8.0 CHEMISTRY (233)

The subject is tested using two theory papers each marked out of 80 marks and a practical paper marked out of 40 marks. The two theory papers are taken in 2 hours while the practical paper is taken in 2¼ hours.

8.1 CANDIDATES' PERFORMANCE

Performance for the subject in 2007, 2008, 2009 and 2010 are shown in the table below:

Table 13: Candidates overall performance in Chemistry in the last four years

Year	Paper	Candidature	Maximum Score	Mean Score	Standard Deviation
2007	1		80	19.67	15.26
	2		80	19.22	13.45
	3		40	11.87	4.95
	Overall	**267,719**	**200**	**50.78**	**31.00**
2008	1		80	18.28	14.78
	2		80	15.74	13.00
	3		40	11.46	5.42
	Overall	**296,937**	**200**	**45.48**	**31.78**
2009	1		80	12.49	9.50
	2		80	14.93	12.04
	3		40	10.86	4.55
	Overall	**329,730**	**200**	**38.23**	**24.53**
2010	1		80	18.78	14.48
	2		80	16.19	13.25
	3		40	14.87	5.60
	Overall	**347,364**	**200**	**49.79**	**31.57**

From the table, it is to be seen that:

8.1.1 The candidature increased from 329,730 to 347,364, an increase of 5.35%.
8.1.2 The mean for 233/1 increased from 12.49 in 2009 to 18.78 in 2010. This was attributed to candidates' ability to respond to all categories of questions appropriately.
8.1.3 The mean for 233/2 improved from 14.93 in 2009 to 16.19 in 2010
8.1.4 The mean for 233/3 improved from a mean score of 10.86 in 2009 to 14.87 in 2010.
8.1.5 The overall subject mean improved from 45.48 in 2009 to 49.79 in 2010.

Questions which were poorly performed are briefly discussed below:

8.2 PAPER 1 (233/1)

Question 14(b)

The formula of a complex ion is $Zn(NH_3)_4^{2+}$. Name the type of bond that is likely to exist between zinc and ammonia in the complex ion. (1 mark)

This was a question on application of knowledge. The question required the candidates to examine the complex ion $Zn(NH_3)_4^{2+}$ closely and establish that the ion is made up of a cation, Zn^{2+} and a neutral molecule with a lone pair of electrons (NH_3).

Weaknesses
Candidates did not realise that the complex had a Zn^{2+} cation and a neutral molecule, NH_3 with a lone pair of electrons.

Candidates have studied bonding in NH_4^+ where the bond between the cation H^+ and the ammonia molecule NH_3 is dative or co-ordinate. Similarly in the complex ion $Zn(NH_3)_4^{2+}$ the ammonia molecule has not changed. It still has its lone pair of electrons. What has changed is the cation H^+ to Zn^{2+}. The change of the cation has not changed the type of bonding.

One of the demands of Vision 2030 is application of knowledge. Students should be encouraged to apply the knowledge they gain during normal classroom teaching to unfamiliar situations.

Expected Response
Dative or co-ordinate bond.

Question 24
Describe how a solid sample of the double salt, ammonium iron (II) sulphate, can be prepared using the following reagents: Aqueous ammonia, sulphuric (VI) acid and iron metal. (3 marks)

In this question, candidates were required to consider all the reagents provided, plan and organise a logical method of synthesising the double salt, ammonium iron (II) sulphate.

Weaknesses
Candidates failed to describe a logical method of synthesising the double salt. Indeed the average and below average candidates who attempted this question lost all the marks. Many of the candidates did not attempt this question.

In the past candidates have been tested on how to prepare soluble and insoluble salts. They have not been tested on preparation of double salts from the time the curriculum was reviewed.

- Students and teachers are strongly reminded that all parts of the syllabus can be tested any time. No part should be ignored whether it is tested frequently or not.

- Salt preparation is one of the easiest topics to teach using the practical approach method. Unfortunately majority of our schools are not properly equipped and therefore result to theoretical teaching. Unless it is absolutely necessary, theorical teaching should be completely avoided.

- In the past it has been emphasised that questions on synthesis require careful planning. If the beginning of a synthesis process is wrong, then **all** the subsequent steps will be wrong and **no** marks can be awarded. Therefore plan before you do.

- In the planning process, they should have learnt that two salts as suggested by the name were required. Iron cannot react with aqueous ammonia. It can only react with sulphuric acid to form iron (II) sulphate as one of the two salts. The other salt can only be prepared from the reaction between ammonia and sulphuric acid to form ammonium sulphate.

Expected Response

React iron metal with sulphuric (VI) acid to form iron (II) sulphate. React aqueous ammonia with sulphuric (VI) acid to form ammonium sulphate. Mix the two solutions to form a mixture of iron (II) sulphate and ammonium sulphate. Evaporate the mixture until crystallisation starts, filter the mixture to obtain the double salt.

8.3 PAPER 2 (233/2)

From analysis contacted it was found that candidates scored poorly in questions 4 and 5. These two questions are briefly discussed below.

Question 4

(a) 50 cm^3 of 1M copper (II) sulphate solution was placed in a 100cm^3 plastic beaker. The temperature of the solution was measured. Excess metal A powder was added to the solution, the mixture stirred, and the maximum temperature of the mixture measured. The experiment was repeated using powders of metals **B** and **C**. The results obtained are given in the table below:

	A	B	C
Maximum temperature (°C)	26.3	31.7	22.0
Initial temperature (°C)	22.0	22.0	22.0

(i) Arrange the metals **A**,**B**,**C** and copper in order of reactivity starting with the least reactive. Give reasons for the order. (3 marks)

(ii) Other than temperature change, state one other observation that was made when the most reactive metal was added to the copper (II) sulphate solution. (1 mark)

(b) The standard enthalpy change of formation of methanol is –239 $kJmol^{-1}$.

(i) Write the thermo chemical equation for the standard enthalpy change of formation of methanol. (1 mark)

(ii) Methanol is manufactured by reacting carbon (II) oxide with hydrogen at 300°C and a pressure of 250 atmospheres.
The equation for the reaction is

$$CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$$

(I) How would the yield of methanol be affected if the manufacturing process above is carried out at, 300°C and a pressure of 400 atmospheres? Explain. (2 marks)

(II) Use the following data to calculate the enthalpy change for the manufacture of methanol from carbon (II) oxide and hydrogen. (3 marks)

$$CO(g) + \frac{1}{2}O_2(g) \longrightarrow CO_2(g); \ \Delta H^\ominus = {}^-283\ kJmol^{-1}$$

$$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l); \ \Delta H^\ominus = {}^-286\ kJmol^{-1}$$

$$CH_3OH(l) + \frac{3}{2}O_2(g) \longrightarrow CO_2(g) + 2H_2O(l); \ \Delta H^\ominus = {}^-715\ kJmol^{-1}$$

(iii) The calculated enthalpy change in part b (ii) (II) above differs from the standard enthalpy change of formation of methanol. Give a reason. (1 mark)

(i) In this question, candidates were required to react three metals with aqueous copper (II) sulphate, observe the maximum temperature reached in each case then arrange the four metals in the order of reactivity.

(ii) They were also required to:

- Write a thermochemical equation for the formation of methanol
- Carry out a calculation on enthalpy change for the formation of methanol.

Weaknesses
Candidates were not able to arrange the four metals in the order of reactivity and therefore they could not give the correct reason.

Questions like this require the candidates to read, comprehend and interpret the data/information given. Candidates should therefore spend time on the question in order to understand its demands.

They should particularly understand why there is no change in temperature when metal **C** is used, why there is a high change in temperature when metal **B** is used and a small change when metal **A** is used. They should relate the changes to reactivity of the metals. When the change in temperature is highest then that metal must be the most reactive and it must be metal **B**. When there is no change in temperature it means that there was no reaction between a solution containing copper ions and metal **C**. Metal **C** therefore must be below copper in the reactivity series.

Teachers should train candidates on how to answer various questions. They must be drilled on how to apply their knowledge on unfamiliar situations in order to solve problems.

Candidates were also not able to write correct thermochemical equation. Like all other types of equations, thermochemical equations must be balanced, have state symbols and must have the value of the heat change.

The weaknesses shown by the candidates are clear evidence that this area of the syllabus is not well understood. It should be known that tests can be set from any part of the syllabus. All areas of the syllabus must be covered adequately.

Calculations involving energy changes continue to be performed poorly. This is one area where constant drilling is a must to the average and below average students. Teachers should ensure that students are exposed to all areas in the topics e.g. drawing of energy diagrams, calculations involving heat of solutions, neutralization formation e.t.c. Data used for this must be obtained from standard text books. Evaluation tests should also be conducted and where there are shortcomings, remedial teaching/redrilling done in order to ensure thorough knowledge in this area.

Expected Responses
4(a)(i) B A copper and C

B has the highest ΔT.
C cannot displace the ions of Cu from solution there is no reaction
A is more reactive than Cu because it displaces its ions from solution

(ii) Blue colour of solution disappeared or brown colour is formed.

(b) (i) $C_{(s)} + 2H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CH_3OH_{(g)}$ $\Delta H = -239$ kJmol^{-1}

(ii) I yield increases/will be higher
$\therefore$ equilibrium shifts to the right or forward reaction is favoured

II $CO_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{2(g)} = -283$ kJoml^{-1}

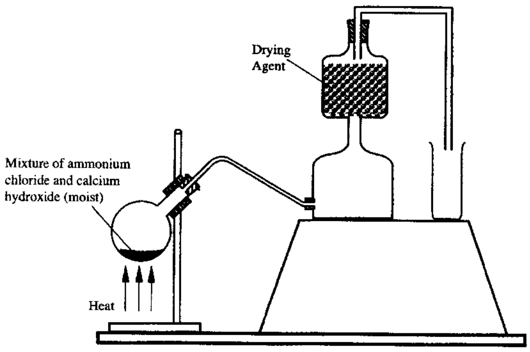
$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{2(l)} = -572 \text{ kJmol}^{-1}$$

$$CO_{2(g)} + 2H_2O_{(l)} \longrightarrow CH_3OH_{(l)} + \frac{3}{2}O_{2(g)} = 715 \text{ kJmol}^{-1}$$

Change in energy
$715 - 283 - 572 = -140 \text{ kJmol}^{-1}$

(iii) ΔH_f for CO is not included.

Question 5
A student set up the apparatus as shown in the diagram below to prepare and collect dry ammonia gas.



(i) Identify **two** mistakes in the set up and give a reason for each mistake. (3 marks)

(I) Mistake ....

Reason ....

(II) Mistake ....

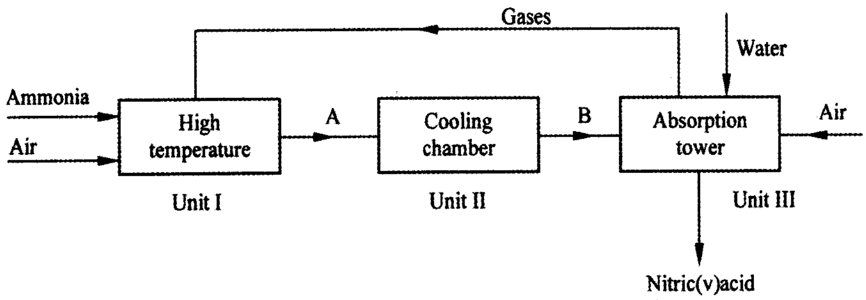
Reason ....

(ii) Name a suitable drying agent for ammonia. (1 mark)

(iii) Write an equation for the reaction that occurred when a mixture of ammonium chloride and calcium hydroxide was heated. (1 mark)

(iv) Describe **one** chemical test for ammonia gas. (1 mark)

(b) Ammonia gas is used to manufacture nitric (V) acid, as shown below.



(i) This process requires the use of a catalyst. In which unit is the catalyst used? (1 mark)

(ii) Identify compounds **A** and **B**. (1 mark)

A ....

B ....

(iii) Using oxidation numbers, explain why the conversion of ammonia to nitric (V) acid is called catalytic oxidation of ammonia. (2 marks)

(iv) Ammonia and nitric (V) acid are used in the manufacture of ammonium nitrate fertilizer. Calculate the amount of nitric (V) acid required to manufacture 1000kg of ammonium nitrate using excess ammonia. (3 marks)

(N = 14.0, H = 1.0, O = 16.0)

(a) In this question, candidates were required to study a diagram on preparation of dry ammonia gas and identify two mistakes giving a reason for each mistake. They were also required to:

- Write an equation for the reaction between ammonium chloride and calcium hydroxide and describe chemical test for ammonia gas.

(b) In part B of the question, they were required to study a flow chart on large scale production of nitric (V) acid and then answer questions like why conversion of ammonia to nitric (V) acid is called catalytic oxidation of ammonia.

Weaknesses

Candidates were able to identify the mistakes in the diagram correctly and give correct reasons for their answers. However, they showed weaknesses in:

(i) writing equations for the reaction between ammonium chloride and calcium hydroxide.
(ii) describing a chemical test for ammonia gas
(iii) using oxidation numbers to explain why conversion of ammonia to nitric (V) acid is called catalytic oxidation of ammonia.

These weaknesses would suggest that candidates may not have been patient enough to study the diagram and the flow chart before answering the questions. Candidates should allow themselves enough time to study and comprehend the questions.

Expected responses

(5(a)(i) Flask is slanting upwards; since the reaction produces a lot of water this may condense and get back to the hot flask and crack it.

The method of collecting the gas is wrong. Since ammonia is less dense than air, it will not find its way into the gas jar.

(ii) A suitable drying agent for ammonia is calcium oxide. Some candidates suggested concentrated sulphuric (V). This would not be suitable because ammonia, being a base, would react with the acid to form a salt.

(iii) $2NH_4Cl_{(s}+Ca(OH)_{2(s)} \longrightarrow 2NH_{3(g)} + 2H_2O_{(l)} + CaCl_{2(s)}$

It should be noted that equations should be balanced and the correct state symbols.

If not balanced, it earns **no** marks at all.
If there are no state symbols or one of them is missing or is wrong, ½ mark is lost.

(iv) pass dry ammonia through dry hydrogen chloride gas. Dense white fumes are formed.

(b)(i) Unit I
It is in unit I where ammonia and oxygen from the air react to form nitrogen (II) oxide. This reaction requires a catalyst.

(ii) A is NO
B is NO_2

(iii) Nitrogen in (NH_3) has an oxidation state of -3 while in HNO_3, the oxidation state is +5.
Increase in oxidation state is called oxidation.

(iv) $NH_3(g) + HNO_3(aq) \longrightarrow NH_4NO_3(aq)$ (½)

Molar mass of NH_4NO_3 (½) = 80 g

Moles of NH_4NO_3 $= \frac{1000\times1000}{80}$

Moles of HNO_3 $= \frac{1000\times1000}{80}$

Because mole ration is 1:1

Molar mass of HNO_3 = 63g

$\therefore$ mass of HNO_3 $= \frac{1000\times1000}{80}\times63$

= 787.5 kg

8.4 PAPER 3 (233/3)

Question 1

You are provided with:

acid **A** labelled solution **A**;
2.0 M sodium hydroxide solution labelled solution **B**;
Solution **C** containing 25.0 g per litre of an alkanoic acid.

You are required to:

(a) prepare a dilute solution of sodium hydroxide, solution **B**.
(b) determine the:
   (i) molar mass of the alkanoic acid
   (ii) reaction ratio between sodium hydroxide and acid **A**.

Procedure 1

Using a pipette and **a pipette filler**, place 25.0 cm^3 of solution **B** into a 250.0 ml volumetric flask. Add about 200 cm^3 of distilled water. Shake well. Add more distilled water to make upto the mark. Label this solution **D**. **Retain the remaining solution B for use in procedure II.**

Fill a burette with solution **C**. Using a clean pipette **and a pipette filler**, place 25.0 cm^3 of solution **D** into a 250 ml conical flask. Add two drops of phenolpthalein indicator and titrate with solution **C**. Record your results **in table 1**. **Repeat the titration** two more times and complete the table.

Table 1	I	II	III
Final burette reading			
Initial burette reading			
Volume of solution **C** (cm^3) added			

(4 marks)

Determine the:

(i) average volume of solution **C** used; (1 mark)

(ii) concentration of solution **D** in moles per litre; (1 mark)

(iii) concentration of the alkanoic acid in solution **C** in moles per litre (1 mole of the acid reacts with 3 moles of the base); (1 mark)

(iv) molar mass of the alkanoic acid. (1 mark)

Procedure II

Fill a **clean** burette with solution **A**. Place 5 cm^3 of solution **A** into a 100 ml beaker. Measure the initial temperature of solution **A** in the beaker and record it in **table II**. Using a 10 ml or a 100 ml measuring cylinder, measure 25 cm^3 of solution **B**. Add it to solution **A** in the beaker and immediately stir the mixture with the thermometer. Record the maximum temperature reached in **table II**. Repeat the experiment with other sets of volumes of solutions **A** and **B** and complete the table.

Table II

Volume of solution **A** (cm^3)	5	9	13	17	21	25
Volume of solution **B** (cm^3)	25	21	17	13	9	5
Maximum temperature (°C)						
Initial temperature (°C)						
Change in temperature, ΔT						

(6 marks)

(a) On the grid provided; plot a graph of ΔT (Vertical axis) against the volume of solution **A**. (3 marks)

(b) From the graph, determine the volume of solution **A** which gave the maximum change in temperature. (1 mark)

(c) Determine the volume of solution **B** that reacted with the volume of solution **A** in (b) above. (1 mark)

(d) Calculate the:

(i) ratio between the volumes of solutions **A** and **B** that neutralised one another; (1 mark)

(ii) concentration in moles per litre of the acid in solution **A**. (Assume that the volume ratio is the same as the mole ratio). (1 mark)

The question required the candidates to:

(i) Select suitable apparatus for carrying out titration
(ii) measure accurately volumes of solutions
(iii) measure and record temperatures of solutions
(iv) plot graphs
(v) interpret points on the graph
(vi) carry out molar calculations

Weaknesses

(i) Average and below average candidates were not able to record data for titration
(ii) They could also not read and record temperatures accurately from a thermometer
(iii) They plotted poor graphs
(iv) Could not interpret correctly the points on the graph
(v) Could not carry out molar calculations

The kind of weaknesses stated above are mainly caused by poor exposure of candidates to practical work. Students are expected to have used various apparatus during teaching. Unfortunately due to lack of apparatus, chemicals and qualified personnel, most of our students do not carry out experiments before they sit for the final examinations. Schools should ensure that laboratories are properly equipped and the necessary personnel made available for the successful teaching of Chemistry.

As suggested in earlier editions of the KCSE report, more examples should be selected from standard text books, past papers and used to drill on candidates on molar calculations.

Progress of students on practical work on molar calculations should be monitored carefully. Depending on the progress, remedial teaching should be arranged in order to bring all candidates at the same acceptable level before they sit for their examinations.

Expected Responses
Table 1

	I	II	III
Final burette reading	13.80	27.80	40.70
Initial burette reading	0.00	13.80	27.30
Volume of solution used (cm^3)	13.80	13.50	13.40

Average volume used $\frac{13.50+13.40}{2} = 13.45cm^3$

Mava = MbVb

2 x 25 = 250 x Vb

$\frac{2\times 25}{250}$ = Vb = 0.20M

Moles of NaOH used = $0.2\times\frac{25}{1000}$ = 0.005 moles

Moles of acid used = $\frac{1}{3}\times 0.0005$

Concentration of acid = $\frac{0.005\times 100}{13.45\times 3}$ = 0.12 M

Molar mass of acid = $\frac{25}{0.12} = 208.3g$

Table 2

Volume of solution A (cm^3)	5	9	13	17	21	25
Volume of solution B (cm^3)	25	21	17	13	9	5
Maximum temperature (°C)	30.5	34.0	36.5	36.5	34.0	30.5
Initial temperature (°C)	26.5	26.5	26.5	26.5	26.5	26.5
ΔT change in temperature	4.0	7.5	10.0	10.0	7.5	4.0

(b) 15 cm^3

(c) $30 - 15 = 15$ cm^3

(d) (i) $15 : 15 = 1 : 1$

(ii) MaVa = MbVb

$$\frac{Ma \times 15}{2 \times 15} = \frac{1}{1}$$

$$Ma = \frac{2 \times 15}{15} = 2$$

$$Ma = 2M$$

Question 2(b)

(b) (i) Using a **metallic** spatula, ignite about one half of solid **G** in a Bunsen burner flame.

OBSERVATIONS	**INFERENCES**
(1 mark)	(1 mark)

(ii) Place the other half of solid **G** into a boiling tube.
Add 15 cm^3 of distilled water and shake well. Label this solution **G**.
Use this solution for the following tests.

I Place 2 cm^3 of solution **G** in a test-tube and determine its pH.

OBSERVATIONS	**INFERENCES**
(1 mark)	(1 mark)

II To about 2 cm^3 of the solution obtained in (ii) above, add 3 drops of acidified potassium manganate (VII).

OBSERVATIONS	INFERENCES
(1 mark)	(1 mark)

III To about 2 cm^3 of the solution obtained in (ii) above, add 2 drops of bromine water.

OBSERVATIONS	INFERENCES
(1 mark)	(1 mark)

(iii) To the remaining solution **G** in the boiling tube, add the other half of solid **F**.

OBSERVATIONS	INFERENCES
(1 mark)	(1 mark)

Question 2(a) was on qualitative analysis. The question was performed quite well by below average, average and above average candidates.

Question 2(b) was on qualitative analysis involving functional groups in organic Chemistry.

The question required the candidates to:

(i) ignite the organic substance
(ii) determine the P^H of a solution of the organic substance
(iii) use acidified potassium manganate (VII) to test for presence of a double or triple bond.
(iv) use bromine water to test for presence of unsaturation
(v) use sodium carbonate to test whether the organic substance forms an acid when dissolved in water.

Weaknesses

(i) Candidates were not able to describe the colour of the flame produced correctly. Some wrote lilac, yellow, black. Due to the incorrect observations they made incorrect inferences hence they lost all the marks.

(ii) Candidates were also not able to get correct colour on the p^H chart and therefore could not deduce the correct p^H of a solution of the organic acid.

(iii) Candidates could not get the colour change of acidified potassium manganate (VII). Some wrote turned brown! Ppt formed, iron fillings moving in solution. This weakness in particular shows that the majority of candidates have not used acidified potassium manganate (VII) to test for unsaturation. Teachers should note that students should be thoroughly drilled on how to carry out experiments. Precautions to be taken to ensure correct observations made should be emphasised. Results of the experiments should be described using scientific language. As has been said before, if the observations in a practical experiment are wrong, the inference will also be wrong. It is **very important** that the observations are accurate.

(iv) Observations should be recorded immediately they are made. In making inferences, correct formulae of the cations, anions e.t.c. present in the samples **must** be correct.

Expected Responses

(i)

OBSERVATIONS	INFERENCES
Burns with a smoky flame	Unsaturated organic cpd or long chain Hydrocarbon

(ii)

OBSERVATIONS	INFERENCES
Colourless solution, turns red P^H 1 – 2	Carboxylic acid present

(iii)

OBSERVATIONS	INFERENCES
- Effervescence colourless gas evolved - Odourless gas (1)	Confirm G was acid and F was a carbonate

I

OBSERVATIONS	INFERENCES
Decolourised $KMnO_4$	Unsaturated alkene or alcohol present

II

OBSERVATIONS	INFERENCES
Bromine water decolourised	Unsaturated alkene present or alkyne

8.5 CONCLUSION

Science subjects should be taught using the practical approach method. For this to be achieved, schools should be equipped with apparatus and the necessary chemicals.

Students must be trained on how to take precautions in order to make accurate observations. They should also be equipped on how to communicate their findings using acceptable scientific language and how to utilize knowledge and skills learnt in their everyday life. Students should always be reminded that Chemistry is our life. Chemistry is our future.