THE NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

CANDIDATES' ITEMS RESPONSE ANALYSIS REPORT FOR THE ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (ACSEE) 2017

132 CHEMISTRY

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TABLE OF CONTENTS

FOREWORD

This Items Response Analysis Report has been prepared to provide feedback to students, teachers, parents, policy makers and the public in general, on the performance of the candidates who sat for Chemistry examination for the Advanced Certificate of Secondary Education Examination (ACSEE) in 2017.

The Advanced Certificate of Secondary Education Examination marks the end of two years of Advanced Secondary Education. It is a summative evaluation which, among other things, shows the effectiveness of the educational system in general and education delivery system in particular. Essentially, the candidates' response to the examination questions is a strong indicator of what the education system was able or unable to offer to students in their two years of advanced secondary education.

The analysis presented in this report is intended to contribute towards understanding of some of the reasons behind the performance of the candidates in Chemistry subject. The report highlights some of the factors that made the candidates score high marks and also the factors that made a few candidates score low marks in each question. The factors which made some of the candidates fail to score high marks include, lack of basic knowledge in question items which involved basic mathematical skills based on chemistry principles, and the ones that needed factual knowledge. The feedback provided will enable the educational administrators, school managers, teachers and students to identify proper measures to be taken in order to improve the candidates' performance in future examinations administered by the Council.

The Council would like to thank Chemistry Coordinators, Examiners and all others who participated in the preparation of this report. The Council would also like to express sincere appreciation to all the staff who participated in analyzing the data used in this report.

The National Examinations Council of Tanzania will highly appreciate constructive comments and suggestions from teachers, students and the public in general for improving future reports.

Dr. Charles E. Msonde
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report analyses the performance of the candidates who sat for the Advanced Certificate of Secondary Education Examination for Chemistry Paper One and Two. The 2017 Chemistry examination was set according to the ACSEE format, which was revised in 2011 to suit the 2010 ACSEE Chemistry syllabus.

Paper 1 consisted of three sections, namely; A, B and C. Section A consisted of six (6) questions of which the candidates were required to attempt only four (4) questions. Section B and C had four (4) questions each, of which the candidates were required to answer three (3) from each section.

Paper 2 had three sections, namely; A, B, and C. Section A had four (4) questions, and section B and C had three (3) questions each. The candidates were required to answer five (5) questions, choosing at least one (1) question from each section.

The analysis of the examination results showed that the overall performance was good as the candidates' scores in most of the questions were above 35 percent of the allocated marks. The results show that the candidates' performance in 2017 has increased as 88.31 percent passed the examination compared to 87.50 percent of the candidates who passed the examination in ACSEE 2016. Hence, the performance in 2017 has increased by 0.81 percent.

This report is presented into four sections. It starts with the introduction, followed by the analysis of the candidates' performance in each question, and then the analysis of performance in each topic. Finally, the conclusion and recommendations for action are given.

2.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE BY QUESTIONS

For each of the analyzed question, an overview of what the candidates were required to do, the general performance and the possible reasons for the observed performance, have been provided. Samples of extracts of the candidates' responses have also been inserted in appropriate sections to illustrate the cases presented.

The performance is classified as either poor/weak, average or good, on the basis of the percentage of the candidates who passed (scored 35 percent or more of the marks allocated in a particular question). If the percentage lies from 0 to 34 is termed poor; 35 to 59, average and 60 to 100 good. Furthermore, green, yellow and red colours have been used in different figures, to denote good, average and poor performance respectively.

2.1 132/1-CHEMISTRY 1

This paper had a total of 14 questions; each carried 10 marks. The pass mark in each question was from 3.5 marks.

2.1.1 Question 1: The Atom

The question comprised parts (a), (b) and (c). In part (a), the candidates were required to distinguish isotopes from isotopy, azimuthal quantum number from magnetic quantum number and atomic mass unit from relative atomic mass. In part (b), the candidates were provided with the information that, "the mass spectrographic measurements of an element X, whose atomic number is 31, indicated peaks at 79.21, 11.2 and 9.59. The isotopic masses are 69, 70 and 71 atomic mass unit (a.m.u) respectively". They were then asked to:

(i) Write the conventional symbols for the three isotopes.
(ii) Calculate the relative atomic mass of X.
(iii) Explain why atomic weights of elements are not whole numbers.

In part (c), the candidates were provided with the information that "the mass number of two atoms, A and B, with the same atomic number, are 235 and 238 respectively, if A contains 143 neutrons in its nucleus". They were then required to find the number of neutrons and electrons in B.

The question was attempted by 86.1 percent of the candidates. The performance was as shown in Figure 1.

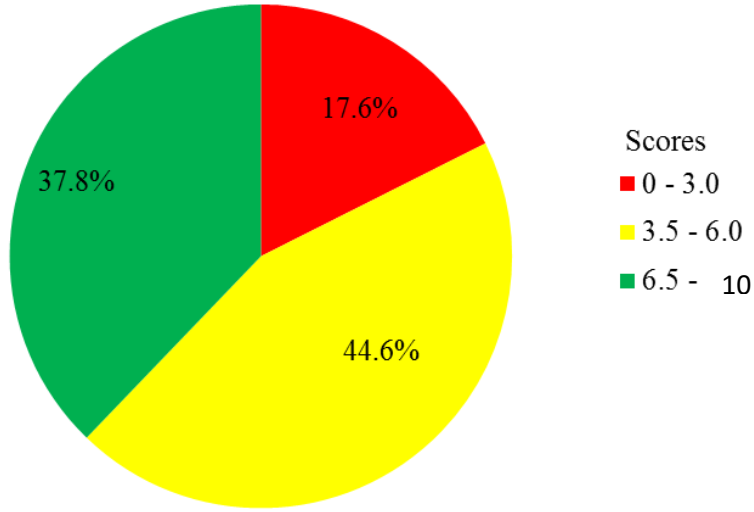
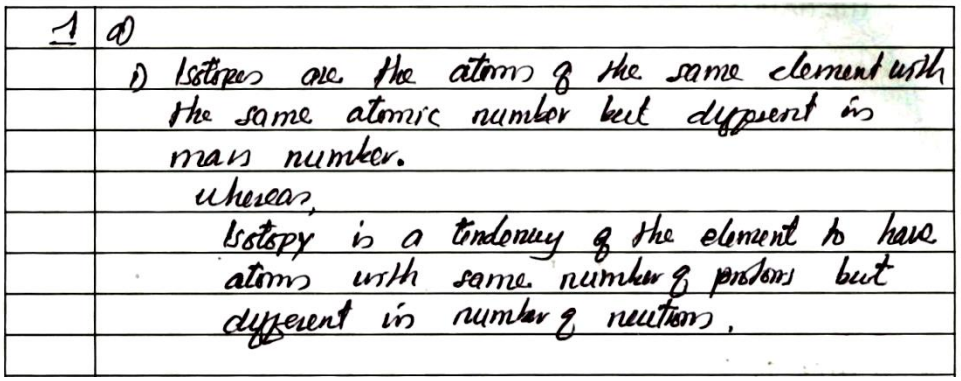


Figure 1: Performance of the candidates in question 1.

Figure 1 indicates that the majority of the candidates (82.4%) scored high marks (3.5 to 10), an indication of good performance in this question. High performance in this question was attributed by the ability of the candidates to distinguish the given terms correctly. They also wrote correctly the conventional symbols, and were able to calculate the relative atomic mass of X. In addition, they explained correctly why the atomic weights are not whole numbers. Moreover, they managed to find the number of neutrons and electrons in element B. This is an indication that the candidates had sufficient knowledge on the structure of an atom, the principles and the rules governing the arrangement of electrons in an atom. Extract 1.1 illustrates this case.

Extract 1.1


1 a)

i) Isotopes are the atoms of the same element with the same atomic number but different in mass number.

whereas,

Isotopy is a tendency of the element to have atoms with same number of protons but different in number of neutrons.

ii) Azimuthal quantum is a quantum number that describes the shapes of atomic orbitals whereas
Magnetic quantum number is a quantum number that shows orientation of designated orbitals

iii) Atomic mass unit is a $\frac{1}{12}$th mass of one Carbon-12 atom.
whereas
Relative atomic mass is the average

b) i) $^{69}_{31}X$, $^{70}_{31}X$ and $^{71}_{31}X$

ii) $R.A.M = \frac{\sum (\text{isotopic mass} \times \text{intensity})}{\text{total intensity}}$

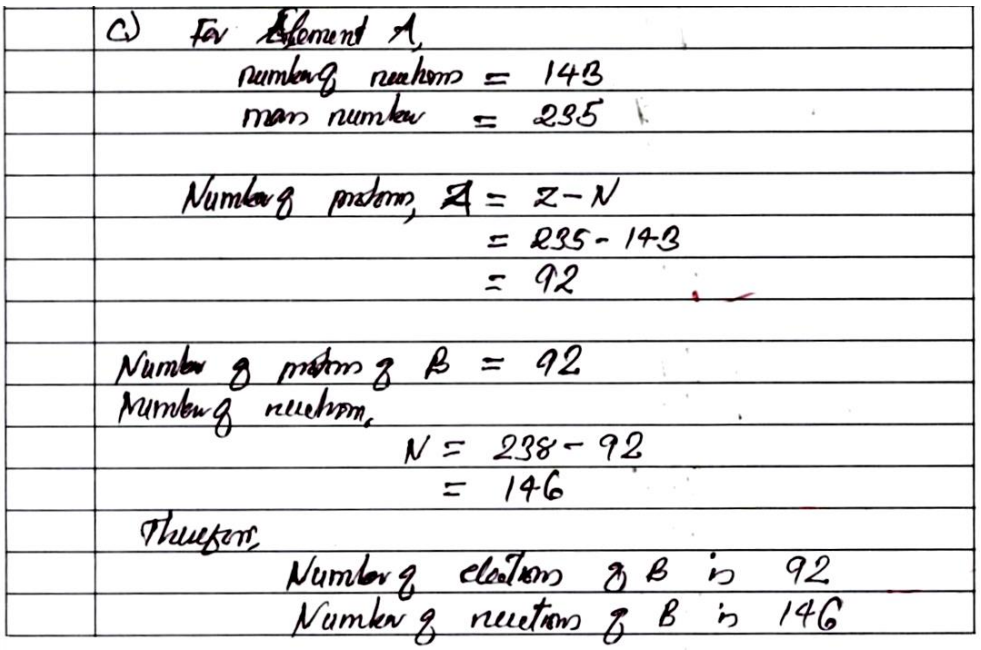
$RAM = \frac{69 \times 79.21 + 70 \times 11.2 + 71 \times 9.59}{79.21 + 11.2 + 9.59}$

$= \frac{6930.58}{100}$

$= 69.3088$

∴ Relative atomic mass of X is 69.3088 a.m.u

iii) This is due to the existence of the isotopes in a particular element.



In Extract 1.1, the candidate was able to distinguish the given terms. He/she correctly wrote the conventional symbols and was able to explain why the relative atomic weights are not whole numbers. He/she also managed to find the number of neutrons and electrons in element B.

However, there were a few candidates (17.6 %) who scored low marks in this question. Some of these candidates failed to differentiate the given terms in part (a), indicating that they had no clear understanding of the asked terms. For example, one candidate wrote 'magnetic quantum number shows the direction of the spin, while azimuthal quantum number is the number which shows the position of electron in atomic shells'. Other candidates failed to write correctly the conventional symbols of the three isotopes of X in part (b). For example, one candidate wrote isotopic peaks instead of the mass number as, "79.2131 X, 11.231 X and 9.531 X". In addition, others didn't even attempt part (c) which required them to find the number of neutrons and electrons. This is an indication of poor background about the structure of an atom which is taught even at the ordinary level. Extract 1.2 illustrates an example of poor responses.

Extract 1.2

1. (a) (i) Isotope - This is the number that an element Contain or radical

Isotopy - This is the ability of a number to have isotopes

(ii) Azimuthal Quantum number This is the number that an element Contain and never change chemically

Magnetic Quantum number This is the number that an element Contain and always never change by Chemical or Physical means.

(iii) Atomic mass - This is the number of mass of an atom.

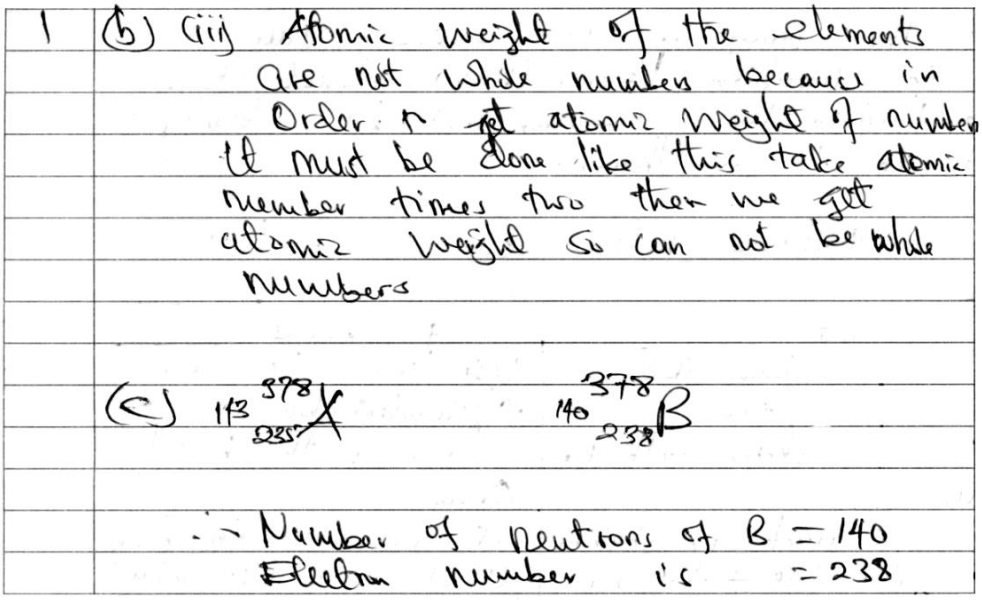
Relative Atomic Mass This is the Atomic number but twice of its Atomic mass.

(b) (i) $^{79.2}_{31}X$ $^{11.2}_{31}X$ $^{9.59}_{31}X$

(ii) $= \frac{(69 \times 79.2) + (70 \times 11.2) + (71 \times 9.59)}{69 + 70 + 71}$

$= \frac{6929.69}{210} = 118.15$

Relative atomic mass of X is 118.15



In Extract 1.2, the candidate failed to distinguish the given terms, wrote incorrect conventional symbols and used an incorrect approach in calculating the relative atomic mass. She/he failed to explain why the relative atomic weights are not whole numbers. Also, the number of neutrons and electrons in element B are wrongly presented.

2.1.2 Question 2: Chemical Bonding

This question had four parts, namely; (a), (b), (c) and (d). In part (a), the candidates were required to define dative bonding, ionic bonding and valence electrons. In part (b), they were required to summarize three major ideas of the valence Shell Electron Pair Repulsion (VSEPR) theory. In part (c), they were required to outline four differences between sigma and pi bonds and finally in part (d), they were required to determine the name of a geometrical structure and give one example of the molecule formed from sp^3 sp^2 and sp hybridized orbitals respectively.

This question was attempted by 62.8 percent of the candidates and the general performance was good as the majority (68.6%) of the candidates scored 3.5 marks and above out of the 10 marks. Figure 2 shows the distribution of the candidates' scores.

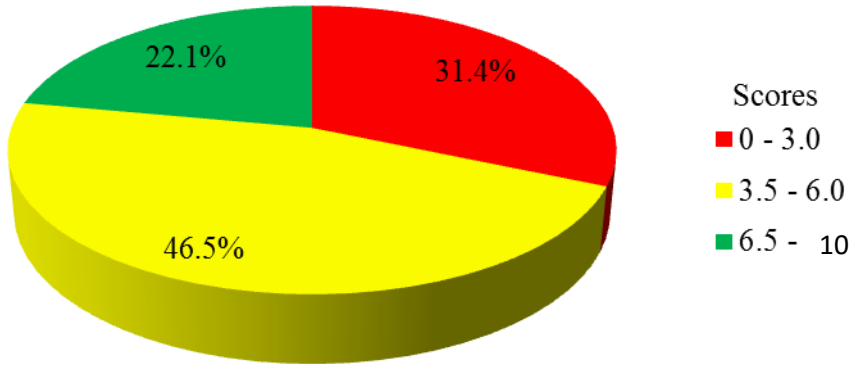
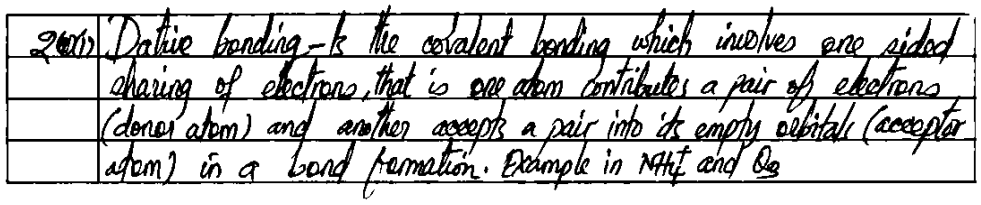
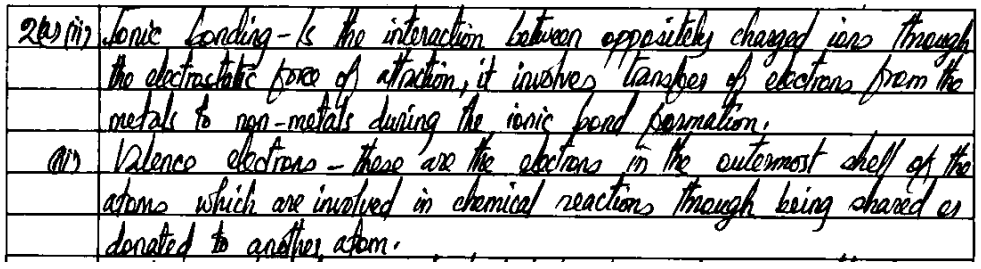


Figure 2: Performance of the candidates in question 2.

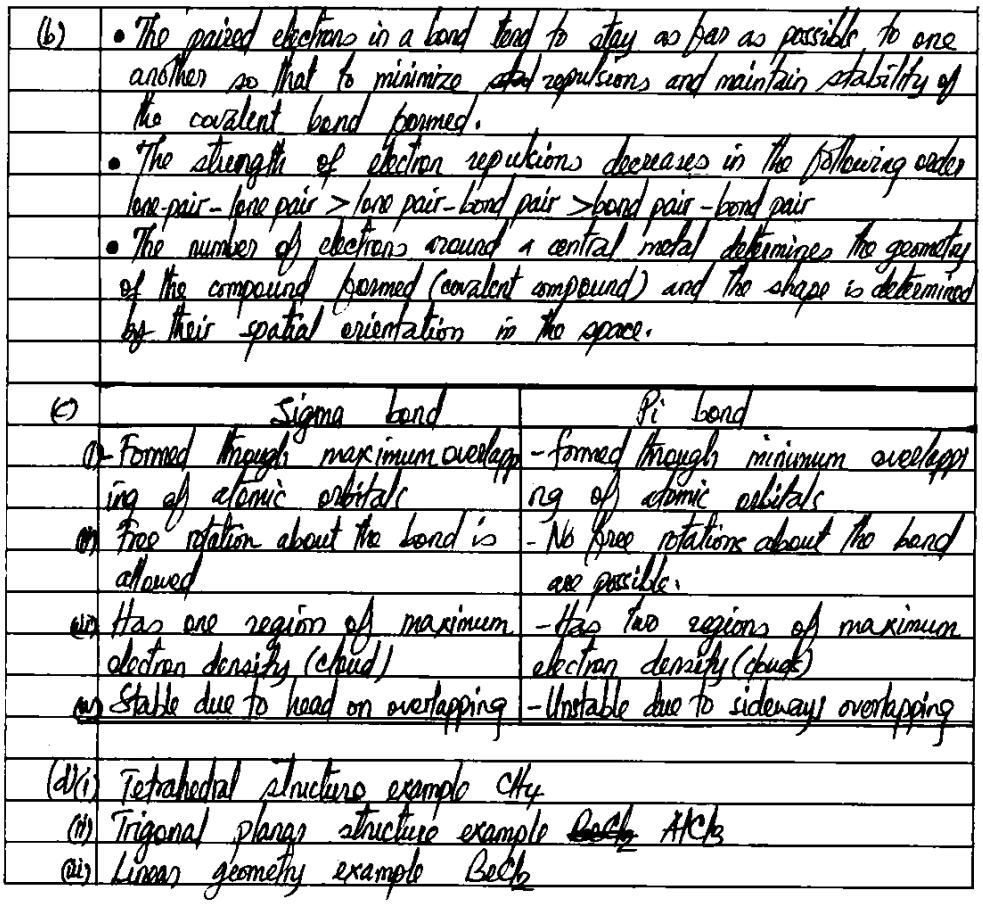
Figure 2 indicates that 46.5 and 22.1 percent of the candidates scored average and good marks respectively, while 31.4 percent failed (0 – 3.0 marks). The majority of the candidates who scored high marks had adequate knowledge about the concepts of chemical bonding. They managed to define dative bonding; ionic bonding and valence electrons. They also summarized correctly the three major ideas of VSEPR theory. Not only that, but they also outlined the four differences between sigma and pi bonds and determined the name of a geometrical structure as demanded by the question. Furthermore, they were able to give one example of the molecule formed from, sp^3 sp^2 and sp hybridized orbitals. Extract 2.1 shows one of the good responses.

Extract 2.1


Dative bonding - is the covalent bonding which involves one sided sharing of electrons, that is one atom contributes a pair of electrons (donor atom) and another accepts a pair into its empty orbitals (acceptor atom) in a bond formation. Example in NH_4^+ and O_3


Ionic bonding - is the interaction between oppositely charged ions through the electrostatic force of attraction, it involves transfer of electrons from the metals to non-metals during the ionic bond formation.

Valence electrons - these are the electrons in the outermost shell of the atoms which are involved in chemical reactions through being shared or donated to another atom.



(b)
- The paired electrons in a bond tend to stay as far as possible to one another so that to minimize the repulsions and maintain stability of the covalent bond formed.
- The strength of electron repulsions decreases in the following order lone pair - lone pair > lone pair - bond pair > bond pair - bond pair
- The number of electrons around a central metal determines the geometry of the compound formed (covalent compound) and the shape is determined by their spatial orientation in the space.

(c)

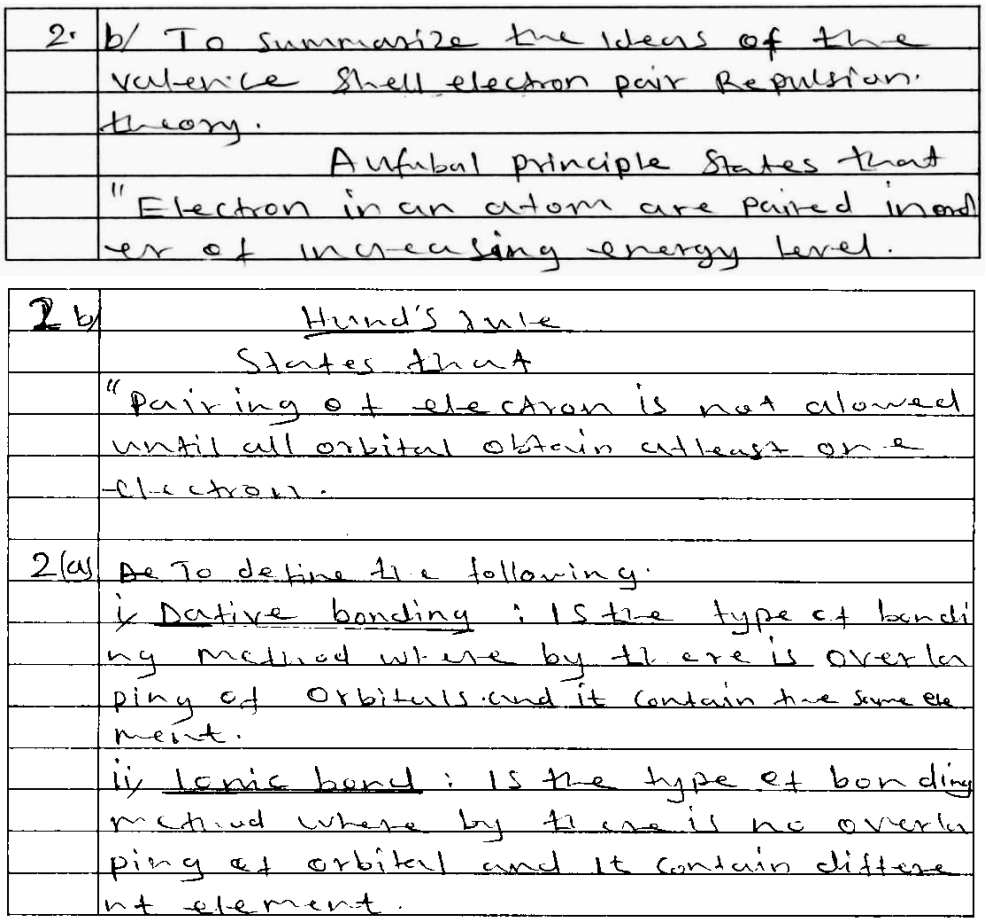
	Sigma bond	Pi bond
(i)	- Formed through maximum overlapping of atomic orbitals	- formed through minimum overlapping of atomic orbitals
(ii)	Free rotation about the bond is allowed	- No free rotations about the bond are possible.
(iii)	Has one region of maximum electron density (cloud)	- Has two regions of maximum electron density (clouds)
(iv)	Stable due to head on overlapping	- Unstable due to sideways overlapping

(d)(i) Tetrahedral structure example CH_4
(ii) Trigonal planar structure example ~~$BeCl_2$~~ $AlCl_3$
(iii) Linear geometry example $BeCl_2$

In Extract 2.1, the candidate managed to define dative bonding, ionic bonding and valence electrons, and was able to summarize the ideas of VSEPR theory. She/he outlined the four differences between sigma and pi bonds, as well as determined the name of a geometrical structure.

On the other hand, the candidates who scored low marks failed to define dative bonding, ionic bonding and valence electrons. They also failed to outline the differences between sigma and pi bonds and to determine the name of a geometrical structure. Other candidates stated the Aufbau Principle and Hund's Rule instead of the summary of valence shell electrons (see Extract 2.2). In other cases, some candidates skipped this question which was an indication of inadequate knowledge in the concept of bonding. Extract 2.2 shows a sample of responses, which do not meet the requirement of the question.

Extract 2.2


2. b/ To summarize the ideas of the valence Shell electron pair Repulsion theory.

Afufubal principle States that "Electron in an atom are paired in order of increasing energy level.

2 b/ Hund's rule States that "pairing of electron is not allowed until all orbital obtain atleast one electron.

2(a) To define the following.

i Dative bonding : IS the type of bonding method where by there is overlaping of Orbitals and it contain the same element.

ii Ionic bond : IS the type of bonding method where by there is no overlaping of orbital and it contain different element.

In Extract 2.2, the definition of dative bonding, ionic bonding and valence electrons were incorrectly stated. The candidates also in part (b) wrote the Afubaul Principle and Hund's rule instead of the ideas of VSEPR theory. Also the candidate did not attempt part (c) and (d) of the question.

2.1.3 Question 3: Gases

In part (a), the candidates were required to write two similarities between diffusion and effusion. They were also provided with the information that, "the rate of effusion of unknown gas was measured to be 24.0 mL/min. Under the same conditions, the measured rate of effusion of pure methane was 47.8 mL/min". The candidates were then required to calculate the molar mass of the unknown gas." Part (b) required the candidates to state four properties of an ideal gas using kinetic theory of gases. In part (c), the candidates were provided with the information that, "a sample of ammonia

gas with a volume of 3.5 dm^3 at a pressure of 1.68 atm was compressed to a volume of 1.35 dm^3 at a constant temperature". They were then required to:

(i) Calculate the final pressure of the gas.

(ii) Name and state the governing gas law in question 3 (c) (i).

The question was attempted by 89.8 percent of the candidates, and the performance is shown in Figure 3.

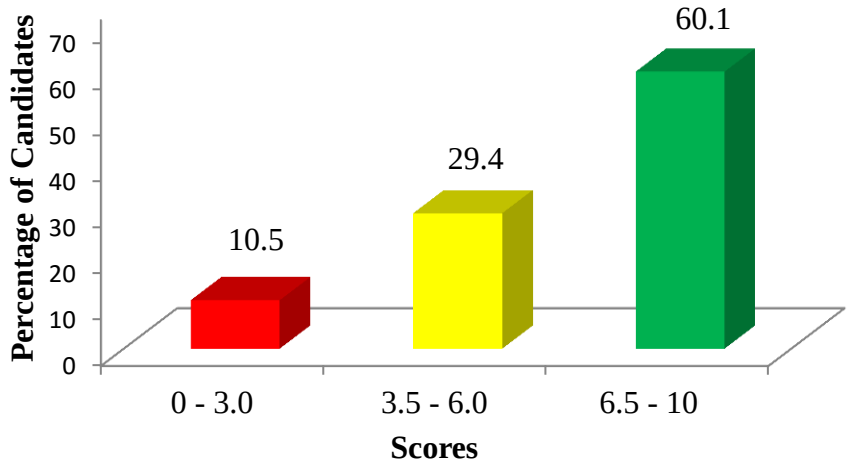


Figure 3: Performance of the candidates in question 3.

Figure 3 shows that 89.5 percent of the candidates scored from 3.5 to 10 marks, implying a good performance in this question. The candidates who got high scores (60.1%) were able to write two similarities between diffusion and effusion. They also managed to calculate the molar mass of the unknown gas from the given information. Furthermore, the candidates stated correctly the four properties of an ideal gas using the kinetic theory of gases and calculated the final pressure of the gas from the data given. Not only that but they were also able to name and state the governing gas law in question 3 (c) (i). Extract 3.1 is an example of good response from one of the candidates.

Extract 3.1

3 a) i) - Both diffusion and effusion involve the movement of gas molecules.

- Both the rate of diffusion and effusion of a gas is inversely proportional to square root of the density of a gas.

ii) Let the rate of effusion of unknown gas be R_u and that of pure methane R_M

Molar mass of methane $(CH_4) = (12 + 4)\ g mol^{-1}$

$M_M = 16\ g mol^{-1}$

By Graham's Law of effusion or diffusion of a gas

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

but ρ = density

$\rho \propto$ molar mass.

$$\frac{R_u}{R_M} = \sqrt{\frac{M_M}{M_u}}$$

$$\frac{24\ ml\ min^{-1}}{47.8\ ml\ min^{-1}} = \sqrt{\frac{16}{M_u}}$$

3 a) ii) $$\left(\frac{24}{47.8}\right)^2 = \frac{16}{M_u}$$

$$M_u = \frac{16}{\left(\frac{24}{47.8}\right)^2}$$

$$M_u = 63.47\ g mol^{-1}$$

∴ The molar mass of the unknown gas is $63.47\ g mol^{-1}$

3 a) ii) $\left(\frac{24}{47.8}\right)^2 = \frac{16}{M_U}$.

$$M_U = \frac{16}{\left(\frac{24}{47.8}\right)^2}$$

$$M_U = 63.47\ gmol^{-1}$$

∴ The molar mass of the unknown gas is $63.47\ gmol^{-1}$

b) - The average kinetic energy of the molecules of an ideal gas is directly proportional to it's absolute temperature.

- The intermolecular forces between molecules of an ideal gas is negligible

- The pressure exerted by an ideal gas is due to the collision of the gas particles and the walls of the container contained

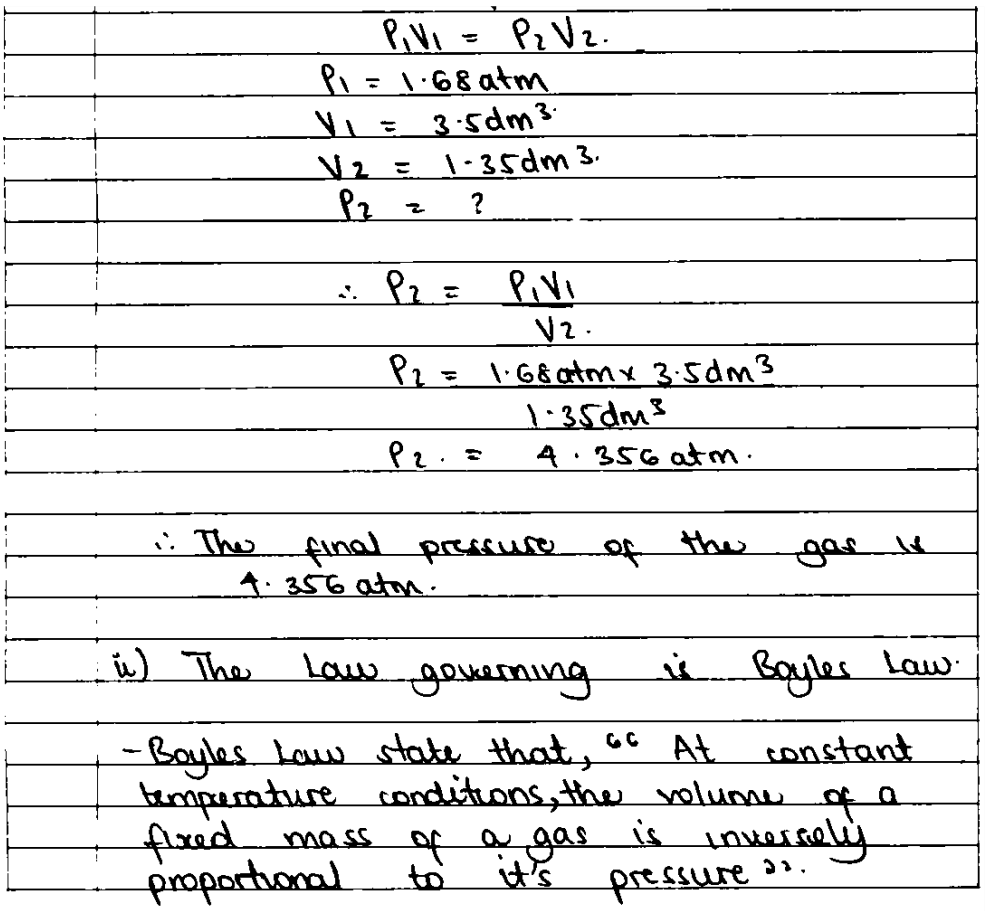
- The collision between the molecules of an ideal gas and the collision between the molecules and the walls of the container

3 b) is perfectly ~~elasti~~ elastic collision

c) i) Since the temperature is constant.

By using Boyle's Law.

$P \propto \frac{1}{V}$.



In Extract 3.1, the candidate managed to write two similarities between diffusion and effusion, calculate the molar mass of the unknown gas, stated correctly the four properties of an ideal gas and calculated the final pressure of the gas. He/she also named and stated Boyles law which governed part 3 (c) (i) of the question.

On the other hand, the candidates who scored low marks failed to write the similarities between diffusion and effusion. For example, one candidate incorrectly wrote, *speed of molecules movement is high*, as one of the similarities between diffusion and effusion. In other cases, others mentioned the differences of diffusion and effusion instead of their similarities. They failed to recognize that the similarities between diffusion and effusion are based on the properties of the gas particles in motion and the spontaneous processes that involve the movement of the gases. Others used incorrect formula, while others plugged in wrong data, hence obtaining an incorrect value of the final pressure of the gas. Not only that, others named Graham's law instead of Boyles law concerned in part 3 (c) (i) of the question. Extract 3.2 is a response of a candidate who performed poorly.

Extract 3.2

3 (a) (i). The similarities of diffusion and effusion.

(a). Both they depend on the presence of pressure.

(b). Both involve the movement of electron either randomly or directional.

(ii). Solution.

Data provided.

effusion 24.0 ml/min gas.

pure methane 47.8 ml/min.

Required Molar mass of the unknown gas ?

Recall from the formula.

$$\sqrt{\frac{24.0 \text{ ml min}}{47.8 \text{ g/mol/min}}}$$

Then: $47.8 - 24.0$

$= 23.8$ g/mol.

The molar mass of unknown gas 23.8 g/mol.

3. (b): The kinetic theories of gas.

(a) All electron exhibit movement of electron which is facilitate by pressure and temperature.

(b): All exerted pressure verified reciprocity of the surface.

(c) The gas move in randomly motion

(d): They exhibit osmosis process.

(c) Solution:

Volume of the pressure 3.5 dm³
pressure exerted to the atmosphere 1.68.

Recall from the formula:

$$\sqrt{\frac{1.68\ g/atm}{3.5\ dm^3}} = 50.26\ atm^{-1}$$

3 (c).(ii) @ Grahams law of diffusion

In Extract 3.2, the candidate presented incorrect similarities between diffusion and effusion. She/he used incorrect method to calculate molar mass of the unknown gas. Also the properties of an ideal gas were incorrectly written.

2.1.4 Question 4: Gases

The candidates were given the following question:

(a) Define the following :
  (i) Relative density of a gas.
  (ii) Normal density of a gas.

(b) Show that the relative molecular mass of a gas is twice its relative vapour density.

(c) (i) A determination of the density of ethanoic acid vapour at 1 atm pressure and 400 K gave a result of 2.74 g/dm^3. Assuming ideal conditions, calculate the apparent molecular weight of ethanoic acid under these conditions.
  (iii) What can you deduce from your results in part 4 (c) (i)? Briefly explain.

(d) A 0.0721 g of water when vapourized at 150 °C and 755mmHg pressure occupied a volume of 140 cm^3. Show that the relative molecular mass of water vapour proves the formula for steam.

The question was attempted by a few (27.8 %) candidates. Out of these candidates, 48.2 percent scored from 3.5 to 6.0 marks out of 10 marks, while a few, (16.7%) scored 6.5 to 10 marks, with 0.1 percent scoring all the 10 marks. On the other hand, 35.1 percent scored from 0 to 3.0 marks with 3.8 percent scoring a zero mark.

Most of the candidates who scored high marks managed to define both terms, i.e relative density of a gas and normal density of a gas. They were able to show the fact that the relative molecular mass of a gas is twice its relative vapour density. Most of them also were able to calculate the apparent molecular weight of ethanoic acid. Not only that, but they were also able to show through the given data that the relative molecular mass of water vapour proves the formula for steam. Extract 4.1 represents a good response from one of the candidates.

Extract 4.1

4 (a) (i) Relative density of a gas is the ratio of the density of a gas to the density of hydrogen gas.

(ii) Normal density is the ratio of mass of a gas per unit volume

(b) Vapour density V.D = $\frac{\text{Density of gas}}{\text{Density of hydrogen gas}}$

$= \frac{\text{mass of one mole of a gas}}{\text{mass of equal mole of hydrogen gas}}$

But

mass of one mole = molar mass of gas $\neq$

$= \frac{\text{molar mass of gas}}{\text{molar mass of hydrogen gas}}$

Also

molar mass of hydrogen gas = 2g/mol

$V.D = \frac{\text{Molar mass of gas}}{2\text{g/mol}}$

∴ Molar mass of gas = 2 × V.D

∴ Relative molecular mass of gas = 2 × vapour density

4(i) From ideal gas equation

$$PV = nRT$$

$$PV = \frac{M}{Mr} RT$$

$$Mr = \frac{M RT}{V P}$$

where Mr = apparent molecular mass

P = pressure

V = volume

T = Temperature

Given: $T = 400K$,

$P = 1 atm$

$\frac{M}{V} = 2.74 g/dm^3$

$R = 0.0821$

$$Mr = \frac{2.74 \times 0.0821 \times 400}{1}$$

$$= 79.98$$

$$= 90 g/mol$$

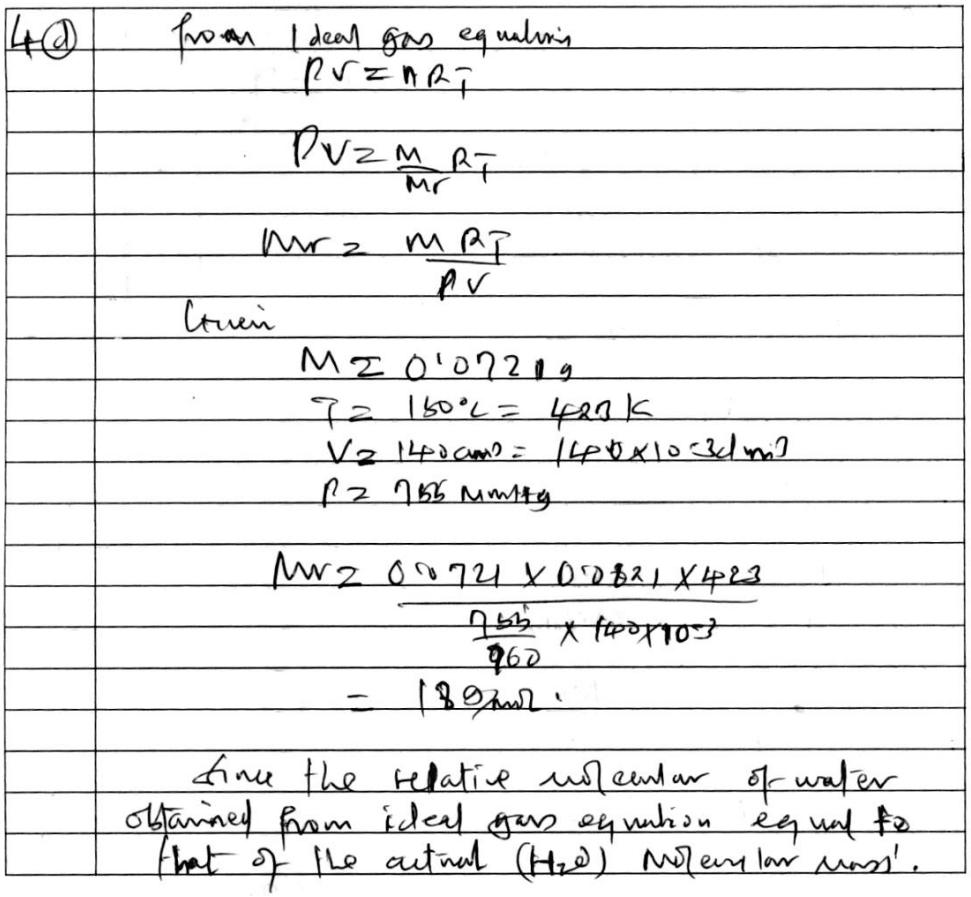
∴ Apparent molecular weight is 90 g/mol

ii) Actual molecular weight of CH_3COOH

$$= 12 + 3 + 12 + 32 + 1$$

$$= 60 g/mol$$

∴ Apparent molecular weight of ethanoic acid is greater than actual because ethanoic undergoes association in aqueous solution has



In Extract 4.1, the candidate managed to define relative density and normal density of a gas, and was able to calculate the apparent molecular weight of ethanoic acid. He/she also correctly explained why the apparent molecular weight of ethanoic acid was greater than the actual relative molecular mass.

However, the analysis of the responses from the candidates who scored low marks reveals insufficient knowledge about the tested concepts. For example in part (b), the candidates failed to recognize that Avogadro's law is the key element which leads to the proof of the relative molecular mass of a gas being twice its relative vapour density. It was also revealed that most of the candidates' responses in this part resulted from guess work. Others failed to apply the ideal gas equation, PV = nRT to show that relative molecular mass of water vapour (steam) is 18.004 g/mol, which is the mass of H_2O molecule. Further analysis shows that some of the candidates failed to convert the unit of pressure from mmHg to atmospheres in order to comply with the units of the ideal gas constant. For example one of the candidates substituted the value given from the question in the ideal gas equation as

$$Mr = \frac{0.0721\,g \times 0.0821\,atm\,mol^{-1}\,K^{-1}\,dm^3 \times 423\,K}{755\,mmHg \times 0.140\,dm^3}$$

$$Mr = 0.0237\,g\,mol^{-1}$$

In this answer, the candidate substituted directly the given pressure, 755 mmHg without changing it into atmospheres, and as a result the candidate got an incorrect answer. This is an indication of lack of skills in unit conversion. Extract 4.2 illustrates one of the poor answers.

Extract 4.2

4 a) Define the following.

(i) Relative density of a gas.

(ii) Normal density of a gas.

b) Show that the relative molecular mass of a gas is twice its relative vapour density

c) i) A determination of the density of ethanoic acid vapour at 1 atm pressure and 400K gave a result of 2.74 g/dm3. Assuming ideal condition, Calculate the apparent molecular weight of ethanoic acid under these conditions.

ii) What can you deduce from your results in 4(c)(i)? Briefly explain.

d) A 0.0721g of water vaporised at 150°C and 755 mmHg pressure occupied a volume of 140 cm^3. Show that the relative molecular mass of water vapour proves the formula for Steam.

In Extract 4.2 the candidate copied the questions from the question paper. This could be an indication that she/he did not have any idea about the definition of relative and normal density of a gas and calculations related to gases; or the candidate failed to allocate enough time for the question.

2.1.5 Question 5: Relative Molecular Masses in Solution

The candidates were given the following question:

(a) (i) Give the meaning of osmotic pressure of a solution.

(ii) Briefly explain in terms of vapour pressure why the freezing point of a solution is lower than that of pure solvent.

(b) When water and ice are mixed, the temperature of the mixture is 0 °C, but, if the methanol (CH_3OH) and ice are mixed, a temperature of +10 °C is readily attained. Explain why the two mixtures show such different temperature behaviours.

(c) Calculate the molar mass of Y given that a solution of 60 g of Y in 1 dm^3 of water exerts an osmotic pressure of 4.31×10^5 Nm^{-2} at 25 °C.

(d) A 0.003 kg of acetic acid (CH_3COOH) is added to 500 cm^3 of water. If 23% of the acid is dissociated, what will be the depression in freezing point? (Kf for water = 1.86 °Ckg/mol, density of water = 0.997g/cm^3).

A total of 14,302 (48.4%) candidates attempted the question, out of which 36.2 percent scored from 3.5 to 6.0 out of 10 marks. The percentage of the candidates who scored from 6.5 to 10 marks were 5.4, with a few (0.048%) scoring all the 10 marks. More than half, (58.4%) of the candidates scored from 0 to 3.0 marks, with 5.4 scoring a zero mark.

The candidates who scored high marks managed to write the correct meaning of the osmotic pressure of a solution and gave the reason why the freezing point of a solution is lower than that of pure solvent. They also explained correctly why the two mixtures show different temperature behaviours and calculated the molar mass of Y. Extract 5.1 shows an example of a good response.

Extract 5.1

5 a) i) Osmotic pressure of a solution is the minimum pressure which should be applied in the solution to prevent the movement of solvent molecules through the solution through a semi-permeable membrane

ii) Freezing point of a solution is the temperature in which liquid and solid phases have the same vapour pressure.

→ On addition of non-volatile solute to a pure solvent, the surface of the ~~pre~~ pure solvent will be occupied by the molecules of non-volatile solute hence reducing the escaping tendency of the molecules of the pure solvent hence resulting to lowering of the vapour pressure of the pure solvent.

→ As a result low temperature will be required for liquid and vapour phase of the solution to have the same vapour pressure. Therefore the freezing point of a solution is lower than that of a pure solvent.

5 b) The mixture of methanol and ice, at temperature of +10°c is readily attained because methanol is highly volatile, when added to ~~water~~ ice increases the vapour pressure of ice hence the vapour pressure of the solution is higher than pure ice ∴. This results to increase in freezing point of ice to +10°c. While the mixture of ice and water have the temperature of 0°c due to absence of ~~non-vv~~ volatile solute.

c) By using $\Pi = \frac{nRT}{V}$.

Where symbols stand their usual meaning

$T = 298k$.

$V = 1dm^3$.

but $1dm^3 = 1 \times 10^{-3} m^3$.

$V = 1 \times 10^{-3} m^3$.

$\Pi = 4.31 \times 105 Nm^{-2}$.

$R = 8.31 Jmol^{-1}k^{-1}$

$n = \frac{\Pi V}{RT}$.

$n = \frac{4.31 \times 10^5 Nm^{-2} \times 1 \times 10^{-3} m^3}{8.31 Jmol^{-1}k^{-1} \times 298k}$.

number of moles of Y (n_Y) = 0.174 moles.

5 c) $n_Y = \frac{\text{mass of Y (g)}}{\text{Molar mass of Y } (gmol^{-1})}$

Molar mass of Y $(gmol^{-1}) = \frac{\text{mass of Y (g)}}{n_Y}$

$= \frac{60g}{0.174 moles}$

$= 344.83 gmol^{-1}$

∴ The molar mass of Y is $344.83 gmol^{-1}$

d) The dissociation of acetic acid.

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

	CH_3COOH	CH_3COO^-	H^+
Initially	1	0	0
At equilibrium	$1-\alpha$	α	α.

$i = 1 - \alpha + \alpha + \alpha.$

$i = 1 + \alpha.$

$i = 1 + 0.23.$

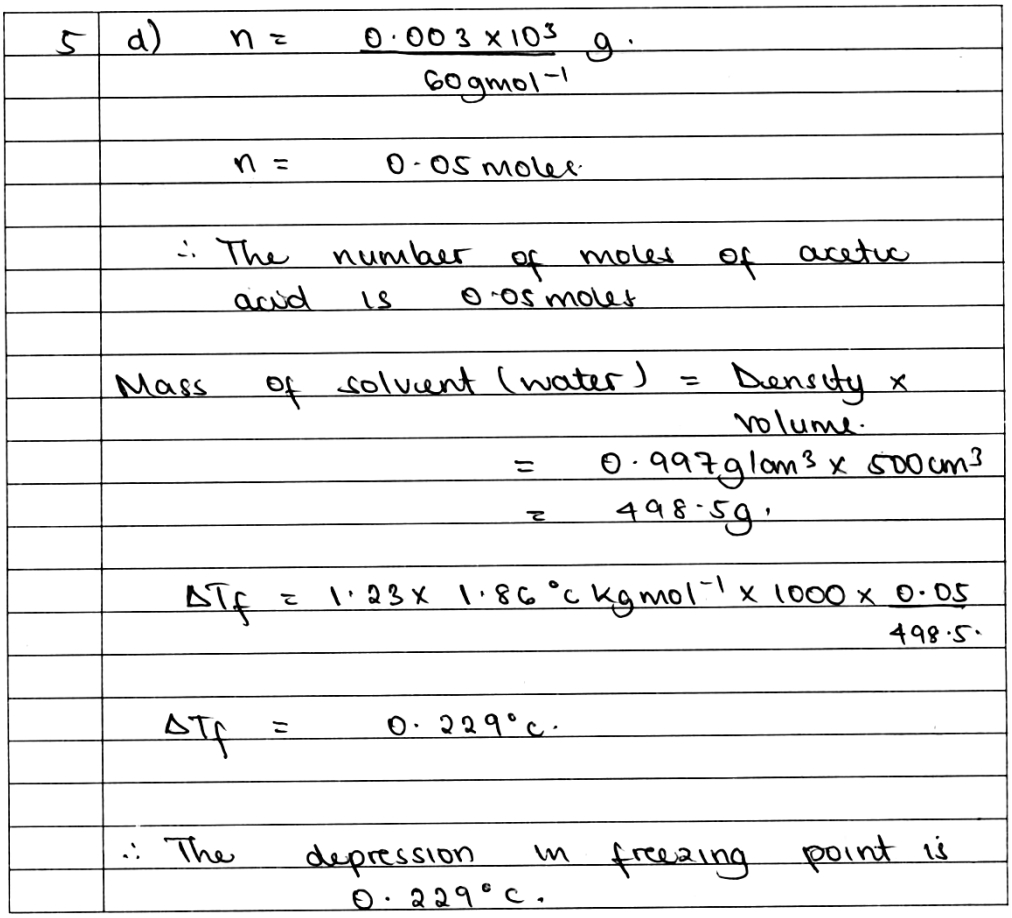
$i = 1.23.$

Where i is vant hoff's vactor.

By freezing point depression.

$\Delta T_f = i K_b m.$

molality = $\frac{\text{number of moles of solute(n)}}{\text{mass of solvent in kg}}$



In Extract 5.1, the candidate correctly responded to every part of the question. All the work is clearly shown.

On the contrary, the candidates who scored low marks failed to give the correct meaning of the osmotic pressure of a solution. Some of them gave the meaning of diffusion instead of osmotic pressure, an indication of insufficient knowledge about the concepts. Further analysis revealed that some of the candidates failed to use the causes of lowering of vapour pressure and freezing point depression in explaining why the freezing point of a solution is lower than that of pure solvent. Similarly, others had no clear understanding of the concepts of intermolecular and intramolecular forces. This concept could have enabled them to explain why the two mixtures show different temperature behaviours in part (b). In other cases, some of the candidates wrongly converted the 0.003 Kg of acetic acid into grams, while others used the degree of dissociation, $\alpha = 23\%$ instead of converting it into 0.23, hence they arrived to an incorrect answer. This indicates lack of knowledge and skills in mathematics. Extract 5.2 illustrates the latter case.

Extract 5.2

5 (a) (i) Osmotic Pressure, is the movement of molecule from low concentration to the high Concentration through semi permeable membrane at a Constant Pressure.

(ii) The freezing of the point of a solution is lower than that of a pure solvent because the solution have endothermic reaction have a tendency to absorve heat from the surrounding

(b) Two mixtures show different temperature behaviour because when water and ice is mixed the ice have low temperature and endothamic reaction, The ice temperature is −4 to +2 up to 0. while CH_3COOH methanol is exothermic reaction that have a tendency to loose the heat from the surrounding.

(c)

Mass of CH_3COOH (msolv) = 0.003 kg

Molar mass of water (Mw) = 0.998 g/cm³

Kf = 1.86 °C kg/mol

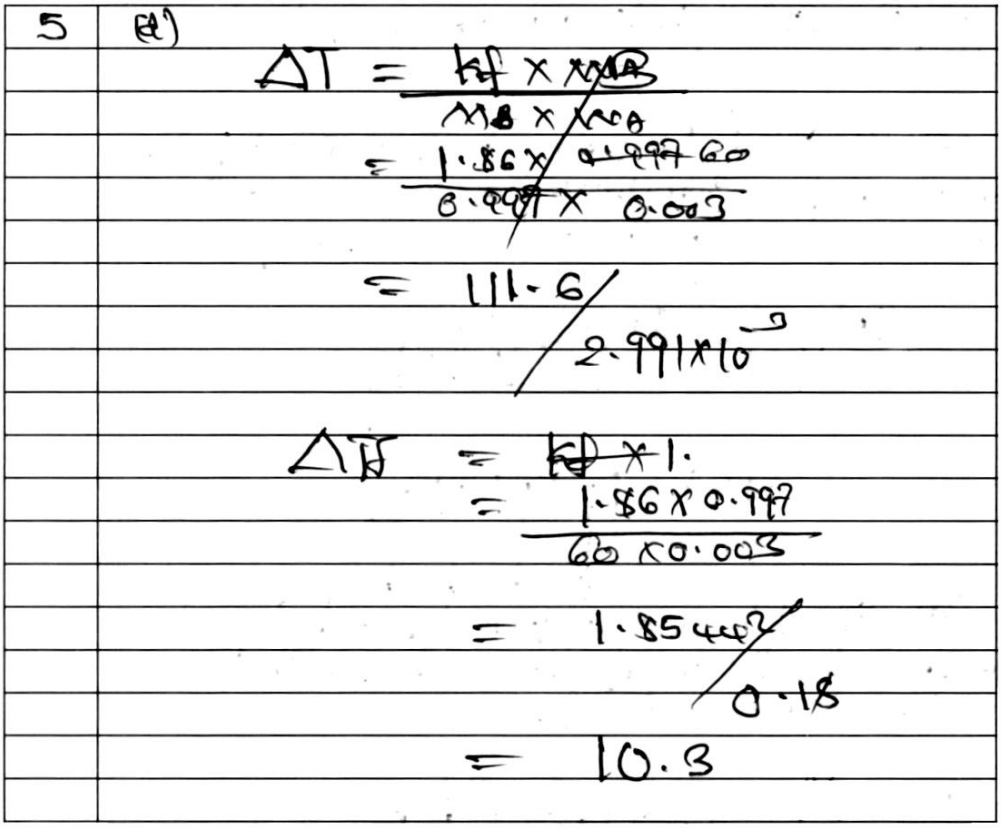
Molar mass of CH_3COOH =

CH_3COOH =

$(12\times1)+(1\times3)+(12\times1)+(16\times1)+(16\times1)+(1\times1)$

$12+3+12+16+16+1$

60 g/dm³



In Extract 5.2, the candidate gave explanations and calculations which do not meet the requirement of the question.

2.1.6 Question 6: Two Components Liquid Systems

In part (a), the candidates were required to define vapour pressure and use Raoult's law of vapour pressure to show that the lowering of vapour pressure is proportional to the mole fraction of the solute. In part (b), the candidates were required to briefly explain why the solution becomes ideal when it is more diluted. In part (c), the candidates were given the information that, "two liquids A and B form an ideal solution when mixed. At 298 K, the vapour pressure of pure A and B for a mixture of 1 mole of A and 3 moles of B are 32 kPa and 16 kPa, respectively". Then they were required to calculate:

(i) the vapour pressure of the mixture.

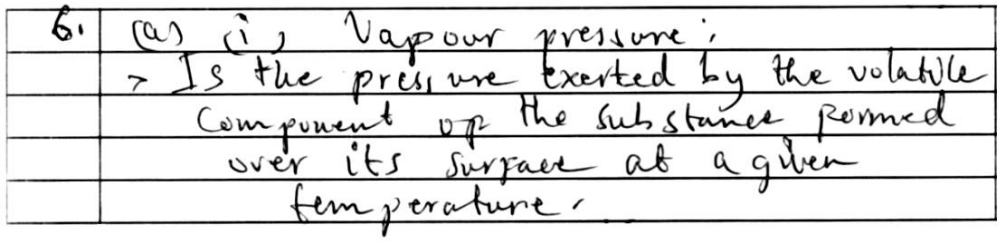
(ii) the mole fraction of liquid A in the vapour which is in equilibrium with the mixture.

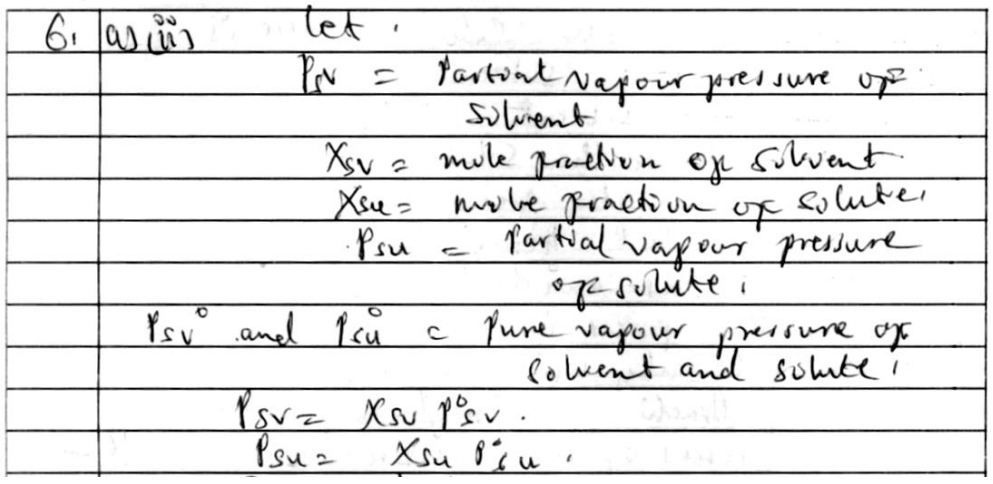
The question was attempted by 66.8 percent of the candidates, out of which 40.0 percent scored from 3.5 to 6.0 marks. The percentage of the candidates

who scored from 6.5 to 10 was 14.4, with 0.2 percent scoring all the 10 marks. The percentage of the candidates who scored from 0 to 3 marks was 45.6, with 6.2 percent scoring a zero mark.

The candidates who scored high marks attempted well most parts of the question. They were able to define vapour pressure and used Raoult's law of vapour pressure to show that the lowering of vapour pressure is proportional to the mole fraction of the solute. The majority of them explained correctly why the solution becomes ideal when it is made more dilute. They also correctly calculated the vapour pressure of the mixture and the mole fraction of liquid A. Extract 6.1 represents a sample of a good response.

Extract 6.1


6. (a) (i) Vapour pressure:
→ Is the pressure exerted by the volatile component of the substance formed over its surface at a given temperature.


6. a (iii) let:
P_{sv} = Partial vapour pressure of solvent
X_{sv} = mole fraction of solvent
X_{su} = mole fraction of solute
P_{su} = Partial vapour pressure of solute
P°_{sv} and P°_{su} = Pure vapour pressure of solvent and solute
$P_{sv} = X_{sv} P^{\circ}_{sv}$.
$P_{su} = X_{su} P^{\circ}_{su}$.

From of Dalton's law:

$P_{soln} = X_{sv} P^{\circ}_{sv} + X_{su} P^{\circ}_{su}$.

but solute is non-volatile

and hence $P^{\circ}_{su} = 0$.

$P_{soln} = X_{sv} P^{\circ}_{sv}$.

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

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

$P^{\circ}_{soln} = P^{\circ}_{sv} - X_{su} P^{\circ}_{sv}$.

$X_{su} P^{\circ}_{sv} = P^{\circ}_{sv} - P_{soln}$.

but $P^{\circ}_{sv} - P_{soln}$ = lowering of vapour pressure

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

$X_{su} P^{\circ}_{sv} = \Delta P$.

but P°_{sv} is constant

$X_{su} \propto \Delta P$.

$\therefore \Delta P \propto X_{su}$ hence shown.

where ΔP is lowering of vapour pressure

X_{su} is mole fraction of solute.

6. (b) Because in dilute solution there is more of solvent - solvent force of attraction than solvent - solute force of attraction hence the solute - solute force of attraction are also very few thus can be neglected hence the solution behaves as an ideal solution.

> Because the forces in the solution will be explained only using solvent-solvent forces of attraction and neglecting solute-solute forces of attraction.

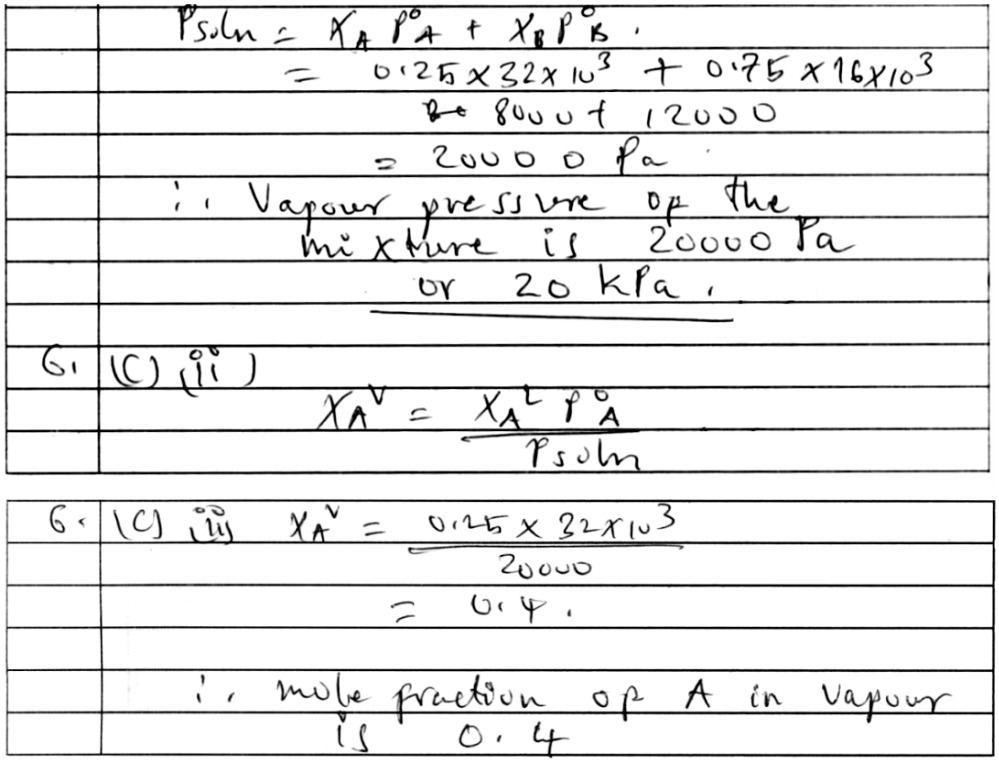
6. (C) (i) $n_A = 1$.

$n_B = 3$.

$n_t = 4$.

$X_A = 1/4 = 0.25$

$X_B = 3/4 = 0.75$



In Extract 6.1, the candidate gave the correct definition of vapour pressure and showed the proportionality between the lowering of vapour pressure and the mole fraction of the solute. She/he also explained correctly why the solution becomes ideal when it is made more dilute, and properly performed all the calculations.

On the contrary, the candidates who scored low marks had insufficient knowledge on the tested concepts. The analysis of the candidates' answers shows that some of them failed to define vapour pressure of the gas. For example one candidate wrongly wrote the definition of vapour pressure as the force per unit area. It was also noted that some candidates mixed the concept of vapour pressure and partial vapour pressure, hence they defined them interchangeably. In other cases, some of the candidates failed to apply Raoult's law of vapour pressure to show that the lowering of vapour pressure is proportional to the mole fraction of the solute.

Further analysis shows that some of the candidates failed to explain why the solution becomes ideal when it is made more dilute. They failed to recognize that dilute solutions deviate less from Raoult's law and that this is the basis of ideal conditions. Others used incorrect formulae to calculate the

vapour pressure and mole fraction. Extract 6.2 illustrates one of the incorrect responses.

Extract 6.2

6 (a) (i) Vapour pressure.
This is the product of mole fraction and partial pressure.

(ii)
6 $P_A = X_A P'_A$

Example.

$P_A = 5$

$P'_A = 3.5$

$X_A = ?$

$5 = X_A\ 3.5$

$X_A = \frac{5}{3.5}$

$X_A = 1.4$

more

lowering P_A to 3

$X_A = \frac{3}{3.5}$

$X_A = 0.86$

This shows lowering of vapour pressure is proportional to mole fraction.

(b) Solution Become more ideal when it becomes more dilute.

. It is because dilute solution has more moleues

(c) Given

$P_A = 32$ kPa

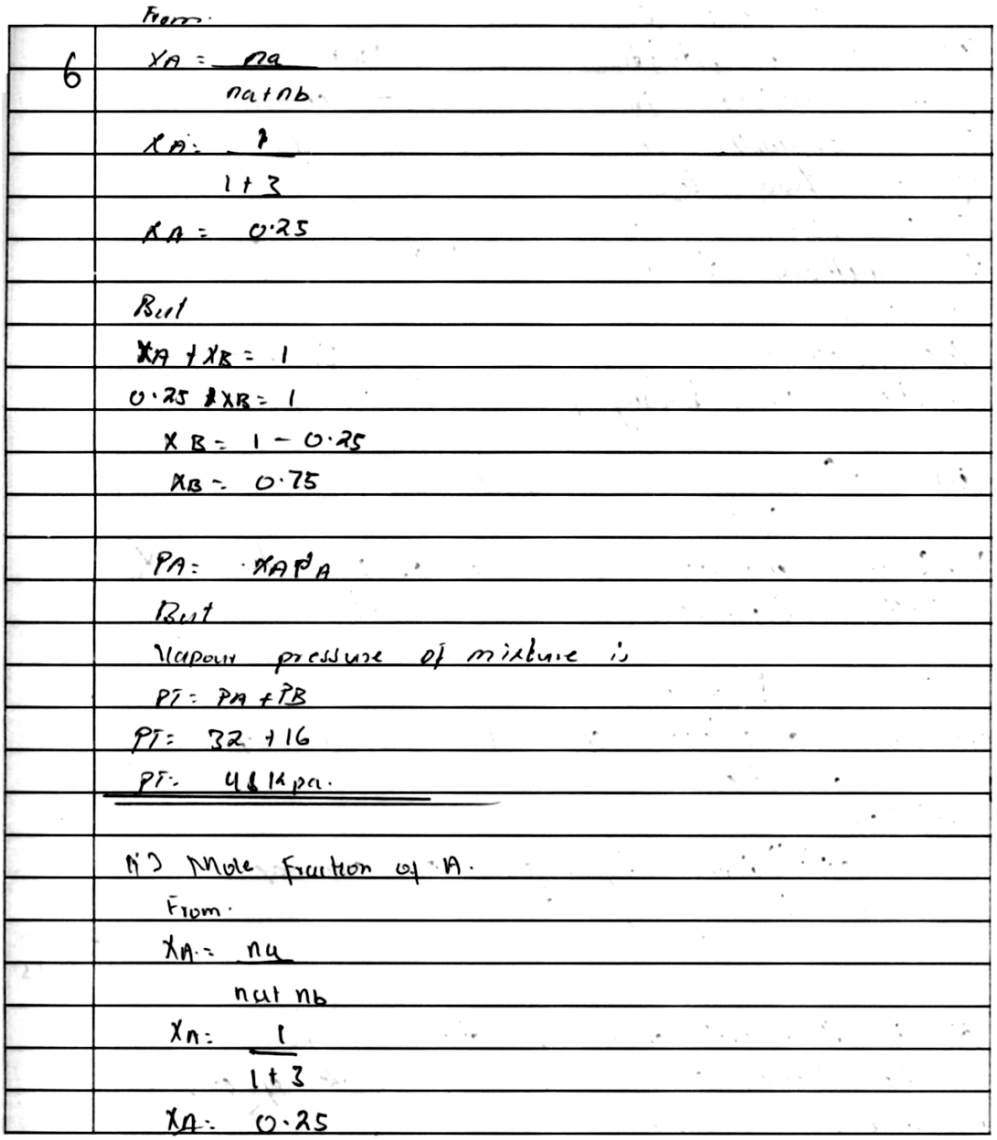
$P_B = 16$ kPa

$n_A =$

$n_B = 3$

$X_A =$

$X_B =$



In Extract 6.2 the given definition of vapour pressure is irrelevant and the calculations made are inappropriate.

2.1.7 Question 7: Two Components Liquid Systems

Part (a) of the question required the candidates to explain in brief the principle of solvent extraction and then compare and contrast fractional distillation from steam distillation. In part (b), they were required to calculate the relative molecular mass of compound B from the provided information that, “steam distillation of a mixture of an organic compound B and water at 98 °C and pressure of 101320 Pa yielded a distillate containing 31.6% by volume of B. The vapour pressure of pure water at this temperature was

94260 Pa. The densities of B and water are 0.961g/cm^3 and 1.000g/cm^3 respectively".

The question was attempted by 38.4 percent of the candidates and the performance is as shown in Figure 4.

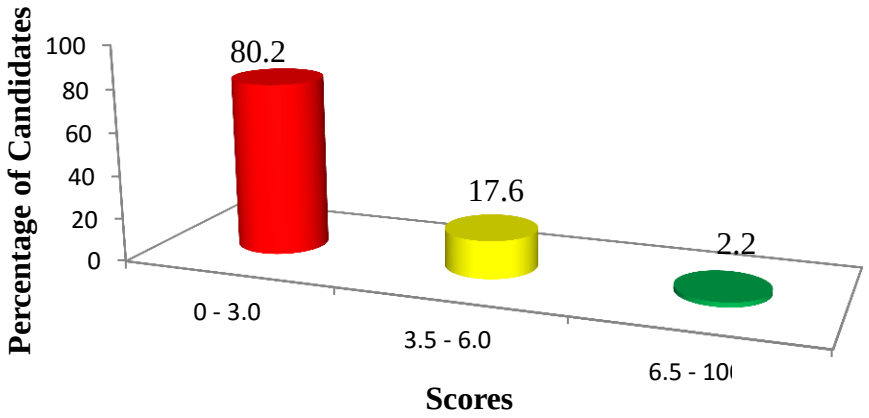


Figure 4: Performance of the candidates in question 7.

As it is seen from figure 4, the percentage of the candidates who scored low marks (0-3) was high (80.2%), while those who scored high marks (6.5-10) was low (2.2%). The figure also shows that 17.6 percent scored average marks (3.5-6.0).

The candidates who did poorly in this question could neither explain the principle of solvent extraction nor compare and contrast fractional distillation from steam distillation. For example, in one script the candidate wrote:

> "*7 (a) (i) the principle of solvent extraction there should be no enthalpy change, the solution should not dissociate no associate, the solvent should be so dilute and the solution must be partially miscible liquid."*

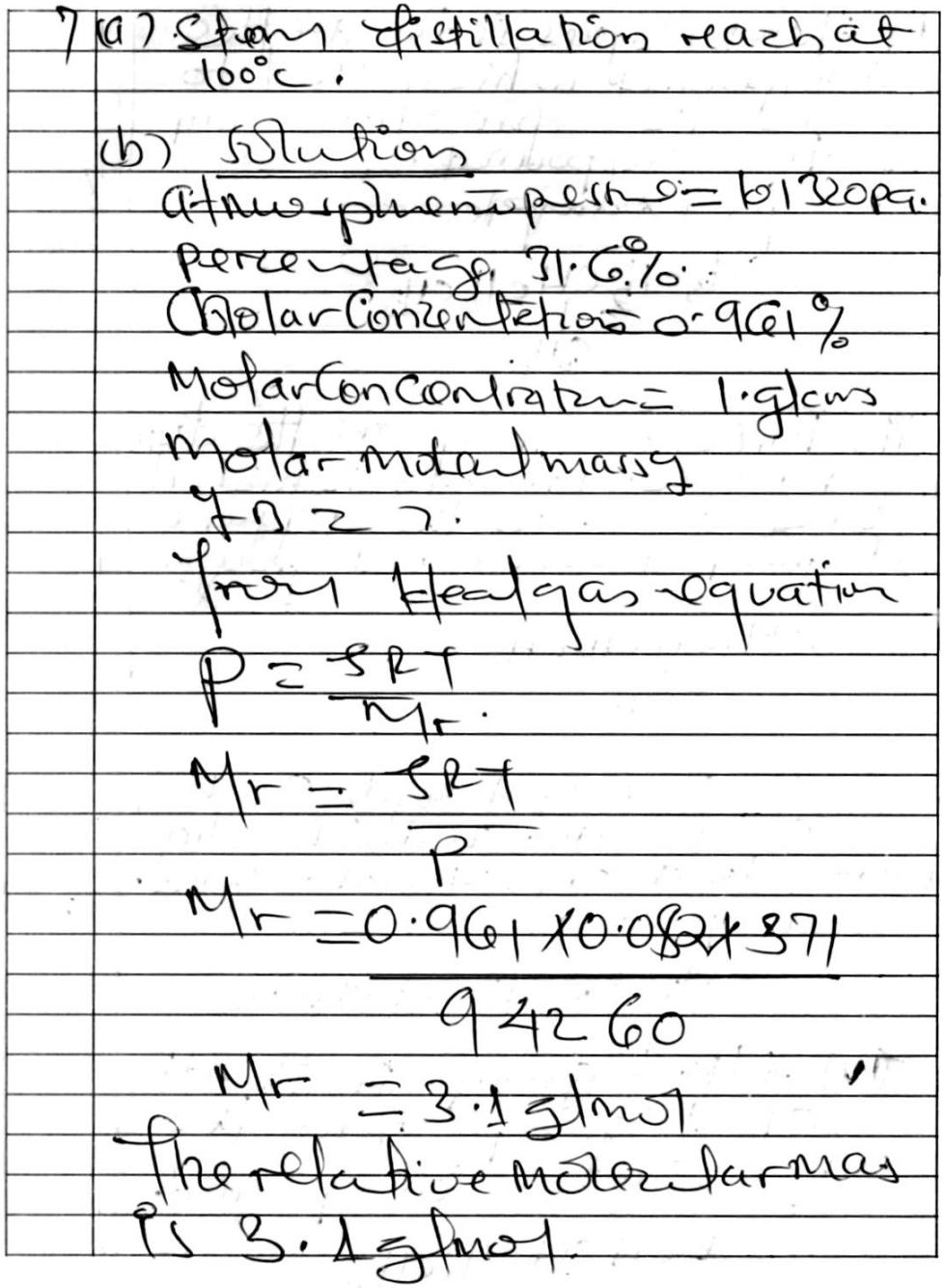
Such incorrect and unclear answers are among the examples which show that the candidates lacked knowledge of the tested concepts and therefore resorted to writing anything regardless of whether it is meaningful or not. It was also noted that some of them faced difficulties in writing the correct formula for calculating vapour pressure and steam distillation. This had an adversary effect on the calculation of relative molecular mass of B, leading to an incorrect answer. Extract 7.1 is a sample answer from a script of a candidate whose performance was poor.

Extract 7.1

7 (a) (i) Principle of solvent extraction is the principle that explain about the removing of solute from the solute by the addition of the second solvent which tend to allow the solute to distribute it self in the two solution.

(ii) Fraction distillation and steam distillation can be compared as follows
- Both of them occur at constant temperature
- Both of them can ~~not~~ obey the Raoults law of vapour pressure.
- Both involve the vapour in the atmosphere.

Contrast between fractional distillation ~~from~~ steam distillation are.
- Fractional distillation involves two layer while steam distillation can not involve two layer.
- Fractional distillation can not attain at 100°c while



In Extract 7.1, the candidate was unable to explain the principle of solvent extraction, and also failed to compare and contrast fractional distillation from steam distillation. She/he used an incorrect formula in calculating the relative molecular mass of B from the information given.

The candidates who scored high marks (6.5 – 10) attempted well most parts of the question. They were able to explain the principles of solvent extraction, compare and contrast fractional distillation from steam distillation and correctly performed all the calculations. Extract 7.2 illustrates one of the candidates' appropriate answers.

Extract 7.2

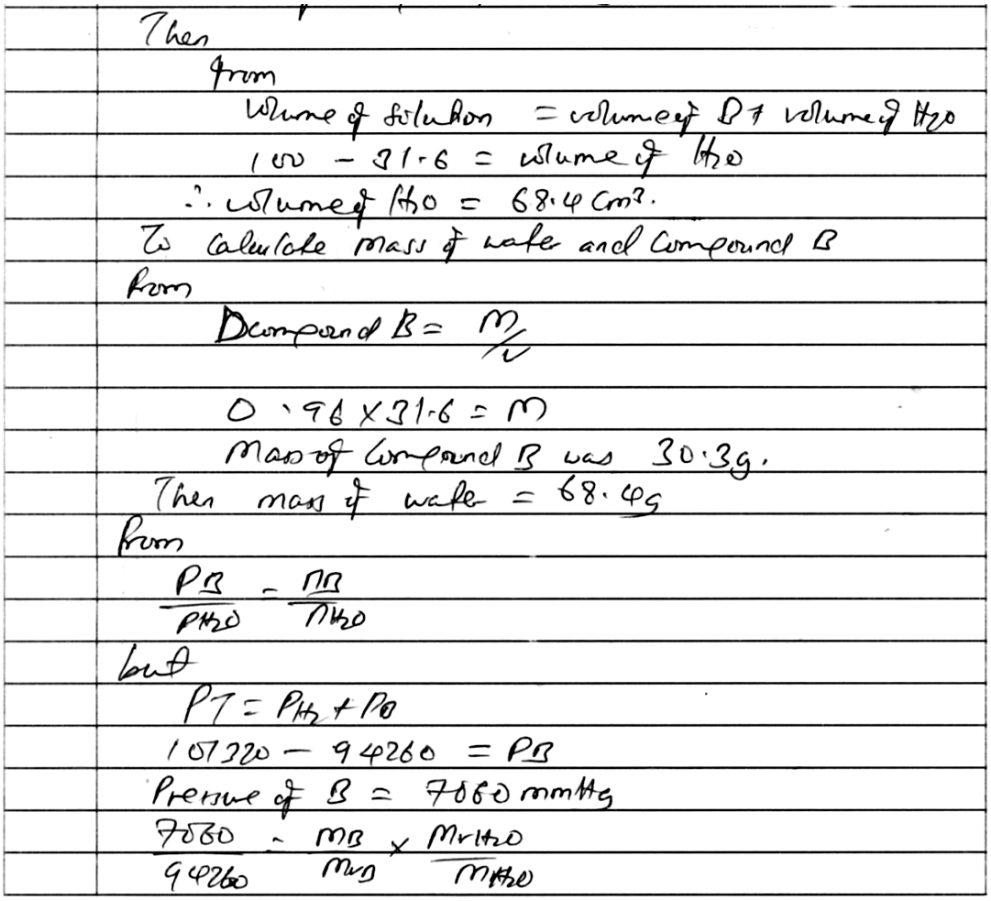
7 a) Solvent extraction this is the method of removing solute in a first solvent by introducing another solvent which is immiscible to the first one, and solute is allowed to distribute itself in the mixture, then extractive solute is removed with significant amount of solute, for successive extraction extractive solvent is added again and again and finally solute is removed the first solvent.

ii) - Both fraction distillation and steam distillation are applied in solution.
- Both involved in separating mixture of two liquids with different boiling point.
- Both affected by concentration.

differences.

Fraction distillation	Steam distillation.
- Separate solution which is miscible	- Separate solution which is immiscible
- molecular weight of liquid it not be higher than that of the water	- Molecular ~~formula~~ weight of a liquid should be higher than that of the water.

7 b) data given
Pressure of organic compound B was 101320
Pressure of water was 54280
Percentage by volume of compound B was 31.6%
Density of compound B was 0.96 g/cm³
Density of water was 1 g/cm³.
from.
volume of Compound B = $\frac{31.6\% \times 100}{100\%}$
volume of Compound b = 31.6 cm³.



Extract 7.2 shows a part of good answer from the candidate who was able to explain the principle of solvent extraction. She/he was able to compared and contrasted fractional distillation from steam distillation and correctly performed all the calculations.

2.1.8 Question 8: Energetics

The question was as follows:

(a) Define the following:
   (i) Standard enthalpy change of neutralization.
   (ii) Heat of solution.
   (iii) Bond energy.
   (iv) Standard enthalpy change of solution.

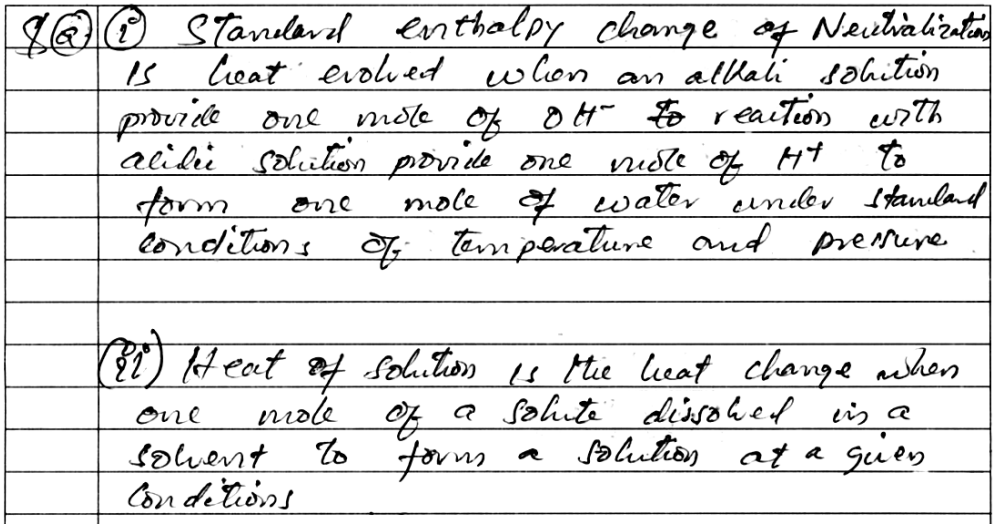
(b) Differentiate between:
   (i) Lattice energy and energy of reaction.
   (ii) Standard molar enthalpy change of dissolution and heat of combustion.

(c) Given the standard enthalpy change of combustion of hydrogen, ΔH^o = -286 kJ/mol; carbon ΔH^o = -394 kJ/mol; methane ΔH^o = -890 kJ/mol; Ethene ΔH^o = -1390 kJ/mol and heat of formation of CH_3CH_2OH = -286 kJ/mol, calculate in kJ/mol the enthalpy change;
(i) of formation of methane.
(ii) of formation of ethane.
(iii) for the reaction $CH_2{=}CH_2(g) + H_2O(g) \rightarrow CH_3CH_2OH(g)$.
(iv) of combustion of 4.48 dm^3 of ethene.

The number of candidates who attempted this question was 25,925, equivalent to 87.7 percent. Out of these, 58.6 percent scored from 0 to 3.0 out of the 10 marks, with 8.0 percent scoring a zero mark. The percentage of the candidates who scored 3.5 to 6.0 marks was 34.4 percent and 6.9 percent scored 6.5 to 10 marks. Only 0.2 percent scored all the 10 marks.

The candidates who scored high marks in this question managed to give the definition of standard enthalpy change of neutralization, heat of solution, bond energy and standard enthalpy change of solution. They were also able to give the differences between, lattice energy and energy of reaction, standard molar enthalpy change of dissolution and heat of combustion. Similarly, they carried out all the calculations as demanded by the question. Extract 8.1 illustrates the case.

Extract 8.1


8(a) (i) Standard enthalpy change of Neutralization is heat evolved when an alkali solution provide one mole of OH^- to reaction with acidic solution provide one mole of H^+ to form one mole of water under standard conditions of temperature and pressure

(ii) Heat of solution is the heat change when one mole of a solute dissolved in a solvent to form a solution at a given conditions

(iii) Bond energy is the heat required to break a bond from which a compound is formed at a given condition

(iv) Standard enthalpy change of combustion is the heat evolved when one mole of substance is completely burnt in oxygen under a standard conditions of temperature and pressure.

(b) (i) Lattice energy is the heat evolved when a one mole of lattice compound is formed from its corresponding gaseous ions. WHILE Energy of reaction is the heat change when one mole of compound is from ~~from~~ its corresponding gaseous atom at their normal physical state.

(ii) Standard molar enthalpy change of dissolution is the heat change when a one mole of substance is dissolve in a solvent under standard conditions WHILE Heat of combustion is the heat evolved when a one mole of a substance is completely burnt in oxygen at a given condition

(c) Given

$H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(l)} \quad \Delta H^\ominus = -286 KJmol^{-1}$

$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \Delta H^\ominus = -394 KJmol^{-1}$

$CH_{4(g)} + 2O_2 \longrightarrow CO_2 + 2H_2O \quad \Delta H^\ominus = -870 KJmol^{-1}$

$C_2H_{2(g)} + \frac{5}{2} O_2 \longrightarrow 2CO_2 + H_2O \quad \Delta H^\ominus = -1300 KJmol^{-1}$

(ii) Formation of Methane

$$C + 2H_2 \longrightarrow CH_4$$

$$\left.\begin{array}{ll} C\!\!\not{O}_2 + 2H_2O \longrightarrow CH_4 + 2\!\!\not{O}_2 & \Delta H = 890 \\ 2H_2 + O_2 \longrightarrow 2H_2O & \Delta H = 2(-286) \\ C + O_2 \longrightarrow C\!\!\not{O}_2 & \Delta H = -394 \end{array}\right\} +$$

$$C + 2H_2 \longrightarrow CH_4$$

9(c) (i) $C + 2H_2 \longrightarrow CH_4$

$\Delta H^\circ = (890 + 2(-286) + (-394))\ kJmol^{-1}$

$\Delta H^\circ = -76\ kJmol^{-1}$.

Heat of formation of Methane $= -76\ kJmol^{-1}$

(ii) Heat of formation of Ethene

$$2C + 2H_2 \longrightarrow C_2H_4$$

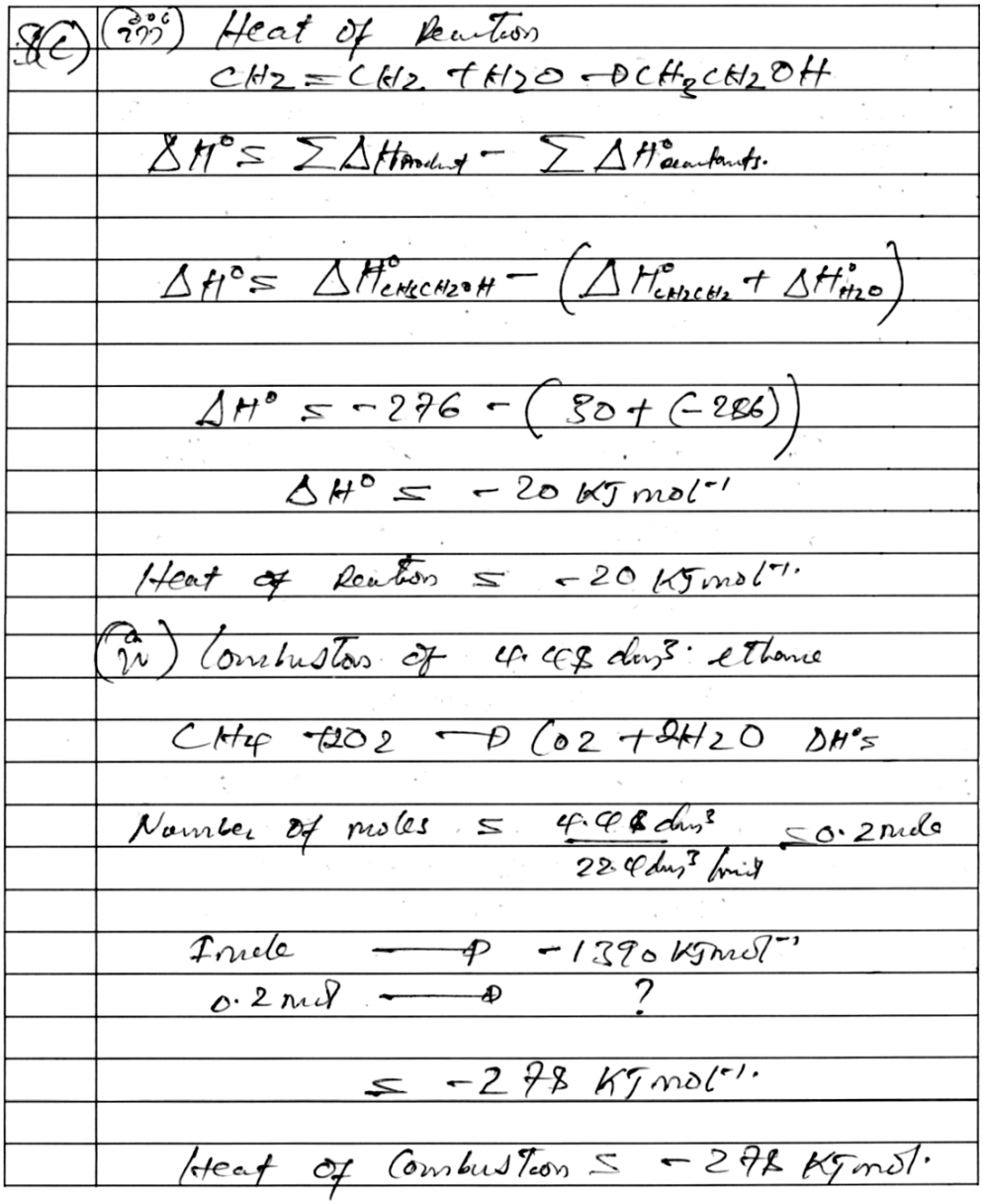
$$\left.\begin{array}{ll} 2C\!\!\not{O}_2 + 2H_2O \longrightarrow C_2H_4 + 3\!\!\not{O}_2 & \Delta H^\circ = 1390 \\ 2C + 2\!\!\not{O}_2 \longrightarrow 2C\!\!\not{O}_2 & \Delta H = 2(-394) \\ 2H_2 + O_2 \longrightarrow 2H_2O & \Delta H = 2(-286) \end{array}\right\} +$$

$$2C + 2H_2 \longrightarrow C_2H_4$$

$\Delta H^\circ = 1390 + 2(-394) + 2(-286)$

$\Delta H^\circ = 30\ kJmol^{-1}$

Heat of formation of Ethene $= 30\ kJmol^{-1}$



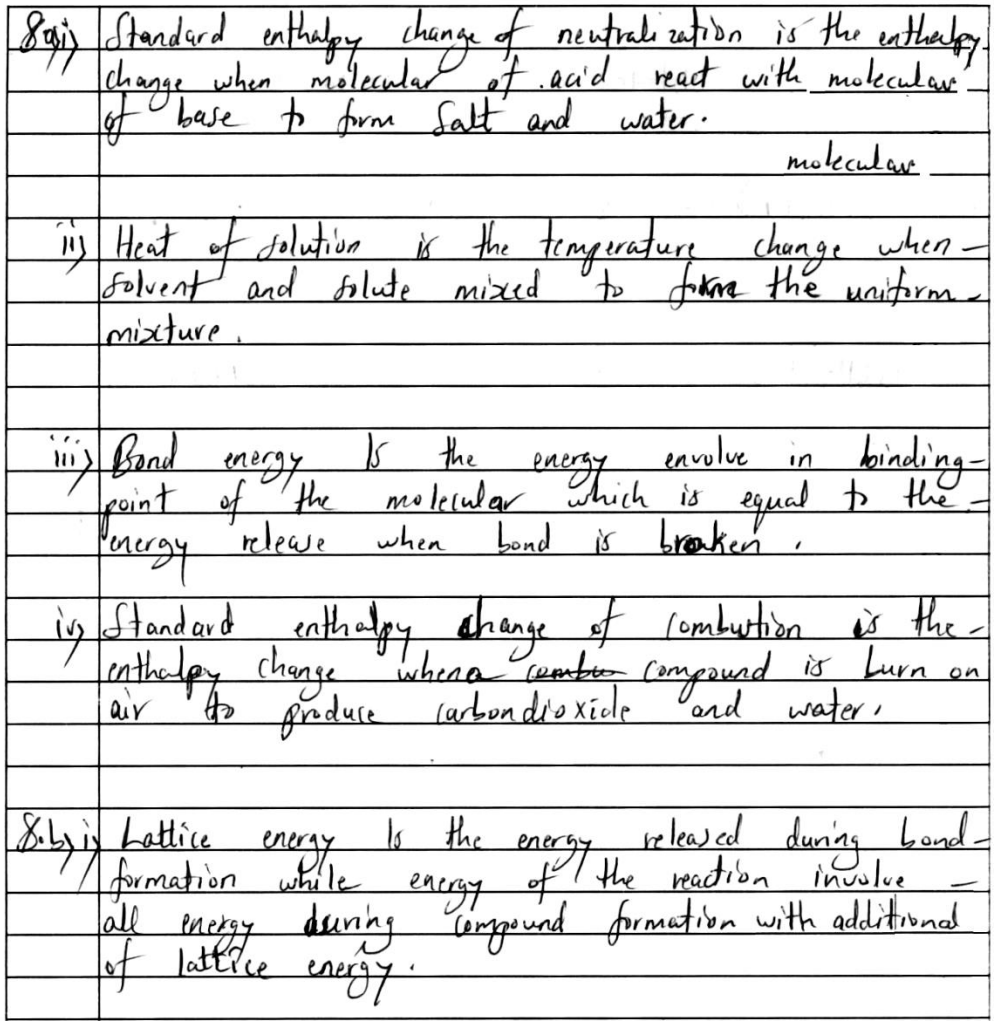
In Extract 8.1 the candidate presented correct answers to all the items in the question. The candidate managed to score full marks.

On the other hand, the candidates who scored low marks failed to define the given terms. For example one candidate defined, “standard enthalpy change of neutralization” as *the enthalpy change when one mole of base dissolves in one mole of acid to obtain salt and water at standard conditions*. In this definition, the candidate did not consider the acids with more than one ionizable hydrogen ions, such as sulphuric acid (H_2SO_4), which ionizes to

form two moles of hydrogen ions. This implies that the candidate lacked sufficient knowledge in the tested concepts.

Further analysis shows that a few candidates failed to differentiate the given terms in part (b). Their responses show that they had a problem of identifying the key words needed for each statement to be meaningful in giving the differences. It was also noted that some of the candidates failed to relate the given data with their respective standard units during calculation. For example they failed to recognize that one mole (22.4L) of ethane gives -1390 kJ/mol, the relationship that leads to the correct answer. Extract 8.2 is provided for illustration.

Extract 8.2


8(a)(i) Standard enthalpy change of neutralization is the enthalpy change when molecular of acid react with molecular of base to form salt and water.
molecular

(ii) Heat of solution is the temperature change when solvent and solute mixed to form the uniform mixture.

(iii) Bond energy is the energy envolve in binding point of the molecular which is equal to the energy release when bond is broaken.

(iv) Standard enthalpy change of combustion is the enthalpy change when a ~~combu~~ compound is burn on air to produce carbondioxide and water.

8(b)(i) Lattice energy is the energy released during bond formation while energy of the reaction involve all energy during compound formation with additional of lattice energy.

iii) Standard molar enthalpy change of dissolution is the enthalpy change during conversion of diatomic gases to form monoatomic gase while heat of combustion is the heat change when a compound is burn in air (presence of oxygen) to form carbondioxide and water.

8.4) Solution:

$2H_2 + O_2 \longrightarrow 2H_2O$ $\Delta H^\circ = -286$ Kjmol ①

$C_2 + 2O_2 \longrightarrow 2CO_2 + H_2O$ $\Delta H^\circ = -394$ Kj/mol -②

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$ $\Delta H^\circ = -890$ Kj/mol --③

$2H_2 + C_2 \longrightarrow CH_4$ $Df^\circ = ?$

reverse eqn (iii)

$CO_2 + 2H_2O \longrightarrow CH_4 + 2O_2$ $+890$ Kj/Mol.

$+ \quad 2H_2 + O_2 \longrightarrow 2H_2O$ -286 Kj/Mol.

$CO_2 + 2H_2 \longrightarrow CH_4 + O_2$ $+604$ Kj/Mol.

$+ \quad C_2 + 2O_2 \longrightarrow CO_2$ -394 Kj/Mol.

$C_2 + O_2 + 2H_2 \longrightarrow CH_4$ $= 208$ Kj/Mol.

$= 208$ Kj/Mol.

ii) Solution.

$CH_3CH_3 + \frac{7}{2}O_2 \longrightarrow 2CO_2 + 3H_2O$ $\Delta H^\circ = -1390$

$C_2 + 3H_2 \longrightarrow CH_3CH_3 = ?$ Kj/Mol.

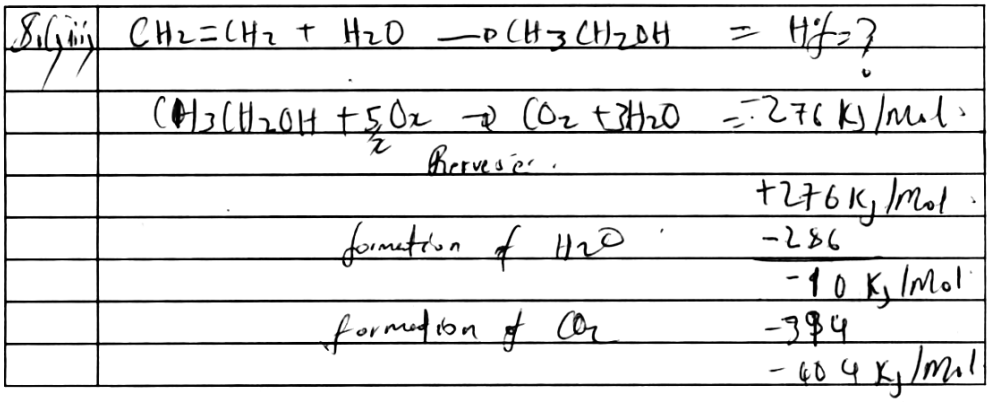
$2CO_2 + 3H_2O \longrightarrow CH_3CH_3 + \frac{7}{2}O_2$ $\Delta H^\circ = +1390$

$2H_2 + O_2 \longrightarrow 2H_2O$ $+ \quad -286$

1104

$- \quad 394$

Heat of formation of ethene $= 710$ Kj/Mol



In Extract 8.2, the candidates failed to define the given thermochemistry terms. She/he also incorrectly calculated the enthalpy change of formation of methane and ethane.

2.1.9 Question 9: Energetics

This question was divided into two parts; (a) and (b). In part (a), the candidates were required to use the information given in the table as follows:

Process	ΔH°_{298} (kJmol^{-})
$Na(s) \rightarrow Na(g)$	+108
$\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$	+121
$Na(s) \rightarrow Na^+(g) + e^-$	+496
$Cl(g) + e^- \rightarrow Cl(g)$	-349
$NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$	+787
$NaCl(s) + H_2O(l) \rightarrow Na^+(aq) + Cl^-(aq)$	+4.0

They were then asked to:

(i) Calculate the enthalpy change for the process $2Cl(g) \rightarrow Cl_2(g)$.

(ii) Calculate the standard molar enthalpy change for the process: $NaCl(s) + \frac{1}{2}Cl_2(g) \rightarrow Na^+(g) + Cl^-(g)$.

(iii) Compare the difference between enthalpy change for the processes: $NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$ and $NaCl(s) + H_2O(l) \rightarrow Na^+(aq) + Cl^-(aq)$, and then comment on the differences.

In part (b), the candidates were provided with the information that, "Magnesium displaces copper from copper (II) sulphate solution according to the equation: $CuSO_4(aq) + Mg(s) \rightarrow Cu(s) + MgSO_4(aq)$. When an excess

magnesium was added to 100 cm^3 of 0.1$moldm^{-3}$ copper (II) sulphate, the temperature increased by 46.3 ^oC. It is known that the density and specific heat capacity of the solution are 1.0 g cm^{-3} and 4.18 $Jg^{-1o}C^{-1}$ respectively". Then they were asked to calculate:

(i) The molar enthalpy change for the reaction.
(ii) Minimum quantity of magnesium required.
(iii) The change in temperature if only 0.8 g magnesium was added.

The number of candidates who attempted this question was 20,536, equivalent to 69.4 percent. The performance was as shown in Figure 5.

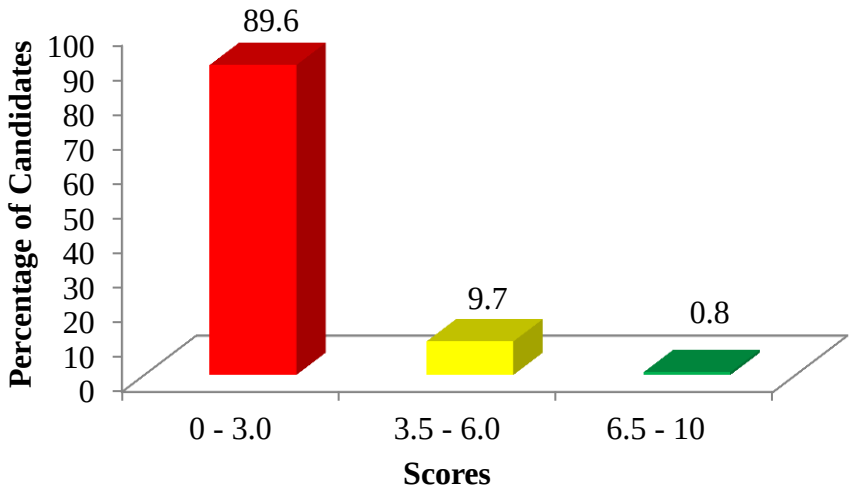
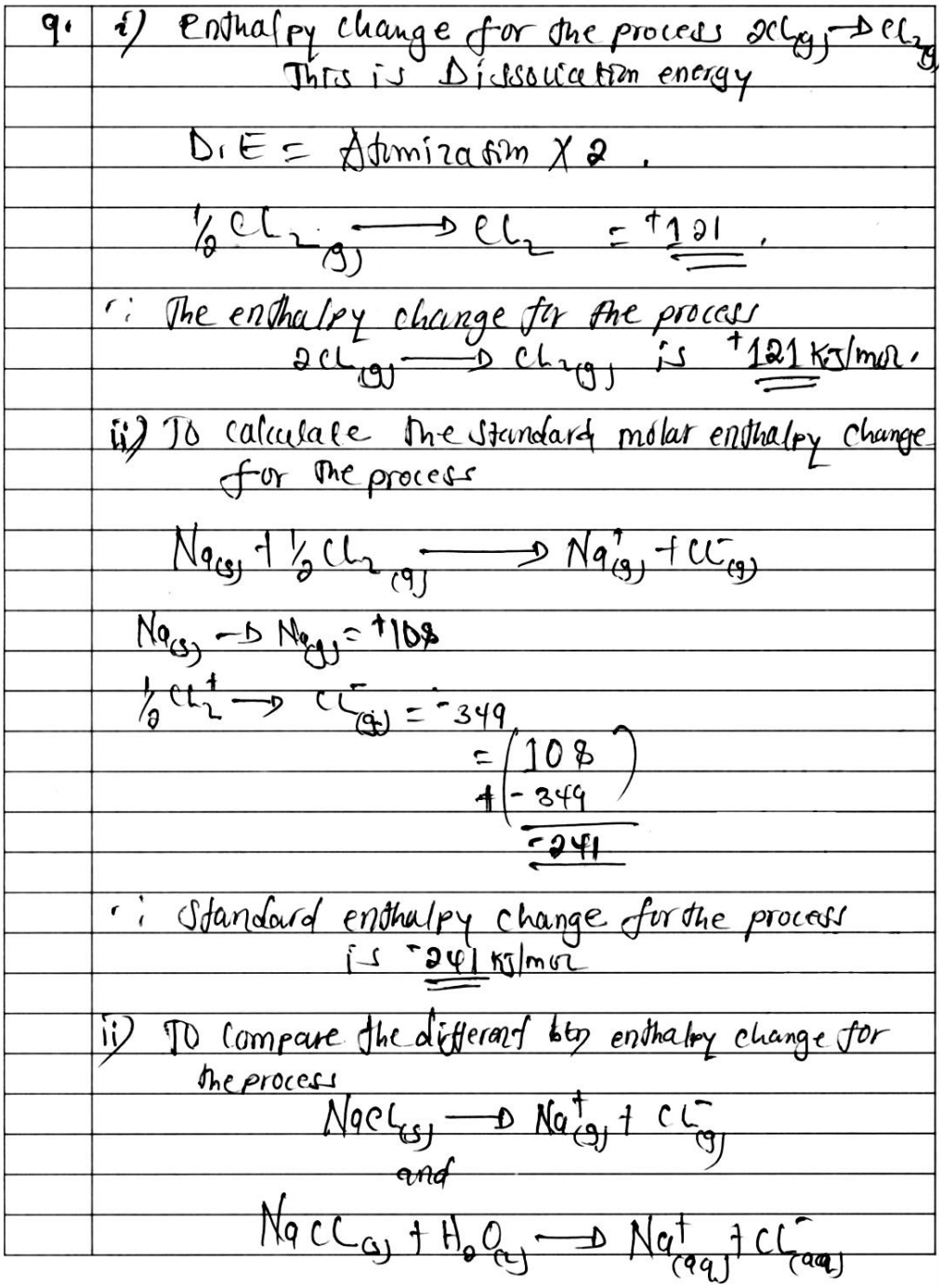


Figure 5: Performance of the candidates in question 9.

Figure 5 shows that the performance of the candidates in this question was poor as 89.6 percent of the candidates scored from 0 to 3.0 marks. Some of the candidates who scored low marks failed to calculate the enthalpy change for the reaction $2Cl(g) \rightarrow Cl_2(g)$ and the standard molar enthalpy change for the reaction $NaCl(s) + \frac{1}{2}Cl_2(g) \rightarrow Na^+(g) + Cl^-(g)$. This was attributed to the failure of the candidates to break the overall energy terms of Born Haber cycle for the formation of sodium chloride crystals into several complete and independent steps as required in the question. They also failed to recognize that the standard enthalpy change is always given in one mole of the substance and it is applied as the reference point for other quantity of the substances in the question. It was also noted that the majority of the candidates failed to apply the correct formula in calculating the molar enthalpy change and the

minimum quantity of magnesium in part (b). Extract 9.1 shows a sample of a poor response.

Extract 9.1



9.@ $NaCl_{(s)} \longrightarrow Na^{+}_{(g)} + Cl^{-}_{(g)}$ and

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

- Different:

i) $NaCl_{(s)} \rightarrow Na^{+} + Cl^{-}_{(g)}$ this equation to the reactant does not involve combination of water while

ii) the second equation of the reactant involve the combination of water.

iii) Incase of product side equation number one involve formation of ions which is gas form. While the second equation which is $NaCl_{(s)} + H_2O_{(l)} \longrightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$ have product involve formation of ions incase of aquoes solution.

Simmilarities:

i) Both are endothermic reaction

ii) Both involve formation of Na and Cl compound

(b) $CuSO_{4(aq)} + Mg_{(s)} \longrightarrow Cu_{(s)} + MgSO_{4(aq)}$

i) molar enthalpy change for the reaction

Delta:

Volume of Mg = $100cm^3$

~~no of moles of Mg =~~

Volume of $CuSO_4$ = $0.1 mol/dm^3$

Final temperature = $46.3 + 273 = 319.3K$.

Initial temperature =

S.P. Heat capacity = $1.0 g/cm^3$ of Mg

" " = $4.185 J/g$ of $CuSO_4$

9. (b)

i) Molar enthalpy change for the reaction is = (final − initial) moles

(1.0 − 0.1)

= 0.9

∴ Molar enthalpy change for the reaction is 0.9 KJ/mol

ii) Minimum quantity of Mg required

iii) Change in temperature if only 0.8g Mg was added

46.3°C − 4.18

= 42.12

∴ Change in temperature if only 0.8g of Mg was added is 42.12.

In Extract 9.1, the candidate failed to calculate and compare the enthalpy change for the given processes. The minimum quantity of the magnesium required and the change of temperature were incorrectly calculated.

However, the candidates who scored high marks were able to calculate the enthalpy change and were able to differentiate correctly the enthalpy change for the processes given. They also commented correctly on the differences of the enthalpy changes for the reactions of the given processes. It was also noted that the candidates also calculated correctly the quantity of magnesium required and the change of temperature, see Extract 9.2.

Extract 9.2

9 (a) (i) from data given

$\frac{1}{2} Cl_2(g) \longrightarrow Cl(g)$ $\Delta H^{\ominus}_{298K} = +121\ kJ/mol$

to reverse this equation

$Cl \longrightarrow \frac{1}{2} Cl_2$ $\Delta H^{\ominus}_{298K} = -121\ kJ/mol$

to multiply by 2

$2Cl_{(g)} \longrightarrow Cl_{2(g)}$ $\Delta H^{\theta}_{298K} = -242 kJ/mol$

∴ enthalpy for process $2Cl_{(g)} \longrightarrow Cl_{2(g)}$ is $-242 kJ/mol$.

(ii)

$Na_{(s)} \longrightarrow Na_{(g)}$ $\Delta H^{\theta}_{298} = +108 kJmol^{-1}$

$Na_{(g)} \longrightarrow Na^{+} + e^{-}$ $\Delta H^{\theta}_{298} = +496 kJmol^{-1}$

$\frac{1}{2}Cl_{2(g)} \longrightarrow Cl_{(g)}$ $\Delta H^{\theta}_{298} = +121 kJ/mol$

$Cl_{(g)} + e^{-} \longrightarrow Cl^{-}_{(g)}$ $\Delta H^{\theta}_{298} = -349 kJ/mol$

to add the equations above.

$Na + \frac{1}{2}Cl_2 \longrightarrow Na^{+} + Cl^{-}$ $\Delta H^{\theta}_{298} = +376 kJ/mol$

$Na_{(g)} + \frac{1}{2}Cl_{2(g)} \longrightarrow Na^{+}_{(g)} + Cl^{-}_{(g)}$ $\Delta H^{\theta}_{298} = +376 kJ/mol$

(iii) More heat is given out in formin $Na^{+}(aq)$ and $Cl^{-}(aq)$ as compared to formation of $Na^{+}(g)$ and $Cl^{-}(g)$ because $Na^{+}(g)$ and $Cl^{-}(g)$ hydrated in water which is exothermic reaction.

9 (b) (i) Mass of solution(M) = density × volume

$= 1 g/cm^3 \times 100 cm^3$

$= 100 g$.

enthalpy change $\Delta H = -MC\Delta T$

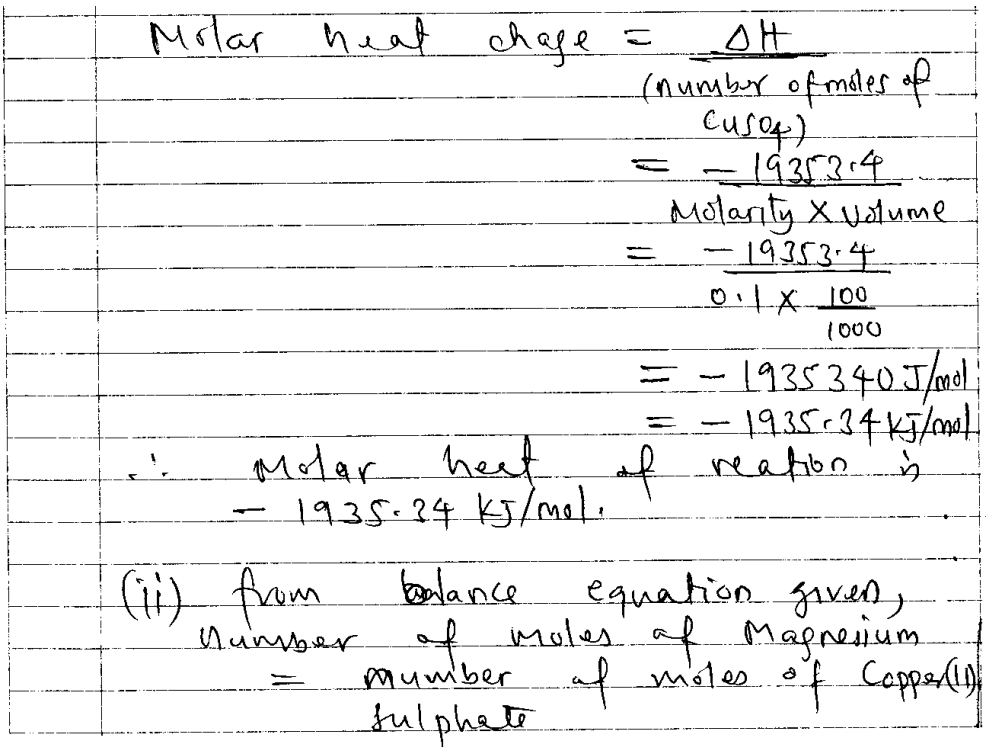
where C = specific capacity of solution = $4.18 J/g°C$.

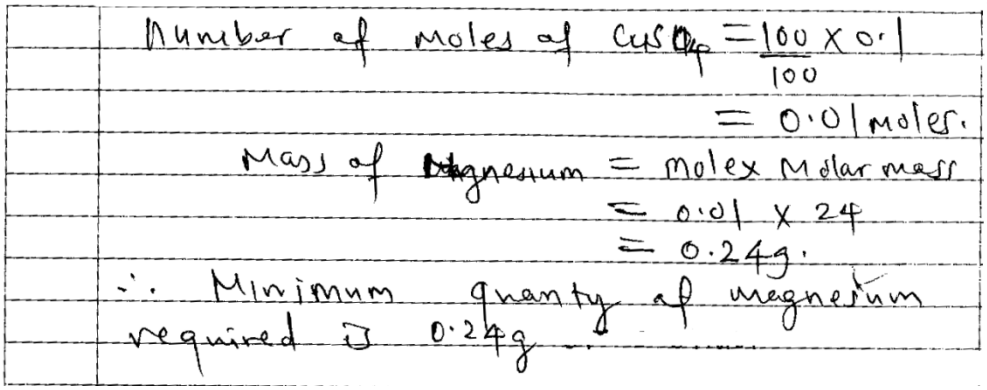
ΔT = Increase in temperature of solution

$= 46.3$

So $\Delta H = -100 \times 4.18 \times 46.3$

$= -19353.4 J$





In Extract 9.2 the candidate correctly calculated the enthalpy change and gave the differences between the enthalpy changes. The appropriate approaches were used in calculating the molar enthalpy change, minimum quantity of magnesium and the change in temperature of magnesium.

2.1.10 Question 10: Chemical Equilibrium

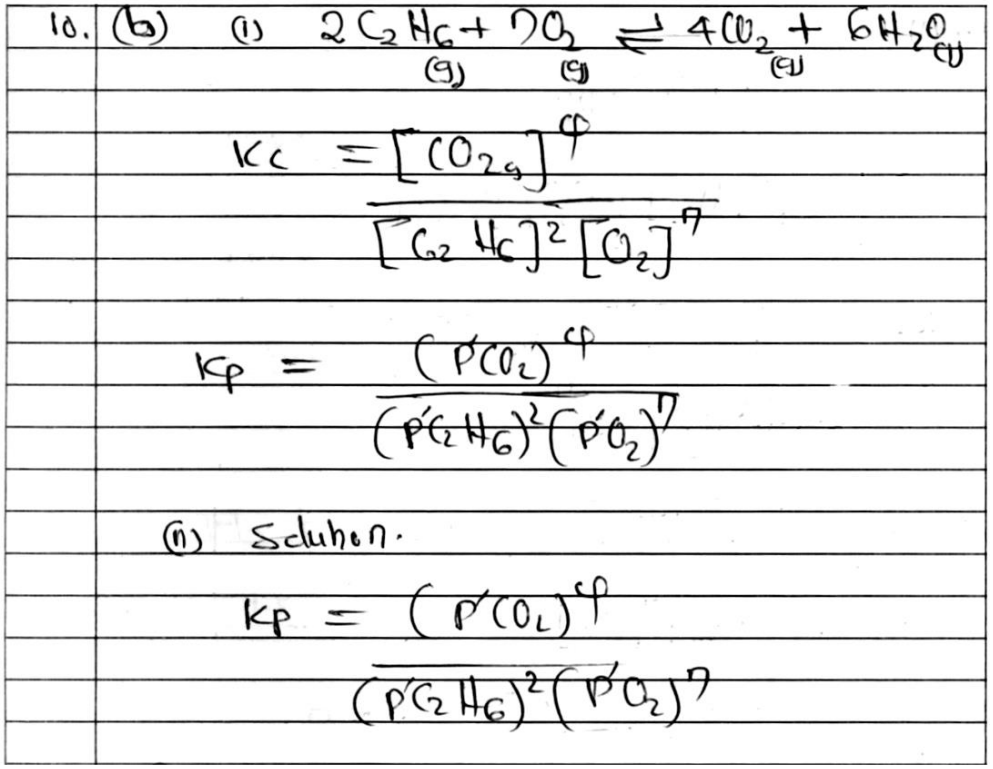
Part (a) of this question required the candidates to differentiate between equilibrium constant, K_c and rate constant, K; equilibrium position and rate of reaction. In part (b), the candidates were required to write K_c and K_p expressions and derive the relationship between K_c and K_p for the equilibrium reaction, $2C_2H_6(g) + 7O_2(g) \rightleftharpoons 4CO_2(g) + 6H_2O(l)$. In part (c), they were provided with the information that, "a 7.52 cm^3 of a gas H

was mixed with 7.0 cm^3 of gas Q in a one litre flask at 298 K. At equilibrium, 10.93 cm^3 of gas HQ was formed". They were then required to calculate the equilibrium constant, K_c for the reaction:
$H_2(g) + Q_2(g) \rightleftharpoons 2HQ(g)$.

The question was attempted by 93.7 percent of the candidates, of which 34.8 percent scored from 3.5 to 6.0 marks and 20.1 percent scored from 6.5 to 10 marks. The candidates who scored from 0 to 3.0 marks were 45.1 percent, of which 6.4 percent scored a zero mark.

The candidates who scored high marks were able to differentiate between equilibrium constant (K_c) and rate constant (K); equilibrium position and rate of reaction. They also wrote the correct K_c and K_p expressions and derived the relationship between K_c and K_p as demanded by the question. In addition, they made correct calculation of the equilibrium constant (Kc) for the given reaction. Extract 10.1 illustrates the case.

Extract 10.1



From $\frac{P'V}{V} = \frac{nRT}{V}$ where P' = partial pressure.

$$P' = [\ ]RT$$

$$P'CO_2 = [CO_2]RT$$

$$P'C_2H_6 = [C_2H_6]RT$$

$$P'O_2 = [O_2]RT$$

10. (b) (ii)

$$Kp = \frac{([CO_2]RT)^4}{([C_2H_6]RT)^2([O_2]RT)^7}$$

$$Kp = \frac{[CO_2]^4}{[C_2H_6]^2[O_2]^7} \times (RT)^{4-(2+7)}$$

But $\frac{[CO_2]^4}{[C_2H_6]^2[O_2]^7} = Kc$

$$Kp = Kc(RT)^{-5}$$

$$\therefore Kp = Kc\,RT^{-5}$$

10. (c) Solution.

From Avogadro's Law.

$V \propto n$

7.52 cm^3 of H = 7.52 moles of H

7.0 cm^3 of Cl = 7.0 moles of Cl

10.93 cm^3 of HCl = 10.93 ml HCl

$H_2 + Cl_2 \rightleftharpoons 2HCl$

	H_2	Cl_2	HCl
moles/ml.	7.52	7.0	0
Change.	$-x$	$-x$	$+2x$

at equalibrium.

$(7.52-x)$	$(7-x)$	$2x$

But

$$\frac{2x}{2} = \frac{10.93 \text{ moles of HCl}}{2}$$

$$x = 5.465$$

moles of H_2 = 7.52 − 5.465

= 2.055 mole

moles of Cl_2 = 7 − 5.465

= 1.535 mole

mole of HCl = 10.93 mole

Extract 10.1 shows part (b) and (c) of the candidate's response, whereby he/she managed to write the correct K_c and K_p expressions and derived the relationship between K_c and Kp. The equilibrium constant (Kc) for the given reaction was also calculated correctly.

On the other hand, the candidates who scored low marks failed to differentiate the given terms. It was also revealed that in writing the K_c and K_p expressions, some of the candidates made a mistake for not including the coefficients of the balanced chemical equation in the expression, hence produced incorrect K_c and K_p expressions. The failure to write the correct K_c and K_p expression had an adversary effect on the derivation of the relationship between K_c and K_p. Moreover, some of the candidates failed to calculate the equilibrium constant, K_c for the given reaction. For example, one candidate calculated it as follows:

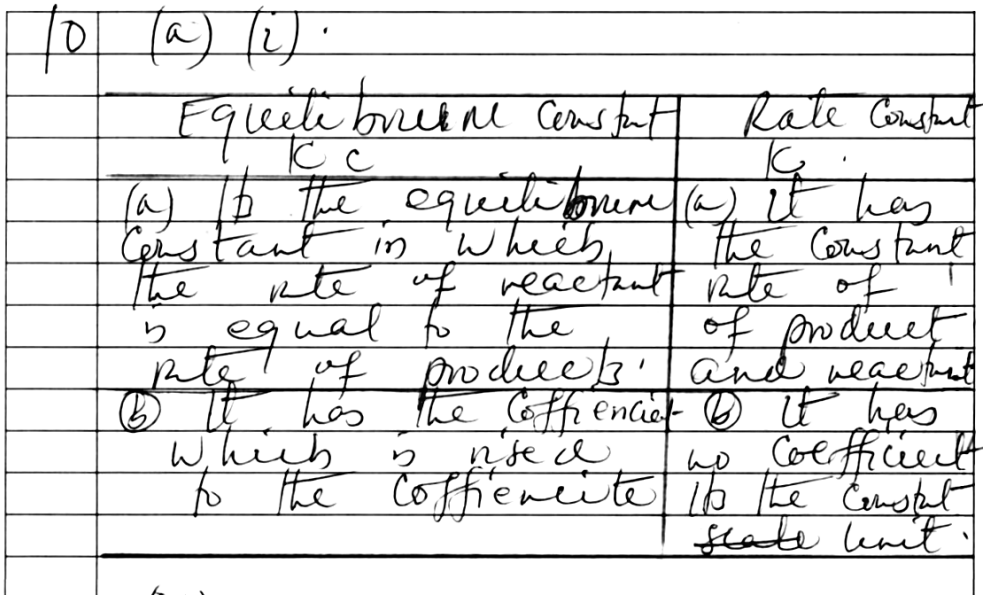
$$\text{"kc} = \frac{[HQ]^2}{[H_2][Q_2]}$$

$$\text{kc} = \frac{(10.96)^2}{(7.52)(7.0)}$$

$$\text{kc} = 2.2695$$

In this calculation, the candidate did not consider the amount of reactants before the reaction with respect to the amount remained at equilibrium, hence arrived to a wrong answer. Extract 10.2 is a response of a candidate who performed poorly.

Extract 10.2


10 (a) (i).

Equilibrium Constant Kc	Rate Constant K.
(a) It is the equilibrium Constant in which the rate of reactant is equal to the rate of products.	(a) It has the Constant rate of of product and reactant
(b) It has the Coffrencia which is used to the Coffrencite	(b) It has no Coefficient to the Constant Scale unit.

10. a(ii).

Equilibrium position	Rate of reaction.
ⓐ It has the constant position of rate of the equilibrium of an element.	ⓐ It has the different rate of reaction of products and reactant.

10 b (i).

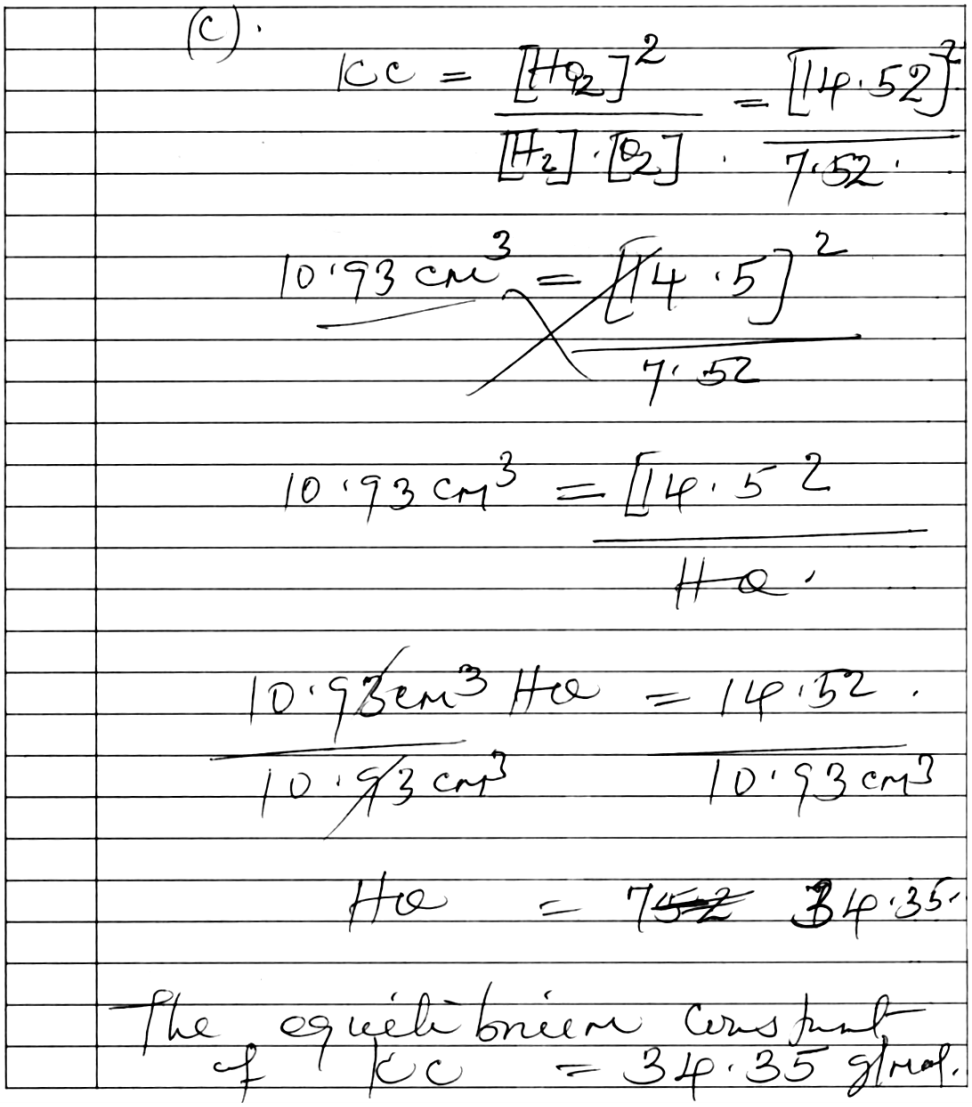
$$Kc = \frac{[CO_2]^4 \cdot [H_2O]^6}{[C_2H_6]^2 \cdot [O_2]^7}$$

$$Kp = [H_2O]^6$$

10 (b). (ii). The relationship between Kc and Kp. are -

ⓐ both express they equilibrium reaction of an element.

Ⓑ. both they rised by coefficiency of the (experimental power).



In Extract 10.2, the candidate failed to differentiate the given terms and wrote incorrect expressions of Kc and Kp. The candidate also failed to derive the relationship between K_c and K_p, and the equilibrium constant was wrongly calculated.

2.1.11 Question 11: Aliphatic Hydrocarbons

Part (a) of this question required the candidates to explain briefly using one appropriate example in each case, the meaning of: homologous series, functional group, unsaturated hydrocarbon, and alkyl group. In part (b), they were required to write the formula of methyl, butyl, ethyl and propyl groups respectively. In part (c), the candidates were required to complete the following reactions:

(i) $CaC_2(s) + 2H_2O(l) \longrightarrow$

(ii) $CH_3CH_2OH \xrightarrow{\text{cold conc } H_2SO_4}$

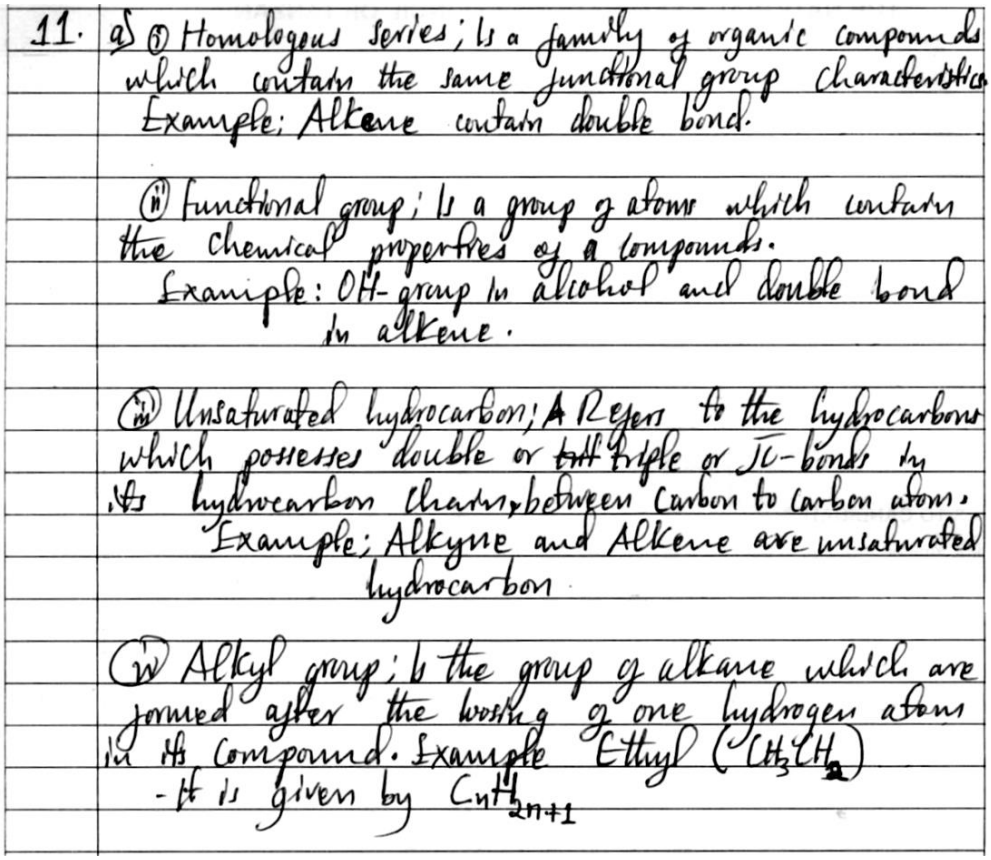
(iii) $CH_3CH_2Cl + KOH \xrightarrow[heat]{alcohol}$

(iv) $CH_3CH{=}CH_2 + H_2O \xrightarrow{H^+}$

The question was attempted by 91.0 percent of the candidates, out of which 40.7 percent scored 6.5 to 10 marks, with 4.8 percent scoring all the 10 marks. The candidates who scored 3.5 to 6.0 were 31.1 percent, while 28.2 percent scored 0 to 3.0 marks and 4.8 percent scored a zero mark.

The candidates who scored high marks managed to explain the organic terms giving examples in each case. Furthermore, they wrote the formula of Methyl, butyl, ethyl and propyl groups as required. The candidates also completed the given reactions correctly, see Extract 11.1.

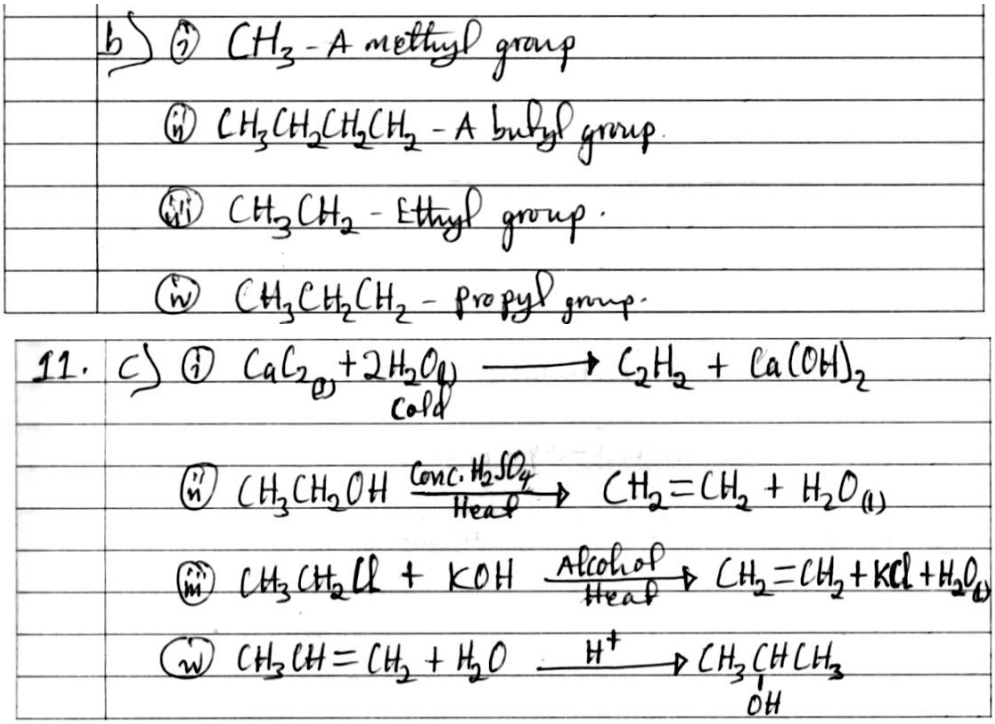
Extract 11.1


11. a) (i) Homologous series; Is a family of organic compounds which contain the same functional group characteristics
Example; Alkene contain double bond.

(ii) Functional group; Is a group of atoms which contains the chemical properties of a compounds.
Example: OH- group in alcohol and double bond in alkene.

(iii) Unsaturated hydrocarbon; A Refers to the hydrocarbons which possesses double or ~~triple~~ triple or π-bonds in its hydrocarbon chains, between Carbon to Carbon atoms.
Example; Alkyne and Alkene are unsaturated hydrocarbon

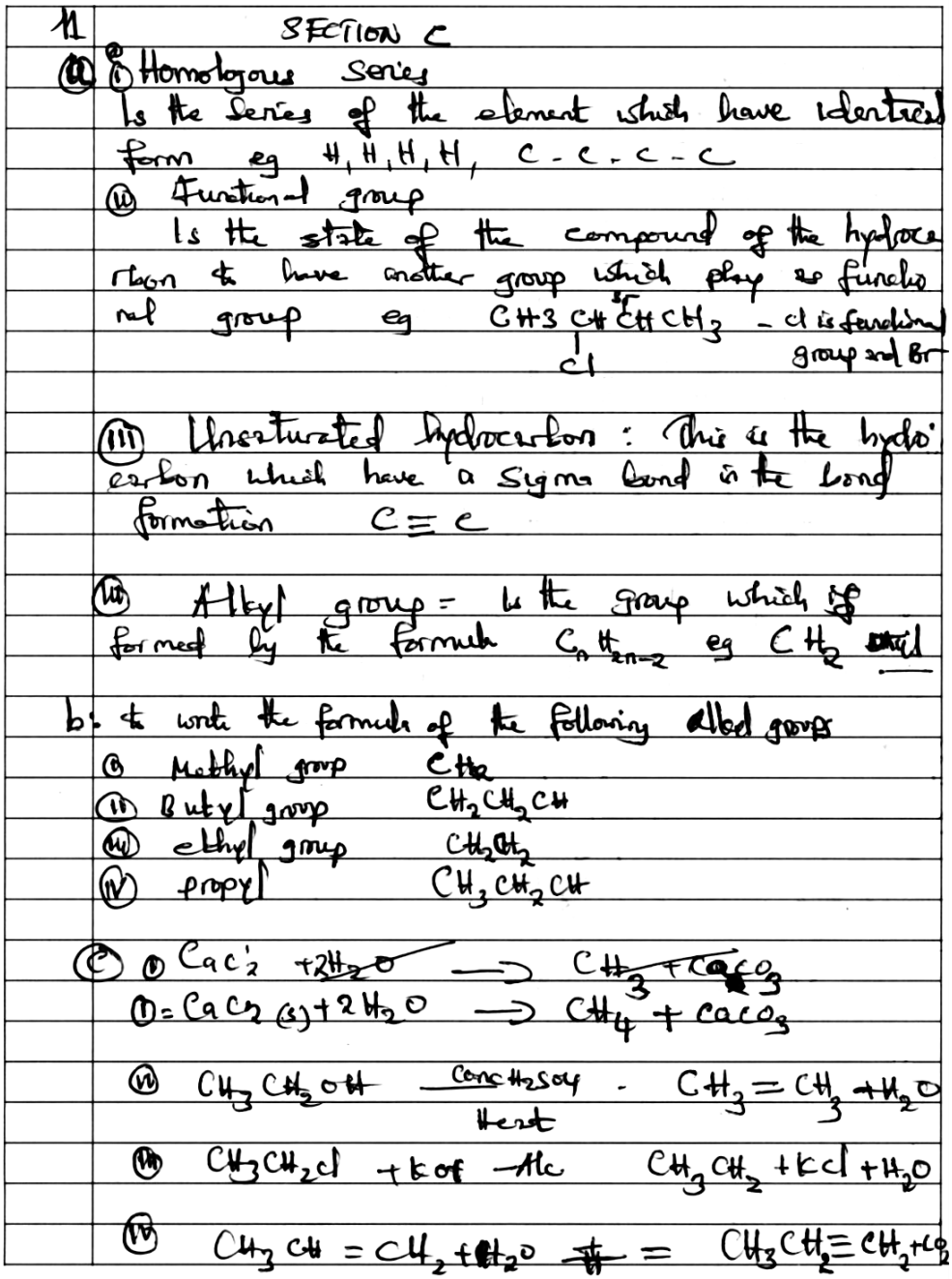
(iv) Alkyl group; Is the group of alkane which are formed after the loosing of one hydrogen atoms in its Compound. Example Ethyl (CH_3CH_2)
- It is given by C_nH_{2n+1}



In Extract 11.1, the candidate managed to explain the meaning of the organic terms and wrote the formula of the functional groups as demanded by the question. She/he also completed correctly, the organic reactions provided.

However, the candidates who scored low marks failed to explain the meaning of the required organic terms. For example, one candidate wrote "unsaturated hydrocarbon are the organic compounds which have only four hydrogen atoms", and gave an example of "CH_4". This answer is incorrect, since unsaturated hydrocarbons contain multiple bonds between their carbon atoms. In other cases, some of the candidates gave incorrect formulae of the alkyl group, while others gave incorrect products of the organic reactions provided. These candidates had insufficient knowledge about organic chemistry, particularly hydrocarbons. Extract 11.2 is a response of a candidate who performed poorly.

Extract 11.2



In Extract 11.2, the candidate who failed to explain the meaning of the organic terms, wrote incorrect formula of the functional groups and wrongly presented the organic reactions.

2.1.12 Question 12: Aromatic Hydrocarbons

In part (a), the candidates were required to define, resonance energy and aromatic compound. In part (b), they were required to explain briefly why methyl benzene (toluene) is more reactive than benzene. In part (c), the candidates were required to write equations to show what will happen when methyl benzene is:

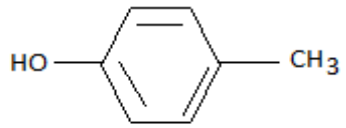
(i) treated with chloromethane (CH_3Cl) in the presence of aluminium chloride ($AlCl_3$).

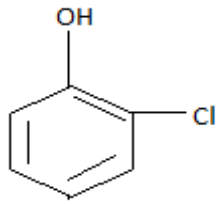
(ii) treated with chlorine in the presence of ultraviolet (uv) light.

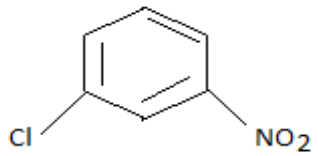
(iii) refluxed with potassium manganate (VII) ($KMnO_4$) in the presence of an acid.

(iv) burnt in excess oxygen.

In part (d, the candidates were required to indicate with reasons the substituent group which entered first in the following aromatic compounds:

(i)


(ii)


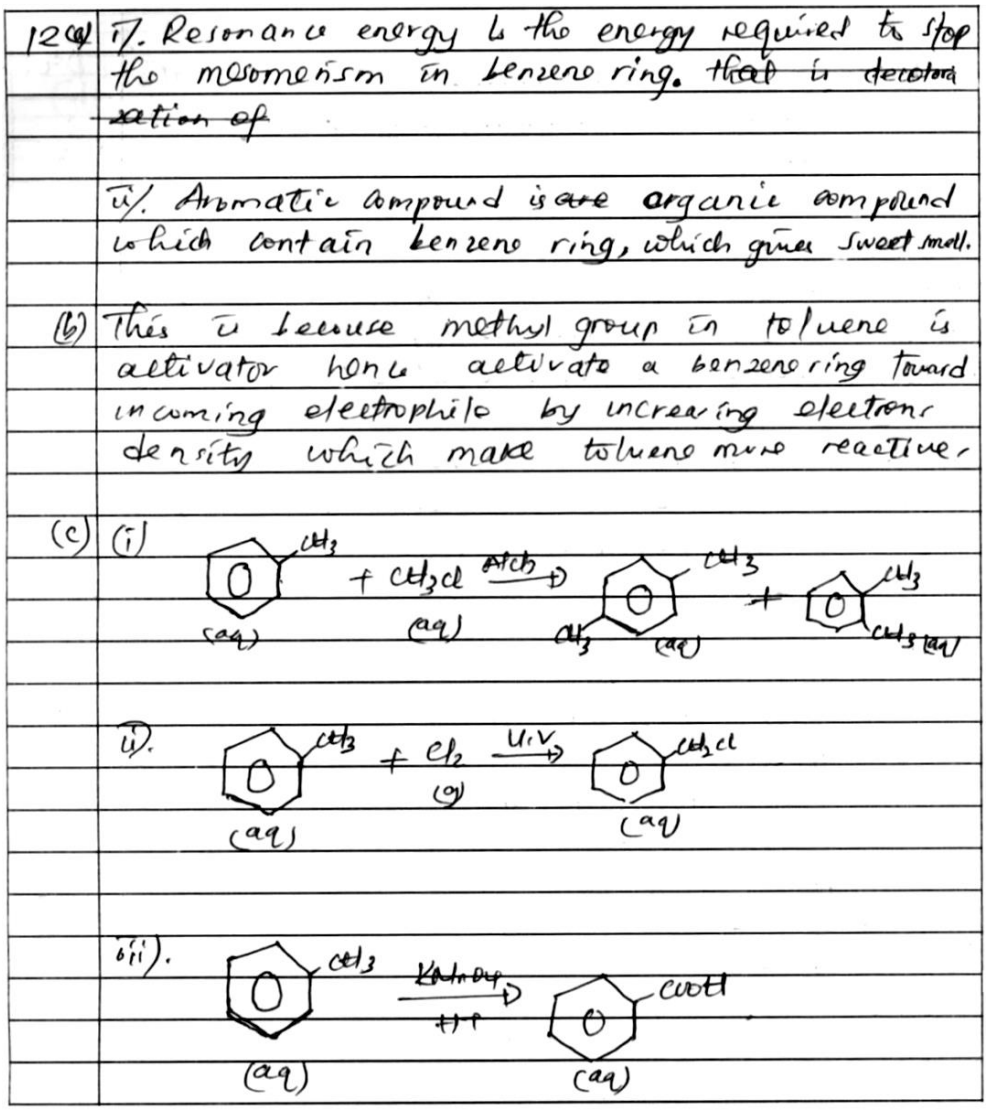
(iii)


The question was attempted by 64.7 percent of the candidates and the general performance was good as 68.5 percent scored above 3.5 marks out of 10 marks. The candidates who scored 6.0 to 10 marks were 28.9 percent, with 1.0 percent scoring all the 10 marks. However, 31.5 percent scored 0 to 3.0 marks with 5.0 percent scoring a zero mark.

The candidates who scored high marks were able to define the terms resonance energy and aromatic compound and explained correctly why methyl benzene (toluene) is more reactive than benzene. The candidates also correctly wrote the equations showing what will happen when methyl

benzene was treated with the given reagents. They also indicated with reasons the substituent group which entered first in the di-substituted aromatic compounds. Extract 12.1 displays a sample answer from one of the candidates.

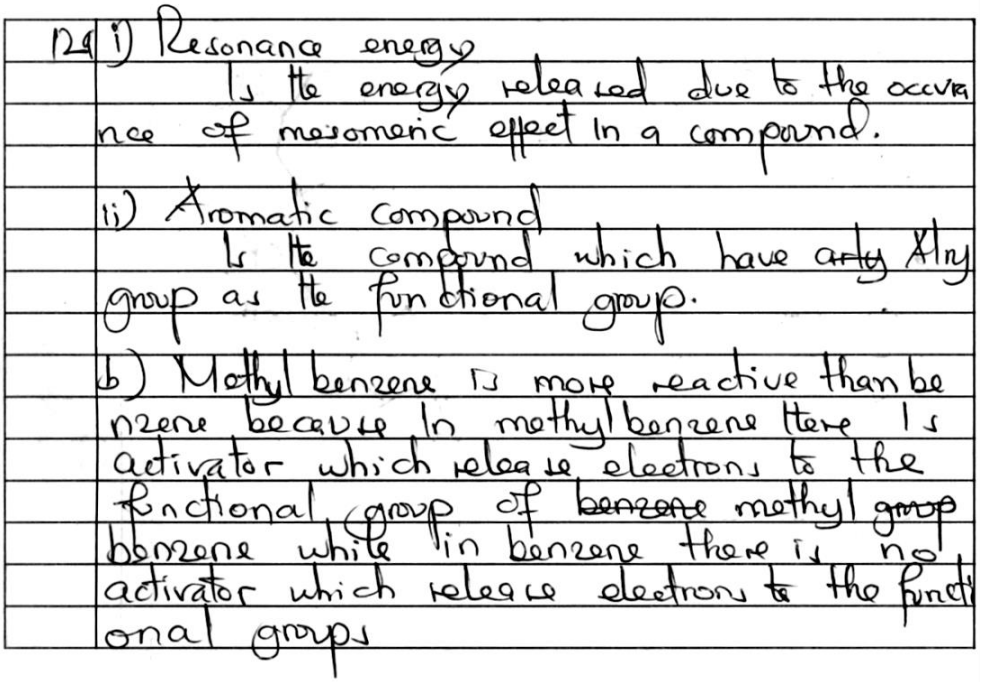
Extract 12.1



Extract 12.1 is a part of the answer in which the candidate was able to define the terms resonance energy and aromatic compound and explained correctly why methyl benzene (toluene) is more reactive than benzene. She/he correctly wrote the equations and their products in part (c) of the question.

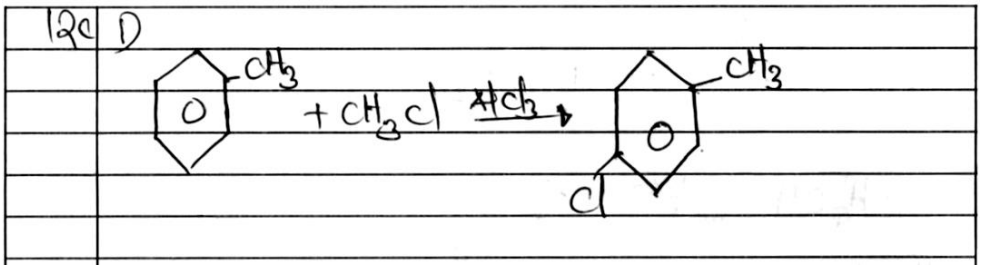
However, the candidates who scored low marks failed to define the terms resonance energy, and aromatic compound. They also failed to write equations of some of the reactions of methylbenzene with the given reagents. Further analysis shows that the candidates had problems in indicating the substituent groups which entered first in the given aromatic compounds. They failed to recognize that substituent in the benzene ring will determine the position in the ring at which further substitution will occur. This is an indication of insufficient knowledge about properties of aromatic compounds. Extract 12.2 illustrates one of the poor responses.

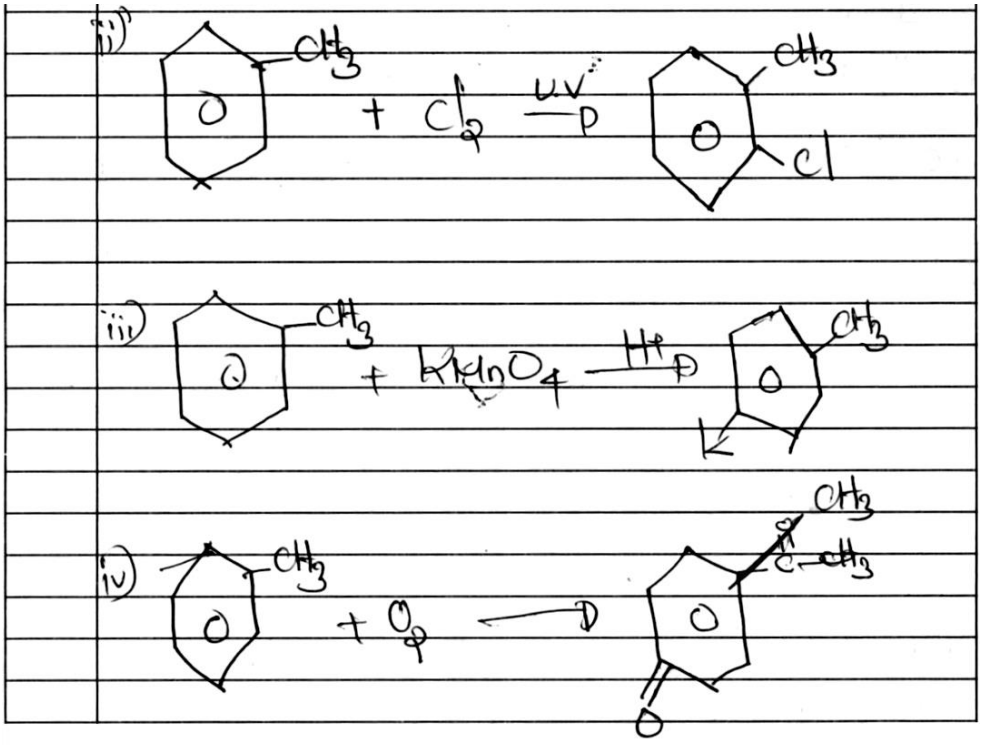
Extract 12.2


12a i) Resonance energy
Is the energy released due to the occurrence of mesomeric effect in a compound.

ii) Aromatic compound
Is the compound which have ~~any~~ Any group as the functional group.

b) Methyl benzene is more reactive than benzene because in methyl benzene there is activator which release electrons to the functional group of ~~benzene~~ methyl group benzene while in benzene there is no activator which release electrons to the functional groups





Extract 12.2 shows part (a), (b) and (c) of the candidate's response whereby she/he gave an incorrect definition of resonance energy and aromatic compound. The explanations given in part (b) were partial and the reaction equations showing how methyl benzene reacts with the given reagents were incorrect.

2.1.13 Question 13: Halogen Derivatives of Hydrocarbons

The question comprised parts (a), (b), (c) and (d). In part (a), the candidates were required to explain briefly why alkyl chlorides are not friendly to the environment. In part (b), they were required to write the structure of the organic compounds, 2-chloro-3-methylpentane and Pent-2-ene. In part (c), they were required to give the IUPAC names of the following compounds:

(i) $CH_3\underset{\displaystyle Cl}{\underset{|}{C}}HCH\overset{\displaystyle Br}{\overset{|}{C}}HCH_3$

(ii) $ClCH_2C{\equiv}CCH_2Br$

(iii) $CHF_2CBrClF$

(iv) $CCl_3CHClCCl_3$

In part (d), the candidates were provided with the information that, "a primary alkyl halide, A, (C_4H_9Br) reacted with alcoholic KOH to give compound B. Compound B reacted with HBr to give C which is an isomer of A. When C (in ether solution) reacted with Na metal, it gave compound D (C_8H_{18})". They were then asked to give the structure of A and write equations for all the reactions.

The percentage of candidates who attempted this question was 79.8. 36.9 percent of them scored from 3.5 to 6.0 marks, 17.0 percent scored from 6.5 to 10 marks, with 0.05 percent scoring all the10 marks. The candidates who scored from 0 to 3.0 marks were 46.1 percent of which 3.5 percent scored a zero mark.

The candidates with high scores explained properly why alkyl chlorides are not friendly to the environment. They also wrote correctly the structure of the alkyl halides and the IUPAC names of the given compounds. Besides, the structure of A and equations for all reactions were correctly presented. Extract 13.1 illustrates responses from the script of a candidate who performed well in the question.

Extract 13.1

13 (a)(i) Alkyl chlorides are not friendly to the environment because they are reactive and thereby react with environmental components bringing hazardous conditions for the living organism example ~~CCl4 tetra~~ CCl_3 causes destruction of ozone layer

(b) (i) $CH_3CH(CH_3)CH_2CH_2CH_3$; 2-chloro-3-methylpentane (Cl)

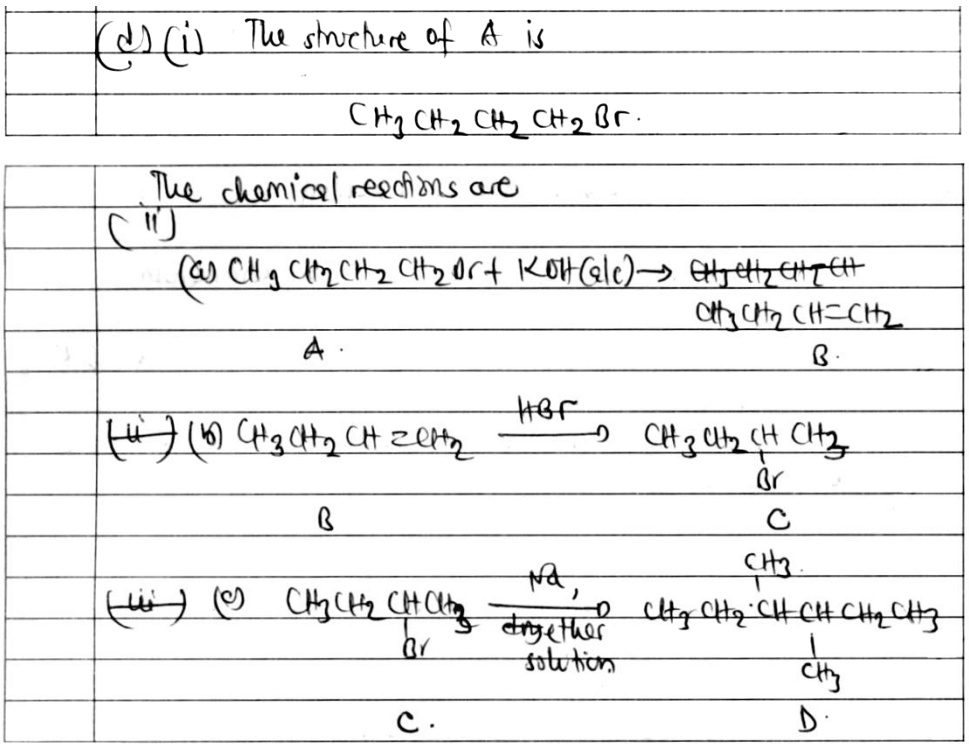
(ii) $CH_3CH=CHCH_2CH_3$; pent-2-ene

(c) (i) 2-bromo-3-chloro butane.

(ii) 1-bromo-4-chloro but-2-yne

(iii) 1-bromo-1-chloro-1,2,2-trifluoro ethane

(iv) 1,1,1,2,3,3,3-heptachloro propane.

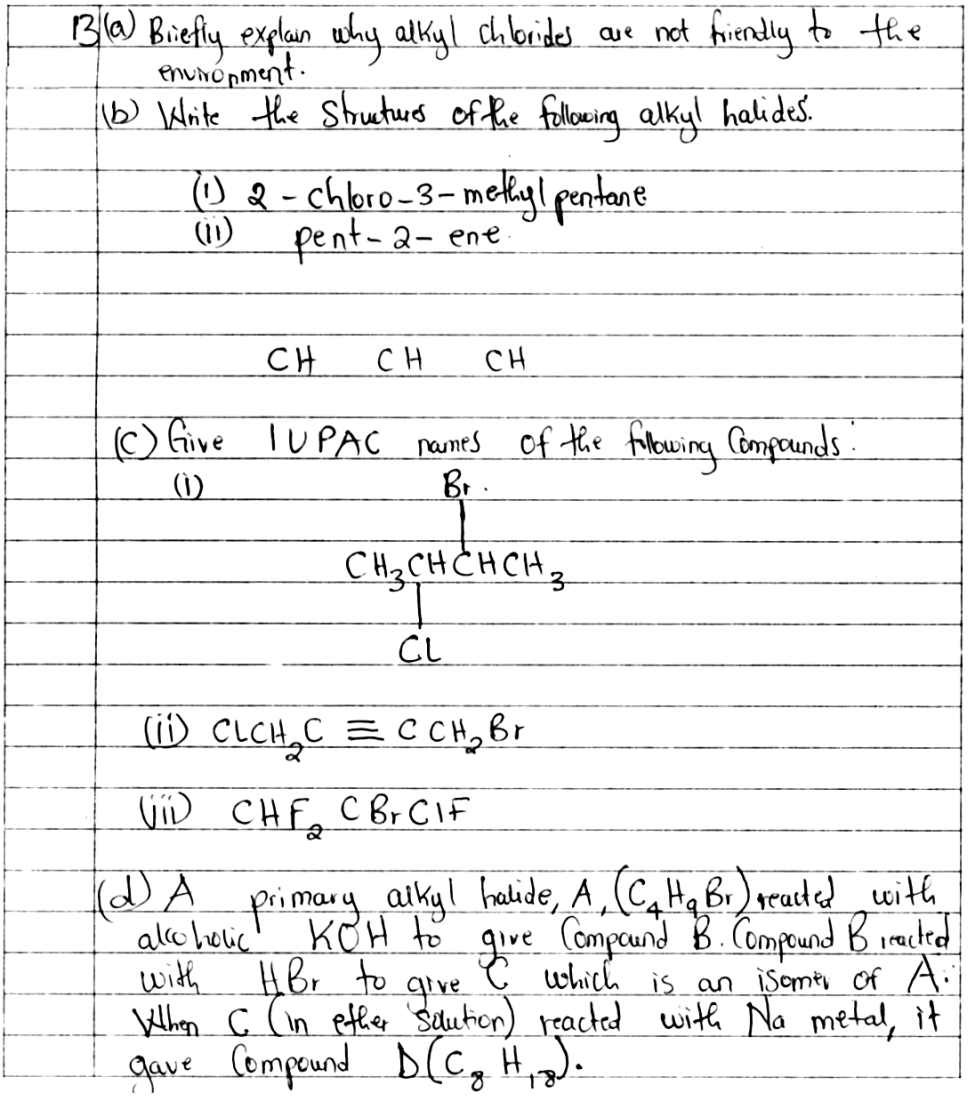


Extract 13.1 is an example of a well presented answer which made the candidate to score high marks.

However, the candidates who scored low marks failed to explain the effect of alkyl chlorides to the environment. Others did not understand the requirement of the question, hence gave expected responses. For example, instead of stating the effects of alkyl chlorides to the environment, one candidate wrote: “Because chlorine gas is poisonous”. It was also revealed that some the candidates failed to write the structure of the organic compounds, which was an indication of poor background of organic chemistry.

Furthermore, some candidates failed to give the IUPAC names of the given compounds. In part (c) (i) for example, one of the candidates wrote: “1Bromo-4-chloro2.2butyl”. Such an answer shows that the candidate had a problem in numbering the carbon atoms properly and did not know where to use ‘commas’ and ‘hyphens’ in naming organic compounds. In the same way, other candidates failed to write the structure and equations for the reactions in part (d). This implies insufficiency knowledge of organic reactions and factors affecting reaction mechanisms. Extract 13.2 illustrates one of the poor answers.

Extract 13.2


13 (a) Briefly explain why alkyl chlorides are not friendly to the environment.

(b) Write the structures of the following alkyl halides.

(i) 2-chloro-3-methyl pentane

(ii) pent-2-ene

CH CH CH

(c) Give IUPAC names of the following compounds:

(i) $CH_3CH(Br)CH(Cl)CH_3$

(ii) $CLCH_2C \equiv CCH_2Br$

(iii) $CHF_2CBrClF$

(d) A primary alkyl halide, A, (C_4H_9Br) reacted with alcoholic KOH to give Compound B. Compound B reacted with HBr to give C which is an isomer of A. When C (in ether solution) reacted with Na metal, it gave Compound D (C_8H_{18}).

In Extract 13.2, the candidate resorted copied all the items of the question, which was an indication of inadequate knowledge on the concept of organic chemistry.

2.1.14 Question 14: Aromatic Hydrocarbons

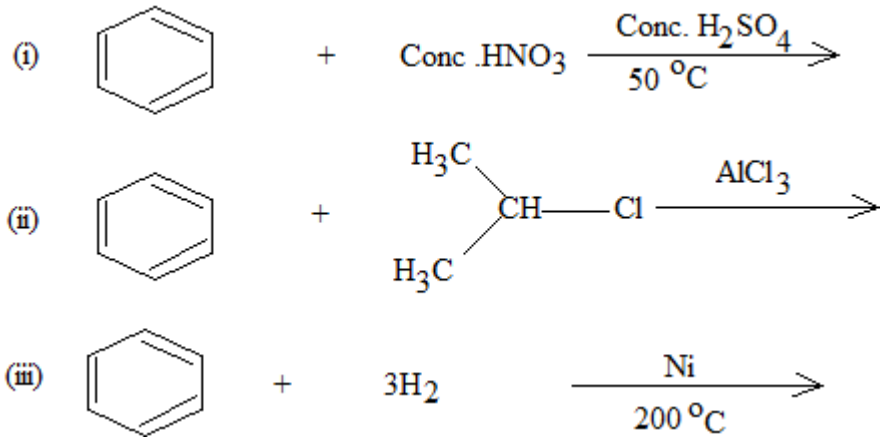
In part (a), the candidates were required to state Markovnikoff's rule. In part (b), they were required to indicate whether the reaction will involve a side chain, aromatic ring or both, and write chemical equations showing the reaction between phenylethene (styrene) and:

(i) Br_2.

(ii) H_2, (Pt) at 25^oC.

(iii) H_2, (Pt) at 200^oC.

In part (c), they were required to complete the following reactions:



In part (d), the candidates were required to arrange the following sets of compounds in order of decreasing relative reactivity to an electrophile E^+.

(i) chlorobenzene, 2,4-dinitrobenzene, 4-nitrochlorobenzene

(ii) methylbenzene, 4-dinitromethylbenzene, 2,4-dinitromethylbenzene.

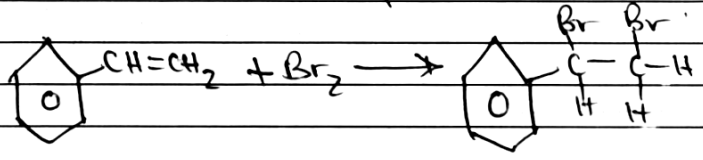
A total of 9,153 (30.9%) candidates attempted this question, out of which 32.5 percent scored from 3.5 to 6.0 out of the 10 marks; 28.7 percent scored from 6.5 to 10 marks, with 2.6 percent scoring all the (10) marks. The candidates who scored below 3.5 marks were 38.8 percent, of which 9.0 percent scored zero.

The candidates with high scores were able to state Markovnikoff's rule. They were also able to indicate whether the reaction will involve the side chain, aromatic ring or both, and wrote chemical equations showing the reaction between phenylethene and the given reagents. Furthermore, they were able to complete the reactions in part (c) and arranged the given compounds in the order of decreasing relative reactivity towards an electrophile E^+. Extract 14.1 illustrates the case.

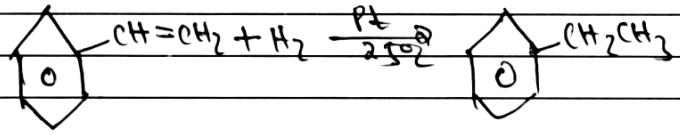
Extract 14.1

14 a) Markovnikoff's rule states that " when an electrophile is added to the unsaturated compounds, tend to combine with the carbon atom having greater number of hydrogen atoms first".

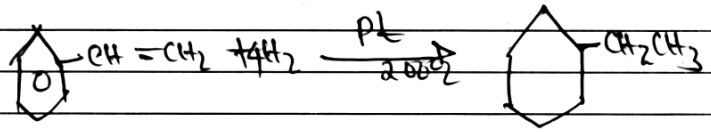
b) i) Reaction will take place to side chain



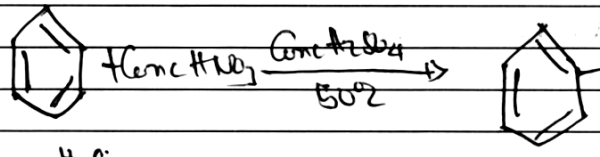
ii) Reaction will take place to side chain



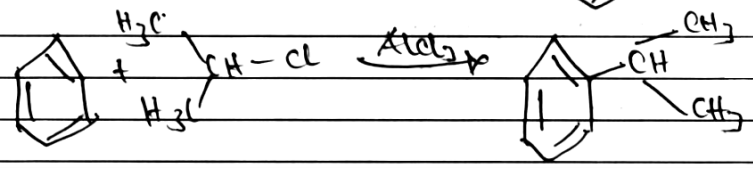
iii) Reaction will take place at both side chain and aromatic ring.

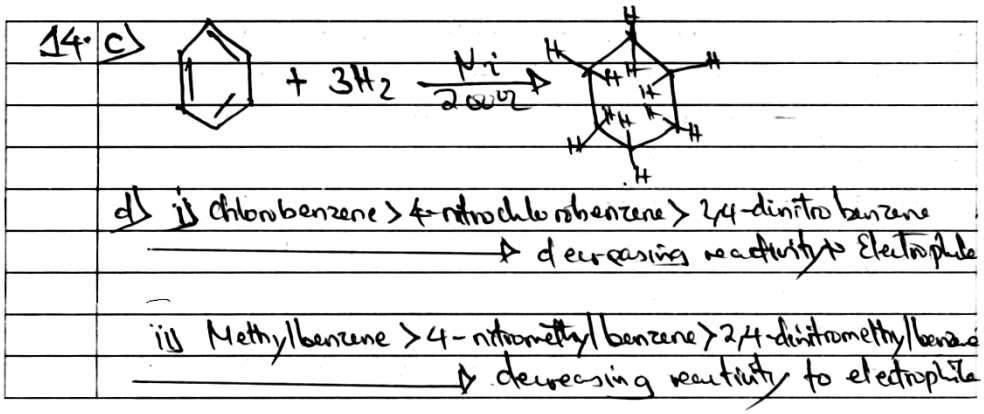


c) i)



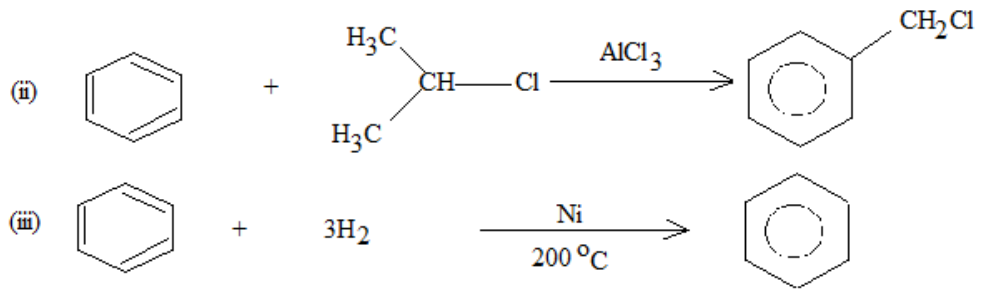
ii)





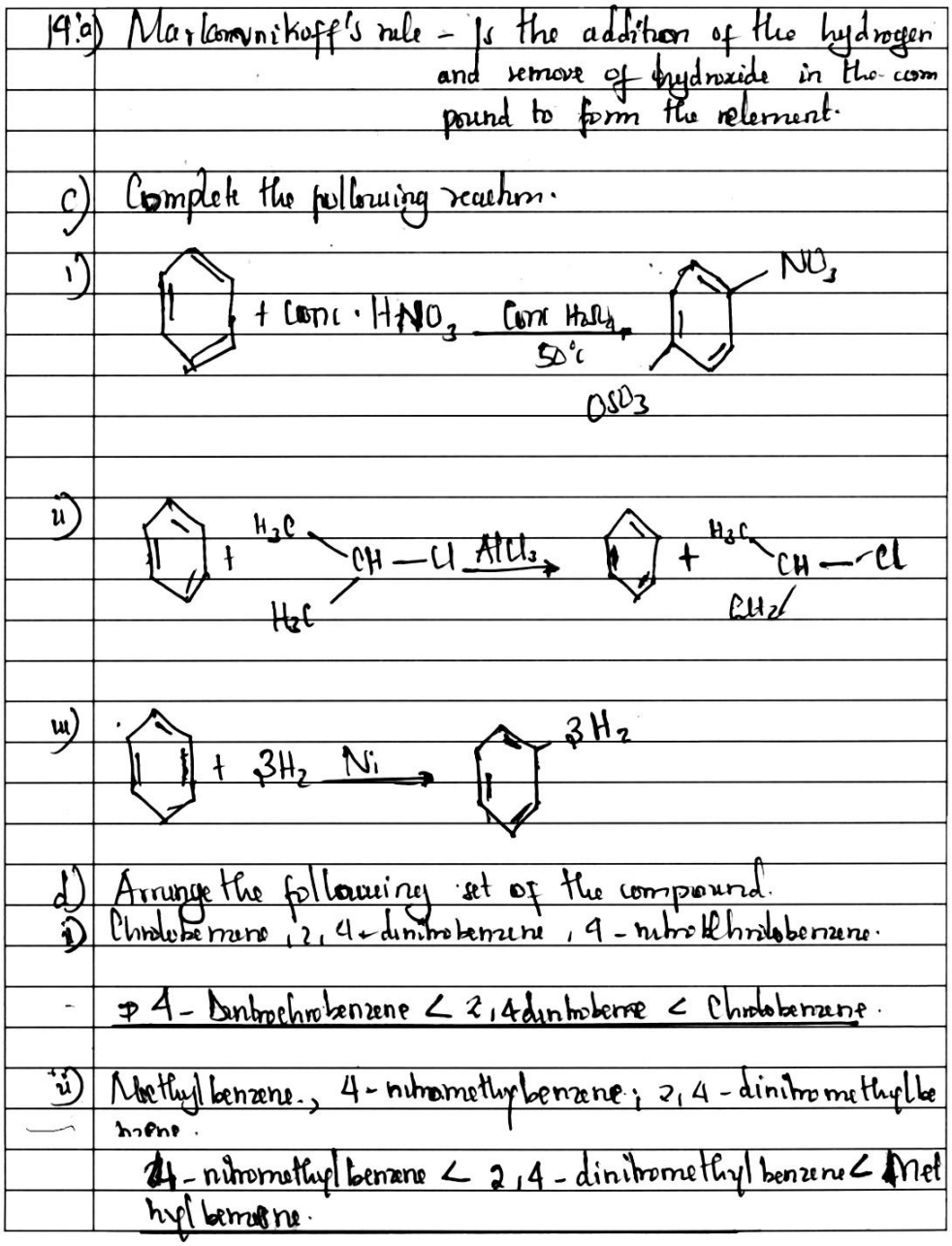
Extract 14.1 is a sample of a good answer in which the candidate presented correctly the Markovnikoff's rule and the position at which the reaction will take place in phenylethene, when reacted with the given reagents. He/she also completed the given reactions and arranged the given compounds in order of decreasing reactivity as demanded by the question.

On the other hand, some of the candidates who scored low marks failed to state the Markovnikoff's rule, while others gave incomplete statements of the rule. In other cases, some candidates failed to indicate whether the reaction will involve the side chain, aromatic ring or both. This led to the failure of writing the chemical equations for the reactions. Furthermore, other candidates failed to complete the reactions between benzene and the given reagents. For example, one candidate wrongly completed the equations as follows:



Such an answer is among the examples which show that the candidates lacked knowledge about the chemical properties of benzene, specifically, about electrophilic substitution reactions of benzene. Moreover, some of the candidates failed to arrange the given compounds in the order of decreasing reactivity towards an electrophile E^+. This is an indication of lack of knowledge about the factors affecting organic reactions.

Extract 14.2



In Extract 14.2, the candidate failed to state the Markovnikoff's rule. She/he produced incorrect organic reaction equations and the arrangement of reactivity towards an electrophile E^+ was incorrectly provided.

2.2 132/2-CHEMISTRY 2

This paper had a total of ten (10) questions. Each question carried 20 marks. The pass mark in each question was 7 marks.

2.2.1 Question 1: Chemical Kinetics

This question had parts (a), (b) and (c). In part (a), the candidates were required to distinguish between: (i) average rate and instantaneous rate, (ii) elementary step and rate determining step, (iii) molecularity and order of reaction and (iv) activated complex and activation energy. In part (b), the candidates were asked to determine the rate law and the rate constant, k, for the reaction $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$, using the following data:

Initial $[N_2O_5]$ M	Initial rate (Ms^{-1})
0.186	9.68×10^{-4}
0.372	19.34×10^{-4}
1.490	77.67×10^{-4}

Part (c) required the candidates to calculate Ea (activation energy) for the reaction between methane and diatomic sulphur, $CH_4(g) + 2S_2(g) \rightarrow CS_2(g) + 2H_2S(g)$ given that at 550 °C, the rate constant for this reaction is 2.2 L $mol^{-1}s^{-1}$ and at 625 °C, the rate constant is 12.8 L mol^{-1} s^{-1}.

This question was chosen by 81.7 percent of the candidates. The performance of the candidates was as shown in Figure 6.

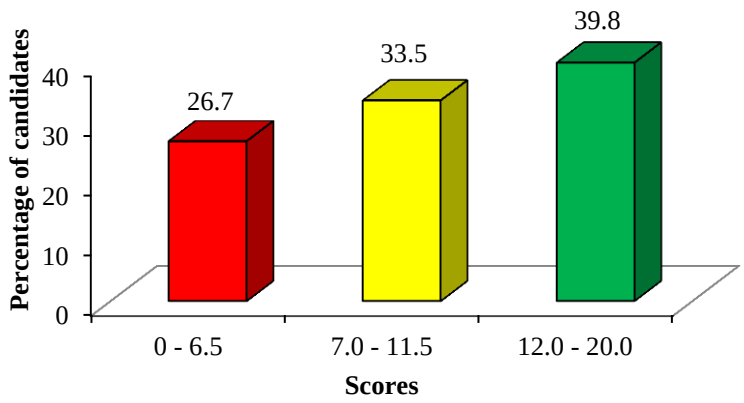


Figure 6: Performance of the candidates in question 1.

As Figure 6 shows, about three-quarters (73.3%) of the candidates passed the question, with the majority (39.8%) scoring from 12.0 to 20 marks. The candidates with high scores correctly distinguished the given terms and determined the rate law and the rate constant k, for the reaction $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$ using the given data, and finally calculated activation energy for the reaction $CH_4(g) + 2S_2(g) \rightarrow CS_2(g) + 2H_2S(g)$. Extract 15.1 is a response from a candidate who was able to give the correct answer.

Extract 15.1

(i) Average rate is the rate of change of reactant or product Concentration per unit time while instantaneous rate is the rate at which Concentration change over a particular period of time

that is Average rate = $\frac{d[A]}{dt}$ while

Instantaneous rate $\frac{\Delta[c]}{\Delta t} = \frac{[c]_2 - [c]_1}{t_2 - t_1}$

(ii) Elementary Step is the reaction of a ~~parti~~ particular step in the reaction mechanism while rate determining step is the slowest step in the reaction mechanism.

(iii) Molecularity is the number of molecule that participate in the elementary reaction while order of reaction is the powers of reactant Concentration in the rate law.

(iv) Activated Complex is the compound which has attained activation energy so as to react while activation energy is the ~~min~~ minimum energy required by the ~~re~~ colliding molecule to react.

(b) Solution.

First find the order of reaction

$$\frac{\text{Rate}_2}{\text{Rate}_1} = \left(\frac{[N_2O_5]_2}{[N_2O_5]_1}\right)^n$$

$$\frac{19.34\times10^{-4}}{9.68\times10^{-4}} = \left(\frac{0.372}{0.186}\right)^n$$

$$1.99 \approx 2 = 2^n$$

$$2^1 = 2^n$$

$$n = 1$$

Therefore the order of reaction is 1.

Rate law $= R \propto [N_2O_5]^1$

$$R = k[N_2O_5]^1$$

∴ Rate law is $R = k[N_2O_5]^1$

The rate constant for ~~rate~~ initial rate, and concentration 1

$$R = k[N_2O_5]$$

$$9.68\times10^{-4} = k[0.186]^1$$

$$k_1 = \frac{9.68\times10^{-4}}{0.186}$$

$$k_1 = 5.204\times10^{-3}$$

find k_2

$$R_2 = k_2[N_2O_5]_2$$

$$19.34\times10^{-4} = k[0.372]$$

$$k_2 = \frac{19.34\times10^{-4}}{0.372}$$

$K_2 = 5.1989 \times 10^{-3}$

find $K_3 = R_3 = K_3[N_2O_5]_3$

$77.67 \times 10^{-4} = K_3 [1.490)$

$K_3 = \frac{77.67 \times 10^{-4}}{1.490}$

$K_3 = 5.21275 \times 10^{-3}$

$K = \frac{K_1 + K_2 + K_3}{3}$

$\frac{5.20 \text{ cp} \times 10^{-3} + 5.1989 \times 10^{-3} + 5.21275 \times 10^{-3}}{3}$

$K = 4.205 \times 10^{-3}$

∴ the rate constant = $4.205 \times 10^{-3} \, s^{-1}$

(c) Data given

$T_1 = 550 + 273k = 823K$

$T_2 = 625 + 273k = 898K$

$K_1 = 2.2 \, L \, mol^{-1} s^{-1}$

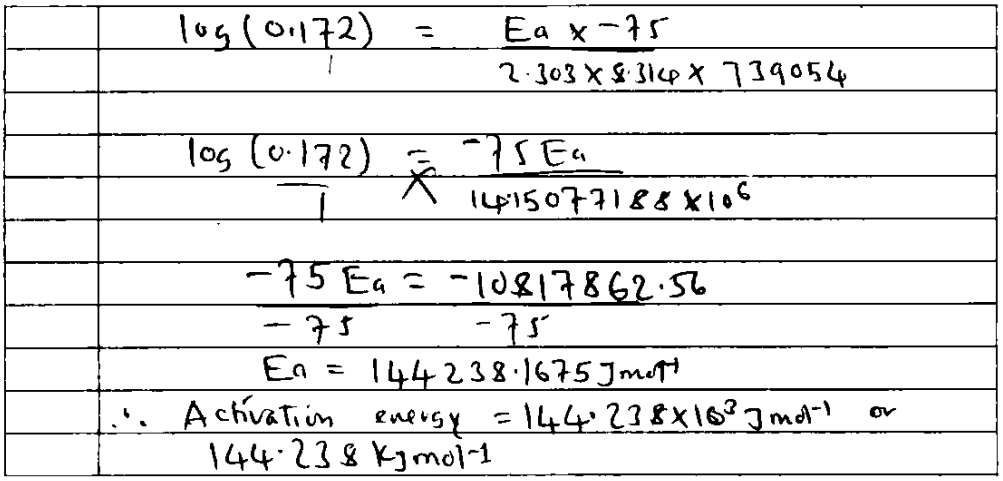
$K_2 = 12.8 \, L \, mol^{-1} s^{-1}$

E_a = required

$R = 8.314$

$\log \left(\frac{K_1}{K_2}\right) = \frac{E_a}{2.303R} \left(\frac{T_1 - T_2}{T_2 \times T_1}\right)$

$\log \left(\frac{2.2}{12.8}\right) = \frac{E_a}{2.303 \times 8.314} \left(\frac{823 - 898}{898 \times 823}\right)$



In Extract 15.1 the candidate gave clear distinctions of the terms in part (a). In part (b), he/she applied appropriate formulae, and step by step did all necessary calculations and managed to obtain 144.23 $kJmol^{-1}$ as the activation energy.

The candidates who failed in this question were unable to score any mark in most of the items. For instance, in part (a), many candidates failed to give a clear distinction about (i) average rate and instantaneous rate, and the elementary step and the rate determining the step in item (ii).

The analysis shows that some of the candidates who failed part (b), wrongly used the stoichiometric coefficients as the order of reaction in determining the rate law, while others substituted incorrect data and hence ended with incorrect answers. In part (c), few of the candidates failed to change the temperature in degree centigrade to Kelvin scale, while some used 0.0821 $Latmmol^{-1}K^{-1}$ molar gas constant instead of 8.31 $Jmol^{-1}K^{-1}$ and some applied wrong formulae in calculations which led to negative activation energy as well. This observation shows that the candidates had low understanding of the constants used and little practices in applying the formula to calculate the activation energy of the chemical reaction. Extract 15.2 provides a candidate's poor response.

Extract 15.2

1 (b)

Rate law state that " The rate of chemical reversible reaction, is directly proportion to molar concentration of the reactants.

$R \propto$ (Reactant Concentration)

$R \propto [C]$

$R = k[C]$

For 1st first Reaction.

Initial concentration = 0.182 M

Initial rate = 9.68×10^{-4} M/s.

$$R = k[N_2O_5]^2$$

$$k = \frac{R}{[N_2O_5]^2}$$

$$k = \frac{9.68 \times 10^{-4}}{(0.186)^2}$$

$$k = 27 \times 10^{-3}$$

For 2nd Second reaction.

Initial concentration = 0.372M

Initial rate = 19.34×10^{-4} M/s

$$R = k[N_2O_5]^2$$

$$k = \frac{R}{[N_2O_5]^2}$$

1 (b)

$$k = \frac{14.34 \times 10^{-4}}{(0.372)^2}$$

$$k = 1.34 \times 10^{-3}\ s$$

For the third reaction. Initial concentration = 1.470

Initial Rate = 77.67×10^{-4}

$$R = k[N_2O_5]^2$$

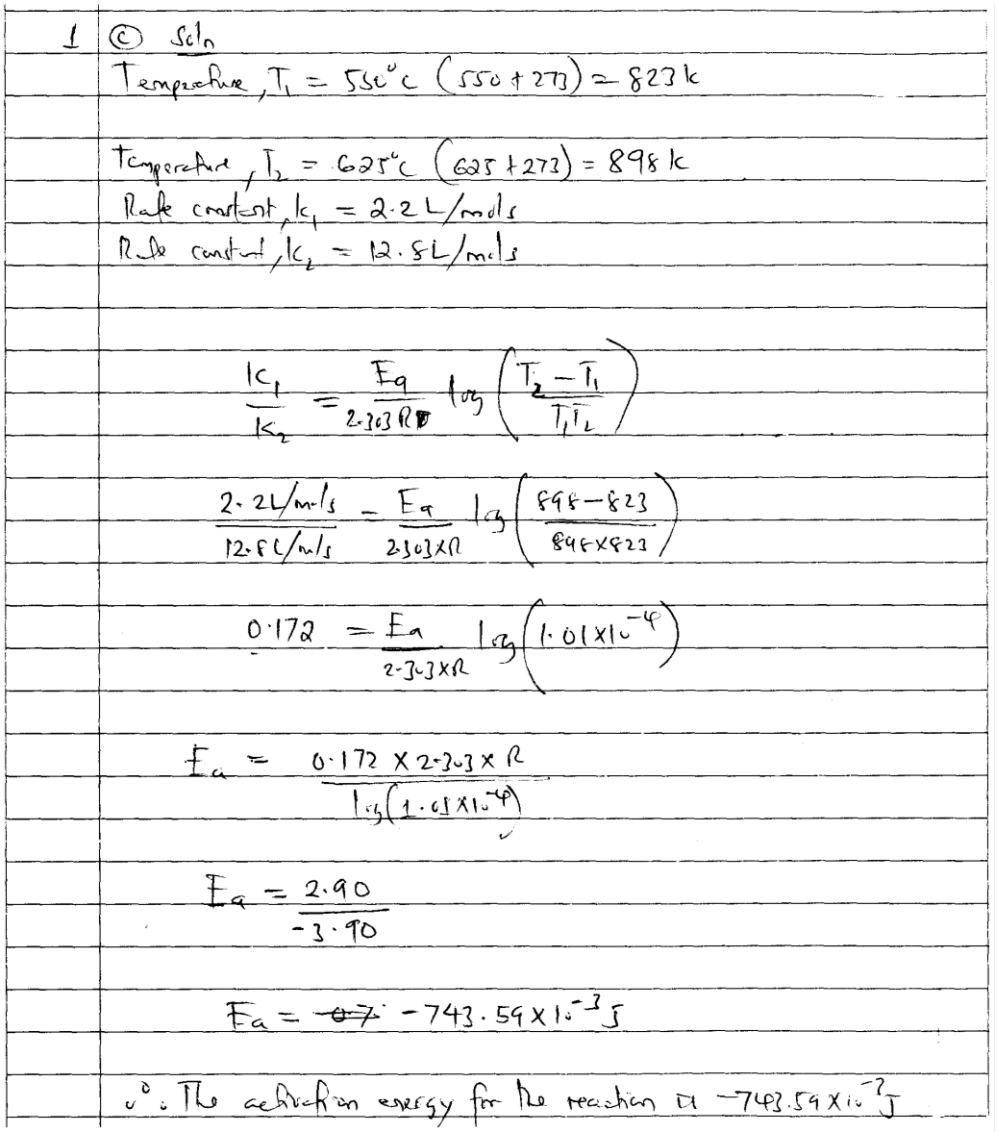
$$k = \frac{R}{[N_2O_5]^2}$$

$$k = \frac{77.67 \times 10^{-4}}{(1.470)^2}$$

$$k = 3.5 \times 10^{-3}\ s$$

1 @(iii) Activated complex, this is the product which obtained after the applied of activation energy while activation energy is the energy which required to make the reactants to reacted.

(iii) Order of reaction is the sum of mole between the reactants during the rate of reaction while Molecularity is the amount of moles which involves in the reaction.



Extract 15.2 indicates a poor response of a candidate. Although the candidate attempted all the parts of the question, he/she could not score any mark.

2.2.2 Question 2: Electrochemistry

This question had parts (a), (b), (c) and (d). In part (a), the candidates were required to give the oxidation numbers of all atoms in the compounds, Cl_2, Cl_2O_7, and $Na_2Cr_2O_7$. In part (b), they were asked to balance the chemical equation for redox reactions.

(i) $Cr_2O_7^{2-}(aq) + Br^-(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + H_2O(l) + Br_2(l)$ and

(ii) $MnO_4^-(aq) + I^-(aq) \rightarrow MnO_2(s) + I_2(s)$ in basic medium.

In part (c), the candidates were provided with the information that, '25 cm^3 containing 3.16 g per litre of $KMnO_4$ were acidified and mixed with 20 cm^3 of KI solution. The liberated iodine was titrated against $Na_2S_2O_3.10H_2O$ solution containing 31.64 g/l. They were then asked to write the balanced ionic equations representing the reactions described and calculate the molarity of $Na_2S_2O_3.10H_2O$ if 26.70 cm^3 of the solution they were required to reach at the end point.

Part (d) required the candidates to calculate the ionization constant of NH_4OH from the information that; "the molar conductivities at infinite dilution at 25 °C of NH_4Cl, NaOH and NaCl are 129.8, 217.4 and 108.9 Scm^2mol^{-1}, respectively and molar conductance of 0.01 M NH_4OH is 9.33 Scm^2mol^{-1}".

About one-third (38.7%) of the candidates opted for this question. Figure 7 shows the scoring of the candidates in this question:

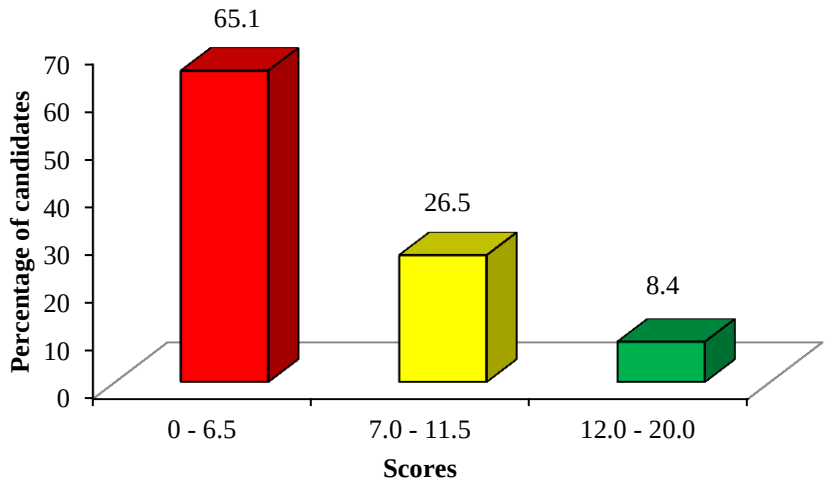


Figure 7: Performance of the candidates in question 2.

The data in Figure 7 shows that that majority of the candidates scored low marks and few scored high marks. However, 34.9 percent of the candidates scored at a pass mark or above (≥ 7 mark) which signifies an average performance. The few (8.4%) candidates who scored high marks (12.0 to 20 marks), most of them were able to give the oxidation numbers of all atoms in the given compounds. They also showed the important steps in balancing the chemical equation for the given redox reactions and finally, calculated

the molarity of $Na_2S_2O_3.10H_2O$ and the ionization constant of NH_4OH from the given data; see Extract 16.1.

Extract 16.1

02. (e) (i) $MnO_4^- + I^- \xrightarrow{H^+} Mn^{2+} + I_2$

Consider, reduction half reaction.

$MnO_4^- \longrightarrow Mn^{2+} + 4H_2O$.

$MnO_4^- + 8H^+ \longrightarrow Mn^{2+} + 4H_2O$.

$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$ —(i)

Also,

Consider, oxidation half reaction.

$I^- \longrightarrow I_2$

$2I^- \longrightarrow I_2 + 2e^-$ —(ii)

Add eqn (i) and (ii) in such a way that number of electrons are eliminated,

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

$5 \times (2I^- \longrightarrow I_2 + 2e^-)$

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

∴ The first ionic equation is

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

Also, second reaction is,

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

Consider, reduction half reaction

$I_2 \longrightarrow 2I^-$

$I_2 + 2e^- \longrightarrow 2I^-$ —(i)

Also,

Consider, oxidation half reaction.

$2S_2O_3^{2-} \longrightarrow S_4O_6^{2-}$

$2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2e^-$ —(ii)

Q2. (c) (i) Add eqn (i) and (ii)

$$\begin{cases} I_2 + 2\bar{e} \longrightarrow 2I^- \\ 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2\bar{e} \end{cases}$$

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

∴ The second ionic equation is

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

Q2. (c) (ii) given;-

Concentration of $KMnO_4$ = 3.16g/Litre

Volume of $KMnO_4$ = 25cm³.

Volume of $Na_2S_2O_3$ = 26.70cm³.

Asked;-

The molarity of $Na_2S_2O_3 \cdot 10H_2O$

From,

1st reaction,

$$2MnO_4^- + 16H^+ + 10I^- \longrightarrow 2Mn^{2+} + 8H_2O + 5I_2 \quad \text{(i)}$$

and 2nd reaction,

$$2S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I^- \quad \text{—(ii)}$$

Multiply eqn (ii) by 5 then add to eqn (i) in order to eliminate iodine gas.

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

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

∴ From the overall reaction, mole Ratio

$$n\,MnO_4^- : nS_2O_3^{2-} = 2:10$$

02. (c) (ii) From,

Molar mass of $KMnO_4$ = 39 + 55 + (4 × 16)

= 158 g/mol

So,

molarity of $KMnO_4$ = $\frac{\text{Concentration}}{\text{molar mass}}$

= $\frac{3.169 \text{ g/litre}}{158 \text{ g/mol}}$

molarity of $KMnO_4$, M_1 = 0.02 M

Volume of $KMnO_4$, V_1 = 25 cm^3.

Volume of $Na_2S_2O_3 \cdot 10H_2O$, V_2 = 26.7 cm^3.

from,

$$\frac{M_1V_1}{M_2V_2} = \frac{n_1}{n_2}$$

$$M_2 = \frac{M_1V_1n_2}{V_2 \cdot n_1}$$

$$M_2 = \frac{0.02 \times 25 \times 10}{26.7 \times 2}$$

$$M_2 = 0.0936 \text{ M}.$$

where, M_2 = Molarity of $Na_2S_2O_3 \cdot 10H_2O$

∴ The molarity of $Na_2S_2O_3 \cdot 10H_2O$ is 0.0936M.

02. (d) given,

Molar conductivity at infinite dilution of NH4Cl = 129.8 $S cm^2 mol^{-1}$

NaOH = 217.45 $S cm^2 mol^{-1}$

02. (d) NaCl = 108.9 Scm^2mol^{-1}.

Also,

Concentration of NH_4OH = 0.01M.

molar conductance of NH_4OH = 9.33 Scm^2mol^{-1}.

Asked;-

Ionization constant of NH_4OH (Kb)

from,

Kolrausch's law of mobility,

$$\lambda_\infty AB = \lambda_\infty A^+ + \lambda_\infty B^-$$

So,

$$\lambda_\infty NH_4OH = \lambda_\infty NH_4Cl + \lambda_\infty NaOH - \lambda_\infty NaCl$$

$$\lambda_\infty = (129.8 + 217.4 - 108.9)\ Scm^2mol^{-1}$$

$$\lambda_\infty NH_4OH = 238.3\ Scm^2mol^{-1}$$

∴ Molar conductivity of NH_4OH at infinite dilution is 238.3 Scm^2mol^{-1}.

from,

$$\text{degree of dissociation, } \alpha = \frac{\lambda_M}{\lambda_\infty}$$

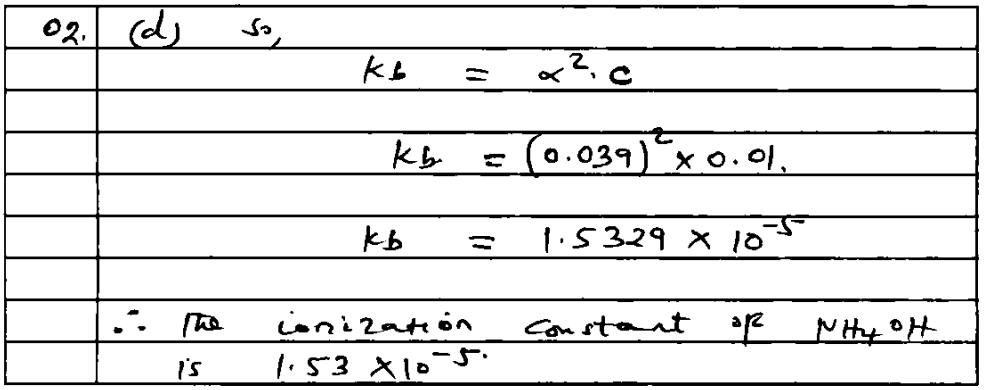
$$= \frac{9.33\ Scm^2mol^{-1}}{238\ Scm^2mol^{-1}}$$

$$\alpha = 0.0392$$

also, from, Ostwald's dilution law,

$$\alpha = \sqrt{\frac{Kb}{c}}$$

$$\alpha^2 = \frac{Kb}{c}$$



Extract 16.1 shows part (c) and (d) of a candidate's response. The candidate used the appropriate formula to calculate the molarity of $Na_2S_2O_3.10H_2O$ and ionization constant of NH_4OH.

On the other hand, the candidates who did poorly, wrongly responded to all parts of the question. In part (a) for instance, they failed to apply the rules of calculating oxidation numbers of elements in the given molecules. The analysis of the responses shows that some of the candidates incorrectly added the relative atomic numbers of the constituent elements in the given molecules/compounds, while others wrote their electronic configurations. It was also noted that other candidates could not distinguish the atom which is oxidized and the one which is reduced. This led to the failure to assign the oxidation numbers. Such responses show that the candidates lacked sufficient knowledge of the sub-topic and the rules applied in the calculation of the oxidation states of species in a compound.

In order to respond well to part (b), the candidates were supposed to have adequate knowledge of writing a balanced half ionic reaction equations for redox reactions in terms of ion-electron transfer, charge and material balance and the overall reaction. It was observed that the candidates lacked this knowledge for one of the candidates responded as follows:

(i) $Cr_2O_7^{2-} + 2Br^- + 14H^+ + 5e^- \rightarrow 2Cr^{3+} + 7H_2O + Br_2(s)$

$\therefore Cr_2O_7^{2-}(aq) + 2Br^-(aq) + 14H^+(aq) + 5e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + Br_2(s)$

(ii) $MnO_4^- + I^- \rightarrow Mno_2 + I_2$

$MnO_4^- + 2I^- + 2H^+ \rightarrow Mno_2 + I_2 + 2OH^-$

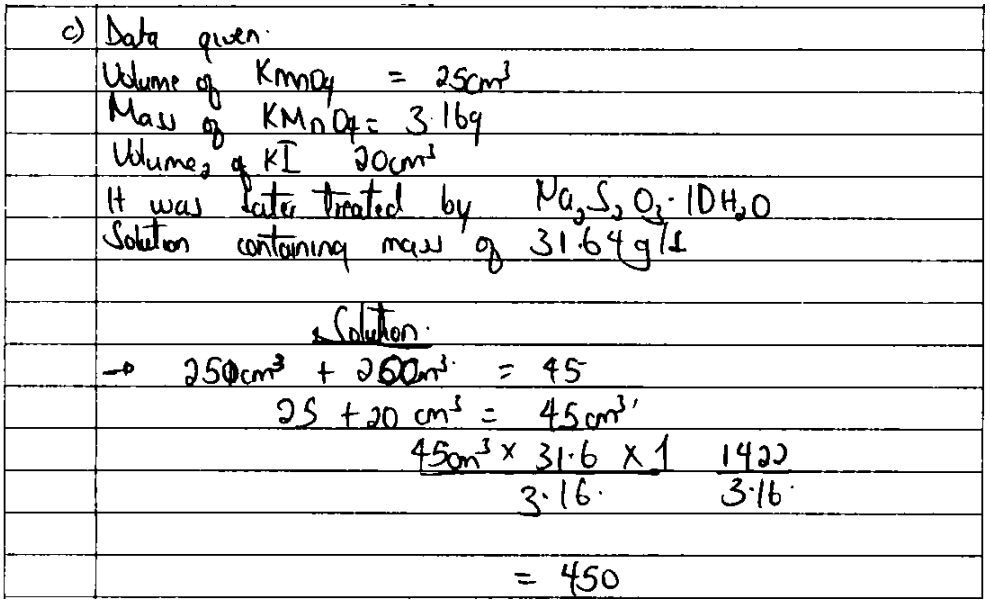
$\therefore MnO_4^- + 2I^- + 2H^+ \rightarrow Mno_2 + I_2 + 2OH^-$:

Such response indicates that the candidate could not adhere to the rules of balancing redox reactions in the basic medium. The cause may be due to lack of practice and adequate knowledge.

In part(c), most of the candidates failed to translate the stated word reaction into the molecular equations, and as a result they could not write the ionic equations in part (c)(i). Failure to write the ionic equations also led to failure to calculate the molarity of $Na_2S_2O_3.10H_2O$ in part (c)(ii). However, few candidates who managed to write the equations in part (c)(i), failed to relate the mole ratio between potassium permanganate and sodium thiosulphate from their half ionic equations which resulted into failure to calculate the original molarity of sodium thiosulphate. This shows that the candidates lacked sufficient exercises on experiments concerning redox titration.

Part (d) was the most difficult to most of the candidates as they failed to calculate the ionization constant of NH_4OH from the given information. The candidates failed to relate the Oswald dilution law for the determination of the degree of dissociation with that of using the ratio of molar conductivity at a given concentration to the molar conductivity at infinite dilution. Extract 16.2 indicates one of the poor responses.

Extract 16.2



Balance a balanced ionic equ representing the req reaction described

$KMnO_4 + KI \longrightarrow KMnO_3 + KI + O_2$.

ii) Calculate the molarity of $Na_2SO_3 \cdot 10H_2O$

Solution

$Na_2SO_3 \cdot 10H_2O$

$(23 \times 2) + 28 + 16 \times 3 \cdot 10 + 1 \times 2 + 16)$

$44 + 28 + 48 \cdot 10 \times 2 + 16$

$44\ 28 + 48 \cdot 22 + 16$

$120 + 38$

$= 158$

The Molarity of $Na_2SO_3 \cdot 10H_2O = 158$

di) Data given

Temp = 25°C

Volume 129.8

217.4

108.9

M.C 9.3 25°C → K

25°C + 273

= 298

Temperature = 298 K

Constant for NH_4OH

$R = 3.31 J mol^{-1} K^{-1}$

Calculate the ionization constant

Extract 16.2 shows that the candidate lacks basic knowledge of important elements of atomic mass, as he/she wrongly assigned S the mass of 28. Similarly, he/she failed to calculate the molar mass of $Na_2S_2O_3.10H_2O$ and ionization constant due to wrong manipulation of the data.

2.2.3 Question 3: Acids Bases and Salts

This question had parts (a), (b), (c) and (d). In part (a), the candidates were required to define, common ion effect, buffer solutions, ionic product of

water and salt hydrolysis. Part (b) required the candidates to explain briefly each of the following observations: (i) ammonia (NH_3) is one of the Lowry-Brønsted bases, (ii) Al^{3+} ion behaves as a Lewis acid when it is in water, (iii) lead (II) chloride is soluble in concentrated HCl solution and (iv) aqueous aluminum nitrate solution turns blue litmus paper red.

In part (c), the candidates were required to write an equation to show how each of the given pairs reacts to form a conjugate acid and a conjugate base. The pairs were (i) Bicarbonate ion and water, (ii) Ammonia and water, (iii) Nitrous ion and hydroxonium ion and (iv) Ammonium ion and carbonate ion. For each reaction, they were asked to identify the acid, base, conjugate acid and conjugate base. Part (d) required the candidates to briefly explain how an acidic buffer solution works to maintain its pH value when a small amount of acid is added to it.

More than half (54.2%) of the candidates opted for this question and 56.2 percent passed (scored 7 to 20 marks). The scoring was as follows: 43.8 percent scored from 0 to 6.5 marks; 31.5 percent scored from 7.0 to 11.5 marks and 24.7 percent scored from 12.0 to 20.0 marks. These data indicate a general average performance.

The majority of the candidates with high scores (12.0 to 20.0 marks) were able to give the definitions of the terms in part (a) and to explain the asked phenomena in part (b). Moreover, they managed to write equations to show how each of the provided pairs reacts to form a conjugate acid and a conjugate base. They also managed to identify the acid, base, conjugate acid and conjugate base in each of the reaction pairs. Finally, they were able to explain how an acidic buffer solution works to maintain its pH value when a small amount of acid is added to it. These candidates had sufficient knowledge on acids, bases and buffers. Extract 17.1 illustrates one of the good responses from the candidates.

Extract 17.1

3 (a) (i) Common ion Effect

This is the effect which arises when a strong salt is introduced into a solution of a weak salt which contains the same ions (either cations or anions) as the ions present in the strong salt, hence destabilizing the dynamic equilibrium system of the weak salt.

3 (a) (ii) Buffer solutions.

These are solutions which can maintain the pH values on addition of small amount of an acid or base

(a)(iii) Ionic product of water.

This is the product of Concentrations of Hydroxonium ions and hydroxyl ions in the solution, that is $K_w = [H^+][OH^-]$.

(a) (iv) Salt hydrolysis

This is the chemical reaction of a salt to give either acidic solution (Cationic salt hydrolysis) or Basic solution (Anionic salt hydrolysis).

3 (b) (i) Bronsted-lowry bases accepts hydrogen protons (H^+) from the Bronsted-lowry acids. NH_3 normally accepts H^+ from acids to give NH_4^+ (Ammonium ion), Hence it is a Bronsted-lowry base.

3 (b)(ii) When in water Al^{3+} hydrat reacts to give $Al(OH)_3$. The $Al(OH)_3$ has empty orbitals in its structure hence it is capable of sharing its empty orbitals ~~at~~ with Lewis bases (accepting lone pairs) thus acting as a Lewis acid.

(b)(iii) In concentrated HCl solution, Lead(II) chloride reacts to give a complex $[Pb(Cl)_4]^{2-}$ which is soluble in water. This is one of the common ion effects.

$$PbCl_2 + \text{Conc. } HCl \longrightarrow [Pb(Cl)_4]^{2-}(aq)$$

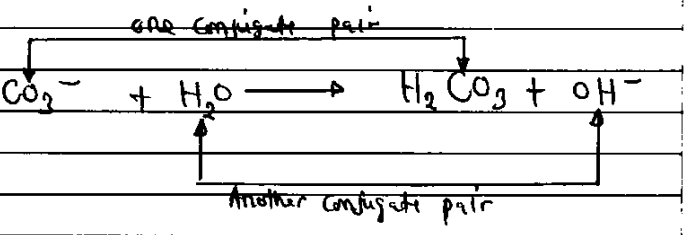
(b)(iv) In solution aluminium nitrate having some degrees of covalent character, it hydrolyses to give acidic solution (H^+). Hence it is this acidic solution that turns blue litmus red.

$$Al(NO_3)_2 + H_2O \longrightarrow Al(OH)_3 + H^+ + NO_3^-$$

OR

$$Al(NO_3)_2 + H_2O \longrightarrow Al(OH)_3 + HNO_3$$

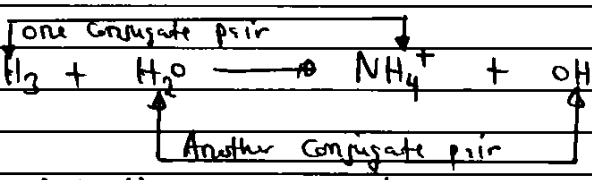
3 (c) (i)



Whereas ⊖ HCO_3^- is a conjugate base of H_2CO_3 which is a conjugate acid

⊖ H_2O is a conjugate acid of OH^- which is a conjugate base.

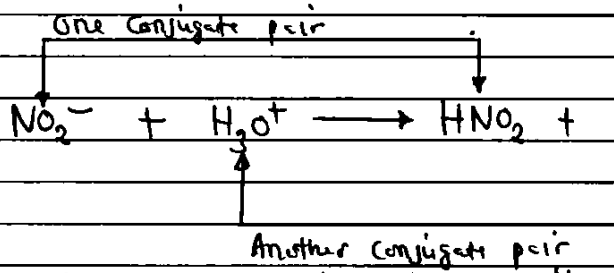
3 (c) (ii)



Where: ⊙ NH_3 is a conjugate base of NH_4^+ which is a conjugate acid

⊙ H_2O is a Conjugate acid of OH^- which is a conjugate base.

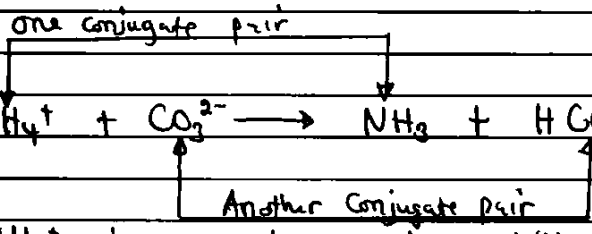
3 (c) (iii)



Where: ⊙ NO_2^- is a Conjugate base of HNO_2 which is a conjugate acid

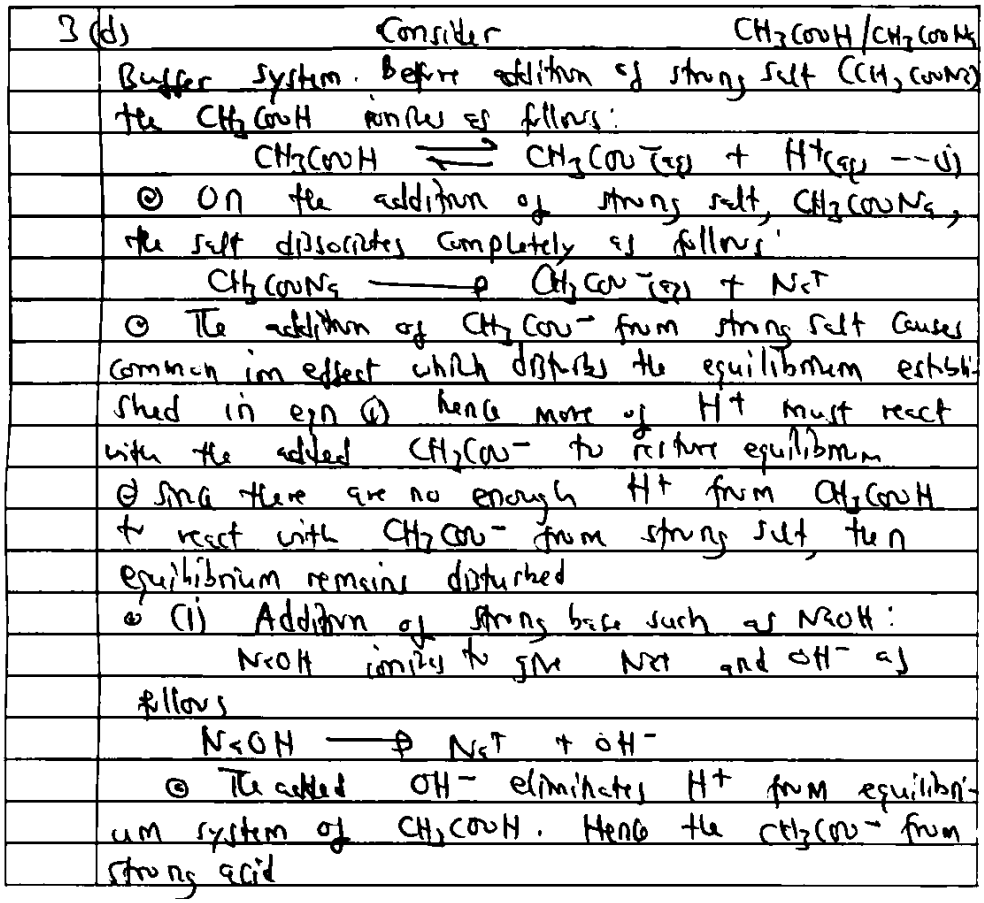
⊙ H_3O^+ is a Conjugate acid of H_2O which is a Conjugate base.

3 (c) (iv)



Where ⊙ NH_4^+ is a conjugate acid of NH_3 which is a conjugate base

⊙ CO_3^{2-} is a Conjugate base of HCO_3^- which is a conjugate acid.



In Extract 17.1 the candidate correctly responded to all the parts of the question. All work is clearly shown.

On the contrary, most of the candidates who scored low marks, managed to give the definitions of the terms in part (a). Part (b) was generally poorly performed by most of the candidates. The candidates were not able to relate some concepts from inorganic chemistry with the tested concepts from the topics of Acids, bases and salts; Solubility and solubility products in physical chemistry.

In part (c), the candidates were not able to write the reaction equations that best explain the conjugate acid – base pairs as given from Brønsted-Lowry theory. Thus, they could not identify the acid, base, conjugate acid and conjugate base. It was noted that some of the candidates mixed up the concepts of Brønsted-Lowry theory of acids and bases with those of Lewis and Arrhenius. This may be caused by inadequate reading and lack of enough exercises on the topic. Similarly in part (d), the candidates failed to

give the correct answer to show how the buffer solution works to maintain the pH value when a small amount of acid or base is added in it. Extract 17.2 provides a sample of a candidate's poor response.

Extract 17.2

3(a)ii/	Buffer solutions is the kind of solution in which they resist the appearance of pH to occur in solution
iii/	Ionic product of water is the product of the which formed due to the ions from the water ions.
iv/	Salt hydrolysis is the extraction of amount of salt efrom the water hence refered to salt hydrolysis that it has ions.
(b) i/	Ammonia (NH_3) is one of the Lowry-Bronsted bases because ammonia in solid state show the characteristics of the Bronsted bases due to the having of hydrogen.
ii/	Al^{3+} ion when it is free it is simple and become a clearly metal ion but when it is in water it behaves as a Lewis acid since it clouded by hydroxyl ions hence forming a character of Lewis acid.
iii/	When Lead (II) chloride is in concentrated HCl solution appeared to be voluble since Lead do reacts with chloine of hydrogen chloride hence due to mixture of that substances inabes lead (II) chloride to be soluble.

All the responses shown by Extract 17.2 are incorrect. The definitions in part (a) and the explanation of the observations in part (b) do not show whether the candidate has ever come across them during the course of study.

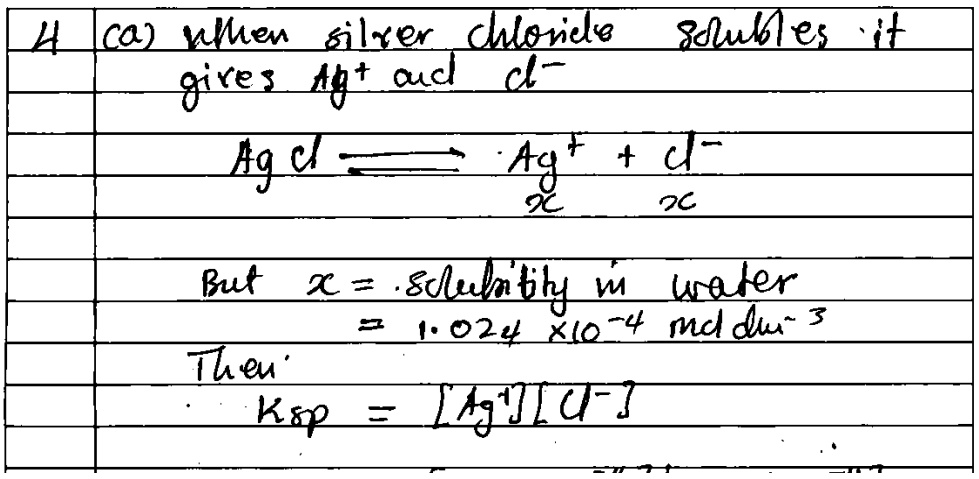
2.2.4 Question 4: Solubility, Solubility Product and Ionic Product

This question had parts (a), (b) and (c). In part (a), the candidates were required to calculate Ksp value of silver chloride, whose solubility is 1.024 x 10^{-4} mol/dm^3 at 18 °C. In part (b), the candidates were required to briefly describe the term "common ion effect" and calculate the solubility of solid CaF_2 in a 0.05 M NaF solution, given that Ksp of CaF_2 is 4.0 x 10^{-11}. In part (c), they were supposed to explain whether a precipitate of barium fluoride will be formed when 100 mL of 0.25 M NaF and 100 mL of 0.015 M $Ba(NO_3)_2$ are mixed and support their answer by calculations, given the Ksp of BaF_2 is 1.7 x 10^{-6}.

Many candidates (81.3%) attempted this question and 59.9 percent scored 7 marks or above. The statistics indicate that 41.1 percent of the candidates scored 0 to 6.5 marks, 38.5 percent scored from 7.0 to 11.5 marks and 20.4 percent scored from 12 to 20 marks. These data imply an average performance.

The majority of the candidates with high scores (12 to 20 marks) were able to calculate Ksp value of silver chloride, describe the term "common ion effect", calculate the solubility of solid CaF_2 in 0.05 MNaF solution and supporting with calculations explained the possibility of formation of a precipitate of barium fluoride when 100 mL of 0.25 M NaF and 100 mL of 0.015 M $Ba(NO_3)_2$ are mixed. Extract 18.1 represents one of the good responses.

Extract 18.1


4 (a) When silver chloride solubles it gives Ag^+ and Cl^-

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

$x \quad x$

But x = solubility in water

$= 1.024 \times 10^{-4}$ mol dm^{-3}

Then:

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

$K_{sp} = [1.024 \times 10^{-4}][1.024 \times 10^{-4}]$

$K_{sp} = [1.024 \times 10^{-4}]^2$

$= 1.048576 \times 10^{-8}\ mol^3 dm^{-6}$

∴ The K_{sp} value of silver chloride is

$1.04857 \times 10^{-8}\ mol^3 dm^{-6}$.

(b)(i) Common ion effect the shifting of equilibrium position of sparingly soluble salt by lowering its solubility due to the addition of ion similar to the one present in the solution. For example the addition of NaF in CaF_2, increase. F^- which already present in CaF_2.

(ii) Given,

K_{sp} of $CaF_2 = 4.0 \times 10^{-11}$

Concentration of NaF = 0.05M

When NaF dissociates gives Na^+ and F^-

$NaF \rightleftharpoons Na^+ + F^-$

0.05M 0.05M 0.05M

For the dissociation of CaF_2

$CaF_2 \rightleftharpoons Ca^{2+} + 2F^-$

1	0	0	initial moles
1−α	α	2α	equilibrium moles
$\frac{1-\alpha}{V}$	$\frac{\alpha}{V}$	$\frac{2\alpha}{V}$	
c(1−α)	cα	cα	Concentration

Now,

$$K_{sp} = \frac{[Ca^{2+}][F^-]^2}{[CaF_2]}$$

$$K_{sp} = \frac{[c\alpha][c\alpha]^2}{[c(1-\alpha)]}$$

$$\Rightarrow K_{sp} = \frac{(c\alpha)^2}{c(1-\alpha)}$$

$$K_{sp} = \frac{c\alpha^2}{1-\alpha}$$

Assuming α is very small and $1-\alpha \simeq 1$

$$K_{sp} = c\alpha^2$$

$$\Rightarrow \alpha = \sqrt{\frac{K_{sp}}{c}}$$

$$= \sqrt{\frac{4.0 \times 10^{-11}}{0.05}}$$

$$= 2.828 \times 10^{-5} \text{ M}$$

Then

$$c\alpha = 2.828 \times 10^{-5} \times 0.05$$

$$= 1.414 \times 10^{-6} \text{ M}$$

Now

$$K_{sp} = [Ca^+][F^-]^2$$

$$= [\alpha][\alpha + 0.05]^2$$

If α is very small and $\alpha + 0.05 \simeq 0.05$

$$K_{sp} = [\alpha][0.05]^2$$

$$\alpha = \frac{K_{sp}}{[0.05]^2}$$

$\Rightarrow K_{sp} = \frac{4.0 \times 10^{-11}}{(0.05)^2}$

$= 1.6 \times 10^{-8}\ M.$

$\therefore$ The solubility of CaF_2 is 1.6×10^{-8}.

4 (c) For NaF

Initial concentration $M_1 = 0.25\ M$

Initial volume $V_1 = 100\ ml$

Final volume $V_2 = (100 + 100)\ ml = 200\ ml$

Final concentration is

$$M_2 = \frac{M_1 V_1}{V_2} = \frac{0.25 \times 100}{200} = 0.125\ M$$

For $Ba(NO_3)_2$

Initial concentration $M_1 = 0.015\ M$

Initial volume $V_1 = 100\ ml$

Final volume $V_2 = 200\ ml$

Final concentration is

$$M_2 = \frac{M_1 V_1}{V_2} = \frac{0.015 \times 100}{200} = 7.5 \times 10^{-3}\ M$$

Now

$NaF \rightleftharpoons Na^+ + F^-$

$0.125 \quad 0.125\ M$

and

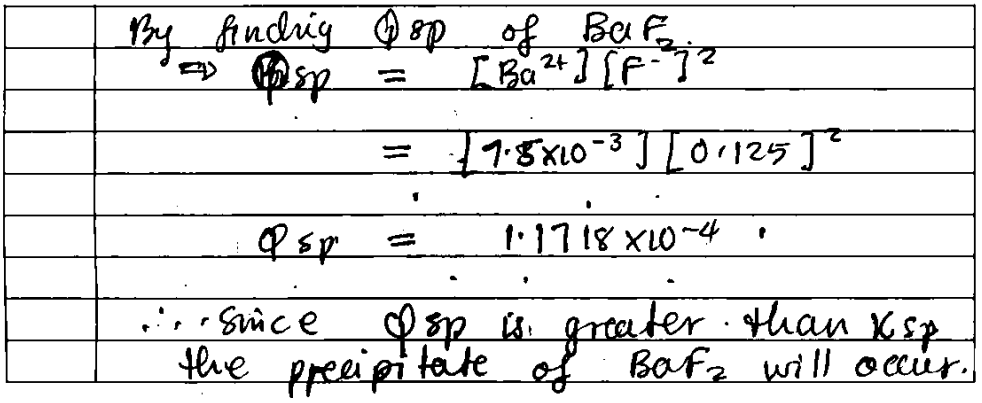
$Ba(NO_3)_2 \rightleftharpoons Ba^{2+} + 2NO_3^-$

$7.5 \times 10^{-3} \quad 7.5 \times 10^{-3}$

For BaF_2

$BaCl_2 \rightleftharpoons Ba^{2+} + 2F^-$

$7.5 \times 10^{-3}\ M \quad 0.125\ M$



In Extract 18.1 the candidate applied correct formulae to all parts, correctly substituted the given data and finally made correct calculations.

On the other hand, the candidates who scored low marks (from 0 to 6.5) failed to write the solubility product equation of silver chloride and as a result wrote a wrong formula of solubility product, which led to an incorrect answer in part (a). This is evident in one of the candidates' answer that is shown below:

"given let the solubility of silver chloride be X=1.024 x 10^{-4}

From $AgCl_2 \rightleftharpoons Ag^{2+} = 2Cl^-$

Ksp = $[Ag2^+][Cl^{-1}]^2$

Then

Ksp = $(X)(2X)^2$

Ksp = $4X^3$then Ksp= $4(1.02x10\text{-}4)^3$

Ksp = 4.2949 x 10^{-12} then the value of Ksp is 4.2949 x 10^{-12} mol^3/dm^9"

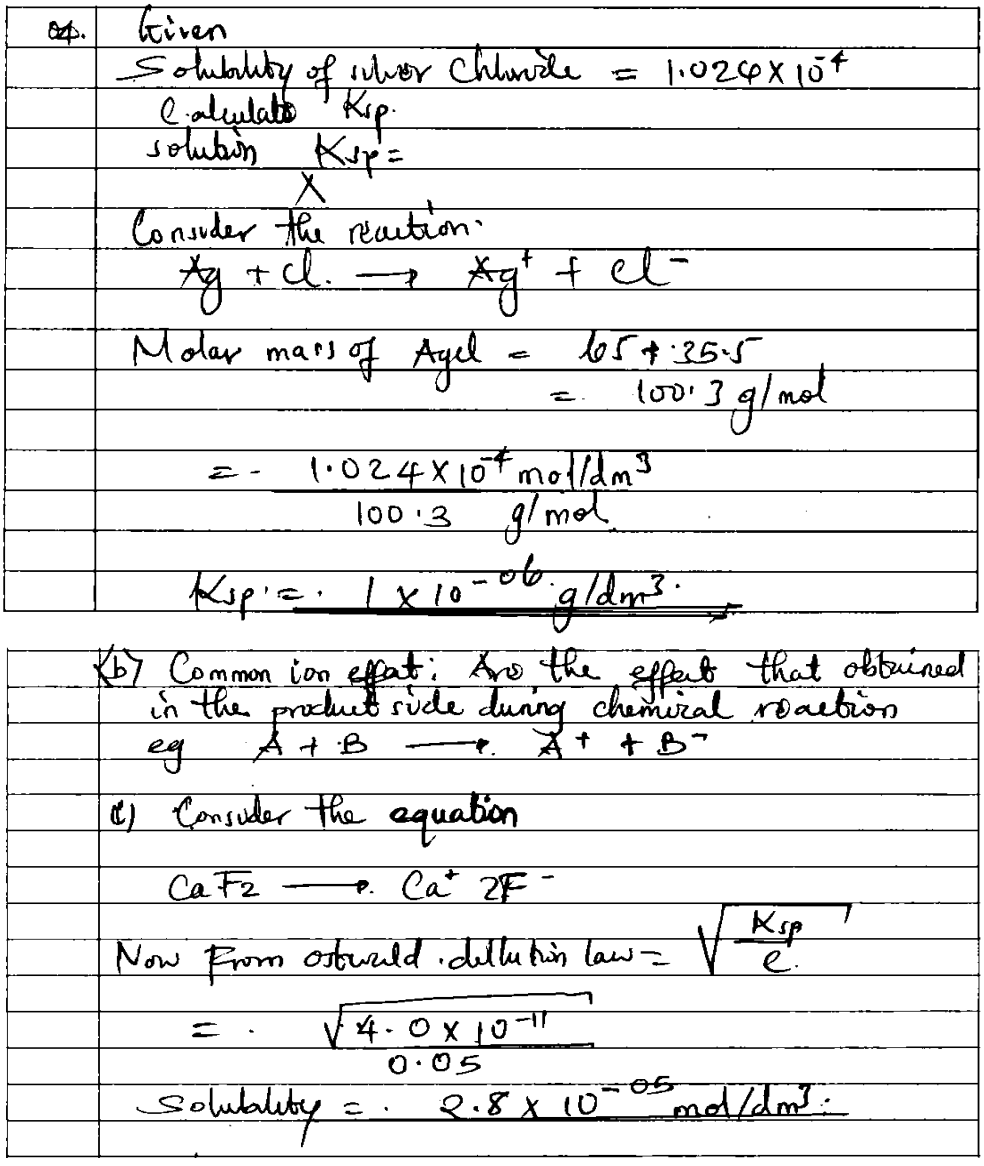
The candidate wrongly wrote the formula for silver chloride as $AgCl_2$ instead of AgCl, and the solubility equation as $AgCl_2 \rightleftharpoons Ag^{2+} = 2Cl^-$ instead of $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$.

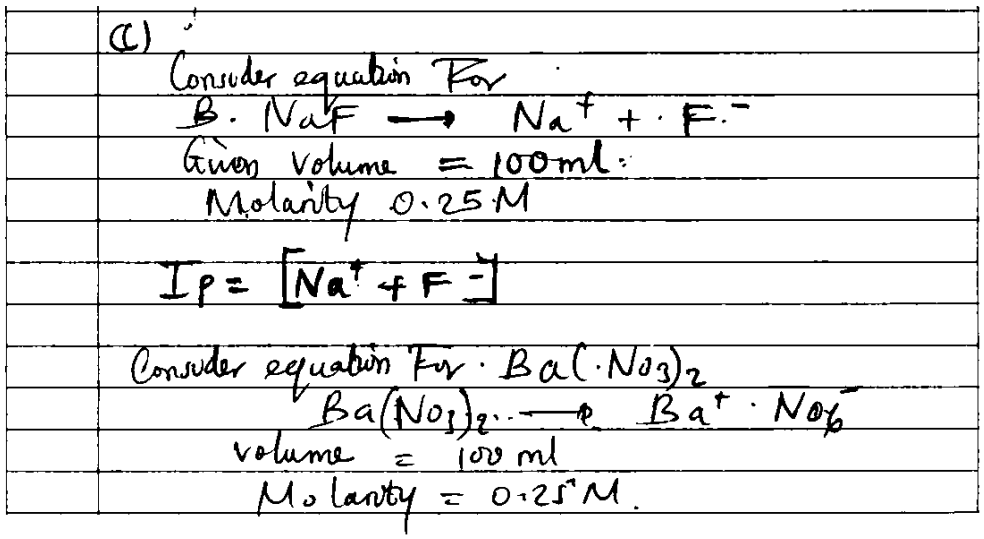
The analysis revealed that the majority of the candidates managed to describe the term "common ion effect" in part b (i). However, most of them had difficulties in calculating the solubility of solid CaF_2 in 0.05 MNaF solution in part b(ii). The failure of the candidates was due to inability to write solubility product formula of CaF_2 and integrate the given concentration of NaF which led to an incorrect answer.

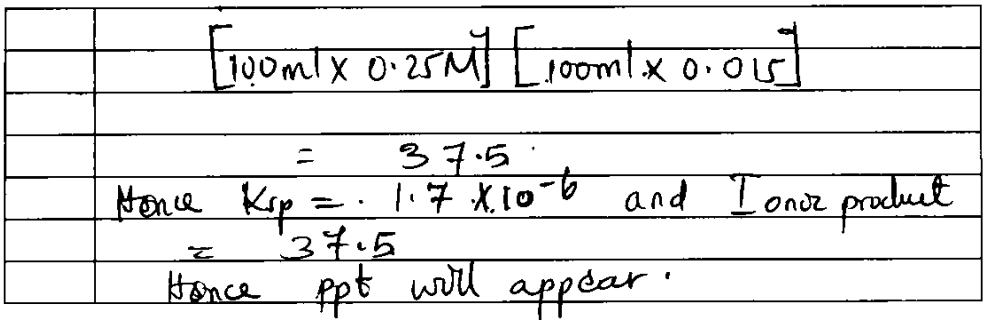
In part (c), some of the candidates just pointed out that the precipitate is formed or not formed without doing any calculations. However, those who attempted to do the calculations, either wrongly wrote the formula for barium fluoride or solubility equation or failed to manipulate the given data to prove the formation of precipitate using calculations.

The failure of the candidates in this question may be due to inadequate reading and lack of enough exercises on the tested concepts. Extract 18.2 provides a sample of a candidate's poor response.

Extract 18.2







In part (a) of Extract 18.2, the candidate wrongly wrote the equation of solubility of AgCl and an incorrect formula for Ksp.

2.2.5 Question 5: Periodic Classification

This question had parts (a), (b), (c) and (d). In part (a), the candidates were required to (i) state the periodic law, (ii) write the advantage of arranging elements in the periodic table on the basis of atomic numbers rather than atomic masses and (iii) give three (3) diagonal similarities between Be and Al. Part (b) asked the candidates to justify that, 'the basic characters of elements in the modern periodic table always increase down the group,' by considering the oxides of group V elements.

In part (c), the candidates were asked to explain the facts that (i) silicon has a higher melting point than it is expected, (ii) graphite is used as a lubricant as well as a cell electrode but not diamond and (iii) the first ionization energy of boron is lower than that of beryllium although boron is towards the right across period 2 in the periodic table.

In part (d), the candidates were given the information that, “A researcher decided to place a newly discovered element at the bottom of group (VII)”. They were then required to explain the expected physical and chemical properties of the new element basing on (i) the state of the element at room temperature and pressure, (ii) redox properties of the element, (iii) atomicity and (iv) reaction with alkali.

The question was opted by 64.2 percent of the candidates and the performance is as shown in Figure 8.

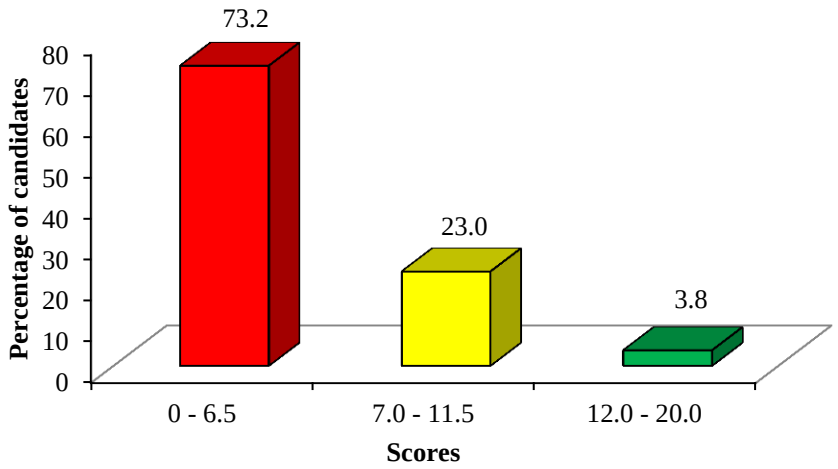


Figure 8: Performance of the candidates in question 5.

As Figure 8 shows, very few candidates (3.8%) managed to score good marks; the majority (73.2%) performed poorly (scored 0 to 6.5 marks). Most of the candidates who failed, just stated the law without specifying whether it is according to Mendeleev or Modern (Mosley) periodic law in part (a)(i), thus they failed to write the advantages of arranging elements in the periodic table basing on atomic numbers in part (a) (ii).

In part (b), the candidates were expected to show the nature of the solution formed when oxides of group (V) elements react with water. Inappropriately, it was found that the majority of the candidates directed their responses on the increase of the number of shells of elements in group V down the group, and the increase of shielding effects down the group. It was also noted that some candidates did not know the elements belonging to group V, hence could not write the correct formula of their oxides and the corresponding reaction equation with water. In other cases, it was revealed

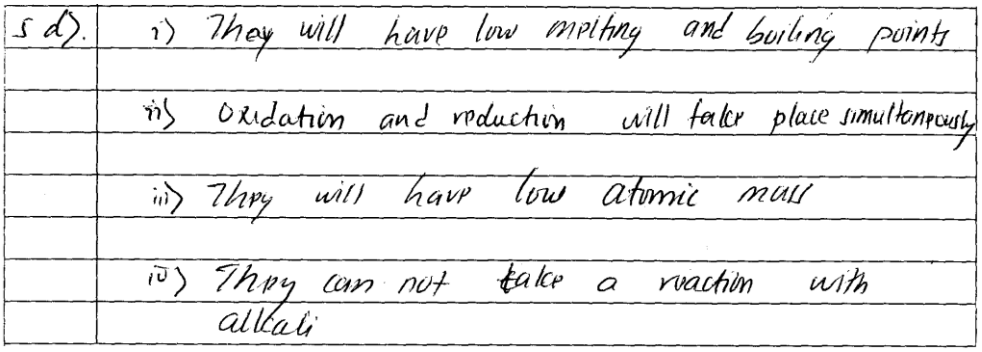
that other candidates wrote anything they knew on oxides irrespective of relevancy to the question. The following response from one of the candidates serves as an example:

The increase the basic character due the oxide for example carbon dioxide and sulphur dioxide which are basic character is due to presence oxide which behave amphoteric properties.

Such answers show that the candidates had insufficient knowledge of the properties of oxides as one goes down the group. Also the responses are not grammatically correct due to language problem.

Similarly, in part (c), many candidates failed to explain why silicon has a higher melting point than it is expected; graphite is used as a lubricant as well as cell electrode but not diamond. They also failed to explain why the first ionization energy of boron is lower than that of beryllium although boron is towards the right across period 2 in the periodic table. Extract 19.1 illustrates this fact.

Extract 19.1



Extract 19.1 shows one of the candidates' incorrect responses to part 5(d). The candidate regarded the element as a gas, thus he/she wrote 'they will have low melting and boiling points'. The candidate was asked about the properties of an element (single) but she/he incorrectly responded as elements (plural).

On the contrary, the candidates with high scores were able to state the periodic law, basing on either Mendeleev or Mosley. They explicitly stated that 'Elements of similar properties are placed in the same group' and overcoming the placement of isotopes as the advantages of arranging the elements in the periodic table on the basis of atomic numbers rather than

atomic masses. Furthermore, they gave three (3) diagonal similarities between Be and Al and justified the increase in basic characters of group V elements oxides down the group in the modern periodic table. They were also able to explain: the anomalous high melting point of silicon, the use of graphite as a lubricant, as well as cell electrode, but not diamond and the first ionization energy of boron being lower than that of beryllium. Extract 19.2 represents a response from the script of the candidate with high scores.

Extract 19.2

5 a)	Periodic law states that the properties of elements in the periodic table are functions of their atomic numbers.
(iii) c)	It helps to remove the doubts which arise for the case of isotopes since atoms of the same element can have different atomic masses though they have the same atomic number. Hence by using atomic numbers the doubts are cleared for such elements.
a)	Both Aluminium and beryllium can form complex compounds eg. Be Na[Be(OH)$_4$] and Al Na[Al(OH)$_4$]

5 a(i) (a) Both beryllium and Aluminium form amphoteric oxides example Al_2O_3 and BeO

(ii) Both Aluminium and Beryllium form Chlorides which are unstable in their molecular mass. Aluminium chloride dimerises while Beryllium Chloride polymerises

(iii) Both form hydroxides which are amphoteric and decompose on heating

5 b) By Considering the group five elements including nitrogen and phosphorus on the top party group. Nitrogen reacts with oxygen to form oxides such as Nitrogen dioxide and nitrogen monoxide in limited supply of oxygen

$N_2 + O_2 \longrightarrow NO_2$

$N_2 + O_2 \longrightarrow NO$

These dissolve in water to form strongly acidic solutions hence showing acidic character.

$NO_2 + H_2O \longrightarrow HNO_3$

nitric acid

strong acid

5. Phosphorus just below nitrogen in the group react with ~~water~~ Oxygen to form oxide. like phosphorus pentaoxide and phosphorus troxide

$P + O_2 \longrightarrow P_2O_5$

$P + O_2 \longrightarrow P_2O_3$

These dissolve in water to form ~~less~~ solutions with less acidity compared to those of nitrogen eg.

$P_2O_5 + H_2O \longrightarrow$ ~~H_3PO_4~~

$P_2O_3 + H_2O \longrightarrow H_3PO_4$

weaker acid

These shows an ~~increase~~ decrease in acidity character and and increase in basic characters down the Group.

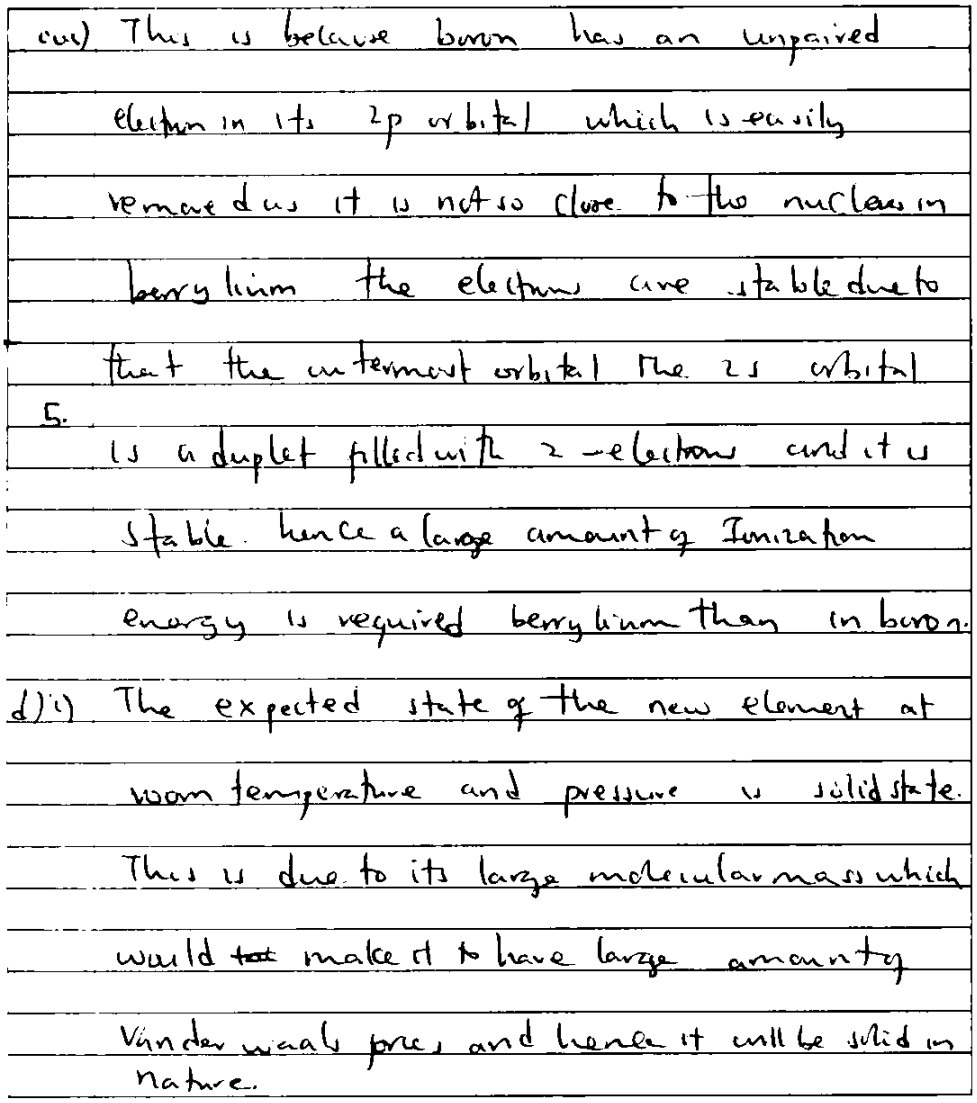
c) These is because silicon forms the giant molecular structure in which several atoms

i) of silicon are closely held together and hence making it to have giant structure and

higher boiling points.

5. Graphite is made up of carbon atoms lying in plate like structure with weak bonds between them hence they can easily slide over one another and hence giving it its slippery nature

ii) which makes it as a lubricant. graphite conducts electricity due to having free electrons in its structure hence can be used as a cell electrode whereas diamond is formed by strong bonds between carbon atoms and hence having a very hard structure and very high melting and boiling points.



Extract 19.2 shows a sample response of a candidate who managed to perform question 5 correctly.

2.2.6 Question 6: Extraction of Metals

This question had parts (a), (b) and (c). In part (a) the candidates were asked to identify four general principles or steps which are followed during metal extraction. Part (b) required the candidates to analyse with the aid of chemical equations, the process of extracting tin (Sn) from its ore (cassiterite) under the sub-headings (i) thermal reduction of the ore (ii), purification of the ore from the impurities and (iii) its two uses in real life.

Part (c) demanded the candidates to design and formulate the major events sequentially without using diagrams and details of chemical reactions

involved to summarise the extraction of aluminum and its purification from bauxite ($Al_2O_3.2H_2O$).

The question was opted by only a few (27.3%) candidates. Out of these, only 18.9 percent passed while 81.1 percent failed. The summary of the performance is as follows: 81.1 scored 0 to 6.5 marks, of which 3.8 percent scored 0; 17.7 percent scored 7.0 to 11.5 marks and 1.2 percent scored 12.0 to 17.0, which was a highest mark. These data show that the overall performance in this question was poor.

Some of candidates who performed poorly (scored 0 to 6.5 marks) managed to perform well in some parts of the question. However, those who scored zero could not give any correct answer.

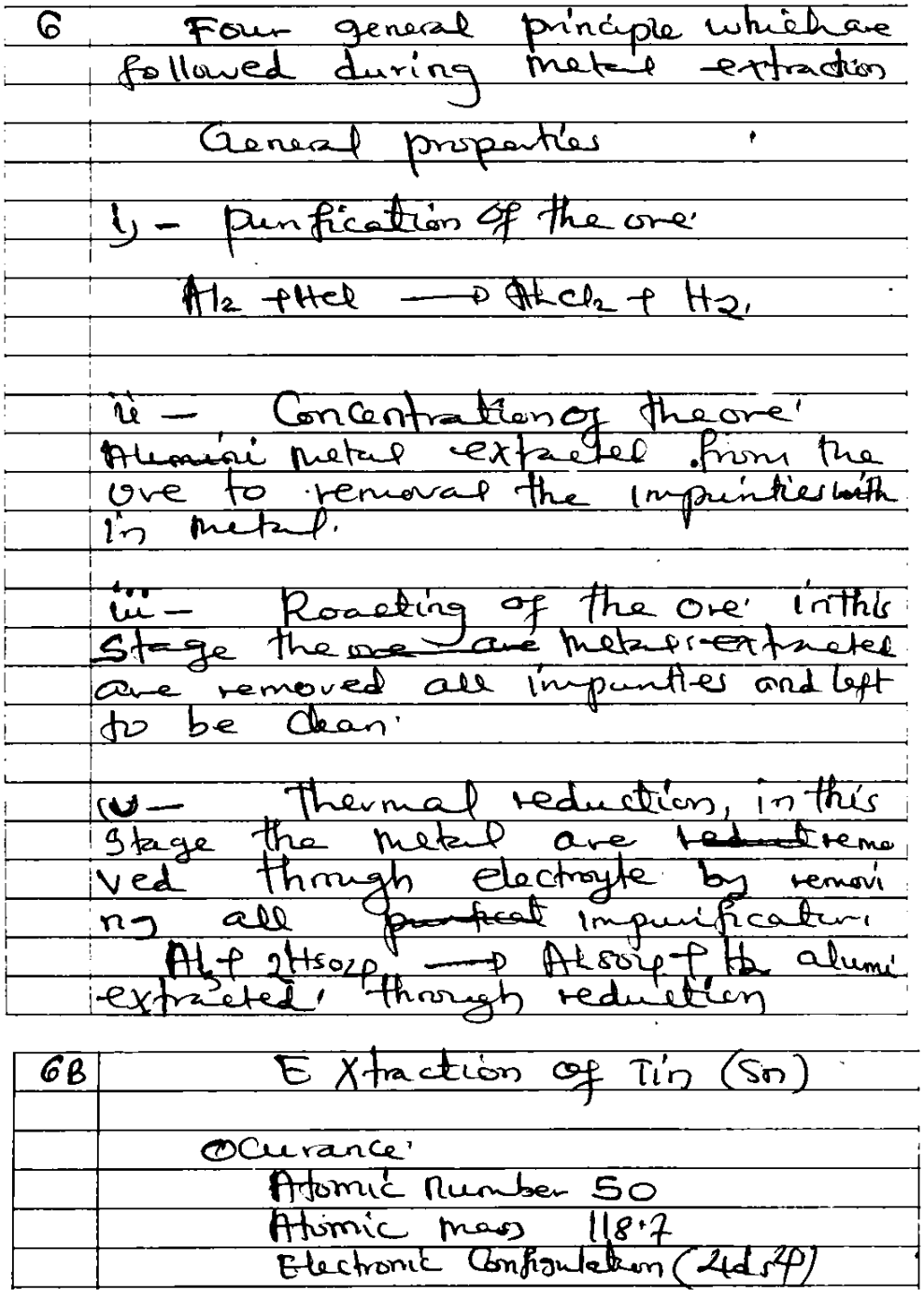
In part (a), some of the candidates mixed up the steps/principles which are followed during metal extraction. For example, mentioning the last step (purification of the metal) before the first one (concentration of ore), while others listed any term used in the extraction of metals regardless it was correct or not. For instance, “mining of the ore, powdering the ore, froth action”, to mention few. The responses of the candidates in this part show that they had insufficient knowledge of the general principles or steps of metal extraction.

In order to respond correctly to part (b), the specific knowledge of extraction of tin and the uses of tin was necessary. The analysis of the candidates' responses showed that they could not distinguish the processes that were taking place in the furnace during thermal reduction and those prior to thermal reduction. It was also observed that the majority lacked knowledge of the formula of the ore of tin (cassiterite), hence were unable to write the required reduction reaction equation. Furthermore, most of the candidates failed to give proper use of tin. The candidates gave the uses of other metals like iron and copper instead of tin. This signifies that the candidates had partial knowledge about tin, its extraction and uses.

The candidates who scored low marks also faced difficulties in responding to part (c). It was observed that the majority of the candidates drew the diagrams and chemical equations to summarise the extraction of aluminum and its purification from bauxite while the question required them to design and formulate the major events sequentially without using diagrams and

details of chemical reactions. Extract 20.1 provides a sample of a candidate's poor response.

Extract 20.1


6 Four general principle which are followed during metal extraction

General properties

i) - purification of the ore

$Al_2 + HCl \longrightarrow AlCl_2 + H_2$

ii - Concentration of the ore' Aluminium metal extracted from the ore to removal the impurities with in metal.

iii - Roasting of the ore' in this Stage the ore are metals extracted are removed all impurities and left to be clean'

iv - Thermal reduction, in this Stage the metal are ~~reduct~~ removed through electrolyte by removing all ~~purified~~ impurification

$Al_2 + 2H_2SO_4 \longrightarrow Al_2SO_4 + H_2$ alumi extracted through reduction

6B Extraction of Tin (Sn)

Occurance'

Atomic Number 50

Atomic mass 118.7

Electronic Configuration (2d 8p)

v) Thermal reduction
Electrolysis reduction

$Sn + O_2 \longrightarrow Sn + O_2 + 2e$

Collect chemical reaction

$Sn + O_2 \longrightarrow Sn + 2CO$

ii) purification of the ore of from the Impurities

$Sn + O_2 \longrightarrow Sn + 2CO + O_2$

$Sn + HCl \longrightarrow SnCl_2 + H_2$

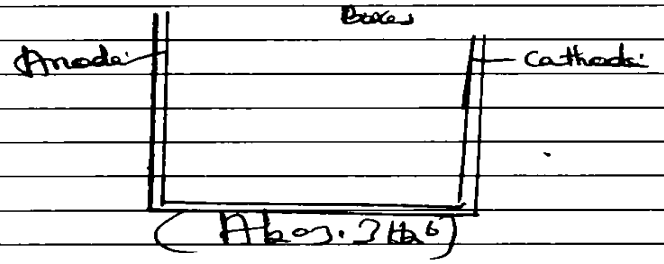
Uses of Tin (Sn)

i) Used in extraction of Metals
ii) Used in Conduction of electricity

6C Extraction of aluminium (Al)

$[Al_2O_3 \cdot 3H_2O]$

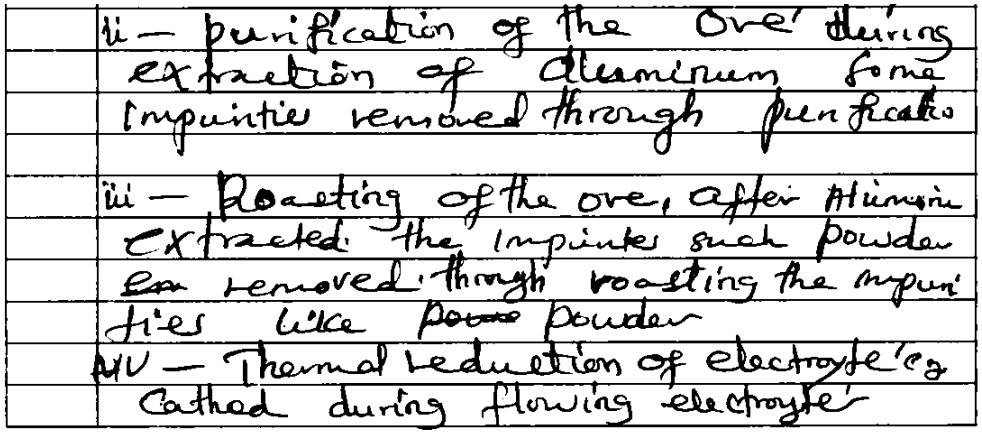
Major events take place in the Concentration of aluminium



Major events take placedering extraction of Aluminium ($Al_2 \cdot 3H_2O$)

i- Concentration of the ore.
eg

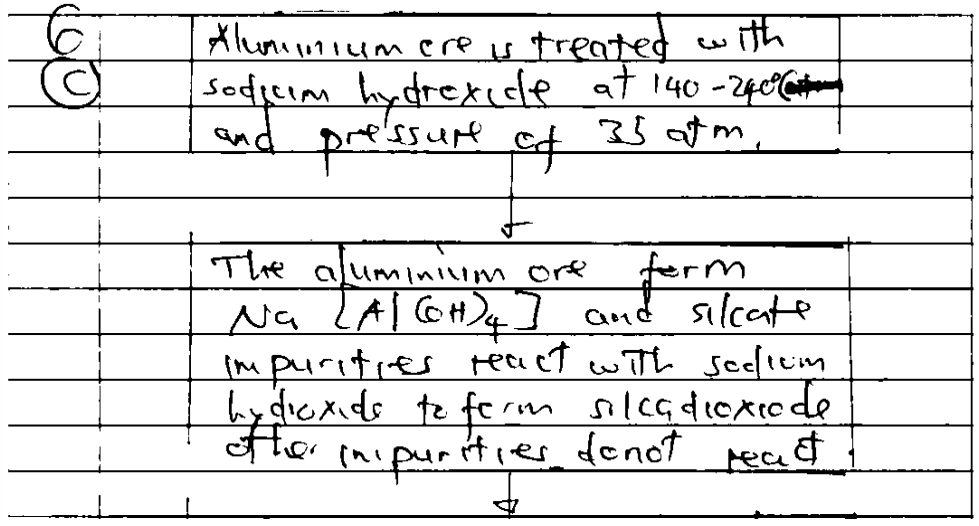
$Al_2 + HNO_3 \longrightarrow AlNO_3 + H_2$

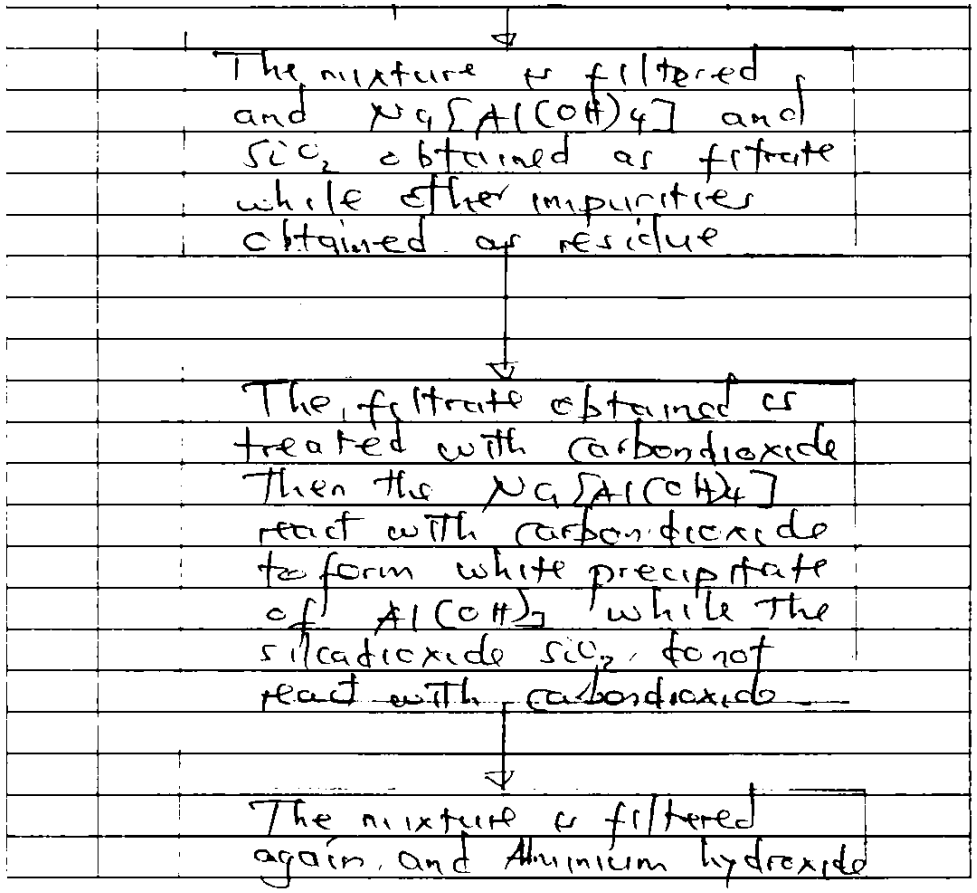


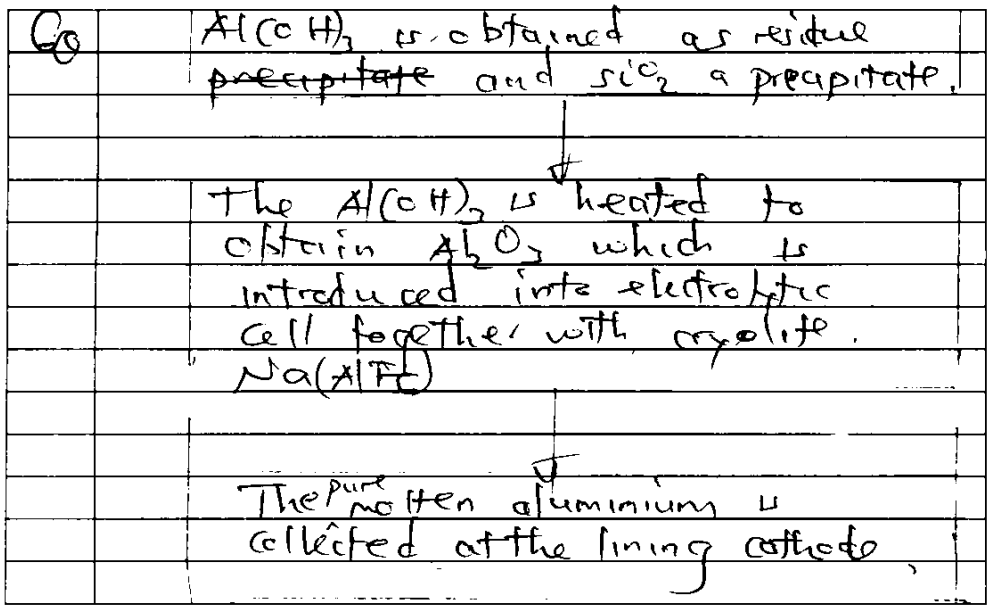
Extract 20.1 indicates an example of a candidate's poor response. The candidate failed in all parts of the question.

Candidates with good performance were able to identify four general principles or steps which are followed during metal extraction, and also analyzed with the aid of chemical equations the process of extracting tin (Sn) from its ore (cassiterite) under the given subheadings. Finally, they designed and formulated the major events in extraction of aluminum and purification from bauxite ($Al_2O_3.2H_2O$). Extract 20.2 is a sample of a good response from the script of one of the candidates.

Extract 20.2







Extract 20.2 shows a response to part 6 (c) of the question. The candidate adhered to the questions demand by designing and

formulating block diagrams to show the major events from the extraction to purification of aluminium.

2.2.7 Question 7: Selected Compounds of Metals; Electrochemistry

This question had parts a, b, c and d. In part (a), the candidates were required to give the formula of (i) the most basic oxide and (ii) the most amphoteric oxide, with reference to the elements of period III of the periodic table. Part (b) required the candidates to briefly explain the action of water on chlorides of period III elements.

Part (c) required the candidates to give reasons to support the observations that (i) when salts of iron are exposed in air they turn from blue green colour to brown, (ii) concentrated nitric acid renders aluminium passive and (iii) zinc and tin are used to protect iron from rusting. In part (d), the candidates were required to state with help of chemical equations, the physical changes that will be observed and their inferences (i) when sodium oxalate solution is added into potassium permanganate solution in acidic medium and (ii) when hydrogen sulphide solution is added into potassium dichromate solution.

The question was opted by 19.8 percent of the candidates. The performance in this question was as follows: 67.4 percent of the candidates scored 0.0 to 6.5 marks; 24.0 percent scored 7 to 11.5 marks and 8.6 percent scored from 12.0 to 19.5 marks. These data indicate that 32.6 percent of the candidates managed to score at least above the pass mark, which is a poor performance.

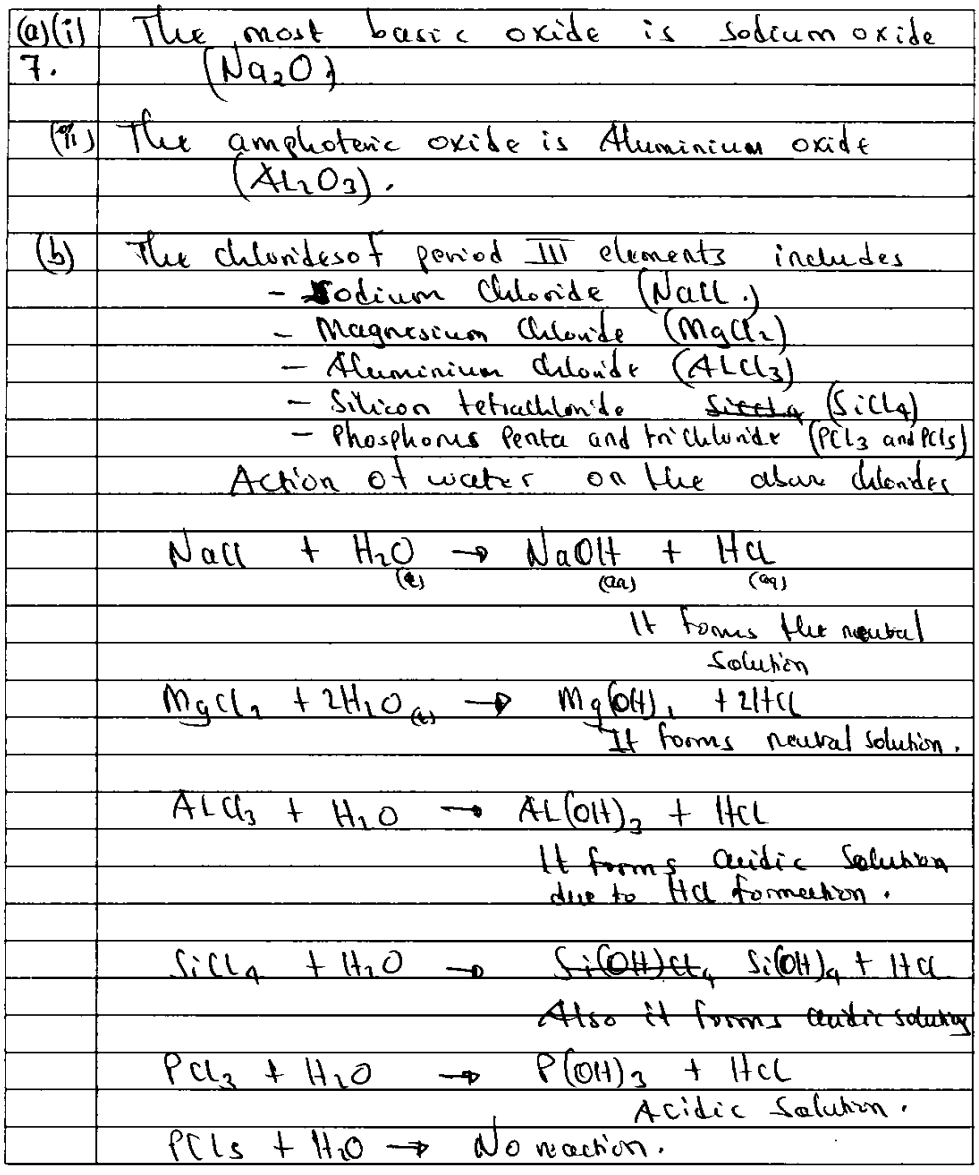
The candidates with good performance (8.6%) were able to identify the elements of period three of periodic table and give the formula of the required oxides. Furthermore, they identified the chlorides of period III and explained how they react with water, supporting with a chemical equation. which indicates that they were good in this area.

The candidates also gave concise reasons, supporting with equations that; (a) (i) salts of iron when exposed in air turn from blue-green colour to brown because of oxidation of iron(II) to iron(III), and (ii) concentrated nitric acid renders aluminium passive because aluminium is oxidized by HNO_3 preventing further reaction. They were also knowledgeable that zinc and tin have more negative electrode potentials than iron, therefore, easily oxidized and hence can protect iron from rusting. Similarly, the candidates were also

able to state with the help of chemical equations the physical changes observed and their inferences when sodium oxalate solution is added into potassium permanganate solution in acidic medium, and when hydrogen sulphide solution is added into potassium dichromate solution.

Extract 21.1 is a sample of a good response from the script of one of the candidates.

Extract 21.1



(c)(i) When salts of iron are exposed in air the turn from blue green colour to brown this is due to the formation of iron III ion since when salt of iron is exposed in air get oxidized to iron (III) that is brown.

$$Fe^{2+} \longrightarrow Fe^{3+} + 3e^-$$

Blue green Brown.

(ii) Concentrated nitric acid renders aluminium passive since aluminium is being oxidized by air to form a protective oxide layer of aluminium that prevent the oxidation of nitric acid.

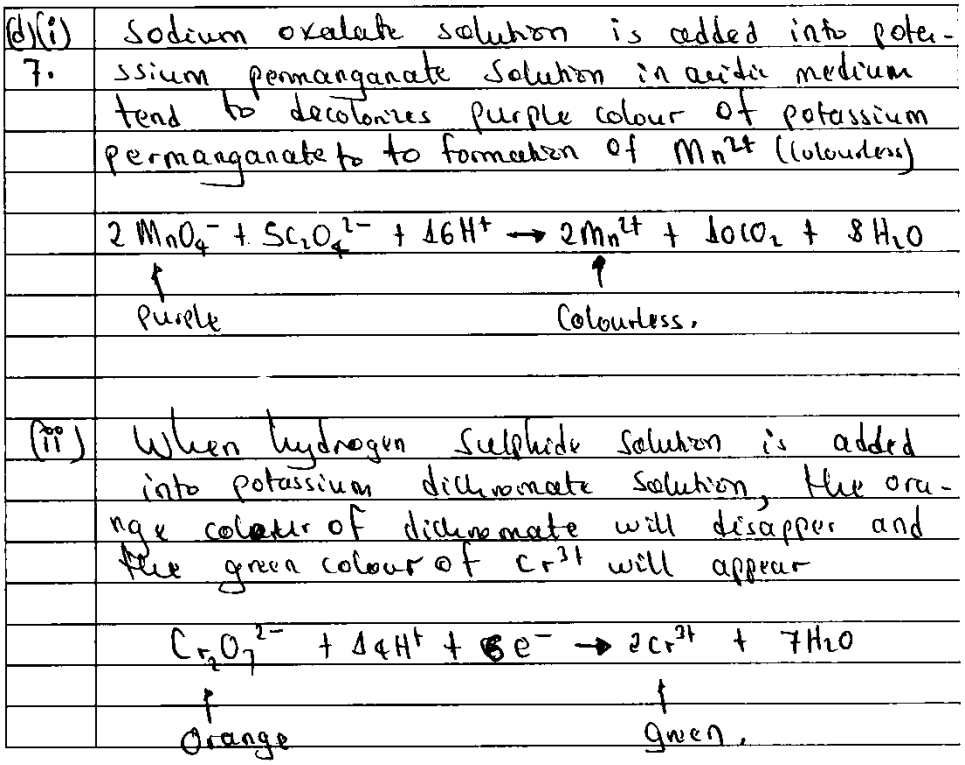
$$Al_{(s)} + O_{2(g)} \longrightarrow Al_2O_{3(s)}$$

(Protective oxide layer).

(iii) Zinc and tin are used to protect iron from rusting since Zinc and tin have more negative electrode potential of $-0.76V$ and $-0.44V$ Respectively while the electrode potential of iron is $-0.44V$, So Zn and Sn get oxidized faster than iron as well as forms the protective layer above iron surface from being oxidized by air moisture to form rust.

$$Zn \rightarrow Zn^{2+} + 2e^-$$
$$Sn \rightarrow Sn^{4+} + 2e^-$$ } oxidations.

$Fe^{2+} + 2e^- \rightarrow Fe$ - reduction, as well as Prevents oxidation of Fe^{2+} to Fe^{3+}.



Extract 21.1 shows a response of a candidate who performed well. The candidate gave correct explanations to each item, supporting them with the formula or reaction equation.

However, as for the case of the candidates who failed the question, they were unable to identify the elements of period III in the periodic table and therefore, could not write the formula of their oxides according to the demand of part (a) of the question. For instance, some of the candidates wrongly wrote elements C and N as elements of period III, whereas they belong to period II. Thus, the candidates ended up giving the formula of acidic and neutral oxides instead of basic and amphoteric oxides. This indicates that the candidates had insufficient knowledge of the position of elements in the periodic table as well as their oxides.

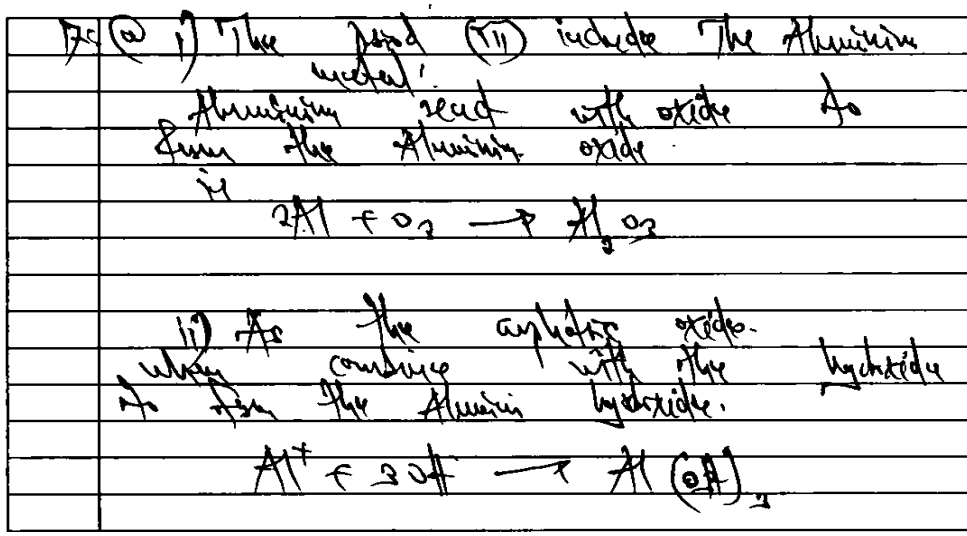
Similarly, most of the candidates performed poorly in part (b) as they failed to explain the action of water on the chlorides of period III elements. As it was noted in part (a), some of the candidates failed to identify the elements of period III, hence could not write the correct formula of the required oxides. Of the candidates who recognized the chlorides of elements in period three, some managed to write the reaction with water but failed to either write the correct products or give correct explanations.

In responding to part (c), the candidates gave various incorrect responses. For example, the majority of them wrongly perceived that iron(III) is oxidized to iron(II) when exposed to air forming brown colour from blue green. They were not aware that what is oxidized is iron(II) and not vice versa. For the case of concentrated nitric acid rendering aluminium passive, some candidates thought of strength of the acid, hence wrote that it was because nitric acid was a strong acid or concentrated acid. For the case of zinc and tin to protect iron from rusting, the candidates gave incorrect responses by indicating that it is because tin and zinc have great ability to resist rust than iron; because iron is a transition metal, while tin and zinc are not. Others wrote iron is more reactive than zinc and tin. They failed to give such reasons like differences in reduction potentials of the two elements with respect to iron.

In part (d), most of the candidates failed to state using chemical equations the physical changes that are observed when sodium oxalate solution is added into potassium permanganate solution in acidic medium, and when hydrogen sulphide solution is added into dichromate solution. The expected physical changes were those which can be observed like colour change, but the majority of the candidates wrote chemical changes. For instance, one of the species is oxidized or reduced; the actions which cannot be seen.

Failure of the candidates in this question is a result of inadequate knowledge of practical oriented questions, particularly redox titration and balancing of redox reactions. Extract 21.2 is an example of one of the poor responses.

Extract 21.2



b) The action of water on chlorides of Aluminium metal.

When the Aluminium metal react with water which contain the chloride which the gas can formed as the hydrogen gas.

$$2Al + 3H_2O \longrightarrow Al_2O_3 + 3H_2$$

c) Sodium salt & iron as reacted in air i.e

$$Fe_2O_3 \longrightarrow Fe + 3O_2$$

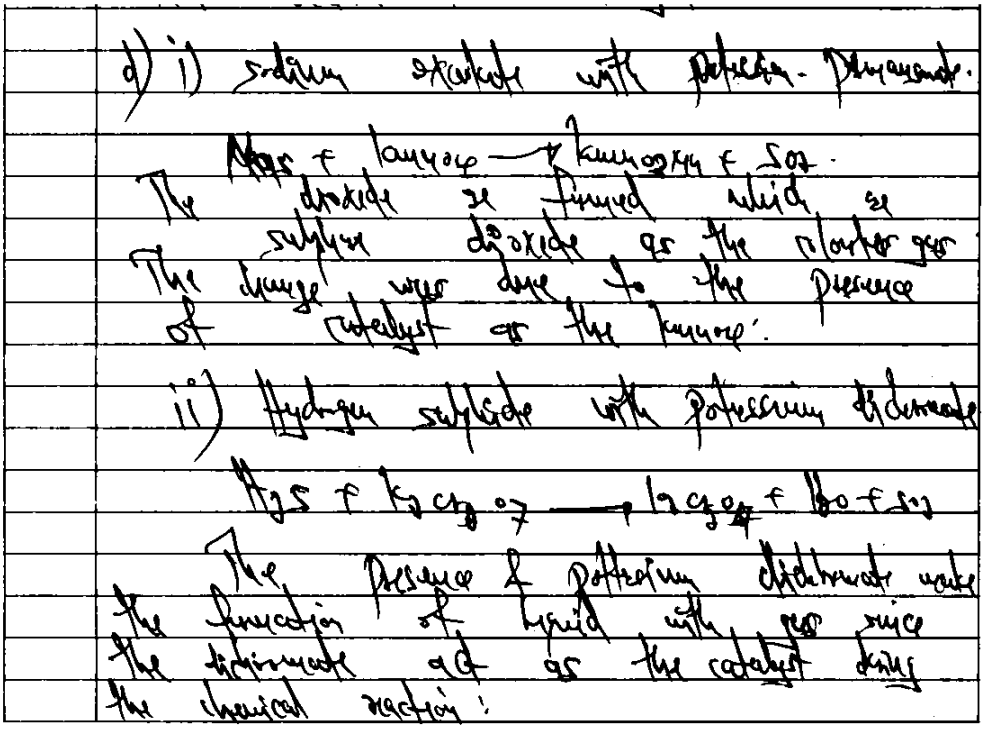
The reduced of oxide is formed in air make the formation of sulphate which is green colour in water.

ii) Concentrated nitric acid reduce Aluminium passive.

$$Al + HNO_3 \longrightarrow Al(NO_3)_3 + H_2$$

The presence of water make the formation of gas as the hydrogen gas which act as the inert Aluminium.

iii) Zinc and tin are used to protect iron from rusting due to the fact as they act as the reducing agent during the chemical reaction as they can reduce the amount of iron which make them metal to be destroyed.



In Extract 31.2, the candidate could not give any correct explanation or reaction equation to any part. For example in part (d) (ii) the candidate incorrectly wrote, "the presence of potassium dichromate waste the formation of hyrid with gas since the dichromate act as the catalyst during chemical reaction".

2.2.8 Question 8: Environmental Chemistry

This question had parts a, b, and c. In part (a), the candidates were required to briefly describe the terms (i) ozone layer, (ii) green-house effect and (iii) acid rain. In part (b), they were required to describe with the aid of chemical equations, how the ozone layer is formed and depleted or destroyed. Part (c) required the candidates to outline six effects of ozone layer depletion.

The question was opted by many (68.5%) candidates. The performance of the candidates was as follows: 74.0 percent scored 0.0 to 6.5 marks, 24.4 percent scored 7.0 to 11.5 marks and 1.6 percent scored 12.0 to 18.5 marks. No candidate scored all the 20 marks. The statistics show that it is only 26.0 percent that managed to score a pass mark (7.0) or above. This showed overall poor performance in this question.

The analysis on the responses of the candidates to part (a) indicates that some of the candidates gave the meaning of the terms instead of describing

them as per the requirement of the question, hence lost some marks. It was also observed that some candidates gave responses which did not address the given terms. For instance, some of the candidates mixed up the greenhouse effect and the effects of ozone layer depletion. As a result they failed to correctly describe the greenhouse effect. This implies that the candidates lacked sufficient knowledge of the terms.

Part (b) was the most difficult to the majority of the candidates. Most of the candidates were not aware that the ozone layer is formed through the process of photo dissociation of oxygen (O_2) molecules by solar radiation. ie.
O_2 + u.v light $\rightarrow$ $O^{\cdot}$ + $O,^{\cdot}$ where the highly reactive free radical oxygen ($O^{\cdot}$) atoms formed combine with O_2 molecules to form ozone.
$O^{\cdot}$ + O_2 + inert gas $\rightarrow$ O_3.

However, some of the candidates did not know that the constituent of the ozone layer is O_3, as they wrote different equations whose products were not O_3. The analysis also revealed that some of the candidates explained about the effect of greenhouse gases on the ozone layer but could not write the equation showing how they deplete/destroy the ozone. This shows that the candidates had inadequate knowledge about the ozone layer, and a result failed to point out the effects of the ozone layer, and as required in part (d). Extract 22.1 provides a sample of a candidate's poor response.

Extract 22.1

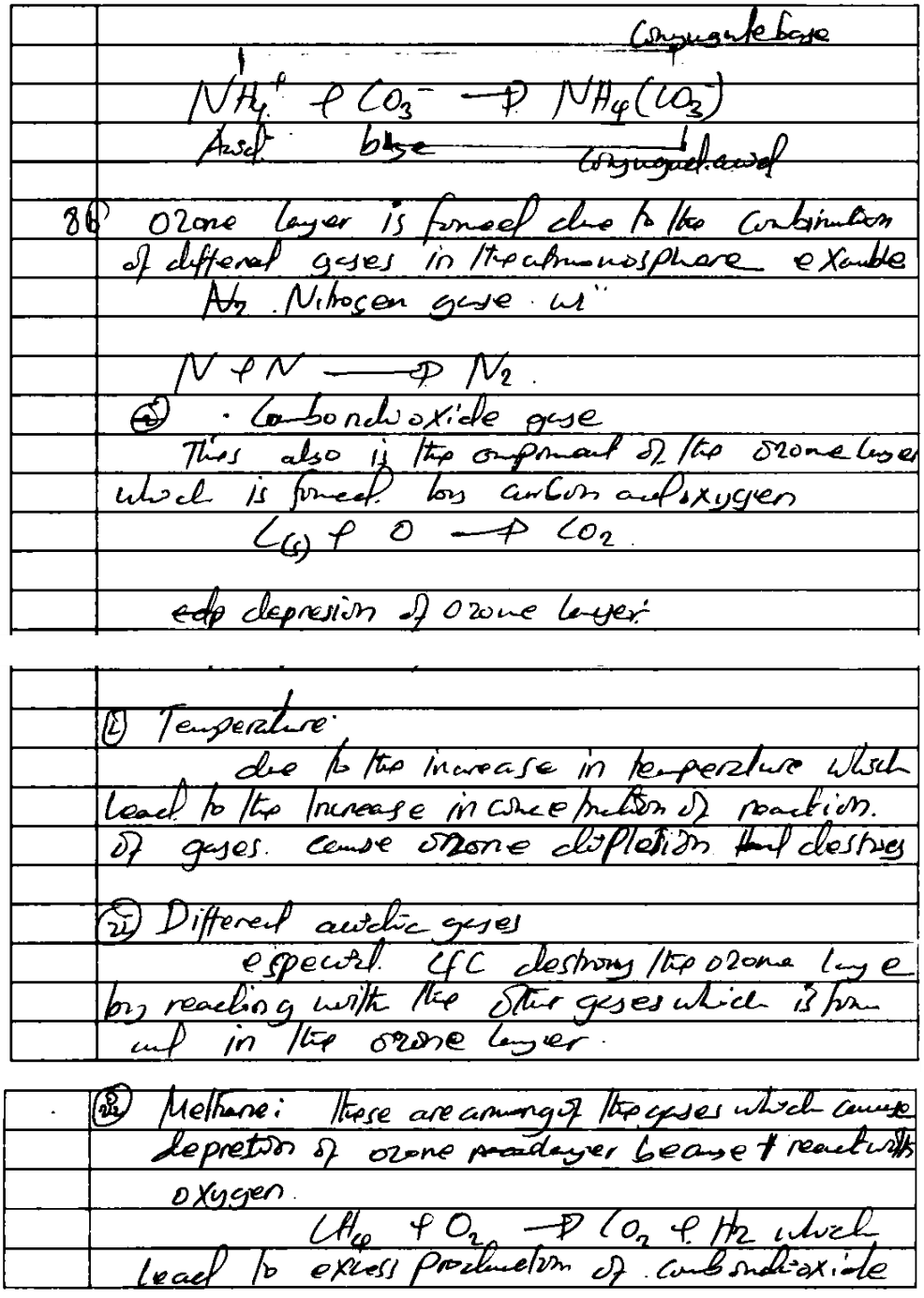
(8) · Ozone layer : This is the layer above the earth surface which is composite of different gases and also ~~for~~ Ionosphere is found in ~~the~~ ozone layer the gases which formed in ozone layer are · Carbondioxide, Oxygen gase. Nitroge n gase and so on.

(9) Green house effect : This is the introduction of green house gases ~~has~~ like Carbon, flor ne and other gases with cause the destruction of ozone ~~layer~~ layer and cause the increase in temperature to world the earth surface this effect is called Global warming which caused by Green house gases

(10) Acid rain : This is the form of rain which contain acid molecules which caused by ~~the~~ introduction of acidic gase to the atmosph ere the acidic gase maybe from the industries due to production of harmful gases which destroy the ozon layer

(c) effect of ozon lose.

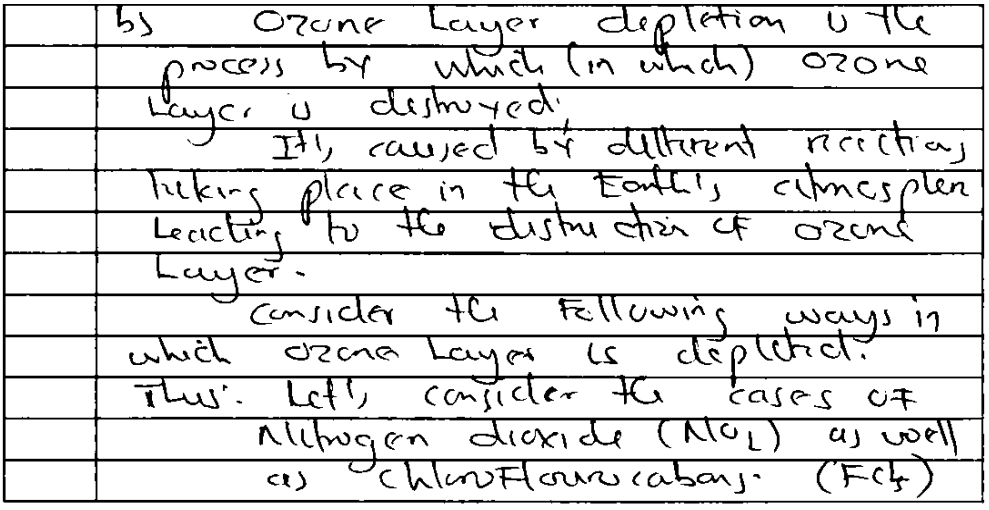
- → Climatic change.
- → Increase in temperature to the earth surface.
- → Acidic rain fall to the earth surface
- → for Communication failed because it depend on Ionosphere
- → Increase in sea temperature level
- → Cause diseases to animals



Extract 22.1 indicates that the candidate wrongly understands that the ozone layer is a composite of different gases like CO_2 and N_2 and the greenhouse effect is the introduction of greenhouse gases which cause destruction of the ozone layer. Similarly, he/she wrongly responded to the remaining parts of the question.

The candidates with good performance (1.6%), especially those who managed to score 15 to 18.5 marks were able to describe the terms, ozone layer, greenhouse effect and, acid rain. They were also able to outline six effects of ozone layer depletion. However, they faced some difficulties in writing one chemical reaction to show how the ozone layer is formed and destroyed, hence could not score all 20.0 marks. Extract 22.2 is one of the good responses from one of the candidates.

Extract 22.2


(b) Ozone Layer depletion is the process by which (in which) ozone layer is destroyed.
It is caused by different reactions taking place in the Earth's atmosphere leading to the distruction of ozone layer.
Consider the following ways in which ozone layer is depleted.
Thus. Let's consider the cases of Nitrogen dioxide (NO_2) as well as Chlorofluorocabons. (FCl)

8.6 A: Through Nitrogen dioxide (NO_2).
High Ultraviolet radiation split the Nitrogen dioxide Molecule (NO_2) Homolytically, Also Lightning can cause the split of Nitrogen dioxide (NO_2) molecule as per equation.

$$NO_2 \xrightarrow[\text{lightning}]{u.v} NO^{\cdot} + O^{\cdot}$$

Then: Nitrogen Monoxide radical Formed is very reactive and reacts with oxygen From the ozone Layer (O_3) and creating the hole in it according to the Following Equation.

$$NO^{\cdot} + O_3 \longrightarrow NO_2 + O_2$$

Hence Depletion

B: Through chlorofluorocarbons. (FCl)
Also: Chlorofluorocarbon (CFC) is the Main agent in depletion of ozone Layer; O_3
Under high Ultraviolet radiation the molecules split according to the Equation

$$CF_2\text{-}Cl_2 \xrightarrow{u.v} {}^{\cdot}ClF_2{}^{\cdot} + Cl^{\cdot}$$

Then chlorine radical Formed also is very reactive and react rapidly with oxygen From ozone Layer (O_3) as per Equation:

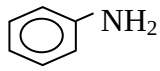
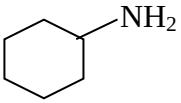
$$O_3 + Cl^{\cdot} \longrightarrow ClO + O_2$$

Hence Leading to the ozone depletion because the proces an catalytic.

In Extract 22.2 the candidate correctly illustrated how the ozone layer is destroyed by the reaction of chlorofluorocarbons (CFCs), and by the reaction with the oxides of nitrogen (NO).

2.2.9 Question 9: Amines

This question had parts a, b, c and d. In part (a), the candidates were required to briefly explain the most basic compound from the following pairs of organic compounds:

(i)  and 

(ii) $CH_3\text{-}NH_2$ and $CH_3\text{-}NH\text{-}CH_3$

In part (b), the candidates were required to give the products of the following organic reactions:

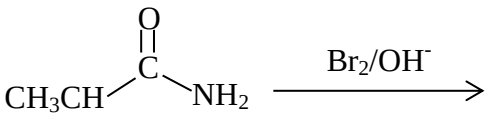
(i) $CH_3C \equiv NH_2 + H_2O, H^+ \rightarrow$

(ii) $CH_3CH_2CONH_2 + LiAlH_4,\ H_2O \rightarrow$

(iii)  + Conc. HCl, Sn $\longrightarrow$

(iv) $CH_3CH_2NH_2 + HNO_3(aq) \rightarrow$

(v)  + $NaNO_2$, conc. $HCl \rightarrow$

(vi) 

Part (c) required the candidates to briefly describe the laboratory preparation of dimethylamine from methane.

In part (d), the candidates were given the following information:

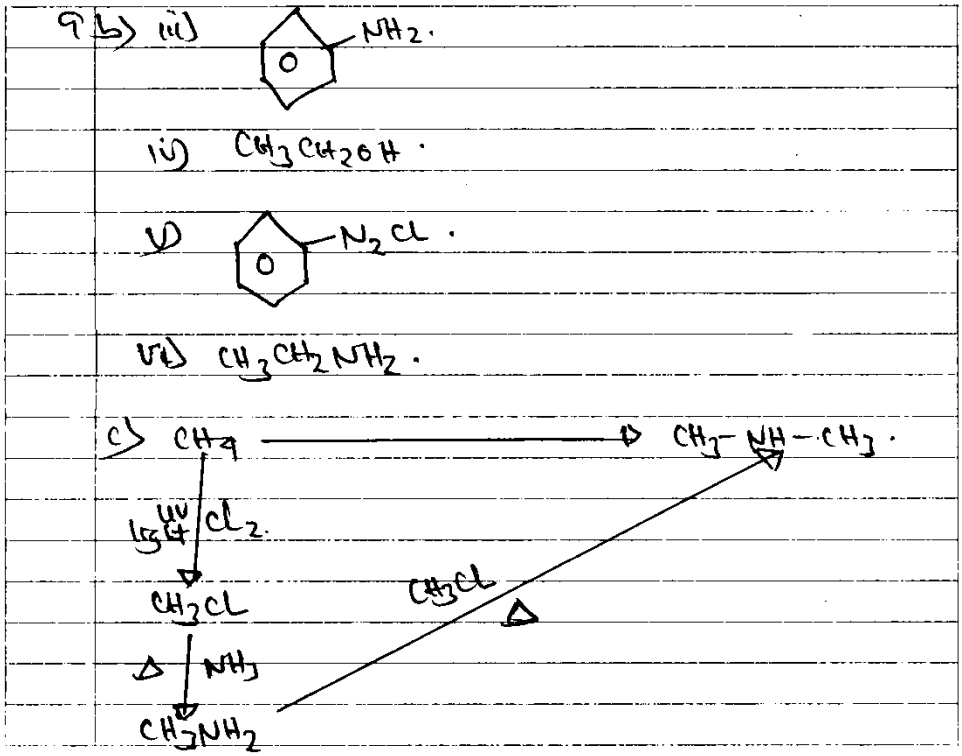
"An organic compound A was treated with nitrous acid and yielded compound B and nitrogen gas was evolved. Compound B has a composition of 60% C, 13.33% H and 26.67% O. Compound B has a vapour density of 30. When compound B was oxidized using H_2CrO_4, it yielded compound C. Compound C forms oxime with hydroxylamine. Compound C also reacts with Fehling's solution to form brick-red precipitate."

Then they were required to (i) work out and suggest the structures of compounds A, B and C and (ii) give the chemical equations for the reactions mentioned.

The question was opted by few (22.4%) candidates and the performance was as follows: 44.1 percent of the candidates scored from 0.0 to 6.5 marks; 29.1 percent scored from 7.0 to 11.5 marks and 26.8 percent scored from 12.0 to19.5 marks. No candidate scored all the 20 marks. Nevertheless, these data show that the performance in this question was average as 55.9 percent scored at least 7.0 marks.

The candidates with good performance were able to explain the most basic compound from the given pairs of organic compounds. They correctly gave the products of the provided organic reaction equations. The candidates were also able to describe the laboratory preparation of dimethylamine from methane. Similarly, they managed to work out and suggest the structures of compound A, B and C; and gave the chemical equations for the reactions mentioned from the given information. Extract 23.1 is a sample of good response from one of the candidates.

Extract 23.1



9. d) Solution

Symbol	C	H	O
% Composition	60	13.33	26.67
% Composition	60	13.33	26.67
RAM	12	1	16
	= 5	= 13.33	= 1.67
divide by the smallest	5 / 1.67	13.33 / 1.67	1.67 / 1.67
	3	8	1

Empirical formula C_3H_8O.

Molecular formula:

Molecular weight = 2 X V.D

= 2 X 30

= 60.

$n(C_3H_8O) = 60$

$n(12X6 + 1X8 + 16) = 60$

$60n = 60$

$n = 1$.

Molecular formula = n (E.F)

= 1 (C_3H_8O)

= C_3H_8O.

Then compound B was C_3H_8O.

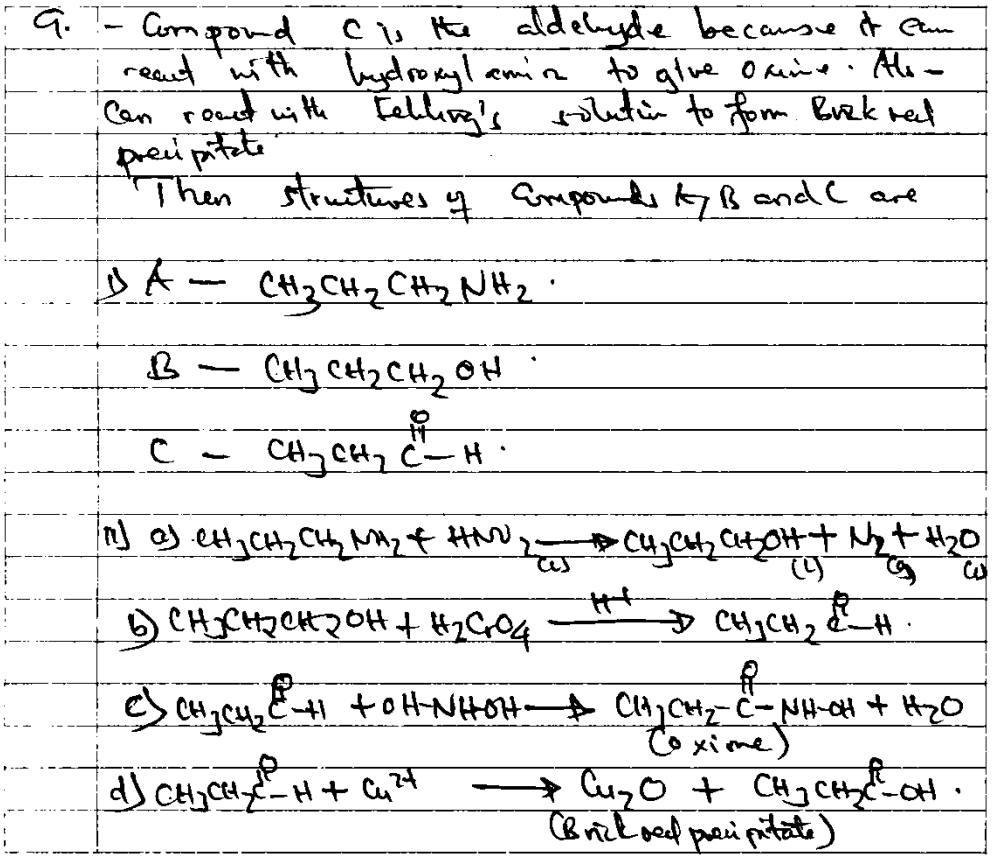
Then compound A was $C_3H_7NH_2$.

On reaction with Nitrous acid gave B.

$C_3H_7NH_2 + HNO_2 \longrightarrow C_3H_7OH$.

-When B oxidized with H_2CrO_4 (weak oxidizing agent) gave C which is carbonyl compound.

$CH_3CH_2CH_2OH \xrightarrow[H^+]{H_2CrO_4} CH_3CH_2\overset{O}{\overset{\|}{C}}-H$.

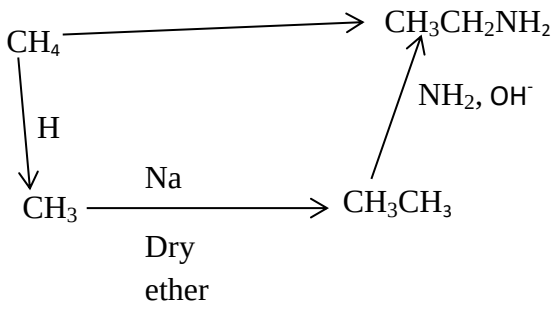


Extract 23.1 is a response of a candidate who managed to perform well in parts (b), (c) and (d) of the question.

For the candidates to respond well to part (a), they should have had sufficient knowledge about the electron releasing power of the given groups towards amino (NH_2) which makes the lone pair of electrons on nitrogen atom more available (reactive) for donation (for acid attack). The candidates with low scores failed to conceptualize this fact. The analysis shows that some of the candidates managed to point out the compound which is more basic, but could not give the reason, hence lost some marks. It was also noted that some of the candidates' answers were incorrectly focused on the structures of the compounds. The structure is either more or less branched and therefore can be either more or less basic than the other.

Part (b), required the candidates to have adequate knowledge of the principles of reaction mechanisms and the factors effecting organic reactions, specifically, preparation and reaction of amines. The candidates with low scores lacked this knowledge. Thus, they were unable to give the

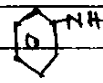
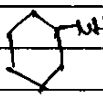
description of the laboratory preparation of dimethylamine from methane in part (c). The following is an example of the answers from one of the candidates who gave a wrong response:



It is evident that the candidate had inadequate knowledge about the principles of reaction mechanisms, the factors effecting organic reactions and how one function group can be converted to another. That is why the candidate failed to recognize the steps required for preparing dimethylamine from methane.

In part (d), some of the candidates managed to find out empirical formula and molecular formula, hence were able to give the structure of compound B. However, the majority of them could not give the required reaction equations, hence failed to give structures of compounds A and C. This failure was caused by insufficient knowledge about the properties of the functional groups concerned, which were supposed to be interpreted from the given reactions in the question. Extract 23.2 provides a sample of a candidate's poor response.

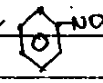
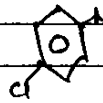
Extract 23.2

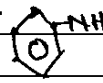
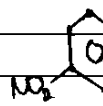
9(a) i/  is more basic than  due to mesomeric effect taking place in the benzene ring.

ii/ CH_3-NH_2 is more basic than $CH_3-NH-CH_3$ due to small molecular weight of the compound.

(b) i/ $CH_3C\equiv N + H_2O \xrightarrow{H^+} CH_3C(=O)NH$

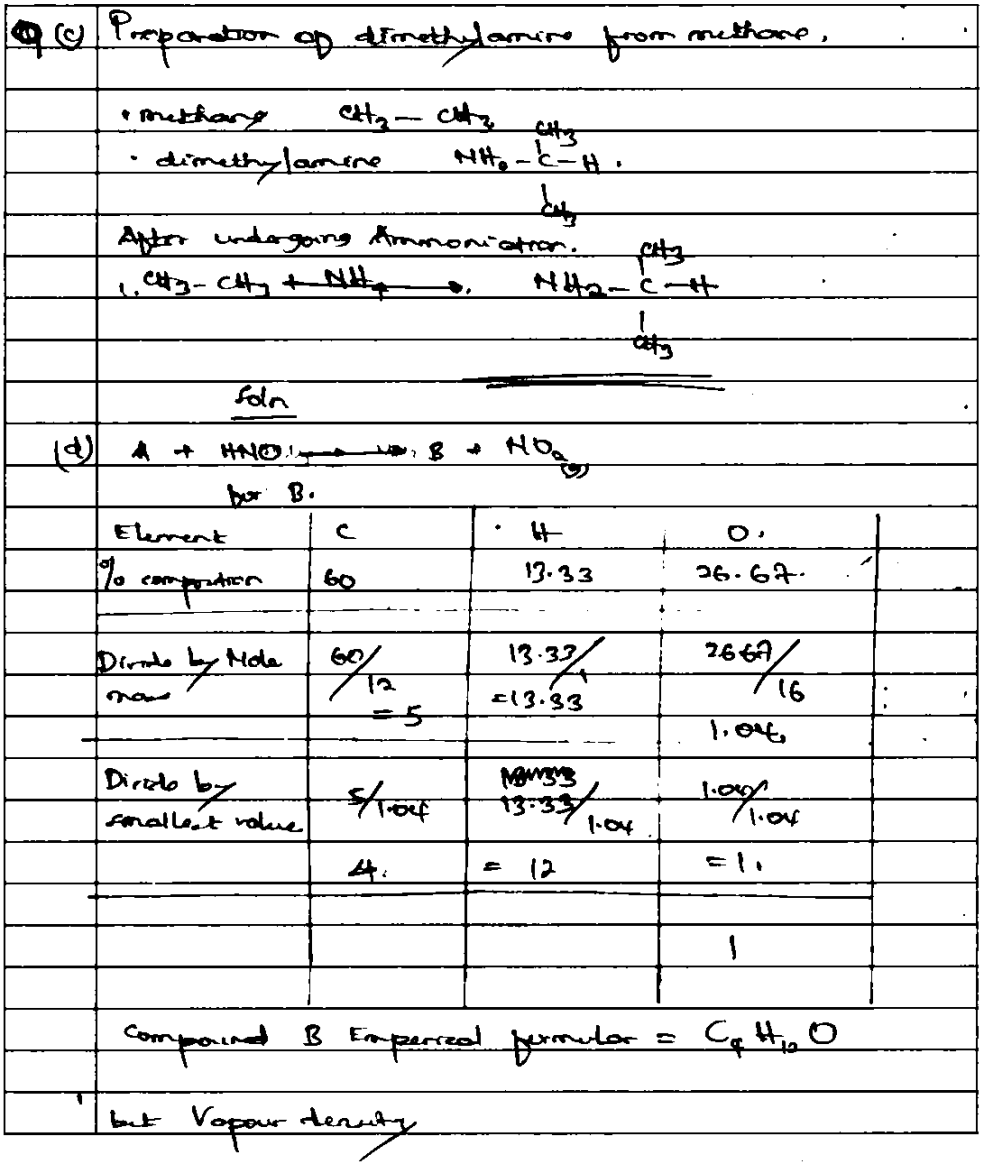
ii/ $CH_3CH_2CONH_2 + LiAlH_4 \xrightarrow{H_2O} CH_3CH_2CH_2(OH)Al(NH_2)_2$

iii/  + Conc. HCl, Sn ⟶  + H_2

iv/  + $NaNO_2$, conc HCl ⟶  + NaCl.

v/ $CH_3CH_2NH_2 + HNO_2$ cold ⟶

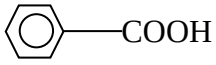
vi/ $CH_3CH_2-C(=O)-NH_2 \xrightarrow{Br_2/OH^-} CH_3CH_2-C(=O)-Br + NH_3$

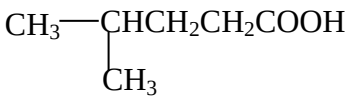


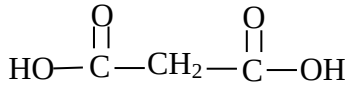
Extract 23.2 indicates the candidate's poor response. The candidate failed in all the parts of the question.

2.2.10 Question 10: Carboxylic Acids and Derivatives

This question had parts (a), (b), (c) and (d). In part (a), the candidates were required to name the following compounds:

(i) 

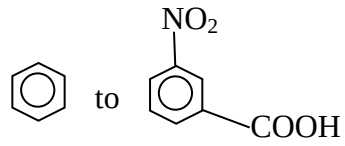
(ii) 

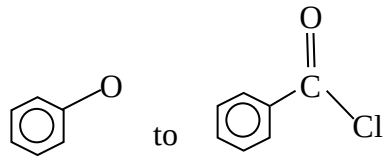
(iii) 

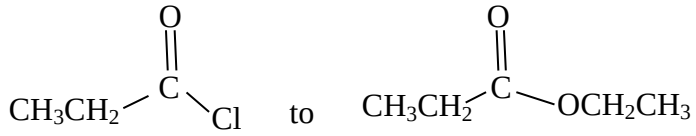
(iv) $CH_3H_2CH\,(OH)–CH_2CH_2COOH$

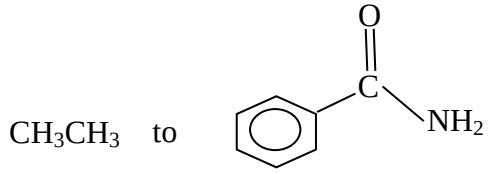
In part (b), the candidates were required to explain the effects of (i) chlorine as electron withdrawing atom and (ii) large-sized alkyl group as electron releasing on the acidity of carboxylic acids.

In part (c), the candidates were asked to show how the conversions of the following organic reactions can be carried out.

(i) 

(ii) 

(iii) 

(vi) 

In part (d), the candidates were given the following information: “Lactic acid ($CH_3CH(OH)CO_2H$) occurs naturally in sour milk. The compound can be synthesized from ethanol by the following route:

$$CH_3CH_2OH \xrightarrow{U} CH_3CHO$$

$$CH_3CHO \xrightarrow{V} CH_3CH(OH)CN$$

$$CH_3CH(OH)CN \xrightarrow{W} CH_3CH(OH)COOH",$$ then they were required to:

(i) give the reagents and conditions if any, for steps U, V and W above.

(ii) give the names of the organic reactions represented by steps V and W.

(iii) name the lactic acid by IUPAC system.

The percentage of the candidates who opted for this question was 35.8. The distribution of candidates' scores is as shown in Figure 9.

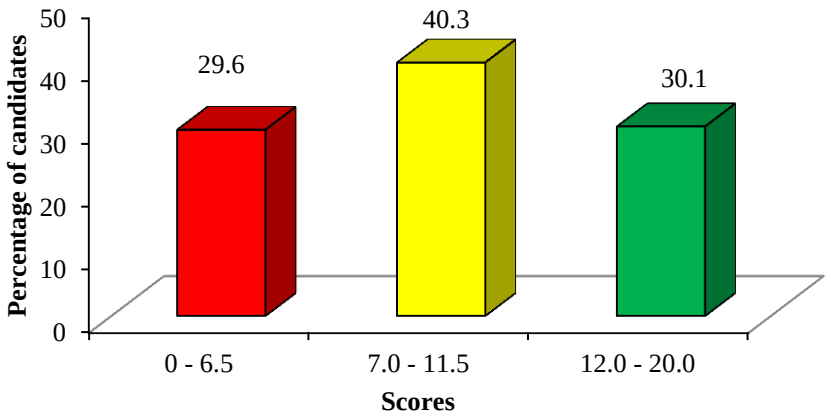


Figure 9: Performance of the candidates in question 10.

Figure 9 shows that the performance was good because 70.4 percent of the candidates scored at least 7.0 marks. The majority (40.3%) of the candidates scored average marks (7.0 to 11.5 marks).

The candidates who scored high marks (30.1%), correctly named the given compounds and explained the effects of chlorine as electron withdrawing atom and large-sized alkyl group as electron releasing on the acidity of carboxylic acids. Similarly, they managed to complete conversions of the given organic reactions. They were also able to give the reagents and conditions of the synthesis of lactic acid from ethanol by following the given route and finally named the lactic acid using the IUPAC system. Extract 24.1 is a sample of a good response from the script of one of the candidates.

Extract 24.1

10 (a) i) Benzene carboxylic acid
or
Benzoic acid.

ii) 4-methyl pentanoic acid

iii) Propan-1,3-dioic acid

iv) 4-hydroxyl hexanoic acid

10 (b) i) Consider

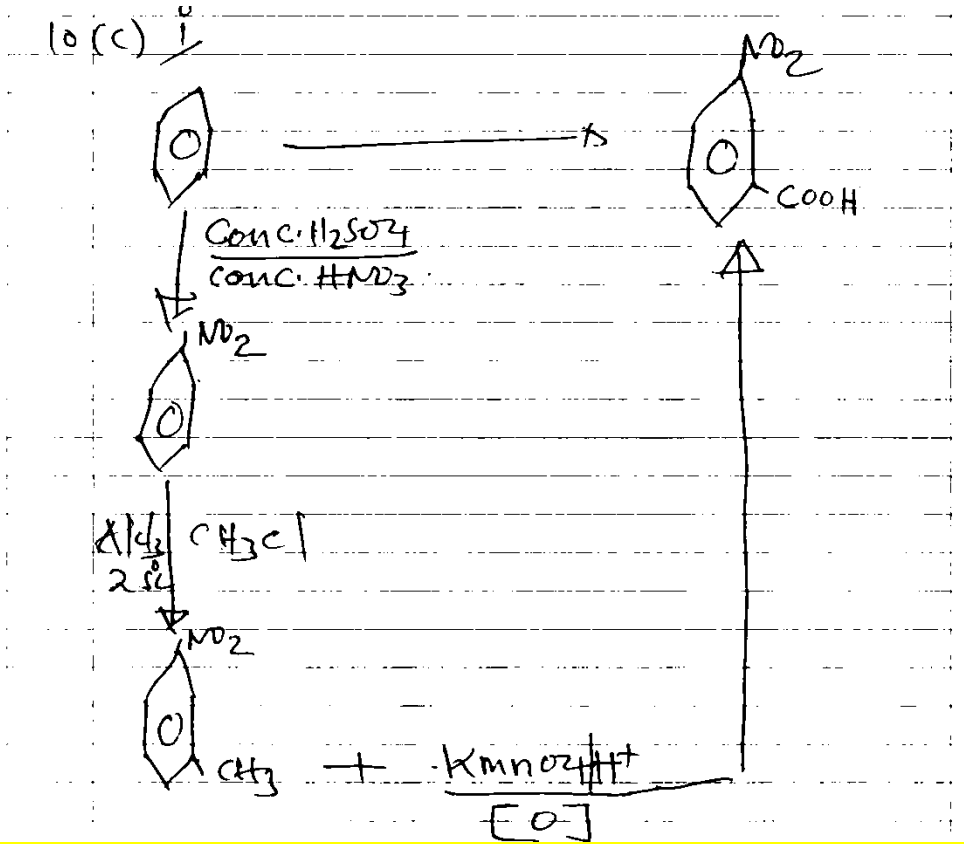
$$R-CH_2CH(Cl)-C(=O)-OH$$

When chlorine as a withdrawing group is attached on the acid it increased the acidity of the carboxylic acid since it cause the weakening of the OH bond strength hence H^+ is easily released into the solution.

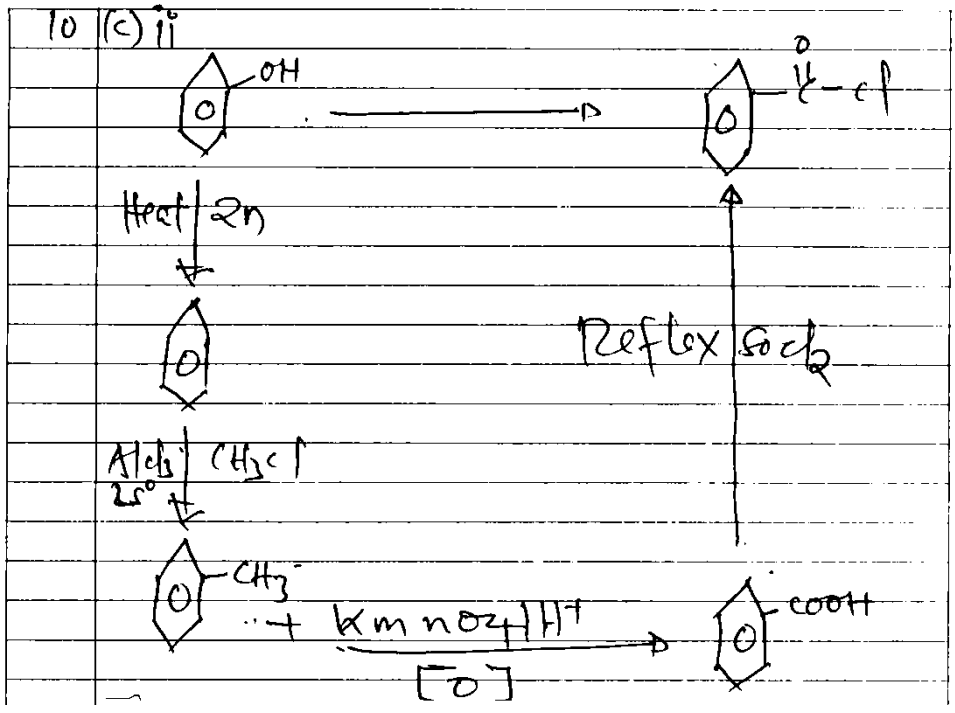
ii) It increase the acidity strength of carboxylic acid by negative inductive effect (-I)

10 (b) ii) The large sized alkyl group cause the acidity of carboxylic acid to DECREASE, since it supplies the electrons to the O→H bond causing the bond to be strong so that it cannot release H^+ into the solution easily.

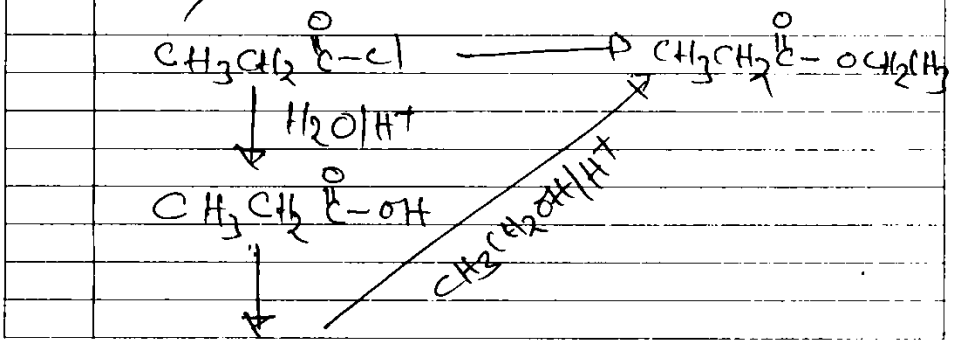
10 (c) i


Conc. H_2SO_4
Conc. HNO_3
NO_2
$AlCl_3$ CH_3Cl
25°
CH_3
$KMnO_4/H^+$
[O]
NO_2
COOH

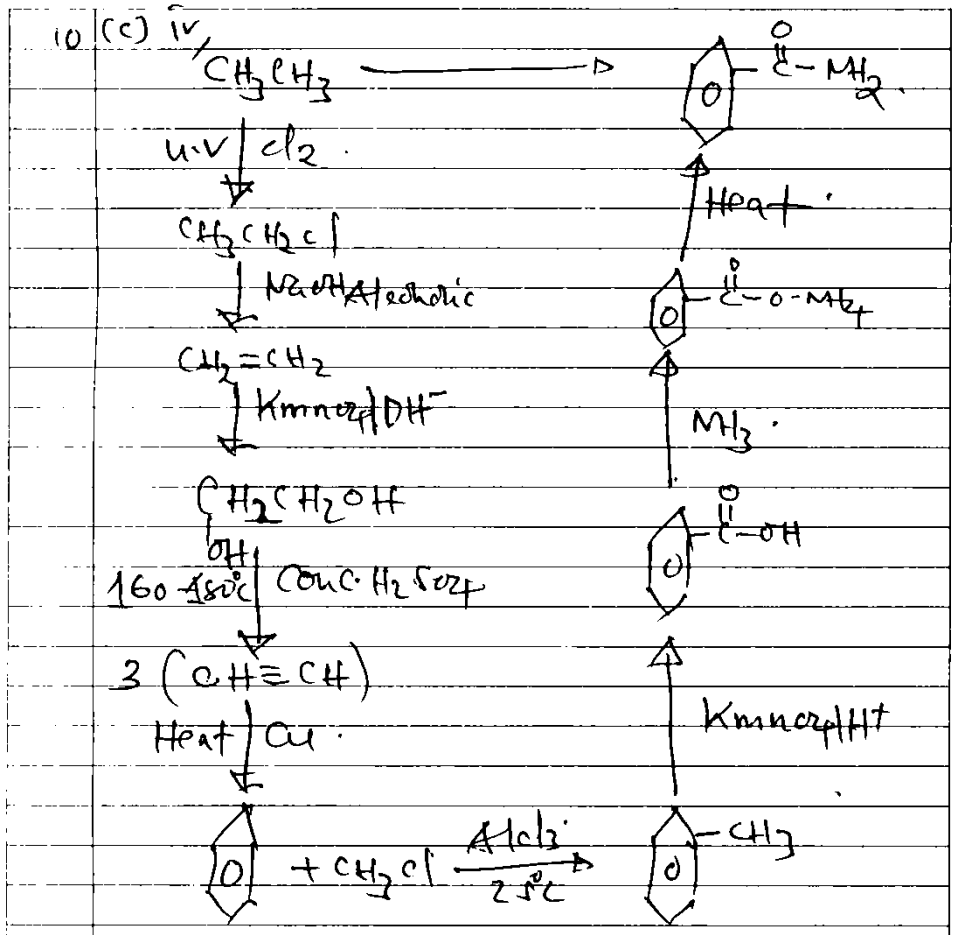
10 (c) ii


OH
Heat | Zn
$AlCl_3$ CH_3Cl
25°
CH_3
$KMnO_4/H^+$
[O]
Reflux
COOH

10 (c) (iii)



10 (c) iv)

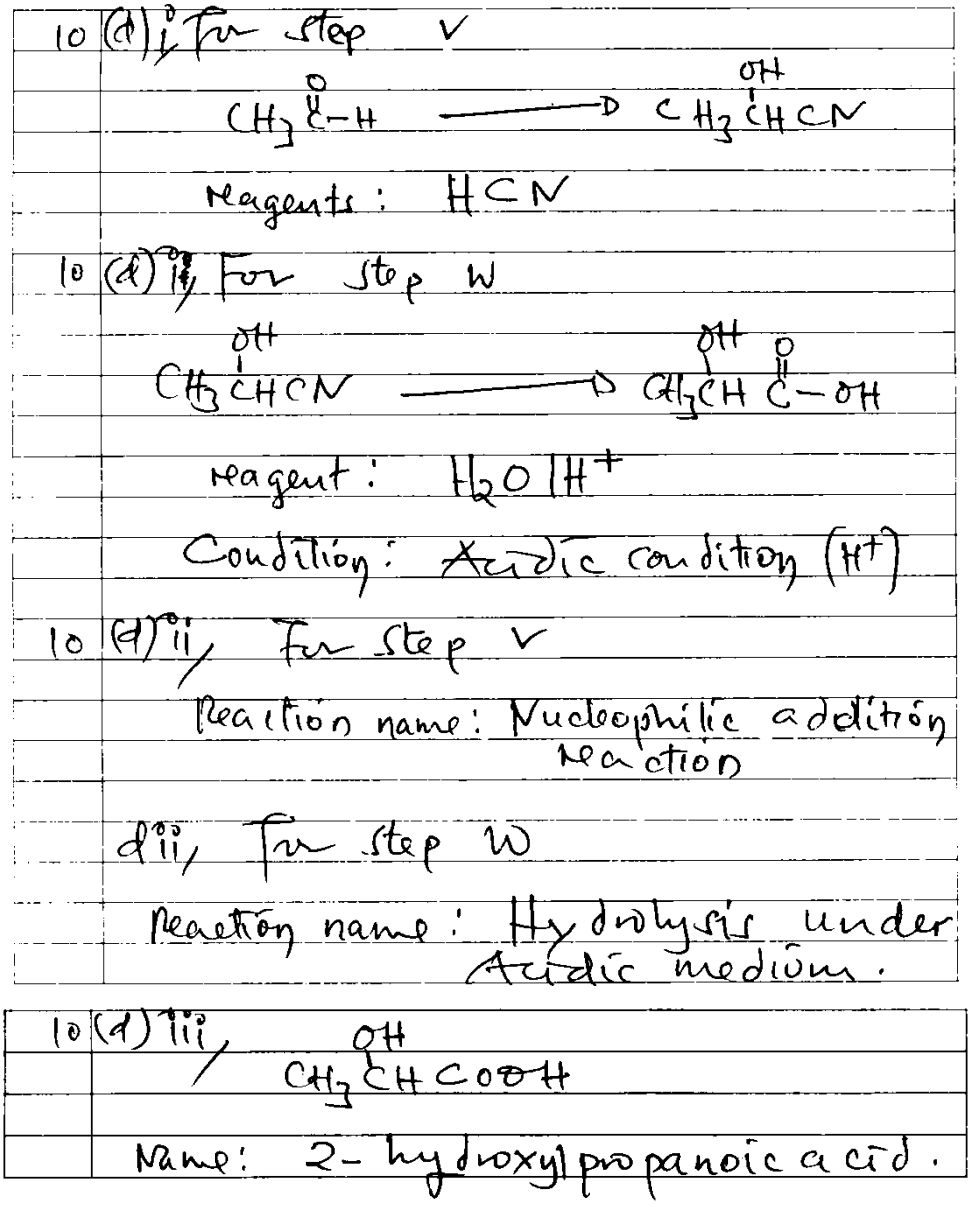


10 (d) i) For step U.

$CH_3CH_2OH \xrightarrow{U} CH_3\overset{O}{\overset{\|}{C}}-H$

Reagent: MnO_2 or H_2CrO_4

Condition: Acidic Condition (H+)



Extract 24.1 shows responses of a candidate who managed to perform well in all he parts of the question. The work of the candidate is systematically presented.

On the other hand, most of the candidates who scored low marks managed to recognize that the compounds in parts (a) were carboxylic acids, and hence correctly named them. However, a few candidates who failed to answer this part regarded the compounds as alcohols, ketones, esters or aldehydes, hence provided incorrect answers. It was also noted that although some recognize

the compounds as carboxylic acids, they failed to use the IUPAC rules to name them.

In order to respond correctly to part (b), the candidates should have had knowledge of inductive effects of the given species. They had to understand that chlorine has negative inductive effects, while large-sized alkyl group has positive inductive effects on carboxylic acid. Hence, choline increases acidity of carboxylic acids while alkyl group decreases it. It was observed that the candidates lacked knowledge of these concepts and therefore failed to point out the effects.

On the other hand, the knowledge of carboxylic acid derivatives, different reagents and types of organic reactions was essential for the candidates to correctly respond to parts (c) and (d). However, it was observed that the responses of the candidates with low scores were the results of guesswork as they were not able to respond to the questions. The following response is one of such responses to part (d).

"(d) $CH_3CH_2OH \xrightarrow[NaAlH_4]{U} CH_3CHO$

$CH_3CHO \xrightarrow[KCN]{V} CH_3CH\ (OH)\ CN$

$CH_3CH\ (OH)\ CN \xrightarrow[[O]]{KMnO_4} CH_3CH\ (OH)\ COOH$

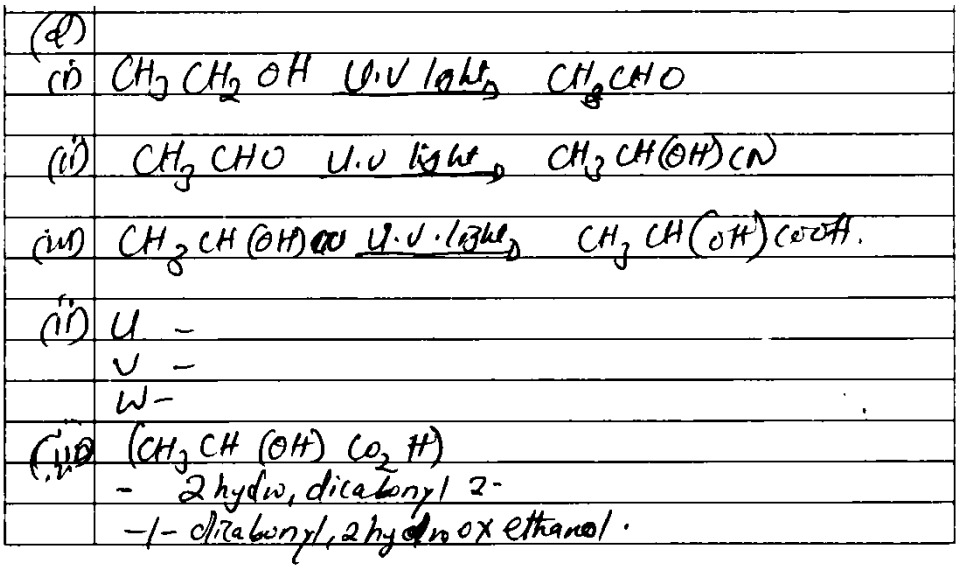
(i) *U= Reagent : $NaAlH_4$*
V = Reagent: KCN
W = Reagent: $KMnO_4$ under [O]

(ii) *V*
W – Strong oxidizing agent

(iii) *2-hydroxo propanoic acid"*

The above responses indicate that the candidate lacked knowledge about the properties of functional groups such as –OH, -CHO, and –COOH, which led to prediction of the type of reagent and conditions required. Extract 24.2 provides a similar poor response.

Extract 24.2



Extract 24.2 shows a poor response where the candidate wrote U. V light as the only reagent of the given reactions. The candidate left part (d)(ii) unanswered and gave irrelevant name of lactic acid.

3.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE IN EACH TOPIC

A total of twenty (20) topics were examined in paper 1 and paper 2. The candidates performed well in the following topics: The Atom (82.4%), Chemical Kinetics (73.5%), Gases (77.2), Aliphatic Hydrocarbon (71.8%), Carboxylic Acid and Derivatives (70.4%), Chemical Bonding (68.6%), and Aromatic Hydrocarbon (64.9%).

The good performance in the stated topics was attributed to the fact that most of the candidates had adequate knowledge and clearly understood the requirement of the respective questions. Moreover, most of them were able to correctly use the English language in answering the questions which required explanations.

The candidates had an average performance in the topics of Acids, Bases and Salts (56.2%); Solubility, Solubility Product and Ionic Product (59.9%), Amines (55.9%), Chemical Equilibrium (54.9%), Halogen Derivatives of Hydrocarbons (53.0%), Relative Molecular Mass in Solution (41.6%),

Electrochemistry (38.9%) and Two Component Liquid Systems (37.1%). On the other hand, the candidates had weak performance in the topics of Selected Compounds of Metals (32.6%), Energetics (25.9%), Periodic Classification (26.8%), Environmental Chemistry (26%) and Extraction of Metals (18.9%).

However, poor performance in the five stated topics was attributed to inadequate knowledge on these topics. For example, in the topic of Extraction of Metals, the candidates failed to explain clearly the major events summarising the extraction of aluminium and writing correct equations during the process of extraction of tin.

The comparison of the candidates' performance between the year 2016 and 2017 shows that, the performance in 9 topics has increased, while it has decreased in 9 topics. Details of performance in different topics are presented in the appendix.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The question-wise analysis of the performance in Chemistry paper one and two for the ACSEE 2017 has shown that overall candidates' performance was average.

The analysis shows that 07 topics had good performance, 08 topics had average performance and 05 topics had poor performance. Good performance was attributed to good mastering of the concepts tested in the respective topics and understanding of the questions' demands.

However, the analysis on individual items indicated that some of the candidates experienced difficulties in answering the question items which involved basic mathematical skills based on chemistry principles, and the ones that needed factual knowledge. This was evident from the analysis made in the questions from the content areas of Energetics, Extraction of Metals, Periodic Classification and Environmental Chemistry.

This performance could be attributed to lack of mathematical skills and inadequate skills in these topics. This insufficiency needs to be dealt with by both teachers and students during the teaching and learning process.

4.2 Recommendations

(i) Teachers should put more emphasis on mathematical-based concepts and skills related to Energetics. This will improve the ability of prospective candidates to deal with problems related to the concepts.

(ii) The prospective candidates should study hard all topics so as to acquire sufficient knowledge, especially on the content areas of Energetics, Extraction of Metals, Periodic Classification and Environmental Chemistry.

(iii) The prospective candidates should be encouraged to improve their ability in reading and writing English Language through reading English books, practicing to speak English and involving themselves in essay writing so as to improve their writing and understanding of different concepts.

Appendix: Summary of the Performance of Candidates – Topic wise

S/.	Topic	2016			2017		
		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	The Atom.	2	75.9	Good	1	82.4	Good
2	Gases.	2	52.1	Average	2	77.2	Good
3	Chemical Kinetics.	-	-	-	1	73.3	Good
4	Aliphatic Hydrocarbons.	2	49.4	Average	1	71.8	Good
5	Carboxylic Acids and Derivatives.	1	63.0	Good	1	70.4	Good
6	Chemical Bonding.	1	63.8	Good	1	68.6	Good
7	Aromatic Hydrocarbons.	1	12.5	Weak	2	64.9	Good
8	Solubility, Solubility Product and Ionic Product.	-	-	-	1	59.9	Average
9	Acids, Bases and Salts,	1	80.9	Good	1	58.1	Average
10	Amines.	1	68.7	Good	1	55.9	Average
11	Chemical Equilibrium.	1	74.2	Good	1	54.9	Average
12	Halogen Derivatives of Hydrocarbons.	1	51.4	Average	1	53.9	Average
13	Relative Molecular Masses in Solution.	2	69.6	Good	1	41.6	Average
14	Electrochemistry.	1	34.0	Weak	1	38.9	Average
15	Two Component Liquid systems.	1	59.2	Average	2	37.1	Average
16	Selected Compounds of Metals.	1	6.5	Weak	1	32.6	Weak
17	Periodic Classification.	1	62.4	Good	1	26.8	Weak
18	Environmental Chemistry	-	-	-	1	26.0	Weak
19	Energetics.	1	49.3	Average	2	25.9	Weak
20	Extraction of Metals.	1	32.8	Weak	1	18.9	Weak
21	Chemical Kinetics; Chemical Equilibrium.	1	89.5	Good	-	-	-
22	Acids, Bases and Salts, Solubility, Solubility Product and Ionic Product.	1	80.9	Good	-	-	-
23	Soil, Environmental Chemistry.	1	57.0	Average	-	-	-