

Name: ..... Comb and Stream: .....

Date: ..... Signature: .....

P525/1

CHEMISTRY (Theory)

Paper 1

April 2025

3 hours

GUIDE

**MENGO SENIOR SCHOOL**  
**END OF TERM I ASSESSMENT 2025**  
**Uganda Advanced Certificate of Education**  
**S.5 CHEMISTRY**  
**Paper 1 (Principal Subject)**  
**3 hours**

**INSTRUCTIONS TO LEARNERS:**

- This paper consists of two sections A and B.
- Section A contains four items which are compulsory.
- Section B has three items; attempt only two items from this section.
- Answer to Section A must be written in the spaces provided and for Section B should be written in the answer sheets provided.
- The periodic table, with relative atomic masses, is attached at the end of the paper.
- Mathematical tables (3-figure tables) are adequate or non-programmable scientific electronic calculators may be used.
- Illustrate your answers with equation(s) where applicable.

Where necessary; use the following:

Molar volume of gas at s.t.p is  $22.4\text{dm}^3$  or  $22400\text{cm}^3$

Standard temperature =  $273\text{K}$ . Standard pressure =  $101325\text{Nm}^{-2}$

**FOR SCORER'S USE ONLY**

ITEMS	1	2	3	4	5	6	TOTAL
SCORES							

**SECTION A**

(Answer ALL items from this section)

**Item 1.**

Tyramine is an organic base found in the venom of wasp stings that is responsible for causing severe pain and swelling when one is stung by a wasp. Patrick, an inquisitive student of S.5 wanted to know the composition and molecular formula of the base in venom. He was instructed by the laboratory technician to extract the venom and use different masses of it for experimentation as follows:

First, he was instructed to mix 0.210g of the venom with excess oxygen, explode the mixture and then pass the products over anhydrous calcium chloride in a U-tube and then into concentrated potassium hydroxide solution placed in a wash bottle. He was able to record a 0.152g difference in mass of content in the U-tube and a 0.540g difference in mass of content in the wash bottle.

In a separate experiment Patrick was instructed to explode 0.135g of the venom which liberated 11.04cm<sup>3</sup> of nitrogen gas at s.t.p. The laboratory technician informed the him that the molecular mass of the base was 137g.

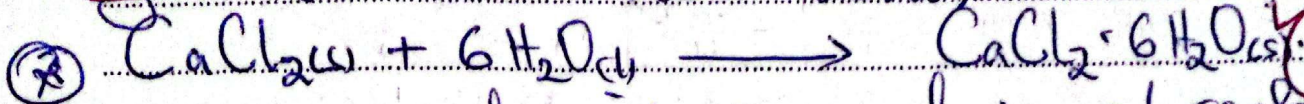
**Task:** As a S.5 chemistry student; help Patrick to understand the nature of the organic base by:

(a) Explaining to him the difference in masses he obtained in the U-tube and that in the wash bottle. (03 scores)

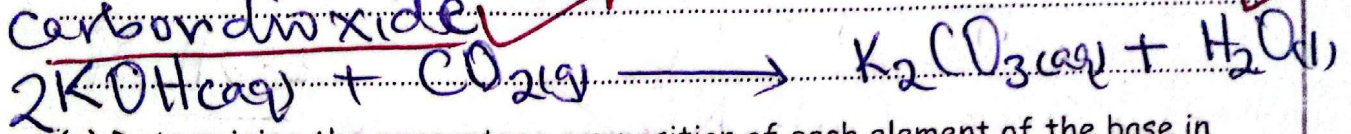
- ① The difference in mass in the U-tube was due to water (vapour) absorbed by the anhydrous calcium chloride coming from oxidation of hydrogen.
- ② The difference in mass in the wash bottle was due to carbon dioxide absorbed by the concentrated potassium hydroxide solution coming from oxidation of carbon. (03 scores)

(b) Identifying the role of anhydrous calcium chloride and potassium hydroxide solution and write balanced equation(s) of reaction(s) where necessary. (03 scores)

① Anhydrous calcium chloride is a drying agent (or water absorbent).



Potassium hydroxide is used to absorb carbon dioxide.



(c) Determining the percentage composition of each element of the base in the venom. (04 scores)

RMM of  $\text{CO}_2 = 12 + 16 \times 2 = 44$

RMM of  $\text{H}_2\text{O} = 2 + 16 = 18$

44g of  $\text{CO}_2$  contain 12g of Carbon

0.540g of  $\text{CO}_2$  contain  $\left(\frac{12 \times 0.540}{44}\right)$  g of C

0.210g of Venom contain  $\left(\frac{12 \times 0.540}{44}\right)$  g of C

100g of Venom contain  $\left(\frac{12 \times 0.540 \times 100}{44 \times 0.210}\right)$  g of C  
 = 70.13% Carbon

18g of  $\text{H}_2\text{O}$  contain 2g of Hydrogen

0.152g of  $\text{H}_2\text{O}$  contain  $\left(\frac{2 \times 0.152}{18}\right)$  g of H

(d) Determining the molecular formula of the base in the venom. (05 scores)

0.210g of Venom contain  $\left(\frac{2 \times 0.152}{18}\right)$  g of H

100g of Venom contain  $\left(\frac{2 \times 0.152 \times 100}{18 \times 0.210}\right)$  g of H  
 = 8.04% of H

22400cm<sup>3</sup> of Nitrogen contain 28g of Nitrogen

11.04cm<sup>3</sup> of Nitrogen contain  $\left(\frac{28 \times 11.04}{22400}\right)$  g of N

0.135g of venom contain  $\left(\frac{28 \times 11.04}{22400}\right)$  g of N

100g of venom contain  $\left(\frac{28 \times 11.04 \times 100}{22400 \times 0.135}\right)$  g of N

Percentage of Nitrogen in Venom = 10.22%

Since total percentage is not 100%, then oxygen is missing.

∴ Percentage of oxygen =  $100 - (70.13 + 8.04 + 10.22)$   
 = 11.61%

Elements	C	H	N	O
Percentages	70.13	8.04	10.22	11.61
Moles	$\frac{70.13}{12}$ = 5.844	$\frac{8.04}{1}$ = 8.04	$\frac{10.22}{14}$ = 0.73	$\frac{11.61}{16}$ = 0.73
Mole ratio	$\frac{5.844}{0.73}$ = 8	$\frac{8.04}{0.73}$ = 11	$\frac{0.73}{0.73}$ = 1	$\frac{0.73}{0.73}$ = 1

$$n = \frac{137}{(12 \times 8 + 1 \times 11 + 14 + 16)}$$

$$n = \frac{137}{137}$$

$$n = 1$$

∴ Molecular formula of base in venom is  $C_8H_{11}NO$

Empirical formula  $C_8H_{11}NO$

Molecular formula = n (Empirical formula)

$$n = \frac{\text{Molecular mass}}{\text{Empirical mass}}$$

Item 2.

During agricultural research at National Agricultural Research Organisation (NARO), investigations were carried to analyse an unusual soil pH which was affecting crop growth in Arua district. Soil samples were taken to the laboratory and analysed. It was found out that the soil contains a sodium salt responsible for the soil pH with a formula  $Na_2CO_3 \cdot xH_2O$ .

The following analytical procedure was carried out.

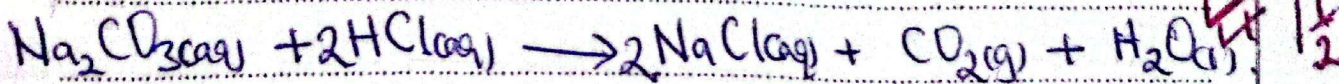
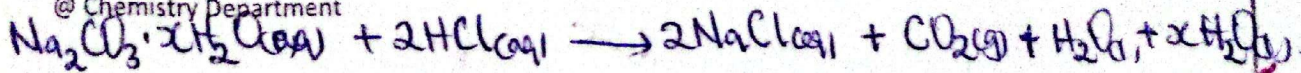
8.58g of  $Na_2CO_3 \cdot xH_2O$  was dissolved in water and made to one liter.  $20cm^3$  of this solution needed  $12cm^3$  of 0.1M hydrochloric acid for complete neutralization.

Task; As a chemistry student, help the organization to discover the actual formula of the salt, the nature of the salt and soil pH by;

(a)(i) Defining a neutralisation reaction.

This is a reaction where an acid reacts with a base (or alkali) to form a salt and water as the only products. (01 mark)

(ii) Writing down a balanced chemical equation for the reaction. ( $1\frac{1}{2}$  scores)



(b) Calculating the moles of hydrochloric acid used. (02 scores)

1000 cm<sup>3</sup> of solution contains 0.1 moles of hydrochloric acid

12 cm<sup>3</sup> of solution contains  $\left(\frac{0.1 \times 12}{1000}\right)$  moles of HCl.

$$= 1.2 \times 10^{-3} \text{ moles of HCl}$$

(or 0.0012 moles of HCl)

(c) Calculating the:

(i) Molarity of the carbonate. (2½ scores)

2 moles of HCl reacted with 1 mole of carbonate

1.2 × 10<sup>-3</sup> moles of HCl reacted with  $\left(\frac{1 \times 1.2 \times 10^{-3}}{2}\right)$  moles of carbonate

= 6 × 10<sup>-4</sup> moles of carbonate

20 cm<sup>3</sup> of solution contains 6 × 10<sup>-4</sup> moles of carbonate

1000 cm<sup>3</sup> of solution contains  $\left(\frac{6 \times 10^{-4} \times 1000}{20}\right)$  moles

(ii) Formula mass of Na<sub>2</sub>CO<sub>3</sub> · xH<sub>2</sub>O.

0.03 moles of Na<sub>2</sub>CO<sub>3</sub> · xH<sub>2</sub>O weigh 8.58g

1 mole of Na<sub>2</sub>CO<sub>3</sub> · xH<sub>2</sub>O weigh  $\frac{8.58}{0.03}$

Formula mass of Na<sub>2</sub>CO<sub>3</sub> · xH<sub>2</sub>O = 286g

(iii) Value of x.

RFM of Na<sub>2</sub>CO<sub>3</sub> · xH<sub>2</sub>O = 286

$$2 \times 23 + 12 + 16 \times 3 + 18x = 286$$

$$106 + 18x = 286$$

$$18x = 286 - 106$$

$$18x = 180$$

$$x = \frac{180}{18}$$

$$x = \underline{10}$$

(d)(i) Writing the chemical formula for the sodium salt and commenting on its nature. (02 scores)

Formula  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$  ✓

Nature: The salt is a white crystalline salt, efflorescent in nature (or loses water of crystallization when exposed to air) and is soluble in water forming alkaline solution. ✓

(ii) Concluding whether the pH of the soil sample is acidic, neutral or alkaline giving a reason for your answer. (1½ scores)

The pH is alkaline ✓

This is because the salt is hydrolysed in aqueous solution forming sodium hydroxide solution which is strongly alkaline. ✓

(e) Giving a recommendation on what can be done in order to improve the yield of the crops. (02 scores)

- To improve yield of crops, we can plant crops that are tolerant to alkaline pH. ✓
- Crop yield can also be improved by addition of salts that neutralize the alkaline pH such as aluminium sulphate or Iron(III) sulphate. ✓
- By applying sulphur which is worked on bacteria to form sulphuric acid that lowers the soil pH, slowly. ✓

Item 3.

The S.5 chemistry club of Mengo S.S, led by Simon and three of his club members were preparing a presentation to the club about chemical formulae, chemical equations, solutions, concentrations and calculations involving gas volumes. His three friends presented to him their research findings:

Jayla said that 'cars release nitrogen dioxide gas, a harmful gas.' She stated that 'when this gas mixes with rainwater in presence of air, it leads to acid rain and this is a chemical reaction.'

James on the other hand, said that 'the gas stove at their home uses bio gas that mainly contains methane which burns to produce a lot of heat used for cooking. He said that this is also a chemical reaction.'

Shanice on the other hand, said that 'in their home bakery, they mix vinegar (acetic acid / ethanoic acid) with baking soda (sodium bicarbonate / sodium

15

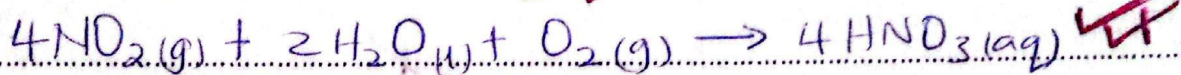
hydrogen carbonate) which causes fizzing of a gas. She then stated that this is a chemical reaction.'

Simon had a vague idea of the reactions his friends had research about.

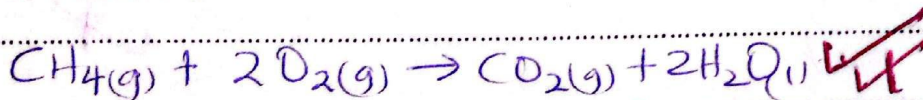
Task: As a chemistry student who knows about chemical reactions, solutions, concentrations and calculations involving gas volumes, help Simon to:

(a)(i) Identify the acid formed in the acid rain and write the equation for the reaction leading to formation of the acid rain. (02 scores)

Nitric acid or  $\text{HNO}_3$  ✓



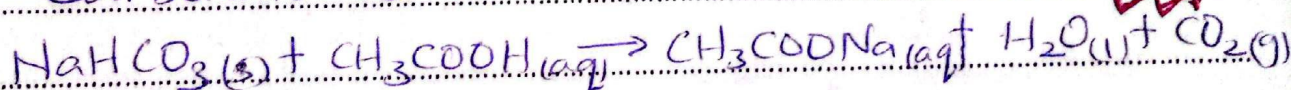
(ii) Write the major equation that involves burning of bio gas and name the type of reaction. (02 scores)



Combustion reaction ✓

(iii) Name the gas released by baking soda and write the chemical equation. (02 scores)

Carbondioxide ✓



(b) Find out the volume of gas produced when 16.8g of baking soda completely reacted with vinegar at s.t.p. (03 scores) ✓

Molar mass of baking soda,  $\text{NaHCO}_3 = 23 + 1 + 48 = 72$  ✓

84g of baking soda produce  $22.4 \text{ dm}^3$  ( $22,400 \text{ cm}^3$ ) of  $\text{CO}_2$  ✓

16.8g of baking soda produce  $\left(\frac{22.4 \times 16.8}{84}\right) \text{ dm}^3$  of  $\text{CO}_2$  ✓  
 $= 4.48 \text{ dm}^3$  or  $4,480 \text{ cm}^3$  ✓

OR

Moles of baking soda =  $\frac{16.8}{72} = 0.2$  moles ✓

mole ratio of baking soda,  $\text{NaHCO}_3 : \text{CO}_2$  is 1:1 ✓

moles of  $\text{CO}_2 = 0.2$  moles ✓

1 mole of  $\text{CO}_2$  occupies  $22.4 \text{ dm}^3$  at stp ✓

0.2 moles of  $\text{CO}_2$  occupy  $\left(\frac{22.4 \times 0.2}{1}\right) \text{ dm}^3$  at stp =  $4.48 \text{ dm}^3$  ✓

(c) Determine the molarity of the acid rain formed if each  $0.112\text{dm}^3$  volume of nitrogen dioxide gas at s.t.p was able to completely dissolve in every  $250\text{cm}^3$  portion of rain water. (04 marks)

$22.4\text{dm}^3$  is volume occupied by 1 mole of  $\text{NO}_2$  at s.t.p

$0.112\text{dm}^3$  is volume occupied by  $(\frac{1}{22.4} \times 0.112)$  moles of  $\text{NO}_2$

= 0.005 moles

4 moles of  $\text{NO}_2$  produce 4 moles of  $\text{HNO}_3$

0.005 moles of  $\text{NO}_2$  produce  $(\frac{4}{4} \times 0.005)$  moles of  $\text{HNO}_3$   
= 0.005 moles

$250\text{cm}^3$  portion of rain water formed 0.005 moles of  $\text{HNO}_3$  (acid rain)

$1000\text{cm}^3$  portion of rain water formed  $(\frac{0.005 \times 1000}{250})$  moles of acid rain  
=  $0.02\text{mol dm}^{-3}$

(d) Explain the shortcomings of the reaction Jayla researched about and how they can be avoided. (02 scores)

The acid rain damages vegetation (by the scorching leaves, and reduce photosynthesis, by soil nutrient leaching, lowering soil pH i.e. soil acidification), harms aquatic ecosystem, corrodes infrastructure and their surface weakens, cause respiratory issues.

The shortcomings are avoided by reducing nitrogen oxide emissions by using catalytic converters, using renewable cleaner energy sources, adding lime to soil and water bodies, using regulatory policies that limit nitrogen oxide emissions, etc.

Item 4.

(a)(i) Mengo Senior School is starting to construct a multipurpose storeyed dining hall complex. A strong foundation fixed with pillars must be laid first before building the walls, other floors and the roof.

Task: State Aufbau's Principle in electron configuration and show how it is related to the construction process. (03 scores)

Aufbau's principle states that, 'electrons are filled in such a way that they fill lower energy orbitals (or levels) first before filling higher ones. Similarly, when

constructing the multi storeyed dining hall complex, the foundation and pillars are laid first in order for the building not to collapse and be stable. This is similar to an atom's stability depending on filling lower energy levels first before higher ones.

(ii) A group of passengers is boarding a drone (public minibus). There are empty rows of seats available, but all the first people choose to sit alone in these rows before sitting next to someone else.

Task: State Hund's Rule in electron configuration and show how it is related to the passengers' scenario. (03 scores)

Hund's rule states that, electrons are filled in an atom such that when filling degenerate orbitals, they fill singly first in parallel spins before pairing up. This is similar to how passengers board a drone by preferring to occupy separate seats first before sharing with others.

This minimises discomfort in the drone and maximises space just like electrons try to minimise repulsion and maximise

ability by filling separate degenerate orbitals singly first in parallel spins before pairing.

(iii) In Mengo Senior School, a student is given an admission number and the also biometric scans for the finger prints are applied in order to differentiate each one of them.

Task: State Pauli's Exclusion Principle and relate it to why is it necessary for each student to have a different admission number and biometric scan. (03 scores)

Pauli's Exclusion Principle states that electrons are arranged in an atom such that an orbital can accommodate a maximum of two electrons which must spin in opposite directions i.e. no two electrons in an atom can have the same set of quantum numbers.

Similarly in school every student is assigned a unique admission number and biometric scans for finger prints are applied since each student has a unique finger print. This is done to avoid confusion and ensure proper identification just like electrons in an atom are uniquely identified by their opposite spins in each orbital.

3

(b) Janet and three of her group members in S.5 Gold came up with observations related to electronic configuration and reactivity of elements. Janet observed that potassium metal is stored under oil but not in water or air. Daniel observed that copper is used in plumbing as metal pipes although it is expensive instead of the less expensive iron. Samalie on the other hand is so much interested in cookery and observed that table salt is commonly used as sodium chloride, while potassium chloride (a salt substitute) may be used but with caution.

Task: As a chemistry student who knows about electronic configuration of atoms of elements and their reactivity, help the following students to understand their observations:

(i) Janet.

(02 scores)

Potassium has an electronic configuration of  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

Potassium has one electron in its outermost shell and also has a large atomic radius (size). Thus the single valence electron is very easy to lose, making potassium extremely reactive especially with water and air, with a risk of fire. Oil prevents contact of potassium with water and air which minimises the risk of fire.

2

(ii) Daniel.

(02 scores)

Copper has an electronic configuration of  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 4s^1$  while iron has an electronic configuration of  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ .

Copper has an electronic configuration with completely filled 3d orbitals and a half-filled 4s orbital making it to be stable and less reactive (does not easily react). However, the electronic structure of iron is neither half filled nor fully filled making it to be unstable. Hence iron is more reactive than copper and can easily corrode (rust) over time hence not ideal for plumbing.

02

(iii) Samalje.

Sodium has an electronic configuration of  $1s^2 2s^2 2p^6 3s^1$  while that of potassium is  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ . Potassium has a larger atomic radius (size) and its valence electron is further from the nucleus than sodium. Thus potassium is more reactive than sodium and too much potassium salt can affect the heart function more than the sodium salt.

(02 scores)

2

15

### SECTION B

(Answer TWO items from this section)

Item 5.

(20 scores)

(a) A spontaneous nuclear reaction involving Thorium-232 leads to release of two alpha particles to form W. W undergoes beta decay to form Z.

(i) Write well-balanced nuclear reactions and determine the identity of W and Z.

(ii) Compare the properties of beta and alpha particles.

(b)(i) An archaeologist discovered a wooden artefact and used carbon-14 to determine its age. The artefact was found to contain 35% of its original carbon-14 content. If the half-life of carbon-14 is 5600 years. Determine the age of the artefact.

(ii) Compare nuclear reaction and chemical reactions.

(c) A sample of a radioactive substance was analysed in a Geiger-Muller counter and its activity measured over a period of time.

Time (s)	0	10	20	30	40	50	60
Activity (counts per second)	800	565	380	283	190	141	95

(i) Plot a graph of activity against time.

(ii) Use your graph to determine half-life of the substance and the decay constant.

(20 scores)

Item 6.

(a) Recently, in a high school newly constructed chemistry laboratory, new shipment of elements arrived, and the labels on their bottles were partially

removed. The only visible information was the atomic numbers which were 11, 13, 24, 17, and 18.

Your teacher is responsible for ensuring that laboratory safety is a priority and chemicals are stored properly to prevent accidents.

**Task:** The teacher has asked you to identify the elements, determine the electronic configurations of the elements and their major ions, clarify on their position in the Periodic Table (Group, Period and Block) hence predict and analyze their reactivity.

Comment on the behavior of the compound formed when elements with atomic number 11 and 17 combine. Also explain how the compound is formed.

Write a brief message to respond to the teacher's assignment.

**Item 7.**

(20 scores)

(a) During agricultural research at National Agricultural Research Organisation (NARO), a mini-handheld spectrometer was used to analyse an unusual soil nutrient which was affecting crop health in Luwero district. When a small sample was vapourised and analysed, four amplified bars of ratio of 0.29 : 4.95 : 4.54 : 10.22 with isotopic masses 204, 206, 207 and 208 respectively were obtained. The research officer produced a report but the district leader could not interpret it and did not know how it comes about.

**Task:** As a S.5 Chemistry learner with knowledge about mass spectrometry;

- (i) Describe how the device was operated to come up with the report.
- (ii) Calculate the relative atomic mass of the soil nutrient and identify it.
- (iii) State the advantages of the method used by the researchers.

(b) A group of researchers used a mass spectrometer to determine the relative atomic mass of chlorine. In their findings, chlorine had two isotopes Cl-35 and Cl-37 and mass spectrum had three significant peaks at 70, 72 and 74. The report shows that the relative atomic mass of chlorine is 35.5.

Peter a new comer in senior five chemistry class is inquisitive about this machine and the mass spectrum obtained.

**Task:** Using the knowledge of chemistry you have obtained;

(i) Explain to Peter:

- Why only three peaks were observed on the mass spectrum.
- Two other uses of the machine in daily life.

(ii) Calculate the percentage abundance of each isotope of chlorine from the data and hence sketch the mass spectrum of chlorine.

END