THE NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

CANDIDATES' ITEM RESPONSE ANALYSIS REPORT FOR THE ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (ACSEE) 2019

132 CHEMISTRY

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TABLE OF CONTENTS

FOREWORD

The National Examinations Council of Tanzania has prepared this Candidates' Items Response Analysis Report (CIRA) for the Advanced Certificate of Secondary Education Examinations (ACSEE) 2019. The purpose of the report is to give feedback to stakeholders such as students, teachers, parents, policy makers and the public in general, on the performance of the candidates who sat for the Chemistry examination.

The Advanced Certificate of Secondary Education Examinations marks the end of two years of Advanced Secondary Education. It is a summative evaluation which, among other things, shows the effectiveness of the education system in general and education delivery system in particular. Essentially, the candidates' responses 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 the Chemistry subject. The report highlights some of the factors that contributed to candidates scoring high marks. It also included the factors that made some of the candidates to score low marks in each question, including but not limited to, inadequate ability to apply principles in interpreting scientific observations and improper approaches in carrying out calculations. The feedback provided in the report will enable the educational stakeholders to identify proper measures to be taken in order to improve the candidates' performance in future examinations administered by the Council.

Lastly, the Council would like to express sincere appreciation to examination officers, examiners and all other staffs who participated in the preparation of this report.

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 Examinations (ACSEE) 2019 for Chemistry Paper 1 and Paper 2. The 2019 Chemistry examination was set according to the 2011 ACSEE format 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 four (4) questions. Section B and C had four (4) questions each, of which the candidates were required to answer three (3) questions 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 a total of five (5) questions, choosing at least one (1) question from each section.

A total of 33,237 candidates sat for the chemistry examination in 2019. 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% of the allocated marks. The results show that the candidates' performance in 2019 has increased by 0.11% as 92.82% passed the examination compared to 92.71% of the candidates who passed the examination in ACSEE 2018.

This report is presented in four sections; introduction, analysis of the candidates' performance in each question, analysis of performance in each topic and finally, the report gives a conclusion and recommendations.

2.0 ANALYSIS OF THE CANDIDATES' PERFORMANCE BY QUESTIONS

For each of the analyzed questions, 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% or more of the marks allocated in a particular question). If the percentage lies from 0 to 34 is termed as poor/weak, 35 to 59 average and 60 to 100 good. Furthermore, green, yellow and red colours have been used in different figures as well as in the Appendix to denote good, average and poor/weak performance, respectively.

2.1 132/1-CHEMISTRY 1

This paper had a total of 14 questions, each carrying 10 marks. The pass mark in each question was 3.5 marks.

2.1.1 Question 1: The Atom

The question consisted of parts (a), (b), (c), (d) and (e). In part (a), the candidates were required to use *s*, *p*, *d* and *f* notations to designate atomic orbitals with the given quantum numbers: (i) $n = 2$ and $l = 1$, (ii) $n = 3$ and $l = 2$, (iii) $n = 4$ and $l = 3$ and (iv) $n = 3$ and $l = 0$.

In part (b), the candidates were given sets of the following quantum numbers:

(i) $n = 2;\ l = 2;\ m_l = 0;\ m_s = +\frac{1}{2}.$

(ii) $n = 3;\ l = 1;\ m_l = 0;\ m_s = -\frac{1}{2}.$

(iii) $n = 1;\ l = 0;\ m_l = +1;\ m_s = +\frac{1}{2}.$

(iv) $n = 3;\ l = 2;\ m_l = +2;\ m_s = -\frac{1}{2}.$

The candidates were thus required to identify and state briefly which of the given sets of quantum numbers were allowable and which were not. In part (c), they were asked to define the terms, atomic number and mass number. Part (d) needed candidates to calculate the number of electrons and neutrons in an atom, ${}^{58}_{27}X$. In part (e), the candidates were asked to state four postulates of Planck’s quantum theory as were derived from black body radiation.

The question was attempted by 27,451 (79.5%) candidates, of whom 11,224 candidates (40.9%) scored marks ranging from 6.0 - 10 indicating a good performance and 8,876 candidates (32.3%) scored 3.5 - 5.5 marks, signifying an average performance. The candidates who scored 0 - 3.0 marks indicating an unsatisfactory performance, were 7,351 (26.8%). Figure 1 shows distribution of the candidates’ scores.

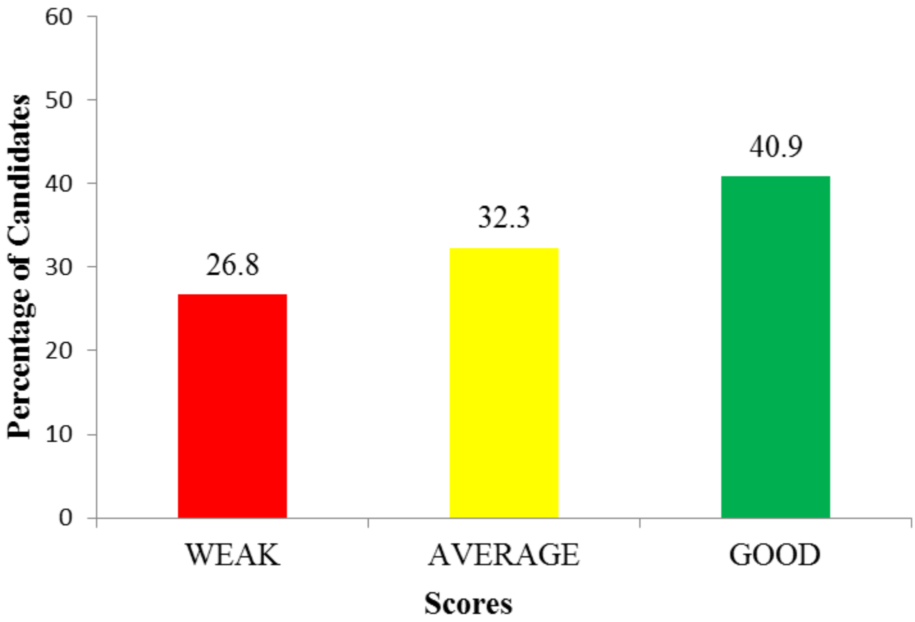
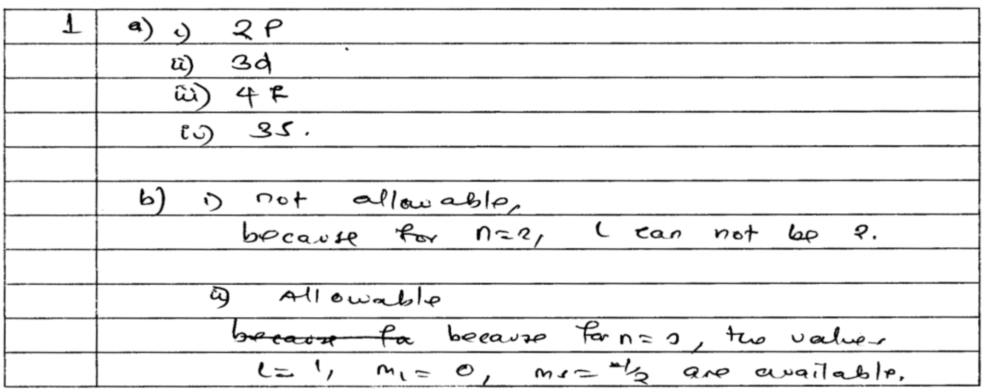
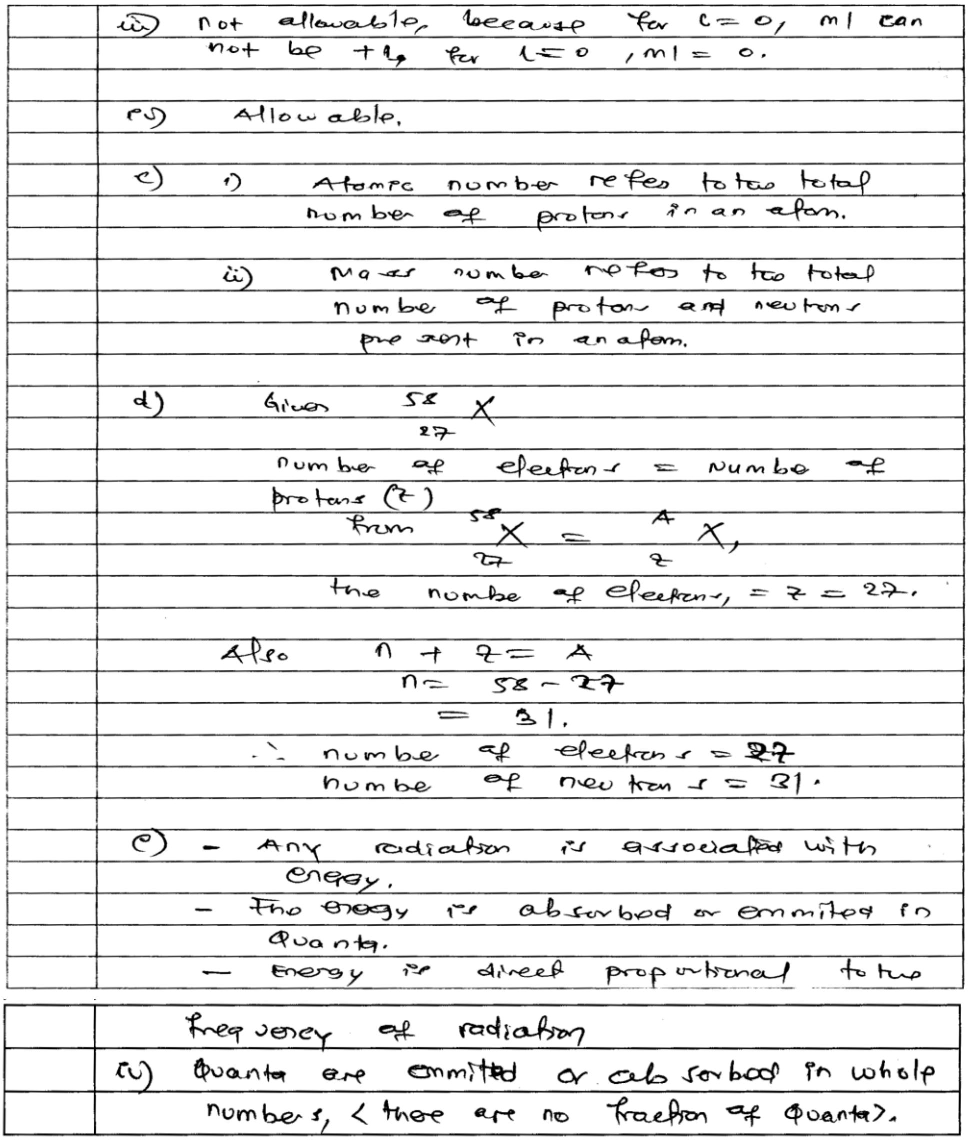


Figure 1: *Performance of the candidates in question 1.*

Figure 1 shows that 73.2% of the candidates scored 3.5 marks and above, indicating a good performance in overall. The candidates who scored all the 10 marks in this question showed good understanding regarding the topic of *The Atom*. This was attributed to the fact that, the candidates had good background on the subject matter as some parts of this topic are also studied in the lower classes. Extract 1.1 illustrates a sample of good responses from a candidate in this question.



1	a) i) 2P
	ii) 3d
	iii) 4f
	iv) 3s.
	b) i) not allowable,
	because for n=2, l can not be 2.
	ii) Allowable
	~~because fa~~ because for n=2, the values
	l=1, m_l=0, m_s=+1/2 are available.


iii) not allowable, because for $l = 0$, m_l can not be $+1$, for $l = 0$, $m_l = 0$.

iv) Allowable.

c) i) Atomic number refers to the total number of protons in an atom.

ii) Mass number refers to the total number of proton and neutrons present in an atom.

d) Given $^{58}_{27}X$

number of electrons = Number of protons (Z)

from $^{58}_{27}X = ^{A}_{Z}X$,

the number of electrons, $= Z = 27$.

Also $n + Z = A$

$n = 58 - 27$

$= 31$.

$\therefore$ number of electrons = 27

number of neutrons = 31.

e) - Any radiation is associated with energy.

- The energy is absorbed or emitted in quanta.

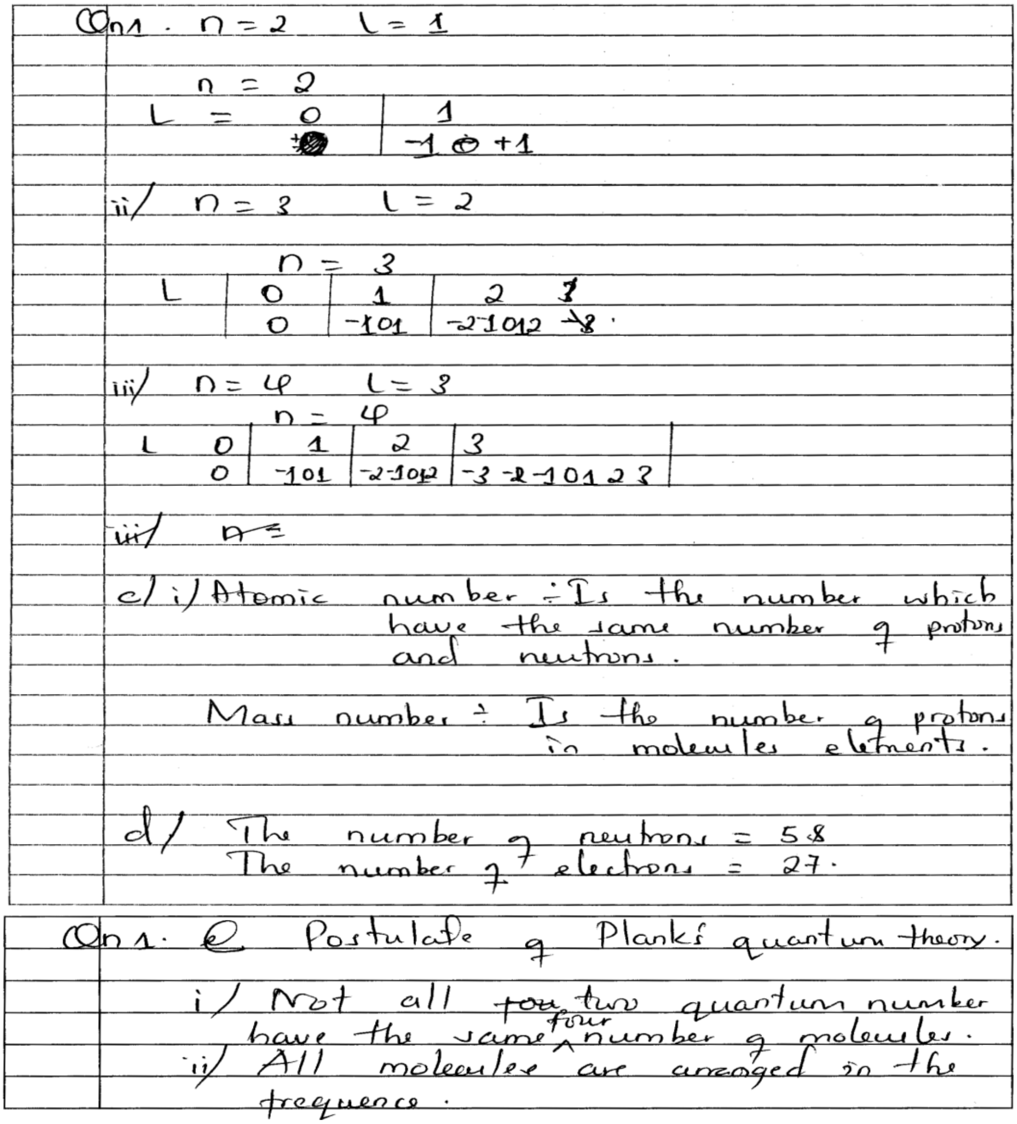
- Energy is direct proportional to the frequency of radiation

iv) Quanta are emitted or absorbed in whole numbers, < there are no fraction of quanta >.

Extract 1.1: A sample of correct responses in question 1.

Extract 1.1 shows responses from a candidate who managed to use correctly the s, p, d and f orbital notations to designate atomic orbitals. He/she managed to answer correctly the remaining parts of the question and scored high marks.

However, the candidates who scored low marks signaled lacking the basic knowledge regarding the electronic configuration in relation to quantum numbers. The responses which lead to low scores signified poor understanding on the topic of *The atoms* despite the fact that it was also taught in the lower classes. For example in part (b) (iii), one of the candidate responded that a set of quantum numbers given was *allowable* instead of *not allowable*. Moreover, they showed little understanding of the modern periodic table of the elements. Extract 1.2 shows a sample of poor responses from one of the candidates.


Qn 1. n = 2 l = 1

n = 2
L = 0 | 1
0 | -1 0 +1

ii/ n = 3 l = 2

n = 3
L | 0 | 1 | 2 3
0 | -1 0 1 | -2 -1 0 1 2 -3.

iii/ n = 4 l = 3
n = 4
L 0 | 1 | 2 | 3
0 | -1 0 1 | -2 -1 0 1 2 | -3 -2 -1 0 1 2 3

iii/ n =

c/ i/ Atomic number :- Is the number which have the same number of protons and neutrons.

Mass number :- Is the number of protons in molecules elements.

d/ The number of neutrons = 58
The number of electrons = 27.

Qn 1. e Postulate of Planks quantum theory.
i/ Not all ~~four~~ two quantum number have the same four number of molecules.
ii/ All molecules are arranged in the frequence.

Extract 1.2: A sample of poor responses in question 1.

Extract 1.2 shows responses of a candidate who deduced the values for m_l instead of designating the atomic orbitals. He/she provided incorrect responses in the remaining parts of the question.

2.1.2 Question 2: The Atom

This question had three parts namely; (a), (b) and (c). In part (a), the candidates were supposed to sketch the hydrogen spectral series based on Bohr atomic energy levels. Part (b) (i) required the candidates to explain how a mass spectrograph of a pure element is used to detect the presence of isotopes. Part (b) (ii) required the candidates to calculate the relative atomic mass of an element using the data given in the following table:

Isotope	Mass of isotope	Natural abundance (%)
1	28.0	92.0
2	29.0	5.0
3	30.0	3.0

Part (c) (i) asked the candidates to use the wave-particle models for energy of a particle to derive the de-Broglie equation. Part (c) (ii) required the candidates to calculate the wavelength of α-particle having a mass of 6.6×10^{-27} kg while moving with a speed of 10^5 cms^{-1}. They were required to show their work clearly including how they manipulated the units.

This question was attempted by 29,262 candidates (84.7%) out of which 14,126 candidates (48.3%) scored 6.0 - 10 marks indicating a good performance; and 8,419 candidates (28.7%) scored 3.5 - 5.5 marks which indicated an average performance. The remaining 6,717 candidates (23.0%) scored 0 - 3.0 marks which signified a poor performance. Figure 2 summarizes the performance of the candidates in question 2.

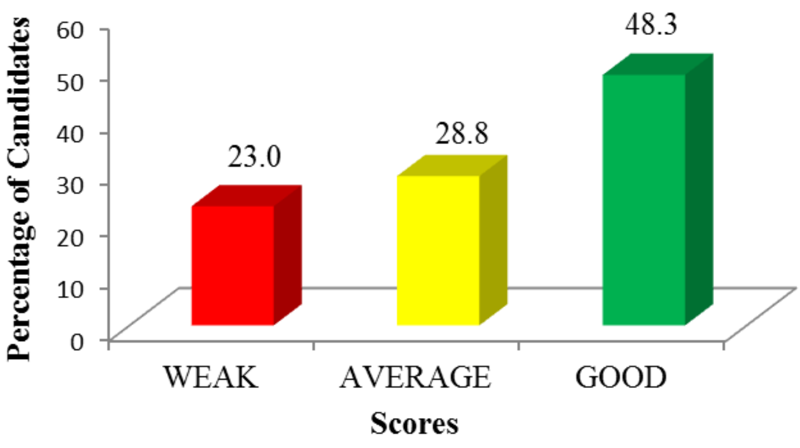


Figure 2: *Performance of the candidates in question 2.*

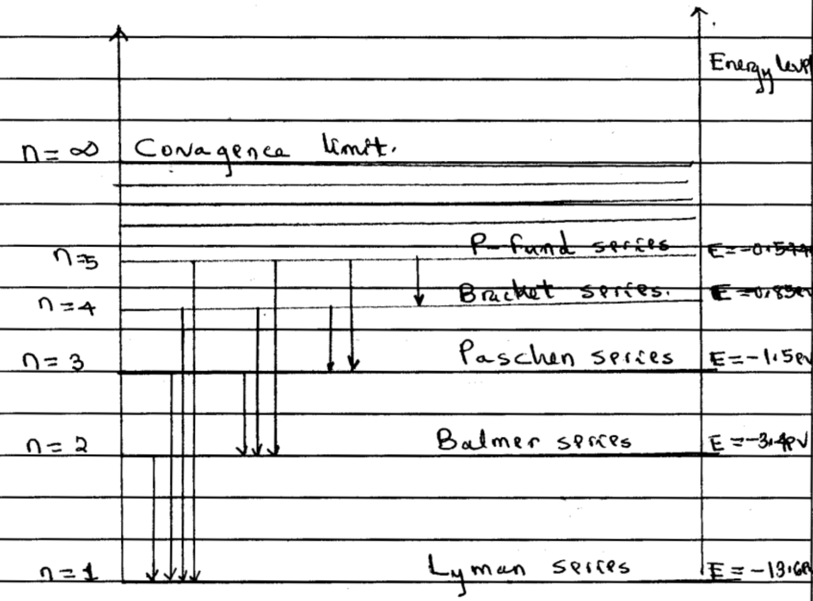
The statistics shows that, the general performance in this question was good, as 77.0 percent of the candidates scored 3.5 marks or above. The candidates, who managed to perform well in this question, sketched the hydrogen spectral series properly based on Bohr atom energy level in part (a). This showed that, they were familiar with the concept of different energy levels of an atom and the movement of electrons from one energy level to another.

In part (b) (i), the candidates were knowledgeable on how a mass spectrograph of a pure element is used to detect the presence of isotopes. This indicated that, the word spectrograph was familiar to them *i.e*. they managed to differentiate between mass spectrometer and mass spectrograph and in fact, they had prior knowledge on the working mechanism of a mass spectrometer.

In part (b) (ii), the candidates managed to calculate the relative atomic mass of an element. This is attributed to possession of appropriate skills regarding mathematical manipulations and wide understanding on the concept of isotopes.

In part (c), the candidates managed to derive the de-Broglie equation and calculated correctly the wavelength of an α-particle having the mass of 6.6×10^{-27} kg while moving with a speed of 10^5 cms^{-1}. Such candidates, showed good understanding on the combined concept of Planck and Einstein. Extract 2.1: An example of a set of responses from one of the candidates with good performance.

2(a) A SKETCH OF A HYDROGEN SPECRAL SERIES.



(b) (i) Due to the different defletion of positively charged ions cause the number of eletrons to neutralize the positively charged ions to be different which cause the production of current transfered to the amplifier and drawn on the chart recorder at the peak.

— The number of peak = The number of isotopes

— The different in deflection caused by the different in mass to charge ratio ($^{m}/_{Q}$)

(ii) from

The Relative atomic mass = $\frac{\Sigma\% \text{ Abundance} \times \text{Mass of isotope}}{100\%}$

2.(b)	(ii) $R.A.M = \frac{92 \times 28 + 29 \times 5 + 3 \times 30}{100}$
	$R.A.M = 28.11.$
	∴ The relative atomic mass of an element is 28.11.
2(c).	(i). From The Einstein Equation.
	$E = mc^2$ ——— (i). ~~At~~ a particle.
	But the particle moved as wave properties in which
	$E = hf.$
	Where $f = \frac{c}{\lambda}.$
	$E = \frac{hc}{\lambda}$ ——— (ii).
	Since the energy is the same
	$\frac{mc^2}{c} = \frac{hc}{\lambda c}$
	$mc = \frac{h}{\lambda}.$
	$\lambda = \frac{h}{mc}.$
	~~B~~. Where λ is the de Broglie wavelength.
	h is the planks constant
	m is the mass of the particle.
	c is the speed of the partile.
	∴ The De Broglie equation is.
	$\lambda = \frac{h}{mc}.$

2.(c)	(ii). from.
	$\lambda = \frac{h}{mc}$.
	But $m = 6.6 \times 10^{-27}$ kg.
	$c = 10^5$ cm s^{-1}.
	$c = 10^5 \times 10^{-2}$ m s^{-1}.
	Because.
	1 cm $= 10^{-2}$ m.
	$h = 6.63 \times 10^{-34}$ J s.
	$\therefore \lambda = \frac{6.63 \times 10^{-34} \text{ Js}}{(6.6 \times 10^{-27} \times 10^5 \times 10^{-2}) \text{ Kg} \times \text{m s}^{-1}}$.
	$\lambda = 1.0045 \times 10^{-10} \frac{\text{J s}^2}{\text{Kg m}}$
	$\lambda = 1.0045 \times 10^{-10} \frac{\text{Kg} \times \text{m}^2 \text{s}^{-2} \cdot \text{s}^2}{\text{K m}}$.
	$\lambda = 1.0045 \times 10^{-10}$ m.
	$\therefore$ The wavelength is 1.0045×10^{-10} m.

Extract 2.1: A sample of correct responses in question 2.

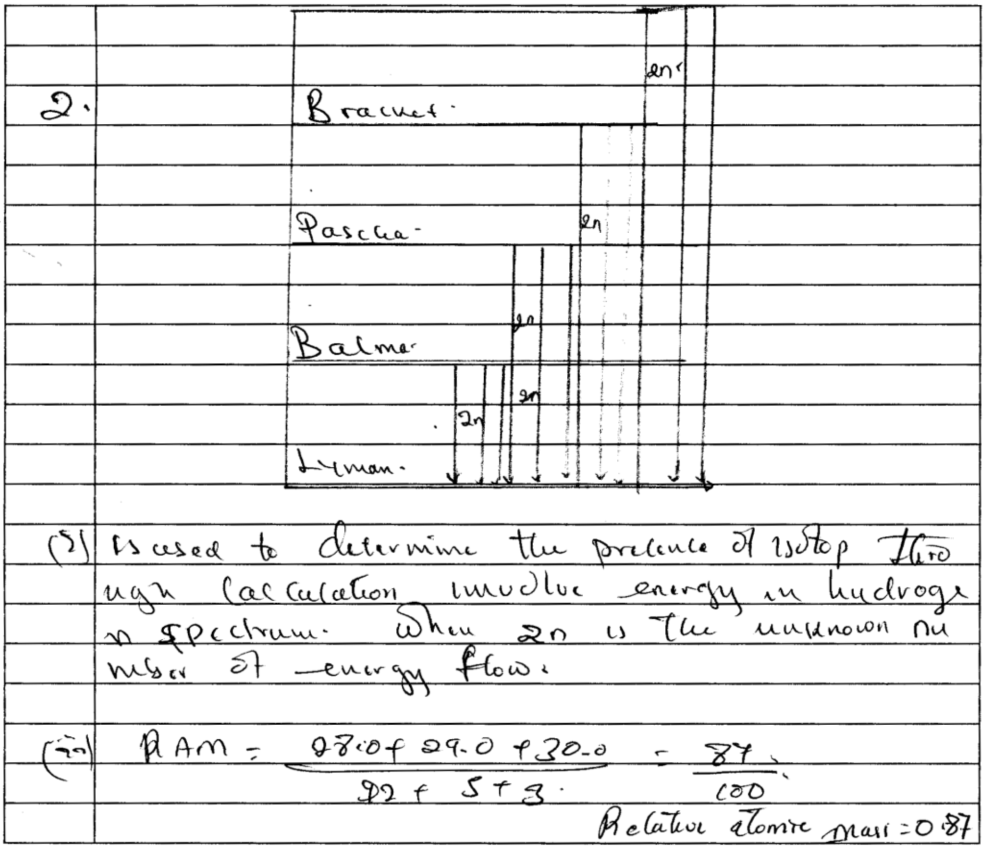
Extract 2.1 represents the responses from a candidate who provided appropriate details and calculated the required of wavelength correctly.

Despite the good performance by the majority of candidates, analysis of the responses showed that, those who failed to do well in this question had the following flaws: In part (a), some of the candidates were not familiar with the concept of different energy levels in an atom and the movement of electrons from one energy level to another. Hence, these candidates failed to sketch correctly the hydrogen spectral series.

In part (b) (i), the candidates were unable to explain how a mass spectrograph of a pure element is used to detect the presence of isotopes. The analysis of the candidates responses in this part of the question suggested that the word spectrograph was not familiar to some candidates *i.e.* they failed to differentiate between mass spectrometer and mass spectrograph which indicated lack of prior knowledge regarding the working mechanism of a mass spectrometer.

In part (b) (ii), some of the candidates failed to calculate the relative atomic mass of an element. This indicated the lack of appropriate competences in mathematical manipulation as well as the knowledge on the concept of isotopes.

In part (c), some of the candidates failed to derive the de-Broglie equation and perform the associated calculations. This was attributed by lack of harmonization of concepts on quantum theory. An example of responses which did not meet the requirements of the question is given in Extract 2.2.

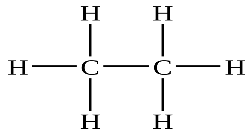


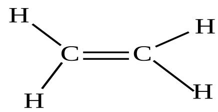
Extract 2.2: A sample of incorrect responses in question 2.

Extract 2.2 is a sample of responses from a candidate who sketched a wrong hydrogen spectral series. The candidate further gave wrong explanations regarding the mass spectrograph and performed incorrect calculation in determining the relative atomic mass of an element.

2.1.3 Question 3: Chemical Bonding

This question had three parts namely; (a), (b) and (c). In part (a), the candidates were required to use the structures of ethane and ethene molecules to answer the subsequent questions as follows:





(i) Write the hybridization of carbon atoms in each of the compound.

(ii) Use a well labelled diagram to describe types of C-C bonds in each compound.

(iii) Briefly explain the concept that each C-H bond length is in ethane molecule is 1.09 Å and C-C bond is 1.54 Å.

(iv) Briefly explain the concept that the C-C double bond in ethene (bond length 1.34 Å) is shorter than C-C single bond in ethane (bond length 1.54 Å).

Part (b) (i) required the candidates to briefly describe how ionic bond formation is favored by ionization enthalpy and electron affinity. Part (b) (ii) required the candidates to briefly describe how covalent bond formation is favored by ionization enthalpy and electron affinity. In part (c), the candidates were required to briefly explain hydrogen bond and coordinate covalent bond; and give one example of a chemical structure for each of the explained phrases.

The question was attempted by few (6,387, 18.5%) candidates. The data analysis showed that majority (4,823, 75.5%) of the candidates scored 0 - 3.0 marks, 1,369 candidates (21.4%) scored 3.5 - 5.5 and 195 candidates, (3.1%) scored 6.0 - 10 marks. Figure 3 summarizes the performance of candidates in this question.

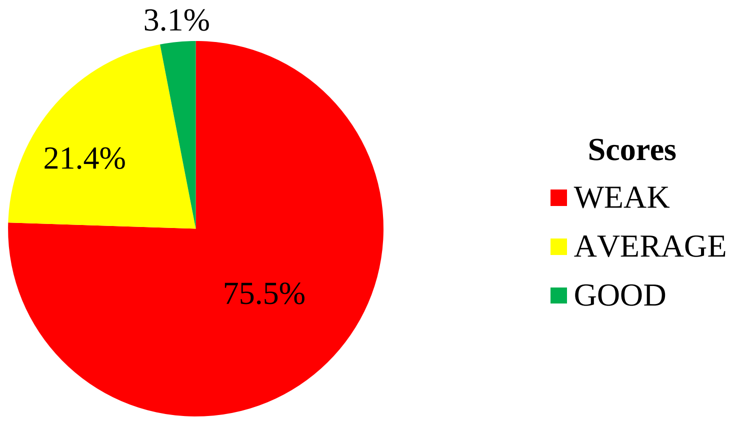
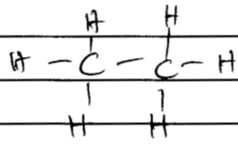
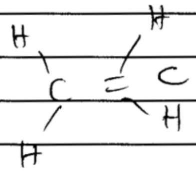


Figure 3: *Performance of the candidates in question 3.*

The statistical analysis showed that, the overall performance was poor as more than two thirds of the candidates totaling 4823 (75.5%) scored below 3.5 marks.

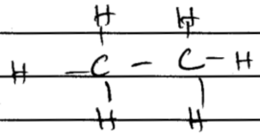
Analysis of the responses provided by the candidates who scored low marks indicated that, they had little understanding on the basic concepts regarding the topic of *Chemical Bonding*; particularly, the concept of hybridization of atomic orbitals. Therefore, they were unable to deduce the relationship between ionic bond formation and ionization enthalpy or electron affinity of an element. An example of poor responses is shown in extract 3.1.

3 a/ Given

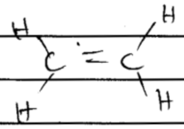
 and 

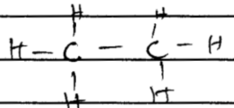
ethane ethene

i/ Hybridization of ethane

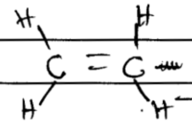
 give σ σ H····H lon pair.

Hybridization in ethene

 gives σ σ H····H lone pair

ii/  C—C single bond formation

Single covalent bond.

iii/  Double covalent bond.

C=C Double bond formation

3 a/ C-H has a bond length 1·09Å
C – C has bond length 1·54 Å

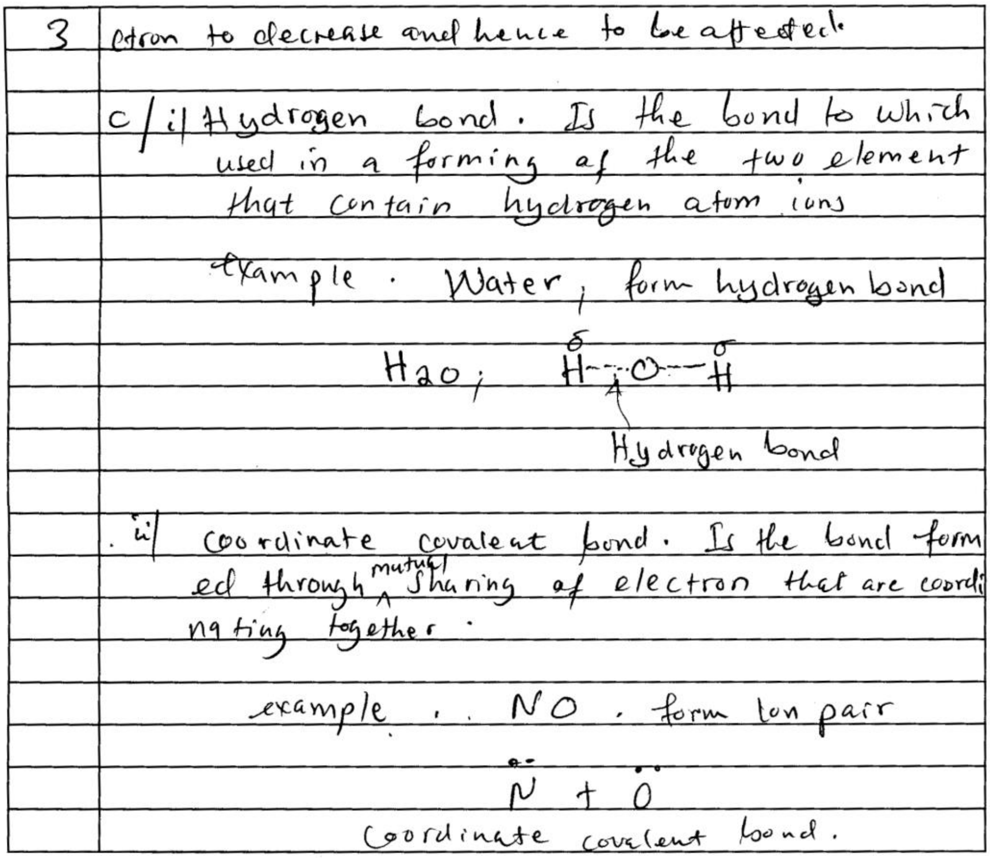
In the C – H they have greater wave length compared to C – C that is because the number of wave length in C-H is greater compared to the number of wave length in C – C Hence the C – C formation is stronger compared to C – H.

iv/ The C-C double bond in ethene is 1·34Å is shorter than C-C single bond in ethane (bond length 1·54Å) Because in the C-C double bond of the ethene has contain a larger number of the electron and they have high number of wavelength compared to the double bond in the C-C single bond ethane.

b/ i/ Ionization bond formation is favoured by ionization enthalpy and electron affinity. Because; Ionic bond tend to the formation of the positively or negatively ions in the compound. also when electron affinity can be inter tend to dissapearance of ions

example: $Na^{2+} + 2Cl^{-} \rightarrow NaCl_2$
formation of ions

ii/ Covalent bond formation favoured by ionization enthalpy and electron affinit Because In the atom the ionization energy when increase tend to the atomic size of the ele


3 | etron to decrease and hence to be affected.

c/ i/ Hydrogen bond. Is the bond to which used in a forming of the two element that contain hydrogen atom ions

example. Water, form hydrogen bond

H2O; H---O---H

Hydrogen bond

ii/ coordinate covalent bond. Is the bond formed through mutual sharing of electron that are coordinating together.

example. . NO. form ion pair

N + O

Coordinate covalent bond.

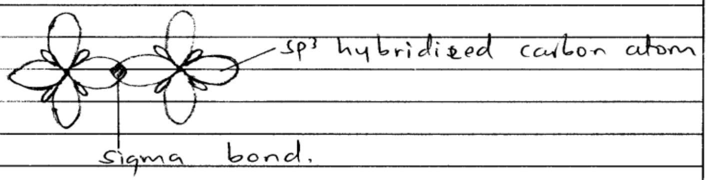
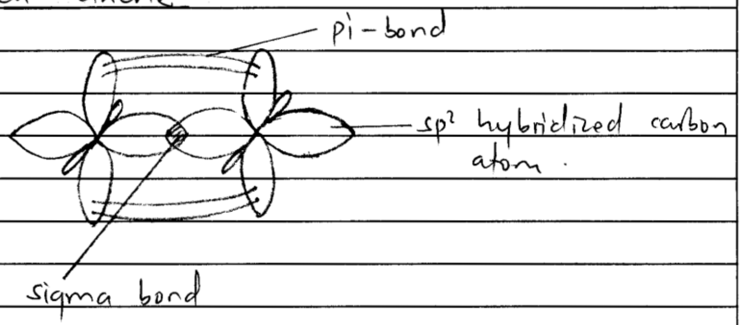
Extract 3.1: A sample of incorrect responses in question 3.

In Extract 3.1, the candidate wrote incorrectly the type of hybridization of carbon atoms in ethane and ethene, failed to use labelled diagrams to describe types of C-C bonds in given compounds. The candidate further gave statements which had no proper meaning in the subsequent parts of the question.

On the other hand, the candidates who managed to score good marks were able to give correct responses to most parts of the question. Further analysis revealed that, the candidates had enough knowledge on the concept of hybridization of atomic orbitals. In addition, they showed to have understood properly the differences between sigma and pie bonds.

Moreover, the candidates who scored high marks in this question signified that they host the basic prior knowledge on the properties and characteristics of ionic and covalent bonds. This enabled them to deduce the relationship between the activation energy and ionization/electron affinity of elements. In addition, they had enough knowledge on how hydrogen and coordinate bonds are formed.

Hence, they provided correct explanations and appropriate examples of compounds asked. Extract 3.2 is a sample response from one of the candidates who scored high marks.

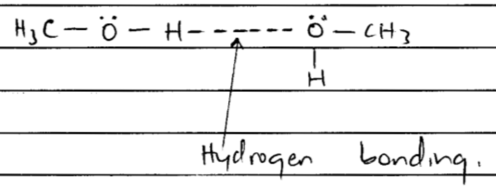
3 (a)	(i) Hybridization of carbon in ethane is sp^3 hybridization
	Hybridization of carbon in etheno is sp^2 hybridization
3 (a)	(ii) In ethane
	
3 (a)	(ii) In ethene
	
3 (a)	(iii) In C-H bond there is a maximum overlapping of the s-orbital and p-orbital therefore forming a short bond length as compared to C-C bond where there is partial overlapping of the p-orbitals.
3 (a)	(iv) In C-C double bond there is both lateral and sideways overlapping of the p-ordbitals. therefore forming a shorter bond compared to C-C single bond where there exists only sideways overlap of p-orbitals.

3 (b) (i) In Ionic bond formation, the metal should have low Ionisation enthalpy so that it can easily lose an electron and the non-metal should have high electron affinity so that it can gain the electron easily.

3(b) (ii) In covalent bond formation, the metal should have high. Ionization ethalpy so that losing an electron won't be easy and the non-metal together with the metal should have nearly equal electron affinity.

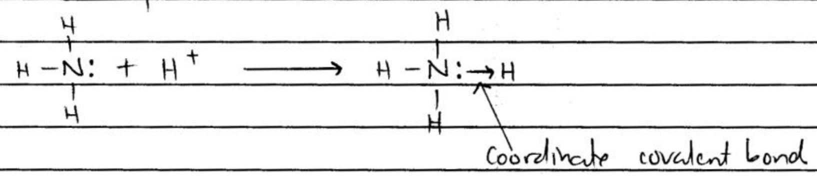
3(c) (i) Hydrogen Bond is a type of bond formed between hydrogen and a most electronegative atom present in a molecule.

Example:



3(c) (ii) Coordinate covalent bond is a type of chemical bond formed when the shared pair of electron. between atoms is contributed by only one atom

3 (c) (ii) Example:



Extract 3.2: A sample of good responses in question 3.

Extract 3.2 shows responses of a candidate who was able to answer correctly most parts of the question. However, the candidate failed to account for the differences observed in C-C and C-H bond lengths in ethane molecule.

2.1.4 Question 4: Two Component Liquid Systems

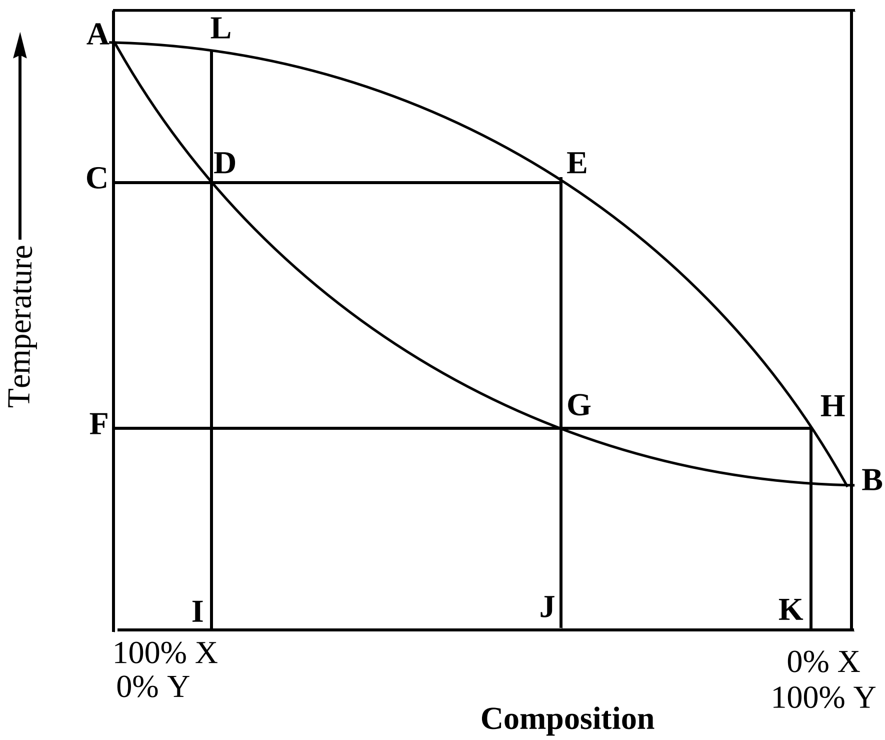
The question had three parts namely; (a), (b) and (c). In part (a), the candidates were required to:

(i) State Raoult's law regarding solutions of liquids in liquids.
(ii) Define azeotropic mixture.
(iii) Use a well-labelled sketch to show differences between minimum and maximum boiling point azeotropic mixtures.

In part (b), the candidates were required to explain the following terms in brief.

(i) Freezing point depression
(ii) Boiling point elevation
(iii) Van't Hoff's factor-*i*

Part (c) required the candidate to study the diagram of a liquid-vapour phases, and answer the questions that followed:



(i) If liquid mixture of composition **I** is heated to a temperature **C**, what will be the composition of the vapour phase?
(ii) If the vapour at **E** is cooled to temperature **F**, what will be the composition of the vapour phase?
(iii) What temperature represents the boiling point of composition **J**?

The question was attempted by 23,462 candidates corresponding to 67.9%, out of which 3778 candidates (16.1%) scored good marks (6 - 10) and 6074 candidates (25.9%) scored 3.5 - 5.5 marks, indicating an average performance. The candidates, who scored 0 - 3.0 marks which indicates an unsatisfactory performance, were 13,610 corresponding to 58.0 percent. Summary of the performance in this question is shown in Figure 4.

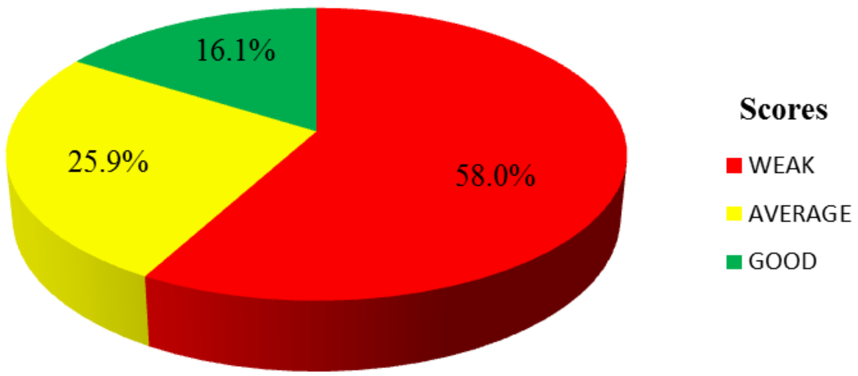


Figure 4: *Performance of the candidates in question 4.*

The overall performance in this question was average as 42.0% of the candidates scored 3.5 marks and above. The candidates who managed to score high marks were able to state Raoult's law regarding solutions of liquids in liquids. They managed to define azeotropic mixture and used well-labelled sketches to show the difference between minimum boiling point and maximum boiling point azeotropes. This indicated that these few candidates were competent in understanding the relationship between the pure pressure, partial pressure and mole fraction of a component in a mixture of liquids. Also, this was attributed to proper understanding of the colligative properties.

Furthermore, the good performance of some candidates in the last part of the question was contributed by having appropriate competencies regarding the knowledge of the effect of temperature on ideal and non-ideal solutions. Extract 4.1 represents a sample of good responses from one of the candidates.

4. (a) (i) Raoult's law

A partial ~~press~~ vapour pressure of a liquid exerted on a liquid to liquid mixture is the product of the vapour pressure of the pure liquid and the mole fraction present in a solution

⇒ Mathematically ; $P'_A = X_A P^o_A$

Where by: P'_A = Partial pressure of a liquid A

X_A = Mole fraction of a liquid A

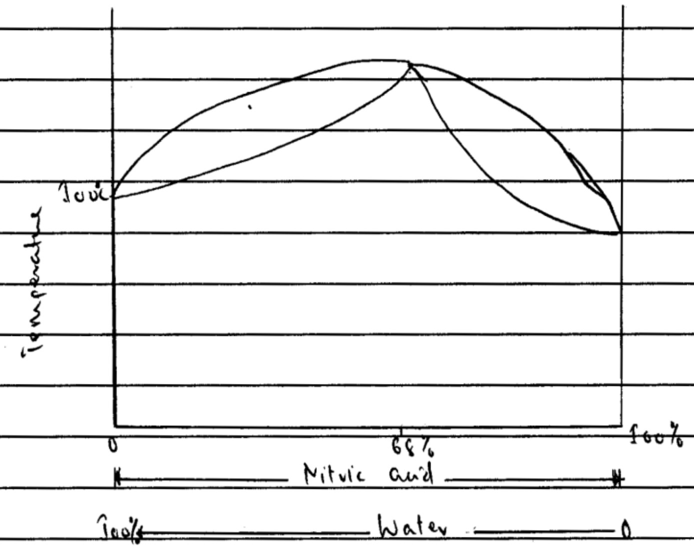
P^o_A = ~~Pure~~ vapour pressure of a liquid A

(ii) Azeotropic mixture is a mixture of liquids in which the vapour phase composition ~~have~~ is equal to the liquid phase composition of the liquids and hence the mixture boils at constant boiling point.

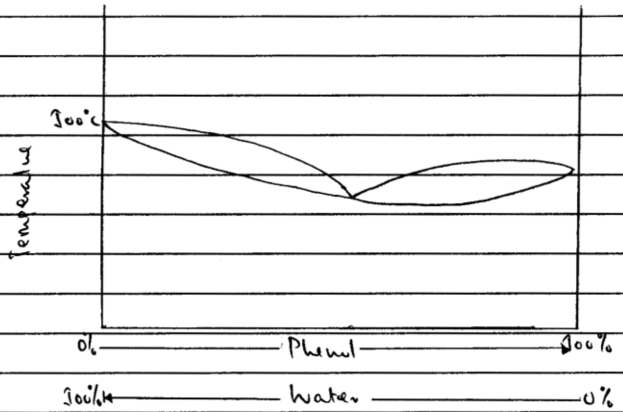
(iii)

1st : Azeotropic mixture having maximum boiling point

Nitric Acid and water at 121°C



4. (a) (iii) 2nd: Azeotropic mixture having minimum boiling point (e.g. water and Methanol)



(b) (i) Freezing point depression is the effect that occurs when a non-volatile solute dissolved in a liquid and resulting to the depresion of the feezing point of the liquid, the freezing point depression depends on the amount of the solute dissolved (COLLIGATIVE PROPERTY)

(ii) Boiling point elevation ~~an~~: Non volatile solute dissolved in a liquid has an effect on the boiling point of the liquid as it hinders slightly escaping of the particle into vapour phase and hence high temperature is needed to boil the liquid.

(iii) Van't Hoff's factor - i : The extent on how the property (colligative property) of a liquid after dissolving solutes deviated from the real pure volume of a liquid.

Mathematically: i = Observed effect/Expected value

4. (c) (i) The composition of the vapour will be at J

(ii) The composition of the vapour phase will be at K

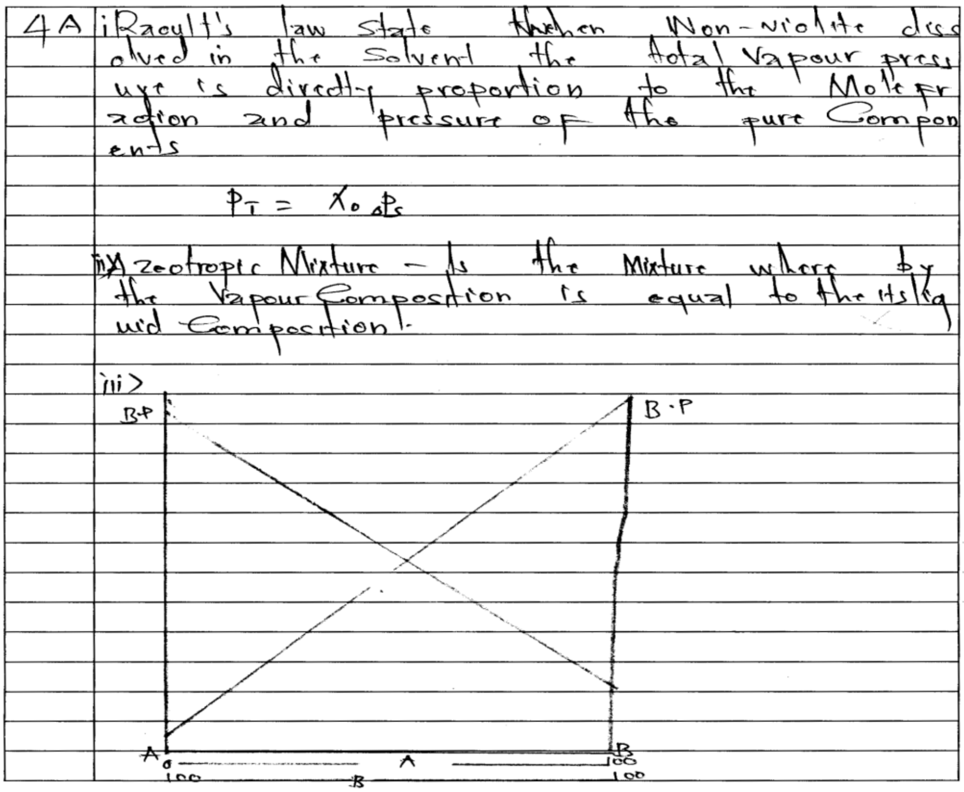
(iii) The boiling point of composition is F

Extract 4.1: A sample of correct responses in question 4.

Extract 4.1 is a sample of responses from a candidate who explained well the terms asked and sketched a proper diagram to show the difference between minimum and maximum boiling point azeotropes.

However in part (a), some candidates were not competent in deriving the relationship between pure pressure, partial pressure and mole fraction of a component in a mixture of liquids. This was attributed to insufficient knowledge on the concept of ideal and non-ideal solutions. Thus, they failed to state Raoult's law regarding solutions of liquids in liquids, define azeotropic mixture and use a well-labelled hand sketch to show the difference between minimum and maximum boiling point azeotropic mixtures.

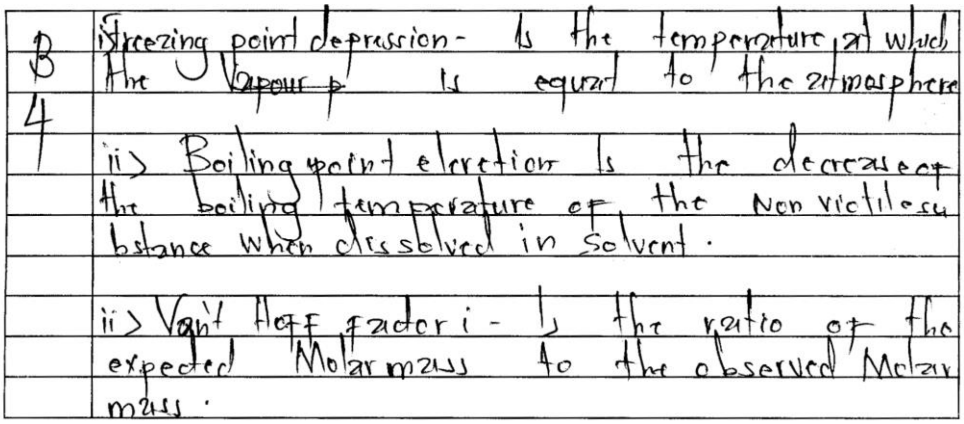
Further loss of marks in this question was attributed to inadequate competences on the concepts regarding the mixture of liquids. This was signified by the candidates who interpreted wrongly, the liquid-vapour phase diagram. Extract 4.2 illustrates an example of poor responses supplied by one of the candidates.


4A i Raoult's law state that when Non-violate dissolved in the Solvent the total Vapour pressure is directly proportion to the Mole fraction and pressure of the pure Components

$P_T = X_0 P_s$

ii) Azeotropic Mixture - Is the Mixture where by the Vapour Composition is equal to the its liquid Composition.

iii)



4 i) Freezing point depression - is the temperature at which the Vapour p is equal to the atmosphere

ii) Boiling point elevation is the decrease of the boiling temperature of the Non volatile substance when dissolved in solvent.

iii) Van't Hoff factor i - is the ratio of the expected Molar mass to the observed Molar mass.

Extract 4.2: A sample of correct responses in question 4.

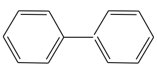
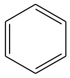
In Extract 4.2, the candidate gave incomplete statements of the Raoult's law regarding the solution of liquids in liquids and the associated definition of terms. The candidate also failed to differentiate the two types of azeotropes using a sketch.

2.1.5 Question 5: Relative Molecular Masses in Solution

The question consisted of three parts namely; (a), (b) and (c). Part (a) (i) required the candidates to explain why the boiling point of a solvent is elevated by an addition of a non-volatile solute. Part (a) (ii) asked the candidates to arrange the following aqueous solutions in order of increasing freezing points and provide clear reasons for the arrangement.
0.01 M C_2H_5OH; 0.01M $Ba_3(PO_4)_2$; 0.01 M Na_2SO_4; 0.01 M KCl; 0.01M Li_3PO_4.

In part (b), the candidates were provided with the following information:

Entry	Value
Molal boiling point constant for benzene, K_b	2.53 ℃ kg mol^{-1}
Molal freezing point constant for benzene, K_f	5.12 ℃ kg mol^{-1}
Boiling point of benzene	80.1 ℃
Freezing point of benzene	5.5 ℃

Then, they were required to calculate the boiling point and freezing point of a solution made by dissolving 2.40 g of biphenyl,  in 75.0 g of benzene,  and required to show their work clearly including how they manipulated the units.

In part (c), the candidates were given the information that, "an aqueous solution of urea, $CO(NH_2)_2$ at a concentration of 1.754 g dm^{-3} is isotonic at the same temperature with an aqueous solution of sugar at a concentration of 10.00 g dm^{-3}". They were then required to calculate the relative molecular mass of sugar.

A total of 10,110 candidates equivalent to 29.3% attempted the question, out of which 64.8% scored 0 - 3.0 marks, 20.5% scored 3.5 - 5.5 marks and 14.7% scored 6.0 - 10 marks. Figure 5 shows the distribution of the candidates' scores.

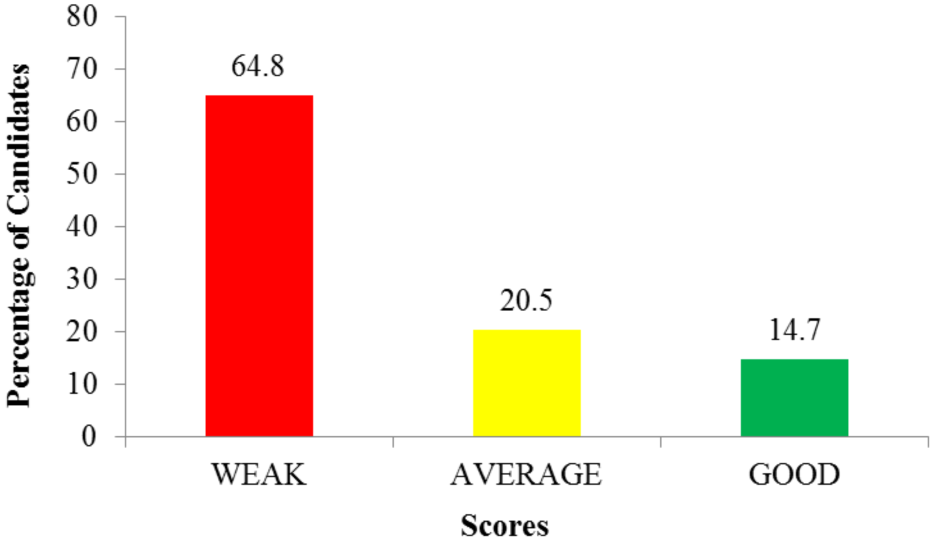
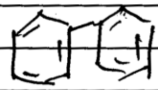


Figure 5: *Performance of the candidates in question 5.*

The overall performance of the candidates in this question was poor as most of them (64.8%) scored the marks below 3.5 (Figure 5). The analysis of the candidates' responses revealed that, majority of those who scored low marks were unable to explain why the boiling point of a solvent is elevated upon an addition of a non-volatile solute. This suggested that the candidates had insufficient knowledge on the topic of *Relative Molecular Masses in Solution* specifically, the colligative properties.

The candidates also lost some marks in part (b) and (d) due to poor mathematical skills and inappropriate manipulations of the units. A sample of poor responses is illustrated in extract 5.1.

5	(a) The Boiling point of solvent is elevated by
	addition of non-volatile this due,
	- when addition of non-volatile it cause the
	decreasing vapour pressure so that in solvent and
	the Molecule will be boiling faster and cause
	the Increasing of boiling point.
	(b)
	Data:
	- Mass of  = 2.40g.
	- Mass of  = 75.0g.
	frozen.
	also
	- Molal boiling point Constant i.(kb) = 2·353 °c
	- Molal boiling point freezing (kf) = 5.12°c
	frozen
	$\Delta Tb = \frac{kb \times M_1}{Mr \times M_2}$

Extract 5.1: A sample of incorrect responses in question 5.

In Extract 5.1, the candidate gave wrong explanations on why the boiling point of a solvent is elevated upon an addition of a non-volatile solute. He/she used inappropriate formula for calculating boiling point elevation, ΔTb.

On the other hand, the candidates who managed to score high marks in this question, were able to understand the requirement of the question. The candidates had good knowledge regarding the effect induced to a solvent upon an addition of a non-volatile solute. The candidates were also knowledgeable on the relationship between the number of moles of ions of the solutes and the extent of depression of freezing point of a pure solvent.

In part (b) and (c) these few candidates managed to calculate correctly, the boiling point and freezing point of a solution. This portrayed the fact that, they had enough capabilities to apply mathematical manipulation skills while recalling appropriate formulae. Extract 5.1 displays an example of good responses from a candidate who gave correct answers.

5(a)(i) When non-volatile solute is added the concentration of solvent decrease and some occupy the surface of solvent and hence escaping tendency of solvent decreases and hence amount of temperature required to make vapour pressure of solution equal to atmospheric pressure increases and hence boiling point is elevated. as non-volatile solute lower vapour pressure.

ii) ~~$Ba_3(PO_4)_2 < Li_3PO_4 < Na_2SO_4 < KCl$~~

$Ba_3(PO_4)_2 < Li_3PO_4 < Na_2SO_4 < KCl < C_2H_5OH$

Increasing freezing point →

5 This is because of dissociation of the solution as the observed depression of freezing point is different compared to expected one

$Ba_3(PO_4)_2 \rightarrow 3Ba^{2+} + 2PO_4^{3-}$

0.01M 0.03 0.02 = 0.05M

$Li_3PO_4 \rightarrow 3Li^+ + PO_4^{3-}$

0.01M 0.03 0.01 = 0.04M

$Na_2SO_4 \rightarrow 2Na^+ + SO_4^{2-}$

0.01M 0.02 0.01 = 0.03M

$KCl \rightarrow K^+ + Cl^-$

0.01M 0.01 0.01 = 0.02M

C_2H_5OH is non-electrolyte or dissociate partially and hence its remain 0.01M.

$\Delta T \propto C$

and hence high C mean more depression in freezing point

(b) soln.

Data given

$K_b = 2.57$, $K_f = 5.12$, $T_b = 80.1°C$

$T_f = 5.5°C$, $M_s = 2.4g$, $M_{sv} = 75g$.

soln

(i) Boiling point

$\Delta T = K_b m$.

but molality = $\frac{n.\ moles}{mass\ of\ solvent}$

$C_{12}H_{10}$ N-moles = $\frac{mass}{molar\ mass}$

molar mass of biphenyl = 154g/mol.

5 $n \cdot moles = \frac{2.4 g}{154 g/mol}$

$= 0.01558 moles$

~~ΔT~~ $molality = \frac{0.01558 moles}{75 \times 10^{-3} kg}$

$= 0.2078 molal.$

$\Delta T = K_b \times m.$

~~$\Delta T = 2.53 \times$~~

$\Delta T = 2.53 °C kg mol^{-1} \times 0.2078 molal,$

$\Delta T = 0.5257 °C$

$T_f = T_0 + \Delta T.$

$T_f = 80.1 °C + 0.5257 °C.$

$= 80.6257 °C.$

Boiling point ~~of~~ solution $= \underline{80.6257 °C}$

Freezing point

$\Delta T = K_f\, m.$

$\Delta T = \frac{K_f \cdot m_{su}}{M_r \times m_{sv}}.$

$\Delta T = \frac{5.12 °C kg mol^{-1} \times 2.4 g}{154 g/mol \times 75 \times 10^{-3} kg}.$

$\Delta T = 1.0639 °C.$

$T_f = T_0 - \Delta T.$

$T_f = 5.5 °C - 1.0639 °C$

$= 4.4361 °C.$

Freezing point of solution $= \underline{4.4361 °C}$

5 (c) Data given

Concentration C_1 = 1.754 g/dm³.

C_2 = 10.0 g/dm³.

Mr = ?

Soln

From osmotic pressure law.

$\pi V = nRT$.

$\pi = CRT$.

For urea

$\pi_1 = C_1RT$ --- (i)

For sugar

$\pi_2 = C_2RT$ --- (ii)

But for isotonic $\pi_1 = \pi_2$.

$C_1RT = C_2RT$

but RT are constant

$C_1 = C_2$.

$$\left(\frac{\text{mass Concentration}}{\text{Molar mass}}\right)_1 = \left(\frac{\text{Mass Concentration}}{\text{Molar mass}}\right)_2$$

molar mass of urea = 12 + 16 + (14 + 2) × 2

= 60 g/mol.

$$\frac{1.754\text{ g/dm}^3}{60\text{ g/mol}} = \frac{10.00\text{ g/dm}^3}{Mr_2}.$$

$1.754 M_2 = 10 \times 60$ g/mol.

$Mr_2 = \left(\frac{10 \times 60}{1.754}\right)$ g/mol.

$Mr_2 = 342.075$ g/mol.

∴ Relative molecular mass of sugar = 342.

Extract 5.2: A sample of correct responses in question 5.

Extract 5.2 depicts the responses of a candidate, who arranged correctly, the given aqueous solutions in the order asked and performed correctly the associated calculations in part 5 (b) and 5 (c).

2.1.6 Question 6: Chemical Equilibrium

This question had three parts namely; (a), (b), and (c). In part (a), the candidates were asked to explain briefly the terms, Reversible reaction and Heterogeneous equilibrium. They were also required to give one example for each of the terms.

Part (b) (i) required the candidates to state the equilibrium law and provide the corresponding expression. Part (b) (ii) required the candidates to list four characteristics of a chemical equilibrium while part (b) (iii) demanded an expression for the equilibrium constant, Kc for the equation:

$Cu(s) + 2Ag^{+}(aq) \rightleftharpoons Cu^{2+}(aq) + 2Ag(s)$

In Part (c), the candidates were given the information "the equilibrium equation for the oxidation of hydrogen chloride to chlorine is $4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$. In a certain experiment, 0.80 moles of hydrogen chloride were mixed with 0.2 moles of oxygen in a closed vessel of capacity 10.00 dm^3. At equilibrium it was found that the mixture contained 0.2 moles of hydrogen chloride'' and they were required to calculate the equilibrium constant, Kc for the reaction.

The question was attempted by a total of 30,598 candidates corresponding to 88.6%, making it one among the most attempted questions. Statistical data shows that, 16.2% of the candidates scored 6.0 - 10 marks, 42.4% scored 3.5 - 5.5 marks, while 28.2% scored 0 - 3.0 marks.

The general performance in this question was good as 71.8% of the candidates scored 3.5 marks or above. The candidates who scored high marks responded correctly to most parts of the question. They managed to explain with respective examples, the meaning of reversible reaction and heterogeneous equilibrium. They also succeeded to state the equilibrium law and provide the corresponding expression. Further analysis revealed that, these candidates were competent enough to understand the terms used in the topic of chemical equilibrium which then helped them to provide correct responses in most parts of the question.

Moreover, their responses indicated that they had good mathematical skills and were able to properly apply the law of mass action to solve the numerical value of equilibrium constant; Kc. Extract 6.1 shows an example of good responses from one of the candidates' work sheet.

6(a) i/ Reversible reaction

Is the type of reaction which proceed in either of the two directions

example

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

ii/ Heterogeneous equillibrium

Is the type of chemical equilibrium in which reactants and products are in different phases.

example $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$.

6 (b) Equilibrium law states that

" For a reversible reaction at constant temperature and pressure, the ratio of the product of concentration of the products to the product of the concentration of the reactants each term raised to the power equal to that of stoichometric coefficient in the balanced equation is a constant and this constant is called Equilibrium constant".

Given

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

where K_c = equilibrium constant

6(b) ii/ Four characteristics of chemical equilibrium.

- The equilibrium must takes place in a closed vessel
- The chemical equilibrium can be attained from any of either side of the equation.

6(b)(ii) • The chemical equilibrium is always in dynamic equilibrium
• The chemical equilibrium is independent of time of which the reaction takes place.

6(b)(iii) Given:

$$Cu_{(s)} + 2Ag^{+}_{(aq)} \rightleftharpoons Cu^{2+}_{(aq)} + 2Ag_{(s)}$$

$$K_c = \frac{[Cu^{2+}]}{[Ag^{+}]^2} \quad \text{expression.}$$

6(c). Given reaction.

	$4HCl_{(g)}$	$+ O_{2(g)}$	$\rightleftharpoons 2Cl_{2(g)}$	$+ 2H_2O_{(g)}$
Initial moles	0.8	0.2	0	0
change in moles	-4x	-x	+2x	+2x
Equilibrium moles	0.8-4x	0.2-x	2x	2x

Volume, V = 10 dm³.
~~wh~~ let "x" be number of moles reacted.
At equilibrium.

$$0.8 - 4x = 0.2\text{moles}$$

$$0.6 = 4x$$

$$x = 0.15\text{moles}$$

Then;
Equilibrium ~~mo~~ concentration

$$[HCl] = \frac{0.2}{10} = 0.02\,mol\,dm^{-3}$$

$$[O_2] = \frac{0.2 - 0.15}{10} = 5\times10^{-3}\,moldm^{-3}.$$

$$[Cl_2] = \frac{2(0.15)}{10} = 0.03\,moldm^{-3}$$

$$[H_2O] = \frac{2\times0.15}{10} = 0.03\,moldm^{-3}.$$

6(c)	from
	$K_c = \frac{[H_2O]^2 [Cl_2]^2}{[O_2]\ [HCl]^4}$
	$= \frac{(0.03)^2 (0.03)^2 mol^4 dm^{-12}}{(5 \times 10^{-3}) (0.02)^4 mol^5 dm^{-13}}$
	$K_c = 1012.5\ mol^{-1} dm$[illegible]
	∴ The equilibrium constant is $1012.5\ mol^{-1} dm$[illegible].

Extract 6.1: A sample of correct responses in question 6.

Extract 6.1 shows responses of a candidate who managed to explain correctly the terms asked and applied the law of mass action to calculate the correct numerical value of an equilibrium constant, Kc.

However, some candidates who scored low marks in part (a), failed to provide correct responses on the key terms. In part (b) they failed to write an expression for Kc. This indicated that, those candidates did not understand the basic concepts and terms regarding the chemical equilibrium. In Part (c), the candidates were unable to calculate the equilibrium constant, Kc, for the given reaction. This was due to inappropriate mathematical manipulation skills and failure to apply the concept of law of mass action to calculate and give a correct numerical value of the equilibrium constant; Kc. Extract 6.2 displays a sample of incorrect responses given by a candidate in this question.

6(a)(i) Reversible reaction is the type of reaction which does not complete for example $CH_3COOH + Na \rightleftharpoons CH_3CO + NaOH$.

(ii) Heterogeneous equilibrium is the type of equilibrium which are differ rent element for example.

$A_a + B_b \rightleftharpoons A_b + B_a$.

6(b)(i) The characteristics of chemical equilibrium.

i/ It is reversible equation
ii/ It is heterogeneous reaction
iii/ It does not complete. reaction
iv/ It is balanced.

6(b) ii/ Expression of Kc for the equation

so

$Cu_{(s)} + 2Ag^+_{(aq)} \rightleftharpoons Cu^{2+}_{(aq)} + 2Ag_{(s)}$

from

$$Kc = \frac{[Product]^A}{[Reactant]^A}$$

$$Kc = \frac{[Cu^{2+}_{(aq)}][Ag]^2}{[Cu_{(s)}][Ag]^2}$$

6(c) Data given

$4HCl_{(g)} + O_{2(g)} \rightleftharpoons 2Cl_{2(g)} + 2H_2O_{(g)}$

CL = 0.20 mole

O_2 = 0.20 mole

HCL 0.20 mol.

Equilibrium constant Kc = ?

Soln.

$4HCl_{(g)} + O_{2(g)} \rightleftharpoons 2Cl_2 + 2H_2O_{(g)}$

[0.20] [0.20] [X 0.20] [X 0.20]

from.

$Kc = \frac{[0.20]^2 [0.20]^2}{[0.20]^4 [0.20]}$

$Kc = \frac{1.6 \times 10^{-3}}{5.12 \times 10^{-7}} = 3.125$

Kc = 3.125

∴ The equilibrium constant is equal to 3.125.

Extract 6.2: A sample of incorrect responses in question 6.

In Extract 6.2 the candidate gave incorrect meaning of the terms, listed incorrect characteristics of chemical equilibrium and gave inappropriate expression for the equilibrium constant, Kc. Moreover, he/she calculated the value of the equilibrium constant, Kc incorrectly.

2.1.7 Question 7: Gases

This question had three parts namely; (a), (b) and (c). In part (a), the candidates were asked to use the kinetic gas equation to explain the following concepts:

(i) The pressure exerted by an ideal gas increases when it is heated at constant volume,

(ii) The volume occupied by an ideal gas increases when it is heated at constant pressure.

In part (b), the candidates were given the information that, "a flammable gas made up of only carbon and hydrogen is generated by a certain anaerobic bacteria in sewage drains. A pure sample of a gas was found to effuse through a certain porous barriers in 1.50 minutes. Under the same conditions of temperature and pressure it takes 4.73 minutes for an equal volume of bromine gas to effuse through the same barrier'' and they were required to calculate the molar mass of an unknown gas and suggest its name, given that molar mass of Br = 159.8 g/mol.

In part (c), the candidates were required to calculate the relative molecular weight of chloroform using Hofmann's method of determination of molecular weight using the following information: Weight of liquid in bulb = 0.2704 g, volume of vapour = 110 cm^3, temperature of vapour = 99.6. ℃, atmospheric pressure = 747 mmHg, vapour pressure of water vapour at 99.6. ℃ = 285.2 mmHg and 1dm^3 of H_2 at s.t.p = 0.09 g.

The question was attempted by 9,423 candidates constituting 27.3%, out of which 82.4% scored 0 - 3.0 marks, 16.0% scored 3.5 - 5.5 marks while only 1.6% of the candidates scored 6.0 - 10 marks. The summary of the performance of the candidates in this question is shown in Figure 6.

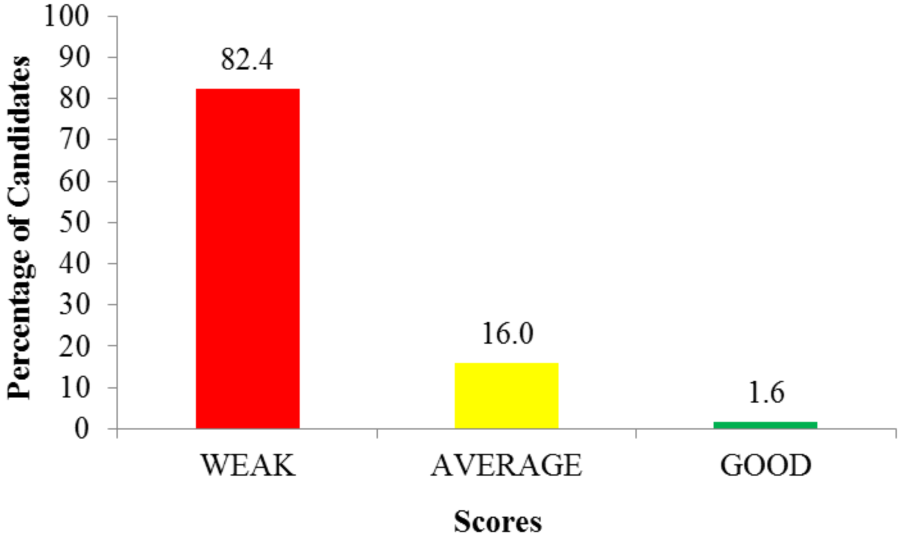


Figure 6: *Performance of the candidates in question 7*

Figure 6 shows that the general performance in this question was poor as 82.4% of the candidates scored below 3.5 marks. Further analysis revealed that 1,101 candidates corresponding to 11.6% scored a zero mark.

Analysis of the responses given by the candidates in this question indicated that most of them did not understand the kinetic gas equation hence, failed to apply it in addressing the concepts asked. They lacked prior knowledge on gas laws specifically, the Boyle's and Charles' law. They were not able to combine them in order to get the ideal gas equation which was needed to explain the scenario asked. In part (c), the candidates failed to apply the Graham's law to calculate the relative molecular weight of an unknown gas.

Furthermore, most of the candidates had to drop most of the marks in the last part of the question as they were not conversant with the Hofmann's method of determining the relative molecular weight of gases. However, some few candidates who made a good attempt, ended up poorly performing due to failure in manipulating the units properly. Extract 7.1 is a sample response from a script of a candidate whose performance was poor.

7(b) Data given
Time taken for unknown gas to effuse (t_z) = 1.50min
Time taken for Bromine gas to effuse (t_{Br}) = 4.73.
Molar mass of Bromine (Mr_{Br}) = 159.8g/mol
Required Molar mass of unknown gas.
from Grahams law of effusion

$$\frac{t_z}{t_{Br}} = \sqrt{\frac{Mr_{Br}}{Mr_z}}$$

$$\frac{1.5\,min}{4.73\,min} = \sqrt{\frac{159.8}{Mr_z}}$$

$$(0.317)^2 = \left(\sqrt{\frac{159.8}{Mr_z}}\right)^2$$

$$\frac{0.101}{1} \times \frac{159.8}{Mr_z}$$

$$\frac{159.8}{0.101} = \frac{0.101 \times Mr_z}{0.101}$$

$$Mr_z = 1.58 \times 10^3 g/m.$$

∴ The molar mass of the unknown gas is 1.58×10^3 g/m

(c) Data given,
Weight of liquid in bulb = 0.2704g
Volume of vapour = 110cm³
Temperature of vapour = 99.6°C
Atmospheric pressure = 747mmHg
Vapour pressure of water vapour = 255.2mmHg
Mass of Hydrogen gas = 0.09g at S.T.P.
Required :- Relative molecular weight of chloroform.

from

$PV = nRT$

$PV = nRT$

but $n = m/Mr$,

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

$\frac{PVMr}{PV} = \frac{mRT}{PV}$.

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

where

Mr - Molar mass

m - Mass

R - ~~gas constant~~ universal gas constant

T - Temperature

P - Pressure

V - Volume.

Then

$Mr = \frac{0.2704 \times 0.982 \times 373.6}{0.375 \times 0.11dm^3}$

$= 2.896 \times 10^3 g/mol$

Extract 7.1: A sample of incorrect responses in question 7.

Extract 7.1 shows a set of responses from a candidate who substituted improperly the data in the formula while calculating the molar mass of an unknown gas. He/she further calculated the relative molecular weight of chloroform incorrectly.

On the other hand, some few candidates responded properly to most parts of the question. Most of them showed appropriate competencies in applying the kinetic gas equation. They derived a suitable relationship of the parameters, pressure, temperature and volume; then they applied the relationship to answer the questions asked. These candidates hosted useful prior knowledge on both Boyle's and Charles' law. They further showed good skills in applying the Graham's law and Hofmann's method to calculate the relative molecular weight of an unknown gas and that of chloroform, respectively. Extract 7.2 shows an example of good responses in most parts of the question.

7 a) i) Because when an ideal gas is heated the kinetic energy of gas molecules increases which increase the speed of gas molecules and the collision of gas molecules themselves and the wall of the container thus the pressure of an ideal gas increase at constant volume.

ie From $PV = \frac{1}{3}Nm\bar{c}^2$ or $PV = nRT$

$P \propto \frac{1}{2}m\bar{c}^2$ at constant V

$P \propto T$ at constant V.

(ii) Because when an ideal gas is heated the kinetic energy of the gas increase and hence their speed also increase which tend to cause the ideal gas molecules to move far away from each other and hence the volume occupied by an ideal gas

7(a) Increases provided that pressure remains constant.

ie $PV = \frac{1}{3}Nmc^2$

$V = \frac{\frac{1}{3}Nmc^2}{P}$

$= \frac{2}{3P} \cdot \frac{1}{2}Nmc^2$

Since $\frac{1}{2}Nmc^2 = KE \propto T$

$V \propto T$ where $\frac{2}{3P}$ = Constant.

7 b) Solution

time in sample X, t_1 = 1.5min

time in Br gas, t_2 = 4.73min

Molar mass of X = ?

Mr of Br = 159.8g/m

From Graham diffusion law

$\frac{t_1}{t_2} = \sqrt{\frac{Mr_X}{Mr_{Br}}}$

$\frac{1.5 \text{ min}}{4.73 \text{ min}} = \sqrt{\frac{Mr_x}{159.8g/m}}$

$\left(\frac{1.5}{4.73}\right)^2 = \frac{Mr_x}{159.8g/m}$

$0.1 \times 159.8g/m = Mr_x$

$Mr_x = 15.98g/mol$

Since $CH_4 = 16$; $15.98 \simeq 16$

∴ The molar mass of unknown gas is 15.98

∴ The gas is methane (CH_4)

7 c) Solution

Data

Weight of liquid in bulb = 0.2704g

Volume of vapour = 110cm³ = 0.11dm³

Temperature of vapour = 99.6°C = 372.6K

Vapour pressure of water vapour = 285.2mmHg

Relative molecular weight of CCl_3 = ?

Volume of H_2 gas at STP = 1dm³

Mass of H_2 = 0.09g.

Atmospheric pressure = 747mmHg.

From

Vapour pressure of chloroform = (747 − 285.2)mmHg

P_{CCl_3} = 461.8mmHg = 0.608atm

From $PV = nRT$

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

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

$= \frac{(0.2704 - 0.09)g\ R.T}{PV}$

since V at STP = 1dm³

at 99.6°, V = ?, P = 285.2mmHg

$P_1V_1 = P_2V_2$

1dm³ × 1atm = 0.375atm × V_2

$V_2 = \frac{1dm^3}{0.375}$

7 c) V = 2.667dm³

From

$Mr = \frac{0.1804g \times 0.0821 atm mol^{-1} K^{-1} dm^3 \times 372.6K}{0.608atm \times 2.667dm^3}$

$\therefore Mr = 3.4 g/mol$

Extract 7.2: A sample of correct responses in question 7.

In Extract 7.2, the candidate used correctly the kinetic gas equation to explain the concepts asked in part (a). He/she correctly calculated the molar mass of an unknown gas and successfully identified the gas. However, the candidate failed to arrive to the correct value of molecular weight of chloroform.

2.1.8 Question 8: Gases

This question had four parts namely; (a), (b), (c) and (d). In part (a), the candidates were required to state and provide mathematical expressions for the gas laws: (i) Boyle's law, (ii) Charles' law, (iii) Graham's law and (iv) Dalton's law of partial pressures.

In part (b), the candidates were required to state five assumptions of the kinetic theory of gases, while part (c) required them to calculate the partial pressure of hydrogen gas when 50 cm^3 of carbon dioxide at 1×10^5 Nm^{-2} are mixed with 150 cm^3 of hydrogen at the same pressure. The pressure of the mixture was given as 1.0×10^5 Nm^{-2}.

In part (d), the candidates were given the information that "In 5 minutes, 15 cm^3 of argon effuse through a pinhole." They they were asked to calculate the volume of Xenon gas which was required to effuse through the same pinhole under the same condition [Atomic masses Ar = 39.95, Xe = 131.291].

This question was attempted by 34,049 candidates equivalent to 98.6% making it the most attempted question in paper 1. The candidates who scored 6.0 - 10 marks were 60.9% while 26.7% and 12.4% scored 3.5 - 5.5 and 0 - 3.0, respectively. Figure 7 gives the summary of statistical analysis in this question.

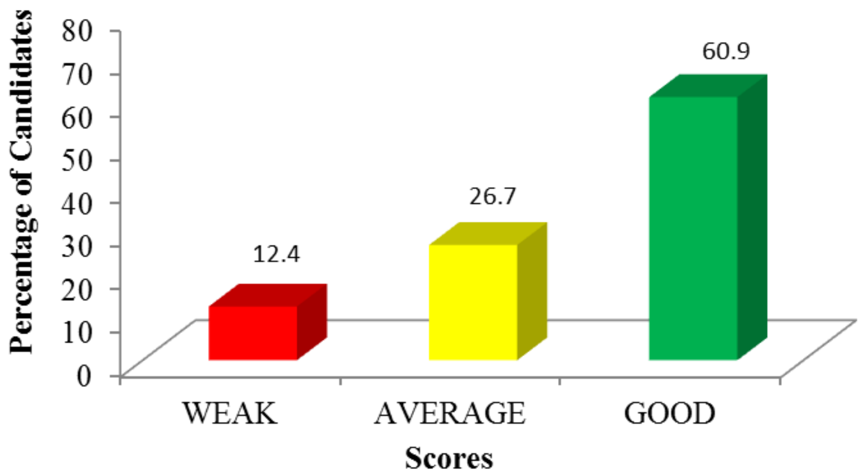


Figure 7: *Performance of the candidates in question 8*

The overall performance was good as most of the candidates (87.6) managed to score the pass mark (3.5 marks) or above. Most of the candidates who scored high marks in this question managed to give the correct responses to the most parts of the question. They stated and provided the correct mathematical expression of gas laws *i.e*. Boyle's law, Charles' law, Graham's law and Dalton's law of partial pressures. This indicated that they were having strong background knowledge on the topic of gas laws which is also studied in the lower classes. They manipulated the Graham's law and got a correct value for the volume of Xenon gas that was supposed to effuse with respect to the given conditions.

Moreover, they were competent in using the kinetic gas equation to derive appropriate formula and used it to calculate the partial pressure of hydrogen gas. Extract 8.1 is a sample of correct responses given by one of the candidates in this question.

8(a)	(i) Boyle's law states that;
	" The volume 'V' of a fixed mass of
	gas is inversely proportional to its
	pressure 'p' at constant temperature."
	That is: $V \propto \frac{1}{P}$
	$P_1V_1 = P_2V_2 =$ Constant.
8(a)	(ii) Charle's law states that;
	" The volume of a fixed mass of gas
	is directly proportional to its absolute
	temperature at constant pressure."
	That is; $V \propto T$
	$\frac{V_1}{T_1} = \frac{V_2}{T_2} =$ constant

8(a) (iii) Graham's law states that;

"The rate of diffusion or effusion of a gas is inversely proportional to the square root of its density when Temperature and pressure are kept constant."

That is; $R \propto \frac{1}{\sqrt{\rho}}$

$R_1\sqrt{\rho_1} = R_2\sqrt{\rho_2} = \text{constant}$.

8(a) (iv) Dalton's law of partial pressures states that;

"When a mixture of two or more than two gases are enclosed in a vessel, the total pressure exerted by the gas is equal to the sum of the partial pressures of the gas when present alon in a vessel."

That is ; $P_{TOTAL} = P_A + P_B$.

8(b) Assumptions of Kinetic theory of gases;

(i) A gas consists of small particles that are in random motion and there exist collision between gas particles themselves and a collision between a gas particle and the wall of a container thus exerting pressure.

8(b)	(ii) The kinetic energy of the gas particles is directly proportional to the absolute temperature of the gas.
	(iii) The collision between the gas particle and the walls of the container is perfectly elastic
	(iv) The Intermolecular forces between gas particles is negligible
	(v) The volume of the gas particles is negligible compared to the volume of the container
	(vi) Force of gravity has no influence on the motion of a gas particle.

8(c)	Given;
	Volume of carbondioxide, $V_{CO_2} = 50cm^3$
	Volume of hydrogen, $V_{H_2} = 150cm^3$.
	Total pressure, $P_T = 1.0 \times 10^5 Nm^{-2}$
	According to Boyle's law;
	$P_1V_1 = P_2V_2$
	But; $P_1 = 1 \times 10^5 Nm^{-2}$
	$V_1 = 50cm^3$.
	$V_2 = 50cm^3 + 150cm^3 = 200cm^3$.
	$\therefore P_2 = \frac{P_1V_1}{V_2}$

8(i)	$P_2 = \frac{1\times10^5 \times 50}{200}$
	$P_2 = 25,000 Nm^{-2}$
	According to Dalton's law of partial pressure;
	$P_T = P_2 + P_{H_2}$
	$P_{H_2} = P_T - P_2$
	$P_{H_2} = 1\times10^5 - 25,000$
	$P_{H_2} = 75,000 Nm^{-2}$
	∴ Partial pressure of Hydrogen = 75,000 Nm^{-2}
8 (b)	From Graham's law of effusion;
	$\frac{R_1}{R_2} = \sqrt{\frac{M_2}{M_1}}$
	where; M_2 is molecular mass of Xenon = 131.29
	M_1 is molecular mass of argon = 39.95
	Given; Rate of diffusion of argon, $R_1 = V_1/t_1$

8 (d) Since; $t_1 = t_2$

$$\frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}}$$

$$\frac{15cm^3}{V_2} = \sqrt{\frac{131.29}{39.95}}$$

$$\frac{15cm^3}{V_2} = 1.8128$$

$$V_2 = \frac{15cm^3}{1.8128}$$

$$V_2 = 8.274\ cm^3$$

Volume of Xenon = $8.274\ cm^3$

Extract 8.1: A sample of correct responses in question 8.

In Extract 8.1, a candidate managed to state and gave correct mathematical expressions on the gas laws asked, postulated appropriately the kinetic theory of gases, and finally calculated correctly the volume of xenon gas.

However, some of the candidates who scored low marks in this question were not competent enough to transform a statement of gas law into its corresponding mathematical expression. This indicated poor background knowledge on gas laws which most of them had studied in the lower classes. This group of candidates failed to properly recall the characteristics of ideal gases as influenced by pressure, volume and temperature. Consequently, they applied the fundamental kinetic equation to deduce the gas laws and calculate the partial pressure of hydrogen gas. Moreover, they showed poor English language proficiency; hence, they could not communicate their ideas properly. Extract 8.2 is a sample answer showing poor responses given by a candidate in this question.

8 (a) Assumption of the Kinetic theory of gasses
All gases are not seen solid and liquid, but are only in gas form
All gesses are more votile than not Compared to solid and liquid
All gasses are stored at specific container of gases
All gases are allways in random motile situation and not static
All gases are less denser Compared to liquid and sol

Extract 8.2: A sample of incorrect responses in question 8.

Extract 8.2 shows responses of a candidate who gave wrong assumptions of the kinetic theory of gases.

2.1.9 Question 9: Energetics

This question consisted of four parts namely; (a), (b) (c) and (d). In Part (a), the candidates were required to calculate the enthalpy for the reaction:
$2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$; given that, the enthalpy of formation of ammonia, $NH_3(g)$ under standard condition is - 46.2 $kJmol^{-1}$. In Part (b), the candidates were given two equations:

$$\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \longrightarrow NO(g)\ \Delta H_r^0 = +90\ kJmol^{-1} \quad \text{and}$$

$$NO_2(g) \longrightarrow \frac{1}{2}O_2(g) + NO(g)\ \Delta H_r^0 = +74\ kJmol^{-1}$$

Then, they were required to (i) calculate the enthalpy for the reaction,
$N_2(g) + 2O_2(g) \longrightarrow 2NO_2(g)$ and (ii), point out which among the two species $NO_2(g)$ and $NO(g)$ was thermodynamically more stable.

In part (c), the candidates were provided with the information, "At 25 ℃, the dissociation energies of $H_2(g)$ and $Cl_2(g)$ are + 435.4 $kJmol^{-1}$ and + 243 $kJmol^{-1}$, respectively. The enthalpy of formation of HCl(g) is - 92.2 $kJmol^{-1}$" and they were required to calculate the dissociation energy for HCl(g).

Finally, part (d) required the candidates to use the given average bond enthalpies to calculate the change in enthalpy of the reaction, ΔH_r, for

$$C_3H_8 + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g)$$

Bond	**Enthalpy**
C-H	= 414 $kJmol^{-1}$
C-C	= 347 $kJmol^{-1}$
C=O	= 741 $kJmol^{-1}$
H-O	= 464 $kJmol^{-1}$
O=O	= 498 $kJmol^{-1}$
C-O	= 335 $kJmol^{-1}$
O-O	= 138 $kJmol^{-1}$

The question was attempted by 18,658 candidates, equivalent to 54.0% as shown in Figure 8.

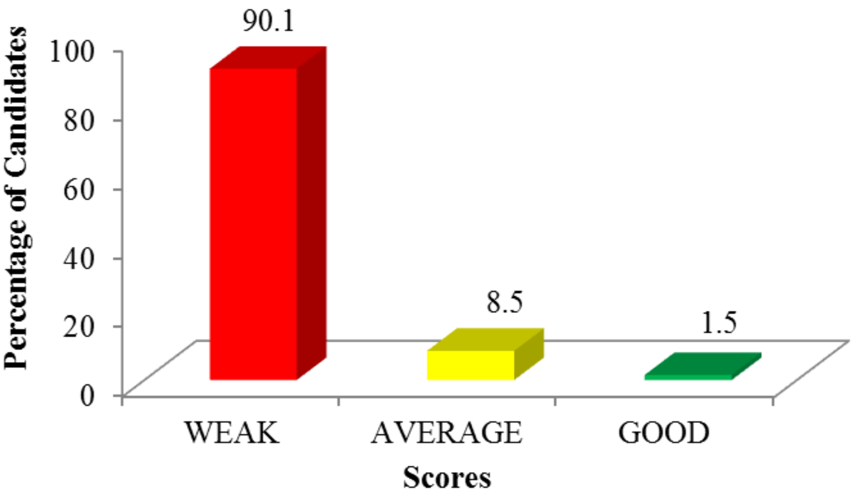


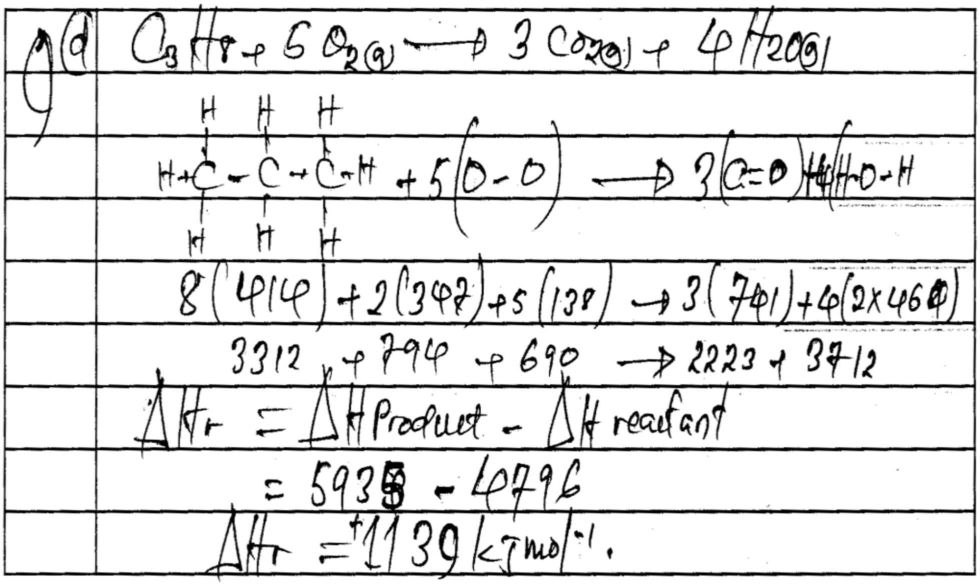
Figure 8: *Performance of the candidates in question 9*

Figure 8 shows that the candidates who scored marks ranging from 0 - 3.0, 3.5 - 5.5 and 6.0 - 10 were 16,807 (90.1%), 1,574 (8.4%) and 273 (1.5%), respectively.

The statistical analysis (Figure 8) indicates that, the overall performance in this question was poor as majority of the candidates (16,807 corresponding to 90.1%) scored below an average mark (< 3.5 mark). Further analysis revealed that of the 90.1 percent who performed poorly, 4,137 (22.2%) scored a zero mark.

Moreover, the analysis revealed that, this question was the most poorly performed of all the questions as only 1,851 candidates (9.9%) managed to get an average mark and above (*i.e.* 3.5 - 10).

Majority of the candidates (90.1%) who scored low mark (0 - 3.0) missed basic concepts regarding the topic of *Energetics*. The analysis on responses supplied by these candidates indicated that they had poor skills in understanding and applying the Hess's law of constant heat summation in calculating the enthalpy changes accompanying chemical reactions. They had poor knowledge on the meaning of positive and negative signs as far as energetics is concerned. Therefore, due to lack of both mathematical and the energetics related skills, the candidates skipped some parts of the question which involved calculations and gave incorrect responses to the rest parts of the question. Extract 9.1 shows a sample of poor responses.


9 (d) $C_3H_8 + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$

H–C–C–C–H + 5(O–O) → 3(O=O) 4(H–O–H)

8(414) + 2(347) + 5(138) → 3(741) + 4(2x464)

3312 + 794 + 690 → 2223 + 3712

ΔHr = ΔH Product – ΔH reactant

= 5935 – 4796

ΔHr = +1139 kJmol⁻¹.

9 (a) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ $\Delta HF = +46.2\ kJ/mol$

(b) (i) Required equation

$N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)}$

from viceverse eqn (2)

$\frac{1}{2}N_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow NO_{(g)}$ $\Delta H_r = +90\ kJ\ mol^{-1}$

$NO_{(g)} + \frac{1}{2}O_{2(g)} \rightarrow NO_{2(g)}$. $\Delta H_r = -74\ kJ\ mol^{-1}$

Overal eqn

$\frac{1}{2}N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)}$

$\Delta H_r = 90 + -74$

$= 16\ kJ\ mol^{-1}$

$\Delta H_r = 16\ kJ\ mol^{-1}$

(ii) The $NO_{2(g)}$ are thermodynamic stable.

(c) Required equation

$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$ $\Delta HF = -92\ kJ\ mol^{-1}$

$\Delta HF = \Delta_i E_{H_2} + \Delta_i E_{Cl_2} + \Delta E_{HCl}$

$-92 =$

Viceverse the equation

$2HCl \rightarrow H_{2(g)} + Cl_2$ $\Delta HF = +92$

$\Delta HF = -435.4 + -243 + \Delta_i E$

$92 = -435.4 + -243 + \Delta E$

$\Delta_i E(HCl) = -678.4 - 92$

$\Delta_i E(HCl) = 770.4\ kJ/mol$.

Extract 9.1: A sample of incorrect responses in question 9.

In Extract 9.1, a candidate calculated incorrectly the enthalpy changes in all parts of the question.

On the other hand, the candidates who scored high marks in this question were conversant with the Hess's law of constant heat summation including its application. Therefore, they were able to correctly calculate the different types of enthalpy changes that accompanied the given chemical reactions. Extract 9.2 shows an example of good responses given by a candidate in this question.

4. (a) Given $\frac{1}{2}N_2 + \frac{3}{2}H_2 \longrightarrow NH_3$ —(i) $\Delta H = -46.2KJ$

Req. ~~$N_2 + H_2$~~

$2NH_3 \longrightarrow N_2 + 3H_2$ $\Delta H_r = ?$

Take eqn (i)

$\times 2 \left\{\frac{1}{2}N_2 + \frac{3}{2}H_2 \longrightarrow NH_3\right\}$ $\Delta H = -46.2 \times 2$

$N_2 + 3H_2 \longrightarrow 2NH_3$ $\Delta H = -92.4KJ$

Reverse

$2NH_3 \longrightarrow N_2 + 3H_2$ $\Delta H = 92.4KJ$

∴ Heat of reaction

Enthalpy of reaction given is $92.4KJmol^{-1}$

(b) ~~$\frac{1}{2}NO$~~ Given

$\frac{1}{2}N_2 + \frac{1}{2}O_2 \longrightarrow NO_{(g)}$ —(i) $\Delta H = +90KJmol^{-1}$

$NO_2 \longrightarrow \frac{1}{2}O_2 + NO_{(g)}$ —(ii) $\Delta H = 74KJmol^{-1}$

(1) $N_2 + 2O_2 \longrightarrow 2NO_2$ $\Delta H_r = ?$

$2\times\left(\frac{1}{2}N_2 + \frac{1}{2}O_2 \longrightarrow NO\right)$ $\Delta H = 90 \times 2\ KJmol^{-1}$

$N_2 + O_2 \longrightarrow 2NO$ $\Delta H_{(i)} = 180\ KJmol^{-1}$

Multiplying eqn (ii) by 2 and reversing

$2\left(NO + \frac{1}{2}O_2 \longrightarrow NO_2\right)$ $\Delta H_{(ii)} = -74 \times 2\ KJmol^{-1}$

$2NO + O_2 \longrightarrow 2NO_2$ $\Delta H_{(ii)} = -148KJmol^{-1}$

Adding the equation to get the required one

$N_2 + 2O_2 \longrightarrow 2NO_2$ $\Delta H = (-148 + 180)\ KJmol^{-1}$

∴ Enthalpy for the reaction $= 32\ KJmol^{-1}$

9(b)	(ii) NO. is more ~~stab~~ thermally stable than NO_2
	Reason:
	~~combustion of NO~~ since enthalpy of formation
	of NO is large, this means that the same
	large amount should be supplied in order to
	break its bonds.
(c)	$HCl \longrightarrow H + Cl$ $\Delta H = ?$
	Given
	$H_2 \longrightarrow 2H$ $\Delta H = 435.4\ kJ\ mol^{-1}$
	$Cl_2 \longrightarrow 2Cl$ $\Delta H =$ ~~235~~ $243\ kJ\ mol^{-1}$
	$H + Cl \longrightarrow$ ~~2H~~ HCl $\Delta H = -92.2\ kJ\ mol^{-1}$
	$\frac{1}{2}H_2 \longrightarrow H$ $\Delta H = \frac{1}{2} \times 435.4 = 217.7$
	$\frac{1}{2}Cl_2 \longrightarrow Cl$ $\Delta H = \frac{1}{2} \times 243 = 121.5$
	$\therefore \Delta H = \sum E_{Products} - \sum E_{Reactant}$
	= ~~4~~
	$(121.5 + 217.7) - (-92.2)$.
	= ~~4~~ $431.4\ kJ\ mol^{-1}$
	$\therefore$ Dissociation energy of HCl is 431.4 kJ

9(d) $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

$\Delta H_r = \sum BE_{Reactant} - \sum BE$ of products

$\sum BE$ of reactants =

$H_3C-CH_2-CH_3 = 8(C-H) + 2(C-C)$
$= 3312 + 694$
$= 4006.$

$5\times(O=O) = 5\times 498$
$= 2490$

$\sum BE_{Reactants} = 2490 + 4006$
$= 6496\ kJ\,mol^{-1}$

Products

$6(C=O) = 6\times 741$
$= 4446\ kJ\,mol^{-1}$

$8(H-O) = 8\times 464$
$= 3712$

$\sum BE$ products $= 8158\ kJ\,mol^{-1}$

$\therefore \Delta H_r = (6496 - 8158)$
$= -1662\ kJ\,mol^{-1}$

Extract 9.2: A sample of correct responses in question 9.

In Extract 9.2 a candidate calculated correctly the enthalpies of the given reactions. Moreover, the candidate managed to arrive to a correct value of dissociation energy in part 9 (c).

2.1.10 Question 10: Energetics

This question consisted of four parts namely: (a), (b) (c) and (d). In Part (a), the candidates were required to define the following phrases as applied in energetics:

(i) Heat (enthalpy) of formation
(ii) Standard enthalpy of formation
(iii) Heat (enthalpy) of fusion
(iv) Heat (enthalpy) of neutralization

In part (b) (i), the candidates were required to state the Hess's law of constant heat summation. In part (b) (ii), the candidates were given a hypothetical reaction:

$aA + bB \longrightarrow cC + dD$ where A, B, C and D were compounds and a, b, c and d were the stoichiometric values. The candidates were required to determine an expression for enthalpy change, ΔH_r^0 for the reaction.

In part (c), they were asked to calculate the standard heat (enthalpy) of formation of ethanol using the following information: the standard heat of combustion of ethanol ΔH_c^o = -1386 kJ mol^{-1}, the standard heat of formation of carbon dioxide, ΔH_f^o (CO_2)= -393 kJ mol^{-1}and the standard heat of formation of water, ΔH_f^o = -287 kJ mol^{-1}.

In part (d), the question was as follows: "the following data were obtained for Born-Haber cycle formation for 1 mole of crystalline NaCl".

Step	Heat (Enthalpy)
Sublimation of Na metal to gaseous Na atoms	ΔH_{sub}^o = + 107.3 kJmol^{-1}
Ionization of gaseous Na atom to Na^+ ions and e^-	ΔH_{IE}^o = + 495.8kJmol^{-1}
Formation of Cl^-(g) ion by addition e^- to Cl(g)	ΔH_{EA}^o = - 348.6 kJmol^{-1}
Formation of NaCl crystals from Na^+(g) and Cl^-(g)	ΔH_L^o = - 787.3 kJmol^{-1}

In a single step $Na(s) + \frac{1}{2}Cl_2(g) \longrightarrow NaCl(s)$, it was found that ΔH_f^0 (NaCl, crystal)= - 412.3 kJmol^{-1}. Calculate heat (enthalpy) of dissociation of 1 mole of Cl_2 gas."

The question was attempted by 25,725 candidates equivalent to 74.5%, out of which 18.8% of the candidates scored 6.0 - 10 marks, 34.6% scored 3.5 - 5.5 marks, while 46.6% scored 0 - 3.0 marks.

The general performance in this question was average as most of the candidates (53.4%) scored 3.5 marks and above. Most of the candidates who scored high marks had good background on the concept of heat changes accompanying chemical reactions. Hence, they were able to provide proper definition for the terms asked. Moreover, they demonstrated appropriate competences on how to apply the Hess's law of constant heat summation to calculate the enthalpy changes that accompanied the given reactions. Most of the candidates, who scored averagely, had provided partial answers to most parts of the question. For instance, some of them were able to define all the terms asked but failed to calculate enthalpies that accompanied the given chemical reactions. This suggests insufficient competencies of these candidates in the topic of *Energetics*, particularly the subtopic, *Hess's law*. Extract 10.1 shows a sample of correct responses in question 10.

10(a)	(i) Heat of formation is the enthalpy change when one mole of substance is formed.
10(a)	(ii) Standard enthalpy of formation is the enthalpy change when one mole of the substance is formed under the standard conditions.
10(a)	(iii) Heat of fusion is the enthalpy change when a solid substance is melted to liquid at it's melting temperature
10(a)	(iv) Heat of neutralization is the enthalpy change when one of H^+ ions react with one mole of OH^- to form one mole of water at the standard conditions.

10(b) (i) Hess's law of constant heat summation states that "the heat of reaction of the chemical reaction is independent in the manner in which it is brought about"

10(b) (ii)

Given $aA + bB \longrightarrow cC + dD$.

$\Delta_r H^\theta = (c\Delta H_C + d\Delta H_D) - (a\Delta H_A + b\Delta H_B)$

10(c) The required equation is,

$2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow C_2H_5OH(aq)$

$C(s) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H = -393$ kJ/mol (i)

$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l)$ $\Delta H = -287$ kJ mol^{-1} — (ii)

$C_2H_5OH(aq) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$ — (iii)
$\Delta H = -1386$ kJ/mol

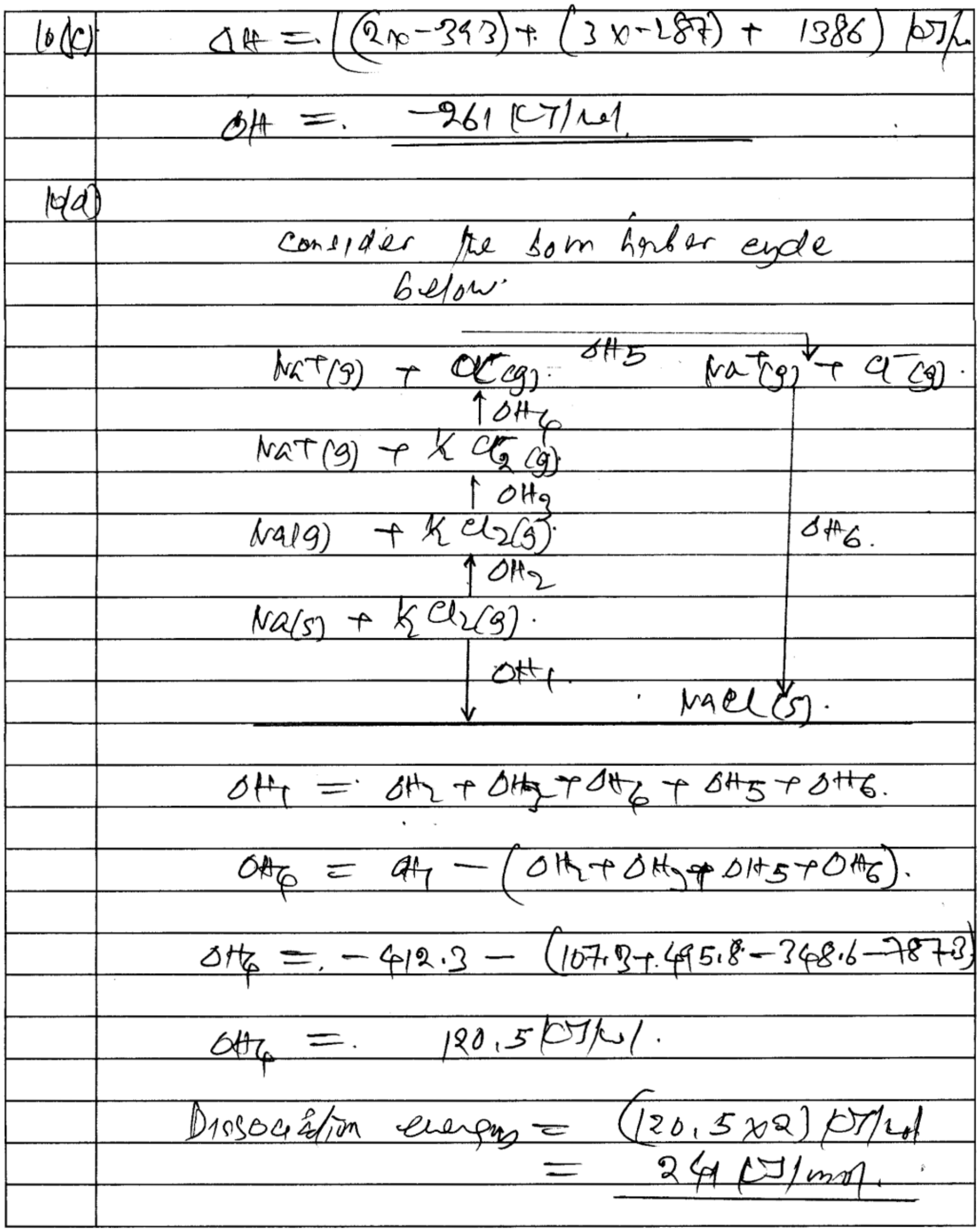
$2C(s) + 2O_2(g) \longrightarrow 2CO_2(g)$. $\Delta H = -393 \times 2$ kJ/mol — (iv)

$3H_2(g) + \frac{3}{2}O_2(g) \longrightarrow 3H_2O(l)$ $\Delta H = -287 \times 3$ kJ/mol — (v)

$3H_2O(l) + 2CO_2(g) \longrightarrow C_2H_5OH(aq) + 3O_2(g)$.
$\Delta H = 1386$ kJ/mol — (vi)

On adding (iv), (v) and (vi)

$2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow C_2H_5OH(aq)$



Extract 10.1: A sample of correct responses in question 10.

Extract 10.1 shows the response of a candidate who defined correctly all the terms asked, provided appropriate statement for the Hess's law of constant heat summation and finally, performed correctly all the calculations required.

However, the candidates who scored low marks demonstrated having poor background knowledge in the topic of *Energetics*. They did not know how to interpret the Hess's law in mathematical terms; hence, failed to calculate correctly all the required enthalpies that accompanied the reactions given. The low mark score shown by these candidates, was also contributed by their weak knowledge on tackling the problems which incorporate the basic operations in mathematics. Extract 10.2 is a sample of poor responses in this question.

10(a)

(i) Heat of formation; Is the amount of energy required to change one mole of solid to gas.

(ii) Standard enthalpy of formation; Is the amount of energy required to remove one mole of liquid to gaseous state.

(iii) Heat of fusion; Is the amount of energy required to form one mole of gas to gas atom.

(iv) Heat of neutralization; It's an amount of water required to neutralize acid and base during chemical ~~requir~~ reaction

10(b)	
(i)	Hess's law of heat summation state that "The change in heat during chemical reactions it direct propor tion to the route that it was brought"
10(c)	Data given
	The standard heat combustion of ethanol, ΔcH^o = -1386KJmol
	The standard heat formation of carbondioxide = -393 KJ mol^{-1}
	The standard heat formation of water = -287 KJmol^{-1}
	The standard ethalpy of ethanol = Required.
	from the formula
	D·E1 + D·E2 + E·A + A·E·
	= -1386KJ/mol + -393KJmol + -287KJmol
	= -2,066.
10(d)	Data given
	Dissociation energy 1 = +107.3KJ mol^{-1}
	Dissociation energy 2 = +495.8 KJ/mol-1
	Electron affinity = -348.6KJmol-1
	lattice energy = -787.3KJ mol
	The standard heat of (ΔfH^o) NaCl = -412.3 KJmol
	The heat dissociation of one mole of Cl_2 required
	from the formula
	= D·E1 + D·E2 + E·A + L·E = ΔfH^o of NaCl
	= +107-3KJmol^{-1} + +495+8 KJmol + 348.6KJmol
	+ -787.3KJmol = -412.3
	= 73.6.
	= 412.3 + 73.6 = -338.7.

Extract 10.2: A sample of incorrect responses in question 10.

Extract 10.2 shows responses from a candidate who, despite knowing some terms which are used in energetics, failed to arrange them properly to get a correct definition. He/she incorrectly used the Hess's law of constant heat summation to perform the calculations required.

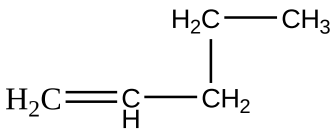
2.1.11 Question 11: Aliphatic Hydrocarbons

This question consisted of four parts namely; (a), (b) (c) and (d). In Part (a), the candidates were required to suggest suitable tests to distinguish the following pairs of compounds: (i) Chlorobenzene and (chloromethyl) benzene (ii) Cyclopentene and pent-2-yne (iii) Chloroform and carbon tetrachloride.

In part (b) (i), the candidates were asked to state and illustrate the type of hybridization at the functional group carbons in alkenes and alkynes. Part (b) (ii) required the candidates to arrange the compounds (ethane, ethene, ethyne and benzene) in order of increasing their acidic strength (starting with the less acidic). Finally, part (b) (iii) required the candidates to use sp^3, sp^2 or sp hybrid orbitals to differentiate sigma (σ) from pie (π) bond.

In part (c), the candidates were provided with the hydrocarbons represented by the following molecular formulae:

1



2

They were required to (i) give the systematic names for the hydrocarbons and (ii), state how each of the given hydrocarbon could have reacted with hydrogen bromide. They were also required to provide systematic names of the products.

In part (d), the candidates were given the information “Propene reacts with hydrogen bromide following markovnikov’s rule to give a substance **A**. When substance **A** is heated in presence of potassium hydroxide, an alcohol **B** is formed”. The candidates were required, in part (d)(i) to deduce the chemical structure of substances **A** and **B.** In part (d) (ii), they were required to illustrate the meaning of the terms “base” and “nucleophile” by referring to the reaction of substance **A** with potassium hydroxide under stated conditions.

The question was attempted by 6,998 candidates constituting 12.9%. Among the candidates who attempted this question, 73.7% scored 0 - 3.0 marks, 23.9% scored 3.5 - 5.5 marks while 2.4% scored 6.0 - 10 marks. The summary of the candidates’ performance is shown in Figure 9.

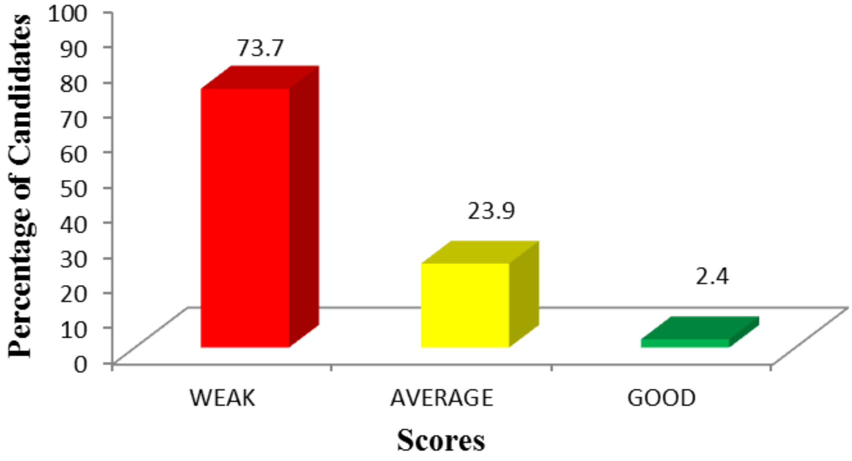
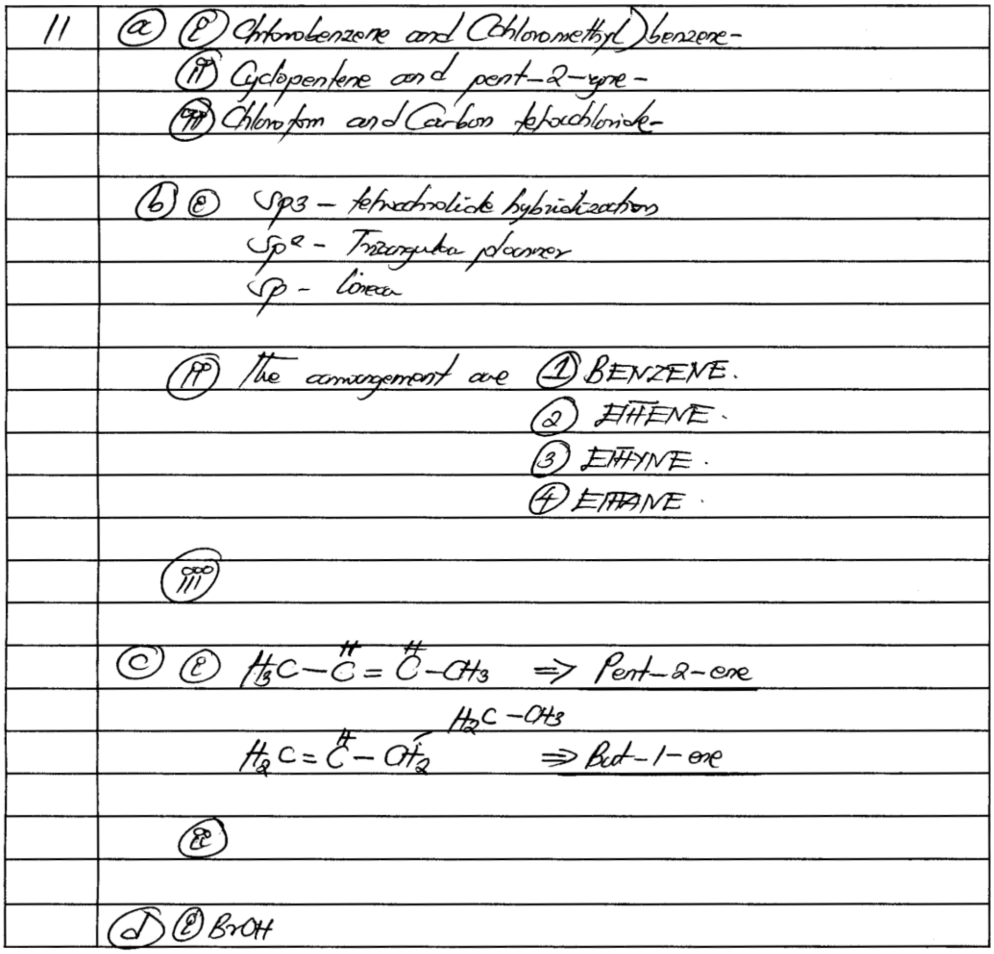


Figure 9: *Performance of the candidates in question 11*

Generally, the performance in this question was poor as the majority (73.78%) of the candidates scored below the pass mark (0 - 3.0 marks). Most of the candidates who scored low marks, failed to provide appropriate distinguishing tests as required by part (a) of the question. This was attributed to lack of enough knowledge on the characteristic reactions undergone by different functional groups. Moreover, these candidates failed to give the type of hybridization of the functional group carbons. This signified insufficient knowledge on the concept of hybridization of atomic orbitals. The candidates also failed to apply the IUPAC (International Union of Pure and Applied Chemistry) system to name the given hydrocarbons.

In addition, the candidates failed to deduce the chemical structures of substances **A** and **B**. This suggested lack of proper competencies regarding the chemical properties of hydrocarbons. Extract 11.1 shows sample responses of a candidate who gave incorrect answers.


11 (a) (i) Chlorobenzene and (Chloromethyl)benzene-
(ii) Cyclopentene and pent-2-yne-
(iii) Chloroform and Carbon tetrachloride-
(b) (i) Sp3 – tetrahedral hybridization
Sp2 – Triangular planner
Sp – linear
(ii) The arrangement are (1) BENZENE.
(2) ETHENE.
(3) ETHYNE.
(4) ETHANE.
(iii)
(c) (i) $H_3C-\overset{H}{C}=\overset{H}{C}-CH_3$ => Pent-2-ene
H_2C-CH_3
$H_2C=\overset{H}{C}-CH_2$ => But-1-ene
(ii)
(d) (i) BrOH

Extract 11.1: A sample of incorrect responses in question 11.

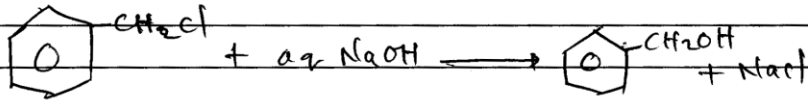
In Extract 11.1 the candidate copied some parts of the question without giving the required responses. He/she gave incorrect answers on the types of hybridization and gave the wrong number of carbon atoms for the named compounds.

However, some few candidates who managed to get good scores in this question, demonstrated good knowledge on various chemical reactions undergone by different functional groups. Thus, they managed to identify and supply distinguishing tests required. The candidates who got high marks, were also knowledgeable about the concept of hybridization. Therefore, they responded correctly in part (b) of the question. Furthermore, they indicated a good mastery of applying the IUPAC rules to properly name all the compounds asked. Extract 11.2 is a sample of good responses to most parts of the question, as hereby given by one of the candidates. However, he/she failed in parts (a) (ii) and (b) (ii).

11. a) Suitable chemical test between

i) Chlorobenzene and (chloromethyl) benzene

→ Using aq NaOH, (Chloromethyl)benzene react with aqueous NaOH to give Benzene alcohol and Sodium Chloride. The NaCl react with $AgNO_3$ to give white precipitate while chlorobenzene can not precipitate.

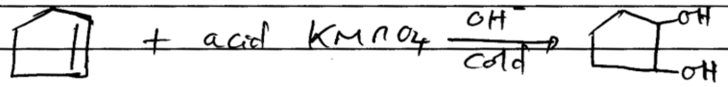


$NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$

(white Precipitate)

ii) Cyclopentene and pent-2-yne

→ cyclopentene decolourize acidified cold $KMnO_4$ from purple to colourless while pent-2-yne can not decolourize.



β . (Purple) (Colourless)

iii) Chloroform and Carbon tetrachloride.

→ Chloro form react with primary amine under alc KOH to give an offensive smelling isocyanide while Carbon tetrachloride can not do so

$CHCl_3 + R-NH_2 + 3KOH \longrightarrow R-\overset{\oplus}{N}\equiv\overset{\ominus}{C}$ (offensive smelling) $+ 3KCl + 3H_2O$

11 b) i) Hybridization of alkene is Sp^2 Hybridization

Hybridization of Alkyne is Sp hybridization

Illustration

Alkene example $CH_2 = CH_2$

$_6C$ $_6C$

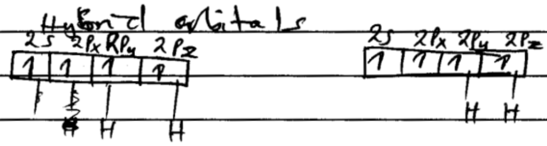
At ground state

$_6C$ = [He] 2s [↑↓] 2p [↑|↑|] [He] 2s [↑↓] 2p [↑|↑|]

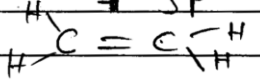
At excited state

$_6C$ [He] 2s [↑] 2p [↑|↑|↑] [He] 2s [↑] 2p [↑|↑|↑]

Hybrid orbitals



→ Sp^2 Hybridization orbital



Alkyne example $H - C \equiv C - H$

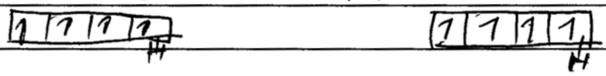
At ground state

$_6C$ [He] 2s [↑↓] 2p [↑|↑|] $_6C$ [He] 2s [↑↓] 2p [↑|↑|]

At excited state

[He] 2s [↑] 2p [↑|↑|↑] [He] 2s [↑] 2p [↑|↑|↑]

Hybridized orbital



11b) i) ~~+~~ SP Hybridization orbital

$H-C \equiv C-H$

ii) In order of increasing acidic Strength

Ethane < ethene < benzene < ethyne

iii) Sigma bond (σ) and pie bond (π)

Sigma bond is the bond which is formed due to end to end overlapping example is than in SP^3 hybridized orbitals such as CH_3-CH_3

while

Pie bond is the bond which is formed due to side way overlapping. example is that formed in SP^2 have one pie bond and in SP have two pie bond. see below

$H_2C=CH_2$ and $H-C\equiv C-H$ respectively.

c) i) $H_3C-CH=CH-CH_3$ Cis-but-2-ene

$H_2C=CH-CH_2-CH_2-CH_3$ Pent-1-ene

ii) Reaction with HBr

$H_3C-CH=CH-CH_3 + HBr \longrightarrow H_3C-CH_2-CH(Br)-CH_3$

2-bromobutane

$H_2C=CH-CH_2CH_2CH_3 + HBr \longrightarrow H_3C-CH(Br)CH_2CH_2CH_3$

2-bromopentane

11 d) i) $CH_3CH=CH_2$ + HBr → $CH_3CH(Br)CH_3$ (A)

Propene (2-bromopropane)

A + aq KOH $\xrightarrow{\Delta}$ B

$CH_3CH(Br)CH_3$ + aq KOH → $CH_3CH(OH)CH_3$

(B)

(Propan-2-ol)

ii) Base is the any substance that contain Hydroxyl ion and its is able to donate as free Hydroxyl ion

Nucleophile - Is the compound atom that contain negatively charged particle its electron donor

$CH_3CH(Br)CH_3$ + aq KOH → $CH_3CH(OH)CH_3$

→ KOH is a base

→ ^-OH is a nucleophile

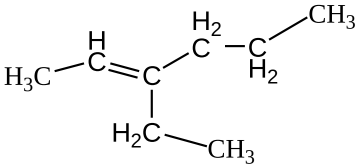
Extract 11.2: A sample of good responses in question 11.

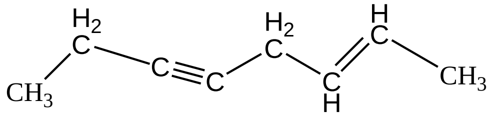
Extract 11.2 shows responses of a candidate who suggested suitable tests to distinguish the given pairs of compounds. The candidate responded correctly in most parts of the question. However, he/she failed to distinguish a pair of compounds given in part (a) (ii) and failed to arrange correctly (in order of increasing the acidic strength) the compounds in part (b) (ii).

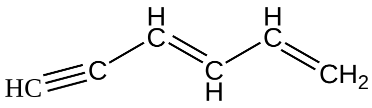
2.1.12 Question 12: Aromatic Hydrocarbons

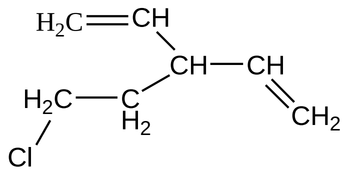
Part (a) (i) of this question required the candidates to define the term isomerism while part (a) (ii), required the candidates to draw three structures of the isomers of pentane and provide their corresponding IUPAC names.

In part (b), the candidates were required to give the IUPAC names of the following compounds:

(i) 

(ii) 

(iii) 

(iv) 

In part (c), the candidates were given the information that "Compound **A** is known to be an aromatic and contains 66.4% carbon, 5.5% hydrogen and 28.1% chlorine by mass. The vapour density of a pure **A** was found to be 63." With this information the candidates were asked to:

(i) Find the empirical formula of compound **A.**
(ii) Find the relative molecular formula of compound **A.**
(iii) Give the chemical structures of the four isomers of compound A and their corresponding IUPAC names.
(iv) Identify the isomers of compound **A** that would react with dilute KOH; and explain their answer briefly."

The question was attempted by 29,924 candidates corresponding to 86.6%. The scores in this question were as follows: 49.2% of the candidates scored marks ranging from 0 - 3.0, 38.3% scored from 3.5 - 5.5 marks while 12.5% of the candidates scored from 6.0 – 10 marks.

Statistical data shows that 50.8% of the candidates scored 3.5 marks and above indicating an average performance in general. The analysis of the candidates' responses in this question indicated that those who scored high marks were knowledgeable about isomerism. They managed to apply the IUPAC rules to name the given compounds correctly. Moreover, they managed to perform the required calculations and give an empirical formula.

In addition, they managed to provide proper explanations on the identified isomers of compound A that reacted with dilute KOH. This was found to be due to sufficient competences developed by the candidates on various chemical reactions involving aromatic hydrocarbons. The candidates who performed averagely, failed to deduce the molecular formula of compound **A** hence, failed in the subsequent parts of the question. Extract 12.1 displays a sample of good responses in this question.

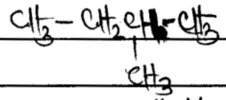
12 (a) i/ Isomerism: Is the occurrance of two or more organic compounds with the same molecular fomuls but different structural arrangement.

ii/ Given,

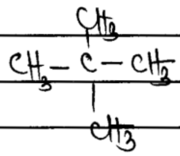
Pentane → C_5H_{12}

→ $CH_3-CH_2-CH_2-CH_2-CH_3$ ~~CH_3~~

n- pentane

→ 

2-methylbutane

→ 

2,2-Dimethylpropane

(b) (i) 3-ethylhex-2-ene

(ii) ~~Octa~~ Octa-2-en-5-yne

(iii) hexa-1,3-dien-5-yne.

(iv) 3-(2-chloroethyl)-penta-1,4-diene

12 (c)

element	C	H	Cl
Percentage abundant	$\frac{66.6}{12}$	$\frac{5.5}{1}$	$\frac{28.1}{35.5}$
Divide by smallest number	$\frac{5.5}{0.79}$	$\frac{5.5}{0.79}$	$\frac{0.79}{0.79}$
Simplest form	6.9	6.9	1
	7	7	1

Empirical formular = C_7H_7Cl

(ii) Vapour density = $\frac{\text{Molecular weight}}{2}$

Molecular weight = 2×V.D

= 2 × 63

= 126 g/mol

Then. (Emprical formular)n = Molecular weight

$(C_7H_7Cl)n = 126$

126.5n = 126.

n = 126/126.5

= 0.9

≈ 1

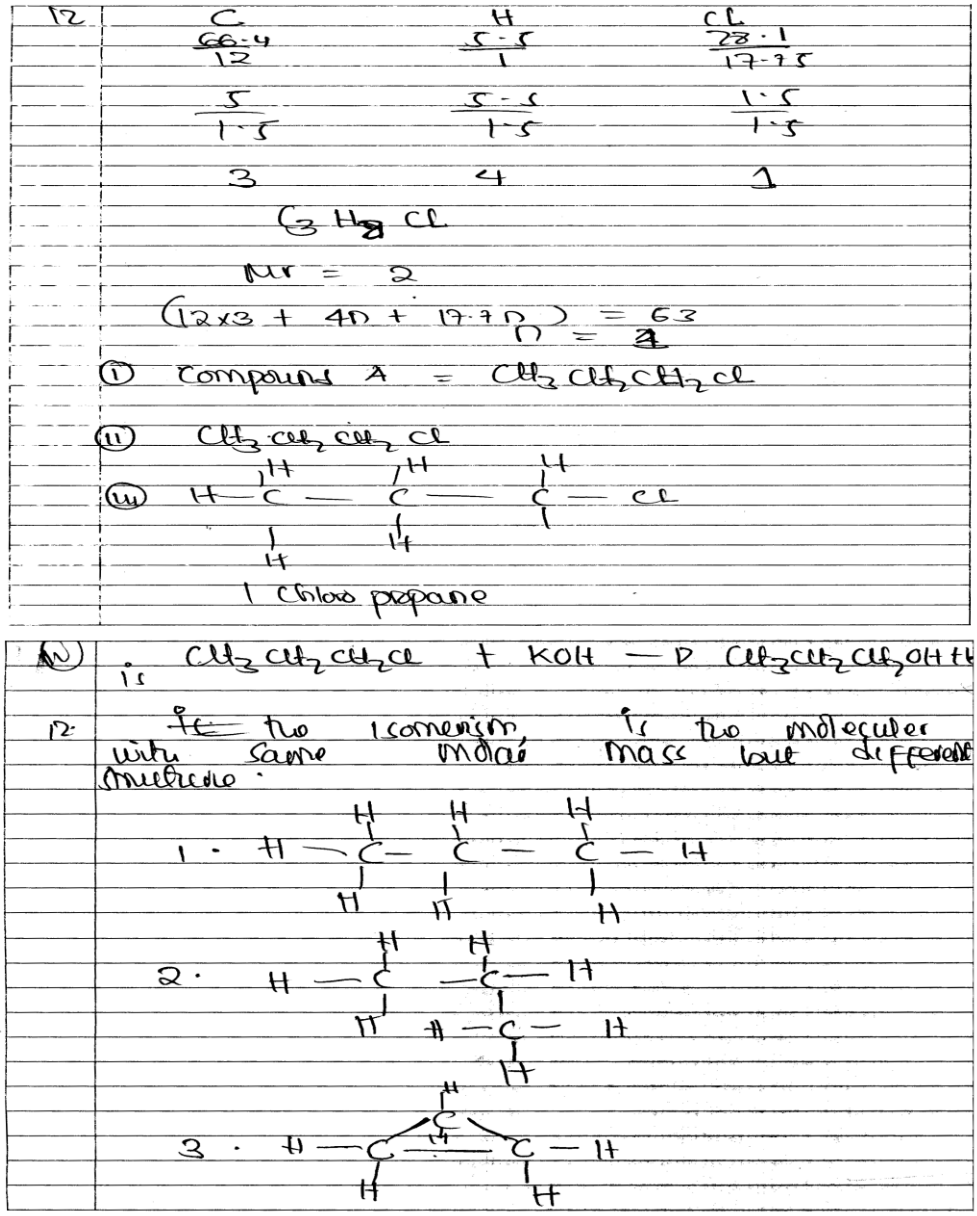
∴ Molecular formular of compound A is C_7H_7Cl.

(iii) Compound A → C_7H_7Cl

Extract 12.1: A sample of good responses in question 12.

Extract 12.1 displays responses from a candidate who drew and named appropriately the isomers of pentane. He/she gave correct responses to the rest parts of the question and scored high marks. However, the candidate gave a partial definition of the term isomerism in part (d) (i).

On the other hand, the candidates who scored low marks showed little understanding of the concept of isomers and their existence. Thus, they provided isomers of pentane with their corresponding names which unfortunately, did not follow the IUPAC system. This, together with the lack of mathematical manipulations skills as well as poor mastery of the characteristic reactions of different functional groups in organic chemistry, lead to loss of marks. Extract 12.2 illustrates a set of poor responses given by one of the candidates.



Extract 12.2: A sample of correct responses in question 12.

In Extract 12.2 a candidate wrongly used 17.75 as an atomic mass of Cl instead of 35.5. Although the candidate seemed to know some organic chemistry structures, he/she failed to organize them properly.

2.1.13 Question 13: Aliphatic Hydrocarbons

The question had four parts; (a), (b), (c) and (d). In part (a), the candidates were required to write all the isomers of C_5H_{12}. Part (b) required the candidates to draw the structural formulae of (i) 2,2-dimethylpropane and (ii) 4-methylpent-2-yne. In part (c), they were asked to name the compounds (i) $CH_3CH{=}CHCH_3$ and (ii) $CH_3C{\equiv}CCH_2CH_3$.

In part (d), the candidates were given the information, "Ozonolysis of a hydrocarbon **R** (C_5H_{10}) in the presence of zinc dust gives compounds **S** (C_2H_3O) and **T** (C_3H_5O). While compound **S** gives negative iodoform test, compound **T** responds positively to iodoform test". Then, they were asked to (i) give the structures **R**, **S** and **T** and (ii) write all reaction equations that took place during the whole process. Part (e) required the candidates to explain how they can differentiate $CH_3C{\equiv}CH$ from $CH_3C{\equiv}CH_3$.

The candidates who attempted this question were 29,488 corresponding to 85.4%. Distribution of scores in this question was as follows: 41.1% scored marks ranging from 0 - 3.0, 41.1% scored from 3.5 - 5.5 while 17.8% scored marks in the range of 6.0 - 10. Performance of the candidates in this question is summarized in Table 1.

Table 1: Number, Percentage and Scores of the Candidates in Question 13

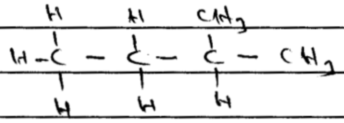
Scores	Number of Candidates	Percentage of Candidates
0.0 - 3.0	12,125	41.1
3.5 - 5.5	12,120	41.1
6.0 – 10	5243	17.8

Table 1 shows that majority of the candidates (58.9%) answered the question correctly (scored 3.5 marks and above). This indicates an average performance in overall.

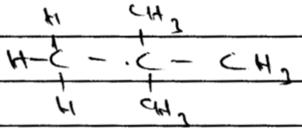
The analysis showed that, most of the candidates who attempted this question were acquainted to most of the concepts accessed. The candidates had good understanding on key concepts such as isomerism, application of IUPAC rules in naming organic compounds as well as different chemical tests exhibited by different functional groups. Extract 13.1 is a sample of good responses provided by a candidate in question 13.

13a) Isomers of C_5H_{12}

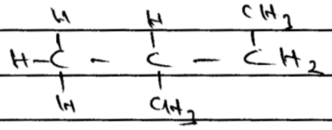
i)



ii)

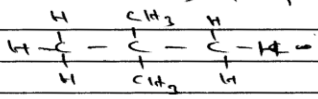


iii)

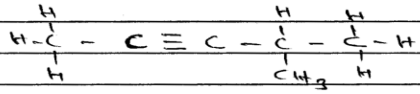


iv) $CH_3 - CH_2 - CH_2 - CH_2 - CH_3$.

13b) i) 2,2 - Dimethyl propane.



ii) 4 - Methyl pent - 2 - yne.



13c) i) But - 2 - ene.

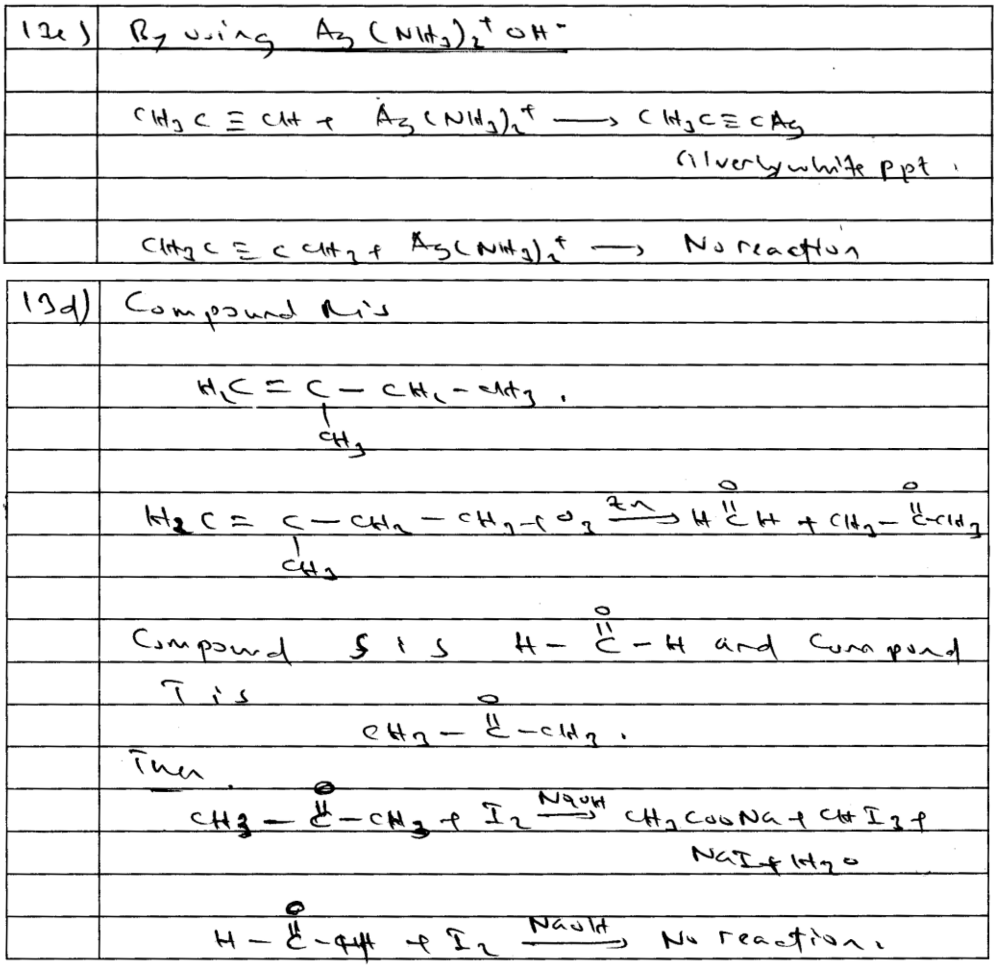
ii) Pent - 2 - yne

13e) By using CuCl

$CH_3C \equiv CH + CuCl \longrightarrow CH_3C \equiv CCu + HCl$

↳ Brick red ppt.

$CH_3C \equiv CCH_3 + CuCl \longrightarrow$ No reaction



12e) By using $Ag(NH_3)_2^+OH^-$

$CH_3C\equiv CH + Ag(NH_3)_2^+ \longrightarrow CH_3C\equiv CAg$
silvery white ppt.

$CH_3C\equiv CCH_3 + Ag(NH_3)_2^+ \longrightarrow$ No reaction

13d) Compound R is

$H_2C=C(CH_3)-CH_2-CH_3$.

$H_2C=C(CH_3)-CH_2-CH_3 + O_3 \xrightarrow{Zn} H\overset{O}{\overset{\|}{C}}H + CH_3-\overset{O}{\overset{\|}{C}}-CH_3$

Compound S is $H-\overset{O}{\overset{\|}{C}}-H$ and Compound T is

$CH_3-\overset{O}{\overset{\|}{C}}-CH_3$.

Then

$CH_3-\overset{O}{\overset{\|}{C}}-CH_3 + I_2 \xrightarrow{NaOH} CH_3COONa + CHI_3 + NaI + H_2O$

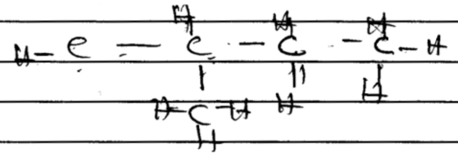
$H-\overset{O}{\overset{\|}{C}}-H + I_2 \xrightarrow{NaOH}$ No reaction.

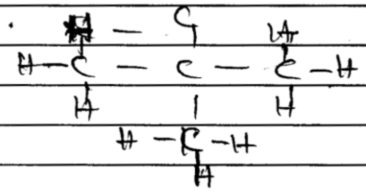
Extract 13.1: A sample of correct responses in question 13.

Extract 13.1 shows responses of a candidate who wrote all the isomers of C_5H_{12} correctly and drew the correct structural formulae of isomers with their corresponding IUPAC names. The candidate, further managed to answer correctly the remaining parts of the question.

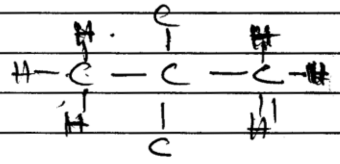
However, the analysis showed that some of the candidates who attempted this question scored low marks. The analysis of these candidate's responses revealed that they were incompetent in the concept of isomerism. Hence, they drew incorrect structures and provided the names without putting into consideration the IUPAC rules. Moreover, the candidates lacked basic knowledge regarding the chemical properties of aliphatic hydrocarbons which is also taught in the ordinary level secondary education. Extract 13.2 illustrates one of the poor responses.

13. (a)

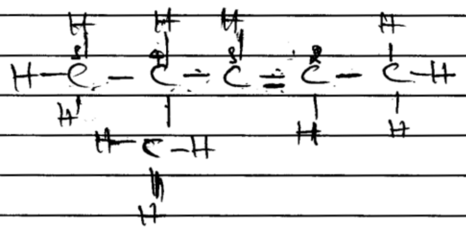




(b) (i) 2, 2 - dimethyl propane



(ii) 4 - methyl pent - 2 - yne

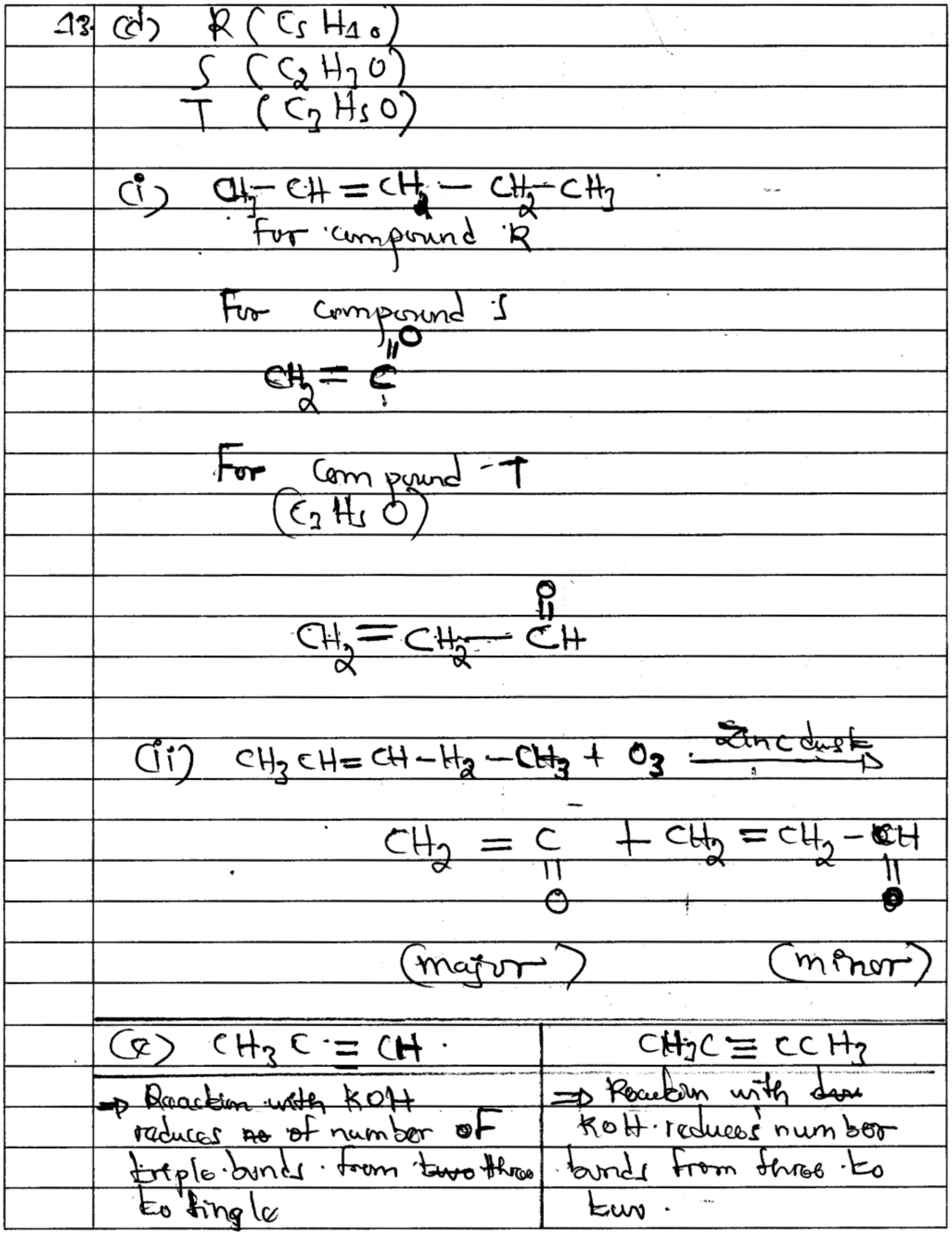


(c) (i) $\underset{4}{C}H_3\underset{3}{C}H = \underset{2}{C}H\underset{1}{C}H_3$

2 - en bub.

(ii) $CH_3C \equiv CCH_2CH_3$

3 - yne pent



13. (d) R (C_5H_{10})
S (C_2H_7O)
T (C_3H_5O)

(i) $CH_3-CH=CH_2-CH_2-CH_3$
For compound R

For compound S
$CH_2=C(=O)$

For compound T
(C_3H_5O)
$CH_2=CH_2-CH(=O)$

(ii) $CH_3CH=CH-H_2-CH_3 + O_3 \xrightarrow{\text{Zinc dust}}$
$CH_2=C(=O) + CH_2=CH_2-CH(=O)$
(major) (minor)

(e) $CH_3C\equiv CH$	$CH_3C\equiv CCH_3$
⇒ ~~Reaction with KOH~~ reduces ~~no of~~ number of triple bonds from ~~two~~ three to single	⇒ Reaction with ~~dsu~~ KOH reduces number bonds from three to two.

Extract 13.2: A sample of incorrect responses in question 13.

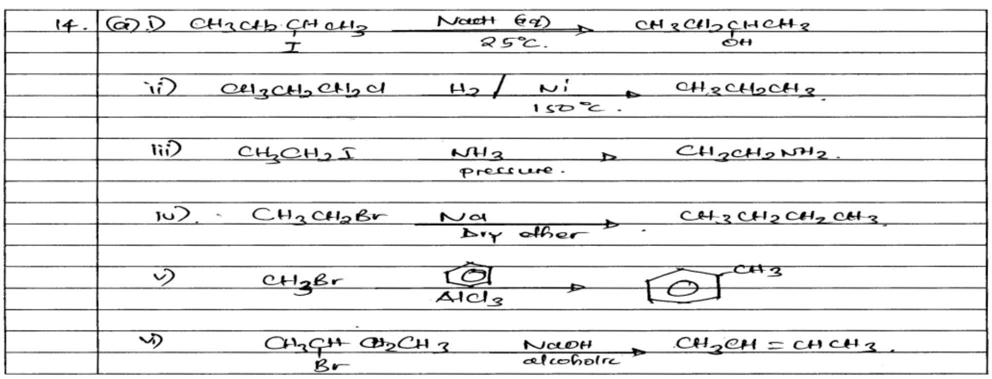
Extract 13.2 shows responses of a candidate who wrote the structural formulae without considering the valency of a carbon atom. The candidate also gave incorrect chemical formulae and equations in the remaining parts of the question.

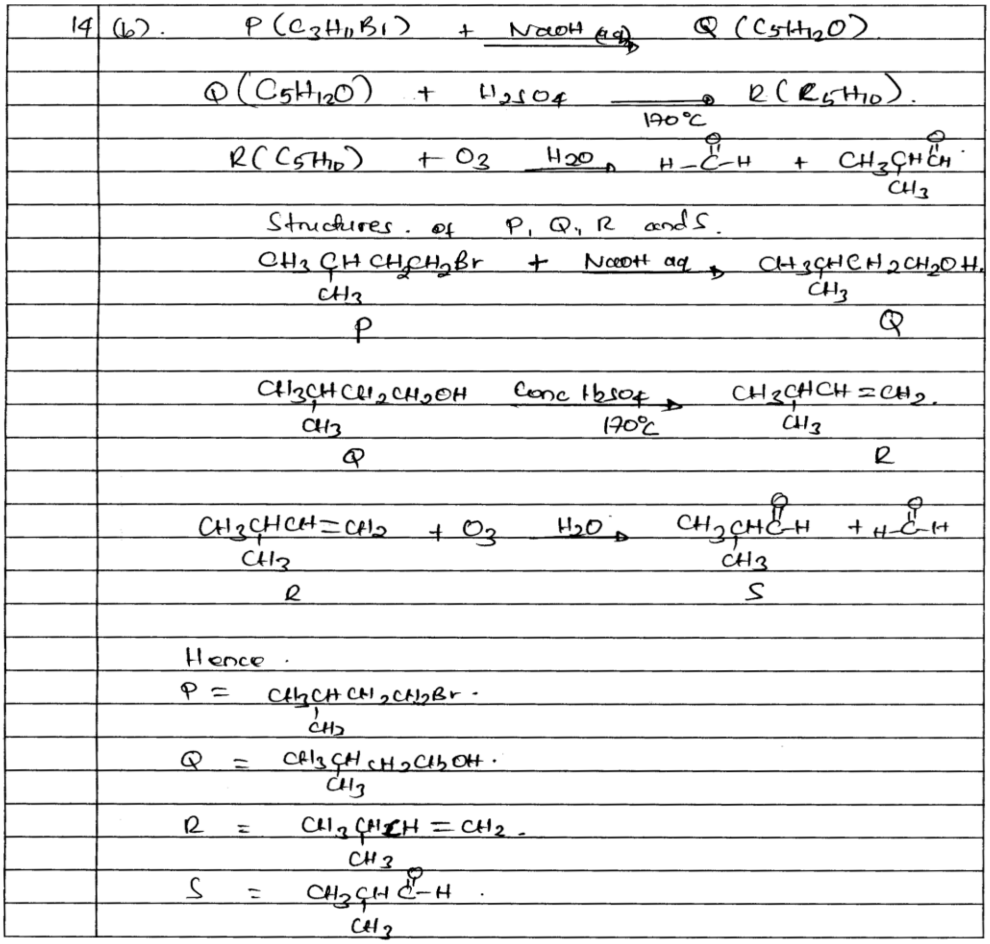
2.1.14 Question 14: Halogen Derivatives of Hydrocarbons

In Part (a), the candidates were required to show a one-step reaction on how the following molecules could be prepared. They were also required to indicate suitable reagents and conditions for their preparations: (i) Butan-2-ol from 2-iodobutane, (ii) Propane from 1-chloropropane, (iii) Ethylamine from iodoethane, (iv) Butane from bromoethane, (v) Methylbenzene from bromoethane and (vi) But-2-ene from 2-bromobutane. In Part (b), the candidates were given the information, “A haloalkane **P** ($C_5H_{11}Br$) reacts with aqueous sodium hydroxide to give **Q** ($C_5H_{12}O$). **Q** reacts with concentrated H_2SO_4 at 170℃ to form **R** (C_5H_{10}) which decolourises bromine water. When **R** is reacted with ozone followed by hydrolysis, methanal and a branched aldehyde **S** is formed.” Then, they were required to use the chemical reactions involved to deduce the structural formula of **P**, **Q**, **R** and **S**.

A total of 14,956 candidates corresponding to 43.3% attempted this question. The scores in this question were as follows: 52.8%, 28.7% and 18.5% of the candidates scored 0 - 3.0, 3.5 - 5.5 and 6.0 - 10 marks, respectively. The general performance of the candidates in this question was average as 47.2% scored marks ranging from 3.5 to 10.

The few candidates who managed to score high marks had adequate knowledge on the chemical properties of halogen derivatives of hydrocarbons, specifically the halo alkanes. They demonstrated possession of good knowledge on characteristic chemical reactions of different families of organic compounds such as alcohols, alkenes, haloalkanes and carbonyl compounds. This was signified as they managed to identify the compounds **P**, **Q**, **R**, and **S** through different reactions. Extract 14.1 represents a set of correct responses from one of the candidate.





14 (b). P ($C_5H_{11}Br$) + NaOH (aq) → Q ($C_5H_{12}O$)

Q ($C_5H_{12}O$) + H_2SO_4 →(170°C) R (C_5H_{10}).

R (C_5H_{10}) + O_3 →(H_2O) H–C(=O)–H + $CH_3CH(CH_3)CHO$

Structures of P, Q, R and S.

$CH_3CH(CH_3)CH_2CH_2Br$ (P) + NaOH aq → $CH_3CH(CH_3)CH_2CH_2OH$ (Q)

$CH_3CH(CH_3)CH_2CH_2OH$ (Q) →(Conc H_2SO_4, 170°C) $CH_3CH(CH_3)CH=CH_2$ (R)

$CH_3CH(CH_3)CH=CH_2$ (R) + O_3 →(H_2O) $CH_3CH(CH_3)C(=O)H$ (S) + H–C(=O)–H

Hence.

P = $CH_3CH(CH_3)CH_2CH_2Br$.

Q = $CH_3CH(CH_3)CH_2CH_2OH$.

R = $CH_3CH(CH_3)CH=CH_2$.

S = $CH_3CH(CH_3)C(=O)-H$.

Extract 14.1: A sample of correct responses in question 14.

Extract 14.1 displays responses of a candidate who interconverted correctly the functional groups. He/she also deduced correctly the structural formula of the compounds **P**, **Q**, **R** and **S**.

On the other hand, the candidates who scored low marks in this question had in adequate knowledge on the chemical properties of halo hydrocarbons especially halo alkanes. Additionally, they showed to have little knowledge on the specific chemical reactions of different families of organic compounds such as alcohols, alkenes, halo alkanes and carbonyl compounds. As a result, they identified wrongly the compounds **P**, **Q**, **R** and **S**. Extract 14.2 is a sample showing poor responses given by one of the candidate.

14 (b) P [$C_5H_{11}Br$]

structural formular.

P = $C_5H_{11}Br$

$CH_3\ CH_2CH_2CH_2CH_2Br$

∴ P = $CH_3CH_2CH_2CH_2CH_2Br$.

Q = $C_5H_{12}O$.

structural formular are

∴Q = $CH_3CH_2\underset{|}{C}H\,CH_2CH_3$
OH

S = CH_3CH_2O

R = C_5H_{10}

structural formular are

∴R = $CH_3CH_2CH{=}CH_2CH$

Reaction.

$CH_3CH_2CH_2CH_2CH_2Br$ + NaOH ⟶ $CH_3CH_2CH_2CH_2CHO$ (Q) + $NaBr_2$.
(P)

$CH_3CH_2CH_2CH_2CH_2OH$ + H_2SO_4 ⟶ $CH_3CH_2CH{=}CH_2CH$ (R).
(Q)

$CH_3CH_2CH{=}CH_2CH$ + O_3/Zn ⟶ CH_3CH_2[illegible] + CH_3CH_2 (S)
(R)

Extract 14.2: A sample of incorrect responses in question 14.

Extract 14.2 shows responses where by a candidate wrote incorrect chemical reactions which, in turn, mislead him/her to deduce correctly, the structural formulae of the compounds asked.

2.2 132/2-CHEMISTRY 2

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

2.2.1 Question 1: Acids, Bases and Salts

This question had four parts; (a), (b), (c) and (d). Part (a) required the candidates to define the following terms and give one example in each: (i) A conjugate base, (ii) A conjugate acid base pair, (iii) A conjugate acid, and (iii) Arrhenius acid. In part (b), the candidates were provided with the following reactions and required to label the conjugate acids and bases.

(i) $S^{2-}(aq) + H_3O^+(aq) \rightleftharpoons HS^-(aq) + H_2O(aq)$
(ii) $NH_4^+(aq) + H_2O(aq) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
(iii) $NH_2^-(aq) + H_2O(aq) \rightleftharpoons NH_3(aq) + OH^-(aq)$
(iv) $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$

In part (c), the candidates were required to calculate the concentration of hydrogen ions and hydroxyl ions in a 0.01 M solution of: (i) Hydrochloric acid and (ii) Acetic acid (α for CH_3COOH was 5%). In part (d), the candidates were provided with the information that, the K_w of water at 25℃ and 65℃ are 10^{-14} and 2.92×10^{-14} $mol^2\ dm^{-6}$, respectively and they were asked the following questions:

(i) State the effect of temperature in the dissociation of water
(ii) Calculate the $[H^+]$ at 65℃
(iii) Find the pH of water at 65℃
(iv) Calculate the pH of water under neutral condition at 65℃.

This question was attempted by 30,619 candidates corresponding to 88.7 percent, being the second most attempted question. Statistical analysis of the candidates performance indicated that, 27.2 percent scored 12 - 20, 37.8 percent scored 7 - 11.5 and 35 percent scored 0 - 6.5 marks. This indicated a good performance overall as the majority of the candidates (65.0%) managed to score an average mark and above (7 - 20).

Most of the candidates with high scores in this question were knowledgeable regarding the Brønsted-Lowry concept of acids and bases; hence, provided correct responses in most parts of the question. Furthermore, the candidates with high scores demonstrated good skills in mathematical manipulations and correctly applied an equation for ionic product of water to calculate $[H^+]$ and the pH of water at 65℃. Extract 15.1 shows the responses from one of the candidates who was able to give the correct answers and scored all the marks.

01. a) i) A conjugate base is the anion of an acid formed acid dissociates to ions.

Example:

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

acid — conjugate base

ii) A conjugate acid base pair is a pair of cation and anion formed when ions dissolve in water.

Example:

$$HCO^-_{3(aq)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + CO^{2-}_{3(aq)}$$

$H_3O^+_{(aq)} / H_2O_{(l)}$ and $HCO^-_{3(aq)} / CO^{2-}_{3(aq)}$ } conjugate acid base pair

iii) A conjugate acid is a cation formed when a base dissociates into its ions when dissolved in water.

Example:

$$NH_4Cl_{(aq)} \longrightarrow NH^+_{4(aq)} + Cl^-_{(aq)}$$

conjugate acid

01\. a i) Arrhenius acid is the ~~substance~~ specie that gives hydrogen proton as the only positive ion when dissolved in water.

Example:

$HNO_{3(aq)} \longrightarrow H^{+}_{(aq)} + NO_{3}^{-}{}_{(aq)}$

b i) $S^{2-}_{(aq)} + H_3O^{+}_{(aq)} \rightleftharpoons HS^{-}_{(aq)} + H_2O_{(l)}$

conjugate acid   conjugate base

ii) $NH_4^{+}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3(aq)} + H_3O^{+}_{(aq)}$

conjugate base   conjugate acid

iii) $NH_2^{-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3(aq)} + OH^{-}_{(aq)}$

conjugate acid   conjugate base

iv) $CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^{-}_{(aq)} + H_3O^{+}_{(aq)}$

conjugate base   conjugate acid.

c i)

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

0.01 M   0.01 M   0.01 M

$[H^+] = [HCl] = 0.01\,M$

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

$pH = -\log(0.01)$

$pH = 2$

01 c

i) $pH + pOH = pKw$

$pOH = pKw - pH$

$pOH = 14 - 2$

$pOH = 12$

but,

$pOH = -\log[OH^-]$

$[OH^-] = \log^{-1}(-pOH)$

$= \log^{-1}(-12)$

$[OH^-] = 1 \times 10^{-12} M$

$\therefore [H^+] = 0.01 M$ and $[OH^-] = 1 \times 10^{-12} M$

ii) $\alpha = 5\%$

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

0.01	0	0
$(0.01 - \alpha)c$	αc	αc

$[H^+] = \alpha c$

$= \frac{5}{100} \times 0.01 M$

$[H^+] = 5 \times 10^{-4} M$

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

$= -\log(5 \times 10^{-4})$

$pH = 3.3$

$pH + pOH = pKw$

$pOH = pKw - pH$

01. b ii) $pOH = 14 - 3.3$

$pOH = 10.7$

$pOH = -\log[OH^-]$

$10.7 = -\log[OH^-]$

$[OH^-] = \log^{-1}(-10.7)$

$[OH^-] = 2 \times 10^{-11} M$

$\therefore [H^+] = 5 \times 10^{-4} M$ and $[OH^-] = 2 \times 10^{-11} M$

d $K_w = 10^{-14} mol^2/dm^6$ at 25°C

$K_w = 2.92 \times 10^{-14} mol^2/dm^6$ at 65°C

i) Increase in temperature increases the extent of dissociation of water.

ii) $H_2O \rightleftharpoons H^+ + OH^-$

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

but

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

$K_w = [H^+]^2$

$2.92 \times 10^{-14} = [H^+]^2$

$[H^+] = 1.7088 \times 10^{-7} M$

$\therefore [H^+] = 1.7088 \times 10^{-7} M$.

01. d (iii) $pH = -\log [H^+]$

$= -\log (1.7088 \times 10^{-14})$

$pH = 6.767$

$\therefore pH = 6.767$.

(iv) $H_2O \rightleftharpoons H^+ + OH^-$

$Kw = [H^+][OH^-]$

but,

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

$Kw = [H^+]^2$

$2.92 \times 10^{-14} = [H^+]^2$

$[H^+] = 1.7088 \times 10^{-7} M$

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

$= -\log (1.7088 \times 10^{-7})$

$pH = 6.767$

$\therefore pH = 6.767$.

Extract 15.1: A sample of correct responses in question 1.

Extract 15.1 shows responses of a candidate who defined the terms properly, labelled correctly the conjugate acids and bases and performed correctly the required calculations.

On the other hand, some of the candidates who scored low marks in this question were not knowledgeable enough about the Brønsted-Lowry concept of acids and bases. Moreover, these candidates had difficulties in performing correct mathematical approaches on specific parts of the question. They were also unable to apply the equation for ionic product of water to calculate $[H^+]$ and the pH of water at 65℃. Extract 15.2 represents the responses from a candidate who gave incorrect answers.

1 (i) Conjugate base: is the reaction of the substance which consist the base only.

(ii) Conjugate acid base pair: is the reaction substance which consist both the acid and base for the same time.

(iii) A conjugate acid: is the reaction which concern with the acidic properties only.

(iv) Arrhenius acid: is the equation which involve the product or reactant of acid alone

(b)

(i) $S^{2-}_{(aq)} + H_3O^+_{(aq)} \rightleftharpoons HS^-_{(aq)} + H_2O_{(L)}$
conjugate acid.

(ii) $NH_4^+{}_{(aq)} + H_2O_{(L)} \rightleftharpoons NH_3{}_{(aq)} + H_3O^+{}_{(aq)}$ is conjugate acid.

(iii) $NH_2^-{}_{(aq)} + H_2O_{(L)} \rightleftharpoons NH_3{}_{(aq)} + OH^-{}_{(aq)}$ is conjugate base.

(iv) $CH_3COOH_{(aq)} + H_2O_{(L)} \rightleftharpoons CH_3COO^-{}_{(aq)} + H_3O^+{}_{(aq)}$ is conjugate base.

1. (i) Data given
Molarity = 0.01M.

$(HCl) = (1+35) = 36$
$HCl = 36\,g/mol.$

Conc = Molarity / Molar mass

Conc = 0.01 M / 36g/mol = 2.77×10^{-4}

Concentration of HCl = 2.77×10^{-4} mol

(ii) CH_3COOH is 5%.

$(12+1\times3+12+16+16\times1)$
$12+3+12+16+16$
49 g/mol

5/100 of CH_3COOH.

$5/100 \times 49 = 2.45$

2.45 g/mol.

Conc = 0.01M / 2.45 g/mol = 4.08×10^{-3} mol^{-1}

Concentration of (CH_3COOH) is 4.08×10^{-3} mol^{-1}

1 (d) (i) The effect of temperature in the dissociation of water is that when the temperature of water increase the rate of water dissociation decrease.

(ii) H^+ at 65°C = $\left(\frac{2.92 \times 10^{-14}}{1 \times 10^{-14}}\right)$

$H^+ = 2.92$.

$[H^+]$ at 65°C = 2.92 $mol^2 dm^{-4}$

Date given
Initial temp = 25°C
Final temp = 65°C
Initial Molar = 10^{-14} $mol^{12} dm^{-6}$
Final molar = 2.92×10^{-14} $mol^{-2} dm^{-6}$

(iii) PH = ?

$\frac{X}{65} = \frac{1 \times 10^{-14}}{2.92 \times 10^{-14}}$

$\frac{X}{65} = 0.0342$

$X = 65 \times 0.0342$

$X = 22.2602$

PH of water at 65°C = 22.26

Extract 15.2: A sample of incorrect responses in question 1.

Extract 15.2 shows responses from a candidate who gave incorrect definitions of terms and performed wrong calculations.

2.2.2 Question 2: Chemical Kinetics

This question had four parts namely; (a), (b), (c) and (d). In part (a) (i), the candidates were required to explain: (i) Average rate of reaction and (ii) Rate constant (k). In part (b) (i), the candidates were asked to briefly explain why they would prefer a catalyst that works at room temperature rather than heating the reactants to 200℃; if they were incharge of a chemical company. In part (b) (ii), the candidates were informed of a student's definition of substance that speeds up a reaction without taking part in the reaction. They were asked to state what they found wrong with the definition.

In part (c), the candidates were asked to explain the following:

(i) Powdered sugar dissolves faster than crystalline sugar.
(ii) It takes more time to cook rice at higher altitudes than low altitudes.
(iii) We save fuel when we use a pressure cooker.
(iv) There is no difference in cooking time between sea level and higher altitude when we use a pressure cooker at both places.

In part (d), the candidates were instructed to consider the reaction with E_a = 75 $kJmol^{-1}$ at 293 K. When a catalyst is used in the same reaction at 20℃, its E_a is lowered to 20 $kJmol^{-1}$". Then they were asked to calculate how fast the catalyzed reaction is with respect to uncatalyzed one.

The question was attempted by 19,009 candidates, equivalent to 55.1 percent, out of which 15,823 candidates (83.2%) scored 0 - 6.5 marks indicating a poor performance and 2,520 candidates (13.3%) scored 7 - 11.5 marks, showing an average performance. The candidates, who scored 12 - 20 marks which indicates a good performance, were 666 (3.5%). The performance of the candidates is summarized in Figure 10.

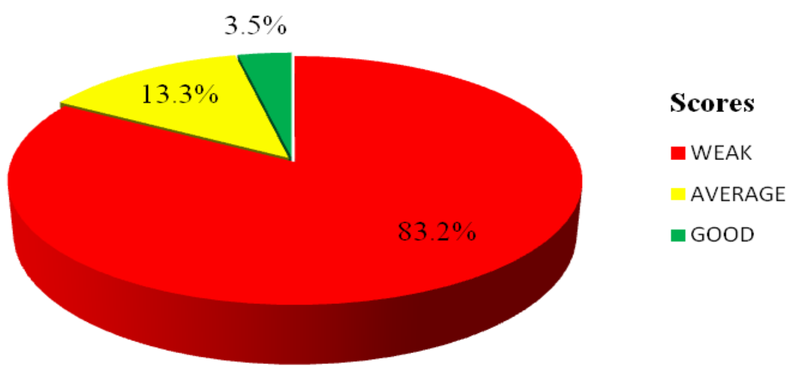
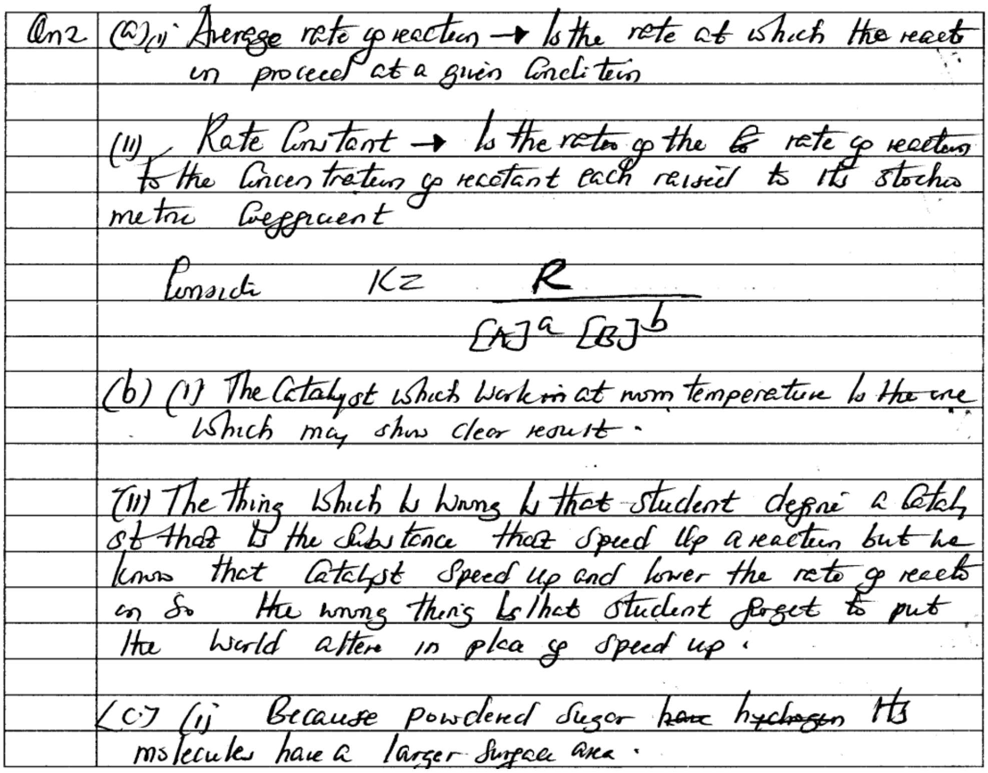


Figure 10: *Performance of the candidates in question 2*

The statistical data in Figure 10 shows that, majority of the candidates (83.2%) scored below 7.0 marks. Hence, the most poorly performed question in the two papers. Further statistical analysis (not shown in Figure 10) indicates that 869 candidates corresponding to 4.6% scored a zero mark while only one candidate was able to score a full mark.

Majority (83.2%) of the candidates answered this question incorrectly due to poor background on the basic concepts regarding chemical kinetics. They lacked appropriate basic mathematical skills which could have enabled them to properly tackle the parts of the question that needed mathematical manipulations. Further analysis of their responses, revealed that the candidates failed to integrate the theoretical part of this topic with the real life activities. Hence, they were not able to figure out how the cooking time is affected by altitude. The lack of these appropriate competences made most of the candidates lose marks. Extract 16.1 shows a sample of responses given by one of the candidates who performed poorly in this question.


Qn2 (a)(i) Average rate of reaction → is the rate at which the reaction proceed at a given condition

(ii) Rate constant → is the ratio of the rate of reaction to the concentration of reactant each raised to its stochiometric coefficient

Consider K = R / [A]^a [B]^b

(b) (i) The catalyst which work at room temperature is the one which may show clear result.

(ii) The thing which is wrong is that student define a catalyst that is the substance that speed up a reaction but he know that catalyst speed up and lower the rate of reaction so the wrong thing is that student forget to put the world alter in place of speed up.

(c) (i) Because powdered sugar have hydrogen its molecule have a larger surface area.

Qn 2. (c) (ii) Because the temperature is low in higher altitude

(iii) Because the fuel move in form of vapour due compression of the pressure cookers and hence no much consumption of fuel.

iv/ Because at sea level and higher altitude both area have low temperature so there is no difference in cooking time between the two region

Extract 16.1: A sample of incorrect responses in question 2.

Extract 16.1 shows some responses from a candidate who gave improper definition of the terms. He/she managed to partly modify the definition of a catalyst, but did not mention that the catalyst participate in the reaction and regenerated at the end. Moreover, the candidate provided wrong explanations in the remaining parts of the question.

On the other hand, the few candidates who gave correct responses showed good understanding of the basic terms used in the topic of *Chemical Kinetics*. They were familiar with the properties and mechanisms of catalysts. Moreover, they showed proper knowledge on the relationship between boiling point and atmospheric pressure, hence scored most of the marks.

These candidates were further knowledgeable about the factors affecting the rate of chemical reactions such as surface area, concentration, pressure and temperature which enabled them to respond correctly in part (c) of the question and scored most of the marks. Extract 16.2 represents a set of good responses shown by one of the candidates.

2a	i) Average rate of reaction - Is the amount of products formed per time for the completion of the reaction. It is dependent on temperature, concentration of reactants and surface area of reactants.

2a	ii) Rate constant (k) - Is a temperature dependant constant which is given by the ratio between the rate of a reaction and the product of concentrations each raised to their order according to the rate law.
b	i) Because the catalyst would enable the reaction to take place at a lower temperature which would make the energy requirements less and the process would be more economical.
	ii) She is wrong about catalysts not taking part in the reaction because they do but they just remain unchanged at the end of the reaction. ~~Also~~, ~~catalysts~~ she is also wrong about catalysts only speeding up reactions as there are catalysts which reduce the speed of a reaction.
c	i) Powdered sugar dissolves faster because it has higher surface area compared to crystalline sugar thus comes into contact with water easier than the other.
	ii) Because at higher altitudes pressure is lower therefore it takes higher temperature and more time for the rice to be softened by the heated water.

2c	iv) Yes, since the pressure cooker maintains the same pressure at all altitudes therefore heat used will be the same and the cooking time will also be similar at both places.
d.	Given.
	$E_a = 75 kJ mol^{-1}$
	$T_1 = 293 K.$
	$T_2 = 293 K.$
	$E_{a_2} = 20 kJ/mol$
	for uncatalysed reaction,
	recall Arrhenius equation.
	$K = Ae^{-E_a/RT}$
	$K_1 = Ae^{-E_a/RT}$
	$\ln K_1 = \ln A + \ln e^{-E_a/RT}$
	$\ln K_1 = \ln A - \frac{E_{a_1}}{RT_1}$ - - - (i)
	for catalysed reaction,
	$\ln K_2 = \ln A - \frac{E_{a_2}}{RT_2}$ - - - (ii)
	taking equation (i) minus equation (2)
	$\ln K_1 - \ln K_2 = -\frac{E_{a_1}}{RT_1} + \frac{E_{a_2}}{RT_2}$
	$\ln K_1/K_2 = \frac{1}{RT}(E_{a_2} - E_{a_1})$
	$\ln K_1/K_2 = \frac{1}{8.314 \times 293}(20 - 75) \times 10^3$
	$\ln K_1/K_2 = -22.59$
	$K_1/K_2 = e^{-22.59}$
2d.	$K_1/K_2 = 1.548 \times 10^{-10}$
	$K_2 = \frac{K_1}{1.548 \times 10^{-10}}$
	$K_2 = 6.46 \times 10^9 K_1$
	∴ The catalysed reaction is 6.46×10^9 times ~~the~~ faster than the uncatalysed reaction.

Extract 16.2: A sample of correct responses in question 2.

Extract 16.2 shows responses of a candidate who managed to define the terms properly and performed the required calculations correctly.

Question 3: Electrochemistry

This question consisted of four parts namely: (a), (b), (c) and (d). Part (a) required the candidates to describe the following:

(i) Standard electrode potential.

(ii) Electrochemical series.

Part (b) (i) required the candidates to write the equation showing how the electromotive force (e.m.f) of the following cell changes with their ions concentration;

$$Ce(s) \,|\, Ce^{3+}(aq) \,\vdots\vdots\, Cr^{3+}(aq) \,|\, Cr(s)$$

While part (b) (i) required the candidates to calculate the value of the equilibrium constant, for the following reaction given that;

$$\varepsilon^{o}\ Ce^{3+} / Ce = -2.33\ v \text{ and } \varepsilon^{o}\ Cr^{3+}/ Cr = -0.41\ v$$

$$Ce(s) + Cr^{3+}(aq) \rightleftharpoons Ce^{3+}(aq) + Cr(s)$$

In part (c) (i), the candidates were required to write down the expression for the e.m.f of a cell for the reaction:

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

In part (c) (ii), the candidates were required to state why the oxidizing power of manganate (VII) ions in (c) (i) was quite sensitive to the concentrations of hydrogen ions. In part (d), the candidates were required to give a brief explanation on any four methods used to prevent rusting.

The question was attempted by 27,402 candidates corresponding to 79.4 percent. The statistical analysis revealed that 10.7 percent of the candidates scored 12.0 - 20.0 marks, 38.3 percent scored 7.0 - 11.5 and 51.0 percent scored 0 - 6.5 marks. Figure 11 summarizes the performance of the candidates in this question.

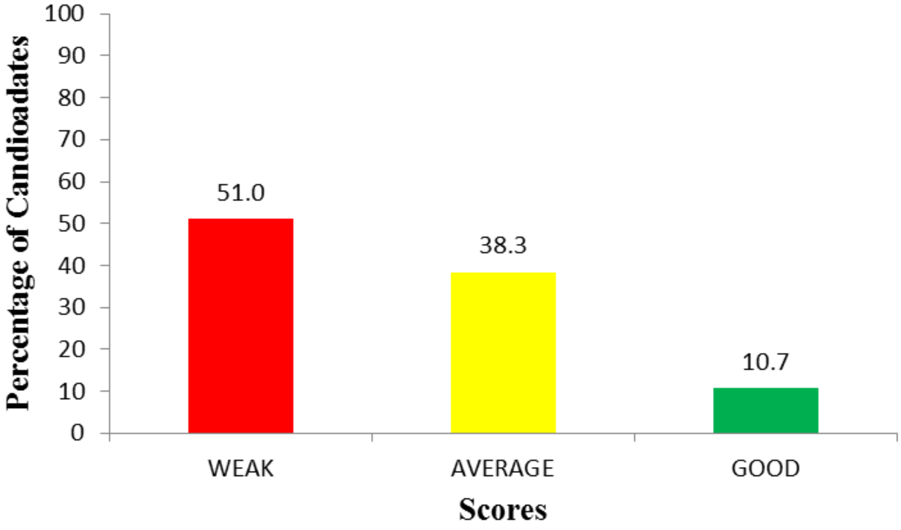


Figure 11: *Performance of the candidates in question 3.*

The data in Figure 11 shows that, 49.1 percent of the candidates passed the question as they scored an average mark and above (7.0 - 20). Most of the candidates who scored high marks in this question were familiar with the basic concepts regarding electrochemistry. They were able to use mathematical expressions to show the dependency of an equilibrium constant of a reaction, to concentration of reactants and products. In addition, these candidates revealed good background knowledge on the concept of rusting, hence, provided correct responses in the last part of the question. Extract 17.1 illustrates an example of good responses from one of the candidates.

3	a) i) Standard electrode potential is the electric potential generated on the electrode when it is in contact with 1M (1 molar) solution of its ions at standard conditions of temperature and pressure i.e 25°c and 1 atm.
	ii) Electrochemical series is the arrangement of elements in order of increasing reduction potential.
	b) i) Soln
	Given $Ce(s)/Ce^{3+}(aq) \| Cr^{3+}(aq)/Cr(s)$
	Emf of cell $= E^{\circ}_{cell} - \frac{0.0591}{3} \log \frac{[Ce^{3+}]}{[Cr^{3+}]}$
	$\therefore E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{3} \log \frac{[Ce^{3+}]}{[Cr^{3+}]}$
	ii) At equilibrium $E_{cell} = 0$.
	$\therefore 0 = E^{\circ}_{cell} - \frac{0.0591}{3} \log \frac{[Ce^{3+}]}{[Cr^{3+}]}$

$$E^\circ_{cell} = \frac{0.0591}{3} \log \frac{[Ce^{3+}]}{[Cr^{3+}]}$$

$$Ce_{(s)} + Cr^{3+}_{(aq)} \rightleftharpoons Ce^{3+} + Cr_{(s)}$$

$$Kc = \frac{[Ce^{3+}]}{[Cr^{3+}]}$$

$$\therefore E^\circ_{cell} = \frac{0.0591}{3} \log Kc$$

$$E^\circ_{cell} = E^R - E^L$$

$$= -0.41V - -2.33V$$

$$= 1.92 V.$$

$$\therefore 1.92 = \frac{0.0591}{3} \log Kc$$

$$\therefore \log^{-1}\left(\frac{3 \times 1.92}{0.0591}\right) = Kc$$

$$Kc = 2.897 \times 10^{97}$$

$\therefore$ Equlibrium constant $= 2.897 \times 10^{97}$

(4.7) Given

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

3 c) i) $E_{cell} = E_{MnO_4^-} - \frac{0.0591}{5} \log KQ$

$E_{cell} = E_{MnO_4^-} - \frac{0.0591}{5} \log \frac{[Mn^{2+}]}{[MnO_4^-][H^+]^8}$

ii) The oxidizing power of manganate ~~(VII)~~ (VII) is sensitive to concentration of hydrogen ions because the effect of concentration of hydrogen ions is eight times the effect of concentration of other components.

d) Methods of rusting prevention:-

i) Coating metal with zinc (zinc plating) this is the method which involves coating the metal with a thin sheet of zinc. It is more effective but cannot be used for food storage appliances.

ii) Tin plating. this involves coating the metal (iron) with tin. Tin prevents the contact of water and air thus prevent ~~the~~ the process of rusting.

iii) Painting - This involves covering an iron (metal) with several layers of rust resisting paints which prevent the contact of iron with water and air

iv) Using plastics. covers to cover the metal surface.

Extract 17.1: A sample of correct responses in question 3.

Extract 17.1 shows correct responses from a candidate who defined correctly the terms asked and showed how the e.m.f of a cell depends on the concentration of its ions. The candidate also wrote the equilibrium expression properly and performed the related calculations correctly. Moreover, he/she supplied appropriate methods for rusting prevention.

However, some of the candidates who attempted this question scored low marks. They failed to deduce the relationship between the electromotive force (e.m.f) of a given cell and the concentration of its ions. This was due to lack of appropriate competences in the subtopic *The Nernst Equation*.

Furthermore, the candidates had insufficient knowledge regarding the subtopic *Oxidation and Reduction*. Hence, they failed to understand the relationship between the oxidizing power of permanganate ions and the concentration of hydrogen ions. Extract 17.2 is an example of poor responses provided by one of the candidates.

8(a)	(i) The standard electrode potential.
	Is the device (apparatus) which used
	to measure electrical betwen eletrolyt
	(ii) Electrochemical series.
	Is the series which used to determine
	cation and anion in the solution.
3 b(i)	$Ce(s) / Ce^{3+} // Cr^{3+} / Cr(s)$.
	$Ce \rightleftharpoons Ce^{3+} - 3e$.
	$Cr^{3+} - 3e \rightleftharpoons Cr$
3 b(ii)	from
	$Ecell = \frac{0.0593}{n} \log Kc$.
	$Ecell = -0.41 + 2.33$
	$Ecell = 1.92$.
	$n = 3$

3(b)(ii)

$$E_{cell} = \frac{0.0593}{3} \log Kc.$$

$$1.92 = \frac{0.0593}{3} \log Kc.$$

$$\frac{1.93}{0.0197} = \frac{0.0197}{0.0197} \log Kc.$$

$$\frac{1.93}{0.0197} = \log Kc$$

$$Kc = \log^{-1}\left(\frac{1.93}{0.0197}\right)$$

$$Kc = 4.35 \times 10^{97}$$

3(c)(i)

$$e.m.f = E_{MnO_4} - E_{H^+}.$$

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

$MnO_4 \rightarrow Mn^{2+}.$

$MnO_4 \rightarrow Mn^{2+} + 4H_2O$

$MnO_4 \rightarrow Mn^{2+} + 4H_2O$

$MnO_4 + 8H \rightarrow Mn^{2+} + 4H_2O$ — (i)

3(d)(i) Painting, is the one methode preventing rusting by painting a colour.

Extract 17.2: A sample of incorrect responses in question 3.

Extract 17.2 shows wrong definitions given by a candidate as well as an unbalanced equation without an expression for the cell e.m.f.

2.2.3 Question 4: Periodic Classification

This question had four parts, namely: (a), (b) (c) and (d). Part (a) (i), required the candidates to define the term isoelectronic species. In part (a) (ii), the candidates were asked to name a species that will be isoelectronic with F^- and Mg^{2+}. In part (b), the candidates were asked to identify the elements of the second period, Li to Ne, with the specifics given below. The candidates were required to give reason for their answer in each case.

(i) An element with the highest first ionization energy.
(ii) An element with the highest electronegativity.
(iii) An element with the largest atomic radius.
(iv) An element that is most reactive non meta.
(v) An element that is the most reactive metal.

In part (c), the candidates were required to write a chemical equation representing the following:

(i) In moist air copper corrodes to produce a greenish layer on the surface.
(ii) Chlorination of calcium hydroxide produces a bleaching agent.
(iii) Adding concentrated H_2SO_4 in sugar produces a dense brownish black mass.
(iv) Action of phosphorus on concentrated HNO_3.
(v) Oxidation of hydrogen peroxide with potassium permanganate in acidic medium.
(vi) Action of zinc on dilute nitric acid.

In part (d), the candidates were supposed to consider that element **A** burns in nitrogen to give an ionic compound **B**. **B** reacts with water to give **C**. **C** reacts with CO_2 to give **D**. Also **C** gives a milky colouration on bubbling with CO_2. Excess bubbling of **C** gives a clear solution **E**. Then they were asked to use chemical equations to identify **A**, **B**, **C**, **D** and **E**.

This question was attempted by 4,923 candidates corresponding to 14.3 percent. This was the question which was attempted by the smallest number of candidates. The statistical data shows that, 82.6 percent of the candidates scored 0 - 6.5 marks, 15.6% scored 7 - 11.5 marks and 1.8% scored 12 - 20 marks. Figure 12 summarizes the performance of the candidates in this question.

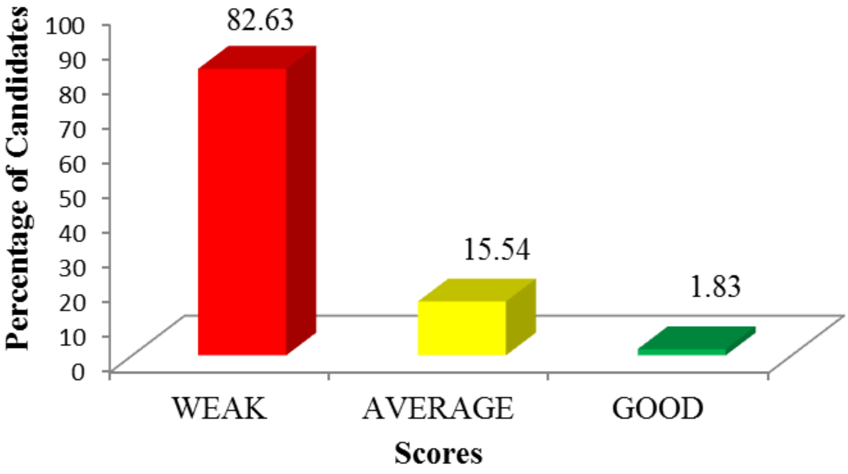


Figure 12: *Performance of the candidates in question 4.*

As shown in Figure 12, the general performance was poor because most of the candidates (82.6%) scored low marks (0 - 6.5). These candidates showed poor understanding of the isoelectronic concept. They also seemed to lack basic knowledge about the structure and arrangement of elements in the modern periodic table. Hence, they were not competent enough to point out the required elements asked. For instance, some candidates gave the meaning of ions in 4 (a) (ii) instead of writing the isoelectronic species asked. Moreover, they failed to write appropriate chemical equations in part (c) and (d). This was attributed to insufficient knowledge regarding periodicity and the chemical properties of different compounds of metals. Extract 18.1 represents a sample of candidates' poor responses.

4 (a) (i) Isoelectronic species are species of electron which resembles to a given electrons in chemical properties and composition

(ii) (1) F^- isoelectronic is Iron (II)
(2) Mg^{2+} Isoelectronic is magnesium oxide.

(b) (i) ~~Neon (N~~ Nitrogen (N) have high ionization energy
(ii) Oxygen (O_2) most electronegativity element
(iii) F. (Fluorine). Noble gas.
(iv) B (Boron) non-metal
(v) ~~Na. (sodium~~ Berylium (Be) metal.

(c) (i) $Cu + 2H_2O_{(aq)} = CuO_{2(aq)} + 2H_{2(l)}$

(ii) $Ca(OH)_{2(aq)} = CaO_{(s)} + H_2O_{(l)}$

4. (c) (iii) $H_2SO_4 + C_6H_{12}O_6 \rightarrow SO_2 + H_2$

(iv) $2P + 2HNO_3 \rightarrow 2PNO_3 + 2H_2O$

(v) $H_2O_2 + KMnO_4 \rightarrow KMnO_4 + H_2O$

(vi) $Zn_{(solid)} + HNO_{3(aq)} \rightarrow ZnNO_3 + H_2O$

4. (b) (i) Data given,

Element X,

Element X process; A, B, C, D, and E,

Solution,

To find A, B, C, D and E.

$X \xrightarrow{\Delta N_2} (A)^{-+}$

$(A)^{+-} + H_2O_{(l)} \rightarrow C$

$C + CO_2 \rightarrow D$

C → gives milky colouring on bubbling CO_2

excess bubble C → Clear solution E.

Extract 18.1: A sample of incorrect responses in question 4.

Extract 18.1 depicts responses of a candidate who gave a wrong definition of the term isoelectronic species. Moreover, the candidate though knew some chemical terms and symbols, he/she failed to organize them properly.

The few candidates, who managed to answer the question correctly, were able to define the term isoelectronic species and named all the required isoelectronic species. For instance, one of the candidates managed to name Ne, O^{2-}, Na^+, Mg^{2+}, and Al^{3+} as isoelectronic species to F^-. Moreover, they understood the periodic table properly hence, managed to answer the remaining parts of the question correctly. In addition, they showed a good mastery of the concept regarding the physical and chemical properties of compounds of metals and non-metals. This enabled them to give appropriate chemical equations in part (c). Extract 18.2 represents one of the best responses in this question.

4 (a) (i) Iso-electronic species are the ions of different elements having the same number of electrons.

(ii)
Isoelectronic with F^- is Ne with 10 electrons

Isoelectronic with Mg^{2+} is Na^+ with 10 electrons

(b)
(i) Neone, Ne
– This is because it is a noble gas with full-filled electronic shells that are more stable. It is also small in size.

(ii) Fluorine, F
– This is because, it is smaller in size with high electron density.

(iii) Lithium, Li
– This is because, it has less effective nuclear attractive force to contract the shells.

(iv) Fluorine, F
– This is because, it is more electronegative element and it is a strongest oxidising agent

(v) Lithium, Li
– This is due to its highest reducing power with lowest ionisation energy compared to other elements in a period.

4 (c)

(i) $Cu_{(s)} + CO_{2(g)} + H_2O_{(l)} \rightarrow CuCO_3$
greenish layer.

(ii)

$2Cl_{2(g)} + 2Ca(OH)_{2(aq)} \rightarrow Ca(ClO)_{2(aq)} + CaCl_{2(aq)} + 2H_2O_{(l)}$

↓ bleaching powder

(iii)

$C_{12}H_{22}O_{11(s)} + H_2SO_4 \xrightarrow{conc.} 12C_{(s)} + 11H_2O_{(l)}$

↓ Black mass

(iv)

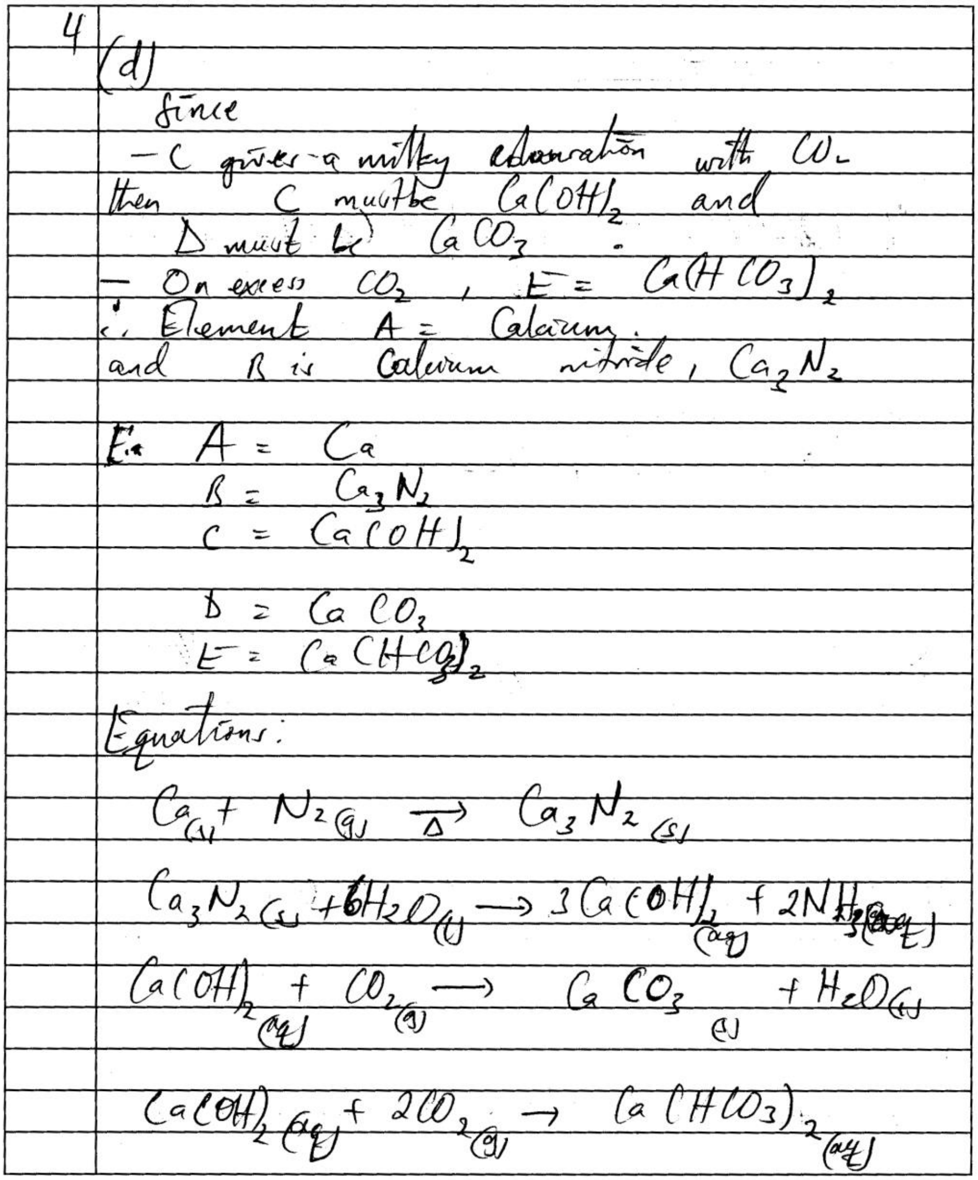
$P_{(s)} + 4HNO_{3(aq)} \rightarrow H_3PO_{3(aq)} + 2N_{2(g)} + \frac{1}{2}O_{2(g)}$

(v)

$2KMnO_{4(aq)} + 3H_2SO_{4(aq)} + 5H_2O_{2(aq)} \rightarrow 5O_{2(g)} + 2MnSO_{4(aq)} + K_2SO_{4(aq)} + 8H_2O_{(l)}$

(vi)

$Zn_{(s)} + 2HNO_{3(aq)} \rightarrow Zn(NO_3)_{2(aq)} + H_{2(g)}$



4 (d)
Since
– C gives a milky observation with CO_2
then C must be $Ca(OH)_2$ and
D must be $CaCO_3$.
– On excess CO_2, E = $Ca(HCO_3)_2$
∴ Element A = Calcium.
and B is Calcium nitride, Ca_3N_2

I.e. A = Ca
B = Ca_3N_2
C = $Ca(OH)_2$
D = $CaCO_3$
E = $Ca(HCO_3)_2$

Equations:

$Ca_{(s)} + N_{2(g)} \xrightarrow{\Delta} Ca_3N_{2(s)}$

$Ca_3N_{2(s)} + 6H_2O_{(l)} \rightarrow 3Ca(OH)_{2(aq)} + 2NH_{3(aq)}$

$Ca(OH)_{2(aq)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$

$Ca(OH)_{2(aq)} + 2CO_{2(g)} \rightarrow Ca(HCO_3)_{2(aq)}$

Extract 18.2: A sample of correct responses in question 4.

Extract 18.2 shows the responses where by a candidate managed to define the term isoelectronic species and named the species that are isoelectronic with F^- and Mg^{2+}. The candidate correctly identified the required elements in part (b) and finally, identified the compounds **A**, **B**, **C**, **D** and **E**.

2.2.4 Question 5: Selected Compounds of Metals

This question had three parts namely; (a), (b), and (c). Part (a) required the candidates to show with the aid of chemical equations, how the following oxides can be prepared:

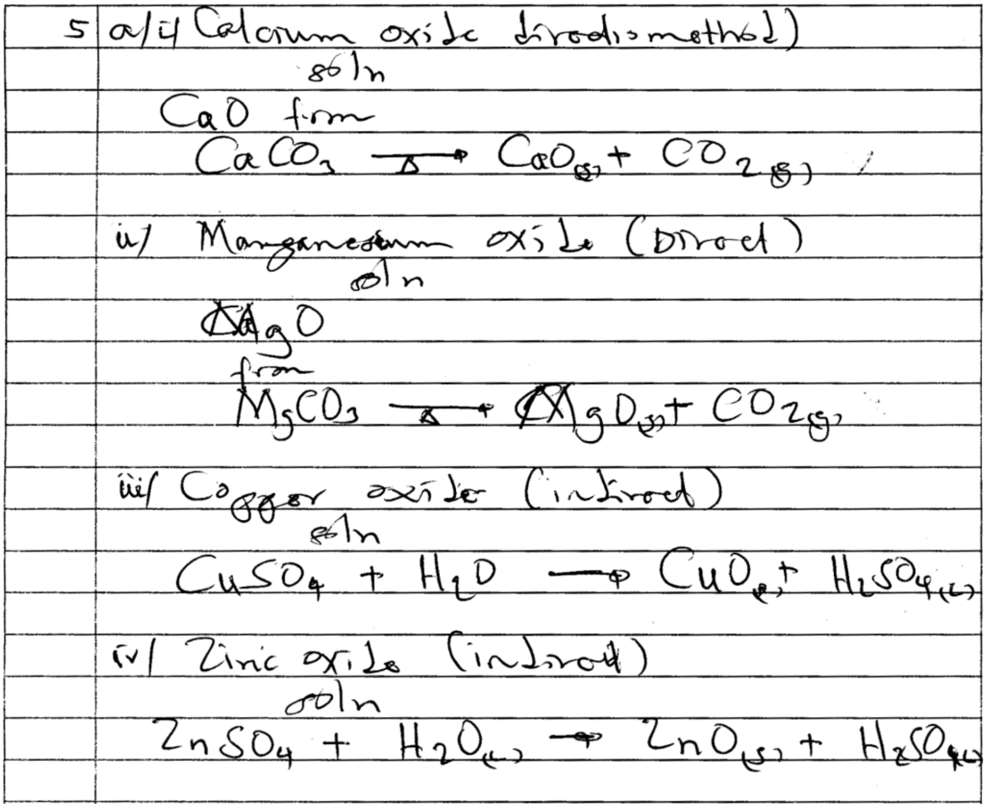
(i) Calcium oxide (Direct method).
(ii) Magnesium oxide (Direct method).
(iii) Copper oxide (Indirect method).
(iv) Zinc oxide (Indirect method).

Part (b) of the question required the candidates to show with the aid of a chemical equation, how the following carbonates can be prepared:
(i) Sodium carbonate.
(ii) Magnesium carbonate.
(iii) Zinc carbonate.

In part (c), the candidates were asked to state three uses of metal oxides.

The question was opted for by 8,428 candidates, equivalent to 24.4%. The candidates who scored 0 - 6.5, 7.0 - 11.5, 12 - 20 marks were 63.8, 24.0 and 12.2%, respectively. Majority (63.8%) of the candidates scored marks ranging from 0 - 6.5 which indicates a poor performance overall. Only a few candidates amounting to 12.2% scored good marks (12.0 - 20).

Most of the candidates with low scores were unable to link between the effect of heating a certain metal or a compound of metal in oxygen and the method of preparation of the asked oxides of metals. For the case of preparation of metal carbonates, most of the candidates had little knowledge on the chemical properties of nitrates, hydroxides, sulphates, chlorides and hydrogen carbonates of the respective metals in question. These weaknesses led them to fail to give proper methods used to prepare the metal oxides and carbonates asked. Extract 19.1 gives an example of poor responses given by one of the candidates to question 5.

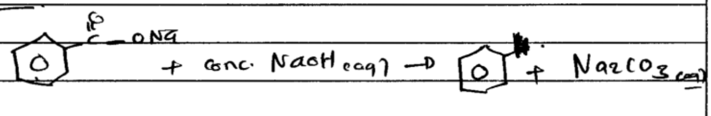

5 a/ i/ Calcium oxide (indirect method)
soln
CaO from
$CaCO_3 \xrightarrow{\Delta} CaO_{(s)} + CO_{2(g)}$
ii/ Manganesium oxide (Direct)
soln
MgO
from
$MgCO_3 \xrightarrow{\Delta} MgO_{(s)} + CO_{2(g)}$
iii/ Copper oxide (indirect)
soln
$CuSO_4 + H_2O \rightarrow CuO_{(s)} + H_2SO_{4(l)}$
iv/ Zinc oxide (indirect)
soln
$ZnSO_4 + H_2O_{(l)} \rightarrow ZnO_{(s)} + H_2SO_{4(l)}$

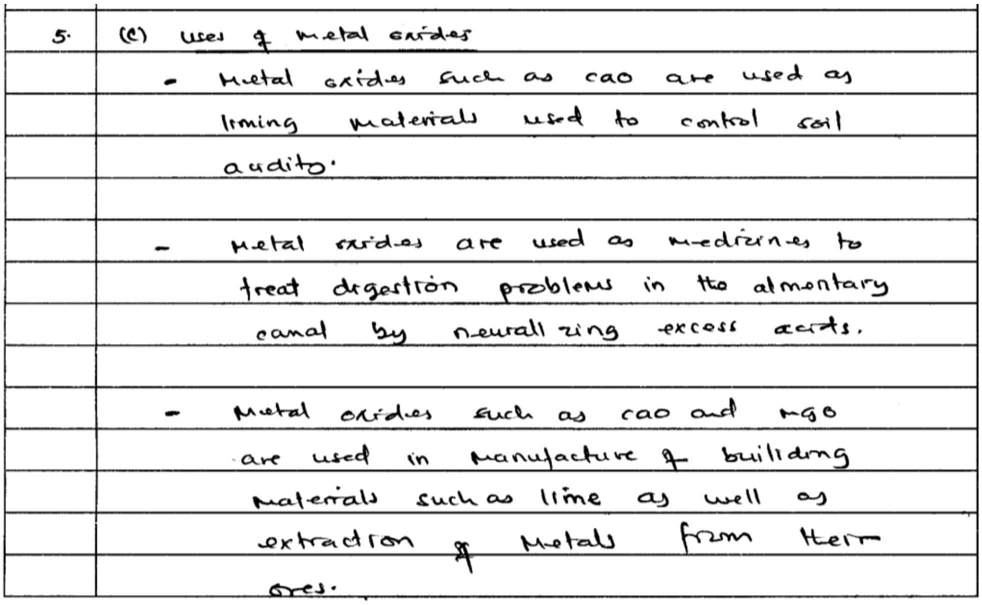
Extract 19.1: A sample of incorrect responses in question 5.

Extract 19.1 represents a set of responses from a candidate who gave indirect instead of direct methods for preparation of metal oxides. He/she also gave incorrect chemical reactions in the remaining part of the question.

On the contrary, the candidates who answered this question correctly were able to link between the effect of heating a certain metal or a compound of metal in oxygen and the method of preparing a particular metal oxide. For the case of preparation of metal carbonates, some few candidates had adequate knowledge on the chemical properties of nitrates, hydroxides, sulphates, chlorides and hydrogen carbonates of the respective metals in question. Thus, they managed to give appropriate chemical equations used to prepare the carbonates in question. Extract 19.2 represents a response from a script of a candidate who got high scores. `

Qn 5.	(i) - Burning calcium in presence of air.
	consider a chemical reaction.
	$2Ca + O_2 \longrightarrow 2CaO$
	Balanced chemical reaction will be.
	$2Ca_{(s)} + O_{2(s)} \longrightarrow 2CaO_{(s)}$.
	(ii). Burning of magnesium in presence of oxygen.
	(air).
	consider the reaction below:-

5.	(a) (ii) $2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$
	(iii). Decomposition of copper carbonate by heating.
	chemical equation will be.
	$CuCO_{3(s)} \xrightarrow{\Delta} CuO_{(s)} + CO_{2(g)}$
	(iv). - Decomposition of zinc carbonate by
	using heat.
	- consider a chemical reaction below:
	$ZnCO_{3(s)} \xrightarrow{\Delta} ZnO_{(s)} + CO_{2(g)}$
5.	(b). (i) - Reaction between sodium benzoate salt
	with concentrated sodium hydroxide.
	reaction
	
	(ii). - The reaction between Magnesium chloride
	and sodium carbonate.
	i.e.
	$MgCl_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow MgCO_{3(s)} + 2NaCl_{(aq)}$



5.	(c) Uses of metal oxides
	- Metal oxides such as cao are used as
	liming materials used to control soil
	audity.
	- metal oxides are used as medizines to
	treat digestion problems in the almentary
	canal by neurall zing excess acids.
	- Metal oxides such as cao and mgo
	are used in manufacture of building
	materials such as lime as well as
	extraction of metals from them
	ores.

Extract 19.2: A sample of correct responses in question 5.

Extract 19.2 displays a set of responses from a candidate who correctly used the chemical equations to show the preparations of metal oxides and carbonates. Finally, she/he managed to state the three uses of metal oxides correctly.

2.2.5 Question 6: Transition Elements

This question consisted of four parts namely; (a), (b) (c) and (d). Part (a) (i) required the candidates to explain how $[PtCl_2(NH_3)_2]$ and $[Pt(NH_3)_6]Cl_4$ differ in electrolytic conductance. In part (a) (ii), the candidates were asked to write the hybridization state of Pt in compounds at 6 (a) (i).

In part (b), the candidates were asked to identify with reasons, the coloured complexes from the following: (i) $[Ti(NO_3)_4]$, (ii) $[Cu(NH_3)_4]BF$, (iii) $[Cr(NH_3)_6]Cl_3$ and (iv) $K_3[VF_6]$. In part (c) (i), the candidates were required to distinguish paramagnetism from diamagnetism. In part (c) (ii), the candidates were asked to identify with a reason, the paramagnetic and diamagnetic compounds between $[Fe(CN)_6]^{4-}$ and $[FeF_6]^{6-}$.

In part (d), the candidates were given the information "An element **X** with a common oxidation state of +2 is obtained as a white gelatinous precipitates when sodium hydroxide is added to its ionic solution. When excess amount of the alkali is used, the precipitate dissolves. The precipitate also dissolves when an aqueous solution of ammonia is added in excess amount". Then, they were asked to deduce an element **X** using proper chemical equations from the given information.

This question was opted for by 9,316 candidates corresponding to 27.0%. Data analysis shows that, very few candidates (3.0%) scored from 12.0 - 20.0 which is a good performance, 20.1% of the candidates scored marks ranging from 7.0 - 11.5 which is an average performance and 76.9% scored from 0 - 6.5 indicating an unsatisfactory performance. Figure 12 summarizes the performance of the candidates in this question.

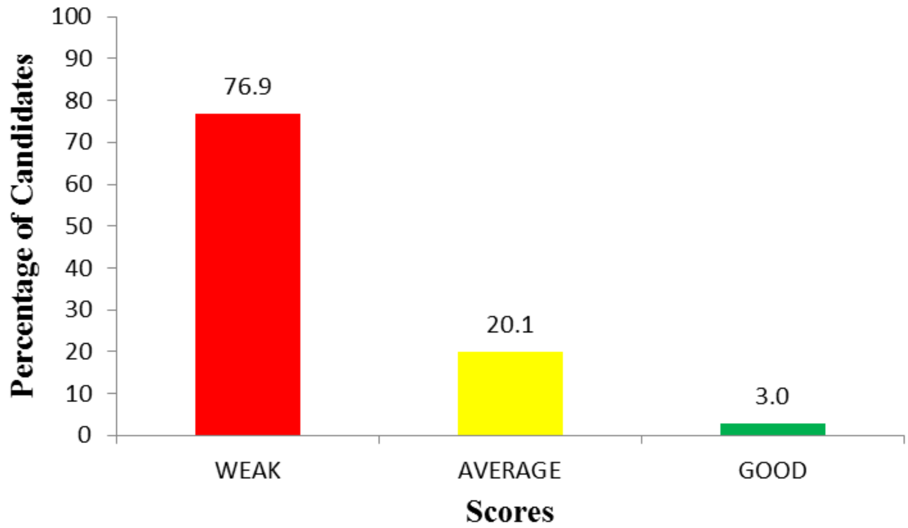


Figure 12: *Performance of the candidates in question 6*

The general performance in this item can be categorized as poor because 7,165 candidates corresponding to 76.9% scored from 0 - 6.5 marks. This indicates an unsatisfactory performance (Figure 12). The poor performance of the candidates in this question was attributed to insufficient competences, in the topics of *Transition Elements* and some concepts from *Selected Compounds of Metals*.

The analysis of the candidate's responses in this an unsatisfactory category revealed that candidates lacked knowledge of important properties that account for complex compound to conduct electricity. They had little knowledge of the Crystal field theory hence, failed to comment on the magnetic property and colour formation in complexes. Furthermore, these candidates seemed to lack prior knowledge on the concept of oxidation state of elements, hence failed to deduce the oxidation state of a central metal atom, a key point to this question. Extract 20.1 is a sample of poor responses from one of the candidates.

6. b) i) $[Ti(NO_3)_4]$
The colour of this complex is Green
This is because the nature of the
ligands. The ligands are strong.

ii) $[Cu(NH_3)_4$ BF
The colour of the complex is Green.
This is because the ligands is strong
the cupper also occur to make the green
colour of the ligands.

6 b) iv) $K_3[VF_6]$
The colour is Green.
This is because the the type of ligands.
The ligand are less to attract colour so the
green can appear.

Extract 20.1: A sample of incorrect responses in question 6.

Extract 20.1 shows responses of a candidate who gave wrong colours for complexes in part b (i) and (ii). The candidate also gave a wrong reason regarding a coloured complex in part (b) (iv).

However, some candidates had good performance in this question. They were able to provide correct responses in most parts of the question. These candidates had good knowledge regarding the formation of a complex compound. They showed understanding of the Crystal Field Theory (CFT) and hence, colour formation in complex compounds. Moreover, these candidates had prior knowledge on the concept of oxidation state of elements as well as characteristic chemical reactions of different compounds of metals like oxides, chlorides, sulphates, hydrogen carbonates, carbonates hydroxides and nitrates. Extract 20.2 shows a sample of good responses.

6(a) (i) $[Pt(NH_3)_6]Cl_4$ is very conducting in aqueous solution and hence has higher electrolytic conductance compared to $[PtCl_2(NH_3)_2]$. This is because, $[Pt(NH_3)_6]Cl_4$ tends to dissociate to form ions in the aqueous solution and these ions allow it to conduct electricity much faster and easily.

$$[Pt(NH_3)_6]Cl_4 \xrightleftharpoons{\text{dissociate}} [Pt(NH_3)_6]^{4+} + 4Cl^-$$

But, $[Pt(NH_3)_2Cl_2]$ cannot conduct as it is in molecular form and has no any ions in aqueous solution

$$[Pt(NH_3)_2Cl_2] \longrightarrow \text{no dissociation.}$$

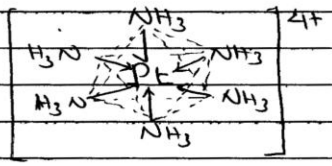
6(a) (ii)

Hybridisation in $[Pt(NH_3)_6]Cl_4$

Oxidation state in the compound.

$$x + (0)6 = +4$$
$$x = +4$$

The shape of the molecule is thus octahedral



Thus, hybridisation state of Pt in $[Pt(NH_3)_6Cl_4$ is sp^3d^2 hybridisation.

Hybridisation in $[Pt(NH_3)_2Cl_2]$

oxidation state in the compound

$$x + (0)2 + (-1)2 = 0$$
$$x - 2 = 0$$
$$x = +2$$

Extract 20.2: A sample of correct responses in question 6.

Extract 20.2 shows responses of a candidate who correctly explained, how the two complex compounds differ in terms of their electrolytic conductivity, and wrote the correct hybridization state of Pt. The candidate responded correctly in the rest part of the question while supporting his/her answers with correct chemical equations.

2.2.6 Question 7: Soil Chemistry

This question had four parts namely; (a), (b), (c) and (d). Part (a) (i) required the candidates to state four significance points of soil colloids. Part (a) (ii) required the candidates to brief explain briefly two effects of soil pH on plant growth. Part (b) of the question required the candidates to explain why it is important to manage soil pH.

In part (c), the candidates were required to consider that a certain soil sample was analyzed in the laboratory and found to contain the following ions in meq /100g of oven dry soil: K^+ = 0.28, Mg^{2+} = 0.12, Ca^{2+} = 1.00, Na^+ = 0.03 and H^+ = 10.00. Then, they were asked to calculate the Percentage Base Saturation (PBS), if the Cation Exchange Capacity (CEC) of the soil is 3.83 meq/100 g of the oven dry soil.

In Part (d), the candidates were given the information, "A 21 g of soil sample was dried in an oven and lost its weight by 1 g. The soil was analyzed and found to contain 0.0015 g of Ca^{2+}". Then the candidates were asked to calculate the concentration (in meq/100g oven dry soil) of Ca^{2+} in the soil sample. They were given the atomic mass of Ca = 40 $gmol^{-1}$.

A total of 26,326 candidate's equivalent to 76.3% opted for this question. The analysis of the candidates performance shows that 6,128 candidates (23.4%) scored from 12.0 – 20 which indicates a good performance. Furthermore, the statistical analysis indicates that 11,076 candidates equivalent to 42.0% scored from 7.0 – 11.5 marks showing an average score while 9,122 candidates (34.6%) scored from 0 - 6.5 marks, indicating an unsatisfactory performance.

The candidates who managed to score high marks in this question reflected possession of prior knowledge regarding soil science hence, they were able to give correct responses to most parts of the question. Extract 21.1 represents responses from one of the candidates with high scores.

7. (a).(i). Significance of soil colloids:

- They provide soil fertility.
- They are sites where the cations , between soil colloids and soil solution.
- They aid in balancing of nutrients.
- They ~~tt~~ give the soil its structure.

(ii). Effects of soil PH on plant growth.

⇒ It may lead to loss of other nutrients required by plants.

⇒ It may lead to the wilting of the plants.

(b).

- To balance nutrients in the soil soil.
- To select which kind of crop to be cultivated or planted.
- To make favourable conditions for ~~o~~ microorganisms in decomposition of organic matter.
- It is important in measuring the cation exchange capacity of the soil.

7\. (c) · Data given ·

$K^+ = 0.28$ Meq/100g

$Mg^{2+} = 0.12$ Meq/100g

$Ca^{2+} = 1.00$ Meq/100g

$Na^+ = 0.03$ Meq/100g

$H^+ = 10.00$ Meq/100g

~~Per~~ Cation exchange Capacity (C·E·C) = 3.83 Meq/100g

Percentage base saturation (P·B·S) = ?

from ·

$$P.B.S = \frac{\Sigma \text{Exchangeable basic cations}}{\text{Cation exchange Capacity}} \times 100\%$$

~~Whe~~ $$P.B.S = \frac{\Sigma \text{exchangeable basic (EB)}}{C.E.C} \times 100\%$$

Where

Σ exchangeable basic cations $= K^+ + Mg^{2+} + Ca^{2+} + Na^+$

$\Sigma EB = 0.28 + 0.12 + 1.00 + 0.03$

$\Sigma EB = 1.43$ Meq/100g

Then ·

$$P.B.S = \frac{\Sigma EB}{C.E.C} \times 100\%$$

$$P.B.S. = \frac{1.43}{3.83} \times 100\%$$

$$P.B.S = 37.34\%$$

∴ The percentage base saturation (PBS) is 37.34%

(d) · Data given ·

Mass of soil sample = 21g

Mass of soil lost = 1g

Mass of calcium = 0.0015 g

7 (d).

Concentration of calcium [Ca^{2+}] in meq/100g of oven dry soil = ?

Molar mass of Calcium = 40g mol^{-1}

- First, because we have given mass of soil sample = 21g and ~~mass lost~~ the soil lost its mass by 1g, so in order to get the mass in calculation of ~~ca~~ concentr~~ation~~ation of Calcium(Ca^{2+}) must be as follows:

$$21g - 1g = 20g$$

∴ The mass of soil sample will be 20g.

Then:

(i) To find the equivalent weight (eq)

$$eq = \frac{\text{Molar mass of cation}}{\text{valency}}$$

$$= \frac{40}{2} = 20g$$

(ii). To find the milliequivalent weight (meq)

from

$$1eq = 1000 \text{ meq}$$

$$Meq = \frac{eq}{1000}, \text{ where } eq = 20g$$

$$Meq = \frac{20g}{1000} = 0.02g$$

Therefore

1 Meq of Ca^{2+} → 0.02g

? = 0.0015g

7.	(d).
	= 0.075 Meq
	This means that,
	0.075 Meq → 20g
	? = 100g
	= 0.375 Meq/100g
	∴ The concentration of (in Meq/100g oven
	dry soil) of calcium in the soil sample is
	0.375 Meq/100g.

Extract 21.1: A sample of correct responses in question 7.

In Extract 21.1, a candidate gave appropriate significances of soil colloids and managed to explain in brief the effects of soil pH on plant growth. Moreover, the candidate calculated correctly the PBS and the concentration of Ca^{2+} in the given soil sample.

However, some of the candidates who performed poorly in this question reflected little knowledge on the topic of *Soil Chemistry*. These candidates failed to apply their prior knowledge on soil science to sort out the methods used to improve soil fertility. They did not understand the concept regarding ions exchange in the soil. As a result, they failed to perform the required calculations. Extract 21.2 is a sample of poor responses from one of the candidates.

7(a)(i) Significance of soil colloids.
(i) exchange of ions.
(ii) Determine the soil PH

II Effect of soil pH on plant growth
(i) Cause plant stress if the plant favour acidic pH while the soil pH is basic

(b)(i) In order to keep soil in accurate state for the particular plant pH.
(ii) To improve soil fertility
(iii) For the better growth of the plant.

(c) Data
Base saturation = K^+ = 0.28, Mg^{2+} = 0.12, Ca^{2+} = 1.00, Na^+ = 0.03
CEC = 3.83 meq/100
PBS % required
soln
From PBS % = $\frac{BS}{CEC} \times 100$
BS = 0.28 + 0.12 + 1.00 + 0.03 = 1.43
PBS % = $\frac{1.43}{3.83} \times 100$ = 42.3 %
Hence percentage base saturation of the soil 42.3 %

(d) Data.
Mass of soil = 21g, change in mass of soil = 1 g
Mass of Ca^{2+} = 0.0015 g.
Molar mass of Ca = 40 g/mol
Concentration of Calcium in meq/100 g required
soln Ca
Number of mole (n) = $\frac{mass}{molar\ mass}$
n of Ca = $\frac{0.0015\ g}{40}$ = 3.75×10^{-5} mole.
But 1 mol = 1 eq
1 eq → 1000 meq = $3.75 \times 10^{-5} \times 1000$ = 0.0375 m
3.75×10^{-5} eq → x
= 0.0375 meq
But Δ soil mass = 20 − 1 = 20 g
$\frac{0.0375 m \times 100\ meq/g}{20\ g}$ = 0.1875 M.
Hence Concentration of Calcium in soil 0.1875 M.

Extract 21.2: A sample of incorrect responses in question 7.

In Extract 21.2, a candidate gave vague statements. The candidate calculated the Percentage Base Saturation (PBS) and the Cation Exchange Capacity (CEC) incorrectly.

2.2.7 Question 8: Hydroxyl Compounds

This question had three parts; (a), (b) and (c). Part (a) supplied the candidates with the statement "An alcohol with a formula $C_6H_{12}OH$ does not react with bromine or bromine water". Then, they were asked to:

(i) State what the information about bromine tells them.
(ii) Identify the number of rings that the compound possesses.
(iii) Draw the structure of the alcohol.
(iv) Suggest the name for the alcohol in (a) (ii).

Part (b) (i) required the candidates to show the structure and give the IUPAC name of the resulting organic compound, when propan -1-ol reacted with ethanoic acid in presence of a mineral acid. In part (b) (ii), the candidates were provided with the statement "Phenol has a structure very much like ethanol", and they were asked to draw the structure of the molecule and predict whether anything would have happened if the two liquids were mixed with hot benzoyl chloride in an acidic medium.

In part (c) (i), the candidates were asked whether alcohol act as a nucleophile by giving a reason. In Part (c) (ii), the candidates were required to explain why apparatuses and chemicals must be dry when using PCl_5 or $SOCl_2$ to test for the presence of an OH^- group.

The question was attempted by 25,984 candidates corresponding to 75.3%. The analysis of the candidates performance shows that, 373 (4.4%) candidates scored marks between 12.0 - 20.0 indicating a good performance. Further analysis shows that 1,475 candidates, corresponding to 17.3% scored average marks ranging from 7.0 – 11.5. 6,674 candidates (78.3%) scored between 0 – 6.5 marks which indicates an unsatisfactory performance. Figure 13 summarizes the performance of the candidates in this question.

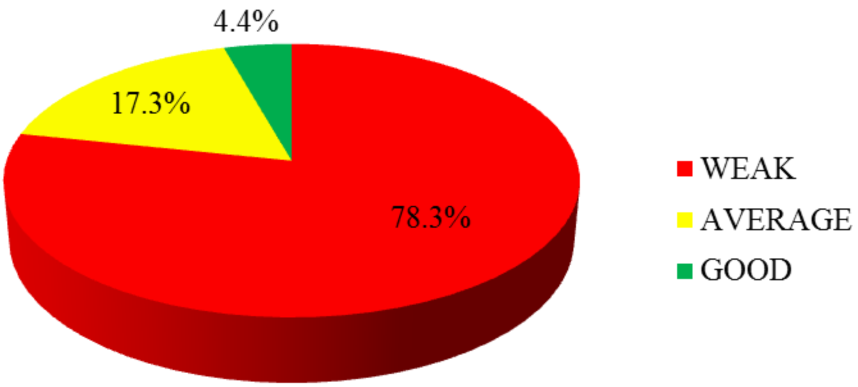


Figure 13: *Performance of the candidates in question 8*

Figure 13 indicates that the overall performance was poor as majority of the candidates corresponding to 78.3% scored an unsatisfactory marks (0 - 6.5). The poor performance in this question was attributed to poor understanding of the chemical properties of both alcohols and phenols. Candidates showed knowledge of only few chemical reactions involving the two functional groups. This was due to lack of appropriate competences to tackle problems of chemical reactions which require creativity and high order thinking. These candidates seemed not knowledgeable enough about the properties of unsaturated compounds. Furthermore, the candidates with low scores had little knowledge on the rules of naming different families of organic compounds.

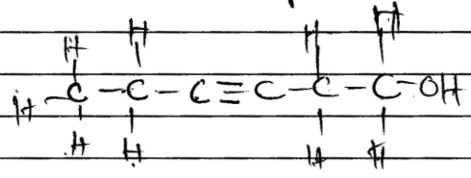
Extract 22.1 represents a sample of poor responses from one of the candidates.

8 a) i) $CH_3CH_2C \equiv CCH_2CH_2OH + Br_2/H_2O \rightarrow$ No reaction.

ii) $CH_3CH_2C \equiv CCH_2CH_2OH$.

⇒ have the six number of ring's.

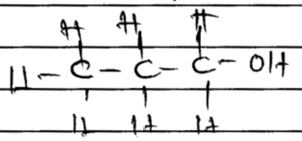
iii) The Structure of Alcohol

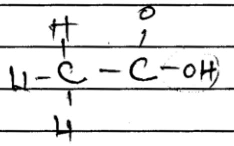


iv) The Name of Alcohol.

⇒ hexan 3-ol.

b) i) Propan-1-ol ethanoic acid

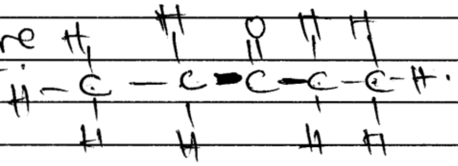




$CH_3CH_2CH_2OH + CH_3COOH \rightarrow$

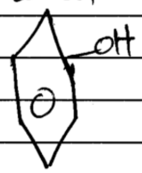
$CH_3CH_2CH_2-\overset{O}{\overset{\|}{C}}-CH_3$.

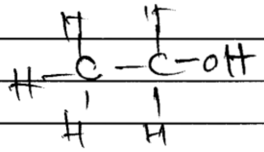
Structure

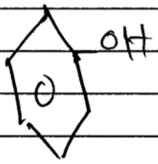


pentan-3-one.

8b. ii) Phenol Ethanol

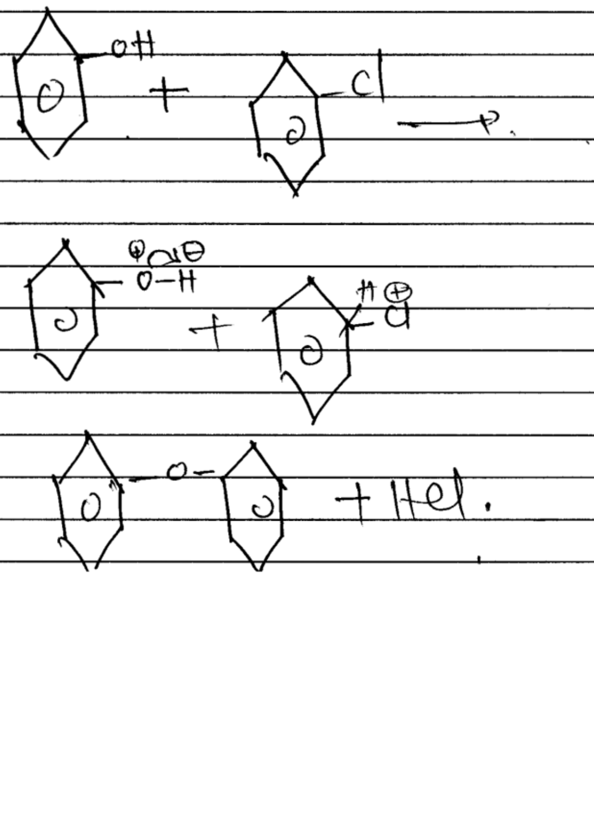


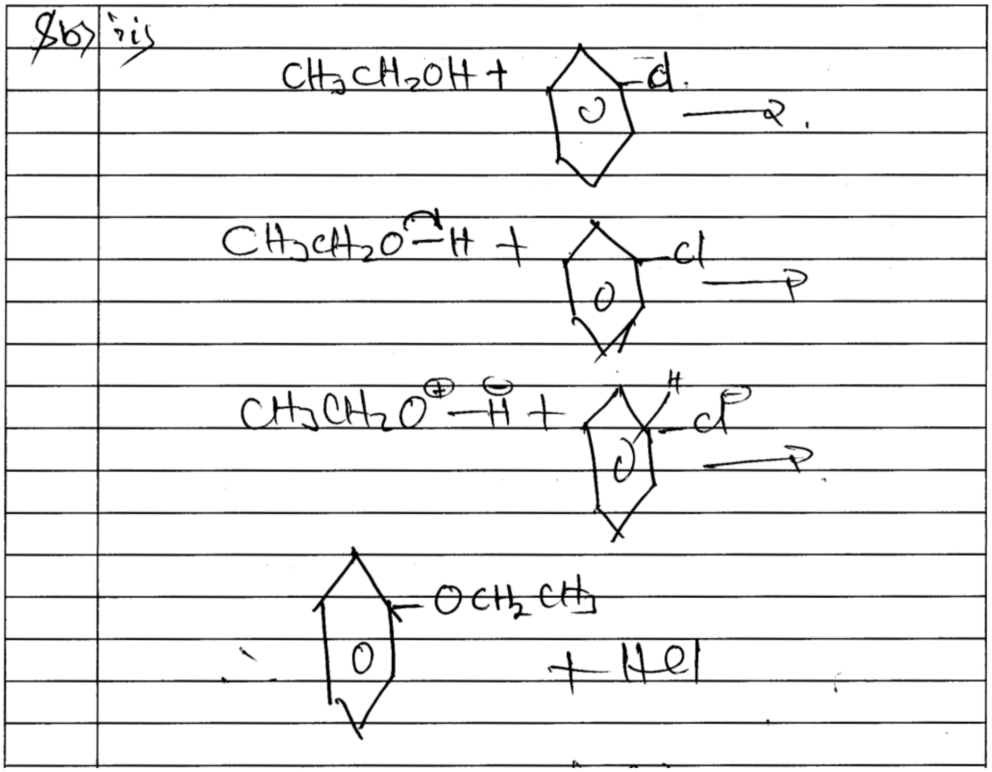




CH_3CH_2OH.

1st

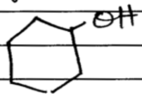
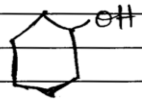




Extract 22.1: A sample of incorrect responses in question 8.

Extract 22.1 represents responses of a candidate who gave a structure of an unsaturated alcohol instead of saturated alcohol in part 8 (a) (ii). The candidate also responded incorrectly, to the remaining parts of the question.

However, few candidates (21.7%) managed to respond correctly to the question by scoring marks ranging from 7.0 – 20. The candidates who responded fairly correctly to the question with an average score answered some parts of the question partially. Though some candidates managed to identify the required alcohol in part (a) (iv), most of them named it incorrectly. Figure 22.2 represents responses from a candidate with a good score.

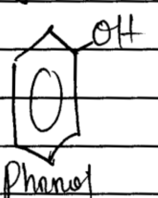
Q8.	(2) (i) The information tell that such an Alcohol does not contain double bond or triple bond in its chain.
	(2) (ii) The Compound Possess a single ring which is
	
	(2) (iii) The Structure of the Alcohol is
	
	(2) (iv) IUPAC name : Cyclohexanol

Q8. (b) (i)

$$CH_3CH_2CH_2OH_{(aq)} + CH_3\overset{O}{\overset{\|}{C}}-OH_{(aq)} \xrightarrow{H_2SO_4} CH_3\overset{O}{\overset{\|}{C}}-O-CH_2CH_2CH_3{}_{(aq)} + H_2O_{(l)}$$

STRUCTURE	IUPAC NAME
$CH_3\overset{O}{\overset{\|}{C}}-OCH_2CH_2CH_3$	Propylethanoate

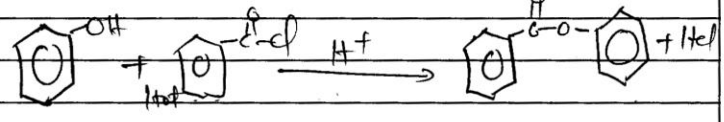
Q8 (b) (ii) The Structure of the Molecules are as follows



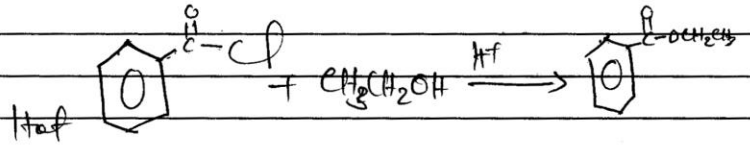
and CH_3CH_2OH

Phenol Ethanol

08. (b) (ii) Phenol react with hot benzoyl chloride in acid Medium to form phenyl Benzoate as follows.



Also Ethanol react with Hot Benzoyl chloride to form ethyl benzoate as follows.



8. (C) (i) Yes Alcohol can act as Nucleophile this is because it posses lone pairs found on Oxygen. thus it can donate the lone pairs to an Electrophile.
ie. $CH_3CH_2\ddot{O}H$ → lone pairs

08. (C) (ii) The Chemical and Apparatus must be dry on testing the presence of OH^- group, because when water is present it will give the wrong results as also it posses OH^- group so the Apparatus and Chemical should be kept dry so as to have Accurate measures / results.
ie $H_2O_{(aq)} \rightleftharpoons H^+_{(aq)} + OH_{(aq)}$

Extract 22.2: A sample of correct responses in question 8.

In Extract 22.2, a candidate proposed correctly the structure of the alcohol asked and managed to answer correctly most of the subsequent parts of the question.

2.2.8 Question 9: Carbonyl Compounds

This question had three parts namely; (a), (b) and (c). In part (a), the candidates were given the information "An unknown compound with a molecular mass of 86 a.m.u contains 69.8% Carbon, 11.6% Hydrogen and the rest is Oxygen. The compound does not reduce Fehling's solution but gives a positive iodoform test". Then they were required to describe the possible structure of the compound. Part (b) required the candidates to show, by using chemical reactions, how propanone reacts with (i) Hydroxylamine, (ii) Hydrazine, (iii) Phenyl hydrazine and (iv) Phosphorus pentachloride. In part (c), the candidates were required to explain the statements:

(i) *o*-hydroxybenzaldehyde is a liquid at room temperature while *p*-hydroxybenzaldehyde is a high melting solid.
(ii) It is incorrect to name butanone as butan-2-one.

A total of 19,310 (55.9%) candidates attempted this question. The statistical data indicated that 58.0%, 27.9% and 14.1% of the candidates scored 0 - 6.5, 7 - 11.5 and 12 - 20 marks, respectively (Table 2).

Table 2: Number,%age and Scores of the Candidates in Question 9

Scores	Number of Candidates	Percentage of Candidates
0.0 – 6.5	11,207	58.0
7.0 – 11.5	5376	27.9
12.0 – 20.0	2727	14.1

The statistical analysis (Table 2) indicates that the general performance of the candidates in this question was average as 42.0 percent of the candidates managed to score 7.0 marks and above. The analysis of the candidates responses revealed that the few candidates who managed to score good marks understood the topic properly as well as the requirements of the question.

Most of the candidates who scored high marks, despite showing good skills in mathematical manipulations and mastery of many chemical reactions involving carbonyl compounds; they provided partial responses in some parts of the question. Extract 23.1 represents responses from a script of a candidate who performed well.

9	a) Element's symbol	C	H	O
	Percentage composition (%)	69.8	11.6	18.6
	Relative Atomic Mass	12	1	16
	Relative number of atoms	69.8/12	11.6/1	18.6/16
		= 5.817	= 11.6	= 1.1625
	Divide by smallest	5.817/1.1625	11.6/1.1625	1.1625/1.1625
	Empirical formula.	5	10	1

∴ Empirical formula is $C_5H_{10}O$

From: (Empirical formula)n = Molecular Mass

$(C_5H_{10}O)n = 86$

9

$(12 \times 5 + 1 \times 10 + 16)n = 86$

$86n = 86$

$n = 86$

∴ Molecular formula = $(C_5H_{10}O)_1$

$= C_5H_{10}O$

– The compound is not aldehyde as it does not reduce fehling's solution

∴ Possible structures are:

(i) $CH_3CH_2CH_2\overset{O}{\overset{\|}{C}}CH_3$ pentan-2-one

(ii) $CH_3\overset{CH_3}{\overset{|}{C}H}\overset{O}{\overset{\|}{C}}CH_3$ 3-methyl butan-2-one.

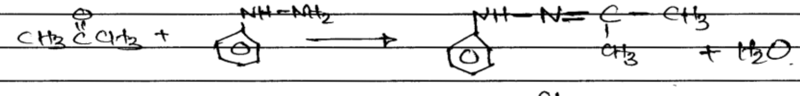
Iodoform test:

$CH_3CH_2CH_2\overset{O}{\overset{\|}{C}}CH_3 + I_2 + NaOH \longrightarrow CH_3CH_2CH_2COONa + CHI_3 + NaI + H_2O$ (yellow precipitate)

$CH_3\overset{CH_3}{\overset{|}{C}H}\overset{O}{\overset{\|}{C}}CH_3 + I_2 + NaOH \longrightarrow CH_3\overset{CH_3}{\overset{|}{C}H}COONa + CHI_3 + NaI + H_2O$ (yellow precipitate)

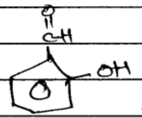
b) i) $CH_3\overset{O}{\overset{\|}{C}}CH_3 + NH_2OH \longrightarrow CH_3\underset{CH_3}{\underset{|}{C}}=N-OH + H_2O$

ii) $CH_3\overset{O}{\overset{\|}{C}}CH_3 + NH_2-NH_2 \longrightarrow CH_3\underset{CH_3}{\underset{|}{C}}=N-NH_2 + H_2O$

iii) 

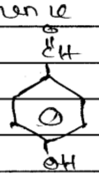
iv) $CH_3\overset{O}{\overset{\|}{C}}CH_3 + PCl_5 \longrightarrow CH_3-\overset{Cl}{\underset{Cl}{C}}-CH_3 + POCl_3$

9c i)



OH o-hydroxybenzaldehyde forms intramolecular hydrogen bonds between hydrogen in OH⁻ group and oxygen in COH group; This hinders the molecule to bond with other molecules by intermolecular hydrogen bonds hence it is liquid at room temperature.

-However;



forms intermolecular hydrogen bonds as COH and OH groups of the same molecule are far away from each other. These bonds make it solid at room temperature as each molecule can form two hydrogen bonds.

ii) $CH_3COCH_2CH_3$; This is because for butanone the ketone group always occupies carbon number 2 and hence there is no any ~~signifcan~~ significant reason of putting 2 on the name of the compound butanone

Extract 23.1: A sample of correct responses in question 9.

In Extract 23.1, a candidate suggested a plausible structure and supplied correct explanation while supporting the proposed answers with appropriate chemical equations.

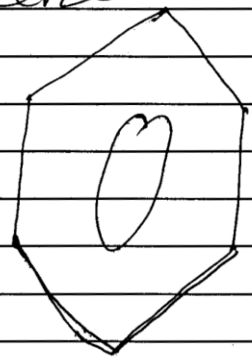
Equally, the analysis of the candidates' responses showed that majority of those who performed unsatisfactorily, wrongly correlated, the effect of hydrogen bonding and the state of the corresponding compound. The implication is that, they failed to understand the requirement of the question. They showed little understanding of the distinguishing chemical reactions of carbonyl compounds. In addition, they were not familiar with the concept of hydrogen bonding, types of hydrogen bonding and the necessary conditions for a certain compound to form a certain type of hydrogen bonding. Extract 23.2 represents one of the candidates' poor responses.

9. (a) 69·8% + 11·6% = 81.4
100% − 81.4% = oxygen percentage
Oxygen = 18·6%
and the Compound has molecular mass of 86 amu.

Compound is made by Carbon + Oxygen + Hydrogen

$C + O_2 + H \longrightarrow CO_2 + H^+.$
$\Longrightarrow H_2O + C$

The Structure of the Compound is benzene



9. (b) i) Propanone + Hydroxyl amine
~~R–C(=O)–R CH₃~~
$CH_3CH_2CH_3$ ~~+R~~ + R ~~+R~~–C(=O)–NH_2

9. (c)(i) in O-hydroxybenzaldehyde there are Less hydrogen bond which Lower the melting liquid
Since in P-hydroxybenzaldehyde there are high hydrogen which tend to high melting solid.

(ii) according to IUPAC system of naming Organic Compound. There is rule guiding nomenclature of Organic Compound where we must start by number as follow
butan-2-one is incorrect
2-methyl butanone correct.

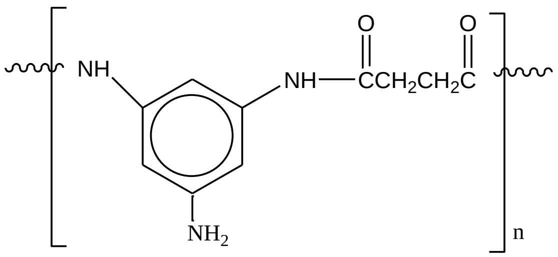
Extract 23.2: A sample of incorrect responses in question 9.

In Extract 23.2, a candidate wrote benzene by guessing, instead of using the given data to calculate the empirical formula and arrive to a correct molecular formula. The candidate also gave incorrect answers to the remaining parts of the question.

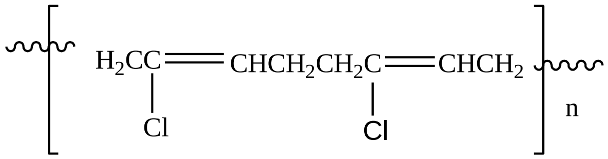
2.2.9 Question 10: Polymers

This question had three parts namely; (a), (b) and (c). In part (a), the candidates were given the polymer, PTFE and were required to show the initiation and propagation steps for the polymer during: (i) Free radical polymerization, (ii) Cationic polymerization, and (iii) Anionic polymerization. Part (b) required the candidates to give the IUPAC names of the monomers in the following polymers:

(i) Semi aromatic polyamide



(ii) Neoprene (oil resistant elastomer)



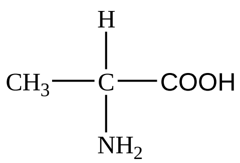
(iii) Saran (packaging film)

$$\sim\!\left[\, CH_2CCl_2CHCH_2Cl_2 \,\right]_n\!\sim$$

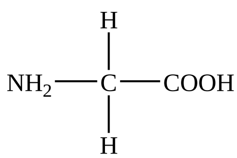
(iv) Oil soluble polymer

$$\sim\!\left[\, H_2CHC{=}CHCH_2 \,\right]_n\!\sim$$

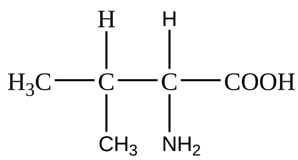
In part (c), the candidates were given the structures of natural amino acid for protein synthesis: Alanine (A), Glycine (G) and Valine (V).



Alanine (A)



Glycine (G)



Valine(V)

The candidates were then asked to:

(i) Identify the functional groups in those amino acids.
(ii) Show how polymerization of those monomers can be done.
(iii) Provide the common name of the resulting polymer in (c) (ii).
(iv) Write the minor product common to all in (c) (ii).
(v) Provide the name given to the bond combining the three amino acids.

The question was attempted by 16,289 candidates constituting 47.2% of all the candidates. The statistical data shows that 12.5%, 27.0% and 60.5% of the candidates scored marks ranging from 12 - 20, 7 - 11.5 and 0 - 6.5, respectively.

Further analysis indicated that, the overall performance in this question was average as more than one third of the candidates (6,437, amounting to 39.5%) scored 7 marks and above.

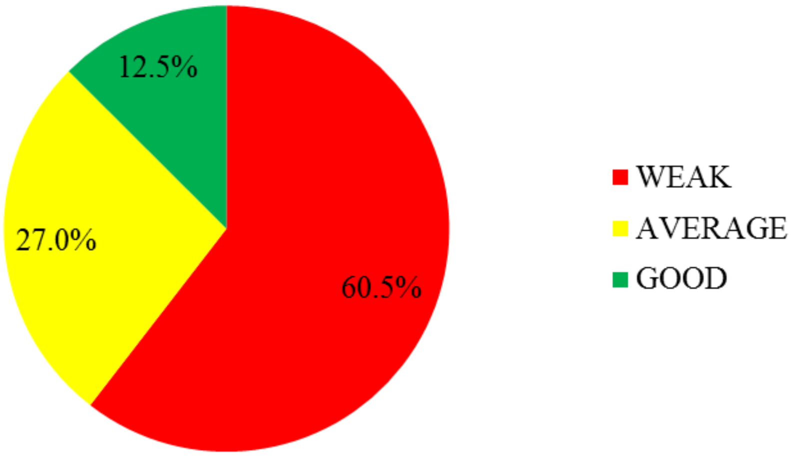


Figure 14: *Performance of the candidates in question 10.*

The few candidates who scored high marks (7.0 – 12.0) had basic knowledge on polymers, specifically the types of polymerization. They showed that they properly understood the concept of nomenclature and applying the IUPAC rules. They also indicated to have accommodated properly, the key types of chemical reactions involving preparation of polymers. The candidates who scored an average mark (7.0 – 12.0) showed to have also mastered the concepts in the topic *Polymers*. However, they provided incorrect responses in some parts of the question. Extract 24.1 shows a sample of good responses from the script of one of the candidates who managed to score full marks.

10 (a) The monomer for the polymer; Poly-tetrafluoroethene (PTFE) is $CF_2=CF_2$ (1,1,2,2-tetrafluoroethene).

(i) In free radical polymerization, these steps are carried as follows:

• The initiation step: This involves homolytic bond cleavage of the organic peroxide when heated at higher temperatures to give free radicals.

That is, $R-O-O-R \xrightarrow{\Delta} R-\dot{O} + R-\dot{O}$

• The propagation step: The free radicals formed in the step above attack the monomers ($CF_2=CF_2$) to form another free radicals, which attack another molecules of monomers until the chain lengthen.

That is,

$$R-\dot{O} + CF_2=CF_2 \longrightarrow R-O-CF_2-\dot{C}F_2$$

$$R-O-CF_2-\dot{C}F_2 + CF_2=CF_2 \longrightarrow R-O-CF_2-CF_2-CF_2-\dot{C}F_2$$

$$R-O-CF_2-CF_2-CF_2-\dot{C}F_2 + CF_2=CF_2 \longrightarrow R-O-CF_2-CF_2-CF_2-CF_2-CF_2-\dot{C}F_2$$

(ii) In cationic polymerization, these steps occur as follows:

• The initiation step: This involves the formation of a Lewis acid initiator and its attack on the monomer molecule ($CF_2=CF_2$ in our case).

That is, $HCl \longrightarrow H^+ + Cl^-$

$$H^+ + CF_2=CF_2 \longrightarrow H-CF_2-\overset{\oplus}{C}F_2$$

10(a) (ii) · Propagation step: The carbocation formed on the initial step attacks further monomer molecules ($CF_2=CF_2$) to form a cation of increased size and the process carries on the same manner.

That is,

$$H-CF_2-\overset{\oplus}{C}F_2 + CF_2=CF_2 \rightarrow H-CF_2-CF_2-CF_2-\overset{\oplus}{C}F_2$$

$$H-CF_2-CF_2-CF_2-\overset{\oplus}{C}F_2 + CF_2=CF_2 \rightarrow H-CF_2-CF_2-CF_2-CF_2-CF_2-\overset{\oplus}{C}F_2$$

$$H\!-\![CF_2-CF_2]_n-CF_2-\overset{\oplus}{C}F_2 + CF_2=CF_2 \rightarrow H\!-\![CF_2-CF_2]_n-CF_2-CF_2-CF_2-\overset{\oplus}{C}F_2$$

And so on.

(iii) In Anionic polymerization, these steps occur as follows:

· The initiation step: This involves the formation of an anion from the base which attacks the monomer molecules ($CF_2=CF_2$) to form a ~~cation~~ anion (carbanion).

That is,

$$NaNH_2 \longrightarrow Na^{\oplus} + NH_2^{\ominus}$$

$$NH_2^{\ominus} + CF_2=CF_2 \longrightarrow NH_2-CF_2-\overset{\ominus}{C}F_2$$

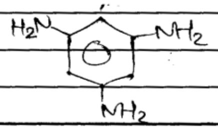
· The propagation step: The carbanion so formed in the initiation step attacks other monomer molecules ($CF_2=CF_2$), leading to increase in size of the chain.

That is,

$$NH_2-CF_2-\overset{\ominus}{C}F_2 + CF_2=CF_2 \rightarrow NH_2-CF_2-CF_2-CF_2-\overset{\ominus}{C}F_2$$

$$NH_2-CF_2-CF_2-CF_2-\overset{\ominus}{C}F_2 + CF_2=CF_2 \rightarrow NH_2\!-\![CF_2-CF_2]_n-CF_2-\overset{\ominus}{C}F_2$$

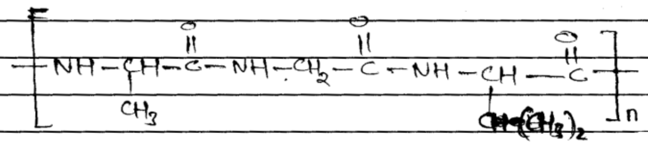
The process is carried until the chain is very long.

10(b)	(i)	MONOMERS	IUPAC NAMES
	(i)		1,3,5-triaminobenzene
		$HO-\overset{O}{\overset{\Vert}{C}}-CH_2CH_2-\overset{O}{\overset{\Vert}{C}}-OH$	Butane-1,4-dioic acid (Butane-1,4-dicarboxylic acid)
	(ii)	$CH_2=\underset{Cl}{\underset{\vert}{C}}-CH=CH_2$	2-chlorobuta-1,3-diene
	(iii)	$CH_2CCl_2CHCH_3$	Butene.
	(iv)	$CH_2=CHCH=CH_2$	Buta-1,3-diene (1,3-butadiene)

(c) (i) The functional groups are:
- The carboxyl group $(-COOH)$
- The amino group $(-NH_2)$

(ii) • Polymerization of Alanine (A), G and V is done as follows:

$CH_3-\underset{NH_2}{\underset{\vert}{CH}}-COOH + H_2N-CH_2-COOH + NH_2-\underset{COOH}{\underset{\vert}{CH}}-CH-(CH_3)_2$

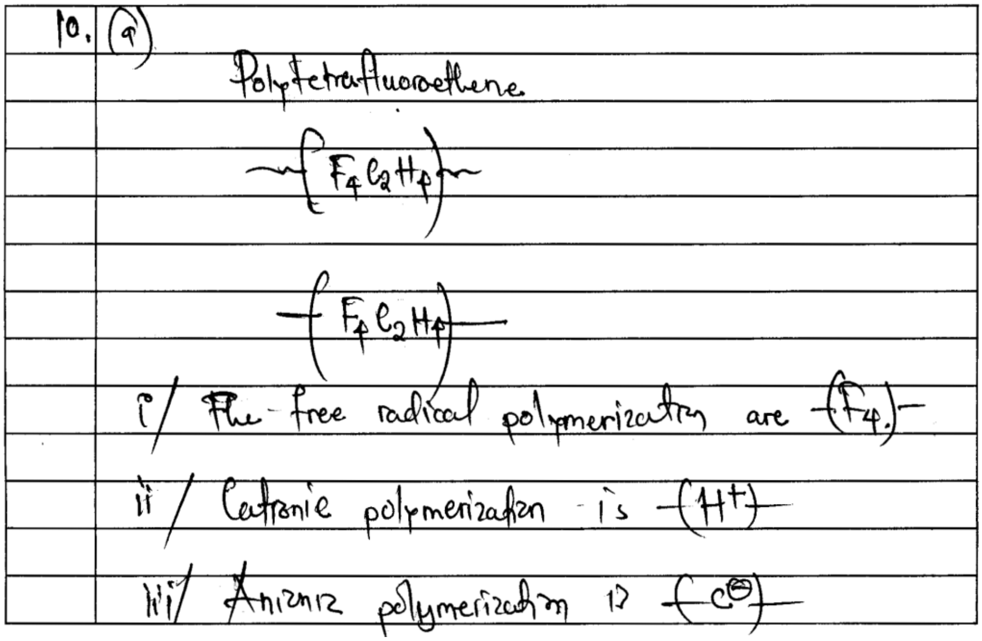
$\longrightarrow$ 

10(c)	
	(iii) The name is Protein.
	(iv) The minor product is H_2O (Water molecule).
	(v) The name is the peptide bond.

Extract 24.1: A sample of correct responses in question 10.

In Extract 24.1, a candidate gave correct steps involved in the polymerization process of PTFE. He/she further managed to supply appropriate responses in the subsequent parts of the question.

Conversely, the analysis of the candidates' responses showed that majority of those who had an unsatisfactory performance, had inadequate knowledge on the IUPAC rules of naming organic compounds. Moreover, they showed to lack appropriate competences regarding chemical reactions involved in the preparation of different types of polymers. These candidates did not know the concept of steric hindrance for proper identification of minor and major products. Thus, they failed to meet the requirement of the question. Extract 24.2 represents a sample of poor responses from one of the candidates.


10. (a)
Polytetrafluoroethene
—[F4 C2 H4]—
—[F4 C2 H4]—
i/ The free radical polymerization are —(F4.)—
ii/ Cationic polymerization is —(H+)—
iii/ Anionic polymerization is —(C⊖)—

10. (b)

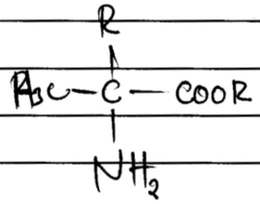
i/ Tribenzeneethanore.

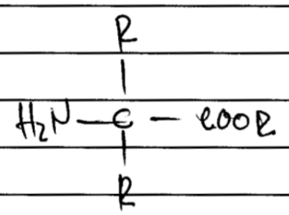
ii/ 2,6-Dichloroprocfene.

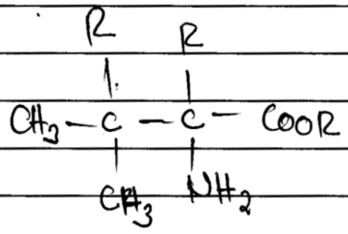
iii/ 2,5-Dichloro-n-butane.

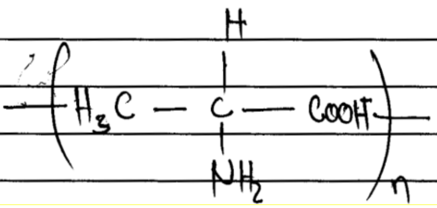
iv/ n-Butene.

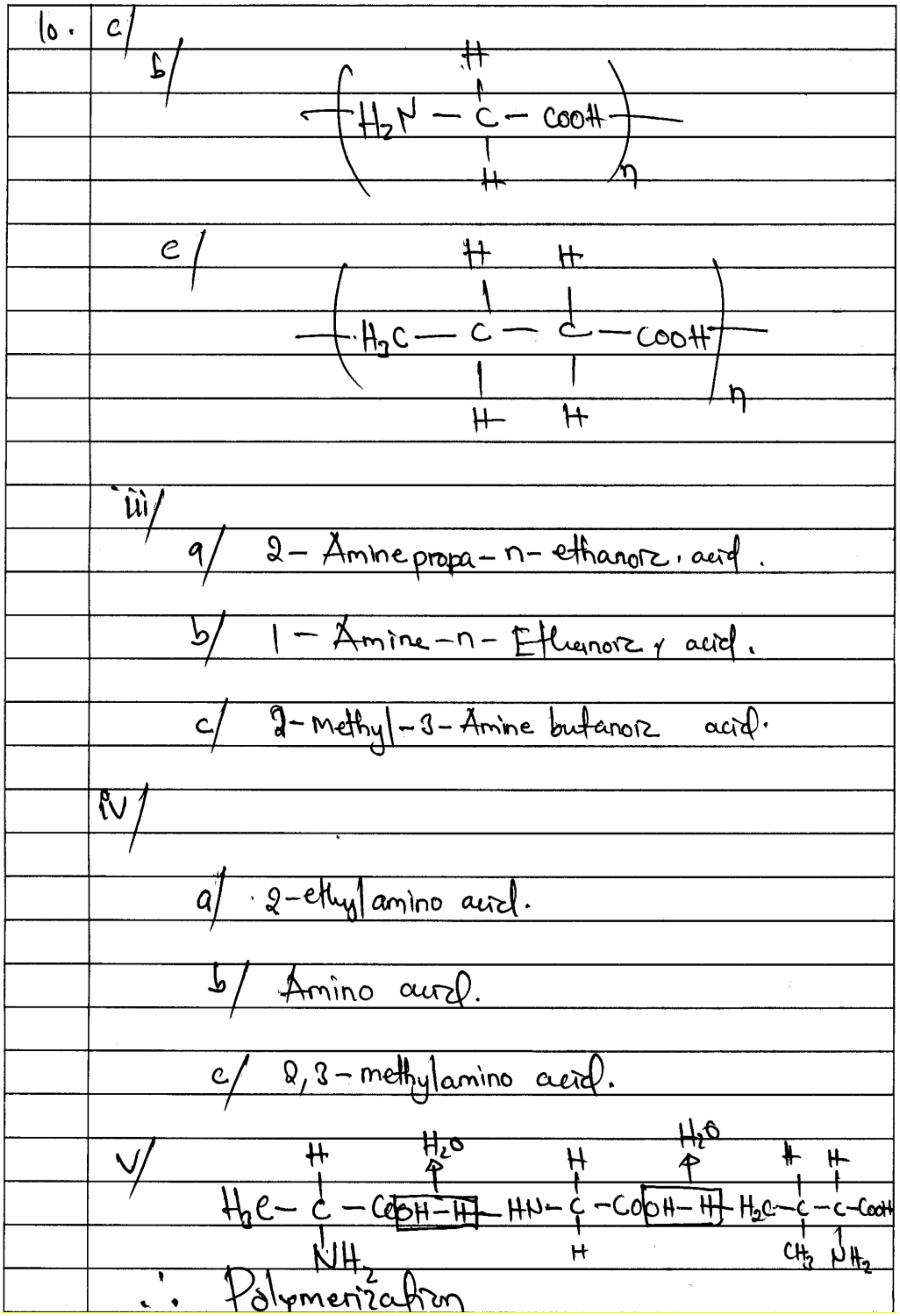
(c)

i/ a/ 

b/ 

c/ 

ii/ a/ 



Extract 24.2: A sample of incorrect responses in question 10.

Extract 24.2 shows responses of a candidate who gave the structure of a polymer in part (a), instead of showing what happens in each step provided. He/she named the monomers incorrectly and repeated to draw the structures of the given amino acids, instead of responding to the requirement of the question.

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* (75.1%), *Chemical Equilibrium* (71.8%), *Soil Chemistry* (65.4%) and *Acids, Bases and Salts* (65.0%).

The good performance in the mentioned topics was attributed to the fact that most of the candidates had adequate knowledge and clearly understood the requirements of the respective questions. Moreover, most of them had good English language proficiency. This was reflected by the given answers to detailed explanations.

The candidates had an average performance in the topics of *Gases* (52.6%), *Aromatic Hydrocarbons* (50.8%), *Electrochemistry* (49.0%), *Halogen Derivatives of Hydrocarbons* (47.2%), *Aliphatic Hydrocarbons* (42.6%), *Carbonyl Compounds* (42.0%), *Two Components Liquid Systems* (42.0%), *Polymers* (39.5%), *Selected Compounds of Metals* (36.2%) and *Relative Molecular Masses in Solution* (35.2%).

The candidates who performed averagely in these topics, apart from showing a good mastery of the content regarding the topic in question, they provided partial answers. Most of them seemed not to capture all the requirements of the questions; suggesting poor time management and insufficient language proficiency hence, loss of some marks.

Further analysis shows that, the candidates had weak performance in the topics of *Energetics* (31.6%), *Chemical Bonding* (24.5%), *Transition Elements* (23.1%), *Hydroxyl Compounds* (21.7%), *Periodic Classification* (17.4%) and *Chemical Kinetics* (16.8%).

Poor performance in the six mentioned topics reflected, to some great extent, the inadequate knowledge and incompetence in writing appropriate chemical formulae and equations. The poor performance also signaled incompetence in tackling problems incorporating mathematical manipulations. These factors, together with the lack of the aforementioned attributes, contributed to an unsatisfactory performance.

The comparison of the candidates' performance between the year 2018 and 2019 shows that, the performance in five topics has increased, while it has decreased in ten topics. More details of the performance in different topics are presented in the appendix section.

4.0 CONCLUSION

The question-wise analysis of the performance in Chemistry paper 1 and 2 for the ACSEE 2019 has shown that overall candidates' performance was good.

The analysis shows that four (4) topics had good performance, ten (10) topics had an average performance and six (6) topics had poor performance. Good performance was attributed to good mastery 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 questions due to inadequate knowledge. This was obvious in the analysis made on the poorly performed questions, from the content areas of *Energetics*, *Chemical Kinetics*, *Chemical Bonding*, *Transition Elements*, *Hydroxyl Compounds* and *Periodic Classification*. Among other factors, this performance could be greatly attributed to:

(a) Lack of mathematical manipulation skills and inadequate knowledge on the tested topics. It was evident from some of the candidates who gave responses which did not relate with the questions asked. Most of them were not able to transpose the formulae and plug in the data provided to arrive at the correct value of the items required.

(b) Inability of the candidates to follow the required steps in answering questions. This was shown by some of the candidates who substituted data into formulae without units' agreement, at the same time, skipping a couple of necessary steps.

(c) Failure of the candidates to understand the requirements of the questions. Some candidates were unable to identify the key words used in the questions. For example, they perceived and responded synonymously to the questioning words such as define and explain.

(d) Lack of English language proficiency. This was manifested by the candidates who gave incorrect sentences to the extent of not being able to communicate their answers.

(e) Failure to apply appropriate formulae and chemical equations. Failure to integrate classroom lessons with real life situations. This was observed in candidates who failed to relate the common chemical substances such as metal oxides with their common uses in daily life.

(f) Lack of enough exposure to practicals. This was justified by a variety of incorrect responses from some of the candidates who failed to interpret the experimental data provided in some questions.

5.0 RECOMMENDATIONS

In order to improve performance of candidates in Chemistry, the following measures are recommended:

(i) Students should practice more on the use of atomic models to demonstrate the overlapping of atomic orbitals to form molecular orbitals.

(ii) Teachers should guide students to perform various calculations regarding the Hess's Law of constant heat summation.

(iii) Students should discuss the kinetic behavior of solid, liquid and gaseous substances at different temperature conditions. The discussion should be verified practically by using marble chips, powdered calcium carbonate, HCl and NH_3.

(iv) Teachers should emphasize on the use of the modern periodic table to deduce the periodic trends in physical properties of elements down the groups.

(v) Teachers should assist students through the use of wall charts, to classify positive, negative and neutral ligands.

(vi) Wall charts showing various reactions of alcohols should be used during teaching and learning process to help students understand the properties of hydroxyl compounds.

Appendix: Summary of the Performance of Candidates – Topicwise

S/N	Topic	2018			2019		
		Number of Questions	Percentage of Candidates who scored an Average of 35 or Above	Remarks	Number of Questions	Percentage of Candidates who scored an Average of 35 or Above	Remarks
1	The Atom	1	79.3	Good	2	75.1	Good
2	Chemical Equilibrium	1	63.3	Good	1	71.8	good
3	Soil Chemistry				1	65.4	Good
4	Acids, Bases and Salts	1	88.2	Good	1	65.0	Good
5	Gases	2	72.2	Good	2	52.6	Average
6	Aromatic Hydrocarbons	1	56.7	Average	1	50.8	Average
7	Electrochemistry	1	62.5	Good	1	49.0	Average
8	Halogen Derivatives of Hydrocarbons	2	22.5	Weak	1	47.2	Average
9	Aliphatic Hydrocarbons	1	48.0	Average	2	42.6	Average
10	Carbonyl Compounds				1	42.0	Average
11	Two Components Liquid system	2	36.4	Average	1	42.0	Average
12	Polymers				1	39.5	Average
13	Selected Compounds of Metals	1	4.1	Weak	1	36.2	Average
14	Relative Molecular Masses in Solution	1	7.6	Weak	1	35.2	Average
15	Energetics	1	33.3	Weak	2	31.6	Weak
16	Chemical Bonding	2	55.3	Average	1	24.5	Weak
17	Transition Elements				1	23.1	Weak
18	Hydroxyl Compounds				1	21.7	Weak
19	Periodic Classification	1	49.5	Average	1	17.4	Weak
20	Chemical Kinetics	1	88.1	Good	1	16.8	Weak