ITEM ONE: EXPERIMENTAL COMPETENCES ASSESSMENT

This rubric evaluates a learner's ability to plan and carry out a chemistry experiment, present and analyse data, interpret findings, draw conclusions, and make recommendations in a scientific and logical manner.
There are **five major** competences assessed:

1. Planning
2. Methodology
3. Data Presentation
4. Data Analysis
5. Conclusion and Recommendations

(1) Planning for the experiment
Planning mainly involves formulating:

- the aim of the experiment;
- the hypothesis; and
- the experimental variables.

Planning assesses a learner's ability to design an experiment before carrying it out. The learner should be able to read and understand the scenario, identify the problem or challenge presented, suggest its possible cause, and select a suitable experimental approach. The learner should also identify the factor to be selected or changed, the factor to be measured, and the factors to be kept constant to ensure a fair and reliable investigation.
(a) Aim of the Experiment
A good aim should clearly state what the experiment is intended to determine and why the investigation is being carried out. It should also include the key variables involved in the experiment.
Components of a Good Aim

Component	Meaning
Purpose	What the experiment intends to determine
Reason / Why	The reason for carrying out the experiment, usually linked to the problem in the scenario
Independent variable	The factor selected, fixed, or changed by the experimenter
Dependent variable	The quantity measured or observed during the experiment
Controlled variables	The factors kept constant to ensure a fair and reliable test

Suggested Aim Structure

To determine/investigate …………………of .... in order to assess/verify/establish/confirm………………… by measuring.....................
………………… required to react with/oxidize a fixed volume of …………………
……………..............................obtained by dissolving/reacting/diluting a fixed
....

- ✓ Use assess when you want to judge whether a value, quality, purity, concentration, or rate is suitable, acceptable, safe, or within a required range.
- ✓ Use verify when there is already a claim, label, stated value, or supplier's information that must be checked.
- ✓ Use establish when the value or identity is unknown, and the investigation is meant to find it out before a decision can be made.
- ✓ Use confirm when preliminary observations, complaints, or earlier tests already suggest a possible problem.

Example

To determine the percentage purity of the supplied sodium hydroxide, BA2, in order to assess its suitability for use in soap making by measuring the volume of standardized sulphuric acid, BA1, required to neutralize a fixed volume of the sodium hydroxide solution.

(b)Hypothesis of the Experiment

A hypothesis is a testable prediction about the expected result of an experiment.

It shows what the learner expects to happen before carrying out the investigation. A good hypothesis should be clear, scientific, and linked to the aim of the experiment.

Components of a Good Hypothesis

Component	Meaning
Prediction	The expected result or expected relationship
Independent variable	The factor selected, fixed, or changed by the experimenter
Dependent variable	The quantity measured or observed during the experiment

Suggested Structure for Writing a Hypothesis

The ………………… is above/below/higher/exceed/greater/lower …………………, determined by measuring ………………… required to react or oxidize a fixed volume or ………………… ....

Example of a Good Hypothesis

The percentage purity of supplied sodium hydroxide is lower than 95%, determined by measuring the volume of standardized sulphuric acid, BA1, required to neutralize with a fixed volume of the sodium hydroxide solution.

Note: A hypothesis should not be written as a question. It should be a **prediction** that can be tested using experimental results.

(c). Variables in an Experiment

Variables are factors in an experiment that may be selected, changed, measured, observed, or kept constant.

There are three main types of variables:

- **Independent variable**
- **Dependent variable**
- **Controlled variables**

Common Examples of Variables

- Volume of solution used
- Time taken for a reaction
- Mass of solid weighed
- Length of a material
- Temperature of the reaction mixture
- Type of reactant used
- Type of chemical or reagent used
- Colour change observed

A learner should write variables clearly. Variables should not be written as single words only, such as volume, mass, or temperature. Instead, the learner should state which volume, which mass, or which temperature is being referred to.

(i) Independent Variable

The independent variable is the factor deliberately selected, changed, or fixed by the experimenter in order to investigate its effect on another factor.

In some practical investigations, the independent variable is varied. In others, especially in titration, it may be a carefully selected fixed quantity of sample used for analysis.

Type of Experiment	Example of Independent Variable
Titration	Fixed volume of solution pipetted into the conical flask
Titration involving a solid	Mass of solid sample weighed
Kinetics	Volume of one reactant
Kinetics	Temperature of the reacting mixture
Thermochemistry	Mass or type of substance reacted

(ii) Dependent Variable

The dependent variable is the factor that is measured or observed during the experiment. Its value changes in response to the independent variable and provides the evidence used to make a conclusion.

Type of Experiment	Example of Dependent Variable
Titration	Volume of solution in the burette required to reach the end point
Kinetics	Time taken for a visible change to occur
Kinetics	Volume of reactant remaining at regular time intervals
Thermochemistry	Temperature change of the reaction mixture

Type of Experiment	Example of Dependent Variable
Thermochemistry	Heat energy released or absorbed during the reaction

(iii) Controlled Variables

Controlled variables are factors that are deliberately kept the same throughout an experiment. They ensure that any change in the measured result is caused by the variable being investigated and not by other factors.

A controlled variable should be stated clearly by giving: the factor kept constant; its fixed value or condition; and where appropriate, how it is kept the same.

Strong controlled variables are those that can directly affect the reaction, the end point, or the measured volume.

Variable Kept Constant	Clear Way of Writing
Mass of solid sample	The mass of the solid sample weighed was kept constant at 1.50 g for each trial.
Volume of solution analysed	The volume of the solution pipetted was kept constant at 25.0 cm^3 in every titration.
Final dilution volume	The solution was made up to the same final volume of 250.0 cm^3 in each preparation.
Temperature of reaction mixture	The temperature of the reacting mixture was kept constant throughout the kinetic experiment.
Volume of reacting mixture	The total volume of the reacting mixture was kept constant in each kinetic trial.
Volume of solution used in thermochemistry	The volume of copper (II) sulphate solution was kept constant at 50.0 cm^3 in each experiment.
Initial temperature	The initial temperature of the reacting solutions was kept constant before mixing.
Mass of metal added	The mass of zinc powder added was kept constant at 1.00 g in each thermochemistry trial.

Example

Variables;
Independent variable: Fixed volume of sodium hydroxide solution, BA2**, pipetted** into the conical flask

Dependent variable: Volume of standardized sulphuric acid, BA1, in the **burette required** to neutralize the fixed volume of BA2/to reach the end point

Controlled variables:

The volume of sodium hydroxide solution, BA2, pipetted into the conical flask kept constant at 25.0 cm^3

Scoring guide

LEVEL	REQUIREMENT	SCORE
HIGH	4A+3H+3V	03
MODERATE	4A+3V	02
LOW	3V	01

(2) Methodology; Competence Assessed

The candidate describes a complete experimental procedure together with mitigated risks.
A good methodology should describe how the experiment was carried out in a clear, logical, accurate, and reproducible way. It should allow another person to repeat the experiment and obtain reliable results.

Requirement	Explanation	Example
Reported speech / passive voice	The procedure should be written as what was done, not as direct instructions or commands.	"25.0 cm^3 of FA1 was pipetted into a conical flask."
Correct apparatus and materials	The apparatus and reagents used should be clearly stated, including how they were used.	Burette, pipette, conical flask, volumetric flask, indicator, FA1, FA2.
Specific quantities	Relevant volumes, masses, concentrations, and number of drops should be stated where necessary.	"25.0 cm^3 of the acid was transferred using a pipette."
Logical sequence	The steps should follow the correct experimental order from preparation to measurement.	Rinsing apparatus → filling the burette → pipetting the solution → adding indicator → titrating.

Procedure one

a) 2.6 g of anhydrous sodium carbonate, Solid E, was weighed accurately using analytical balance into a beaker.
b) The solid was dissolved in a about 100cm^3 of distilled water in a beaker.
c) The solution was transferred into a 250 cm^3 volumetric flask and more distilled water was added up to the 250 cm^3 mark.
d) 25.0 cm^3 of sodium carbonate solution was pipetted into a conical flask.
e) 3 drops of methyl orange indicator were added.
f) BA1 was added from the burette into the conical flask while swirling until the endpoint was reached.
g) The final burette reading was recorded.
h) The titration was repeated twice to obtain consistent titres values.

PROCEDURE TWO

a) 25.0 cm^3 of BA2 was pipetted into a conical flask.
b) 3 drops of methyl orange indicator were added.
c) BA1 was added from the burette while swirling until neutralization was complete.
d) The final burette reading was recorded.
e) The titration was repeated to obtain concordant titres.

Mitigated risks

Danger or risk(explained)	Possible effect (explained	Mitigation with explanation
Sulphuric acid, BA1, is corrosive and may splash during filling of the burette, transfer, or titration.	On contact, it may burn the skin, damage the eyes, or irritate the hands.	A laboratory coat, gloves, and safety goggles were worn to prevent direct contact with acid splashes. Any spill was washed immediately with plenty of water.
Sodium hydroxide solution, BA2, is corrosive and may enter the mouth during pipetting.	If swallowed, it may burn or irritate the mouth and digestive tract.	A pipette filler was used instead of mouth pipetting to prevent sodium hydroxide solution from entering the mouth.
Broken glassware may have sharp edges.	On Contact with the sharp pieces may cut the skin and cause injury.	Glassware was inspected for cracks before use, broken glass ware were not used

Scoring guide

LEVEL	REQUIREMENT	SCORE
HIGH	All Pp + 2Mr	03
MODERATE	All Pp	02
LOW	$\frac{1}{2}$ Pp	01

(3) Data Presentation

Competence assessed:

The candidate presents experimental data clearly, appropriately, and accurately.

The candidate presents data sets appropriately and accurately by recording raw results in a clear scientific table, providing the required number of data sets, and ensuring that values are recorded to the correct precision and fall within the acceptable error margin.

Code	Component	Meaning
Dr	**Data recording**	• Raw readings are recorded in a suitable **closed** table with correct headings and **units,** all rows and columns clearly separated • Titration table should include **rows** for final burette reading, initial burette reading and volume used in that order all with units • Variables: mass **weighed,** pipette **capacity**, all with units written before the titration table
Ds	**Data sets**	• The required number of data sets/trials is recorded. At least **two-thirds of the required data** should be present for the data set to be considered adequate.

Code	Component	Meaning
Dc	**Data correctness/accuracy**	• Values are recorded to the correct number of decimal places and fall within the acceptable central range or error margin.

Table 1: Determination of mass of sodium carbonate used

Measurement	Reading / g
Mass of weighing bottle + sodium carbonate before transfer	18.60
Mass of weighing bottle + remaining sodium carbonate after transfer	16.00
Mass of sodium carbonate transferred	2.60

Table 2: Standardization of sulphuric acid, BA1, using sodium carbonate solution

Pipette volume of sodium carbonate solution = 25.0 cm^3

Titration	1	2	3
Final burette reading / cm^3	12.30	24.60	36.90
Initial burette reading / cm^3	0.00	12.30	24.60
Volume of BA1 used / cm^3	12.30	12.30	12.30

Average titre $= \frac{12.30+12.30}{2} = 12.30\ cm^3$

Table 3: Determination of sodium hydroxide, BA2, using standardized BA1

Pipette volume of BA2 = 25.0 cm^3

Titration	**1**	**2**	**3**
Final burette reading / cm^3	10.00	19.20	28.40
Initial burette reading / cm^3	0.00	10.00	19.20
Volume of BA1 used / cm^3	10.00	9.20	9.20

Average titre $= \frac{9.70+9.80}{2} = 9.75\ cm^3$

high	2Dr + 2Ds + 4Dc	3
medium	2Dr + 2Ds	2
low	2Dr	1

(4) **DATA ANALYSIS(AN_1)**

The candidate should correctly process experimental data using suitable mathematical methods and scientific principles, then interpret the calculated result by explaining its meaning in relation to the experiment, expected standard, and real-life scenario.

Code	**Competence**	**Simple meaning**	**What the learner should do**
Da	**Data analysis**	How the answer was obtained	Use correct calculations, formulae, mole ratios, units, substitutions, and significant figures to obtain the final answer.
Di	**Data interpretation**	What the answer means	Explain the calculated result in relation to the experiment, expected standard, and real-life scenario.

1.Molar mass of sodium carbonate, Na_2CO_3 =$(23 \times 2) + 12 + (16 \times 3)$

$$= 46 + 12 + 48 = 106 \text{ g mol}^{-1}$$

Moles of sodium carbonate in 250cm^3= $\frac{2.6}{106} = 0.02453$ mol

Concentration of sodium carbonate:= $\frac{0.02453x1000}{250} = 0.0981 \text{ mol dm}^{-3}$

2. Moles of sodium carbonate in 25.0 cm^3= $\frac{0.0981 \times 25.0}{1000} = 0.00245$ mol

3. Moles of sulphuric acid reacting with sodium carbonate

Equation:$Na_2CO_3(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + CO_2(g) + H_2O(l)$

Mole ratio:$Na_2CO_3 : H_2SO_4 = 1:1$

Therefore, Moles of $H_2SO_4 = 0.00245$ mol

4. Concentration of sulphuric acid, BA1= $\frac{0.00245 \times 1000}{12.30} = 0.199 \text{ mol dm}^{-3}$

B. Determination of sodium hydroxide concentration

1. Moles of sulphuric acid used to neutralize BA2

Moles of $H_2SO_4 = \frac{0.199 \times 9.20}{1000} = 0.001831$ mol

2. Moles of sodium hydroxide in 25.0 cm^3 of BA2

From the equation: Equation:$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

$$2NaOH : H_2SO_4 = 2:1$$

Therefore: Moles of NaOH $= 2 \times 0.001831 = 0.003662$ mol

3. Concentration of sodium hydroxide, BA2

$$= \frac{0.003662 \times 1000}{25.0} = 0.146 \text{ mol dm}^{-3}$$

C. Percentage purity of sodium hydroxide

Mass concentration of pure sodium hydroxide found

Molar mass of $NaOH$: $23 + 16 + 1 = 40$ g mol^{-1}

$$\text{Mass concentration} = 0.146 \times 40 = 5.84 \text{ g dm}^{-3}$$

4. Percentage purity

Mass concentration stated for BA2:

$$\text{Percentage purity} = \frac{\text{actual mass of pure NaOH}}{\text{mass of supplied sample}} \times 100$$

$$= \frac{5.84}{6.5} \times 100 = 89.8\%$$

Data interpretation

The percentage purity of sodium hydroxide was **89.8%**, which is below **95–99%**, so the sodium hydroxide was impure and may have caused poor-quality soap.

level	requirement	score
HIGH	14Da + Di	3
MEDIUM	14Da	2
LOW	$\frac{1}{2}Da$	1

(e) Conclusion and Recommendation

The candidate draws a valid conclusion from the analysed results and gives a suitable recommendation based on that conclusion.

How to Write a Good Conclusion

A good conclusion should:

Requirement	**Explanation**	**Example**
Answer the aim directly	State what was determined or found.	The percentage purity of the supplied sodium hydroxide, BA2, was determined.
Use the calculated result	Include the final value obtained from data analysis.	The percentage purity of BA2 was found to be 89.8%.
Compare with the standard, if given	State whether the calculated value is above, below, or within the required range.	The value of 89.8% was below the required purity range of 95–99%.
Link to the scenario problem	Explain what the result means in relation to the real-life use of the substance.	Therefore, BA2 was insufficiently pure and could produce poor-quality soap because less sodium hydroxide would be available for saponification.
Accept or reject the hypothesis, if required	State whether the experimental result supports the prediction made before the investigation.	The hypothesis that the purity of BA2 was below 95% was accepted because the experimental value was 89.8%.

Conclusion

The percentage purity of the supplied sodium hydroxide, BA2, was found to be 89.8%. This was below the required purity range of 95–99%, showing that BA2 was impure and unsuitable for producing good-quality soap. The hypothesis that the purity of BA2 was below 95% was therefore accepted.

How to Write a Good Recommendation

A good recommendation should be based on the conclusion. It may give:

Type of recommendation	Meaning	Example
Application advice	What should be done with the sample/product.	The supplied sodium hydroxide, BA2, should not be used for soap making because its purity was below the required range.
Quality control advice	What the producer or supplier should do.	The supplier should provide sodium hydroxide with a purity within the required range of 95–99%.
Improvement of method	How the experiment could be made more accurate.	A digital burette may be used to reduce reading errors.
Further testing	What additional analysis is needed.	The sample should be tested again using another method to confirm the result.

Recommendation

Kikkube Companies Limited should reject or return this sodium hydroxide supply because its purity is below the claimed range. The company should also test future sodium hydroxide supplies by titration before using them in soap production to avoid producing poor-quality soap.

Scoring guide

LEVEL	REQUIREMENT	SCORE
HIGH	C + R	02
LOW	C	01

ITEM TWO: SYSTEMATIC QUALITATIVE ANALYSIS (COMPETENCE-BASED)

Competence-Based Assessment: To attain the highest level of achievement, a candidate is expected to;

Develop clear logical and well sequenced plan using appropriate preliminary tests, specific tests and confirmatory tests for inorganic or organic substances. perform tests accurately, and record observations accurately for preliminary tests, specific tests and confirmatory tests. use observations made to make logical deductions for preliminary test, specific tests and confirmatory tests. give a recommendation based on conclusion.

Major Competences Assessed; There are four major competences assessed:

1. Planning systematic qualitative tests for identification of substances
2. Carrying out the tests and making logical observations
3. Using observations to make logical deductions
4. Drawing conclusions and making recommendations

(1) Planning Systematic Qualitative Tests for Identification of Substances

This competence assesses the learner's ability to develop a **clear, logical, and well-sequenced plan** for identifying unknown substances.

A good qualitative analysis plan should move in the following order:

General tests → Specific tests → Confirmatory tests

What the Planning Should Include

Stage	What it involves	Purpose
Preliminary tests	General tests carried out before detailed analysis They provide initial clues about the nature of the unknown sample before specific identification tests are carried out. Preliminary tests help the learner decide the next suitable tests to perform.	To obtain early clues about the nature of the sample
Specific tests	Tests carried out to identify possible cations, anions, or functional groups Specific tests are carried out after the preliminary tests. They are used to test for the possible ions suggested by the preliminary observations. These tests help to narrow down the possible identities of the substances present before confirmatory tests are carried out.	To narrow down the possible substances present
Confirmatory tests	Tests carried out using specific reagents Confirmatory tests are carried out after the specific tests. They are used to confirm the actual ions present in the sample based on the	To confirm the identity of the ions or functional groups present

	observations obtained from the preliminary and specific tests. These tests give more reliable and characteristic observations which help to identify the cations and anions present in the substance.	

(a). Preliminary Tests

Preliminary Tests for Inorganic Substances

(i). Effect of Heating the Solid Sample

Test	**What the Learner Should Observe**
Two spatula end-ful of sample K in a test tube was heated strongly until there was no further change.	- Initial colour and texture of the solid. - Any colour change on heating. - Formation of a gas: note its colour, smell, effect on moist litmus paper, and carry out an appropriate confirmatory test. - Formation of a colourless condensate on the cooler part of the test tube. State whether the condensate is water, based on an appropriate test. - Formation of a sublimate or solid deposit on the cooler part of the test tube. - Whether the residue changes colour on cooling.

(ii). Preparation of a Solution for Analysis

Nature of sample	**How to prepare solution**
(a)Sample Partly Soluble in Water **(**To two spatula endful of sample K in a test tube $10cm^3$ of water was added shaken strongly then filtered)	1. Add distilled water to a small amount of the sample in a test tube. 2. Shake the mixture thoroughly. 3. Filter the mixture. • Keep the **filtrate** for analysis of ions that dissolved in water. • Keep the **residue** for further tests. • Add dilute acid to the residue and shake to dissolve
(b)Sample Completely Soluble in Water ▪ -Two spatula-endful of Sample K were placed in a test tube. About 5 cm^3 of distilled water was added, and the mixture was shaken	**(i) When One Cation Is Suspected** 1. Add distilled water to the solid sample. 2. Shake well until the sample dissolves. 3. Use separate portions of the resulting solution for tests for the cation and anion.
	(ii) When Two Cations Are Suspected and One Is Soluble in Excess Sodium Hydroxide or Aqueous Ammonia While the Other Is Insoluble

thoroughly to dissolve. ▪ -To the resultant solution, excess dilute sodium hydroxide was added, and the mixture filtered ▪ -The filtrate in the test was acidified using nitric acid and solution divided into portions --the residue was washed and then dissolve in dilute nitric acid	1. Add distilled water to the sample and shake until it dissolves. 2. Add excess sodium hydroxide solution or excess aqueous ammonia to the solution. 3. Filter the mixture. • The **filtrate** contains the cation whose precipitate dissolves in excess sodium hydroxide or aqueous ammonia. • Acidify the filtrate carefully to re-form or recover the cation for confirmatory testing. • The **residue** contains the cation whose precipitate is insoluble in the excess reagent. • Dissolve the residue in dilute acid and use the resulting solution for confirmatory tests for the second cation.
(c) When the Sample Is Insoluble in Water ▪ Two spatula-endful of Sample K were placed in a test tube. About 5 cm^3 of nitric acid was added, and the mixture was shaken thoroughly to dissolve. ▪ -To the resultant solution, excess dilute sodium hydroxide was added, and the mixture filtered ▪ -The filtrate in the test was acidified using nitric acid and solution divided into portions --the residue was washed and then dissolve in dilute nitric acid	**(i) When One Cation Is Suspected** 1. Add dilute acid to a small amount of the sample. 2. Shake well to dissolve the sample where possible. 3. Use the resulting solution for analysis of the cation and anion. **(ii) When Two Cations Are Suspected and One Is Soluble in Excess Sodium Hydroxide or Aqueous Ammonia While the Other Is Insoluble** 1. Add dilute acid to the sample and shake well until as much of the sample as possible dissolves. 2. Add excess sodium hydroxide solution or excess aqueous ammonia to the acid solution. 3. Filter the mixture. • The **filtrate** contains the cation whose hydroxide dissolves in excess sodium hydroxide or forms a soluble complex in excess aqueous ammonia. • Acidify the filtrate carefully to recover the cation for confirmatory testing. • The **residue** contains the cation whose hydroxide is insoluble in the excess reagent. • Dissolve the residue in dilute acid and use the solution obtained for confirmatory tests for the second cation.

2. Specific Tests: Specific Tests for Inorganic Substances

(a) Tests for Cations

Cations may be tested using suitable reagents such as:

- Sodium hydroxide solution
- Aqueous ammonia solution
- Any other suitable reagent that produces a characteristic observation and helps to distinguish between the possible cations

The learner should observe whether a precipitate forms, its colour, and whether it dissolves in excess sodium hydroxide solution or excess aqueous ammonia.

(b) Tests for Anions

Anions in solution may be tested using suitable reagents such as:

- Lead nitrate solution, followed by warming where necessary
- Barium nitrate solution, followed by dilute nitric acid
- Silver nitrate solution, followed by dilute nitric acid
- Copper turnings and concentrated sulphuric acid, followed by gentle warming

The learner should record the colour of any precipitate or gas formed, its solubility in the added reagent, and any other characteristic observation that may help to identify the anion present.

3. Confirmatory Tests

Carry tests Confirmatory tests for cations includes

cation	reagents	observation

Carry tests Confirmatory tests for anions includes

anion	reagents	observation

Below is a table of common cations, their uses, and possible dangers which can be used to made recommendation

Cation	Common compounds/sources	Common uses	Possible dangers
Ca^{2+}	Calcium carbonate, calcium hydroxide, calcium chloride	Animal feeds, cement, soil conditioning, water hardness, bone formation	Calcium hydroxide is alkaline and may irritate or burn skin and eyes. Excess calcium salts may cause scaling in pipes.
Mg^{2+}	Magnesium sulphate, magnesium carbonate, magnesium oxide	Fertilizers, antacids, medicine, plant chlorophyll formation	Some magnesium salts may cause stomach upset if taken in excess. Magnesium oxide dust may irritate the eyes and respiratory system.
Cu^{2+}	Copper (II) sulphate, copper (II) oxide	Fungicides, electroplating, laboratory tests, water treatment in small amounts	Copper(II) salts are harmful if swallowed and may pollute water, affecting fish and aquatic organisms.
Fe^{2+}	Iron (II) sulphate, iron tablets	Treatment of anaemia, fertilizers, laboratory reducing agents	Excess iron compounds may cause stomach irritation and poisoning if swallowed in large amounts.
Fe^{3+}	Iron (III) chloride, iron (III) sulphate	Water treatment, making pigments, qualitative analysis	Iron (III) salts may irritate skin and eyes. Iron (III) chloride is corrosive and may stain surfaces.
Zn^{2+}	Zinc sulphate, zinc oxide, zinc chloride	Galvanising iron, fertilizers, medicines, rubber and paint industries	Zinc salts may be harmful if swallowed in excess. Zinc chloride is corrosive and may irritate skin and eyes.
Al^{3+}	Aluminium sulphate, aluminium chloride	Water purification, antiperspirants, mordants in dyeing	Aluminium salts may irritate skin and eyes. Excess aluminium in water treatment may be unsafe if not controlled.
Pb^{2+}	Lead (II) nitrate, lead (II) oxide, lead carbonate	Batteries, old paints, radiation shielding	Lead compounds are highly toxic. They may damage the brain, nerves, kidneys, and blood system, especially in children.

Cation	Common compounds/sources	Common uses	Possible dangers
Ba^{2+}	Barium chloride, barium nitrate, barium sulphate	Fireworks, laboratory tests, medical imaging as barium sulphate	Soluble barium salts are poisonous and may cause muscle weakness, stomach pain, and heart problems.
Cr^{3+}	Chromium(III) salts	Tanning leather, pigments, electroplating	Some chromium compounds may irritate skin and eyes. Chromium (VI) compounds are much more dangerous and carcinogenic.
Co^{2+}	Cobalt(II) chloride	Humidity indicator, pigments, alloys	Cobalt salts may be harmful if swallowed and may cause skin sensitisation or allergic reactions.
Ni^{2+}	Nickel(II) salts	Electroplating, alloys, rechargeable batteries	Nickel salts may cause skin allergy and may be harmful if inhaled or swallowed.

Here is for anions:

Anion	Common compounds/sources	Common uses	Possible dangers
Sulphates, SO_4^{2-}	Magnesium sulphate, copper (II) sulphate, aluminium sulphate, calcium sulphate	Used in fertilizers, medicines, water treatment, plaster, and laboratory tests	Some sulphates may irritate the skin, eyes, or stomach. Copper (II) sulphate is harmful if swallowed and may pollute water, affecting aquatic life.
Chlorides, Cl^{-}	Sodium chloride, calcium chloride, ammonium chloride, hydrochloric acid	Used as food salt, drying agents, de-icing agents, fertilizers, and laboratory reagents	Concentrated hydrochloric acid is corrosive and may burn the skin and eyes. Excess chlorides may corrode metals.
Bromides, Br^{-}	Potassium bromide, sodium bromide, silver bromide	Used in photography, some medicines, and laboratory tests	Some bromide compounds may be harmful if swallowed in large amounts. Bromine-containing substances may irritate the skin, eyes, and lungs.

Anion	Common compounds/sources	Common uses	Possible dangers
Iodides, I^-	Potassium iodide, sodium iodide, silver iodide	Used in iodised salt, thyroid medicine, photography, and laboratory tests	Excess iodide intake may affect the thyroid gland. Iodine vapour and concentrated iodine solutions may irritate the skin, eyes, and lungs.
Carbonates, CO_3^{2-}	Calcium carbonate, sodium carbonate, magnesium carbonate, potassium carbonate	Used in cement making, glass making, antacids, animal feeds, soil conditioning, and washing soda	Some carbonates are alkaline and may irritate the skin and eyes. Carbonates react with acids to produce carbon dioxide, which may cause pressure build-up in closed containers.
Nitrates, NO_3^-	Potassium nitrate, sodium nitrate, ammonium nitrate, calcium nitrate	Used in fertilizers, food preservation, fireworks, explosives, and laboratory reagents	Nitrates may pollute water and cause algal growth. Some nitrates are oxidising and may intensify fire. Ammonium nitrate can be explosive under unsafe conditions.

Preliminary Tests for Organic Substances

Preliminary tests are carried out before specific and confirmatory tests.

They provide initial information about the physical properties and possible chemical **nature of** an organic substance.

The observations obtained help the learner to suggest possible functional groups and select suitable reagents for further analysis.

Preliminary Test	Expected observation	Expected deductions
Combustion test	-Physical appearance, white solid or colourless liquid -Burn with a blue / yellow non sooty flame, yellow sooty flame.	
Solubility in water	**liquid organic compound** -miscible, -partially miscible **For solids,** dissolve in water sparingly soluble dissolves on warming.	
Litmus paper test	The solution may turn	

Preliminary Test	Expected observation	Expected deductions
	-blue litmus to red -ed to blue or -may have no effect both blue and red	
Solubility in sodium hydroxide solution	The solid organic substance may dissolve or remain insoluble in sodium hydroxide solution.	

The learner should use the preliminary observations only to suggest possible functional groups. The identity of the organic substance should be confirmed using specific and confirmatory tests.

Specific Tests for Organic Substances

Specific tests for organic substances may be grouped into:

1. Tests for identifying the functional group present
2. Tests for classifying compounds within the same functional group

Tests for Identifying Functional Groups

These tests help to establish the type of functional group present in the organic substance.

Functional Group Suspected	**Suitable Test**	**Positive Observation**
hydroxyl –OH	Add carboxylic acid +conc sulphuric acid and boil	Sweet fruity smell
carbonyl C=O	Add 2,4-dinitrophenylhydrazine solution.	Yellow or orange precipitate forms.
Carboxyl, –COOH	Add sodium carbonate or sodium hydrogen carbonate solution. or magnesium powder	Effervescence occurs due to carbon dioxide gas.
Phenol, Ar–OH	Add neutral iron (III) chloride solution. Or Add bromine water.	Violet, purple, blue, or green coloration forms. Bromine water is decolourised and a white precipitate may form
Amine, $–NH_2$ or related group	Add dilute hydrochloric acid.	The substance dissolves to form a soluble ammonium salt.
Carbon–carbon double bond, C=C	Add bromine water and shake. Or Add acidified potassium manganate (VII) solution.	Orange/brown bromine water is decolourised. Purple solution is decolourised.
Carbon halogen bond	Hot sodium hydroxide solution, nitric acid and silver nitrate	

B. Tests for Classifying Organic Compounds

These tests are used after the functional group has been identified. They help to distinguish compounds within the same functional-group family.

Functional Group Identified	Classification Required	Suitable Test	Observation and Deduction
Alcohol	Primary, secondary, or tertiary alcohol	Warm with acidified potassium dichromate (VI) solution.	A primary or secondary alcohol changes the orange solution to green. A tertiary alcohol shows no colour change under normal conditions.
	Primary, secondary, or tertiary alcohol	Luca's reagent test, where available. Iodine and sodium hydroxide	Tertiary alcohols form cloudiness quickly; secondary alcohols form cloudiness more slowly; primary alcohols show little or no cloudiness at room temperature.
Carbonyl compound	Aldehyde or ketone	$K_2Cr_2O_7/H^+$,+ warm Tollens' reagent or Fehling's solution. Iodine and sodium hydroxide	. A positive Tollens' or Fehling's test indicates an aldehyde; no reaction indicates a ketone.
Amine	Primary, secondary, or tertiary amine	React with nitrous acid under suitable conditions.	Primary aliphatic amines evolve nitrogen gas; secondary amines form yellow oily products; tertiary amines generally do not evolve nitrogen gas.
Carboxylic acid	Aliphatic or aromatic carboxylic acid	Observe solubility in water and compare physical properties.	Lower aliphatic acids are usually soluble in water, while many aromatic acids are less soluble and may be solids.
Phenol and carboxylic acid	Distinguish between phenol and carboxylic acid	Add sodium hydrogen carbonate solution.	Carboxylic acids produce effervescence, while phenols do not normally react.

The learner should first identify the functional group, then use an appropriate classification test only where classification is required.

Scoring guide

LEVEL	REQUIREMENT	SCORE
HIGH	Pp + Ps + Pc	06
MODERATE	Pp + Ps	04
LOW	Pp	02

(b)carrying out the tests and making logical observations

Competence assessed:

The candidate carries out practical tests correctly and makes clear, accurate, and logical observations.

This competence measures the learner's ability to follow the correct experimental procedure, handle reagents and apparatus properly, observe changes carefully, and record observations in a systematic scientific way.

Scoring guide

LEVEL	REQUIREMENT	SCORE
HIGH	Op + Os + Oc	06
MODERATE	Op + Os	04
LOW	Op	02

(c) Making Logical Deductions

Competence assessed:

The candidate interprets the observations obtained from the tests and uses scientific knowledge to make logical deductions about the substances, ions, gases, or functional groups present in the sample.

This competence measures the learner's ability to interpret observations and relate them to the possible ions, gases, functional groups, or chemical changes present in the sample.

Scoring guide

LEVEL	REQUIREMENT	SCORE
HIGH	Dp + Ds + Dc	06
MODERATE	Dp + Ds	04
LOW	Dp	02

(d) Drawing Conclusions and Making Recommendations

Competence assessed:

The candidate uses the experimental findings to state a clear final identity of the substance or ions present, and gives a practical recommendation that directly addresses the original problem in the scenario.

The learner should provide:

Expected component	Meaning
Clear conclusion	The final identity of the substance, ion, gas, or functional group identified from the tests.
Evidence-based conclusion	The conclusion should be based on the observations and deductions made during the experiment.
Practical recommendation	A useful action, advice, or application based on the conclusion.
Relevant recommendation	The recommendation should address the problem in the scenario.

Advice to learners

- The conclusion must answer the original problem or aim of the investigation.
- The recommendation must be practical, relevant, and based on the conclusion.
- Avoid recommendations that are not connected to the experimental findings.

Scoring guide

LEVEL	REQUIREMENT	SCORE
HIGH	C + R	06
LOW	C	02

Common Uses of Organic Compounds and Their Dangers

Organic compound/class	Common examples	Common uses	Possible dangers
Alcohols	Ethanol, methanol, propan-2-ol	Used as fuels, solvents, disinfectants, perfumes, and in alcoholic drinks	Many alcohols are flammable. Methanol is poisonous and may cause blindness or death if swallowed. Vapours may irritate the eyes and lungs.
Carboxylic acids	Ethanoic acid, citric acid, benzoic acid, methanoic acid	Used in food preservation, flavouring, cleaning agents, medicines, and manufacture of esters	Concentrated acids may irritate or burn the skin and eyes. Some have sharp smells and may irritate the nose and throat.
Aldehydes	Methanal, ethanal	Used in making plastics, disinfectants, preservatives, and resins	Many aldehydes are irritating and toxic. Methanal vapour is harmful and may irritate the eyes, skin, and respiratory system.
Ketones	Propanone, butanone	Used as solvents in paints, nail-polish removers, adhesives, and cleaning agents	Ketones are usually flammable. Their vapours may cause dizziness, headache, and irritation of the eyes and throat.
Phenols	Phenol, cresols	Used in disinfectants, antiseptics, resins, plastics, and medicines	Phenols are corrosive and poisonous. They may burn the skin and cause poisoning if absorbed or swallowed.
Amines	Methylamine, aniline	Used in making dyes, medicines, pesticides, and plastics	Some amines have unpleasant smells and may irritate the skin, eyes, and lungs. Some are toxic if swallowed or inhaled.

Sample scenario

Item two

Soil supplements are important in crop production because they provide mineral nutrients needed for chlorophyll formation, tissue development, and enzyme-controlled processes in plants. These supplements are usually made from mixtures of compounds containing useful mineral ions; therefore, qualitative analysis can reveal the essential ions present in the supplement.
In the farming community of Busongora, maize and bean farmers had been experiencing yellowing leaves, weak plants, poor root development, and low yields. Recently, a local supplier introduced a new soil supplement called **FEEDZ**, claiming that it could restore missing mineral nutrients and improve crop growth. However, after farmers started applying the new supplement, the plants remained yellow and weak, raising concern that the product might not contain the mineral ions claimed by the supplier.
The district agricultural officer was concerned that **FEEDZ** could be counterfeit, wrongly labelled, or lacking the required mineral ions. The officer therefore requested that qualitative analysis be carried out to confirm whether the supplement contains the mineral ions needed by the crops before recommending it for wider use.
Preliminary tests on sample X showed that the powder was partly soluble in water. The insoluble residue dissolved in dilute acid without effervescence, the filtrate produced a colourless gas when treated with aluminium powder and sodium hydroxide solution, these observations suggested that the sample could contain two cations and two anions, but the investigation was not completed. The sample was therefore taken to the school laboratory for further qualitative analysis.

Task

As a chemistry learner assisting the laboratory technician, carry out qualitative analysis on sample X to identify the ions present and advise the agricultural officer on whether the supplement should be recommended to farmers.

TESTS	OBSERVATIONS	DEDUCTIONS
(a) Two spatula end-ful of sample X in a test tube was heated strongly until there was no further change	White powdery solid yellow residue hot and white on cooling White fumes, turn blue litmus red and acidified potassium dichromate green Brown fumes pungent Colourless condensate turns anhydrous copper (II)sulphate blue	Non-transition metal ions present ZnO, therefore Zn^{2+} suspected SO_2 gas evolved, SO_4^{2-} Present NO_2, evolved NO_3- present **Hydrated sample**
(b) To two spatula end-fuls of sample X in a test tube, about 10 cm³ of distilled water was added. The	White residue	Non-transition metal ions present

mixture was shaken thoroughly and then filtered. The filtrate and residue obtained were kept for further tests. The filtrate was divided into portions	Colourless filtrate	Non-transition metal ions present
(i)To the 1st portion dilute sodium hydroxide solution was added drop-wise until it was in excess	White precipitate was formed and was insoluble in excess	Mg^{2},Ba^{2+}, Ca^{2+} Suspected
(ii) To the 2nd portion dilute ammonia solution was added drop-wise until it was in excess	White precipitate was formed and was insoluble in excess	Mg^{2},Ba^{2+}, Suspected
(iii)To the 3rd portion 2 drops of dilute sulphuric acid were added Or 2 drops of potassium chromate were added followed by sodium hydroxide solution	There was no observable change	Mg^{2}, suspected Ba^{2+} absent
(iv) To the 4th To the portion of the solution, half a spatula end-ful of solid ammonium chloride was added, followed by a few drops of disodium hydrogen phosphate solution and then excess ammonia solution.	White precipitate was formed and was insoluble in excess ammonia	Mg^{2} confirmed present
(v) To the 5th portion 2 drops of lead (II) nitrate solution was added and the resultant mixture warm	White precipitate insoluble on warming	SO_4^{2-} present
(vi) To the 6th portion 2 drops of barium nitrate solution was added followed by dilute nitric acid	White precipitate insoluble on in dilute nitric acid	SO_4^{2-} confirmed present
(vii) To the 7th portion small amount of aluminum powder was added followed by dilute sodium hydroxide	Effervescence of white fumes turn red litmus paper blue and forms dense white fumes with concentrated hydrochloric acid	NH_3 evolved NO_3^- ions present
(viii) To the 7th portion small amount of copper turnings were added		NO_2 gas evolved NO_3^- ions present

followed by 5 drops of concentrated sulphuric acid then warmed	Pale brown fumes ,pungent turns blue litmus red	
c)The residue was washed with water then dissolved in dilute nitric acid the resultant solution was divide into three	White residue dissolved to form a colourless solution	Non-transition metal ions present
(i)To the 1st portion dilute sodium hydroxide solution was added drop-wise until it was in excess	White precipitate was formed and was soluble in excess sodium hydroxide	Al^{3+} Pb^{2+} Zn^{2+} suspected
ii) To the 2nd portion dilute ammonia solution was added drop-wise until it was in excess	White precipitate was formed and was soluble in excess ammonia	Zn^{2+} suspected
(iii) To the 3rd portion of the solution, half a spatula end-ful of solid ammonium chloride was added, followed by a few drops of disodium hydrogen phosphate solution and then excess ammonia solution.	White precipitate was formed and was soluble in excess ammonia	Zn^{2+}confirmed present

Conclusion

Sample X contains, Mg^{2+} , Zn^{2+} SO_4^{2-} and NO_3^-

Recommendation

Sample X should be recommended as a soil supplement because it contains useful mineral ions: **Mg^{2+}, Zn^{2+}, SO_4^{2-}, and NO_3^-**, which support crop growth. However, **quantitative analysis** should first be carried out to determine whether these ions are present in the correct amounts before FEEDZ is supplied widely to farmers.

Magnesium ions are important for chlorophyll formation and can help reduce yellowing of leaves.
Nitrate ions support leaf and shoot growth, while sulphate ions support protein formation and enzyme activity.
Zinc ions are needed in small amounts for enzyme-controlled processes and healthy plant development.

Sample Item two

Organic compounds have many applications such as being used as solvents in industries, preservation of food stuffs and biological tissues. A secondary school is organising a science exhibition where students will showcase various chemical products made using organic compounds among other substances.

When the organisers of the exhibition requested for samples, it was discovered that one of the containers did not bear a label. The organisers asked the students to use the content of the unlabelled container to determine the nature of organic compound as well as its likely application so that a label is printed before the exhibition. The students, however, did not know how this could be done and, hence, needed help.

You have been provided with liquid **Q** which is a sample of the unknown organic compound obtained from the unlabelled container.

Task:

a) Design and carry out systematic qualitative analysis investigation to generate information to be printed on the label.

(*At least* **8** *tests are required*).

b) Make justifiable recommendations on the most likely applications of **Q**.

TESTS	OBSERVATIONS	DEDUCTIONS
a) A small amount of **Q** was burnt on spatula end.	Colourless liquid burnt with a yellow non-sooty flame	**Q** is an aliphatic organic compound Carbon content
b) To $1cm^3$ of **Q** in a test tube was added 2cm3 of distilled water. The mixture was shaken and the mixture tested with both red and blue limus paper	**Q** was completely miscible with water The solution had no effect on both red and blue litmus paper	Polar aliphatic compound with low molecular mass Neutral compounds present (alcohol or carbonyls)
c) To 1 cm^3 of **Q** in a test tube was added Brady's reagent.	There was no observable change	Carbonyl compounds present
d) To 1 cm^3 of **Q** in a test tube was added $1cm^3$ of ethanoic acid and then 3 drops of concentrated sulphuric acid and the mixture heated then poured in water in a beaker	Sweet pleasant fruity smell	Ester formed Alcohols present
e)To 1 cm^3 **Q** in a test tube, 3 drops of acidified potassium dichromate(vi) sodium were added and mixture warmed (heated)	Orange solution turned green.	Primary alcohol or secondary alcohol present.

f)To 1 cm^3 of **Q** in test tube was added 3 drops of acidified potassium dichromate (VI) solution and the mixture heated. The mixture was cooled and then Fehling's reagent added and heated.	Orange solution formed green then. No reddish brown ppt was formed with Fehling's reagent.	Secondary alcohol oxidized to ketone.
g) To 1 cm^3 of **Q** was added to Luca's reagent.	A cloudy solution formed after 8 minutes.	Secondary alcohol present.
h) To 1 cm^3 of **Q** in a test tube, 3cm^3 of iodine solution was added followed by little sodium hydroxide solution.	Yellow precipitate formed	Secondary alcohol of the form CH_3CHR present.

Conclusion; Q is an aliphatic secondary alcohol of the form CH_3CHR.

Recommendations

Q can be used to make perfumes since it is a low molecular mass aliphatic alcohol.

Q can be used to make sanitizers since it is polar and soluble of low molecular mass.

Q can be used to make nail vanish remover since it has a hydro-carbon group that can dissolve non-polar compounds.

CATION	COLOUR	NaOH	NH_3	COMFORMATORY
Ba^{2+}				
Mg^{2+}				
Ca^{2+}				
Al^{3+}				
Pb^{2+}				
Zn^{2+}				
Cu^{2+}				
Ni^{2+}				
Fe^{2+}				
Cr^{3+}				
Co^{2+}				
Fe^{3+}				
Mn^{2+}				