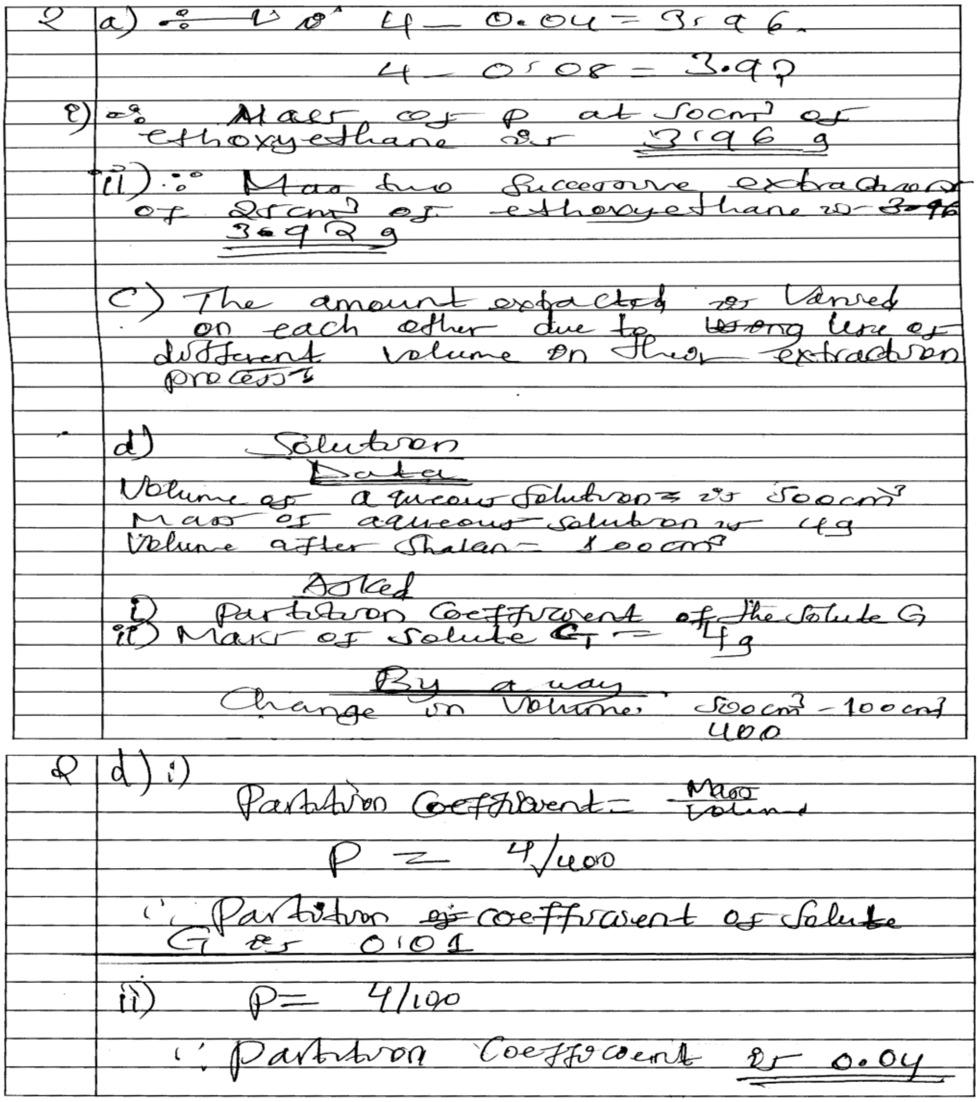
$M_r = 0.125g$

∴ The mass of solute G which will remain in aqueous layer of further shaking is 0.125g.

Extract 12.1: A sample of correct responses in question 2

In Extract 12.1, the candidate correctly wrote the expression for partition coefficient, substituted the data and manipulated the units. As a result, he/she got correct answers in all parts of the question.

However, some of the candidates (31.0%) scored low marks in this question. The analysis of responses on the scripts indicated that these candidates understood the concept of solvent extraction but failed to manipulate the partition coefficient expression correctly. Thus, they failed to get correct answers. Extract 12.2 shows one of the incorrect responses given by one of the candidates in question 2.



2 a) ∴ 4 − 0.04 = 3.96
4 − 0.08 = 3.92

b) i) ∴ Mass of P at 50cm³ of ethoxyethane is 3.96 g

ii) ∴ Mass two successive extraction of 25cm³ of ethoxyethane is 3.92 g

c) The amount extracted is varied on each other due to wrong use of different volume on their extraction process.

d) Solution

Data

Volume of aqueous solution is 500cm³
Mass of aqueous solution is 4g
Volume after shaken = 100cm³

Asked

i) partition coefficient of the solute G
ii) Mass of solute G = 4g

By a way

Change in volume, 500cm³ − 100cm³
400

2 d) i)

Partition Coefficient = Mass / Volume

P = 4/400

∴ Partition of coefficient of solute G is 0.01

ii) P = 4/100

∴ Partition coefficient is 0.04

Extract 12.2: A sample of incorrect responses in question 2

In Extract 12.2, the candidate incorrectly subtracted 0.04 from the value of partition coefficient in part (a) and gave incorrect answer in part (b) (ii). The candidate used incorrect approaches in subsequent parts of the question, hence missed all the marks.

2.2.3 Question 3: Solubility, Solubility Product and Ionic Product

The question consisted of three parts, namely: (a), (b) and (c). In part (a), candidates were given the information that *"To a solution containing 0.1 M* Cl^- *and 0.01 M* CrO_4^-*, a solution of* $AgNO_3$ *is added slowly".* Then the candidates were asked as follows: "*(a) (i) by showing a work clearly to identify which salt will precipitate first between AgCl and* Ag_2CrO_4*? Show clearly how you arrived to your answer. (ii) Find the concentration of the ion that will precipitate first at the time the second ion will start precipitating Use* K_{sp} *(AgCl) = 2.72 × 10* $^{-10}$ *and* K_{sp} *(*Ag_2CrO_4*) = 2.4 ×* 10^{-12}*"* In part (b), candidates were asked to calculate the solubility of Ag_2CrO_4 in water if the value of solubility product was 1.3×10^{-10} $(mol/L)^3$. In Part (c), candidates were given the information that*: "A standard solution of AgCl(aq) at 36 °C has a conductivity of* 1.32×10^{-6}*. If its molar conductivity at infinity dilution is 120* $\Omega^{-1}cm^2mol^{-1}$*, calculate; (i) the solubility of AgCl in* g/dm^3*. (ii) the solubility product of AgCl at the given temperature."*

The question was attempted by a total of 31,773 (92.1%) candidates, making it the second most attempted question in paper 2. The statistical analysis shows that 3,658 (11.5%) of the candidates scored from 12 – 20 marks, 10,413 (32.8%) scored from 7.0 - 15 and 17,702 (55.7%) scored from 0 - 6.5 marks. Figure 13 summarizes the data.

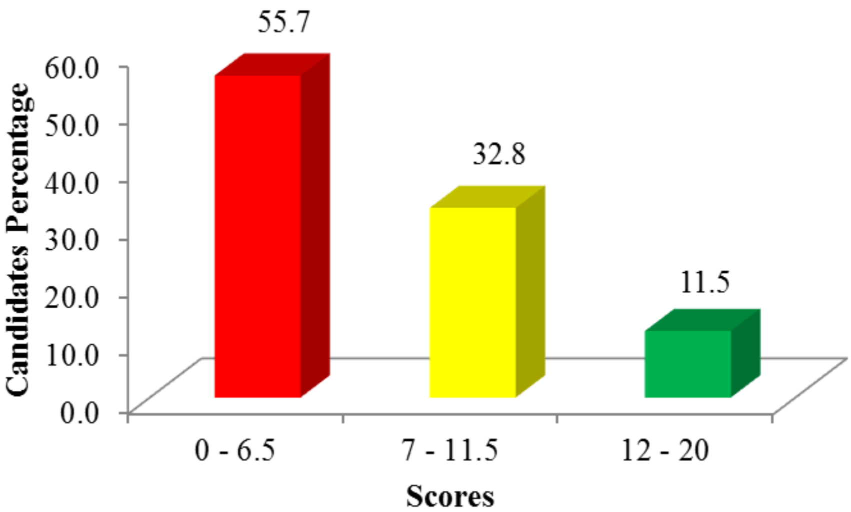
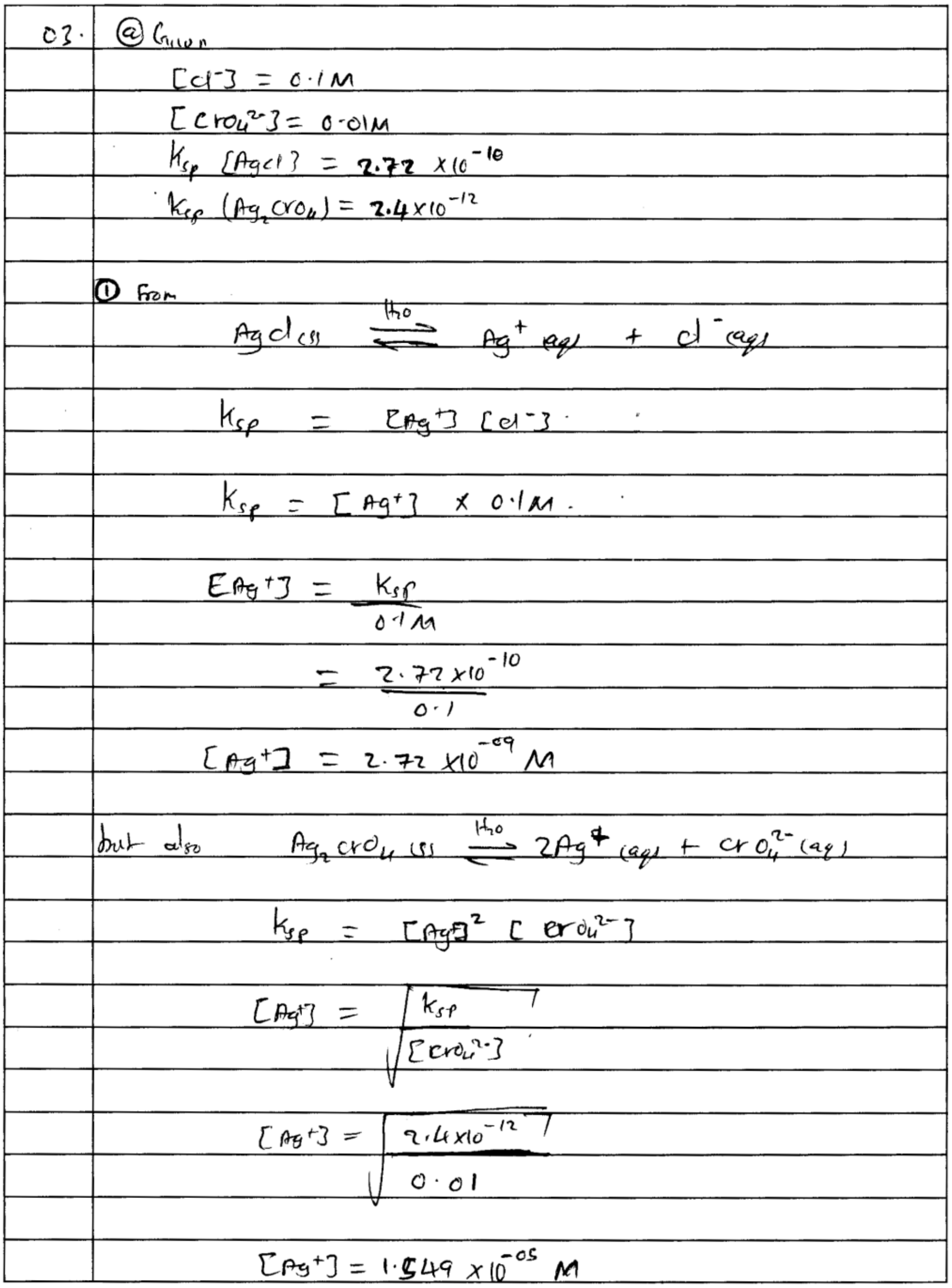


Figure 13: *Performance of the candidates in question 3*

The data in Figure 13 show that 44.3 per cent of the candidates scored from 7.0 – 20 marks, which indicates an average performance in the question. The candidates who managed to score high marks in this question had good knowledge of predicting precipitation using both ionic and solubility product. They used right formulae and correctly manipulated the units while calculating the solubility and solubility product. Extract 13.1 displays an example of correct responses from one of the candidates in this question.



03. (a) Given

$[Cl^-] = 0.1M$

$[CrO_4^{2-}] = 0.01M$

$K_{sp}\ [AgCl] = 2.72 \times 10^{-10}$

$K_{sp}\ (Ag_2CrO_4) = 2.4 \times 10^{-12}$

(i) From

$AgCl_{(s)} \overset{H_2O}{\rightleftharpoons} Ag^+_{(aq)} + Cl^-_{(aq)}$

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

$K_{sp} = [Ag^+] \times 0.1M$

$[Ag^+] = \frac{K_{sp}}{0.1M}$

$= \frac{2.72 \times 10^{-10}}{0.1}$

$[Ag^+] = 2.72 \times 10^{-09}\ M$

but also $Ag_2CrO_{4(s)} \overset{H_2O}{\rightleftharpoons} 2Ag^+_{(aq)} + CrO_4^{2-}{}_{(aq)}$

$K_{sp} = [Ag^+]^2 [CrO_4^{2-}]$

$[Ag^+] = \sqrt{\frac{K_{sp}}{[CrO_4^{2-}]}}$

$[Ag^+] = \sqrt{\frac{2.4 \times 10^{-12}}{0.01}}$

$[Ag^+] = 1.549 \times 10^{-05}\ M$

03 (a) (i) Since the solubility of [Ag^+] in AgCl is smaller than the solubility of [Ag^+] in Ag_2CrO_4 then AgCl will precipitate first and fast than Ag_2CrO_4.

(ii) Given

K_{sp} Ag_2CrO_4 = 2.4×10^{-12}

K_{sp} AgCl = 2.72×10^{-10}

When the second ion will precipitate first it means that the concentration of [Ag^+] present is equal = 1.549×10^{-05} M

So from

$$AgCl_{(s)} \xrightleftharpoons{H_2O} Ag^+_{(aq)} + Cl^-_{(aq)}$$

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

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

$$[Cl^-] = \frac{2.72 \times 10^{-10}}{1.549 \times 10^{-5} M}$$

$$[Cl^-] = 1.756 \times 10^{-05} M$$

∴ The concentration of the ion is 1.756×10^{-05} M

03 (b) Given.

K_{sp} = 1.3×10^{-11} $(mol/L)^3$

~~Molar mass of Ag_2CrO_4 =~~

From

$$Ag_2CrO_4 \xrightleftharpoons{H_2O} 2Ag^+_{(aq)} + CrO_4^{2-}{}_{(aq)}$$

$$\quad\quad 2x \quad\quad x$$

$$K_{sp} = [Ag^+]^2 [CrO_4^{2-}]$$

$$K_{sp} = 4x^2 \cdot x$$

$$K_{sp} = 4x^3$$

$$x^3 = \frac{K_{sp}}{4}$$

$$x^3 = \frac{1.3 \times 10^{-11} M^3}{4}$$

$$x = \sqrt[3]{\frac{1.3 \times 10^{-11} M^3}{4}}$$

$$x = 1.481 \times 10^{-4} \text{ mol/dm}^3$$

∴ The solubility of Ag_2CrO_4 is 1.481×10^{-4} mol/dm³

03 (c) $K = 1.32 \times 10^{-6}\ \Omega^{-1} cm^{-1} mol^{-1}$

$\Lambda_m^{\infty} = 120\ \Omega^{-1} cm^2 mol^{-1}$ Mr of AgCl = 143.5 g/mol

(i) from

$$\Lambda_m^{\infty} = \frac{K}{C_m}$$

but Cm = Solubility

$$C_m = \frac{K}{\Lambda_m^{\infty}}$$

$$= \frac{1.32 \times 10^{-6}\ \Omega^{-1} cm^{-1} mol^{-1}}{120\ \Omega^{-1} cm^2 mol^{-2}}$$

$$= 1.1 \times 10^{-08}\ mol/cm^3$$

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

$\Rightarrow$ $1\ cm^3 = 10^{-3}\ dm^3$

$$C_m = 1.1 \times 10^{-08}\ mol/10^{-3} dm^3$$

$$C_m = 1.1 \times 10^{-08} \times 1000\ mol/dm^3$$

$$C_m = 1.1 \times 10^{-05}\ mol/dm^3$$

~~∴ The molar con solubility of AgCl~~ i.

Conc = molarity × molar mass

$= 1.1 \times 10^{-05}\ mol/dm^3 \times 143.5\ g/mol$

$= 1.5785 \times 10^{-03}\ g/dm^3$

∴ The solubility of AgCl is $1.5785 \times 10^{-03}\ g/dm^3$.

03 (c) (ii)

From $AgCl_{(s)} \underset{}{\overset{H_2O}{\rightleftharpoons}} Ag^+_{(aq)} + Cl^-_{(aq)}$

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

but

$[Ag^+] = [Cl^-]$.

but molar solubility of AgCl from above is 1.1×10^{-05} mol/dm^3

$[Ag^+] = [Cl^-] = 1.1 \times 10^{-05}$ mol/dm^3.

$K_{sp} = [1.1 \times 10^{-05} \times 1.1 \times 10^{-05}] (mol/dm^3)^2$

$K_{sp} = 1.21 \times 10^{-10} M^2$

$\therefore$ The solubility product of AgCl is $1.21 \times 10^{-10} M^2$

Extract 13.1: A sample of correct responses in question 3

In Extract 13.1, the candidate predicted through calculations, the salt which will precipitate first correctly. The candidate managed to calculate the solubility of Ag_2CrO_4 in water in part (b). Lastly, he/she used appropriate formulae and an approach to calculate the solubility and solubility product of AgCl in part (c) (i) and (c) (ii).

However, 55.7 per cent of the candidates failed to answer most parts of this question, and hence, scored weakly. The analysis of the responses indicates that these candidates had insufficient knowledge of the concept of fractional precipitation. They incorrectly calculated the solubility and solubility products asked. Others skipped some parts of the question. Extract 13.2 shows incorrect responses provided by one of the candidates.

3 a) ii) Data given:

Ksp of AgCl $= 2.72 \times 10^{-10}$

and Ksp of $Ag_2CrO_4 = 2.4 \times 10^{-12}$.

~~At AgCl~~

~~AgCl ⟶ [Ag] [~~

At AgCl

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

$[AgCl] = [Ag^+][Cl^-]$

$Ksp = [Ag][Cl]$

Let $[AgCl] = x$.

$Ksp = x \times x$

~~$Ksp = x^2$~~

$Ksp = x^2$

$2.72 \times 10^{-10} = x^2$

$\sqrt{2.72 \times 10^{-10}} = \sqrt{x^2}$

$x = 1.649 \times 10^{-5}$

∴ The concentration of AgCl is 1.649×10^{-5} mol/l³

At Ag_2CrO_4

$Ag_2CrO_4 \longrightarrow 2Ag^+ + CrO_4$

$[Ag_2CrO_4] = [CrO_4]$

$2[Ag_2CrO_4] = [Ag^+]$

Let Ag_2CrO_4 to be x

$Ksp = [Ag^+]^2 [CrO_4]$

$Ksp = x^2 \cdot x$

$Ksp = x^3$

3/ a/ ii/ $Ksp = x^3$

$2.4 \times 10^{-12} = x^3$

$\sqrt{2.4 \times 10^{-12}} = \sqrt{x^3}$

$x = 1.339 \times 10^{-4}$.

∴ The concentration of Ag_2CrO_4 is 1.339×10^{-4} mol/L^3

b/ Solubility Ag_2CrO_4 in water

$ksp = 1.3 \times 10^{-11}$

$Ag_2CrO_4 \longrightarrow Ag^{2+} + CrO_4$

$[Ag_2CrO_4] = CrO_4$

$2[Ag_2CrO_4] = [Ag]$

$Ksp = [Ag]^2[CrO_4]$

$Ksp = 2(1.3 \times 10^{-11})(1.3 \times 10^{-11})$

$Ksp = (2.6 \times 10^{-11})^2(1.3 \times 10^{-11})$

$Ksp = (6.76 \times 10^{-22})(1.3 \times 10^{-11})$

$Ksp = 8.786 \times 10^{-33}$

∴ The solubility of Ag_2CrO_4 in water is 8.788×10^{-33} mol^{3}L^{10}

3 c/ Data given

Temperature 36°C

Ampre $= 1.32 \times 10^{-6} \Omega^{-1} cm^{-1} mol^{-1}$

AgCl in g/dm^3 = ?

$Ksp = AgCl$

$AgCl \longrightarrow Ag + Cl$

~~Ag~~

$Ksp = [Ag^+][Cl]$

~~Ksp~~ $[Ag^+][Cl][AgCl]$

Extract 13.2: A sample of incorrect responses in question 3

In Extract 13.2, the candidate used an incorrect approach in all parts of the question in calculating the solubility and solubility products from the given data.

2.2.4 Question 4: Periodic Classification

This question had four parts, namely (a), (b) (c) and (d). In part (a), candidates were required to state the reason(s) for each of the following facts; "*(i) Although* Na^+, Mg^{2+} *and* Al^{3+} *ions have the same electronic configuration, they have different radii (ii) At ordinary temperature, phosphorus pentachloride* (PCl_5) *is a white solid with unexpected high melting point (iii) Sodium chloride (NaCl) and unhydrous aluminum chloride* ($AlCl_3$) *are both chloride of metals of period (III). Molten sodium chloride can be electrolyzed while molten unhydrous aluminum chloride cannot (iv) The first ionization energy increases from left to right across a period but the first ionization energy of magnesium is larger than that of aluminum. (v) Lithium and potassium are metals of group (I). In aqueous solution, lithium is a poor conductor of electricity while potassium is a good conductor (vi) Boiling point of water* (H_2O) *is higher than that of hydrogen sulphide* (H_2S)*. All are hydrides of group (IV) elements.*" In Part (b) (i), candidates were required to give factors that were used to classify the elements in the periodic table, while part (b) (ii), required candidates to account for the fact that the third period of the periodic system of elements has only eight elements, not eighteen as expected. In part (c), candidates were given the information that: "*Ammonia* (NH_3) *and phosphene,* (PH_3) *are hydrides of the first two elements in group VA. Some physical properties of ammonia and phosphene are given in the following table;*

Compound	***Boiling point (°C)***	***Solubility in water (mol/dm³)***
Ammonia, NH_3	*-33*	*31.1*
Phosphene, PH_3	*-88*	8.88×10^{-4}

Then, the candidates were required to (i) suggest one reason for such difference in boiling temperature (ii) explain with a reason why ammonia is more soluble in water than in phosphene.

This question was attempted by 30,544 (88.5%) candidates, out of which, 2,485 (8.1%) scored from 12.0 – 20 marks, 8,520 (27.9%) scored from 7.0 – 11.5 marks and 19,539 .(64.0%) scored from 0 – 6.5 marks. Figure 14 summarizes the performance of the candidates in this question.

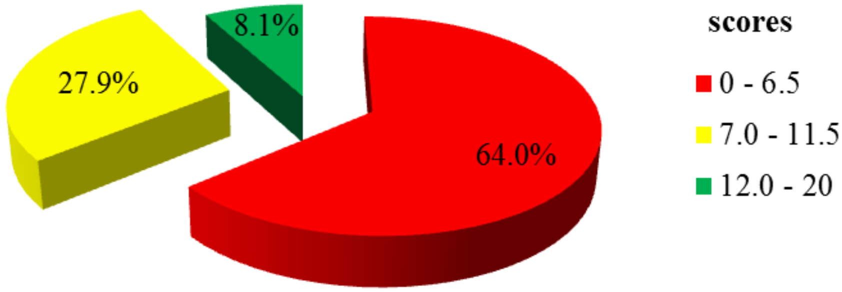


Figure 14: *Performance of the candidates in question 4*

The candidates (8.1%) with good scores (12.0 – 20 marks) in this question showed a good knowledge of the topic of *Periodic Classification*. The candidates showed to have acquired appropriate level of competencies in periodicity, periodic trends in physical and chemical properties as well as diagonal relationship. Extract 14.1 shows a sample of responses from one of the candidate with high scores in this question.

04 a) i) By considering table below

element	number of electron	proton
Na^+	10	11
Mg^{2+}	10	12
Al^{3+}	10	13.

Since All three element has same number of electron hence same electronic configuration but due to different nuclear attractive force ~~ext~~ exerted by the proton toward electron atomic radius do varies thus alluminium has smallest size followed by magnesium and then sodium because their progressive decrease in nuclear attractive force from Alluminium to sodium.

ii) At ordinary temperature PCl_5 exist in the ionic form of $[PCl_4]^+$ where it's chlorine atom are strongly held by attractive force in a crystal lattice and thus due to the stronger bond it inturn led to higher melting point of PCl_5 and exist as white solid.

iii) Since sodium chloride is more ionic thus it's good conductor of heat and electricity which do inturn used electrolysis means can be electrolysed. But $AlCl_3$ due to smaller size of alluminium means higher polarizing power hence alluminium chloride to exist as covalent compound hence poor conductor of heat and electricity which inturn can not be electrolysed.

04 a). iv). By considering electronic configuration of magnessium and alluminium.

$Mg^{?} = 1s^2 \; 2s^2 \; 2p^6 \; 3s^2$

[1↓] [1↓] [1↓|1↓|1↓] [1↓]

$Al = 1s^2 \; 2s^2 \; 2p^6 \; 3s^2 \; 3p^1$

[1↓] [1↓] [1↓|1↓|1↓] [1↓] [1| |]

> First ionization energy of magnessium is large because magnesium possesed stable electronic configuration thus extra energy is required to unpaired electron but Allominium possesed the only one unpaired electron.

Also:

> The distance of outer orbital from nucleus thus magnesium valence electron is at 3s-orbital mean near the nucleus but Allominium valence orbital is at 3p-orbital far from nucleus.

lastly:

> Allominium experience stronger screening effect than the magnesiom atom.

04 a) v). lithium is very smaller in size as do compaired with potassiom and thus in the acquous solution lithium is highly hydrated due to stronger nuclear attractive which attract lone pair of water and thus its atoms become heavy as the result of lower mobility which inturn lithiom become poor conductor but the potassiom is not hydrated due to larger size hence good conductor of electricity.

04 9) vi). > Oxygen atom in water posses lone pair thus water has greater ability of do forming hydrogen bonding between its molecules thus due to hydrogen bonding boiling point of water is so higher.

But.

> H_2S it's sulphur atom posses no any lone pair as the result this inturn cause lower boiling point due to small strength of its bond.

04 (b). i) Ammonia (NH_3) has larger boiling point than phosphene because nitrogen atom has lone pair hence it can form hydrogen bonding between its molecules.

ii) Ammonia is more soluble in water because ~~am~~ it can form hydrogen bond between NH_3 and H_2O thus due to hydrogen bonding solubility of ammonia in water do increase But phosphine since phosphorus has no lone pair thus it can not form hydrogen bonding with water hence lower solubility.

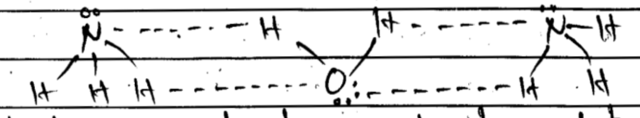


Illustration of hydrogen bonding between water and ammonia.

04 a) Element do exhibit diagonal relationship because of the following reasons:-
i) Posses same polarizing power
ii) Same atomic radius and the nuclear attractive force
iii) Same electronegativity.
Examples are:-
1st Beryllium and Alluminium experience diagonal relationship. like
> Both they can form complex
> Both do undergo association in the acqous solution (Al_2Cl_6 and Be_nCl_n)
> Both posses amphoteric oxide and hydroxide.

2nd: lithium and magnesium experience diagonal relationship. like.
> Both can react with nitrogen to form nitride
> Both posses unstable carbonate and bicarbonate which decompose on heating.

04 b) i) > Atomic number is the factor which play role in arrangement of element in periodic table
> Also physical and chemical properties play role in classification of element

ii). This is because during arrangement electron are filled in the shells and thus period 3 element has three shells thus all of 18 eighteen electron can be filled in the three shells.

Extract 14.1: A sample of correct responses in question 4

In Extract 14.1, the candidate correctly commented on all facts given in part (a). In part (b), the candidate gave appropriate factors used in classifying elements in the periodic table and gave a proper account for the fact asked in part (b) (ii). He/she used the concept of hydrogen bonding appropriately to answer part (c). Lastly, the candidate gave an appropriate explanation of existence of diagonal relationship between elements in the periodic table of elements.

On the other hand, 64.0 per cent of the candidates performed weakly in this question. The analysis of responses given by these candidates indicates that they had insufficient knowledge of the features of the modern periodic table as well as the modern periodic law. Moreover, they showed lack of knowledge of periodic trends in both physical and chemical properties. As a result, they missed most of the marks allocated to this question. Extract 14.2 is an example of wrong responses given by one of the candidates in question 4.

4 a)
i) Yes Because all are in group and have different radii because it increasing number of shell.

ii) $PCl_5 \longrightarrow PCl_3 + PCl_2$ because
Chlorine is most electronegative atom in group seven which soluble in water.

iii) $NaCl + AlCl_3 \rightarrow Al(NaCl_3)$
Because Aluminium chloride is less reactive metal which can support electrolyte and Aluminium chloride is not strong oxidizing agent.

iv) due to increasing number of shell.

v) Because Lithium are less reactive metal and have small number of electron shell

vi) Because in group number seven (VII) has Halogen which react with metal and give salt and (H_2O) is weak electrostatic force of attraction.

b i) Density of element

4	b ii) Vanadium Aluminium which
	c). i) temperature q phosphene is
	less than temperature q Ammonia
	ii) Becaus Ammonia is strong
	acid salt ~~tha~~ than phosphene
	d) Because of increasing vacant orbital
	in valence shell and form solution
	example. Aluminium and Magnesium
	ii) Lithium and hydrogen.

Extract 14.2: A sample of incorrect responses in question

In Extract 14.2, the candidate incorrectly responded to parts (a) (i) and (ii). He/she wrote incorrect equation in (a) (iii) and gave incorrect answers to the remaining parts of the question. Hence, he/she missed all the allocated marks.

2.2.5 Question 5: Hydroxyl Compounds

This question had two parts, namely (a) and (b). Part (a) of the question required candidates to use their knowledge of the hydroxyl group to write the chemical reaction equations with their IUPAC names showing what happens when propan-1-ol is treated with each of the following:

(i) excess HBr under reflux
(ii) a small amount of concentrated H_2SO_4
(iii) acidified $KMnO_4$
(iv) ethanoic acid in the presence of concentrated H_2SO_4
(v) $SOCl_2$

In part (b), candidates were given the information *"Compound **A** ($C_{10}H_{12}O$) gives off oxygen gas on treatment with sodium metal and also decolorizes Br_2 in CCl_4 to give organic compound **B.** Compound **A** on treatment with I_2 in NaOH gives Iodoform and salt **C** which after acidification gives a white solid **D** ($C_7H_6O_2$)."* and were required to use their knowledge of organic chemistry to identify the structures of **A, B, C** and **D**.

A total of 26,720 (77.4%) candidates attempted this question. The performance of the candidates is summarized in Table 1.

Table 1: Number, Percentages and Scores of the Candidates in Question 5

Scores	Number of Candidates	Percentage of Candidates
0 – 6.5	19,603	73.4
7.0 - 11.5	6526	24.4
12.0 – 20	591	2.2

Statistical data in Table 1 show that the overall performance of the candidates in the question was weak, as 73.4 per cent of the candidates scored lowly. The candidates who scored low marks in the question appeared to have faced difficulties in understanding and naming organic structures. They also showed the lack of knowledge about the properties of hydroxyl compounds. As a result, the candidates failed to give appropriate chemical reaction equations and their names according to IUPAC rules. For example one of the candidates responded to part (a) (i) – (iii) of the question as follows:

$$(i)\ CH_3CH_2CH_2CH_2CH_2OH + HBr \xrightarrow{reflux} CH_3CH_2CH_2CH_2CH_2Br + H_2O$$

1-bromopentane water

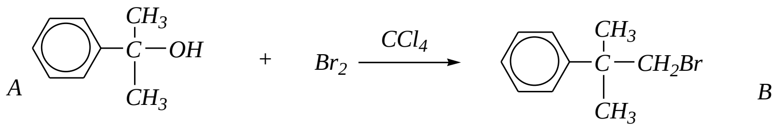
$$(ii)\ CH_3CH_2CH_2CH_2CH_2OH + conc.H_2SO_4 \xrightarrow{reflux} CH_3CH_2CH_2CH = CH_2 + H_2O$$

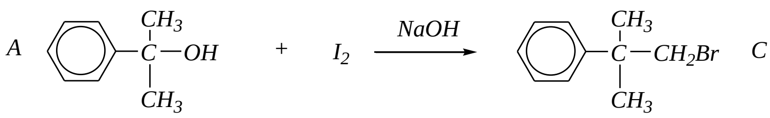
pent-1-ene water

$$(iii)\ CH_3CH_2CH_2CH_2CH_2OH + KMnO_4 \xrightarrow{H^+} CH_3CH_2CH_2CHO + H_2O$$

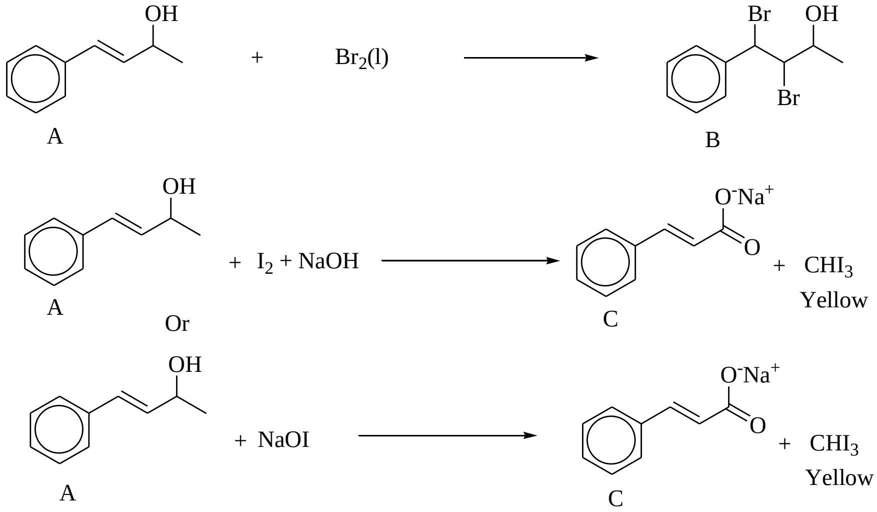
pentanal water

These responses provided by the candidates were contrary to the requirement of the question; as he/she used pentan-1-ol instead of propan-1-ol in parts (i) – (iii). Thus, the candidate got incorrect structures and hence IUPAC names. Moreover, one of the candidates wrongly identified some of the structures (B and C) in part (b) as follows:

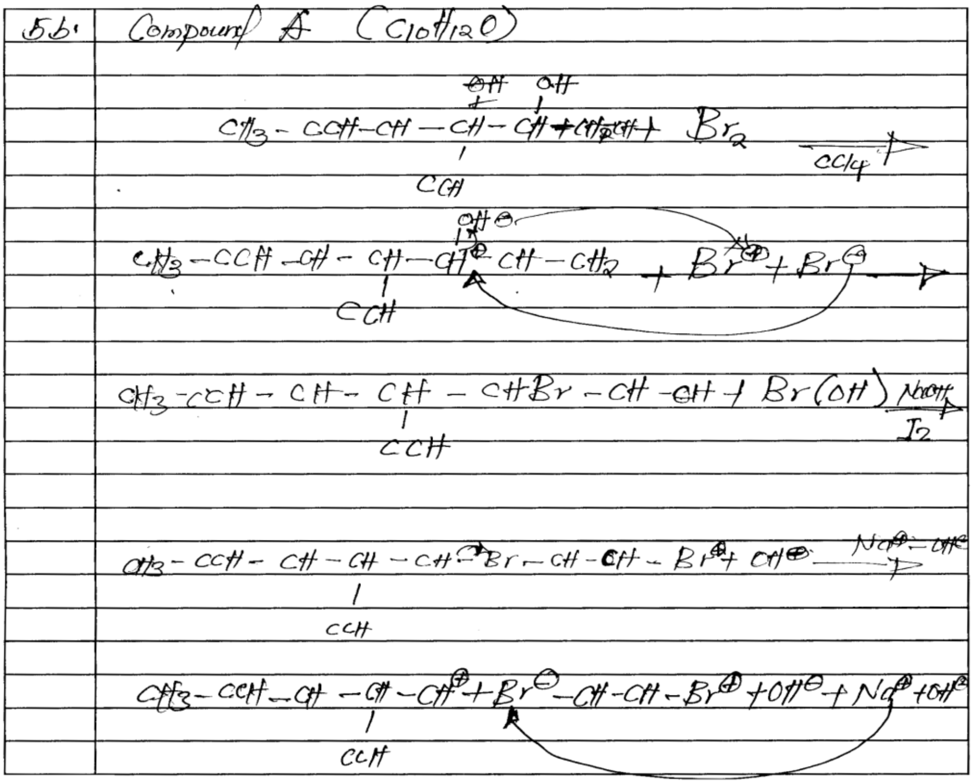


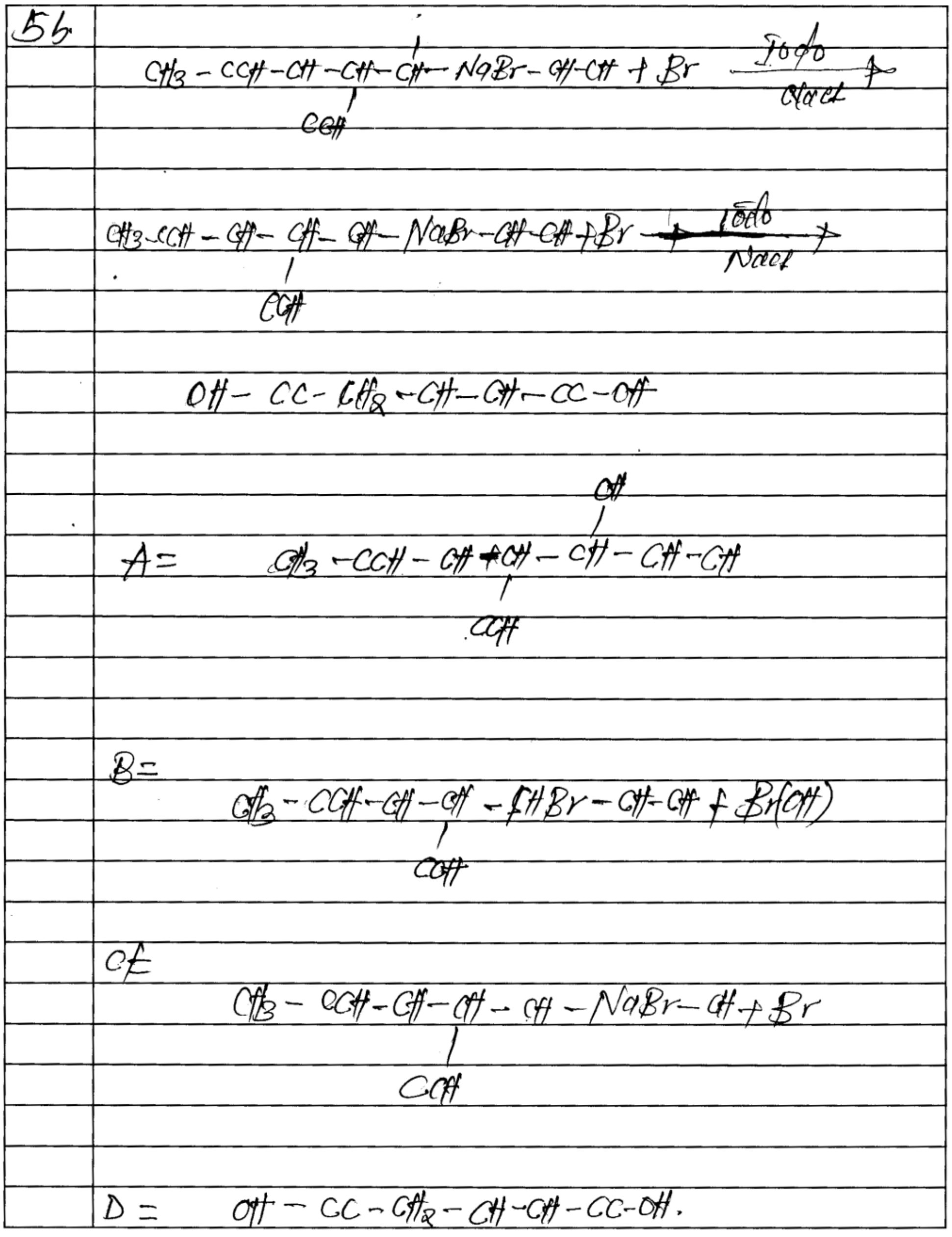


In his/her responses above, the candidate wrote an incorrect structure for compound A, hence all the results he/she obtained in part (b) of the question were incorrect. The candidate was supposed to identify compounds B and C as follows:



Extract 15.1 is another sample of incorrect responses given by one of the candidates in question 5.





5b

CH3 – CCH – CH – CH – CH – NaBr – CH – CH + Br (Iodo / NaCl)

CCH

CH3 – CCH – CH – CH – CH – NaBr – CH – CH + Br (Iodo / NaCl)

CCH

OH – CC – CH2 – CH – CH – CC – OH

A = CH3 – CCH – CH – CH – CH – CH – CH (CH, CCH)

B = CH3 – CCH – CH – CH – CHBr – CH – CH + Br(CH) (CCH)

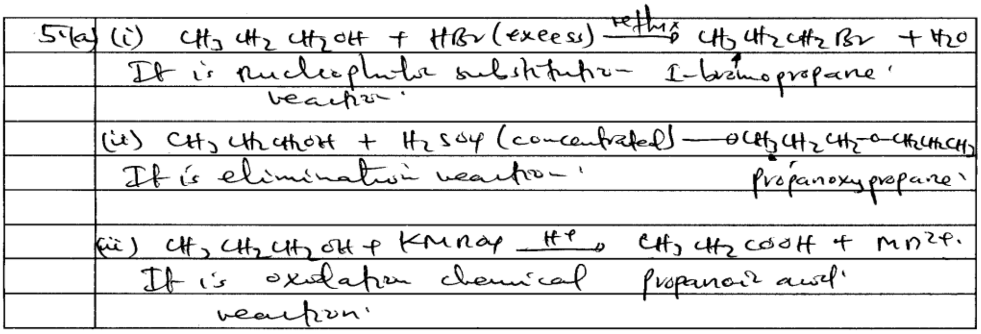
C = CH3 – CCH – CH – CH – CH – NaBr – CH + Br (CCH)

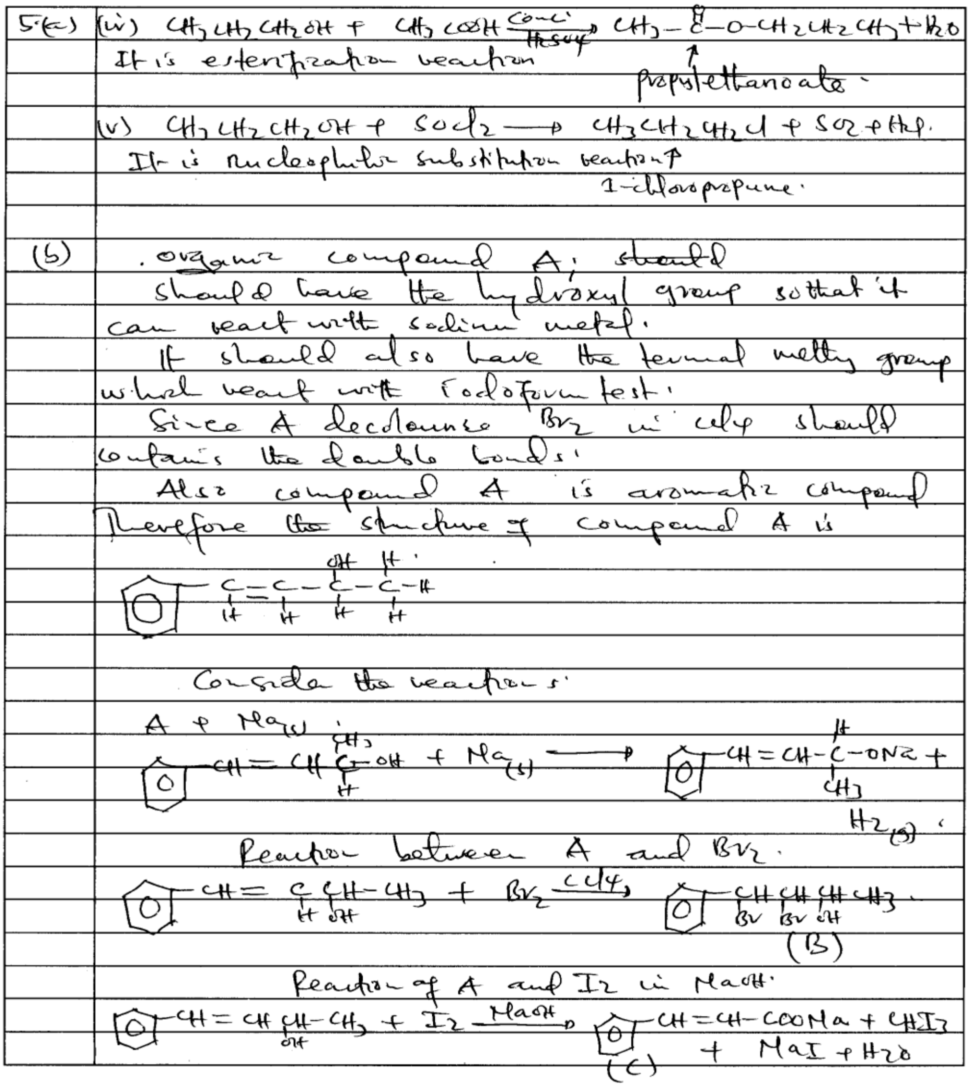
D = OH – CC – CH2 – CH – CH – CC – OH.

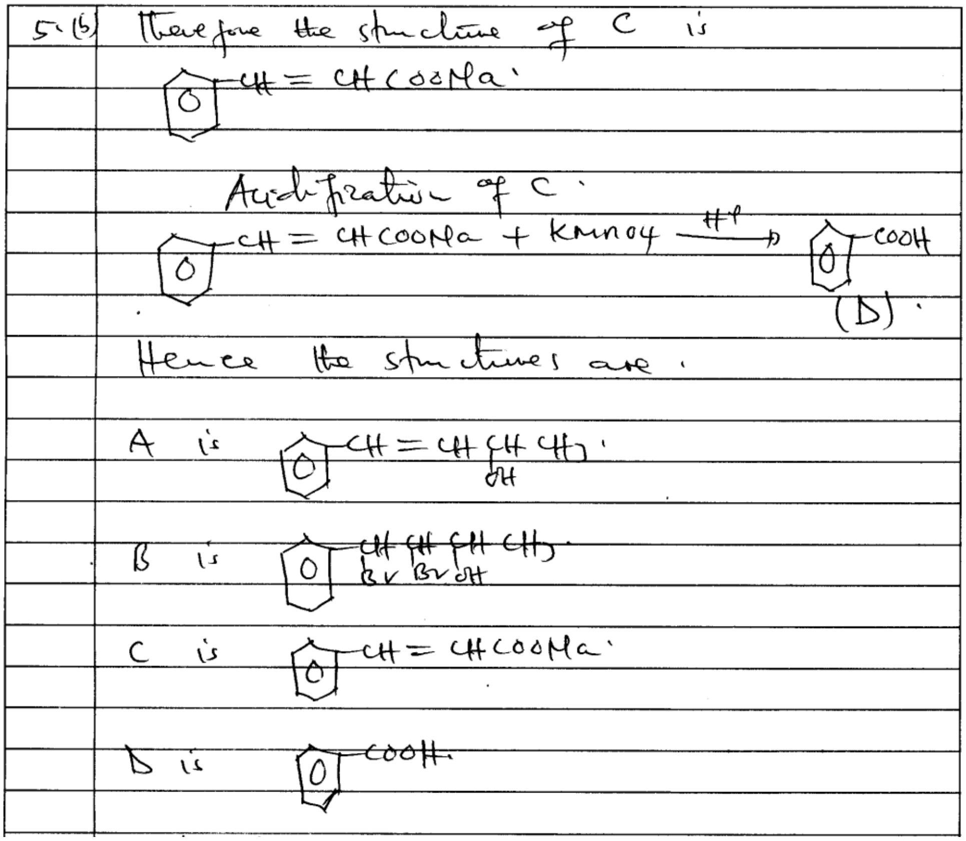
Extract 15.1: A sample of incorrect responses in question 5

In Extract 15.1, the candidate gave wrong reaction mechanisms in contrary to the requirement of the question and missed all the marks allocated to this question.

Despite the fact that the majority of the candidates (73.4%, Table 1) scored below the pass mark, a few (2.2%) of those who attempted the question managed to perform well. The analysis of responses indicates that these candidates were competent in understanding both physical and chemical properties of hydroxyl compounds as well as their associated chemical reactions. Extract 15.2 shows a sample of correct responses from a script of one of the candidates in question 5.







Extract 15.2: A sample of correct responses in question 5

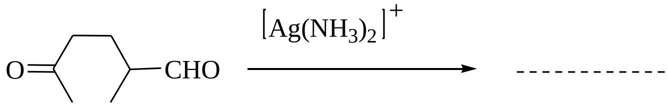
In Extract 15.2 the candidate wrote the correct structure for compound A and appropriate chemical reactions which enabled him/her to identify the correct structures for subsequent compounds (B-D).

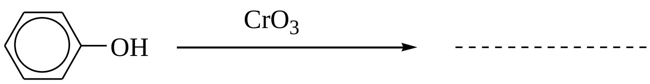
2.2.6 Question 6: Carbonyl Compounds and Carboxylic Acids and its Derivatives

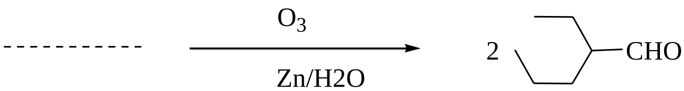
This question had three parts, namely (a), (b) and (c). Part (a) required candidates to distinguish between the following pairs of organic compounds, (i)-(iv) while supporting their answers with chemical equations.

(i) Propanal and Propanone
(ii) Ethanal and benzaldehyde
(iii) Pentanal and Pentan-2-one
(iv) 3-Pentanone and 2-pentanone

In part (b), candidates were asked as follows: "*An organic compound* ***A*** *which has characteristics odour is treated with 50% NaOH to give* ***B*** *(C_7H_8O) and* ***C*** *which is a sodium salt of an organic acid. Oxidation of* ***B*** *gives back **A**. Heating **C** with soda lime yields an aromatic hydrocarbon **D**. Deduce the structures of **A**, **B**, **C** and **D**.*" In part (c), candidates were required to complete the following reaction equations by giving the missing reagents /products.

(i) 

(ii) 

(iii) 

(iv) 

The question was opted by 10,894 candidates equivalent to 31.6 per cent. The question was the least attempted by the candidates in ACSEE 2021 Chemistry theory examination. The distribution of the candidates' scores is as shown in Table 2.

Table 2: Number, Percentages and Scores of the Candidates in Question 6

Scores	Number of Candidates	Percentage of Candidates
0 – 6.5	5,578	51.2
7.0 - 11.5	2,555	23.5
12.0 – 20	2,761	25.3

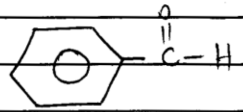
Statistical data in Table 2 indicates that a total of 5,316 (48.8%) candidates out of 10,894 (31.6%) who attempted this question managed to score a pass mark or above (≥6.5 marks). This indicated that the overall performance in this question was average.

The candidates (25.3%) with good performance in this question had adequate knowledge about chemical reactions of carbonyl compounds and carboxylic acids. Thus, they showed appropriate competencies in interconversion of aldehydes, ketones, hydroxyl, carboxylic acids and alkenes functional groups. Moreover, they showed to be familiar with basic reagents and conditions that were needed to perform such conversions. The candidates (23.5%) who performed averagely provided partial answers to most parts of the question. Extract 16.1 shows a sample of correct responses from one of the candidates in question 6.

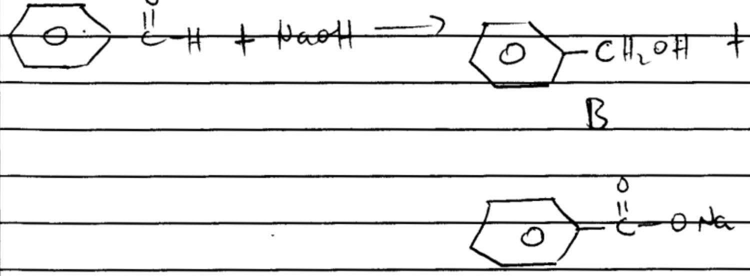
06.	a) i) CH_3CH_2CHO and $CH_3\overset{O}{\overset{\|\|}{C}}CH_3$ can be distinguished
	by Iodoform reaction.
	whereby $CH_3\overset{O}{\overset{\|\|}{C}}CH_3 + 3I_2 + 4NaOH \rightarrow CHI_3 + CH_3\overset{O}{\overset{\|\|}{C}}-ONa + 3NaI + 3H_2O$
	ppt
	but ~~$CH_3\overset{O}{\overset{\|\|}{C}}CH_3$~~ $+ 3I_2 + 4NaOH \rightarrow$ no reaction.(no ppt)
	CH_3CH_2CHO
	ii) CH_3CHO and C_6H_5-CHO can be distinguished by
	Iodoform reaction.
	whereby $CH_3CHO + 3I_2 + 4NaOH \rightarrow CHI_3 + H-\overset{O}{\overset{\|\|}{C}}-ONa + 3NaI + 3H_2O$
	ppt.
	$C_6H_5-CHO + 3I_2 + 4NaOH \rightarrow$ no reaction (no ppt)
	iii) $CH_3CH_2CH_2CH_2CHO$ and $CH_3-\overset{O}{\overset{\|\|}{C}}-CH_2CH_2CH_3$ can
	be distinguished by Iodoform reaction (or Silver mirror test)
	ppt..
	whereby $CH_3-\overset{O}{\overset{\|\|}{C}}-CH_2CH_2CH_3 + 3I_2 + 4NaOH \rightarrow CHI_3 + CH_3CH_2CH_2\overset{O}{\overset{\|\|}{C}}-ONa$
	$+ 3NaI + 3H_2O$.
	while
	$CH_3CH_2CH_2CH_2CHO + 3I_2 + 4NaOH \rightarrow$ no reaction (no ppt)
	iv) $CH_3CH_2-\overset{O}{\overset{\|\|}{C}}-CH_2CH_3$ and $CH_3\overset{O}{\overset{\|\|}{C}}-CH_2CH_2CH_3$ can be
	distinguished by Iodoform reaction whereby
	$CH_3\overset{O}{\overset{\|\|}{C}}CH_2CH_2CH_3 \xrightarrow[4NaOH]{3I_2} CHI_3 + CH_3CH_2CH_2\overset{O}{\overset{\|\|}{C}}-ONa + 3NaI + 3H_2O$
	ppt
	while 3-pentanone cannot give positive Iodoform reaction.

06. b)

A —



Reaction 1

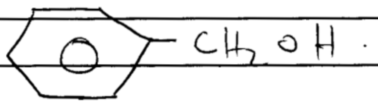


B

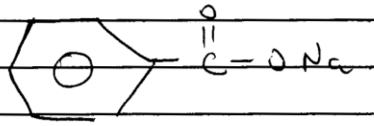
C

Thus;

B —

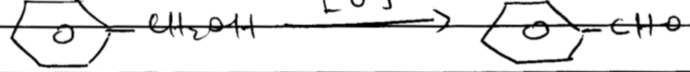


C —

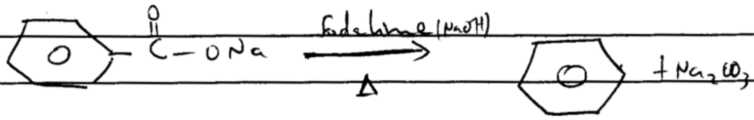


Reaction 2;

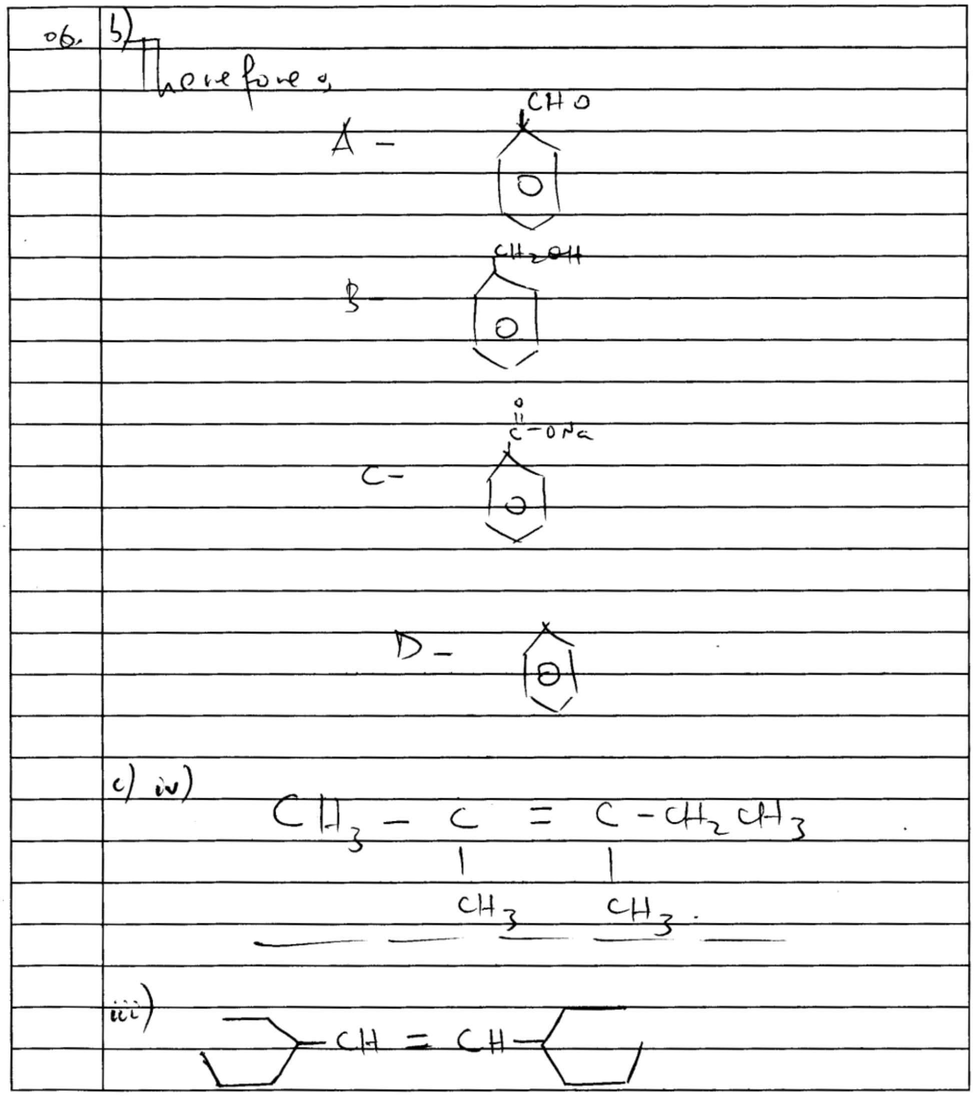
B A



Reaction 3;



D



Extract 16.1: A sample of correct responses in question 6

Extract 16.1 shows responses of a candidate who understood the concept of iodoform test properly. Thus, they managed to differentiate the organic compounds given in part (a) properly. In part (b), the candidate deduced the structures of compounds **A**, **B**, **C** and **D** appropriately. Lastly, he/she correctly gave the missing reagents in part (c) (iii) and (iv).

On the other hand, 51.2 per cent of the candidates had weak performance in this question. This category of the candidates showed to have insufficient knowledge of reactions undergone by carbonyl compounds and carboxylic acids. They were not knowledgeable of chemical reactions of aldehydes, ketones and organic acids such as nucleophilic addition, reactions of alkyl group adjacent to carbonyl carbon atom and redox reactions. Thus, they provided incorrect responses to most parts of the question. Extract 16.2 is a sample of poor responses from one of the candidates in question 6.

6. i) When propanone in addition of $KMnO_4$ reaction will be precipitate to occur but in propanal when add $KMnO_4$ no reaction to occur.

ii) When adding benzaldehyde in the solution of $AgNO_3$ reaction will occur in ~~white~~ blue but when adding Ethanal silver nitrate no reaction will occur.

iii). When adding sulphuric acid ~~with~~ in pentan-2-one white precipitate will formed but when adding sulphuric acid in pentanal no reaction will occur.

6 a) i) Reaction between 3-pentanone and 2-pentanone.

When adding ($KMnO_4$) potassium per manganate in 2-pentanone reaction will occur to brown colour but when adding ~~3-~~ ($KMnO_4$) in 3-pentanone no reaction will occur.

b) b/. Solution

$2NaOH + CH_3CH_2CH_2CH_3 \rightarrow CH_3CH_2CH_2OH + NaOH$

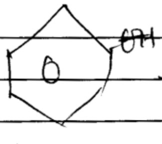
$CH_3CH_2CH_2CH_3 + ZnO \rightarrow CH_3CH_2CH_3$

$CH_3CH_2COOH + NaCO_3 \xrightarrow{CaO} CH_4 + 2NaCO_3$

A → NaOH + $NaCO_3$

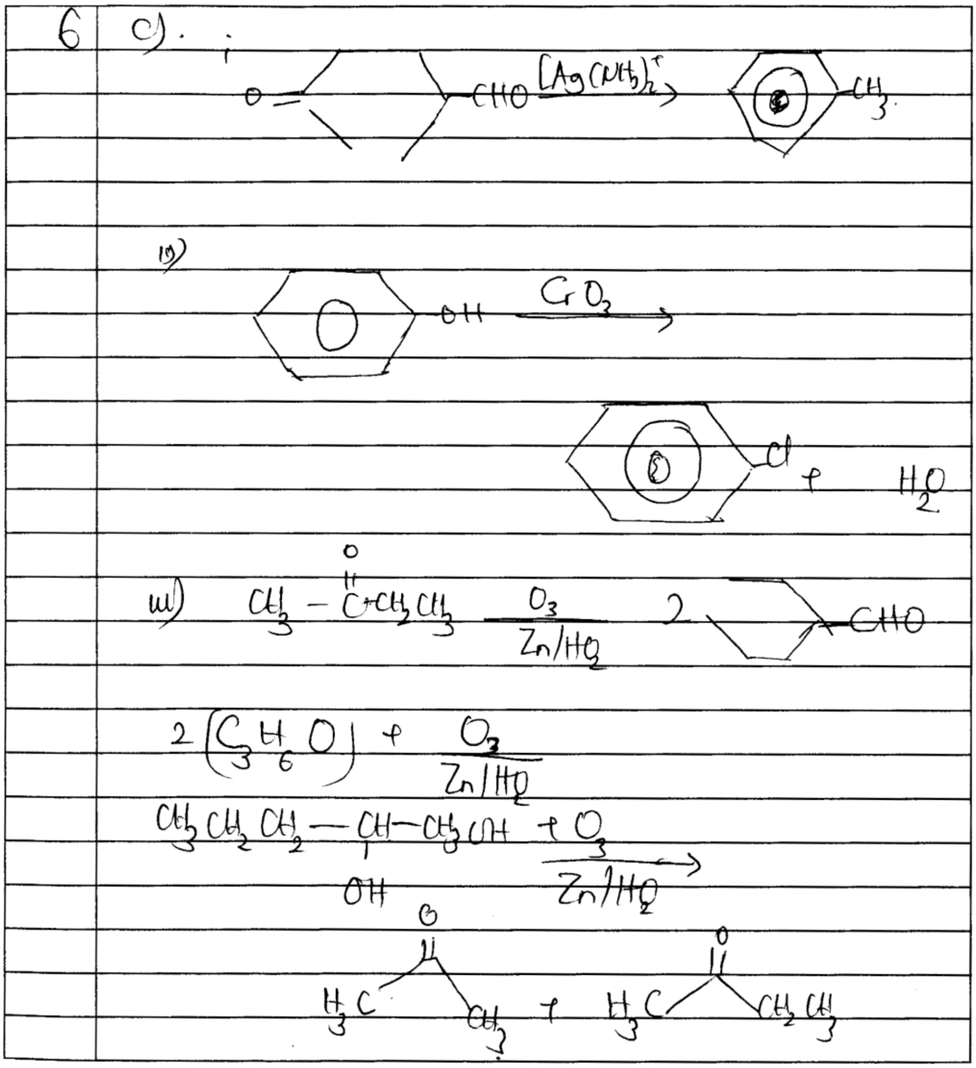
B → $CaCO_3$

d →



+ ~~CaO_2~~

c) → ~~$NaCO_3$~~



Extract 16.2: A sample of incorrect responses in question 6

In Extract 16.2, the candidate wrote statements which had no proper meaning in part (a) (i) and gave inappropriate approach for differentiating the given compounds in (a) (ii). In part (a) (iii), the candidate used sulphuric acid to differentiate the given organic compounds instead of the iodoform test. He/she also wrote incorrect chemical reactions in all subsequent parts of the question and missed all of the marks allocated to the question.

2.3 132/3-CHEMISTRY 3

This was an actual practical paper which was examined in three equivalent alternatives, namely **132/3A Chemistry 3A**, **132/3B Chemistry 3B** and **132/3C Chemistry 3C**. The candidate was 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. 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. Candidates were required to answer all the questions. The pass mark for question 1 was 7.0 marks while for questions 2 and 3 was 5.5 marks. The overall performance in practical examination was taken as an average of candidates' performance in question 1, 2 and 3.

A total of 34,497 candidates sat for the Chemistry practical examination in ACSEE 2021. The analysis of the Practical examination results showed that the overall performance was good, as most candidates (90.0%) scored an average marks or above.

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:

***U1**: A solution containing hydrochloric acid and acetic acid;*

***U2**: 0.1 M sodium hydroxide solution;*

***POP**: Phenolphthalein indicator;*

***MO**: Methyl orange indicator.*

Procedure

*(i) Using a pipette filler, pipette 20 or 25 cm^3 of a solution **U1** into a conical flask.*

*(ii) Add two to three drops of **MO** indicator.*

*(iii) Titrate the solution against solution **U2** until a colour change is observed.*

(iv) Record the first titre value.

*(v) Add two to three drops of **POP**.*

(vi) Continue to titrate until the second colour change is observed.

(vii) Record the second titre value.

(viii) Repeat the titration steps (i) to (vii) three more times and record the results as shown in Table 1.

Table 1: Table of results

Burette Reading	***Pilot***	***1***	***2***	***3***
Final readings (cm^3) using ***MO***				
Final readings (cm^3) using ***POP***				
Initial readings (cm^3)				
Volume used (cm^3) using ***MO***				
Volume used (cm^3) using ***POP***				

Summary

(i) The volume of the pipette used was _____________.

*(ii) _____________ cm^3 of **U1** required ____________cm^3 of **U2** when **MO** was used, and ________________ cm^3 of **U2** when **POP** was used.*

Questions

*(a) Calculate the concentration of the acid solution, **U1**, in g dm^{-3} when:*

*(i) **POP** was used.*

*(ii) **MO** was used.*

*(b) What is the colour change during titration when **MO** was used as an indicator and when **POP** was used.*

(c) Name the compounds reacted during the first and second titrations"

Question 1 of 132/3**B** Chemistry 3B was as follows:

You are provided with the following:

***M1**: A solution made by dissolving 6.25 g of $CuSO_4.XH_2O$ in distilled water to make a 250 cm^3 of a solution;*

***M2**: A solution made by dissolving 12.40 g of $Na_2S_2O_3.5H_2O$ in distilled water to make a 500 cm^3 of a solution;*

***M3**: A solution of 10% KI;*

***M4**: A starch solution.*

Theory

A quantitative reaction between copper sulphate and potassium iodide can be represented by the following equation:

$2Cu^{2+} + 4I^- \rightarrow Cu_2I_2 + I_2$ ....(i)

The liberated iodine can be titrated against sodium thiosulphate whose reaction can be represented as follows:

$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$ ....(ii)

Procedure

(i) *Pipette 20 cm^3 or 25 cm^3 of **M1** into a conical flask. Add 10 cm^3 of solution **M3** and shake well the mixture.*

(ii) *Titrate the mixture at step (i) with solution **M2** from the burette until a pale yellow colour appears. Then, add about 2 cm^3 of solution **M4**. Continue titrating until the pale yellow colour just disappears and a pale yellow green colour appears.*

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

Summary

(i) *The volume of the pipette used was _______________.*

(ii) *_____________ cm^3 of **M1** liberated iodine that required ____________ cm^3 of **M2** for complete reaction.*

Questions

(a) *Calculate the concentration of **M2** in mol/dm^3*

(b) *Write the half-reaction equations to show the oxidation and reduction processes taking place in procedure (ii) indicating in each case the oxidants and reductants.*

(c) *Calculate the:*
- *(i)* *molarity of **M1**.*
- *(ii)* *concentration of **M1** in g/dm^3.*
- *(iii)* *value of X in the formula $CuSO_4.XH_2O$.*

Question 1 of 132/3**C** Chemistry 3C was as follows:

"You are provided with the following:

***A**:* *A solution made by dissolving 1.58 g of $KMnO_4$ in a 0.5 dm^3 of a solution.*

***B**:* *A solution made by dissolving 5.8 g of $Na_2S_2O_3.XH_2O$ in a 0.25 dm^3 of a solution.*

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

***D**:* *A starch solution;*

E: *A solution of dilute H_2SO_4.*

Theory

Quantitatively, potassium permanganate and potassium iodide react in an acidic medium as represented by the reaction equation,

$MnO_4^- + I^- \rightarrow Mn^{2+} + I_2$ ....(i).

The liberated iodine, I_2 is titrated against sodium thiosulphate, $Na_2S_2O_3$ and the reaction taking place during this titration is represented as

$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$ ....(ii).

Procedure

(i) *Pipette 20 or 25 cm^3 of a solution **A** into a conical flask. Using a measuring cylinder, add an equal amount of **C** (20 or 25 cm^3) followed by 20.00 cm^3 or 25.00 cm^3 of **E** in the same flask.*

(ii) *Titrate the liberated iodine with **B** until the colour change is observed. Add 2 cm^3 of **D** and continue to titrate until the permanent colour change is observed.*

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

Summary

(i) *The volume of the pipette used was _____________.*

(ii) *____________cm^3 of **A** liberated iodine that required __________ cm^3 of **B** for complete reaction.*

Questions

(a) *State the role of solution **D** in this experiment.*

(b) *State the main purpose of adding solution **C** into a conical flask containing acidified solution of **A**.*

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

(d) *Calculate the;*

(i) *concentration of **A** in g/dm^3.*

(ii) *molarity of **A**.*

(iii) *molarity of $Na_2S_2O_3$.*

(iv) *concentration of $Na_2S_2O_3$ in g/dm^3.*

(e) *Find the value of X in the formula $Na_2S_2O_3.XH_2O$.*"

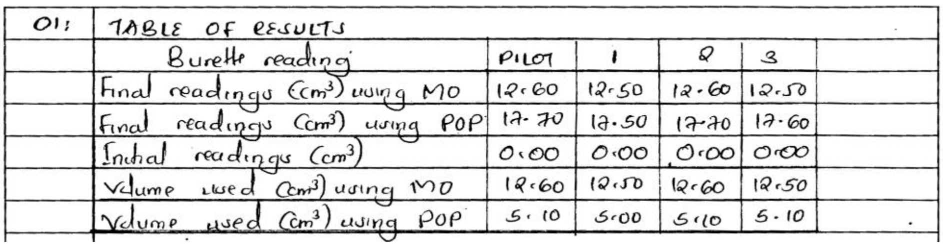
Question 1 was attempted by all of the candidates registered for 132 Chemistry amounting to 34,481. The distribution of the candidates' scores in question 1 is summarized in Table 3.

Table 3: Number, Percentages and Scores of the Candidates in Question 1

Scores	Number of Candidates	Percentage of Candidates
0 – 6.5	1,908	5.5
7.0 - 11.5	7,907	23.0
12.0 – 20	24,666	71.5

The general performance of the candidates in this question was good, as a total of 32,573 (94.5%) candidates managed to score an average mark or above (Table 3). The candidates (71.5%) who managed to score high marks in this question showed to have gained appropriate skills in volumetric standardization. In alternative A, the candidates managed to standardize a mixture of acetic acid and hydrochloric acid using a common standard base sodium hydroxide. In alternative B, they managed to standardize hydrated copper(II) sulphate with unknown number of molecules of water of crystallization, **X** while those in alternative C, managed to standardize hydrated sodium thiosulphate with an unknown number of molecules of water of crystallization, **X**.

Extracts 17.1, 17.2 and 17.3 are samples of correct responses for question 1 given by the candidates in alternative A, B, and C, respectively.



01:	TABLE OF RESULTS				
	Burette reading	PILOT	1	2	3
	Final readings (cm³) using MO	12.60	12.50	12.60	12.50
	Final readings (cm³) using POP	17.70	17.50	17.70	17.60
	Initial readings (cm³)	0.00	0.00	0.00	0.00
	Volume used (cm³) using MO	12.60	12.50	12.60	12.50
	Volume used (cm³) using POP	5.10	5.00	5.10	5.10

Average volume when MO was used.

Soln.

Recall from.

$$\text{Average volume} = \frac{(\text{Volume}_1 + \text{Volume}_2 + \text{Volume}_3)}{3} cm^3$$

$$\text{Average volume} = \frac{(12.50 + 12.60 + 12.50)}{3} cm^3$$

$$\text{Average volume} = \frac{(37.60)}{3} cm^3 = 12.5333.$$

Hence the average volume when MO was used $= 12.533 \approx 12.5 cm^3$

Average volume when POP was used

Soln

Recall from

$$\text{Average volume} = \frac{(\text{volume}_1 + \text{volume}_2 + \text{volume}_3)}{3} cm^3$$

$$\text{Average volume} = \frac{(5.00 + 5.10 + 5.10)}{3} cm^3$$

01:

$$\text{Average volume} = \frac{15.2}{3} cm^3 = 5.066.$$

Hence the average volume used when P.O.P was used $= 5.0666 \approx 5.10 cm^3$

Summary.

i) The volume of the pipette used was $25 cm^3$

ii) $25 cm^3$ of U_1 required $12.53 cm^3$ of U_2 when MO was used, and $5.10 cm^3$ of U_2 when P.O.P was used

d) i) when P.O.P was used Soln.

Data given

Molarity of base (NaOH), $M_b = 0.1M$.

Molarity of acid (~~HCl~~ CH_3COOH), $M_a = ?$

Volume of acid (~~HCl~~ CH_3COOH), $V_a = 25 cm^3$

Volume of base (NaOH), $V_b = 5.10 cm^3$

Number of mole of acid (~~HCl~~ CH_3COOH), $n_a = 1$

Number of mole of base (NaOH), $n_b = 1$

Consider the equations below inorder to determine number of mole reacted

When MO was used $\rightarrow HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(aq)}$ ---------- (i)

When P.O.P was used $\rightarrow CH_3COOH_{(aq)} + NaOH_{(aq)} \longrightarrow CH_3COONa_{(aq)} + H_2O_{(aq)}$ ---- (ii)

Since P.O.P was used the equation ---(ii) is considered

Then recall from

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

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

$$M_a = \frac{0.1 \times 5.10 \times 1}{25 \times 1} = 0.02M$$

01· (a)(i) Found that Molarity of acetic acid = 0·02M

Then recall from.

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

$$Molarity = \frac{Concentration}{Molar\ mass\ (CH_3COOH)}$$

$$Concentration = Molarity \times Molar\ mass_{CH_3COOH}$$

$$= 0{\cdot}02 \times (12+3+12+16+16+1)$$

$$= 0{\cdot}02 \times 60 = 1{\cdot}2\ g/dm^3$$

Hence

Concentration of acid solution, U, in g/dm³ when P.O.P was used is $1{\cdot}2\ g/dm^3$

(ii) When M.O was used

Soln.

When MO was used equation --(i) will be considered

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(s)} + H_2O$$

where

number of moles of acid HCl, na = 1

number of moles of base, NaCl, nb = 1

Molarity of base, NaCl, Mb = 0·1M

Molarity of acid, HCl, Ma = ?

Volume of acid HCl, $Va = 25cm^3$

Volume of base, NaCl, $Vb = 12{\cdot}53cm^3$

Then recall from

$$\frac{MaVana}{Vana} = \frac{MbVbnb}{Vana}$$

$$Ma = \frac{0{\cdot}1 \times 12{\cdot}53 \times 1}{25 \times 1} = 0{\cdot}050127 \approx 0{\cdot}05M$$

$$Ma = 0{\cdot}05M$$

01; (a)(ii) Then recall from.

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

$$Concentration = Molar\ mass \times Molarity$$

~~= (23 + 35·5) × 0·05~~

$$= (1 + 35{\cdot}5) \times 0{\cdot}05$$

$$= 36{\cdot}5 \times 0{\cdot}05 = 1{\cdot}825\ g/dm^3$$

$$= 1{\cdot}825\ g/dm^3$$

Hence

Concentration of acid solution when, ~~P.O.P~~ M.O was used is $1{\cdot}825\ g/dm^3$

(b) The colour changed from PINK to YELLOW when MO was used and from YELLOW to PINK when POP was used, as indicators

(c) The compounds reacted during the first titration were hydrochloric acid and NaOH.

ie

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(s)} + H_2O_{(aq)}$$

– The compounds reacted during the second titration were Acetic acid and sodium hydroxide

$$CH_3COOH_{(aq)} + NaOH_{(aq)} \longrightarrow CH_3COONa_{(s)} + H_2O_{(aq)}$$

Extract 17.1*:* A sample of correct responses in question 1 of the alternative practical A

In Extract 17.1, the candidate filled the table of results appropriately by observing the required decimal points (two decimal places). The candidate calculated the titre value correctly and 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 given acids and the base. Hence, determined proportional volumes correctly. Thereafter, he/she performed all the required calculations in the remaining parts of the question correctly.

1 Table of values.

Titre	PILOT	1	2	3
Final volume in cm^3	25.40	24.80	49.80	25.20
Initial volume in cm^3	0.00	0.00	24.80	0.00
Volume used in cm^3	25.40	24.80	25.00	25.20

Mean titre $= \frac{V_1 + V_2 + V_3}{3}$

$= \frac{24.80 + 25.00 + 25.20}{3}$

Mean titre $= 25.00 cm^3$

SUMMARY

1 i) The volume of pipette used was 25 cm^3.

ii) 25 cm^3 of M_1 liberated iodine that required 25.00 cm^3 of M_2 for complete reaction.

1@ Concentration $= \frac{\text{Mass}}{\text{Volume}}$

1 dm^3 = 1000 cm^3

x = 500 cm^3

x = 0.5 dm^3

$= \frac{12.4g}{0.5 dm^3}$

Concentration = 24.8 g/dm^3

1@	Molarity = $\frac{\text{Concentration}}{\text{Molarmass}}$
	$Mr(Na_2S_2O_3 \cdot 5H_2O) = 248 g/mol$
	$= \frac{24.8}{248}$
	$= 0.1\ mol/dm^3$
	∴ Concentration of $M_2 = 0.1 mol/dm^3$.
1 b)	Half reduction reaction
	$I_2 \longrightarrow I^-$
	$I_2 \longrightarrow 2I^-$
	$I_{2(aq)} + 2e \longrightarrow 2I^-_{(aq)}$
	∴ $I_{2(aq)} + 2\bar{e} \longrightarrow 2I^-_{(aq)}$ oxidant
	Half oxidation reaction
	$S_2O_3^{2-} \longrightarrow S_4O_6^{2-}$
	$2S_2O_3^{2-} \longrightarrow S_4O_6^{2-}$
	$2S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2\bar{e}$
	∴ $2S_2O_3^{2-}{}_{(aq)} \longrightarrow S_4O_6^{2-}{}_{(aq)} + 2\bar{e}$ Reductant
	∴ Oxidant is I_2
	Reductant is $S_2O_3^{2-}$

1 c)	i) To obtain overall equuction
	$+\begin{cases} 2Cu^{2+} + 4I^- \longrightarrow Cu_2I_2 + I_2. \\ 2S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2+} + 2I^-. \end{cases}$
	Overall equation.
	$2Cu^{2+} + 2S_2O_3^{2+} + 2I^- \longrightarrow Cu_2I_2 + S_4O_6^{2-}$
	From this the ratio is 2 : 2.
	Given
	Molarity of $CuSO_4 (M_{Cu^{2+}})$ =
	Volume of $CuSO_4 (V_{Cu^{2+}}) = 25 cm^3$
	Molarity of $Na_2S_2O_3 (M_{S_2O_3^{2-}}) = 0.1 M$
	Volume of $Na_2S_2O_3 (M_{S_2O_3^{2-}}) = 25 cm^3$
	Number of moles of $CuSO_4 (n_{Cu^{2+}}) = 2$
	Number of moles of $Na_2S_2O_3 (n_{S_2O_3^{2-}}) = 2$
	From,
	$\frac{M_{Cu^{2+}} V_{Cu^{2+}}}{M_{S_2O_3^{2-}} V_{S_2O_3^{2-}}} = \frac{n_{Cu^{2+}}}{n_{S_2O_3^{2-}}}$
	$M_{Cu^{2+}} = \frac{M_{S_2O_3^{2-}} V_{S_2O_3^{2-}} n_{Cu^{2+}}}{V_{Cu^{2+}} n_{S_2O_3^{2-}}}$
	$= \frac{0.1 \times 25 \times 2}{25 \times 2}$
	$= 0.1 mol/dm^3$.
	∴ Molarity of $M_1 = 0.1 mol/dm^3$

1 c) ii) Concentration = $\frac{\text{mass}}{\text{Volume}}$

$= \frac{6.25g}{250 \times 10^{-3}}$

$= 25 g/dm^3$

∴ Concentration of M_1 = $25 g/dm^3$.

1 c iii) From,

Molarity = $\frac{\text{Concentration}}{\text{Molarmass}}$

Molarmass = $\frac{\text{Concentration}}{\text{Molarity}}$

$= \frac{25}{0.1}$

Molar mass = 250 g/mol

$Mr(CuSO_4 \cdot xH_2O) = 250$

$64 + 32 + (16 \times 4) + 18x = 250$

$160 + 18x = 250$

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

$x = 5$

∴ The value of $x = 5$

Extract 17.2*:* A sample of correct responses in question 1 of the alternative practical B

In Extract 17.2, the candidate filled the table of results and gave the volumes in two decimal places as required. He/she was able to arrive to a correct titre value that was within the required range (i.e ±0.5 cm^3). The candidate answered the remaining parts of the question correctly.

01. ~~THE~~ TABLE OF RESULTS.

Titre values	Pilot	1	2	3.
Final Volume (cm^3)	21.40	21.20	42.50	20.90
initial volume (cm^3)	00.00	00.00	21.20	00.00
Volume used (cm^3)	21.40	21.20	21.30	20.90

The Average volume = $\frac{T_1 + T_2 + T_3}{3}$

$= \frac{21.20 + 21.30 + 20.90}{3}$

$= 21.13 cm^3$.

(i) The volume of the pipette used was $20 cm^3$.

(ii) 20 cm^3 of A liberated Iodine that required 21.13 cm^3 of B for complete reaction.

(a) the role of D in this experiment is that, it acts as an indicator.

(b) the main purpose of adding solution C into a conical flask containing acidified solution of A is to make sure that Iodine is liberated from the solutions, and the liberated Iodine reacts with sodium thiosulphate $Na_2S_2O_3$.

Q1. (c) It is advisable to add solution D just close to the end point in the experiment so as to avoid the formation of starch complex.

(d)(i) concentration of A in g/dm^3.

concentration of A = $\frac{\text{mass}}{\text{volume}}$

concentration of A = $\frac{1.58 g}{0.5 dm^3}$

concentration of A = 3.16 g/dm^3.

∴ concentration of A = 3.16 g/dm^3

(ii) molarity of A = $\frac{\text{concentration}}{\text{molar mass}}$

molarity of A = $\frac{3.16 \text{ g/dm}^3}{158 \text{ mol/dm}^3}$

molarity of A = 0.02 M.

∴ Molarity of A = 0.02 M.

Q1(d)(iii) Molarity of $Na_2S_2O_3$.

$\frac{M_{Na_2S_2O_3} V_{Na_2S_2O_3}}{n_{Na_2S_2O_3}} = \frac{M_{KMnO_4} V_{KMnO_4}}{n_{KMnO_4}}$

$M_{Na_2S_2O_3} = \frac{n_{Na_2S_2O_3} M_{KMnO_4} V_{KMnO_4}}{n_{KMnO_4} V_{Na_2S_2O_3}}$

From the balanced chemical equation.

$2MnO_4^- + 10S_2O_3^{2-} + 16H^+ + 5I_2 \rightarrow 2Mn^{2+} + 5S_4O_6^{2-} + 8H_2O + 2I_2$

number of moles are 2 : 10.

$$M_{Na_2S_2O_3} = \frac{10 \times 0.02 \times 20 cm^3}{2 \times 21.13}$$

$M_{Na_2S_2O_3} = 0.0946 M$.

∴ Molarity of $Na_2S_2O_3$ is 0.0946 M.

(iv) concentration of $Na_2S_2O_3$ in g/dm^3.

$$concentration = \frac{mass}{Volume}$$

$$concentration = \frac{5.8 g}{0.25 dm^3}$$

concentration = 23.2 g/dm^3.

∴ concentration of $Na_2S_2O_3$ = 23.2 g/dm^3.

Q1. (e) To find the value of x.

$$\frac{\text{concentration of anhydrous}}{\text{concentration of hydrated}} = \frac{\text{molar mass of anhydrous}}{\text{molar mass of hydrated}}$$

concentration of anhydrous = Molarity × molar mass.

= 0.0946 × 158

= 14.9468 g/dm^3.

from the formula.

$$\frac{14.9468 g/dm^3}{23.2 g/dm^3} = \frac{158}{158 + 18x}$$

14.9468 × (158 + 18x) = 23.2 × 158

2361.5944 + 269.0424x = 3665.6

269.0424 x = 3665.6 − 2361.5944

$$x = \frac{1304.0056}{269.0424}$$

x = 5

∴ The value of x = 5.

Extract 17.3*:* A sample of correct responses in question 1 of the alternative practical C

In Extract 17.3, the candidate observed all the required conditions in filling the table and correctly calculated the required concentrations. Finally, he/she performed appropriate calculations to get the correct value of **X** (the number of molecules of water of crystallization).

However, some of the few candidates amounting to 1,908 (5.5%) scored low marks (from 0 – 6.5) in question 1 (Table 3). The analysis of responses in their scripts shows that they had insufficient knowledge of the subtopic of *Volumetric Analysis* despite the fact that it was studied in the topic of *Volumetric Analysis and Related Calculations* in form three. This is signified by the mistakes observed in their responses such as failing to record and manipulate experimental data according to the requirement of the question. Some of the candidates designed and filled the volumetric table (Table of results) using one decimal place instead of two. Moreover, they lacked accuracy in performing the titration experiment. Hence, they got titre values which are out of range. Additionally, some of the candidates used indicators **MO** and **POP** in contrary to the experimental procedures. As a result, they observed irrelevant colours.

Another factor which contributed to the weak performance of these candidates was using wrong chemical equations. For example, in responding to part (a) of the alternative paper A, one of the candidates wrote the reactions that took place when MO and POP were used as "$CH_3COOH + NaOH \xrightarrow{MO} CH_3COONa + H_2O$

$HCl + NaOH \xrightarrow{POP} NaCl + H_2O$".

Although the chemical reactions are correct and balanced, the candidate exchanged them. The candidate was supposed to be familiar with the concept of choosing suitable indicators. Thus he/she would have realized that 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:

$$HCl + NaOH \xrightarrow{MO} NaCl + H_2O$$

$$CH_3COOH + NaOH \xrightarrow{POP} CH_3COONa + H_2O\ .$$

Yet, some of the candidates, while responding to part (a) of the same alternative paper, wrote the formulae for the reacting species incorrectly.

Hence, they failed to proceed correctly to other parts of the question. For example, one of the candidates wrote the formula for the acetic acid as *CH_3CH_2COOH* instead of CH_3COOH. Due to that mistake, the candidate missed the marks intended for both writing the correct chemical equation and correct value of **U1** in g/dm^3.

It was also noted in the scripts of the candidates who attempted alternative B that some of them incorrectly identified the oxidant and reductant agents in part (b). For example, one of the candidates wrote, "*$2S_2O_3^{2-}$ is oxidant and $S_4O_6^{2-}$ is a reductant*" contrary to the fact. The candidate was supposed to deduce $S_2O_3^{2-}$ as the reducing agent and I_2 as an oxidizing agent in the experiment. Extracts 17.4, 17.5 and 17.6 show sample responses given by the candidates in question 1 of the alternative papers A, B and C, respectively.

1. Table of result.

Burette Reading	Pilot	1	2	3
Final reading (cm³) Using MO	11.09	11·06	11·06	11·06.
Final reading (cm³) Using P·OP	18·03	17·09	17·08	17·08.
Initial reading (cm³)	0·00	0·00	0·00	0·00
Volume used (cm³) Using MO	11·09	11·06	11·06	11·06
Volume used Using POP	6·94	6·03	6·02	6·02

(i) The volume of pipette used was 25cm³

(ii) 25 cm³ of U1 required 11·06 cm³ of U2 when MO was used and 6·02 cm³ of U2 when POP was used

When POP was used.

(a) (i) Soln.

Concentration = Mass/Volume.

But Density = mass/volume.

Mass = density × Volume.

Mass 1 × 6·02.

Mass = 6·02 g

Concentration = 6·02g / 6·02 × 10⁻³ dm³

Concentration = 1×10³ g/dm³

Concentration = 1×10³ g/dm³.

1.(a) When MO was used

Contetration = Mass / Volume.

But

Density = Mass / Volume.

Mass = Density × Volume.

1 × 25

Mass = 25g.

Volume of MO = 11.06 cm³ → dm³

11.06cm³ / 1000 = 0.01106 dm³.

Concentration = Mass / Volume.

Concentration = 25g / 0.01106dm³.

Concentration = 2.26 × 10³.

Concentration = 2.3 × 10³ g/dm³.

Extract 17.4*:* A sample of incorrect responses in question 1 of the alternative practical A

In Extract 17.4, although the candidate filled in results in the table, he/she failed to perform the required calculations. The candidate wrongly used the formula $Concentration = mass / volume$ to calculate the required concentration in part (a). The candidate was supposed to substitute the required data in the formula, $M_a = \frac{n_a \times M_b \times V_b}{n_b \times V_a}$ 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.

1.		Pilot	1	2	3
	final read	33.00	34.00	33.00	35.00
	Start read	00.00	00.00	00.00	00.00
	Total read.	33.00	34.00	33.00	35.00

Average = (34.00 + 33.00 + 35.00) / 3

Average = 34.00 cm³

i/ the volume of the pipette was 3400 cm^3

ii/ 25 cm^3 of M1 liberated iodine that required 10 cm^3 of M2 for complete reaction.

(a) Conc = $\frac{Mass}{Mr}$

Conc = $\frac{12.40g}{248}$

Conc = 0.05

∴ Conc = 0.05 mol/dm^3

(b) $2Cu^{2+} + 4I^- \rightarrow Cu_2I_2 + I_2$ --- (i)

$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$ --- (ii)

Extract 17.5*:* A sample of incorrect responses in question 1 of the alternative practical B

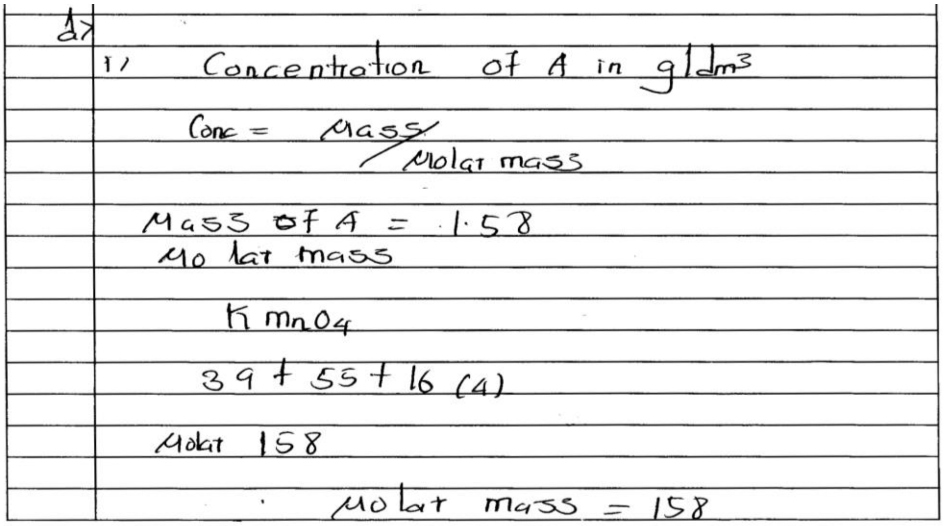
In Extract 17.5, the candidate, apart from getting the volumes out of range, used a wrong formula to calculate the concentration in part (a) of the question. In part (b), he/she gave incorrect half-reaction equations instead of $2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2e^-$ for oxidation and $2Cu^{2+} + 2I^- + 2e^- \rightarrow Cu_2I_2$ for reduction process.

1

Summary

i7 26.8.

b) The main purpose of adding solution C is to neutralize the solution A which have already acidified.



d) i) Concentration of A in g/dm³

Conc = Mass / Molar mass

Mass of A = 1.58

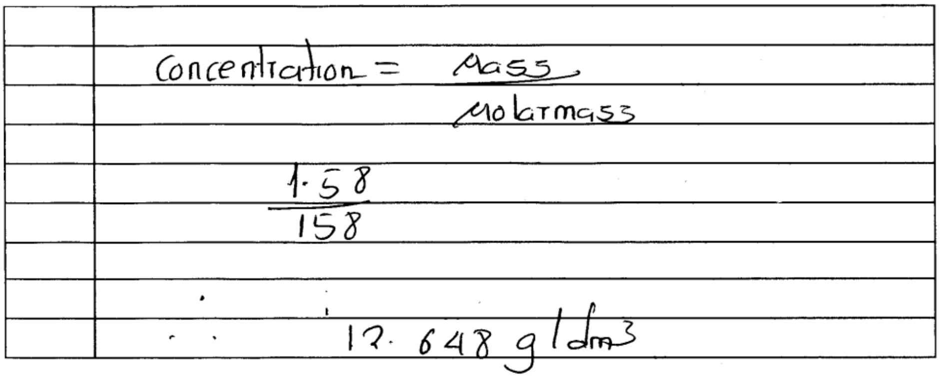
Molar mass

KMnO4

39 + 55 + 16 (4)

Molar 158

Molar mass = 158



Concentration = Mass / Molarmass

1.58 / 158

12.648 g/dm³

Extract 17.6: A sample of incorrect responses in question 1 of the alternative practical C

In Extract 17.6, the candidate tried to design a table of results but did not fill in any data. He/she wrote the volume 26.8 cm^3 without indicating if it was a volume of the pipette used or the mean titre value as required in the summary part of the question. In part (b), the candidate gave a wrong purpose for adding solution **C** into a conical flask containing solution **A**. The candidate was expected to respond that the main purpose for adding solution **C** (iodine) into a conical flask containing solution **A**, was to liberate iodine which would then react with solution **B** (sodium thiosulphate) from the burette.

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:*

***A1**: A solution of 0.2 M sodium thiosulphate;*

***A2**: A solution of 0.1 M hydrochloric acid;*

***A3**: Distilled water;*

Stop watch/clock;

*A sheet of white paper marked **X**.*

Theory

The rate of reaction between thiosulphate and an acid is given by:

Reaction = $-\frac{d[\text{thiosulphate}]}{dt} = K[\text{thiosulphate}]^m[\text{acid}]^n$, *where **K** is the rate constant and the integers **m** and **n** are orders of reaction with respect to thiosulphate and acid.*

Procedure

*(i) Put a 50 cm^3 beaker on top of a letter **X** on the white paper in such a way that the mark is clearly seen through the bottom of the beaker.*

*(ii) Measure 2 cm^3 of **A1** and 8 cm^3 of **A3** and put them in the beaker placed on top of a sheet of white paper in procedure (i) above.*

*(iii) Measure 10 cm^3 of **A2** and pour in the beaker containing **A1** and **A3** and immediately start a stop watch.*

*(iv) Record the time taken for the precipitation to obscure the mark **X**.*

(v) Repeat the experiment for different sets of volumes as shown in Table 2:

Table 2: Experimental Table

Experiment	***Volume of A1 (cm^3)***	***Volume of A3 (cm^3) water***	***Volume of A2 (cm^3)***	***Time (sec)***	***1/time (s^{-1})***
(a)	*2*	*8*	*10*		
(b)	*4*	*6*	*10*		
(c)	*6*	*4*	*10*		
(d)	*8*	*2*	*10*		
(e)	*10*	*0*	*10*		

Questions

(a) *Write the ionic equation for the reaction.*
(b) *Calculate the value of* ***m****.*
(c) *Given that, the value of* ***n = 2****, find the value of* ***K*** *for experiments (a) and (b), then comment on the value of* ***K*** *obtained.*
(d) *From the experiment conducted, is it possible for the value of* ***n*** *to be found? Give a reason for your answer.*
(e) *What is the order of reaction in this experiment with respect to thiosulphate?*"

Question 2 of 132/3B Chemistry 3B was as follows:

"*You are provided with the following:*
C1*:* *0.2 M sodium thiosulphate solution;*
C2*:* *0.1 M hydrochloric acid solution;*
C3*:* *Distilled water;*
Stop watch/clock;
A white plain sheet of paper marked ***X****.*

Theory

The rate of reaction between thiosulphate ion and an acid is given by,

Reaction rate = $\frac{\delta[S_2O_3^{2-}]}{\delta t} = K[S_2O_3^{2-}]^m[H^+]^n$. *Where m is the order of the reaction with respect to* $S_2O_3^{2-}$ *and n is the order of reaction with respect to* H^+.

Procedure

(i) *Place a 50 cm*^{3} *beaker on top of a white plain paper marked* ***X*** *in such a way that the mark is clearly seen through the bottom of the beaker.*
(ii) *Measure 2 cm*^{3} *of* ***C1*** *and 8 cm*^{3} *of* ***C3*** *and put them in a 50 cm*^{3} *beaker in procedure (i) above.*
(iii) *Measure 10 cm*^{3} *of* ***C2*** *and pour the content into a beaker in procedure (ii) and immediately start the stop watch.*
(iv) *Record the time taken for the mark* ***X*** *to disappear.*

(v) *Discard the contents and clean the conical flask, then, repeat the procedures (i) to (iv) using the specifications as indicated in Table 1.*

Table 1: Experimental Table

Experiment	***Volume of C1 (cm³)***	***Volume of C3 (cm³)***	***Volume of C2 (cm³)***	***Time, t (sec.)***	$\frac{1}{time}(S^{-1})$
A	*2*	*8*	*10*		
B	*4*	*6*	*10*		
C	*6*	*4*	*10*		
D	*8*	*2*	*10*		
E	*10*	*0*	*10*		

Questions

(a) *Write the ionic equation for the experiment.*

(b) *Plot the graph of* $\frac{1}{t}$ *(vertical axis) against the volume of sodium thiosulphate (horizontal axis).*

(c) *Determine the order of the reaction with respect to sodium thiosulphate from the graph.*

(d) *Given that, the value of n is 2, determine the order of reaction with respect to sodium thiosulphate using rate law equation.*

(e) *Comment on the order of reaction obtained in (c) and (d).*

(f) *Find the value of K.*

(g) *What causes the precipitate to occur in the reaction?*"

Question 2 of 132/3C Chemistry 3C was as follows:

"*You are provided with the following:*

***C1**:* *A solution of 0.1 M* $Na_2S_2O_3$*;*

***C2**:* *A solution of 0.1 M HCl;*

Stop watch/clock;

Thermometer;

*White plain sheet of paper marked **X**.*

Procedure

(i) *Put a 50 cm^3 beaker on top of a white sheet of paper marked **X** in such a way that the mark is clearly seen through the bottom of the beaker.*

(ii) *Put about 200 cm^3 of water into a 250 or 300 cm^3 beaker. Heat the beaker containing water. Use this as the water bath.*

(iii) *Measure 10 cm^3 of **C1** and 10 cm^3 of **C2** and put into separate boiling test tubes.*

(iv) *Take the test tubes containing **C1** and **C2** and put into the water bath; allow the contents to warm to 35 ℃.*

(v) *Pour the contents into a 50 cm^3 beaker placed on top of a mark **X** and immediately start a stop clock. Record the time taken for the mark **X** to disappear.*

(vi) *Repeat procedures (iii) to (v) by varying the temperature of the contents as indicated in Table 1.*

Table 1: Experimental data

Temperature (℃)	***Time for reaction, t (Sec)***	***1/t (Sec^{-1})***
35		
40		
45		
50		
55		
60		

Questions

(a) *(i)* *Write a balanced reaction equation for the experiment.*

(ii) *Explain what makes letter **X** to disappear.*

(b) *Using different axes, plot a graph of;*

(i) *time, t (s) used against temperature, T (^oC).*

(ii) $1/\text{time}$ *(s^{-1}) against temperature, T (^oC).*

(c) *Study the graphs in (b) and explain how the rate of reaction changes with temperature.”*

The question was attempted by a total of 34,411 (99.8%) candidates, out of which, 23,193 (67.4%) scored from 9.0 – 15 marks, indicating a good score. Further, 7,620 (22.1%) scored from 5.5 – 8.5 marks, indicating an average score and 3,598 (10.5%) scored from 0 – 5.0 marks, indicating a weak score.

The overall performance of the candidates in the question was good, as the majority (89.5%) of the candidates scored a pass mark or above (≥5.5 marks). The candidates who performed well in question 2 showed to have mastered the concepts about the subtopic of *Physical Chemistry Analysis* properly. These candidates managed to determine the order of the given reaction in the alternative papers A and 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 correct responses for question 2 given by a candidate in alternative A, B, and C, respectively.

2. Table of results.

Experiment	Volume of A_1 (cm^3)	Volume A_3 (cm^3)	Volume of A_2 (cm^3)	Time (sec)	1/time (sec^{-1})
a	2	8	10	422	2.3697×10^{-3}
b	4	6	10	208	4.8077×10^{-3}
c	6	4	10	119	8.4034×10^{-3}
d	8	2	10	79	0.0127
e	10	0	10	63	0.0159

(a) $S_2O_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \longrightarrow SO_{2(g)} + S_{(s)} + H_2O_{(l)}$

$\therefore S_2O_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \longrightarrow SO_{2(s)} + S_{(s)} + H_2O_{(l)}$

b) By using experiments d and e.

$R = K[\text{Thiosulphate}]^m[\text{acid}]^n$.

Assuming volume is directly proportional to concentration.

and let Rd and Re be the rates of experiment d and e respectively.

$\therefore Rd = K[\text{thiosulphate}]^m[\text{acid}]^n$ —— i)

$Re = K[\text{thiosulphate}]^m[\text{acid}]^n$ —— ii)

Taking $\frac{ii}{i} = \frac{0.0159}{0.0127} = \frac{K}{K}\left[\frac{10cm^3}{8cm^3}\right]^m\left[\frac{10cm^3}{10cm^3}\right]^n$

$\therefore 1.252 = \left(\frac{10}{8}\right)^m$

2 (b) $1.252 = (1.25)^m$

Apply logarithm both sides

$\log(1.252) = m \log(1.25)$

$m = 1.0072$

$m \approx 1$

$\therefore m \approx 1$ (1 significant figure).

(c) Given $n = 2$

For experiment a

$R = K[\text{thiosulphate}][\text{Acid}]^2$

$R = K(2cm^3)(10cm^3)^2$

$2.3697 \times 10^{-3}/s = 200\,cm^9 K$

$K = 1.18485 \times 10^{-5}/cm^9 s$

$\therefore K \approx 1.185 \times 10^{-5} cm^{-9} s^{-1}$ (4 s.f)

$\approx 1.18 \times 10^{-5} cm^{-9} s^{-1}$ (3 s.f)

For experiment b

$R = K[\text{thiosulphate}][\text{Acid}]^2$

$4.8077 \times 10^{-3} = K(4cm^3) \times (10cm^3)^2$

$K = 1.201925 \times 10^{-5} cm^{-9} s^{-1}$

$K \approx 1.20 \times 10^{-5} cm^{-9} s^{-1}$ (3 s.f)

hence, the value of K obtained is approaching to the same value. This shows that the rate constant of any reaction is not altered by

2 (c) varying concentration of reactants specifically thiosulphate in the question given.

(d) It is not possible to find the value of "n" since the concentration of HCl is kept constant hence not possible to determine its order of reaction.

(e) The order of reaction in this experiment with respect to thiosulphate is 1st order since $m = 1$.

Extract 18.1: A sample of correct responses in question 2 of the alternative practical A

In Extract 18.1, the candidate managed to fill in the experimental data in the table and performed all the required calculations correctly.

2. Experimental table.

Exp.	Volume of C_1 (cm^3)	Volume of C_3 (cm^3)	Volume of C_2 (cm^3)	Time (t) (sec)	1/time (sec^{-1})
A	2	8	10	872	1.5×10^{-3}
B	4	6	10	302	3.3×10^{-3}
C	6	4	10	166	6.02×10^{-3}
D	8	2	10	125	8×10^{-3}
E	10	0	10	94	10.6×10^{-3}

Questions

a) The ionic equation.

from

$Na_2S_2O_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + SO_2(g) + S(s) + H_2O(l)$

$2Na^+(aq) + S_2O_3^{2-}(aq) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow 2Na^+(aq) + 2Cl^-(aq)$

$+ SO_2(g) + S(s) + H_2O(l)$

∴ The ionic equation is

$S_2O_3^{2-}(aq) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow SO_2(g) + S(s) + H_2O(l)$

$S_2O_3^{2-}(aq) + 2H^+(aq) + \longrightarrow SO_2(g) + S(s) + H_2O(l)$

2d. $n = 2$

$R = K[S_2O_3^{2-}]^m[H^+]^n$

$R = 1/t$.

for experiment 1

$1.2 \times 10^{-3} = K[2]^m[10]^2$ ---- (i)

for experiment 2

$3.3 \times 10^{-3} = K(4)^m(10)^2$ ---- (ii)

dividing equations (i) and (ii)

$$2 \approx \frac{3.3 \times 10^{-3}}{1.5 \times 10^{-3}} = \frac{K(4)^m(10)^2}{K(2)^m(10)^2}$$

$2^1 = 2^m$

$m = 1$

∴ The order of reaction with respect to $Na_2S_2O_3$ is 1.

c) Slope of the graph.

$$\text{Slope}, m = \frac{\Delta 1/t}{\Delta V}$$

$$= \frac{7 \times 10^{-3} - 4 \times 10^{-3}}{7 - 4.5}$$

$$= \frac{3 \times 10^{-3}}{2.5}$$

∴ Slope $= 1.2 \times 10^{-3}\ sec^{-1}\ cm^{-3}$

Since the slope of the graph is positive with negative

2c) intercept the graph is of first order.

d) The order of reaction obtained in (c) and (d) are the same showing That the graph is of first order of reaction with respect to $Na_2S_2O_3$ is first order.

f) for experiment 1

$R = K[S_2O_3^{2-}]^1 [H]^2$

$1.2 \times 10^{-3} = K_1 [2]^1 [10]^2$

$K_1 = \frac{1.2 \times 10^{-3}}{(2)^1 (10)^2}$

$K_1 = 6 \times 10^{-6} \text{ mol}^{-3} dm^6 sec^{-1}$

for exp 2

R $3.3 \times 10^{-3} = K_2 [4)^1 (10)^2$

$K_2 = \frac{3.3 \times 10^{-3}}{400}$

$K_2 = 8.25 \times 10^{-6} \text{ mol}^{-3} dm^6 sec^{-1}$

for exp 3

$6.02 \times 10^{-3} = K_3 (6)^1 (10)^2$

$K_3 = \frac{6.02 \times 10^{-3}}{600}$

$K_3 = 1.0 \times 10^{-5} \text{ mol}^{-3} dm^6 sec^{-1}$

2f) exp 4

$8 \times 10^{-3} = K_4 (8)^1 (10)^2$

$K_4 = \frac{8 \times 10^{-3}}{800}$

$K_4 = 1 \times 10^{-5} \text{ mol}^{-3} dm^6 sec^{-1}$

exp 5

$10.6 \times 10^{-3} = K_5 (10)^1 (10)^2$

$K_5 = \frac{10.6 \times 10^{-3}}{1000}$

$K_5 = 1.06 \times 10^{-5} \text{ mol}^{-3} dm^6 sec^{-1}$

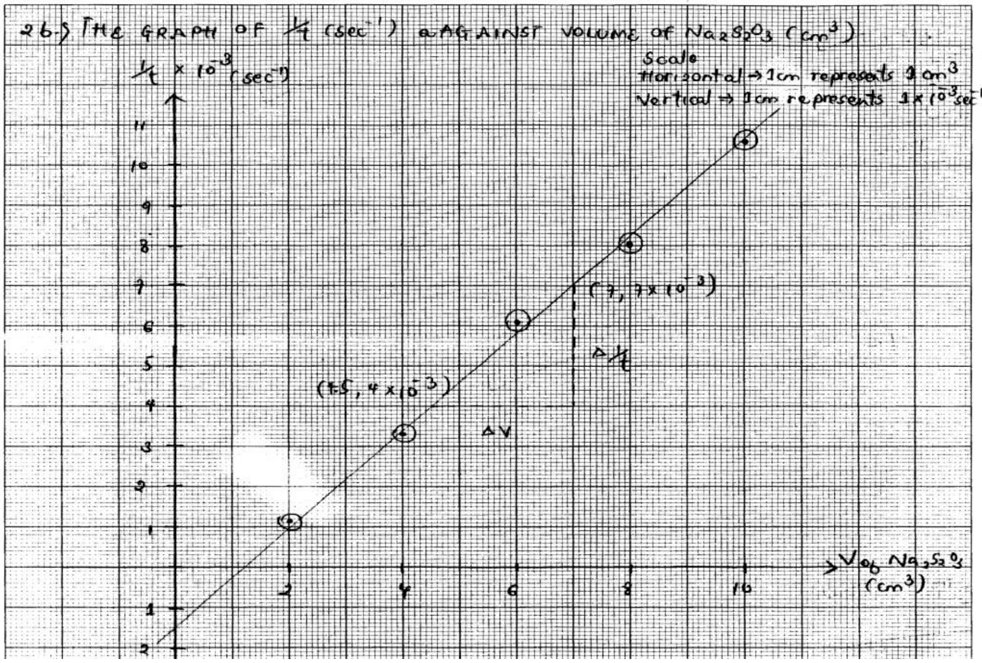
Average value of $K = \frac{K_1 + K_2 + K_3 + K_4 + K_5}{5}$

$K_{average} = \frac{6 \times 10^{-6} + 8.25 \times 10^{-6} + 1.0 \times 10^{-5} + 1 \times 10^{-5} + 1.06 \times 10^{-5}}{5}$

$= 8.97 \times 10^{-6}$

∴ Value of $K = 8.97 \times 10^{-6} \text{ mol}^{-3} dm^6 sec^{-1}$

5) The precipitate occur due to the formation of sulphur which is solid (insoluble)



Extract 18.2: A sample of correct responses in question 2 of the alternative practical B

In Extract 18.2, the candidate filled in the experimental table appropriately and correctly performed the required calculations in all parts of the question. In part (b), the candidate correctly plotted the graph of rate (s^{-1}) against the volume of sodium thiosulphate while taking into account the essential features of a graph.

Ans.

Experimental data

Temperature (°C)	Time for reaction, t (sec)	1/t (sec⁻¹)
35	51	1.96×10^{-2}
40	42	2.38×10^{-2}
45	38	2.63×10^{-2}
50	26	3.84×10^{-2}
55	19	5.26×10^{-2}
60	12	8.33×10^{-2}

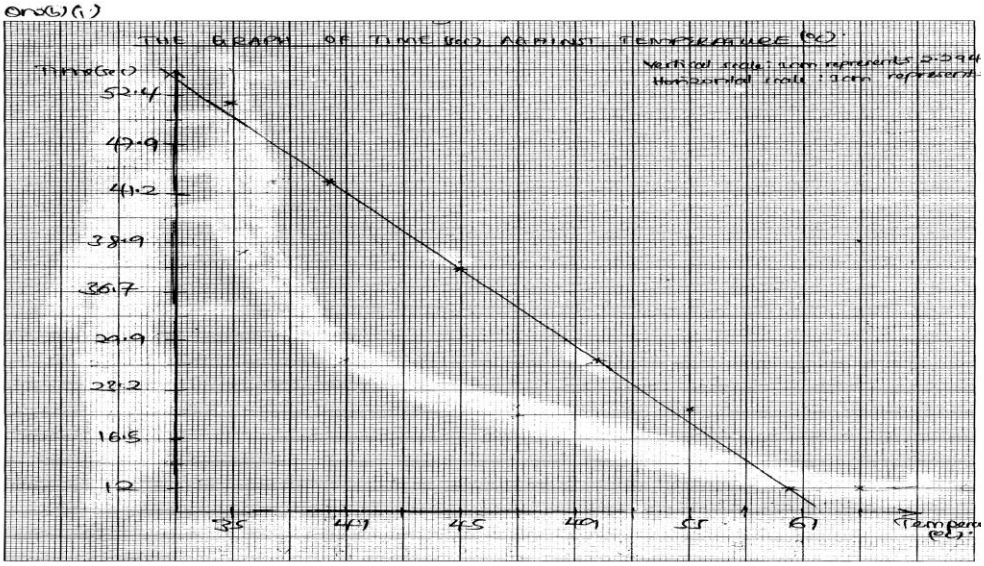
a) i) Balanced reaction equation for experiment i

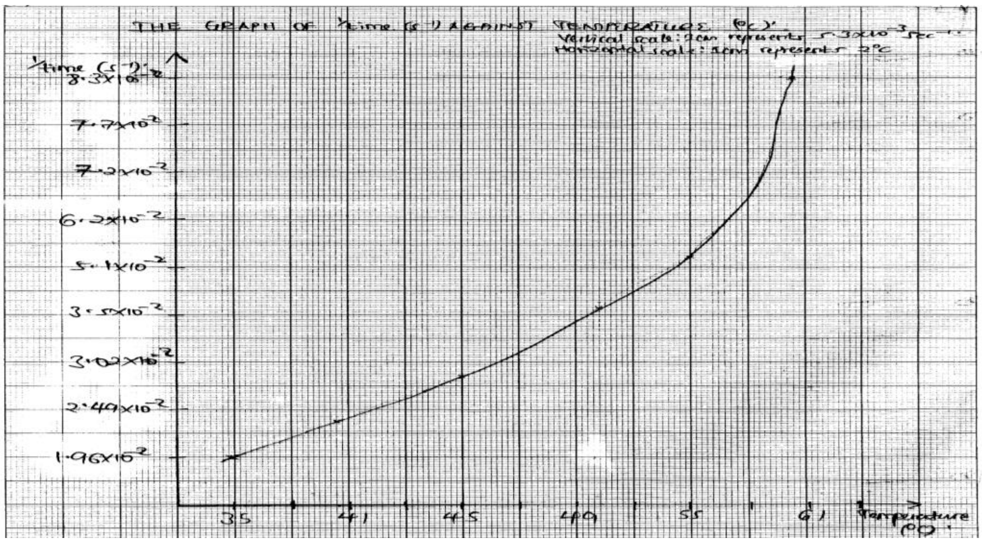
$Na_2S_2O_{3(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + SO_{2(g)} + S_{(s)} + H_2O_{(l)}$

Qn(a)(ii) The letter x was disappeared due to the formation of sulphur that cause the clouds formation thus the letter x disappeared.

c/ i) The temperature increases with the decrease in time where by, when the temperature increases, it leads to the increase in the rate of reaction, this increasing in temperature tend to increase the kinetic energy in the reaction mixture thus cause ~~coll~~ collision of particles to increase, thus due to this it also speeds up the rate of formation of clouds which cause disappearance of letter x, that is the increase in the rate of the reaction.

Qn(b)(i)





Extract 18.3*:* A sample of correct responses in question 2 of the alternative practical C

In Extract 18.3, the candidate managed to fill in the required experimental data in a table. The candidate managed to plot the graphs required and made correct interpretations.

However, some of the candidates (10.5%) scored low marks in this question. These candidates showed to have insufficient skills of determining the order of chemical reactions (alternative papers A and C) and analysing the factors affecting the rate of a chemical reaction (alternative paper B) experimentally. For example, one of the candidates, in attempting question 2 (a) and (c) of the alternative paper A, responded as follows:

“ $SO_2CO_3^{-2}(aq) \longrightarrow H_2O(l) + SO_2^{-2}(g) + S^{2-}$

Solution

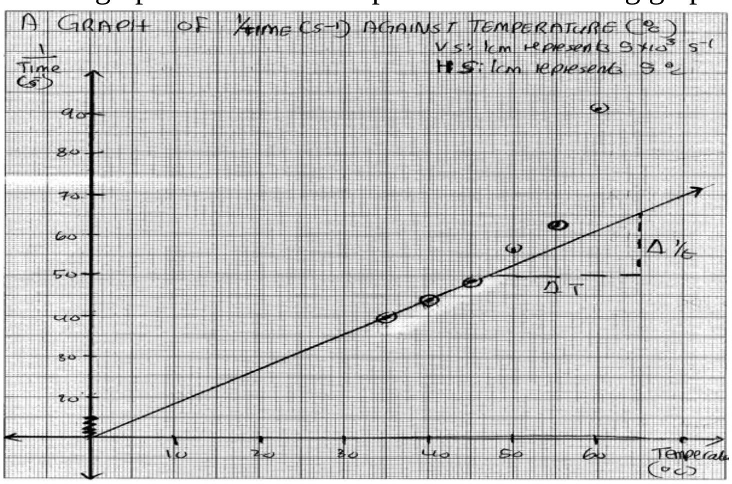
$n = 2$

$$k = \frac{Rate}{(SO_2CO_3}$$

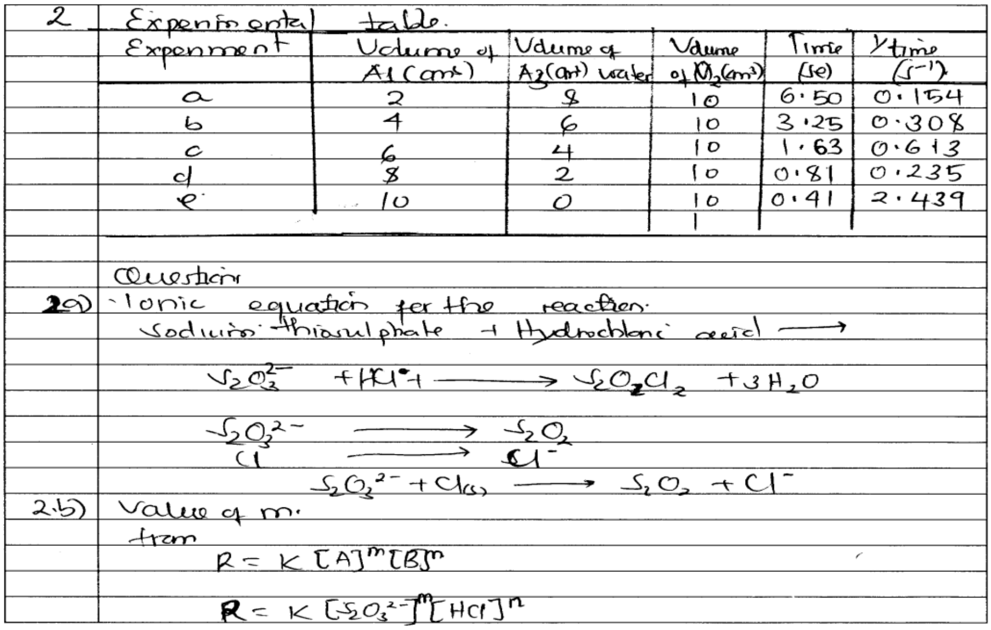
$$k = \frac{2}{\frac{1}{2}}, k = 2 \times \tfrac{1}{2} = \tfrac{2}{2}$$

K = 1”

In his/her responses, the candidate gave an incorrect ionic equation and incorrectly deduced the value of rate constant. This signified the lack of appropriate skills in chemical reactions and rate constant determination. Further analysis of the responses given by the candidates with low scores indicates that they were not knowledgeable of plotting appropriate graphs. For example, while responding to part (b) (ii) of the question in the alternative paper C, the candidate drew a straight line in contrary to the data points on his/her graph. The candidate plotted the following graph:



In his/her graph, the candidate joined the data points incorrectly. That is, the candidate did not use a free hand to draw the best line (which was a curve in this case) by passing through the data points indicated. Extracts 18.4, 18.5 and 18.6 show samples of incorrect responses in question 2 given by a candidate in alternative A, B, and C, respectively.



2 Experimental table.

Experiment	Volume of A1 (cm³)	Volume of A2 (cm³) water	Volume of O₂ (cm³)	Time (se)	1/time (s⁻¹)
a	2	8	10	6.50	0.154
b	4	6	10	3.25	0.308
c	6	4	10	1.63	0.613
d	8	2	10	0.81	0.235
e	10	0	10	0.41	2.439

Question

2a) Ionic equation for the reaction.
Sodium thiosulphate + Hydrochloric acid ⟶

$S_2O_3^{2-} + HCl^+ \longrightarrow S_2O_2Cl_2 + 3H_2O$

$S_2O_3^{2-} \longrightarrow S_2O_2$

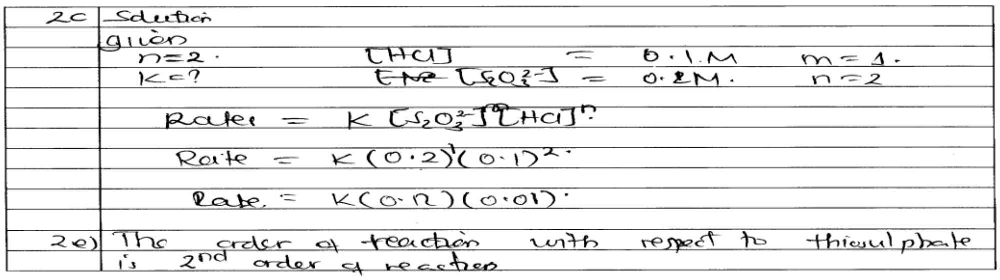
$Cl \longrightarrow Cl^-$

$S_2O_3^{2-} + Cl_{(s)} \longrightarrow S_2O_2 + Cl^-$

2.b) Value of m.
from

$R = K[A]^m[B]^n$

$R = K[S_2O_3^{2-}]^m[HCl]^n$



2c Solution
given

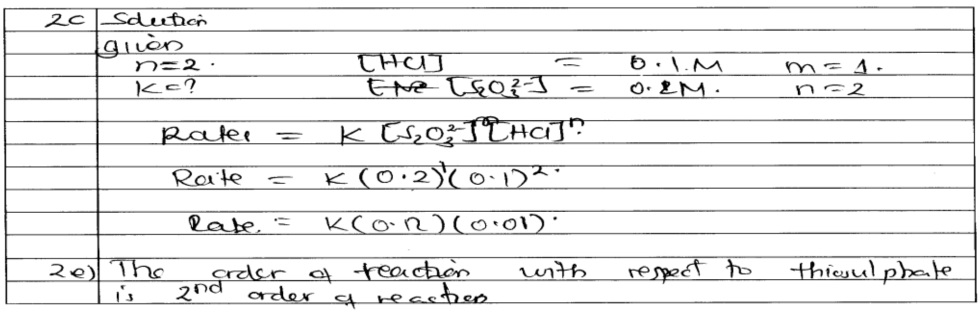
n=2. [HCl] = 0.1M m = 1.
K=? [SO₃²⁻] = 0.2M. n = 2

$Rate = K[S_2O_3^{2-}]^m[HCl]^n$

$Rate = K(0.2)^1(0.1)^2$

$Rate = K(0.2)(0.01)$

2e) The order of reaction with respect to thiosulphate is 2nd order of reaction



2c Solution
given

n=2. [HCl] = 0.1M m = 1.
K=? [SO₃²⁻] = 0.2M. n = 2

$Rate = K[S_2O_3^{2-}]^m[HCl]^n$

$Rate = K(0.2)^1(0.1)^2$

$Rate = K(0.2)(0.01)$

2e) The order of reaction with respect to thiosulphate is 2nd order of reaction

Extract 18.4: A sample of incorrect responses in question 2 of the alternative practical A

In Extract 18.4, the candidate incorrectly manipulated the data in the table of results, gave incorrect chemical equations and used incorrect data to calculate the rate of reaction.

2(a) $NaOH + HCl \rightarrow NaCl + H_2O$

$Na^+ OH^- + H^+ + Cl^- \rightarrow Na^+ + Cl^- + H_2O$

$OH^- + H^+ \rightarrow H_2O$

2(b) Table 1: Experimental Table.

Experiment	Volume of C_1 (cm³)	volume of C_3 (cm³)	volume of C_2 (cm³)	Time t (sec)	$\frac{1}{time}$ (sec⁻¹)
A	2	8	40	4	0.5
B	4	6	10	6	0.25
C	6	4	40	8	0.16
D	8	2	40	10	0.12
e	40	0	40	12	0.1

2(c) HCl when react with $Na_2S_2O_3$ precipitate occur because of the presence of Cl₂ gas Cl, when Cl react with H_2 to form HCl is too soluble that make reaction to precipitate

Extract 18.5*:* A sample of incorrect responses in question 2 of the alternative practical B

In Extract 18.5, the candidate incorrectly gave a neutralization reaction instead of an ionic reaction between HCl and $Na_2S_2O_3$ in part (a) of the question. In part (b), the candidate filled in the column for rate (s^{-1}), however the data were incorrect. Lastly, the candidate gave a reason for the occurrence of the precipitates in the experiment to be Cl. The candidate had a pre-idea that Cl^- can precipitate (of course it can if the salt formed was insoluble) but that scenario was not correct at this juncture because NaCl that was formed in the reaction is soluble. Precipitation in this case, as lightly highlighted in previous paragraph, was caused by the deposition of sulphur.

2. (a)

(i)

$2Na_2S_2O_3 + 2HCl \rightarrow NaCl_2 + SO_3 + H_2O$
(aq) (aq)

(ii) The formation of sulphur make x to dessapear which is SO_3

2. (a)

(i)

$2Na_2S_2O_3 + 2HCl \rightarrow NaCl_2 + SO_3 + H_2O$
(aq) (aq)

(ii) The formation of sulphur make x to dessapear which is SO_3

2 (b) Time(s) used against T

T (s) v/ T °C

from

$\log T = \frac{Ea}{2.303} R\left(\frac{1}{T}\right) - \log A$

$y = m + c$

Extract 18.6*:* A sample of incorrect responses in question 2 of the alternative practical C

In Extract 18.6, the candidate incorrectly wrote the reaction between $Na_2S_2O_3$ and HCl in part (a). In part (b), the candidate tried to state the nature of the graph from Arrhenius equation. However, he/she did not plot the graph as per the requirement of the question.

2.3.3 Question 3: Qualitative Analysis

Chemistry 3A, 3B and 3C

In 132/3A Chemistry 3A the question was as follows:

"*Sample **M** is a simple salt containing one cation and one anion. Carefully, carry out qualitative analysis experiment to identify the ions present in the salt based on the following tests:*

(a) *Appearance of the sample.*
(b) *Action of heat on the sample.*
(c) *Solubility.*
(d) *Action of aqueous sodium hydroxide on solution of **M**.*
(e) *Action of freshly prepared $FeSO_4$ solution on solution of **M** followed by concentrated H_2SO_4 through the side of the test tube.*
(f) *Action of lead ethanoate and then boil.*
(g) *Perform a confirmatory test for the cation and anion.*"

Questions

(i) *Prepare a relevant Table showing the qualitative analysis results.*
(ii) *Write a balanced chemical equation for the reaction in experiment*

In alternative B, the question was as follows:

"*You are provided with sample **Z** containing* **two** *cations and* **two** *anions. Carry out the experiments described in Table 2. Record carefully your observations, make appropriate inferences and finally identify the cations and anion present in sample **Z**.*

Table 2: Experimental Results

S/n	***Experiment***		***Observations***	***Inference***
(a)	*Take a spatulaful of sample **Z** into a boiling test tube then add about 3 cm^3 of distilled water. Heat gently the mixture for about one minute while swirling the test tube. Filter to obtain a clear solution and divide the resulting solution into three portions.*			
	(i)	*To the first portion add*		

S/n	Experiment		Observations	Inference
		NaOH solution.		
	(ii)	*To the second portion add dilute HNO_3 followed by $AgNO_3$ and then NH_3 solution.*		
	(iii)	*To the third portion, add ammonia solution.*		
(b)	*(i)*	*Dissolve the residue in a little quantity of HCl as possible and identify any resulting gas.*		
	(ii)	*Dilute the resulting solution in (a) (i) with distilled water and divide the solution into three portions.*		
		• *To the first portion, add few drops of $CaCl_2$ solution.*		
		• *To the second portion, add dilute NH_4OH till no further change.*		
		• *To the third portion add excess ammonia solution followed by ammonium oxalate solution.*		

Questions

(i) *Write the molecular formulas for the samples.*

(ii) *What are the cations and anions in the sample?*"

In alternative C, the candidates were asked as follows:

"*Sample **K** is a simple salt containing one cation and one anion. Carefully, carry out qualitative analysis experiment to identify the ions present in the salt based on the following tests:*

(h) *Appearance of the sample.*

(i) *Action of heat on the sample.*
(j) *Solubility.*
(k) *Action of aqueous sodium hydroxide on solution of **K**.*
(l) *Action of ammonia solution on solution of **K**.*
(m) *Action of $FeCl_3$ solution on solution of **K** followed by dilute HCl then boil.*
(n) *Perform flame test for sample **K**.*
(o) *Perform a confirmatory test for the cation and anion.*

Questions

(i) *Prepare a relevant Table showing the qualitative analysis results.*
(ii) *Write the molecular formula for the sample.*
(iii) *Write a balanced chemical equation of the reaction in experiment (b).*"

This question was attempted by all (100%) candidates. The candidates' performance in this question 3 is summarized in Table 4.

Table 4: Number, Percentages and Scores of the Candidates in Question 3

Scores	Number of Candidates	Percentage of Candidates
0 – 5.0	4,770	13.8
5.5 – 8.5	8,786	25.5
9.0 – 15	20,931	60.7

The candidates' overall performance in this question was good, as the majority (86.2%) of the candidates passed the question (scored marks ≥5.5). The candidates with a good performance in the question showed to have sufficient knowledge of carrying out qualitative analysis to identify cations and anions in a mixture of salts (in alternative A and B) or a single salt (in alternative C). Extracts 19.1, 19.2 and 19.3 show samples of correct responses in question 3 given by candidates in alternative A, B, and C, respectively.

3(i) S/n	Experiment	Observations	Inference.
(a)	Appearance of the sample		
	(i) Colour	White	Transition metals are absent
	(ii) Texture	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
(b)	Action of heat on the sample	Colourless gas with chocking smell which turns wet red litmus paper blue evolves and white sublimate on the cooler part of the test tube is formed	NH_4^+ may be present
(c)	Solubility	Soluble in cold water	(i) Cl^- may be present except those of Ag^+ and Pb^{2+} (ii) Na^+, K^+, NH_4^+ may be present (iii) CO_3^{2-} of Na, K^+, NH_4^+ may be present (iv) $C_2O_4^{2-}$ of Na^+, K^+, NH_4^+ may be present (v) SO_4^{2-} may be present except of Ba^{2+}, Sr^{2+}, Ca^{2+} and Pb^{2+} (vi) NO_3^-, CH_3COO^-, HCO_3^- may be present

3(i) S/n	Experiment	Observation	Inference
(d)	Action of aqueous sodium hydroxide on solution of M.	No precipitate	NH_4^+ may be present
(e)	Action of freshly prepared $FeSO_4$ solution on solution of M followed by concentrated H_2SO_4 through the side of the test tube.	No formation of a brown ring at the junction of the liquids	NO_3^- may be absent

				Salts of
	(f)	Action of lead	White precipitate	Cl^- may be
		ethanoate and then	formed which dissolve	present
		boil	on heating.	
	(g)	Confirmatory test for	Colourless gas which turns	NH_4^+ confirmed
		cation. To a small	wet red litmus paper	
		solid sample dilute	blue and forms white	
		NaOH was added	fumes with concentrated	
		and warmed and red	HCl evolves	
		litmus paper was		
		passed on the mouth		
		of the test tube. A glass		
		rod was dipped in concentrated		
		HCl and passed to mouth		
		of test tube		

3(i)	S/n	Experiment	Observation	Inference
	(g)	Confirmatory test for	White precipitate	
		anion. When dilute	soluble in dilute	Cl^- confirmed,
		HNO_3 followed by	ammonium ethanoate	
		$AgNO_3$ solution were	solution is formed	
		added to about 2 cm^3 of		
		the solution of M.		

(ii) A balanced chemical equation for the reaction in experiment (b) is

$$NH_4Cl_{(s)} \xrightarrow{\Delta} NH_{3(g)} + HCl_{(g)}$$

Extract 19.1: A sample of correct responses in question 3 of alternative practical A

In Extract 19.1, the candidate properly followed the procedures given and identified the cation and anion correctly. Moreover, the candidate wrote the equation required correctly.

03.	S/N	Experiment	Observations	Inference.
	a.	A spatulaful of sample Z was taken into a boiling test tube then about 8cm³ of distilled water was added. The mixture of about one minute was heated gently while swirled the test tube. To obtain the clear solution the mixture was filtered then divided the result solution into three portions	Sample Z was insoluble in hot or cold water	SO_4^{2-} of Ba^{2+}, Sr^{2+}, Ca^{2+} and Pb^{2+} may be present. Cl^- of Ag^+ may be present. CO_3^{2-} may be present except those of Na^+, K^+, NH_4^+. $C_2O_4^{2-}$ may be present except those of Na^+, K^+ and NH_4^+
	i.	To the first portion the NaOH solution was added in the portion.	White precipitate was formed	Zn^{2+} may be present
	ii	To the second portion the dilute HNO_3 was added followed by $AgNO_3$ and then NH_3 solution.	White precipitate soluble in dilute ammonia solution was formed	Cl^- confirmed.
	iii	To the third portion ammonia solution was added.	White precipitate was formed	Zn^{2+} confirmed.

03	S/N	Experiment.	Observation	Inference.
	bi.	The residue in a little quantity of HCl was dissolved in it as possible and resulting gas was identified..	Effervescence of a colourless gas which turn lime water milky was formed	CO_3^{2-}, HCO_3^- may be present
	.	Diluted resulting solution in a(i) was diluted with water and divided into solution into three portions.	The solution was soluble in cold water	Cl^- may be present except those of Ag^+ and Pb^{2+} CO_3^{2-} of Na^+ K^+ NH_4^+ may be present SO_4^{2-} may be present except those of Ba^{2+}, Sr^{2+} Ca^{2+} and Pb^{2+}
	ii.	To the first portion few drops of $BaCl_2$ solution was added.	White precipitate was formed before warming the contents	CO_3^{2-} confirmed
		To the second portion the dilute NH_4OH was added till no further change	The precipitate was dissolved	Ca^{2+}, Sr^{2+} may be present.
		To the third portion the ammonia solution was added in excess followed by ammonium oxalate solution	White precipitate was formed	Ca^{2+} confirmed

B i.	The Molecular formulas for the samples.
	$CaCO_{3(s)}$ and $ZnCl_{2(s)}$.
ii)	The Cations are Ca^{2+} and Zn^{2+}
	The anions are CO_3^{2-} and Cl^-

Extract 19.2*:* A sample of correct responses in question 3 of the alternative practical B

In Extract 19.2, the candidate properly followed the procedures given and identified the presence of cations, Ca^{2+} and Zn^{2+} and anions, CO_3^{2-} and Cl^- correctly.

3 (i)	EXPERIMENT	OBSERVATION	INFERENCE.
(a)	~~The Sam~~		
	(i) The Colour of Sample K	The white Colour of Sample K was obierved	Non-transition metals may be present
	(ii) The texture of Sample K	The Crystalline form of Sample K was observed	NO_3^-, SO_4^{2-}, Cl^-, $C_2O_4^{2-}$, CrO_4^{2-}, NO_2^-, CH_3COO^-, $Cr_2O_7^{2-}$ may be present
	(iii) Deliquescence	The sample K absorbed water from the atmosphere to form solution	NO_3^-, Cl^-, SO_4^{2-} may be present.
(b).	To about 0.5g of Sample K was transfered in a clean dry test tube and heat the content gently and then strongly	Residue that was yellow when hot and white cold was observed	Zn^{2+} may be present.
(c)	To about 0.5g of sample K was transfered in a clean dry test tube followed by addition of enough ~~water~~ amount of distilled water to dissolve it.	The sample K was soluble in cold distilled water	NO_3^-, CH_3COO^-, HCO_3^- may be present. SO_4^{2-} may be present except those of Ba^{2+}, Sr^{2+}, Ca^{2+} and Pb^{2+}

3 (c)	EXPERIMENT	OBSERVATION	INFERENCE.
			Cl^- may be Present except those of Ag^+ and Pb^{2+}
(d)	To about 2cm³ of sample solution K was put in a dry test tube followed by addition of Sodium hydroxide until in excess	White precipitate dissolved in excess NaOH was observed	Zn^{2+} may be Present
(e)	To about 2cm³ of sample solution K was put in a dry test tube followed by addition of ammonia solution until in excess	White precipitate dissolved in excess NH_4OH was observed	Zn^{2+} may be Present.
(f)	To about 2cm³ of sample solution K was put in a dry test tube followed by addition of $FeCl_3$ solution then dilute HCl and then ~~boiled~~ the mixture was boiled	No gas was evolved	CH_3COO^-, HCO_3^-, SO_4^{2-} was absent.

3	EXPERIMENT	OBSERVATION	INFERENCE.
(g)	The clean glass rod was dipped in concentrated HCl, then to the sample K followed by heating it on a flame	The brick red spark was observed	Zn^{2+} may be Present
(h)	CONFIRMATORY TEST FOR THE CATION.		
	To about 2cm³ of sample solution K was put in a dry test tube followed by addition of Potassium hexacyano ferrate (II) solution	Bluish - white precipitate was formed	Zn^{2+} confirmed

	CONFIRMATORY TEST FOR THE ANION.	Brown fumes was evolved	NO_3^- confirmed
	To about 0.5g of sample solid K was put in a clean and dry test tube followed by addition of copper turnings followed by concentrated H_2SO_4 then warmed		

3 (a i)	The cation present was Zn^{2+}
	The Anion present was NO_3^-
	The molecular formular for the sample K was $Zn(NO_3)_2$
(a ii)	$Zn(NO_3)_2 \xrightarrow{\Delta} ZnO + 2NO_2 + \frac{1}{2}O_2$
	The balanced chemical equation of the reaction in experiment (b) was
	$\therefore Zn(NO_3)_{2(aq)} \xrightarrow{\Delta} ZnO_{(s)} + 2NO_{2(g)} + \frac{1}{2}O_{2(g)}$

Extract 19.3: A sample of correct responses in question 3 of the alternative practical C

In Extract 19.3, the candidate performed the given tests properly and identified the presence of cation Zn^{2+} and anion CO_3^{2-} correctly. Lastly, the candidate wrote a well-balanced chemical equation that happened when a salt was heated (test b).

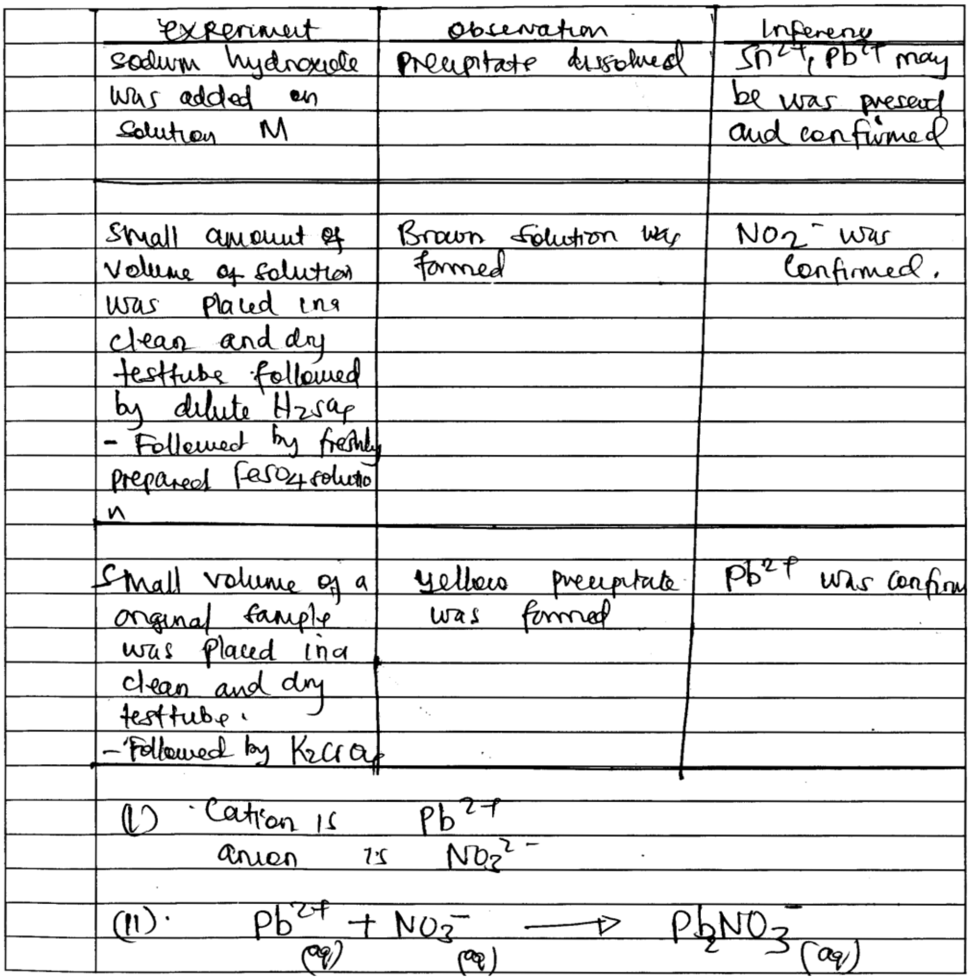
However, it was noted during the analysis of the candidates' responses that a few of them were not competent enough in carrying out experiments to identify unknown salt(s). Some of the candidates reported incorrect observations and inferences. Thus, they scored weakly in most parts of the procedures. For example, one of the candidates who attempted alternative practical A, wrote the following in procedure (d) and (e):

(d)	Action of acquous sodium hydroxedo on soluteon M; - To a sample M. Solution small amount of sodium hydroxide were added	White precipitate soluble in excess NaOH	Zn^{2+} May be present.
(e)	To a small sample solute n M Freshly Prepared $FeSO_4$ solution were added followed by Concentrated sulphuric acid H_2SO_4.	Brown ring is formed at the junction of the liquid.	NO_3^- cormfirmed

The observations and inferences given by the candidate contradicted the fact. The following were the correct observations and inferences in part (d) and (e), for the sample salt (NH_4Cl) that was given to them anonymously:

Experiment	Observations	Inference
(d)	No precipitate formed, ammonia gas was formed on warming	NH_4^+ may be present
(e)	No brown ring test formed.	NO_3^- probably absent.

Moreover, some of the candidates gave incorrect chemical equations in some parts of the experiments in alternative practicals A and C as well as the molecular formula in alternative practical B. For example, one of the candidates in part (ii) of the alternative practical A, wrote as follows: " $NH_4^+(aq) + Cl^-(aq) \longrightarrow NH_4Cl(aq)$ *Conclusion, the cation is* NH_4^+*, the anion is* Cl^-" instead of the equation showing action of heat on the sample (NH_4Cl). In alternative practical C, one of the candidates wrote a chemical equation of what happened at the experiment (b) as: "$Zn(NO_3)_2 \xrightarrow[\Delta]{} ZnO + NO_2$", which is not correct regarding the decomposition of the salt. Extracts 19.4, 19.5 and 19.6 show samples of incorrect responses in question 3 given by candidates in alternative practicals A, B, and C, respectively.



Experiment	Observation	Inference
Sodium hydroxide was added on solution M	Precipitate dissolved	Sn^{2+}, Pb^{2+} may be was present and confirmed
Small amount of volume of solution was placed in a clean and dry testtube followed by dilute H_2SO_4 - Followed by freshly prepared $FeSO_4$ solution	Brown solution was formed	NO_2^- was confirmed.
Small volume of a original sample was placed in a clean and dry testtube. - Followed by K_2CrO_4	yellow precipitate was formed	Pb^{2+} was confirm

(i) Cation is Pb^{2+}
anion is NO_3^{2-}

(ii) $Pb^{2+}_{(aq)} + NO_3^-{}_{(aq)} \longrightarrow Pb_2NO_{3(aq)}$

Extract 19.4*:* A sample of incorrect responses in question 3 of alternative practical A

In Extract 19.4, the candidate identified the cation to be Pb^{2+} and anion NO_3^{2-} instead of NH_4^+ as the cation and Cl^- as an anion.

3	Experiment	Observation	inference.
(a)	A sample 2 was placed into a boiling test tube then 3 cm^3 of distilled water were added to the sample. followed by heating gently the mixture. a filter paper was used to divide the resulting solutions into ~~clear~~ three portions.	- White sublimate and colourless gas with chocking smell which turns moist red litmus paper blue was obsered	NH_4^+ may be present.
(i)	To the first portion NaOH solution was added.	white dense fume where observed.	Sb^{3+}, Bi^{3+}, Mg^{2+} may be present.
(ii)	To the portion number 2 dilute HNO_3 were added followed by $AgNO_3$ and then NH_3 solution	White precipitate soluble in Amonia solution ~~gas evolves on wa~~ was ~~fuming~~ formed.	Cl^- confirmed. ~~NH_4^+ may be~~ present.
(iii) (b)	The Dissolved residue was added with a little quantity of HCl	- no gas were evolved.	SO_4^{2-}; Cl^-, NO_3^- may be present.

3	(i) NH_4Cl , $ZnSO_4$
	(ii) The cations are.
	NH_4^+ and Zn^{2+}
	The anions are
	Cl^- and SO_4^{2-}

Extract 19.5*:* A sample of incorrect responses in question 3 of the alternative practical B.

In Extract 19.5, the candidate gave incorrect observations and inferences in part (a) which could be obtained if a given sample was heated in a dry tube and not when dissolved in distilled water as suggested by the candidate. As a result, the candidate wrongly identified the presence of NH_4^+ and suggested that the mixture of salt to consists of NH_4Cl and $ZnSO_4$ instead of $ZnCl_2$/$CaCl_2$ and $CaCO_3$/$ZnCO_3$.

S/N	PROCEDURE	OBSERVATION	INFERENCE
(a)	A nichrome wire was dipped in conc. HCl, then to the sample followed by heating.	Golden - yellow flame observed	Na^+ may be present
(b).	CONFIRMATORY TEST		
	1. For anion To $2cm^3$ of sample K in a test tube, dil. HNO_3 was added followed by ammonia solution and to the neutral boiled solution, $FeCl_3$ was added.	A Deep red colour observed	CH_3COO^- present and confirmed
	II. For cation A nichrome wire was dipped in conc. HCl, then to the residue of the dried supernant of sample K, followed by heating	Golden yellow flam observed	Na^+ present and confirmed. ×
II.	CH_3COONa		
III.	$NaOH + CH_3COOH \rightarrow CH_3COONa + H_2O$		

Extract 19.6*:* A sample of incorrect responses in question 3 of the alternative practical C

In Extract 19.6, the candidate gave a wrong colour for the flame test and incorrectly confirmed the cations and anions present. Finally, the candidate gave incorrect molecular formula and chemical equation intended for parts (ii) and (iii) of the question, respectively.

3.0 THE ANALYSIS OF THE CANDIDATES' PERFORMANCE IN EACH TOPIC

The ACSEE 132 Chemistry examination in 2021 consisted of questions from a total of 18 topics, out of which, 11 topics (*Chemical Equilibrium*; *Chemical Bonding*; *The Atom*; *Gases*; *Energetics*; *Relative Molecular*

Masses in Solution; *Aromatic Hydrocarbons*; *Halogen Derivatives of Hydrocarbons*; *Soil Chemistry* and *Aliphatic Hydrocarbons*) were examined in Chemistry paper 1. In Chemistry paper 2, seven topics (*Two Components Liquid System*; *Carbonyl compounds/Carboxylic Acids and Derivatives*; *Electrochemistry*; *Solubility, Solubility Product and Ionic Product*; *Periodic Classification* and *Hydroxyl Compounds*) were examined. Chemistry practicals consisted of three subtopics *Volumetric Analysis*, *Physical Chemistry Analysis* and *Qualitative Analysis* which were derived from a topic of *Chemical Analysis*.

Among the tested topics in Chemistry theory (paper 1 and 2), a topic of *Chemical Equilibrium* which was examined in question 8 was the most well performed topic by the candidates (as 81.5 per cent of the candidates were able to score an average or above average marks). Other topics which had good performance were *Chemical Bonding* (74.5%), *Chemical Kinetics* (69.0%), *The Atom* (66.4%), *Gases* (62.8%) and *Energetics* (60.5%). The performance of the candidates in the topic of *Chemical Analysis* was good, as the majority (90.0%) of the candidates who sat for one of the alternative practical papers scored average marks or above. The performance of the candidates in the topic of *Chemical Analysis* was taken as an average performance of the subtopics *Volumetric Analysis* (94.5%), *Qualitative Analysis* (89.5%) and *Physical Chemistry Analysis* (86.2%) examined in questions 1, 2 and 3, respectively. The candidates who performed well managed to understand the requirements of the questions. They showed appropriate competencies in the topics tested.

Further analysis indicates that the candidates had an average performance in the topics of *Relative Molecular Masses in Solution* (53.9%); *Aromatic Hydrocarbons/Halogen Derivatives of Hydrocarbons* (51.9%); *Carbonyl Compounds/Carboxylic acids and Derivatives* (48.8%); *Electrochemistry* (46.9%); *Solubility, Solubility Product and Ionic Product* (44.3%) and *Periodic Classification* (36.0%). Despite the fact that some of the candidates had appropriate knowledge of the tested topics, they provided partial answers and were not keen on understanding specific requirements of the questions. Thus, they performed averagely in most of the tested topics.

Despite the good and average performances of most candidates in the aforementioned topics, some of the candidates performed weakly in the topics of *Soil Chemistry* (33.9%); *Aliphatic Hydrocarbons* (32.4%); *Hydroxyl Compounds* (26.6%) and *Selected Compounds of Metals* (14.2%).

Further analysis of the data indicates that the topic of *Selected Compounds of Metals* (14.2%) was the most poorly performed topic in 2021. In 2019, the performance in the topic was 41.3 per cent. It was also noted that the performance of the candidates in the topic of *Periodic Classification* (36.0%) improved compared to candidates' performance in the topic in 2019 (17.4%) and 2020 (28.9%). The analysis of responses given by the candidates with weak scores in these topics indicates that they had insufficient knowledge of the subject matter under question. As a result, they gave wrong formulae, chemical equations and followed incorrect approaches when performing calculations. The summary of the candidates' performance in different topics of theoretical and practical examinations are presented in the appendices A and B, respectively.

4.0 CONCLUSIONS

The general performance of the candidates who sat for Chemistry examination in 2021 was good, as 94.81 per cent passed. The analysis of the candidates' responses in each of the questions from the theoretical and practical paper indicates that the majority of the candidates were conversant with the tested topics. The performance in practicals was a bit higher than in 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 it is possible. Responses from the candidates who performed weakly indicate that they lacked or had insufficient knowledge of the subject matter tested.

5.0 RECOMMENDATIONS

The weak and average performances observed in the tested topics can be improved through collaborative efforts of teachers and prospective candidates during the teaching and learning processes. Based on the analysis of 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 topics 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 to discuss various types of chemical reactions and their inferences using wall charts. This will help learners to grasp much of the concepts and build a long term memory of the topic of *Selected Compounds of Metals.*

(c) Teachers should guide learners to form small groups and perform practical tasks on chemical reactions; involving the identification of *oxides*, *hydroxides*, *carbonates*, *hydrogen carbonates*, *sulphates*, *chlorides* and *nitrates*. Thereafter, 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 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, the teaching and learning processes will be more meaningful.

Appendix A: The summary of the Performance of the Candidates Topic-wise in Theory Papers

S/N	Topic	2020			2021		
		Number of Questions	The Percentage of the Candidates who Scored an Average of 35 or Above	Remarks	Number of Questions	The Percentage of the Candidates who Scored an Average of 35 or Above	Remarks
1	Chemical Equilibrium	1	70.2	Good	1	81.5	Good
2	Chemical Bonding	1	35.4	Average	1	74.5	Good
3	Two Components Liquid System	1	30.5	Weak	1	69.0	Good
4	The Atom	1	79.8	Good	1	66.4	Good
5	Gases	1	83.6	Good	1	62.8	Good
6	Energetics	1	54.8	Average		60.5	Good
7	Relative Molecular Masses in Solution	1	61.3	Good	1	53.9	Average
8	Aromatic Hydrocarbons	1	86.3	Good			
	Aromatic Hydrocarbons and Halogen Derivatives of Hydrocarbons				1	51.9	Average
9	Carbonyl Compounds/Carboxylic Acids and Derivatives	1	42.1	Average		48.8	Average
10	Electrochemistry				1	46.9	Average
11	Solubility, Solubility Product and Ionic Product	1	59.4	Average	1	44.3	Average
12	Periodic Classification	1	28.9	Weak	1	36.0	Average
13	Soil Chemistry	1	82.5	Good	1	33.9	Weak
14	Aliphatic Hydrocarbons	1	86.6	Good	1	32.4	Weak
15	Hydroxyl Compounds	1	43.1	Average	1	26.6	Weak
16	Selected Compounds of Metals	1	41.3	Average	1	14.2	Weak

Appendix B: The Summary of the Performance of the Candidates Topic-wise in Practical Paper

Topic	**Subtopic**	**2021**		
		Number of Questions	**The Percentage of the Candidates who Scored an Average of 35 or Above**	**Remarks**
Chemical Analysis	Volumetric Analysis	1	94.5	Good
	Qualitative Analysis	1	89.5	Good
	Physical Chemistry Analysis	1	86.2	Good