3.5 CHEMISTRY (233)

Chemistry is tested in three papers, paper 1 (233/1), paper 2 (233/2) and paper 3 (233/3). Paper 1 and paper 2 are theory papers while paper 3 is a practical. Paper 1 (233/1) tests Forms 1, 2, 3 and 4 content whereby each question carries a maximum of 3 marks while paper 2 tests content from specific topics from forms 1, 2, 3, and 4 and assesses a wide range of skills. A question in paper 2 can carry up to a minimum of 10 and a maximum of 14 marks. Paper 3 tests in depth both quantitative and qualitative practical skills attained by the candidates from forms 1, 2, 3, and 4 and assesses a wide range of skills. This report is based on the analysis of performance of candidates who sat the year 2020 KCSE Chemistry.

3.5.1 CANDIDATES GENERAL PERFORMANCE

The following table shows the performance of Chemistry in the last five years.

Table 13: Candidates Performance in Chemistry for the last five years: 2016, 2017, 2018, 2019 and 2020

Year	Paper	Candidature	Maximum Score	Mean Score	Standard Deviation
2016	1		80	19.15	14.85
	2		80	14.66	12.85
	3	**566,836**	40	13.63	6.31
	Overall		**200**	**47.42**	**34.01**
2017	1		80	17.03	14.67
	2		80	17.97	14.32
	3		40	14.1	6.11
	Overall	**606,515**	**200**	**48.09**	**32.87**
2018	1		80	19.36	14.57
	2		80	16.96	14.17
	3		40	14.44	6.45
	Overall	**656,163**	**200**	**53.76**	**33.45**
2019	1		80	20.00	14.98
	2		80	18.00	13.07
	3		40	13.00	6.70
	Overall	**691,802**	**200**	**52.17**	**32.71**
2020	1		80	15.02	14.28
	2		80	12.05	10.9
	3		40	17.95	7.47
	Overall	**740,831**	**200**	**45.01**	**30.19**

From the table, it is observable that:

(i) Candidature for chemistry increased from **691,802** in 2019 to **740,831** in 2020 an increment of about 7.1 %. Candidature has been improving over the years.

(ii) Performance in paper 1 declined considerably with 4.98 units from a mean of 20.00 to a mean of 15.02. The decrease was equivalent to 24.9%.

iii) Performance in paper 2 declined considerably with 5.95 units from a mean of 18.00 in 2019 to 12.05 in 2020. This was a decrease of 33.1%.

iv) Performance in paper 3 increased considerably with 4.95 units from a mean of 13.00 to 17.95 an equivalence increase of 38.08%.

v) The standard deviation in the paper 1 remained near the ideal indicating that the test items were able to discriminate between low and high achievers. The SDs for paper 2 was below the ideal hence the paper did not distinguish between the low and high performers hence the paper may have been balanced in terms of difficulty versus easiness. However, the standard deviation of the practical paper improved from 6.70 to 7.47 although still below the ideal standard deviation.

vi) The overall performance of chemistry declined from a mean of **52.17** (26.09%) in 2019 to **45.01** (22.51%) in 2020 a decrease of 7.16 points equivalent to 13.72%. Teachers are advised to teach the syllabus but not the text books in order to cover the expected content as specified in the syllabus. A variety of text books authorized by the curriculum body should be used for instruction but not only one recommended text book.

3.5.2 ANALYSIS OF QUESTIONS PERFORMED POORLY

Questions which were performed poorly are analysed and briefly discussed below. The discussion is based on comments from the chief examiners reports and analysis of the candidates' responses from the sampled answer scripts. The discussion aims at pointing out candidates' weaknesses and proposed suggestions on the measures which if put in place the performance would improve.

3.5.3 Chemistry paper 1 (233/1)

The questions which were reported to have been poorly performed are briefly discussed below in view of pointing out the candidates' weaknesses and the proposed suggestions on the measures to be put in place in order to improve performance in future.

Question 7

Draw a labelled diagram of the setup of apparatus that can be used to electrolyse lead(II) bromide.

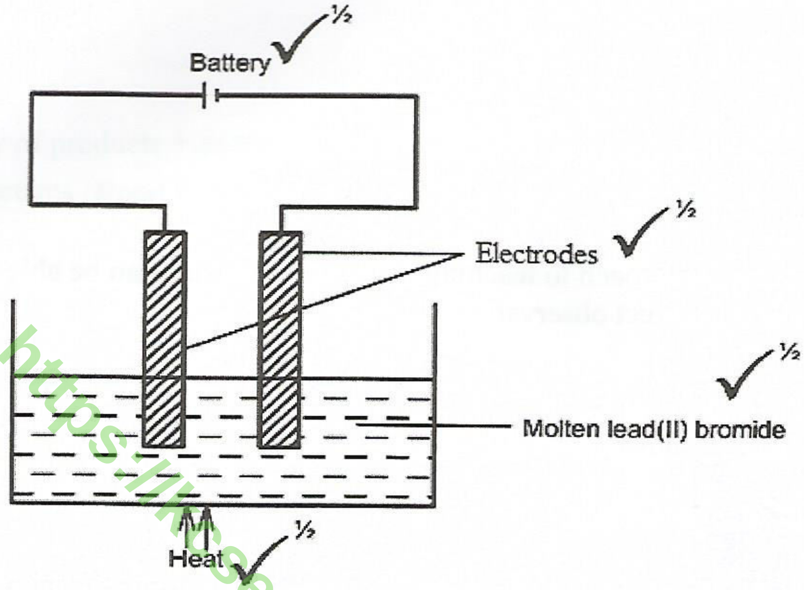
Requirements

Candidates were required to draw a set-up of electrolysis of lead(II) bromide.

Weaknesses

Most candidates confused between simple electrolytic cell and an electrochemical cell and many of them used a bulb instead of battery as a source of electricity.

Expected Response



Advice to teachers
Teachers should employ experimental approach to teach and expose students to drawing set ups of various experiments.

Question 11
Excess dilute hydrochloric acid was added to an alloy of copper and zinc in a beaker.

(a) State the observations made. (2 marks)

(b) Excess aqueous sodium hydroxide was added to 2 cm^3 of the solution obtained in the reaction. Write an ionic equation for the reaction that occurred. (1 mark)

Requirements
In this question, candidates were required to state the observations made when an alloy of copper and zinc is reacted with excess hydrochloric acid and write an ionic equation for the reaction between a sample of the filtrate obtained and excess sodium hydroxide solution.

Weaknesses
Majority of the candidates could not relate practical with theory and give the correct observations made and inability to write an ionic equation.

Expected Response

(a) -effervescence ✓ 1

- colourless solution formed ✓ ½

- brown residue ✓ ½

(b) $Zn^{2+}(aq) + 4OH^{-}(aq) \rightarrow [Zn(OH)_4]^{2-}(aq)$ ✓ 1

OR

$Zn(OH)_2(s) + 2OH^{-}(aq)$ $\qquad$ $[Zn(OH)_4]^{2-}(aq)$

Advice to teachers

Teachers should apply practical approach to teaching so that the students can be able to relate theory to practice and be able to make correct observations and write ionic equations.

Question 16

Methane reacts with bromine as shown in the following equation.

$$CH_4(g) + Br_2(g) \rightarrow CH_3Br(g) + HBr(g)$$

Using the bond energies in **Table 4**, calculate the enthalpy change, ΔH for the reaction.

Table 4

Bond	**Bond energy (kJ mol^{-1})**
C – H	412
C – Br	276
Br – Br	193
H – Br	366

Requirements

This question required candidates to determine enthalpy change, ΔH of reaction using bonds and bond energies provided.

Weaknesses

Most of the candidates could not identify from the equations bonds broken and bonds formed.

Expected Responses

Bonds broken	Bonds formed
C – H	C – Br
Br – Br	H – Br

Energy absorbed (bond breaking) $= 412 + 193$

$= +605\text{kJ}$ ✓ 1

Energy released (bond formation) $= 276 + 366$

$= -642\text{kJ}$ ✓ 1

$\Delta H = +605 + -642$

$= -37kJ$ ✓ 1

OR

ΔH = Energy of products + energy of reactants.

Energy of reactants (Bond breaking)

$= (4 \times (+412)) + +193$

$= +1841kJ$

Energy of the products (Bond formation)

$= (3 \times -412) + -276 + -366$

$= -1878kJ$

ΔH of reaction = $+1841 + -1878$ ✓ ½

= -37kJ ✓ ½

Advice to teachers

Teachers should expose students to more calculations involving bond breakage and bond formation.

Question 25

Complete combustion of one mole of an alkanol, C_xH_yOH gave four moles of water.

(C =12.0, H =1.0, O =16.0)

Determine the:

(a) values of x and y

(i) x (1 mark)

(ii) y (1 mark)

(b) number of moles of oxygen required for the complete combustion. (1 mark)

Requirements

This question required candidates to determine the values of x and y in the formula of an alkanol and the number of moles of oxygen required for complete combustion of the alkanol.

Weaknesses

Most of the candidates were unable to calculate the number of carbon and hydrogen atoms in the alkanol.

Expected Responses

a) i) 4 Moles of $H_2O = 8H$ ½ ✓

$yH + H = 8H$

$yH = 8H - H$

$yH = 7H$

$y = 7$ ½ ✓

(ii) $C_xH_{2x+1}OH$, where x is the number of carbon atoms

$\therefore 2x+1 = 7$ ½✓

$2x = 6$

$x = 3$ ½✓

b) Moles of O is **$4H_2O + 3CO_2 = 10$ Oxygen** ✓ ½

$O + 2xO = 10\ O$

$2xO = 10\ O$

$2x = 9$

$x = 4.5$

9 Oxygen atoms required = 4.5 moles of O_2

OR

$C_xH_yOH + O_2 \longrightarrow XCO_2 + 4H_2O$

But $y = 2x+1$

Where $x=3$

$y=2x3+1=7$

$2x+1 = 8$

$2x=6$

$X=3$

$C_3H_7OH + {}^9/_2O_2 \longrightarrow 3CO_2 + 4H_2O$

$\therefore$ Moles of O_2 = 4.5

Advice to teachers

Teachers should expose students to more questions on the mole in order for them to get the concept correctly.

Question 28

Figure 5 shows variation of number of outermost electrons **(a)** with atomic number of elements in the periodic table.

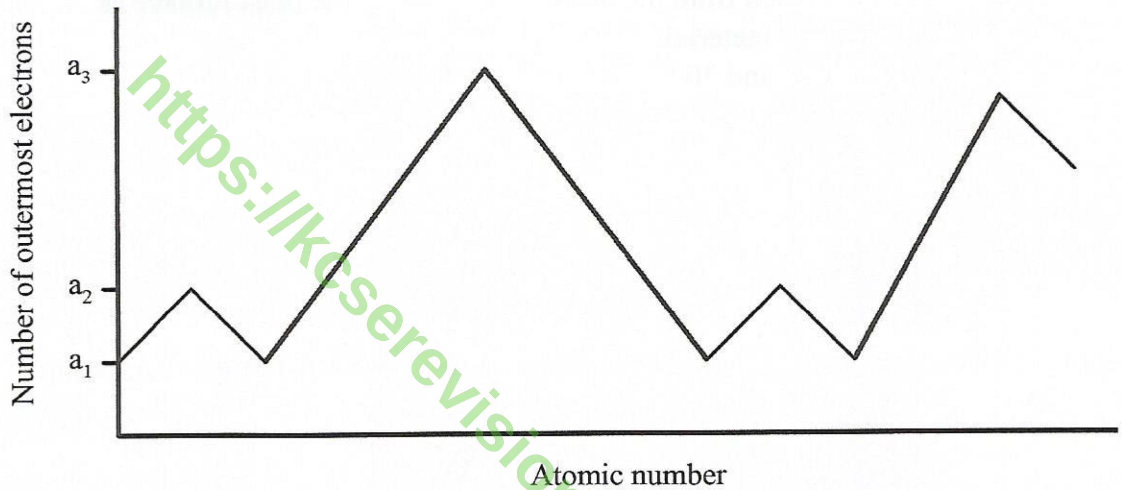


Figure 5

(a) Give the values of:

(i) **a1** (1 mark)

(ii) **a3** (1 mark)

(b) State why elements with **a1** and **a2** outermost electrons do ***not*** react with each other. (1 mark)

Requirements

The question required candidates to interpret a graph of number of outermost electrons against atomic number of elements in the periodic table.

Weaknesses

Most of the candidates were unable to interpret the graph correctly hence could not give the values of **a1** and **a3** and state why elements with **a1** and **a2** in the outermost electrons do not react with each other.

Expected Responses

a) (i) $a_1 = 1$ ✓ 1

(ii) $a_3 = 8$ ✓ 1

b) Both elements have a tendency of losing electrons. ✓ 1 (Both form positive ions).

Advice to teachers

Teachers should expose students to more questions involving interpretation of graphs.

3.5.3 Chemistry paper 2 (233/2)

Question 3

(a) One of the ores of iron is haematite, Fe_2O_3. Give the name and formula of **two** other ores of iron. (2 marks)

	Name	Formula
(i)		
(ii)		

(b) In a certain factory, iron is extracted from the haematite ore using the blast furnace as shown in **Figure 1**. The other raw materials are coke, limestone and air. The melting and boiling points of iron are 1535 °C and 3000 °C, respectively.

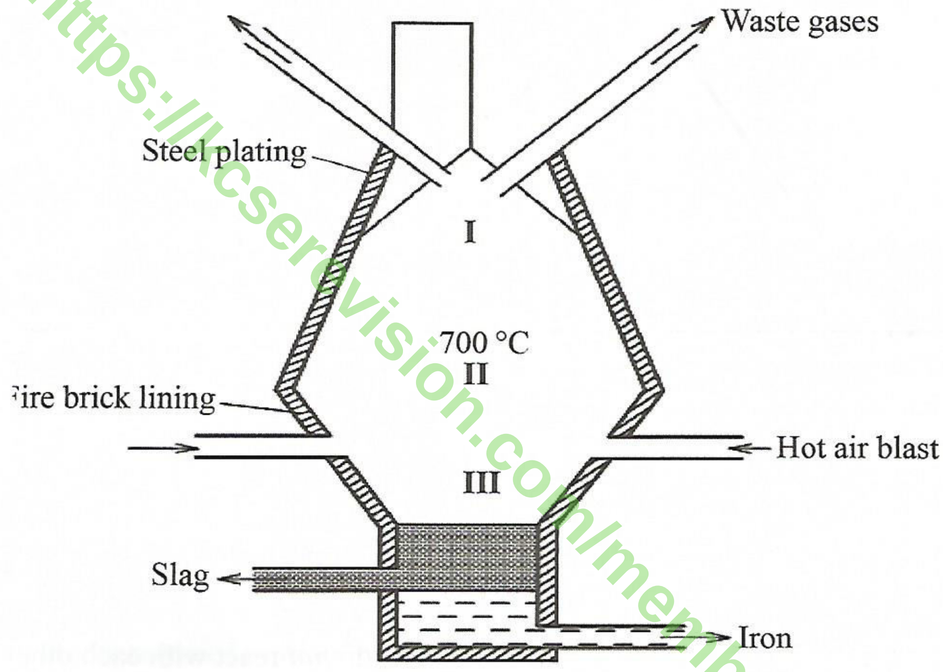


Figure 1

(i) State how the temperature in region **I** compares with that in region **II**. Give a reason. (1 mark)

(ii) The main reducing agent in the furnace is carbon(II) oxide formed by the reaction:

$CO_2(g) + C(s) \rightarrow 2CO(g)$

Write **two** equations to show how carbon(IV) oxide is formed in the furnace. (2 marks)

I.
II.

(iii) Suggest a value for the temperature in region **III**. Give a reason. (2 marks)

(iv) Name the main component in the slag. (1 mark)

(v) State **one** role that slag plays in the blast furnace. (1 mark)

(vi) The iron produced in the blast furnace is brittle due to presence of impurities.

I. Name the main impurity in this iron. (1 mark)

II. State **one** use of this iron. (1 mark)

(vii) Recycling is one method used to reduce production costs. State and explain the by products that can be recycled in this factory. (2 marks)

Requirements

The question required candidates to apply knowledge on extraction of Iron using a diagram of the blast furnace.

Weaknesses

Majority of the candidates were not able to apply the knowledge of extraction of Iron and answer the related questions.

Expected Responses

		Name	Formula
(a)	(i)	Siderite ✓ ½	$FeCO_3$ ✓ ½
	(ii)	Magnetite ✓ ½	Fe_3O_4 ✓ ½
		Iron pyrites	FeS_2

(Any two correct)

(b) (i) Temperature in region I is lower than that in region II

(700ºC) ✓ ½ because the raw materials are not pre-heated. ✓ ½

OR

Reaction in region I is endothermic while in region II is exothermic.

(ii) I. $C(s) + O_2(g) \rightarrow CO_2(g)$ ✓ 1

OR

$3CO(g) + Fe_2O_3(s) \longrightarrow 3CO_2(g) + 2Fe(l)$

II. $CaCO_3(g) \xrightarrow{Heat} CaO(s) + CO_2(g)$ ✓ 1

(iii) Accept any value between 1535ºC and 3000ºC ✓ 1.
The temperature keeps the iron in molten state ✓ 1.

(iv) Calcium silicate / $CaSiO_3$ ✓ 1

(v) It forms a protective layer over the iron so that the iron does not react with the ✓ 1 hot air.

(vi) I. - Carbon ✓ 1

II. - Making manhole covers; ✓ 1
- Bunsen burner bases;
- Electric poles;
- Fire grills.
- Iron boxes
- Manufacture of steel
- Electric arch furnaces
- Iron pipes

(Any one correct)

(vii) - The waste gases ✓ 1 should be used to preheat the air blast ✓ 1.
- Carbon(IV) oxide is reduced to carbon(II) oxide which acts as a reducing agent.
- Carbon(II) oxide is used as a reducing agent

Advice to teachers

Teachers should guide the students in discussions on extraction of the various metals and expose them to a variety revision questions in order for them to conceptualise the content on extraction of metals.

Question 6

(a) Water containing hydrogen carbonate, HCO_3^-, and calcium Ca^{2+} ions, is said to be hard water.

(i) Describe **one** way in which HCO_3^- ions get into river water. (1 mark)

(ii) Explain the disadvantage of using this type of water in boilers. (2 marks)

(b) Analysis of a river water sample showed the presence of the following ions:

Ca^{2+}, Na^+, Cl^-, NO_3^-

(i) Name the type of water hardness present in the sample. (1 mark)

(ii) Describe **one** precipitation method that can be used to soften the water. (2 marks)

(iii) The water sample was passed through a resin as shown in **Figure 3.**

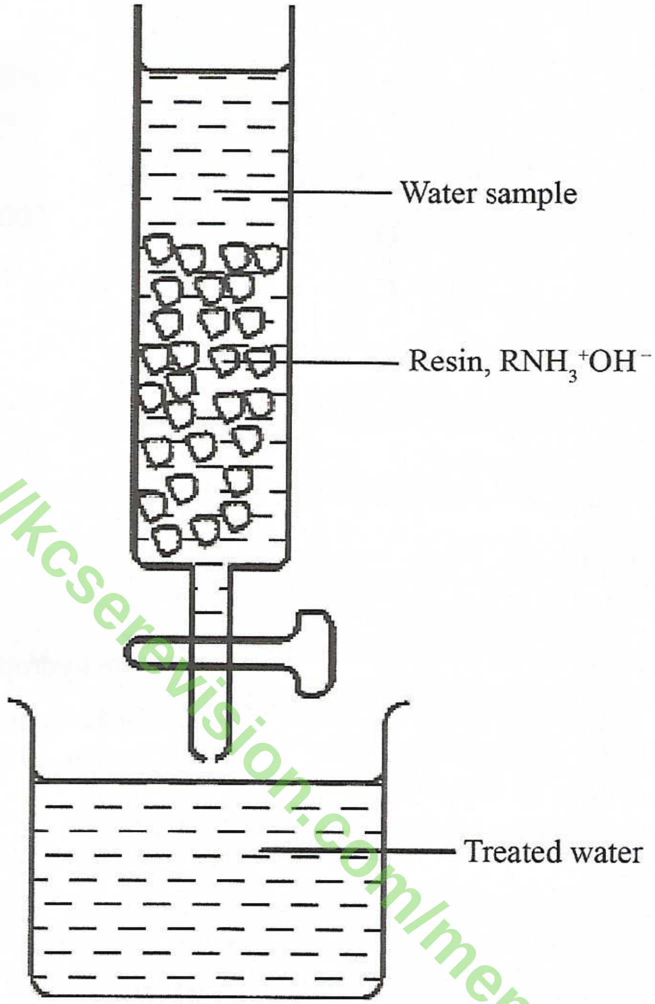


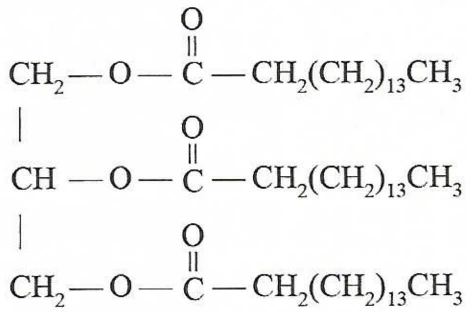
Figure 3

I. Write an equation for a reaction that took place in the column. (1 mark)

II. Complete treatment of the water sample required passing it through another resin. Give the formula of this resin. (1 mark)

III. Explain why a river water sample that has been treated using resins may still require boiling to make it safe for drinking. (2 marks)

(c) Compound **C** was used to prepare a potassium soap.



Compound **C**

(i) Give the formula of the potassium soap obtained. (1 mark)

(ii) State **one** difference in the properties of potassium and sodium soaps. (1 mark)

(d) A soapless detergent has the formula
$CH_3(CH_2)_{10}CH_2OSO_3Na$
With reference to this formula, identify the hydrophobic and the hydrophilic parts of the detergent.

Hydrophobic (1 mark)

Hydrophilic (1 mark)

Requirements

Candidates were required to apply the knowledge of salts, water hardness, removal of water hardness and detergents to respond to the related questions.

Weaknesses
Majority of the candidates were unable to apply knowledge salts, water hardness, removal of water hardness and detergents to respond appropriately to the related questions.

Expected Responses

(a) (i) When it rains carbon(IV) oxide in air dissolves in the water to form acid rain.

$$CO_2 + H_2O \rightarrow H_2CO_3 \checkmark \tfrac{1}{2}$$

The acid rain reacts with carbonate rocks of magnesium and calcium to form soluble magnesium hydrogen carbonate and calcium hydrogen carbonate. ✓½

(ii) At high temperatures calcium hydrogen carbonate decomposes ✓1 to form scales (insoluble calcium carbonate) in boilers that causes poor thermal conductivity✓1.

(b) (i) Permanent hardness. ✓ 1

(ii) Aqueous sodium carbonate is added to the water✓ 1. Carbonate ions (**CO_3^{2-}**) precipitates calcium ions (**Ca^{2+}**) to form insoluble calcium carbonate which is then filtered off ✓ 1

(iii) I. $RNH_3^+OH^-(s) + Cl^-(aq) \rightarrow RNH_3Cl(s) + OH^-(aq)$

$2RNH_3^+OH^-(s) + NO_3^-(aq) \longrightarrow RNH_3NO_3(s) + OH^-(aq)$

II. $RSO_3^-H^+$ ✓ 1/$RCOO^-H^+$

Any correct 1 mark

III. Resins do not remove micro-organisms/bacteria/pathogens/germs, ✓ 1 boiling of water kills ✓ 1 micro-organisms that might be present in water.

$CH_3(CH_2)_{13}CH_2\overset{\overset{O}{\|}}{C}-O^-K^+$

(c) (i) ✓ 1

$C_{15}H_{31}COOK$✓ 1

(ii) Potassium soaps are soft/mild while sodium soaps are hard. ✓ 1

(d) Hydrophobic – $CH_3(CH_2)_{13}CH_2$- ✓ 1

Hydrophilic - $-OSO_3^-Na^+$ ✓ 1

Advice to teachers

Teachers should guide the students in practical experiences and discussions through the content on salts, water hardness, removal of water hardness and detergents. Students should be exposed to a variety of questions on salts, water hardness, removal of water hardness and detergents.

3.5.6 Chemistry paper 3 (233/3)

The practical paper was tested using three questions. Question 1 tested skills and competencies about enthalpy changes (Physical Chemistry). **Question 1** tested Knowledge, skills and competencies on:

- Measuring volumes of solutions;
- Manipulation of apparatus;
- Measuring, reading and recording temperatures;
- Measuring, reading and recording time using stop watches;
- Drawing a graph of temperature against time;
- Graph interpretation;
- Calculations on moles and molar enthalpy of solution.

Question 2 involved qualitative analysis of an Inorganic compound while **question 3** involved qualitative analysis of an organic liquid. The two questions demanded the candidates to perform experiments using appropriate apparatus and chemicals, make correct observations, record the observations and inferences correctly and ability to follow instructions. Majority of the candidates were able to make correct observations with a good number of them not able to write the correct formulae of ions and use scientific language. In addition, the candidates experienced challenges in making inferences where they had difficulties in writing the correct inferences.

Question 1 has continued to be identified to pose challenge among most of the candidates.

Question 1

You are provided with:
- 5.3 g **solid A**, sodium carbonate;
- **Solution B**, hydrochloric acid.

You are required to determine the:
- Molar heat of the solution of **solid A**;
- Concentration of the hydrochloric acid, **solution B**.

PROCEDURE I

Using a burette, place 30.0 cm3 of distilled water in a 100 ml plastic beaker. Stir the water with a thermometer and measure its temperature after every half-minute interval. Record the readings in **Table 1**.

At exactly 2 minutes, add **all** of solid **A** to the water at once. Stir well and continue measuring the temperature of the mixture after every half-minute interval. Record the readings in **Table 1**.

Retain the mixture in the beaker for use in Procedure II.

(a) Table 1

Time (minutes)	0	$^1/_2$	1	$1^1/_2$	2	$2^1/_2$	3	$3^1/_2$	4	$4^1/_2$	5
Temperature (°C)					X						

(c) Determine from the graph, the temperature change, ΔT. (1 mark)

(d) Calculate the:

(i) number of moles of **solid A** used. (RFM 5 106) (1 mark)

(ii) molar enthalpy of solution, ΔHsoln and show the sign of ΔHsoln.
(Assume that for the solution, density = 1.0 gcm^{-3} and specific heat capacity = 4.2 $Jg^{-1}K^{-1}$) (2 marks)

PROCEDURE II

(i) Fill a burette with **solution B**.

(ii) Transfer all of the mixture in the 100 ml plastic beaker from **procedure I** into a 250 ml volumetric flask. Add distilled water to make up to the mark and shake. Label the mixture as **solution A**.

(iii) Using a pipette and pipette filler, place 25.0 cm^3 of **solution A** into a 250 ml conical flask. Add two or three drops of phenolphthalein indicator and titrate with **solution B**. **Do not pour out the contents of the conical flask.**
Record the readings in **Table 2**
Add two or three drops of methyl orange indicator to the contents of the conical flask. Titrate the mixture with **solution B** and record the readings of this second titration in **Table 3**.
Repeat **Procedure II, step (iii)** and complete **Tables 2** and **3**.

(e) (i) **Table 2,** using phenolphthalein indicator.

	I	II
Final burette reading		
Initial burette reading		
Volume of Solution **B** used, cm^3		

(3 Marks)

Average volume, V1, of **solution B** used = (½ mark)

(ii) **Table 3**, using methyl orange indicator.

	I	II
Final burette reading		
Initial burette reading		
Volume of Solution **B** used, cm^3		

(3 marks)

Average volume, V2, of **solution B** used = (½ mark)

(f) Calculate the:

(i) concentration, in moles per litre, of sodium carbonate in **solution A**. (1 mark)
RFM = 106

(ii) number of moles of sodium carbonate in 25.0 cm^3 of **solution A**. (1 mark)

(iii) number of moles of hydrochloric acid in the total volume, $V_1 + V_2$, of **solution B**. (1 mark)

(iv) concentration, in moles per litre, of hydrochloric acid in **solution B**. (1 mark)

Requirements

Candidates were required to manipulate apparatus to measure volumes of solutions, measure and record time using clocks /stop watches, measure and record temperature, make observations on colour change, manipulate data, perform some calculations, draw a graph of temperature against time and interpret the graph.

Weaknesses

Majority of the candidates were unable to read and record time and temperature accurately, choose a suitable scale for the graph, draw the correct graph, interpret the graph, follow the experimental procedure correctly and perform calculations correctly.

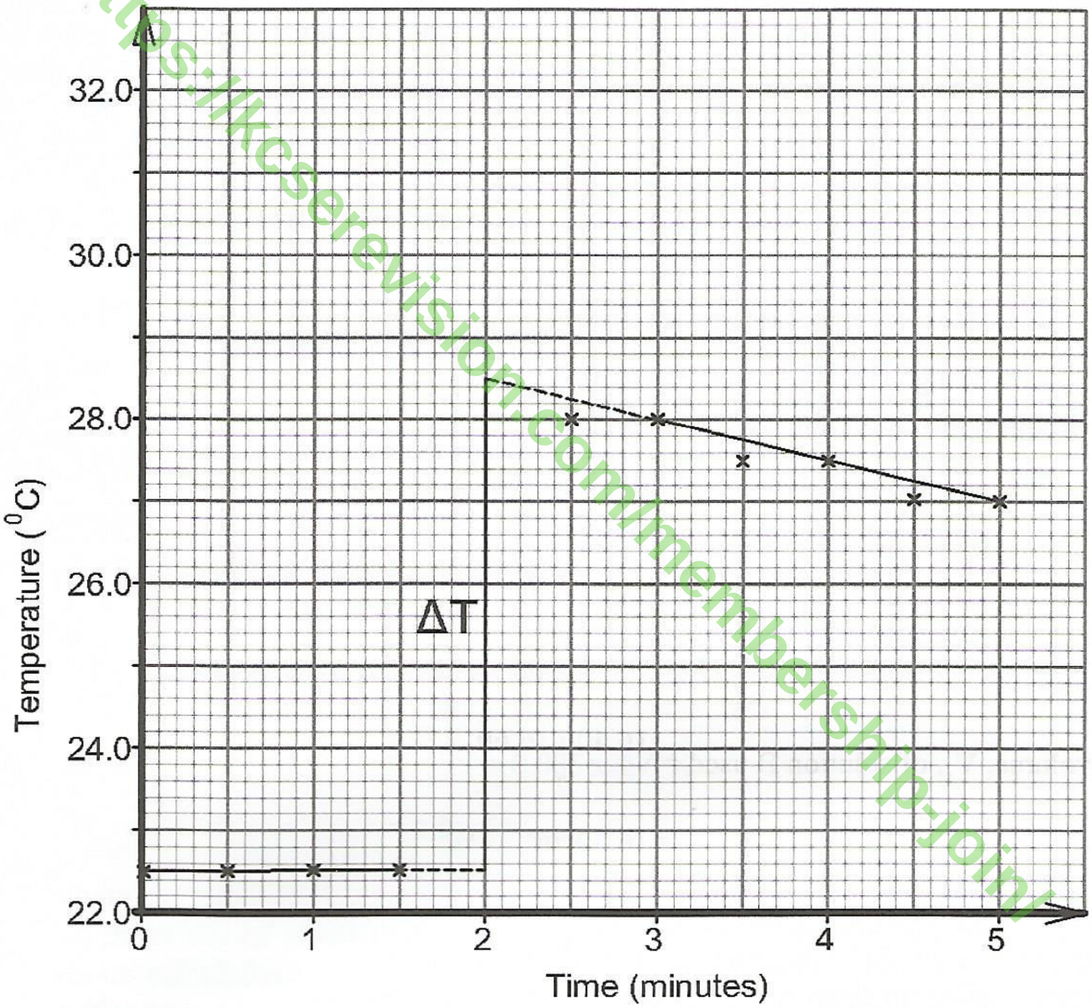
Expected Responses

(a)**Table 1**

Time (Minutes)	0	½	1	1 ½	2	2 ½	3	3 ½	4	4 ½	5
Temperature (°C)	22.5	22.5	22.5	22.5	**X**	28.0	28.0	27.5	27.5	27.0	27.0

- Complete table……………………………………………………………(1 mark)
- Use of decimals……………………………………………………………… ($^1/_2$ mark)
- Trend in temperature readings (constant, rise and drop) …………………………..(1 mark)
- Accuracy at Time = $1^1/_2$ minutes being ± 2°Cof the school value……………… ($^1/_2$ mark)

(b)



Labelling …………………………………………………………………………..…....($^1/_2$ mark)

Scale……………………………………………………………………………...……($^1/_2$ mark)

Plots…………………………………………………………………………….....…...(1 mark)

Lines (extrapolation)…………………………………………………………………..(1 mark)

(c) ΔT = (28.5 – 22.5)°C ½

= 6.0 °C ½

(Showing on the graph ½ mark; Correct ΔT ½ mark)

OR

(Correct ΔT with or without showing on the graph / no working presented1 mark)

(d) (i) No. of moles of **solid A** used = $^{5.3}/_{106}$ ½

$= \mathbf{0.05}$ ½

(ii) Molar enthalpy of solution

$$\left(\frac{-30 \times 4.2 \times 6.0}{0.05}\right)J \quad 1$$

= -15,120J/mol **OR** - 15.12 Kj/mol 1

Penalise ½ mark for absence of or incorrect units or/and if the negative sign is missing.

PROCEDURE II

Table 2

(e) (i)

	I	II
Final burette reading	16.90	16.60
Initial burette reading	0.50	0.00
Volume of Solution **B** used, cm^3	16.40	16.60

- Complete table ....(1 mark)
- Use of decimal places (2 or 1consistently..($^1/_2$ mark)
- Accuracy compared to school Value (S.V) ....(1mark)
- Final Accuracy ....(½ mark)

Average volume, $\mathbf{V_1}$, of solution B used = $\frac{16.40+16.60}{2}$

$= 16.50cm^3$ ½

Table 3

(ii)

	I	II
Final burette reading	33.30	33.30
Initial burette reading	16.90	16.80
Volume of Solution **B** used, cm^3	16.40	16.50

- Complete table ....(1 mark)
- Use of decimal places (2 or 1 consistently...($^1/_2$ mark)
- Accuracy compared to school Value (S.V) ....(1 mark)
- Final Accuracy..(½ mark)

- Average volume, V_2, of solution **B** used = $\dfrac{16.40+16.50}{2}$

$= 16.45cm^3$ ½

(f) (i) **Solution A** contains 0.05 moles in $250cm^3$

Concentration =

$= \dfrac{0.05 \times 1000}{250}$ mol l^{-1} ½

= **0.20 mol l^{-1}** ½

OR

Concentration in g/dm^3 = g/dm^3

Molarity of solution A = = 0.2 M

OR

Molarity of solution A == 0.2 M

(ii) Moles of sodium carbonate in $25cm^3$ of solution A=

$= \dfrac{25 \times 0.20}{1000}$ ✓ ½

= **0.005**✓ ½

OR

= = 0.005 moles

(iii) Moles of hydrochloric acid, solution B = Answer in f(ii)

= 0.005 x 2✓ ½

= **0.01**✓ ½

Advice to teachers

Teachers should make use of practical approach to teaching and learning of Chemistry. Emphasis should be made on calculations relating to moles and enthalpy changes, data manipulation, graph interpretation and the use of correct scientific terms in reporting observations and inferences. Teachers are advised to expose learners to as many practicals as possible in order to give them an opportunity to interact with apparatus and chemicals with emphasis on following the procedure to avert accidents in the laboratory.

CONCLUSION

There was an improved performance in the Chemistry practical as opposed to decline in the two theory papers. It is worth noting that part of the practical examination involves the ability of the students to follow instructions in carrying out all the tests. Teachers should therefore train students to perform experiments with strict adherence to the instructions provided. This will enable them attain the expected results without challenges.