233 - CHEMISTRY

GENERAL OBJECTIVES

By the end of the course, the learners should be able to:

1. select and handle appropriate apparatus for use in experimental work;
2. make accurate measurements, observations and draw logical conclusions from experiments;
3. observe and appreciate the need for safety precautions during experimental investigations;
4. understand and appreciate the use of chemical symbols and formulae in writing equations;
5. use appropriate chemical terms in describing physical and chemical processes
6. identify patterns in the physical and chemical behaviour of substances.
7. apply the knowledge acquired to promote positive environmental and health practices.
8. use the knowledge and skills acquired to solve problems in everyday life.
9. apply principles and skills acquired in technological and industrial development.
10. acquire adequate knowledge in chemistry for further education and for training.

1.0.0 INTRODUCTION TO CHEMISTRY

1.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) explain what the study of chemistry is about;
b) name and state the uses of common apparatus in the laboratory;
c) describe a Bunsen burner and its flame;
d) state laboratory safety rules.

1.2.0 Content

1.2.1 Review the following topics

- Properties of matter
- States of matter
- Mixtures and their separations
- Conductors and non-conductors of electricity
- Mention of drugs (prescription, dosage and abuse)

1.2.2 Chemistry and the Society

- Definition of chemistry and its role in the society.

1.2.3 Chemistry Laboratory

- Heating apparatus (Bunsen burner, spirit lamp, candle, gas or kerosene stove and electric heater).
- Parts of a Bunsen burner and its flame.
- Measuring apparatus (volume, temperature, mass, time).
- Other apparatus (glass ware, spatula, deflagrating spoon, crucible, wire gauze)
- Laboratory safety rules.

2.0.0 SIMPLE CLASSIFICATION OF SUBSTANCES

2.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) carry out simple experiments to obtain pure substances from mixtures;
b) state the criteria for identifying a pure substance;
c) define and determine the melting point and boiling point of a substance;
d) explain the three states of matter (solid, liquid, gas) in terms of a simplified form of the kinetic theory;
e) state the effect of heat on a variety of substances;
f) distinguish between permanent and non-permanent changes;
g) define an element, a compound, an atom and a molecule;
h) name and write the chemical symbols of common elements;
i) recognize the constituents of matter from given examples;
j) distinguish between mixtures and compounds;
k) apply separation techniques to extract various substances from natural sources.

2.2.0 Content

2.2.1 Separation of Mixtures

- Filtration, evaporation and condensation.
- Distillation (simple and fractional), chromatography, solvent extraction as a method of extracting oil from nut seeds, crystallization, separation by using separating funnel, sublimation and decantation.
- Simple criteria for purity; melting point and boiling point.

2.2.2 Effect of Heat on Substances

- States of matter (solid, liquid, gas); the Kinetic theory.
- Melting and boiling, condensation and evaporation of liquids in terms of kinetic theory.
- Permanent and non-permanent changes (illustrate using iodine, wax, copper (II) sulphate crystals, potassium manganate (VII), zinc (II) oxide etc).

2.2.3 Constituents of Matter

- Elements, atoms, molecules and compounds.
- Names and symbols of common elements.
- Simple word equations.

2.2.4 Applications

- Fractional distillation of crude oil (eg. Changamwe oil refinery) and liquid air, salt extraction eg. Magadi Soda Company and Ngomeni; removal of stains from fabrics (dry cleaning); obtaining cream from milk.

2.3.0 Projects

- Extraction of natural dyes, medicines and oils from plants.
- Construction and use of a fractionating column.

3.0.0 AIR AND COMBUSTION

3.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) state the percentage composition of air by volume;
b) carryout simple experiments to show that oxygen is the active part of air;
c) determine the percentage of oxygen in air using suitable methods;
d) describe the combustion of specified elements in air and oxygen and name the products;
e) explain how liquefied air can be separated into its components by fractional distillation;
f) carry out experiments to investigate the conditions necessary for rusting, and state the composition of rust;
g) state methods of preventing rusting;
h) prepare oxygen, investigate its properties and state its uses;
i) arrange some elements in order of their reactivity with oxygen using experimental data;
j) classify the products of burning elements in oxygen as either acidic or basic;
k) state pollution effects due to burning of substances in air;
l) state the uses of reactivity series.

3.2.0 Content

3.2.1 Composition of Air

Approximate percentage of nitrogen and oxygen in air by volume (mention of carbon (iv) oxide and noble gases as other constituents of air).

- Quantitative determination of oxygen in air using copper, iron filings and burning candle.
- Burning of substances in air, carbon, sulphur, phosphorus (CARE), sodium and copper.
- Oxygen as an active part of air (mass changes involved).
- Fractional distillation of liquefied air.
- Rusting: conditions composition and prevention.

3.2.2 Oxygen

- Laboratory preparation of oxygen using 20 volume by volume (v/v) hydrogen peroxide with manganese (IV) oxide or reaction of sodium peroxide with water (relate methods of collection to the properties of the gas).
- Properties; physical and chemical.
- Combustion of elements in oxygen (metals and non-metals).
- Competition for combined oxygen illustrated by the reaction of magnesium with carbon dioxide, lead (II) oxide) and copper (II) oxide.
- Mention of atmospheric pollution due to burning in oxygen.

3.2.3 Reactivity Series

- Order of reactivity of elements from reaction with oxygen: potassium, sodium. Calcium, magnesium, aluminium, carbon, zinc, iron, lead and copper. (It is not possible to establish the full series practically).
- Uses: oxy-acetylene in welding, life support functions.

3.2.4 Application

Extraction of metals (use the concept of reactivity series only).

3.3.0 Projects

Determination of oxygen in water from different sources. Investigate industrial processes of large scale oxygen production (eg. the British Oxygen Company (BOC) Kenya Limited).

4.0.0 WATER AND HYDROGEN

4.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) state sources of water;
b) describe an experiment to show that water is a product of burning organic matter;
c) describe an experiment to show that water contains hydrogen;
d) state the products of reactions of cold water and steam with different metals;
e) list the order of reactivity of metals as obtained from metal water reactions;
f) prepare hydrogen, investigate its properties and state its uses;
g) define oxidation as oxygen gain and reduction as removal of oxygen;
h) explain metal oxide reactions with hydrogen in terms of reduction and oxidation.

4.2.0 Content

4.2.1 Water

- Sources of water: burning of organic matter eg. burning candle in air (test for carbon dioxide and water vapour using lime water and cobalt chloride paper or anhydrous copper (II) sulphate respectively).
- Water as an oxide of hydrogen – reaction of sodium. Calcium, magnesium with cold water and reaction of magnesium, zinc, iron with steam.

4.2.2 Hydrogen

- Laboratory preparation of hydrogen by reacting a metal with a dilute acid (relate methods of collection to properties of the gas). Test for hydrogen.
- Properties: physical and chemical.
- Oxidation and reduction (oxygen gain and removal only) eg. in metal oxide – hydrogen reaction. (Caution: experiments involving the burning of hydrogen are explosive).
- Uses (manufacture of margarine, rocket fuels, ammonia, hydrochloric acid, oxyhydrogen flame for welding and weather balloons.

4.3.0 Projects

Identification of common pollutants of water from local sources and suggesting their control.

5.0.0 STRUCTURE OF THE ATOM AND THE PERIODIC TABLE

5.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) name and write the chemical symbols of the first twenty elements of the periodic table;
b) describe the structure of the atom and write the electron arrangement of the first twenty elements of the periodic table;
c) explain the electron arrangement of the atom in terms of energy levels;
d) define atomic number, mass number, isotopes and relative atomic mass;
e) calculate the relative atomic masses from isotopic composition;
f) explain the position of an element in the periodic table in terms of the electron arrangement;
g) define valency and oxidation number of an element;
h) predict the type of ion formed from a given electron arrangement of an atom;
i) predict the valencies and oxidation numbers from position of elements in the periodic table;
j) derive the formulae of some simple compounds from valencies of elements and radicals;
k) write simple balanced chemical equations.

5.2.0 Content

5.2.1 The Structure of the atom

- Names and symbols of the first twenty elements of the periodic table.
- Simple structure of the atom: protons, electrons and neutrons, electron energy levels in atoms.

5.2.2 Atomic Characteristics

- Definitions of atomic numbers, mass number, isotopes and relative atomic mass (reference C-12); examples of isotopes.
- Calculations of relative atomic mass from relative abundance of isotopes of an element.

5.2.3 The Periodic Table

- Build up of the periodic table for the first twenty elements on the basis of energy levels.
  - rows (periods)
  - columns (groups)

5.2.4 Ion Formation

- Formation of simple ions (cations and anions): qualitative treatment of the ionization energy and electron affinity.
- Writing of the electron arrangement of ions formed from atoms; lithium, sodium, fluorine, chlorine, aluminium, magnesium and sulphur; definition of valency and oxidation numbers.
- Derive valency and oxidation number of an element from atoms; its position in the periodic table.
- Names and formulae of common radicals.

- Use of valencies in determining the chemical formulae of some common compounds.
- Write simple balanced chemical equations.

5.3.0 Projects

- Atomic model construction. Note: The use of chemical equations with state symbols should be emphasized.

6.0.0 CHEMICAL FAMILIES: PATERNS IN PROPERTIES

6.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) identify alkali metals, alkaline-earth metals, halogens and noble gases in the periodic table and write their electron arrangement;
b) state and explain trends in physical properties of alkali metals, alkaline-earth metals, halogens and noble gases;
c) state and explain the trends in reactivity of the alkali metals, alkaline-earth metals and halogens;
d) explain the similarities in formulae of compounds formed by alkali metals, alkaline-earth metals and halogens;
e) state the uses of alkaline metals, alkaline-earth metals, halogens and noble gases;
f) explain the uncreactive nature of the noble gases in terms of their electron arrangement;
g) Identify the elements in a given period and write their electron arrangement;
h) state and explain the trends in physical properties of elements in a period.
i) state and explain the trends in chemical behaviour of elements in a given period.

6.2.0 Content

6.2.1 Alkali Metals (Group 1) - Lithium, Sodium and Potassium

- Electron arrangement, gradation in size of the atom, ion and trends in ionization energy.
- Physical properties; appearance, melting point, boiling point, thermal and electrical conductivity.
- Reaction with air, water and chlorine.
- Similarity of ions and formulae of hydroxides, oxides and chlorides of alkali metals.
- Uses of alkali metals (sodium only)

6.2.2 Alkaline – Earth Metals (Group 2) - Beryllium, Magnesium and Calcium

- Electron arrangement, gradation in size of atom, ion and trends of ionization energy.
- Physical properties: appearance, melting point, boiling point, thermal and electrical conductivity.
- Reaction with air, water, chlorine and dilute acids. (Caution: Reaction between calcium and acid is violent. Use very dilute acid).

- Similarity of ions and formulae of oxides, hydroxides and chlorides.
- Importance of alkaline-earth metals.

6.2.3 Halogens (Group 7) - Fluorine, Chlorine, Bromine and Iodine

- Electron arrangement of fluorine and chlorine, gradation in size of atoms and ions.
- Physical properties (appearance, melting point, boiling point, thermal and electrical conductivity).
- Reaction with metals, sodium, zinc, iron and water.
- Similarity of ions and formulae of compounds.
- Importance of fluorine, chlorine, bromine and iodine.

6.2.4 Noble Gases (Group 8) - Helium, Neon, Argon

- Electron arrangement and gradation in size of atoms.
- Electron arrangement – the basis of low reactivity of helium, neon and argon.
- Importance of noble gases.

6.2.5 Properties and Trends across a period

- Period three elements (sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine and argon).
- Electron arrangement of the period three elements.
- Physical properties of period three elements (atomic size, ionization energy, melting point, boiling point, thermal and electrical conductivity).
- Reaction of period three elements with oxygen, water and dilute acids.

(Caution: Reaction of sodium with acids is explosive. Give theoretical treatment only).

6.3.0 Projects

- Construction of models of the periodic table.

7.1.0 STRUCTURE AND BONDING

7.2.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) describe the role of the outer electrons in determining chemical bonding;
b) explain qualitatively the formation of covalent and ionic bonds;
c) illustrate the covalent and ionic bonds using diagrams;
d) explain the unique nature of metallic bonding;
e) state the effect of intermolecular forces of attraction on physical properties of substances;
f) distinguish between bond types on the basis physical properties of substances;
g) compare and explain the changes of bond type across a period;
h) select appropriate materials for use based on bond type.

7.3.0 Content

7.3.1 The Role of Outer Electrons in Chemical Bonding

- Significance of the outer electrons in chemical bonding.
- The noble gas electron arrangement.
- Electron transfer and ionic bonding.
- Electron sharing and covalent bonding.
- Use of dot (.) and cross (x) diagrams to illustrate bonding, electrostatic forces of attraction in the following: molecular (iodine), giant covalent (diamond, graphite and silicon (IV) oxide), giant ionic (sodium chloride) and giant metallic (copper).
- Other types of bonds: coordinate, hydrogen bond, Van der waals forces of attraction (simple explanation only).
- The influence of hydrogen bonds and Van der waals forces on physical properties (melting point, boiling point, solubility, electrical and thermal conductivity).

7.3.2 Types of Bonds Across a Period (Period 3)

- Changes in the types of chemical bonds in the oxides and chlorides of sodium, magnesium, aluminium, silicion, phosphorous, sulphur and chlorine.

NOTE: Use of models to illustrate bonding should be encouraged.

7.3.3 Application

Selection of materials for various uses; eg. diamond, graphite and aluminium.

7.4.0 Projects

Investigation of materials in terms of their structure and bonding.

8.0.0 GAS LAWS

8.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) state Boyle's and Charles' laws;
b) carry out calculations involving the gas laws;
c) use combined gas law in calculations;
d) state Graham's law of diffusion;
e) explain diffusion in liquids and gases in terms of kinetic theory;
f) relate the rate of diffusion to the relative molecular mass of a gas.

8.2.0 Content

8.2.1 Boyle's law and Charles' Law

- Boyle's law, Charles Law and the combined gas laws.
- Explanation of the laws (use graphs to illustrate).
- Calculations involving gas laws.

Note: Use of SI units should be emphasized.

8.2.2 Graham's Law of Diffusion

- Graham's law of diffusion; experiments illustrating diffusion of bromine gas, dissolving of copper (II) sulphate crystals or potassium manganate (VII) crystals in water. Explain diffusion in terms of kinetic theory.
- Relationship between rate of diffusion and density or relative molecular mass of a gas (illustrate with ammonia and hydrogen chloride).
- Calculations on diffusion.

9.0.0 THE MOLE: FORMULAE AND CHEMICAL EQUATIONS

9.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) define the mole;
b) relate the mole to the relative atomic mass;
c) convert mass into moles and vice versa;
d) determine the empirical and molecular formulae of compounds from experimental results and given data;
e) explain the terms concentration, molarity and dilution of a solution;
f) define molar solution;
g) prepare molar solutions;
h) carry out titrations and calculations involving molar solutions;
i) write correct full formulae and ionic equations of reactions with state symbols;
j) define molar gas volume and atomicity of gases;
k) state Avagadro's and Gay Lussac's laws and carry out related calculations.

9.2.0 Content

9.2.1 The Mole as a Basic Unit

- The mole as a basic unit. Molar mass.
- Relative atomic mass (reference to carbon – 12) the mole as a number of particles (illustrated using 'counting by weighing' experiments).
- Conversion of mass in grammes to moles and vice versa (consider atoms, molecules and compounds).

9.2.2 Determination of Formulae

- Empirical and molecular formulae; quantitative determination of composition of magnesium oxide and copper (II) oxide.

9.2.3 Molar Solutions

- Preparations of molar solutions. Molarity of a solution.
- Concentration and dilution.
- Stoichiometry of chemical reactions. (Use of ionic and full formulae equations in calculation of reacting quantities). Reactions that may be considered;

- $Ba^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow BaCO_3(s)$ (precipitation)
- $Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI_2(s)$ (precipitation)
- $Cu^{2+}(aq) + Fe(s) \longrightarrow Cu(s) + Fe^{2+}(aq)$ (displacement)

- Evolution of gas by action of an acid on solids eg.

- $Na_2CO_3\,(s) + 2HCl\,(aq) \longrightarrow 2NaCl\,(aq) + CO_2\,(g) + H_2O\,(l)$

- Acid/base titrations (use of pipette fillers recommended) (Use balanced ionic and full formulae equations in calculation of reacting quantities.)
- Redox titration involving acidified MnO^-_4/Fe^{2+} and $Cr_2O_7^{2-}/Fe^{2+}$ (writing of redox equations not required).

9.2.4 Molar Gas Volume

- Molar gas volume and atomicity of gases.
- Avogadro's and Gay-Lussac's laws and related calculations.

9.3.0 Projects

Carry out counting by weighing experiments.

10.0.0 CARBON AND SOME OF ITS COMPOUNDS

10.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) define allotropy and allotropes;
b) explain the physical properties of the carbon allotropes in terms of bonding and how the properties are related to the uses of the allotropes;
c) describe some chemical properties of carbon;
d) describe laboratory preparation and properties of carbon (IV) oxide (carbon dioxide);
e) state and explain the physical and chemical properties of carbon (IV) oxide (carbon dioxide);
f) describe laboratory preparation and some properties of carbon (II) oxide (carbon monoxide);
g) describe the chemical reactions of carbonates and hydrogen carbonates;
h) describe the manufacture of sodium carbonate;
i) explain the advantages and disadvantages of carbon (IV) oxide gas in the atmosphere;
j) explain the importance of carbon compounds in the natural environment and industry.

10.2.0 Content

10.2.1 Forms of Carbon

- Diamond, graphite and charcoal: structure, physical properties and uses (relate uses to structure and physical properties)

10.2.2 Chemical Properties of Carbon

- Consider combustion, reaction with acids and reducing action.

10.2.3 Preparation and Properties of Carbon (IV) Oxide (Carbon dioxide) – Relate methods of collection to the properties of the gas

- Reactions of the gas with water, lime water and alkalis.

- Uses of carbon (IV) oxide (carbon dioxide).

10.2.4 Preparation and Properties of Carbon (II) Oxide (Carbon Monoxide)

- Preparation of carbon (II) oxide (carbon monoxide) physical properties.
- Chemical properties; combustion, reducing action, poisonous nature such as car exhausts fumes and charcoal fire.

(Note: only theoretical treatment required because of its poisonous nature)

10.2.5 Carbonates and Hydrogen Carbonates

- Action of heat and dilute acids on some carbonates and hydrogen carbonates.
- Production and manufacture of sodium carbonate (Magadi Soda Company and solvay process).

(Note: use simple schematic diagrams to illustrate solvay process).

10.2.6 Importance of Carbon and its Oxides

- Carbon cycle.
- Soft drinks manufacture.
- Fire extinguishers.
- The effects of Carbon (IV) oxide (carbon dioxide) and carbon (II) oxide (carbon monoxide) on the environment.

10.3.0 Projects

- Construction and use of simple fire extinguishers.
- Construction of carbon cycle chart.

11.0.0 NITROGEN AND ITS COMPOUNDS

11.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) describe the isolation of nitrogen from air;
b) describe the laboratory preparation of nitrogen and state its properties and uses;
c) describe the laboratory preparation, and state the properties and uses of the oxides of nitrogen;
d) describe the laboratory preparation of ammonia and state its properties and uses;
e) explain the difference in chemical reactions of ammonia gas and its aqueous solution;
f) describe the industrial manufacture of ammonia;
g) calculate the percentage of nitrogen in nitrogen containing fertilizers;
h) describe the preparation and manufacture of nitric acid;
i) describe and explain the reactions of both dilute and concentrated nitric acid;
j) state the uses of nitric acid;
k) identify the products formed when different nitrates are heated;

l) explain the pollution effects of nitrogen compounds in the environment.

11.2.0 Content

11.2.1 Isolation of Nitrogen Gas from Air

- Isolation of nitrogen gas from air, laboratory and in industry.

11.2.2 Laboratory Preparation of Nitrogen Gas

- Laboratory preparation of nitrogen gas.
- Properties
  - inert character
  - burning magnesium and sulphur in nitrogen gas
- Uses of nitrogen gas.

11.2.3 Oxides of Nitrogen (nitrogen (I) Oxide, Nitrogen (II) oxide, Nitrogen (IV) oxide)

- Laboratory preparations.
- Properties and uses of the oxides.

11.2.4 Ammonia

Laboratory preparation and properties of ammonia gas (relate method of collection to the properties of the gas):

- Solubility in water
  - reaction of aqueous ammonia (NH_4OH) with cations.
  - reactions of ammonia with air/oxygen (catalysed and uncatalysed), copper (II) oxide and hydrogen chloride,
- Manufacture of ammonia by Haber process. (state optimum conditions only).
- Uses of ammonia.
- Fertilizers: mention of various nitrogen containing fertilizers, (sulphate, nitrates and phosphate), amount of nitrogen in various fertilizers.

11.2.5 Nitric Acid

- Laboratory preparation and manufacture of nitric acid.
- Reaction of dilute nitric acid with; metals, carbonates, hydroxides and oxides.
- Reaction of concentrated nitric acid as an oxidizing agent; iron (II) solution, sulphur and copper metal.
- Uses of nitric acid.

11.2.6 Action of heat on Nitrates

- Effect of heat on nitrates of sodium, potassium, copper, lead and silver (silver nitrate may be considered theoretically due to its cost).
- Test for nitrates.

11.2.7 Pollution Effects of Nitrogen Compounds in the Environment

12.0.0 SULPHUR AND ITS COMPOUNDS

12.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) describe the allotropes of sulphur;
b) describe the extraction and state the properties and uses of sulphur;
c) describe the preparation and state the properties and uses of sulphur (IV) oxide (sulphur dioxide) and sulphur (VI) oxide (sulphur trioxide);

d) carry out tests to distinguish between sulphite and sulphate ions;
e) explain the preparation and manufacture of sulphuric acid and state its uses;
f) distinguish between the reactions of dilute and concentrated sulphuric acid and state its uses;
g) describe the preparation and state properties of hydrogen sulphide;
h) explain environmental pollution caused by sulphur containing compounds.

12.2.0 Content

12.2.1 Occurrence and Extraction of Sulphur
- Extraction by Frasch process.
- Allotropes of sulphur.
- Physical and chemical properties of sulphur.
- Uses of sulphur.

12.2.2 Sulphur (IV) Oxide (sulphur dioxide)
- Preparation (relate method of collection to properties of the gas)
- Properties (acid character, bleaching action, reducing action eg. test with potassium chromate (VI) and combination with oxygen to form sulphur (VI) oxide (Sulphur trioxide). Oxidizing action eg. with magnesium and hydrogen sulphide).
- Test for sulphate and sulphite ions.
- Uses of sulphur (IV) oxide.

12.2.3 Manufacture of Sulphuric Acid
- Contact process (state optimum conditions only) eg. Kel Chemical Ltd in Thika and East Africa Heavy Chemicals, Webuye).
- Pollution control in contact process.

12.2.4 Properties of Sulphuric Acid
- Reaction of concentrated sulphuric acid as:
  - dehydrating agent (sucrose, ethanol, hydrated copper (II) sulphate).
  - oxidizing agent (copper, zinc, sulphur and carbon).
- displacement reaction (sodium chloride solid, potassium nitrate solid).
- Reactions of dilute sulphuric acid with:
  - metals
  - carbonates
  - metal hydroxides
  - metal oxides

12.2.5 Hydrogen Sulphide
- Preparation and physical properties
- Chemical properties (reducing action)

Note: Only theoretical treatment is required.

12.2.6. Pollution of atmosphere by compounds of sulphur (hydrogen sulphide and oxides of sulphur).

13.0.0 CHLORINE AND ITS COMPOUNDS

13.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) describe and explain the laboratory preparation of chlorine;
b) state and explain the properties and uses of chlorine;
c) describe and explain the preparation of hydrogen chloride gas;
d) state and explain the properties and uses of hydrogen chloride gas;
e) explain the effect of a solvent on the properties of hydrogen chloride;
f) manufacture of hydrochloric acid;
g) explain environmental pollution caused by chlorine and chlorine containing compounds.

13.2.0 Content

13.2.1 Chlorine

- Preparation of chlorine by reaction of concentrated hydrochloric acid with manganese (IV) oxide or any other suitable oxidizing agent (relate method of collection to its properties).
- Physical properties.
- Chemical properties. Reaction of chlorine with:
  - hydrogen
  - metal (magnesium and iron)
  - non-metals phosphorous (caution)
  - reducing agents (hydrogen sulphide, sulphites and ammonia)
  - water and alkali solutions (both dilute and concentrated)
  - bromides and iodides (displacement reactions)
  - bleaching action.
- Test for chlorides in dry solids and aqueous solution.
- Uses of chlorine.

13.2.2 Hydrogen Chloride

- Preparation of hydrogen chloride gas by reaction of sodium chloride with concentrated sulphuric acid (relate method of collection to properties of the gas).
- Properties (physical and chemical).

13.2.3 Effect of solvent on the Properties of Hydrogen Chloride

- Reactions of aqueous hydrogen chloride. Compare the properties of aqueous hydrogen chloride and a solution of hydrogen chloride in methylbenzene:
  - acid nature, litmus, reaction with metals, bases, carbonates and hydrogen carbonates.
  - Redox reaction with potassium manganate (VII) to produce chlorine.
- Test for hydrogen chloride gas with ammonia.

13.2.4 Uses of Hydrogen Chloride Gas

- Industrial manufacture of hydrochloric acid (eg Pan Paper, Webuye).
- Uses of hydrochloric acid.

13.2.4 Pollution of environment by chlorine and its compounds eg. CFC, DDT etc.

13.3.0 Projects

- Determination of chlorine content of various bleaching powders and liquids .
- Purification and treatment of water.

14.0.0 ACIDS, BASES AND INDICATORS

14.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) prepare and use plant extracts as acid-base indicators;
b) use indicators to identify acids and bases;
c) state simple properties of acids and bases;
d) name uses of acids and bases;
e) state effects of acids on substances.

14.2.0 Content

14.2.1 Acid/Base Indicators

- Plant – extracts as simple acid – base indicators.
- Common acid-base indicators phenol pthalein, methyl orange, screened methyl orange, universal indicator and pH scale.
- Acidic, neutral and basic/alkaline solutions illustrated by use of the following examples; water, aqueous solution/suspension; lemon juice, soap, wood ash, baking powder, anti-acid tablets and powders, toothpaste, sour milk, ammonia, ammonium sulphate, sodium chloride, sodium hydroxide, carbon (IV) oxide, sulphur (IV) oxide. Sulphuric acid, hydrochloric acid, nitric acid, calcium hydroxide and magnesium oxide.

14.2.2 Simple Properties of acids and bases

- Reaction of dilute acids with metals, metal oxides, hydroxides, carbonates and hydrogen carbonates.
- Effects of acids on substances.

14.2.3 Application

- Uses of acids and bases.

14.3.0 Projects

- Investigate various plants extracts and use them as acid/base indicators.

15.0.0 SALTS

15.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) select and use appropriate methods of preparing particular salts;
b) explain the terms saturated solution, crystallization, neutralization and precipitation;
c) write ionic equations for the preparation of salts;
d) state types of salts;
e) identify soluble and insoluble salts;
f) describe and explain from experimental observations the action of heat on various salts;
g) state uses of some salts.

15.2.0 Content

15.2.1 Methods of Preparing Salts

- Preparation of soluble salts by reaction of acids with; metals, metal hydroxides, metal oxides, metal carbonates and metal hydrogen carbonates.
- Preparation of insoluble salts by precipitation (ionic equations required).
- Direct combination reaction (eg. sodium with chlorine, iron with sulphur).
- Types of salts; normal, acid and double salts.

15.2.2 Solubility of Salts

- Solubility of sulphates, chlorides, nitrates and carbonates in water.
- Relationship between method of preparation and solubility.

Note: The solubility of hydroxides should be considered along with others.

15.2.3 Action of Heat on Salts

- Effect of heat on the following salts; carbonates, nitrates, sulphates and hydrated salts (include ammonium salts).
- Applications:
  - use of lime to change soil pH.
  - Use of salts as anti-acids.
  - Use of salts as inorganic fertilizers.

15.3.0 Projects

- Analysing anti-acid drugs.

16.0.0 ACIDS, BASES AND SALTS

16.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) define acids, bases and salts;
b) explain the differences between aqueous solutions of weak and strong acids; weak and strong bases; based on the degree to which they dissociate into ions;
c) write formulae and ionic equations for specified acid-base and precipitation reactions;
d) explain the effect of solvent in acid-base character;
e) test for the presence of specified cations and anions;
f) identify the precipitates and complex ions produced by specified cation-anion reactions;
g) explain the use of solubility curves in salt extraction;
h) state the types and causes of hardness of water;
i) state the effects and explain the methods of removal of water hardness.

16.2.0 Content

16.2.1 Acids and Bases

- Acids as substances which dissociate in water to give hydrogen ions.
- Bases as substances which dissociate in water to give hydroxide ions.

- Weak and strong acids and bases; pH scale and electrical conductivity, (use aqueous solutions of; hydrochloric acid, ethanoic acid, sodium hydroxide and ammonia of the same concentration to illustrate).

16.2.2 Characteristics of Amphoteric Oxides and Hydroxides

- Reaction with acids and alkalis (aluminium oxide, zinc (II) oxide, zinc hydroxide, lead hydroxide and aluminium hydroxide).

16.2.3 Effect of Solvent

- Characteristics of hydrogen chloride in methyl benzene and aqueous solution, (illustrate with dry litmus, magnesium and marble chips).
- Reactions of dry and aqueous ammonia.

16.2.4 Salts

- Salts as ionic compounds formed when cations derived from bases combine with anions derived from acids.
- Precipitation reactions (use ionic equations).
- Reactions involving the following cations in aqueous solutions: magnesium, calcium, iron (II), iron (III), barium (II), zinc (II), aluminium (III), copper (II) with; sodium hydroxide, ammonia solution, chloride, carbonate, sulphite and sulphate ions.

16.2.5 Complex Ions

Dissolving of specific metal hydroxides in excess aqueous ammonia and sodium hydroxide solution.

Formulae of the following required,

$[Cu(NH_3)_4]^{2+}$
$[Zn(NH_3)_4]^{2+}$, $[Al(OH)_4]^-$
$[Pb(OH)_4]^{2-}$ and $[Zn(OH)_4]^{2-}$

Equations not required:

- Solubility; definition and relationship with temperature.
- Solubility curves for sodium chloride, potassium nitrate, potassium chlorate (V), calcium sulphate and sodium carbonate.
- Fractional crystallization of salts.
- Extraction of sodium carbonate from Lake Magadi and sodium chloride at Ngomeni.

16.2.6 Water Hardness

- Types of water hardness: causes and effects.
- Methods of removal of water hardness; boiling, distillation, precipitation and use of ion exchange.

16.3.0 Projects

a) Salt extraction from ash or soil.
b) Investigation of water hardness and its removal.

17.0.0 ENERGY CHANGES IN CHEMICAL AND PHYSICAL PROCESSES

17.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) define exothermic and endothermic reactions using ΔH notation;
b) draw energy level diagrams;
c) explain fusion and vaporization as evidence of inter-particle forces;
d) explain that energy changes in chemical reactions are due to bond formation and bond breaking;
e) define and explain various types of heat changes;
f) carry out experiments to determine enthalpy changes for some reactions.
g) write correct simple thermochemical equations;
h) state Hess' Law and carry out related calculations;
i) state and explain the factors that influence the choice of fuel;
j) explain the environmental effects of fuel.

17.2.0 Content

17.2.1 Endothermic and exothermic reactions

- Enthalpy notation (ΔH) for exorthermic and endothermic reactions.

17.2.2 Latent Heat

- Molar heat of fusion and vaporization as evidence of overcoming forces of attraction between particles.

17.2.3 Quantitative determination of enthalpies

- Formation of hydrogen chloride gas from hydrogen gas and chlorine gas; formation of chloromethane from methane and chlorine gas.
- Quantitative determination of enthalpies of:
- Solution (eg ammonium nitrate, sodium hydroxide and conc. Sulphuric acid)
    - combustion (eg methanol/ethanol)
    - displacement (eg copper from copper (II) ions by iron or zinc)
    - neutralization (eg. sodium hydroxide and dilute hydrochloric acid).

17.2.4 Simple energy level diagrams

- Hess' Law (energy level diagrams and themochemical cycles), use molar enthalpy of formation for illustration.
- Relate heat of solution to hydration and lattice energy.

17.2.5 Common fuels; energy contents of:

- Charcoal, fuel oil, ethanol (methylated spirit), liquid petroleum gas (LPG), petroleum, kerosene and diesel.
- Choice of fuel;
    - precautions necessary when using fuels.

17.2.6 Pollution by common fuels eg. internal combustion engine

17.3.0 Projects

- Comparison of heat energy values of fuels.

18.0.0 REACTION RATES AND REVERSIBLE REACTIONS

18.1.1 Specific Objectives

By the end of this topic, the learner should be able to:

a) define rate of reaction;
b) explain the term activation energy;
c) describe some methods used to measure rates of reaction;
d) explain the effects of different factors on reaction rates;
e) illustrate reaction rates graphically and interpret experimental data;
f) state examples of simple reversible reactions;
g) explain chemical equilibrium as a state of 'balance';
h) explain the effect of different factors on the position of equilibrium.

18.2.0 Content

18.2.1 Reaction rates

- Definition of rate of reaction;
- Collision theory and activation energy (qualitative treatment only);
- Qualitative treatment of the effects of concentration, pressure, temperature, surface area, light and catalysts on rates of reactions. (No reaction mechanisms required);
- Experiments involving the following reactions:
  - Calcium carbonate (marble chips) with dilute acid (hydrochloric or nitric acid)
  - Sodium thiosulphate with dilute hydrochloric acid
  - Metal with dilute acid (e.g. magnesium with hydrochloric acid)
  - Hydrogen peroxide with various catalysts e.g. manganese (IV) oxide (Graphical presentation of results required).

18.2.2 Reversible reactions

- Equilibrium as the state of balance (example acid/alkali plus indicator, chromate/dichromate, hydrated and anhydrous copper (II) sulphate)
- The effect of changing concentration, pressure and temperature on position of equilibrium. Le Chatelier's Principle
- Uses in industrial processes (Contact and Haber processes).

19.0.0 EFFECT OF AN ELECTRIC CURRENT ON SUBSTANCES

19.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) define the terms conductor and non-conductor, electrolyte and non-electrolyte;
b) classify solutions and molten substances as electrolytes and non-electrolytes
c) distinguish between electrolytes and non-electrolytes in terms of the particles they contain;
d) explain the process of electrolysis and define the terms anode and cathode;
e) state the products of electrolysis of a binary electrolyte;

f) state some applications of electrolysis.

19.2.0 Content

19.2.1 Conduction of electricity

- Conductors and non-conductors
- Test for conduction of electricity by;
  - Solids, metals and non-metals (wood, aluminum foil, sodium chloride, sugar and lead (II) bromide)
  - Aqueous solutions of sugar, urea, copper (II) chloride, sodium chloride and mineral acids
  - Melts: Sulphur, lead (II) bromide or lead (II) Iodide and sugar
- Electrolytes and non-electrolytes
- Ions as the particles in electrolyte solutions and melts
- Molecules as the particles in non-electrolyte solutions and melts.

19.2.2 Electrolysis

- Passage of a direct electric current through an electrolyte (electrolysis of molten lead (II) bromide or lead (II) iodide)
- Anode and cathode
- Applications of electrolysis
  - electroplating
  - production and purification of metals

Note details of the processes not required at this level.

20.0.0 ELECTROCHEMISTRY

20.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) explain redox reactions in terms of gain and loss of electrons;
b) identify changes in oxidation numbers during redox reactions;
c) write balanced redox equations ;
d) explain an electrochemical cell in terms of electron transfer process;
e) draw cell diagrams and write the cell notations;
f) explain the construction and working of an electrochemical cell such as zinc – copper cell.
g) Compare oxidizing and reducing power of ions from displacement reactions
h) Calculate electromotive force of a cell given the standard electrode potentials
i) State and explain the factors that affect preferential discharge of ions during electrolysis
j) Relate the quantity of electricity passed to amount of substances liberated at the electrodes
k) Describe some applications of electrolysis.

20.2.0 Content

20.2.1 Redox reactions

- Electron transfer (gain and loss of electrons)
- Determination of oxidation numbers

- Use an illustration of iron (II) (acidified with dilute sulphuric acid) to in (III) with hydrogen peroxide
- Identify reactant – Iron (II) (aq) and product Iron (III) (aq) with hydroxide ion. Other examples; sodium/water magnesium/dilute acid (hydrochloric acid/sulphuric acid)

20.2.2 Displacement reactions (as redox reactions)

- Reduction power
  - Reaction of metal/metal –cation (M/M^{2+}) Calcium, magnesium, zinc, iron, lead, copper
- Oxidizing power of halogens: chlorine, bromine and iodine only.

20.2.3 Electrochemical cell

- Qualitative treatment of the electron flow in Zn (s)/Zn^{2+} (aq)//Cu^{2+} (aq) / $Cu_{(s)}$ cell

Note: Conventions, vertical line(/) represents a phase boundary where a potential difference develops e.g. Zn (s)/Zn^{2+} (aq) two vertical parallel lines (//) represent a salt bridge

- Standard electrode potentials (simple calculations involving E^0 values required)

20.2.4 Electrolysis

- The role of water in electrolysis
- Preferential discharge in electrolysis of the following solutions
  - Sodium chloride
  - Dilute sulphuric acid (acidified water)
  - Magnesium sulphate
  - Electrolysis of copper (II) sulphate using graphite and copper electrodes (product changes in electrolytes)
- Factors affecting preferential discharge
  - Quantitative treatment of electrolysis (Note: First Faraday's law only)

20.2.5 Applications

- Extraction of metals
- Manufacture of sodium hydroxide, chlorine, hydrogen (electrolysis of brine)
- Copper refining, electroplating

20.3.0 Projects

- Investigating further electroplating processes, prevention of rusting (cathodic protection) investigate various types of cells.

21.0.0 METALS

21.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) name the chief ores of some metals;

b) describe and explain general methods used in the extraction of metals from their ores;

c) select and describe suitable methods for the extraction of some metals from their ores;

d) describe and explain physical and chemical properties of some metals;
e) state and explain various uses of these metals and their alloys;
f) describe the effect of industrial production processes of metals on the environment.

21.2.0 Content

21.2.1 Metals: Methods of extraction

- Chief metal ores of sodium, aluminium, zinc, iron, copper and lead
- General methods of extraction (electrolysis and reduction)
- The electrolytic production of sodium and aluminium
- Extraction of iron, copper and zinc from their ores

21.2.2 Properties of Metals (sodium aluminium, iron, copper and zinc)

- Physical properties (melting point, boiling point, thermal and electrical conductivity, density, malleability and ductility)
- Chemical properties (reaction with air, water, chlorine, dilute hydrochloric acid and oxidizing acids (concentrated nitric and sulphuric acid)

Note: The reaction of sodium and dilute acid is explosive

21.2.3 Uses of metals and their alloys (alloys: brass, bronze, steel, duralumin)

- construction (aircraft, bridges etc) electrical materials (copper)

21.2.4 Pollution effect of the industrial production of metals on the environment

21.3.0 Projects

- Analysis of ores
- Construction of a mini-blast furnance

22.0.0 ORGANIC CHEMISTRY I (HYDROCARBONS)

22.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) define a hydrocarbon;
b) name and draw the structures of simple hydrocarbons (alkanes, alkenes and alkynes);
c) state the features of a homologous series;
d) draw and name isomers of simple hydrocarbons containing not more than five carbon atoms;
e) describe the general methods of preparing alkanes, alkenes and alkynes;
f) explain the physical and chemical properties of alkanes, alkenes and alkynes;
g) state the uses of alkanes, alkenes and alkynes.

22.2.0 Content

22.2.1 Alkanes

- Definition of a hydrocarbon
- General formula: occurrence, nomenclature (consider straight chain alkanes of up to ten carbon atoms) fractional distillation of crude oil
- Isomerism (butane and pentane)

- Preparation of methane and ethane
- Trends in physical properties (melting point, boiling point, density and solubility in water and in organic solvents)
- Chemical properties: burning and substitution reactions with chlorine or bromine (details of reaction mechanism not required)
- Uses of alkanes.

22.2.2 Alkenes

- General formula: nomenclature (consider straight chain alkenes of up to six carbon atoms)
- Isomerism (butene and pentene)
- Preparation of ethene, trends in physical properties (melting point, boiling point, solubility in water and non-polar solvents)
- Chemical properties (combustion, addition of chlorine, bromine, hydrogen, hydrogen halides, and ethene) details of mechanism not required)
- Test for unsaturation (use acidified potassium manganate (VII) or bromine water)
- Uses of alkenes

22.2.3 Alkynes

- General formula, nomenclature (consider straight chain alkynes of up to six carbon atoms)
- Isomerism (butyne)
- Preparation of ethyne; trends in physical properties (melting point, boiling point, density, solubility in water and non-polar solvents)
- Chemical properties (combustion and addition reactions with chlorine hydrogen, bromine, hydrogen halides)
- Uses of alkynes.

23.0.0 ORGANIC CHEMISTRY II (ALKANOLS AND ALKANOIC ACIDS)

23.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) name and draw the structures of simple alkanols and alkanoic acids:
b) describe the preparation and explain the physical and chemical properties of alkanols and alkanoic acids;
c) state the main features of the homologous series;
d) state and explain the uses of some alkanols and alkanoic acids;
e) describe the preparation, properties and uses of detergents;
f) explain the effect of hard water on detergents;
g) list some natural, synthetic polymers, fibres and state their uses;
h) describe the preparation, properties and uses of some synthetic polymers;
i) identify the structure of a polymer given the monomer;
j) state the advantages of synthetic materials compared to those of natural; origin in terms of both structure and properties.

23.2.0 Content

23.2.1 Alkanols

- General formula (ROH) Nomenclature (primary alcohols upto 10 carbon atoms)

- Preparation of alkanols from
  - Hydrolysis of alkenes
  - Fermentation of carbohydrates
- Physical properties
  - Gradual change in physical properties of primary alkanols (mention hydrogen bonding)
- Chemical properties
  - reactions with oxygen (burning), sodium, concentrated sulphuric acid (to give alkenes) ester formation and oxidation to give alkanoic acids
- uses – solvents, fuels and pharmaceuticals.

23.2.2 Alkanoic acids

- General formula RCOOH Primary alkanoic acids upto 10 carbon atoms) nomenclature
- Preparation by oxidation of primary alkanols
- Physical properties
  - gradual change in physical properties of alkanoic acids (mention hydrogen bonding)
- chemical properties
  - acid properties; salt and ester (alkanoates) formation (up to 2 carbon atoms only)

Note: equations involving these reactions are required (state symbols are not required)

23.2.3 Soap detergent

- Soapy detergents (soaps)
  - laboratory preparation by hydrolysis of fats or oils with alkalis
  - mode of action
  - Water hardness
  - Pollution effects

- Soapless detergents
  - manufacture
  - mode of action
  - pollution effect
- Polymers
- Name of some natural polymers and fibres
  - cellulose materials (cotton, wood, paper, silk)
  - Hydrocarbons (rubber and its vulcanization)
- Names of some synthetic polymers and fibres
  - Polythene,, polychloroethene (pvc)
  - Polyphenylethene (polystyrene)
  - Terylene, nylon and Perspex
- Synthetic rubber
  - Preparation, properties and uses of synthetic polymers

- Equations to show addition polymerisation for example formation of polythene, polychloroethene and polyphenylethene

- Advantages and disadvantages of synthetic polymers and fibres over those of natural origin should be mentioned (include biological degradability of the materials)
- Uses of polymers and fibres (manufactur of beer, spirits, soaps and detergents, drugs, textiles, packaging materials pipes, tyres)

23.3.0 Projects

- Fermentation of various carbohydrates to produce ethanol
- Soap preparation
- Investigation on effects of soap and detergents on aquatic life
- Investigate methods of recycling and disposal of plastics
- Investigation of strength of polymers and fibres

24.0.0 RADIOACTIVITY

24.1.0 Specific Objectives

By the end of this topic, the learner should be able to:

a) define radioactivity, half-life, radioisotope and nuclides;
b) state types of radioactivity;
c) name the particles emitted during radioactive decay and state their properties;
d) carry out simple calculations involving half-life ($t_{½}$);
e) write balanced nuclear equations;
f) distinguish between nuclear fission and fusion;
g) state uses of some radioisotopes;
h) state dangers associated with radioactivity.

24.2.0 Content

24.2.1 Stability of isotopes of elements

- Stability of isotopes of elements
- Radioactivity; types of radiation (alpha (α) beta (β) particles and gamma (γ) rays; characteristics and properties
- Radioactive decay as measured by half-life ($t_{½}$), calculations involving half- life ($t_{½}$)
- Nuclear equations: changes in nuclei resulting from radioactive decay by (alpha (α) beta (β) particles and gamma (γ) rays.
- Qualitative treatment of fission and fusion
  - mention nuclear reactions as source of energy

Note: Nuclear reactions are different from chemical reactions.

24.2.2 Applications

Uses and importance of radioisotopes in chemistry, medicine, carbon dating and agriculture.

24.2.3 Pollution effects of radioactivity

Dangers of radio isotopes

Environmental pollution e.g. the Chernobyl disaster, titanium mining in Kwale.