

**WEST AFRICAN SENIOR SCHOOL CERTIFICATE EXAMINATION
CHEMISTRY**

1. PREAMBLE

The Syllabus is drawn purposely for examinations, hence the topics are not necessarily arranged in the order in which they should be taught.

It is drawn entirely from the Teaching Syllabuses of the member countries and contains three sections : SECTIONS A, B and C.

SECTION A contains portions of topics which candidates from member countries are required to treat to the same depth.

SECTIONS B and C contain portions of topics which are peculiar to the teaching syllabuses of particular member countries.

Candidates will be tested from SECTION A and either SECTION B or SECTION C only.

The following assumptions are made in the drawing of the syllabus:

- (1) that candidates must have covered the Integrated Science or General Science and Mathematics syllabuses at the Junior Secondary School (J.S.S) level;
- (2) that candidates would have carried out as many of the suggested activities and project work as possible, and consequently would have developed the intended competencies and skills as spelt out in the respective teaching Syllabuses;
- (3) that each school has a well-equipped laboratory.

Candidates are required to be familiar with the use of significant figures, S.I. Units and the IUPAC system of nomenclature.

2. AIMS

- (1) The broad aims of the syllabus are to provide knowledge in Chemistry adequate for students who:
 - (a) will end their study of Chemistry at the Senior Secondary School level;
 - (b) require application of Chemistry in their vocational studies;
 - (c) wish to continue the study of Chemistry at tertiary institutions.

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- (2) The objectives of the syllabus are to:
- (a) build upon the knowledge acquired in Integrated Science or General Science at the J.S.S level;
 - (b) provide students with basic knowledge in chemical concepts and principles through efficient selection of content;
 - (c) enable students to appreciate the scientific method which involves experimentation, accurate observation, recording, deduction and interpretation of scientific data;
 - (d) enable students to develop laboratory skills, including an awareness of hazards in the laboratory and the safety measures required to prevent them;
 - (e) create an awareness of the inter-relationship between chemistry and other disciplines;
 - (f) show chemistry and its link with the industry, the environment and everyday life, in terms of benefits and hazards.

3. SCHEME OF EXTERNAL EXAMINATION

There shall be three papers – Paper 1, Paper 2 and Paper 3. Candidates will be required to take either Papers 1 and 2 or Papers 2 and 3 only.

Paper 1: Shall be a two-hour practical test and shall be taken by school candidates only. The paper shall contain three questions carrying 50 marks and shall form 25% of the total marks for the external examination.

Candidates will be required to answer **all** the three questions.
The questions shall be distributed as follows:

One question on quantitative analysis;
One question on qualitative analysis and the third question shall test candidates' familiarity with the practical activities suggested in their teaching syllabuses.

Paper 2: Shall be a three-hour theory paper covering the entire syllabus and carrying a total of 150 marks i.e. 75% of the total marks of the external examination. The paper shall have two parts - Part A and Part B.

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- Part A: Shall contain fifty objective tests drawn from Section A of the syllabus. Candidates will be required to answer **all** the questions within 60 minutes for 50 marks.
- Part B: Shall contain three sections: Sections I, II and III.
- Section I: Shall contain four essay questions drawn from section A (common section) of the syllabus.

Candidates will be required to answer any **three** of the questions. Each question shall carry 25 marks.
- Sections II and III : shall contain two questions each drawn from SECTIONS B and C of the syllabus respectively.

Candidates will be required to answer **one** question from one section only. Each question in the sections shall carry 25 marks.
- Paper 3: Shall be a test of knowledge of practical work and shall be an alternative to Paper 1 (i.e. the actual practical paper).

The paper shall be taken by private candidates **only**. It shall contain three questions as specified for Paper 1.

Candidates will be required to answer **all** the three questions within 2 hours for 50 marks.

4. CONTINUOUS ASSESSMENT

The continuous assessment component shall form 30% of the total marks for the assessment of candidates.

Details of the input into the continuous assessment shall be given by the Council.

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SECTION 'A'

(FOR ALL CANDIDATES)

CONTENT	NOTES
<p>1. STRUCTURE OF THE ATOM</p> <p>(a) Gross features of the atom</p> <p>(b) (i) Atomic number/proton number; number of neutrons, isotopes; atomic mass.</p> <p>(ii) Relative Atomic mass (A_r) and relative molecular mass (M_r) based on Carbon-12 scale.</p> <p>(iii) Atoms, molecules and ions</p> <p>(c) Nuclear chemistry</p> <p>(i) Types and nature of radiations</p> <p>(ii) Half life as a measure of the stability of the nucleus</p> <p>(iii) Nuclear reactions: Fission and Fusion in nuclear reactors.</p>	<p>(1) Short account of Dalton's atomic theory and J. J. Thompson's experiment should be given.</p> <p>(2) Outline description of Rutherford's alpha particle scattering experiment to establish the structure of the atom. Treatment should illustrate scientific method and development of a model.</p> <p>(1) Definitions and representation in symbols of atoms and sub-atomic particles.</p> <p>(2) Atomic mass as the weighted average mass of isotopes. Calculation of relative mass of chlorine should be used as an example.</p> <p>Definition of particles and treatment of particles as building blocks of matter.</p> <p>(1) Distinction between ordinary reactions and nuclear reactions.</p> <p>(2) Charges, relative mass and penetrating power of radiations.</p> <p>(3) Balancing of simple nuclear equations.</p> <p>Qualitative treatment (only) of half life.</p> <p>(1) Natural and artificial radioactivity. Detection of radiation by Geiger-Muller counter.</p> <p>(2) Generation of electricity; atomic bombs.</p>

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CONTENT	NOTES
(iv) Effects and application of radioactivity.	(1) Carbon dating (qualitative treatment only). (2) Use of radioactivity in agriculture, medicine and industry.
(d) Electronic Energy levels	Experimental evidence and interpretation of line spectra (qualitative treatment only).
(i) Arrangement of electrons in the main and sub-energy levels.	Mention should be made of the arrangements of electrons in the main shells (K, L, M) as 2:8:18.
(ii) Orbitals	Origin of s, p, d and f orbitals as sub-energy levels; shapes of s and p orbitals only.
(iii) Rules and principles for filling in electrons	(1) Aufbau Principle, Hund's Rule of Maximum Multiplicity and Pauli Exclusion Principle. (2) Abbreviated and detailed electronic configuration in terms of s, p, and d orbitals from hydrogen to zinc.
2. PERIODIC CHEMISTRY	
(a) Periodicity of the elements:	
(i) Periodic Law;	(1) Electronic configurations leading to group and periodic classifications. (2) Periodic properties for the first 18 elements: atomic size, ionic size, ionization energy, electron affinity, electronegativity. Simple discrepancies should be accounted for.
(ii) Trends in periodic properties: Down a group and across a period.	(3) Progression from: (i) metallic to non-metallic character of elements; (ii) ionic to covalent bonding in compounds.
(b) elements (i) Periodic gradation of in group i.e. the halogens: $F_2/Cl_2/Br_2/I_2$.	Recognition of group variations noting any anomalies. Treatment should include the following: (i) physical states, melting and boiling points;

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<p>(ii) Properties of chlorine as a typical halogen</p> <p>(c) Elements of the first transition series.</p>	<p>(ii) redox properties of the elements: displacement reaction of one halogen by another.</p> <p>Properties should include:</p> <ul style="list-style-type: none"> (i) variable oxidation states; (ii) reaction with water and alkali (balanced equations required). <p>(1) Their electronic configuration, physical properties and chemical reactivities of the elements and their compounds.</p> <p>(2) Physical properties should include: physical states, metallic properties and magnetic properties.</p> <p>(3) Other properties of the transition metals should include:</p> <ul style="list-style-type: none"> (i) Variable oxidation states; (ii) Formation of coloured compounds; (iii) Complex ion formation; (iv) Catalytic abilities
<p>(a) Inter-atomic bonding</p> <p>(i) Ionic bonding</p> <p>(I) Factors influencing its formation</p> <p>(II) Properties of ionic compounds.</p>	<p>Lewis dot structure for ionic and covalent compounds.</p> <p>Formation of stable compounds from ions. Factors should include: ionisation energy; electron affinity; electronegativity difference.</p> <p>Typical properties of ionic compounds using binary compounds which are largely ionic. e.g. melting points, boiling point and solubility in various solvents.</p>

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CONTENT	NOTES
(ii) Covalent bonding (I) Factors influencing covalent bond formation; (II) Properties of covalent compounds.	Co-ordinate bond as a type of covalent bond. Factors should include: ionization energy; electron affinity and electronegativity difference Typical properties compared with those of ionic compounds e.g. Melting point, boiling point, solubility in various solvents like water, hexane, ether.
(b) Simple molecules and their shapes	Models should be used where applicable: (i) Linear: CO_2 (ii) Non linear: H_2O (iii) Tetrahedral: CH_4 (iv) Pyramidal: NH_3
(c) Metallic Bonding	(1) Factors should include: atomic radius, ionization potential, and number of valence electrons. Type of specific packing not required.
(i) Factors influencing its formation.	
(ii) Properties of metals	(2) Typical properties including conductivity; malleability, ductility demonstrated using metals like Mg, Zn, Sn, Fe.
(d) Intermolecular bonding	(1) Relative physical properties of polar and non-polar compounds. Description of formation and nature should be treated. Dipole-dipole and induced dipole forces should be treated under van der Waal's forces.
(i) van der Waal's forces;	
(ii) Hydrogen bonding.	(2) Variation of the melting points and boiling points of noble gases, halogens and alkanes in a homologous series explained in term of van der Waal's forces; and variation in the boiling points of H_2O , H_2S , H_2Se , H_2Te explained using hydrogen bonding.
(e) Comparison of all bond types.	

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CONTENT	NOTES
<p>4. STOICHIOMETRY AND CHEMICAL REACTIONS</p> <p>(a) Symbols, Formulae and Equations.</p> <ul style="list-style-type: none"> (i) Chemical symbols (ii) Empirical and molecular formulae (iii) Chemical equations (iv) Laws of Chemical combination <p>(b) (i) Amount of substance.</p> <ul style="list-style-type: none"> (ii) Mole ratios <p>(c) Solutions</p>	<p>Calculations involving formulae and equations will be required. Mass and volume relationships in chemical reactions and the stoichiometry of such reactions as:</p> <ul style="list-style-type: none"> (i) precipitation; (ii) evolution of gases; (iii) displacement of metal ions; (iv) analysis of chlorides; (v) formation and reduction of metallic oxides <p>Experimental illustrations of:</p> <ul style="list-style-type: none"> (1) Law of conservation of mass. (2) Law of constant composition. (3) Law of multiple proportion. <p>(1) Mass and volume measurements;</p> <p>(2) The mole as a unit of measurement; Avogadro's Constant, (L=the number of atoms in 12.00g of ^{12}C).</p> <p>(3) Molar quantities and their uses.</p> <p>(4) Mole of electrons; atoms, molecules, formula units etc.</p> <p>Use of mole ratios in determining stoichiometry of chemical reactions. Simple calculations to determine number of entities, amount of substance, mass, concentration, volume and other quantities.</p> <p>(1) Concept of solution as made up of solvent and solute.</p>

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CONTENT	NOTES
<p>(i) Concentration terms</p> <p>(ii) Standard solutions</p>	<p>(2) Mass (g) or mole (mol) per unit volume. Emphasis on current IUPAC chemical terminology, symbols and conventions.</p> <p>(3) Preparation of some primary standard solutions using anhydrous Na_2CO_3, $(\text{COOH})_2$, $2\text{H}_2\text{O}$.</p> <p>(4) Dilution factor.</p>

5. STATES OF MATTER

- (a) Kinetic model of matter
 - (i) Postulates of the kinetic model of matter.
 - (ii) The use of the kinetic model to explain
 - (I) the nature of solids, liquids and gases;
 - (II) the changes of state of matter.

- (1) Changes of state of matter should be explained in terms of movement of particles. It should be emphasized that randomness decreases (and orderliness increases) from gaseous state to liquid state and to solid state.
- (2) Illustrations of changes of state using the different forms of water, iodine, sulphur, napthalene etc.
- (3) Brownian motion to be illustrated using any of the following experiments:
 - (i) Pollen grains/powdered sulphur in water (viewed under a microscope).
 - (ii) Smoke in a glass container illuminated by a strong light from the side.
 - (iii) A dusty room being swept and viewed from outside under sunlight.

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(III) Diffusion	Demonstration could be given using the following: (i) Diffusion of bromine/iodine/NO ₂ from a sealed tube into an empty tube. (ii) Spread of scent of ammonia in a room.
(b) The Gases	
(i) The Gas Laws	(1) Charles'; Boyle's; Dalton's; Graham's; Avogadro's laws and the ideal gas equation; Qualitative explanation of each of the gas laws using the kinetic model. Mathematical relations of the gas laws and calculations based on the laws will be required. Molar volume of a gas =22.4dm ³ at s.t.p.
(ii) Preparation and properties of gases	(2) Derivation of the general gas law. $\frac{PV}{T} = K.$
(c) Liquids	(1) Laboratory preparation of gases lighter than air (H ₂ , NH ₃) and gases heavier than air (CO ₂ , HCl and SO ₂) to illustrate the principles of purification and collection of gases. (2) Chemical properties of the gases mentioned above (i.e. H ₂ , NH ₃ , CO ₂ , HCl and SO ₂).
Concept of vapour pressure	(1) Liquids as an intermediate state between gases and solids in the kinetic-molecular sense should be emphasized. (2) Simple methods for determination of boiling points. (3) Standard boiling point.
(d) Solids	
(i) Types and structures.	(1) Ionic, metallic, covalent and molecular solids. Comparison of their properties.

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<p>(ii) Structures, properties and uses of diamond and graphite.</p> <p>6. ENERGY AND ENERGY CHANGES</p> <p>(a) Energy changes in physical and chemical processes</p> <p>(b) Description, definition and illustrations of energy changes and effects.</p>	<p>(2) Regular arrangements of ions, molecules and atoms in three dimensions in the solid state should be emphasized. Knowledge of specific packing arrangements not required.</p> <p>(3) Melting points as indicator of purity of solids.</p> <p>Properties and uses – dependent on structures.</p> <p>Enthalpy, energy diagrams. Forms of energy, energy content, transfer of energy.</p> <p>(1) Exothermic and endothermic processes.</p> <p>(2) Total energy of a system as the sum of various forms of energy e.g. kinetic, potential, electrical, heat, sound etc. Enthalpy changes of the following: Formation, combustion, Solution, neutralization.</p> <p>(3) Practical knowledge of the measurement of the heats of neutralisation and solution.</p> <p>(4) Uses of energy changes including energy content of foods and fuels.</p>
<p>7. ACIDS, BASES AND SALTS</p> <p>(a) Definitions of acids and bases.</p> <p>(b) Physical and chemical properties of acids and bases.</p>	<p>(1) Arrhenius concept of acids and bases.</p> <p>(2) Effects of acids and bases on indicators, metals and trioxocarbonate (IV) salts.</p> <p>(1) Conductivities, taste etc.</p> <p>(2) Concept of amphotericism.</p> <p>(3) Balanced chemical equations of all reactions.</p>

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CONTENT	NOTES
(c) Acids, bases and salts as electrolytes	Electrolytes and non-electrolytes; strong and weak electrolytes. Evidence from conductivity and enthalpy of neutralisation.
(d) pH	(1) Knowledge of pH scale (2) pH as a measure of acidity and alkalinity.
(e) Weak acids and weak bases	(1) Behaviour of acids and bases in water as example of equilibrium system (2) Qualitative comparison of the conductances of molar solutions of strong and weak acids and bases.
(f) Hydrolysis	(1) Qualitative explanation of hydrolysis. (2) Behavior of some salts (e.g. NH_4Cl , AlCl_3 , Na_2CO_3 , CH_3COONa) in water as examples of equilibrium systems.
(g) Acid –base indicators	(1) Indicators as weak organic acids or bases (organic dyes). (2) Colour of indicator at any pH dependent on relative amounts of acid and base forms. (3) Working pH ranges of methyl orange and phenolphthalein.
(h) Acid-base titrations	(1) Correct use of relevant apparatus. (2) Knowledge of how acid-base indicators work in titrations. (3) Titration involving weak acids versus strong bases, strong acids versus weak bases and strong acids versus strong bases using the appropriate indicators and their applications in quantitative determination; e.g. concentrations, purity, water of crystallisation and composition.

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CONTENT	NOTES
8. SOLUBILITY OF SUBSTANCES <ul style="list-style-type: none"> (a) General principles 	<ul style="list-style-type: none"> (1) Saturated and unsaturated solutions. (2) Saturated solution as an equilibrium system. (3) Solubility expressed in mol dm⁻³ (4) Solubility curves and their uses. (5) Relationship between solubility and crystallisation. (6) Crystallisation as a method of purification. (7) Solubility of sparingly soluble salts. Complete dissociation of the portion that dissolves (Qualitative treatment only).
<ul style="list-style-type: none"> (b) Practical application of solubility 9. RATES OF REACTIONS AND EQUILIBRIUM SYSTEMS <ul style="list-style-type: none"> (a) Rate of reaction <ul style="list-style-type: none"> (i) Factors affecting rates: physical states, concentration of reactants, temperature, catalysts and medium. (ii) Theory of reaction rates. 	<p>Generalisations of solubility of salts and their applications in qualitative analyses.</p> <p>Definition of reaction rates</p> <ul style="list-style-type: none"> (1) For gaseous systems, pressure may be used as concentration term. (2) Appropriate experimental demonstration for each factor is required. (1) Collision theory and activation energy theory to be treated qualitatively only. (2) Factors influencing collisions: temperature and concentration. (3) Effective collision. (4) Activation energy. (5) Energy profile showing activation energy and

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	enthalpy change.
CONTENT	NOTES

(b) Equilibrium <ul style="list-style-type: none"> (i) General principles (ii) Le Chatelier's principle 	<p>Reversible reactions i.e. dynamic equilibrium. The equilibrium constant K must be treated qualitatively. It must be stressed that K for a system is constant at constant temperature.</p> <p>Prediction of the effects of external influence of concentration, temperature and pressure changes on equilibrium systems.</p>
10. REDOX REACTIONS <ul style="list-style-type: none"> (a) Oxidation and reduction processes (b) Oxidising and reducing agents (c) Redox equations 	
	<ul style="list-style-type: none"> (1) Oxidation and reduction in terms of <ul style="list-style-type: none"> (i) addition and removal of oxygen and hydrogen; (ii) loss and gain of electrons; (iii) change in oxidation numbers/states. (2) Oxidation numbers/states. <ul style="list-style-type: none"> (1) Definition of oxidising and reducing agents in terms of: <ul style="list-style-type: none"> (i) addition and removal of oxygen and hydrogen; (ii) loss and gain of electrons; (iii) change in oxidation numbers/state. (2) Tests for oxidants and reductants. <p>Balancing redox equations by:</p> <ul style="list-style-type: none"> (i) ion, electron or change in oxidation number/state method; (ii) half reactions and overall reactions IUPAC system required

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CONTENT	NOTES
(d) Electrochemical Cells (i) (I) Standard Electrode Potential (II) Drawing and writing of cell diagrams. (ii) E.M.F. of Cells (iii) Application of Electrochemical cells	(1) Standard hydrogen electrode: Meaning of standard electrode potential and its measurement. (2) Only metal/metal ion systems should be used. (1) Electrochemical cells as a combination of two half-cells. (2) The meaning of the magnitude and sign of the emf. (1) Distinction between primary and secondary cells. (2) Daniel cell, lead battery cell, dry cells, fuel cells and their use as generators of electrical energy from chemical reactions.
(e) Electrolysis (i) Principles of electrolysis (ii) Factors influencing discharge of species	Mechanism of electrolysis: Compare with electrochemical cells (1) Limit electrolytes to molten PbBr ₂ /NaCl, dilute NaCl solution, concentrated NaCl solution, CuSO _{4(aq)} ; dilute H ₂ SO ₄ (using platinum or graphite and copper electrodes). (2) Faraday's Laws: Simple calculations based on the relation F = Le = 96,500 C and mole ratios to determine mass, volume of gases, number of entities, charges etc. using half reactions and overall reactions.
(iii) Practical Applications	Electroplating, smelting of aluminium etc.
(f) Corrosion of metals	(1) Corrosion treated as redox process (2) Rusting of iron and its economic cost. (3) Prevention based on relative magnitude of electrode potentials and preventive methods like galvanising, sacrificial cathodic protection and non-redox methods.

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CONTENT	NOTES
11. CHEMISTRY OF CARBON COMPOUNDS <ul style="list-style-type: none"> (a) Classification and nomenclature <ul style="list-style-type: none"> (i) Root names (ii) Functional groups (b) Separation and purification (c) Determination of empirical and molecular formulae and molecular structures of organic compounds. (d) General Properties <ul style="list-style-type: none"> (i) Homologous series (ii) Isomerism (e) Alkanes: <ul style="list-style-type: none"> (i) Sources and properties 	<ul style="list-style-type: none"> (1) Broad classification into straight chain, branched chain, aromatic and alicyclic compounds. (2) Systematic nomenclature of the following compounds: Alkanes, alkenes, alkynes, alkanols, alkanoic acids, alkanoates (esters and salts) and amines. <p>Methods to be discussed should include: distillation, crystallisation, drying, chromatography.</p> <ul style="list-style-type: none"> (1) Gradation in physical properties. (2) Effects on the physical properties by introduction of active groups into the inert alkane. (1) Examples should be limited to compounds having maximum of five carbon atoms. (2) Differences between structural and geometric/stereo isomerism. <ul style="list-style-type: none"> (1) Laboratory and industrial preparations and other sources. (2) Nomenclature and structure (3) Reactivity: <ul style="list-style-type: none"> (i) combustion; (ii) substitution reactions; (iii) cracking of large alkane molecules.

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CONTENT	NOTES
(ii) Uses	Importance as fuels, as starting materials for synthesis. Uses of haloalkanes and pollution effects.
(iii) Petroleum	<ul style="list-style-type: none"> (1) Composition. (2) Fractional distillation and major products; (3) Cracking and reforming; (4) Petro-chemicals: Starting materials of organic synthesis; (5) Quality of petrol. Meaning of octane number.
(f) Alkenes:	
(i) Sources and properties	<ul style="list-style-type: none"> (1) Laboratory preparation; (2) Nomenclature and structure; (3) Addition reactions with halogens, bromine water, hydrogen halides; (4) Oxidation: Hydroxylation with aqueous KMnO_4.
(ii) Laboratory detection	Use of reaction with Br_2/CCl_4 and $\text{KMnO}_4(\text{aq})$ as means of characterising alkenes.
(g) Alkynes:	
Sources and Uses	<ul style="list-style-type: none"> (1) Nomenclature and structure; (2) Industrial production of ethyne; (3) Uses of ethyne.
(h) Benzene	
(i) Structure and physical properties	<ul style="list-style-type: none"> (1) Resonance in benzene. Stability leading to substitution reactions. Halogenations (mechanism not required)
(ii) Chemical properties	<ul style="list-style-type: none"> (2) Addition reactions: hydrogenation and halogenation; (3) Compare reactions with those of alkenes.

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CONTENT	NOTES
(i) Alkanols	(1) Laboratory preparation including hydration of alkenes.
(i) Sources, nomenclature and structure	(2) Industrial and local production of ethanol including alcoholic beverages. Harmful impurities and methods of purification should be mentioned.
(ii) Classification	Primary, secondary and tertiary alkanols.
(iii) Physical properties	Including those due to intermolecular hydrogen bonding.
(iv) Chemical Properties	(1) Reaction with: (i) Na, (ii) alkanoic acids (esterification); (iii) conc. H_2SO_4 (2) Oxidation by: (i) $\text{KMnO}_{4(\text{aq})}$; (ii) $\text{K}_2\text{Cr}_2\text{O}_{7(\text{aq})}$; (iii) $\text{I}_2/\text{NaOH}_{(\text{aq})}$.
(v) Laboratory test	
(j) Alkanoic Acids	
(i) Sources, nomenclature and structure	
(ii) Physical properties	Including those due to intermolecular hydrogen bonding.
(iii) Chemical properties	Acid properties only: i.e. reactions with H_2O , NaOH , NaHCO_3 .
(iv) Laboratory test	Reaction with NaHCO_3 .
(v) Uses and properties	Uses and properties of ethanoic and phenylmethanoic (benzoic) acids as examples of aliphatic and aromatic acids respectively.

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CONTENT	NOTES
(k) Alkanoates as derivatives of alkanoic acids	Preparation of alkyl alkanoates (esters) from alkanoic acids.
(i) Sources, nomenclature and structure	
(ii) Physical properties	
(iii) Chemical properties	Hydrolysis of esters (mechanism not required).
(l) Fats and oils :	Alkanoates (esters)
Sources, physical and chemical properties.	(1) Saponification, hardening of oils. (2) Detergents as soapless detergents.
	Comparison of soapless detergents with soapy detergents and their action on soft water and hard water.
(m) Amino acids	Difunctional nature of amino acids.
(n) Natural and synthetic polymers	
(i) Definitions	(1) Polymerisation; (2) Addition and condensation polymers; (3) Plastics and resins; (4) Thermoplastic and thermosetting polymers.
(ii) Important properties of polymers	
(iii) Natural polymers	
(I) Carbohydrates: formulae, properties and uses.	(1) Classification as monosaccharides, disaccharides and polysaccharides; reducing and non reducing sugars using glucose, fructose, sucrose/maltose and starch/cellulose as examples. (2) Hydrolysis of sucrose and starch

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CONTENT	NOTES
(II) Proteins	(1) As polymers of amino acid molecules linked by peptide or amide linkage. (2) Hydrolysis (3) Uses in living systems.
(iv) Synthetic polymers	Classification and preparation based on the monomers and co-polymers
12. CHEMISTRY, INDUSTRY AND THE ENVIRONMENT	
(a) Chemistry in industry	(1) Natural resources in candidate's own country (2) Chemical industries in candidate's own country and their corresponding raw materials. Distinction between fine and heavy chemicals. (3) Factors that determine siting of chemical industries. (4) Effect of industries on the community.
(b) (i) Extraction of metals: (I) Al and Fe; (II) Au or Sn.	(1) Raw materials, processing, main products, by-products, recycling. (2) Uses of the metals.
(ii) Alloys	Common alloys of Cu, Al, Pb, and Fe and their uses.
(c) Pollution Air, water and soil pollution.	(1) Sources, effects and control, (2) Greenhouse effect and depletion of the ozone layer, (3) Biodegradable and non-biodegradable pollutants.
(d) Biotechnology	Food processing, fermentation including production of kenkey/gari, bread and alcoholic beverages e.g. Local gin.

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13. PRACTICALS

(a) GENERAL SKILLS AND PRINCIPLES

Candidates will be expected to be familiar with the following skills and principles:

- (i) Measurement of mass and volume;
- (ii) Preparation and dilution of standard solutions;
- (iii) Filtration, recrystallisation and melting point determination;
- (iv) Measurement of heats of neutralisation and solution;
- (v) Determination of pH value of various solutions by colorimetry;
- (vi) Determination of rates of reaction from concentration versus time curves;

(b) QUANTITATIVE ANALYSIS

Acid-base titrations

The use of standard solutions of acids and alkalis and the indicators methyl orange and phenolphthalein to determine the following:

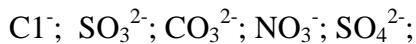
- (i) The concentrations of acid and alkaline solutions;
- (ii) The molar masses of acids and bases and water of crystallization;
- (iii) The solubility of acids and bases;
- (iv) The percentage purity of acids and bases.

(c) QUALITATIVE ANALYSIS: No formal scheme of analysis is required.

- (i) (a) Characteristic tests of the following cations with dilute $\text{NaOH}_{(\text{aq})}$ and $\text{NH}_3_{(\text{aq})}$;
 NH_4^+ ; Ca^{2+} ; Pb^{2+} ; Cu^{2+} , Fe^{2+} ; Fe^{3+} ; Al^{3+} ; and Zn^{2+}
(b) Confirmatory tests for the above cations.

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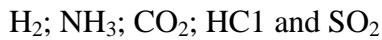
- (ii) (a) Characteristic reaction of dilute HC1 on solids or aqueous solutions and conc. H₂SO₄ on solid samples of the following:



- (b) Confirmatory tests for the above anions

- (iii) Comparative study of the halogens; displacement reactions.

- (iv) Characteristic test for the following gases:



- (v) Characteristic test tube reactions of the functional groups in the following simple organic compounds: Alkenes; alkanols; alkanoic acids, sugars (using Fehling's and Benedict's solutions only); starch (iodine test only) and proteins (using the Ninhydrin test, Xanthoproteic test, Biuret test and Millon's test only).

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**SECTION 'B'
(FOR CANDIDATES IN GHANA)**

CONTENT	NOTES
1. STRUCTURE OF THE ATOM Elementary treatment of mass spectrometry.	Qualitative knowledge of the principles and operations of the mass spectrometer, spectra and their use in determining isotopes, relative atomic and molecular masses only.
2. PERIODIC CHEMISTRY (a) Periodicity of the elements (b) Periodic gradation of the elements in the second period and of Na, Mg, Al and Si in the third period. (c) Periodic gradation of elements in group VII (i.e halogens)	Periodic properties should include atomisation energy. (1) Differences and similarities between the properties of elements in the second and third periods should be stated. (2) Tendency of compounds to decompose on heating to give compounds of more stable structures. (1) Inter-atomic bond energies;

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CONTENT	NOTES
	<p>(2) Variable oxidation states for F_2, Br_2 & I_2;</p> <p>(3) Reaction of F_2, Br_2 and I_2 with water and alkali (balanced equations required);</p> <p>(4) Comparison of PK_a values (acid strengths) of the hydrogen halides.</p> <p>(d) Elements of the first transition series</p> <p>Chemical reactivity of the metals with air, water, acids and comparison with s-block elements.</p>
3. BONDING	
(a) Ionic bonding	
(i) Factors influencing its formation	Factors should include lattice energy. Influence of ionic charge and ionic size (charge density) on lattice energy and on properties of ionic compounds.
(ii) Covalent bonding: polarization	<p>(1) Concept of polarizing power and polarizability of ions.</p> <p>(2) Polarization effects should be explained in terms of ionic radius and charge and that it introduces covalent character. Examples of binary compounds only (e.g. AlCl_3, BeCl_2) should be used.</p>
(b) Hybridization	<p>(1) Hybridization as mixing of orbitals: sp^3, sp^2 and sp hybrid orbitals.</p> <p>(2) Overlap of orbitals-sigma bonds as head-on overlap and pi bonds as sideways overlap.</p>
(i) Covalent bonding	Simple treatment of shapes of molecules using electron repulsion in hybrid orbitals leading to structure and displayed formulae. Treatment should be limited to the following molecules only: BCl_3 , C_2H_2 , BeCl_2 , and C_2H_4
(ii) Shapes of molecules.	

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CONTENT	NOTES	
(c) Inter molecular bonding (i) van der Waal's forces (ii) Hydrogen bonding	Discussion of factors influencing strength of inter atomic forces should be related to the density of element(s) and compound(s) Variation in the boiling points should include compounds such as H ₂ Se, H ₂ Te.	
4. SOLUTIONS	Preparation of dilute solutions from concentrated solutions of known density and percentage composition (w/v, w/w).	
5. STATES OF MATTER	Derivation of PV = nRT required. Structures dependent on hybridisation of carbon.	
6. ENERGY AND ENERGY CHANGES	(a) Energy changes in physical and chemical processes (b) Description, definition and illustrations of energy changes and effects. Hess' law (d) Bond Energy	(1) Definition and understanding of the meaning of the energy terms: surroundings, open and closed systems. (2) Energy cycles. (1) Definition of enthalpies of hydration, atomisation, sublimation and lattice energy will be required. (2) Description of indirect methods of measurement of energy changes. (1) Use of different cycles to illustrate Hess' Law. (2) Simple calculations using chemical equations, energy cycles or diagrams with given energy changes. (1) Bond energy as an average value. (2) Bond energy in covalent molecules and its use in assessment of bond strength, energy content and enthalpy of reaction.

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CONTENT	NOTES
7. ACIDS; BASES AND SALTS	
(a) Definitions of acids and bases	(1) Bronsted-Lowry and Lewis concept of acids and bases. (2) Conjugate acid-base pair concept in terms of equilibrium.
(b) pH and pOH	(1) pOH as a measure of alkalinity (and acidity). (2) Calculation of $[H^+]$, $[OH^-]$ and the corresponding pH and pOH of given solutions.
(c) Weak acids and weak bases	(1) K_a , pK_a and K_b , pK_b as measurements of acid and basic strengths respectively. Calculations involving K_a , pK_a and K_b , pK_b .
(d) Buffer solutions	Qualitative definition. Examples of buffers from the laboratory and in living systems.
(e) Acid/base titrations	Use of titrimetric means to determine the composition of a mixture of CO_3^{2-} and HCO_3^- by double indicator method.
8. SOLUBILITY OF SUBSTANCES	
Dissolution of ionic and covalent compounds.	Expression of solubility in $g\ dm^{-3}$ Dissolution in terms of the destruction of forces holding units together e.g., balance between lattice energy and solvation energy in ionic compounds and van der Waal's forces in covalent compounds.
9. RATES OF REACTIONS AND EQUILIBRIUM SYSTEMS	
(a) Order of reaction.	(1) Deduction of order and hence rate from experimental data.

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CONTENT	NOTES
	<ul style="list-style-type: none"> (2) Simple relation between rates and concentration of first order and second order reactions. (3) General rate law equation.
(b) Equilibrium law of mass action.	<ul style="list-style-type: none"> (1) Mathematical expression of K. (2) Relationship between K_p and K_c; calculation of K_p and K_c from given set of data.
10. REDOX REACTIONS	
Redox titrations	<ul style="list-style-type: none"> (1) Use in solving analytical problems. (2) Exercises should be limited to the following systems: <ul style="list-style-type: none"> (i) Acidic KMnO_4 versus $\text{Fe}^{2+}_{(\text{aq})}$; (ii) Acidic KMnO_4 versus $\text{C}_2\text{O}_4^{2-}_{(\text{aq})}$; (iii) $\text{I}_2/\text{KI}_{(\text{aq})}$ versus $\text{S}_2\text{O}_3^{2-}_{(\text{aq})}$.
11. CHEMISTRY OF CARBON COMPOUNDS	
(a) Classification and nomenclature.	<ul style="list-style-type: none"> (1) Broad classification to include heterocyclic compounds. (2) Nomenclature should include amides, anhydrides and alkanoyl halides.
(b) Separation and purification	Other methods should include solvent extraction and melting point determination.
(c) Determination of empirical and molecular formulae	Outline of steps in the following: <ul style="list-style-type: none"> (i) Detection of N, S and the halogens (ii) Estimation of C, H and O.
(d) Reactivity of organic compounds	<ul style="list-style-type: none"> (1) Inductive effect and mesomeric effect. (2) Resonance should be illustrated with the ethanoate and nitro groups too. (3) Nucleophiles, electrophiles, free radicals and ions.

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CONTENT	NOTES
(e) Alkanes	Halogenation – free radical mechanism
(f) Alkenes: Sources and properties.	(1) Industrial manufacture (2) Mechanism of reaction illustrated with hydrogen halides e.g. HBr.
(g) Alkynes: Sources and uses:	Relative molar enthalpies of combustion of ethene and ethyne.
(h) Benzene: Structure and properties	Uses of hexachlorocyclohexane and benzene hexachloride.
(i) Alkanols	
(i) Sources, nomenclature and structure	Preparation by the hydrolysis of haloalkanes.
(ii) Chemical properties	Reaction with $(\text{NH}_4)_2[\text{Ce}(\text{NO}_3)_6]/\text{HNO}_3_{(\text{aq})}$
(iii) Laboratory test	Reaction with $(\text{NH}_4)_2[\text{Ce}(\text{NO}_3)_6]/\text{HNO}_3_{(\text{aq})}$ $\text{I}_2/\text{NaOH}_{(\text{aq})}$ for $\text{CH}_3\text{CH}(\text{OH}) - \text{R}$ group.
(j) Alkanoic acid derivatives	Study of amides included. i.e. Sources, preparation, physical properties, chemical properties (e.g. hydrolysis and laboratory tests for amides (using warm NaOH)).
(k) Carbohydrates	Structure of glucose, sucrose and starch.
(l) Proteins	Formation.
12. CHEMISTRY, INDUSTRY AND THE ENVIRONMENT	
(a) Conservation	Resource management
(b) Biotechnology	(1) Waste recycling e.g. production of fertilizer and of methane as a source of fuel. (2) Production of drugs using micro-organisms

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CONTENT	NOTES
<p>13. PRACTICALS</p> <p>(a) General skills and principles</p> <p>(b) Acid-base titrations</p> <p>(c) Redox titrations</p> <p>(d) Qualitative Analysis</p>	<p>Determination of equilibrium constants for simple systems.</p> <p>Analysis of $\text{Na}_2\text{CO}_3/\text{NaHCO}_3$ mixture by double indicator method.</p> <p>Stoichiometry of reactions.</p> <p>Titrations of the following systems to solve analytical problems:</p> <ul style="list-style-type: none"> (1) Acidic MnO_4^- versus Fe^{2+} (2) Acidic MnO_4^- versus $\text{C}_2\text{O}_4^{2-}$ (3) I_2/KI versus $\text{S}_2\text{O}_3^{2-}$ <ul style="list-style-type: none"> (1) Characteristic tests for cations using $\text{H}_2\text{S}_{(\text{g})}$ (2) Confirmatory test for Na^+ (3) Tests for Br^- and I^- (4) Characteristic test tube reactions of amides.

SECTION C
(FOR CANDIDATES IN NIGERIA, SIERRA-LEONE AND THE GAMBIA)

CONTENT	NOTES
<p>1. BONDING</p> <p>Shapes of molecules</p>	<p>The shapes of the following molecules should also be treated:</p> <p>H_2 and O_2</p>
<p>2. STATES OF MATTER</p> <p>The Gas Laws</p>	<p>Statement of Gay Lussac's Law and calculations based on the law.</p>

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CONTENT	NOTES
3. ENERGY AND ENERGY CHANGES Enthalpies of reaction	Measurement of the enthalpy of combustion (in outline) by calorimetry
4. ACIDS, BASES AND SALTS (a) Methods of preparation of simple salts (b) Deliquescent, Efflorescent and hygroscopic substances.	The use of deliquescent and hygroscopic substances as drying agents should be emphasized.
5. REDOX REACTIONS (a) Electrolysis of molten/fused salts and solutions	Electrolysis of the following solutions should also be carried out: $\text{NaOH}_{(\text{aq})}$ $\text{KI}_{(\text{aq})}$ and $\text{CuCl}_2_{(\text{aq})}$
6. CHEMISTRY OF CARBON COMPOUNDS (a) Allotropes of carbon other than diamond and graphite (b) Coal: (i) Different types (ii) Destructive distillation of coal and uses of the products. (c) Coke (i) Gaseification and uses (ii) Manufacture of synthetic gas and uses.	(1) Structures, properties and uses. (2) The uses of the allotropes should be correlated with their properties and structures. (3) Combustion of allotropes Different types should include anthracite, peat and lignite.

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CONTENT	NOTES
(d) Oxides of carbon (i) Carbon (IV) oxide: uses (ii) Carbon (II) oxide: properties and uses	
(e) Alkynes – Chemical properties	Tests to distinguish between alkanes, alkenes and alkynes.
(f) Benzene: Uses	
(g) Alkanols	Recognition of the structures of mono-, di- and triols,
(h) Alkanoic acids	Recognition of mono and dioic acids.
7. NON METALS AND THEIR COMPOUNDS	
(a) Oxygen: (i) Laboratory and Industrial preparation, (ii) Properties and uses; (iii) Binary Compounds of oxygen: Acidic oxides, basic oxides, amphoteric oxides and neutral oxides.	
(b) Water and solution (i) Composition of water (ii) Water as a solvent (iii) Hardness of water: causes and methods of removing it. (iv) Treatment of water for town supply	Test for water will be required. Reference should be made to the electrolysis of acidulated water (1) Advantages and disadvantages of hard water and soft water. (2) Experiments to compare the degree of hardness in different samples of water.

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CONTENT	NOTES
(c) Halogens:	
(i) Chlorine: Laboratory preparation, properties and reactions	
(iii) Uses of halogen compounds	Uses should include silver halide in photography and sodium oxochlorate (I) as a bleaching agent.
(d) Nitrogen	
(i) Preparation and properties	
(ii) Uses of nitrogen	Both laboratory and industrial preparations from liquefied air are required.
(iii) Compounds of nitrogen	
(I) Ammonia – Industrial preparation and uses.	
(II) Trioxonitrate (V) acid - Laboratory preparation, reactions and uses.	
(III) Trioxonitrate (V) salts	Action of heat will be required.
(e) Sulphur	
(i) Allotropes and uses	
(ii) Compounds of sulphur	
(I) Sulphides	
(II) Trioxosulphate (IV) acid and its salts.	
(III) Tetraoxosulphate (VI) acid- Industrial preparation, reactions and uses.	For industrial preparation, only the Contact Process should be discussed.
(f) The noble gases – properties and uses.	

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CONTENT	NOTES
<p>8. METALS AND THEIR COMPOUNDS</p> <p>(a) Properties and uses of sodium and its compounds.</p> <p>(b) Properties and uses of calcium and its compounds.</p> <p>(c) Reactivities of iron and aluminium with air, water and acids.</p> <p>(d) Copper</p> <ul style="list-style-type: none">(i) Purification(ii) Chemical properties(iii) Uses of copper and its compounds.	<p>The compounds must be limited to NaCl, NaOH, Na₂CO₃, NaHCO₃, NaNO₃, Na₂SO₄ and NaClO.</p> <p>The compounds must be limited to CaCO₃, CaO, CaSO₄, CaCl₂, Ca(OH)₂</p> <p>The compounds must be limited to CuSO₄, CuO and CuCl₂.</p>