LATEST EDITION

# CHEMISTRY

# JUPEB SYLLABUS

# SYLLABUS FOR SCI - J153
# CHEMISTRY

## GENERAL OBJECTIVES

At the end of the series of courses, candidates should be able to:

1. provide a course of instruction and other facilities for the acquisition of knowledge in the field of Chemistry;
2. build on the knowledge and skills acquired in chemistry at the Senior Secondary School level;
3. provide candidates with advanced knowledge in chemical concepts and principles through efficient selection of content;
4. enable candidates improve on and develop new laboratory skills including an awareness of hazards and safety in the laboratory;
5. provide candidates with unique and sufficient academic and technical knowledge relevant for professional careers in industries, governmental agencies, research institutes and the academia; and
6. make the study of Chemistry enjoyable and satisfying by creating a sustained interest in the subject.

## FIRST SEMESTER COURSES

CHM 001: GENERAL CHEMISTRY (3 UNITS)
CHM 002: PHYSICAL CHEMISTRY (3 UNITS)

## SECOND SEMESTER COURSES

CHM 003: INORGANIC CHEMISTRY (3 UNITS)
CHM 004: ORGANIC CHEMISTRY (3 UNITS)

## COURSE DESCRIPTION

**CHM 001: General Chemistry** (3 Units)

### Specific Objectives

At the end of this course, candidates should be able to:

1. determine scientific quantities and units;
2. apply the terms relative atomic, isotopic, molecular and formula masses, based on $^{12}C$ scale in chemistry;
3. define the term mole in terms of Avogadro constant;
4. determine empirical and molecular formulae, using combustion data;
5. discuss the development of the modern atomic structure;

6. state the electronic configuration of atoms and ions given the proton number;
7. explain qualitatively the variation in atomic radius and ionic radius;
8. describe chemical bonding (ionic, covalent, coordinate metallic, etc.);
9. explain the shapes of, and bond angles in molecules using the valence shell electron pair repulsion theory.

## Course Content

| S/N | Topic | Sub-topic | Detail |
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| 1 | Measurement | Units of Measurement | Basic S.I. Units, derived units, conversion of units, significant figures, precision and accuracy, errors (systematic and random errors). Exact numbers. |
| 2 | Nature of matter | States of Matter | Solid, liquid and gaseous states, properties and inter-conversion. |
| 3 | Atomic Masses | Relative Atomic Mass, Relative Molecular Mass | Definitions and calculations of molar masses of atoms and molecules based on $^{12}C$ scale, use of mass spectrometry in the determination of Relative Atomic Mass and Relative Molecular Mass. |
| 4 | Atomic Structure | Dalton's Atomic Theory | Dalton's atomic theory. |
| | | Discovery of Sub-Atomic Particles | Various experiments that led to the discovery of neutrons, protons, electrons and nucleus (cathode ray, Millikan's oil drop, Rutherford's and Thompson's experiments), calculations of relative abundances and isotopic mass; |
| | | Planck's Theory | Black body radiation, photoelectric effect, quantisation of energy; |
| | | Bohr's Theory | Bohr's assumption, atomic spectra of hydrogen(no derivation is required) and determination of spectra lines, determination of |

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| | | Wave Theory Of Atom | ionisation energy from line spectra(when n=∞);<br><br>Particle wave duality. |
| | | Electronic Configuration of Atoms and Ions | Atomic orbitals, quantum numbers(n,l,m,s), electronic energy levels, degeneracy of atomic orbitals, shapes of atomic orbitals(s,p and d orbitals)<br><br>Aufbau principle, Pauli's exclusion principle, Hund's rule, (n+1) rule. |
| 5 | Periodicity | Periodic Table<br><br>Atomic Properties | Development of the modern periodic table, building up periods, identifying blocks and groups of elements, Periodic law.<br>Trends of atomic size, ionisation potential, electron affinity, electronegativity and ionic radii, isoelectric species. |
| 6 | Mole Concept | Mole and Avogadro's Constant<br><br>Empirical and Molecular Formulae<br><br>Stoichiometry<br><br>Solution Stoichiometry | Various ways of defining the mole, Avogadro's constant, molar mass.<br><br>Definition and calculations of Empirical and Molecular formulae from percentage composition by mass and combustion data.<br><br>Balancing chemical equations, calculations based on stoichiometric coefficients, reaction that involve limiting reactants, calculation of actual and percentage yields.<br><br>Calculation of molarity and gram concentration, preparation of standard solutions, serial dilution. |

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| 7 | Types of chemical reactions | Neutralisation<br><br>Precipitation<br>Oxidation and Reduction | Definition, identification of neutralization reactions.<br><br>Predicting solubilities.<br><br>Various definitions of oxidation and reduction reaction with emphasis on definition of terms of electron transfer, calculation of oxidation numbers, balancing of redox reactions by oxidation state and half-reaction method (both in acidic and basic media). |
| 8 | Chemical Bonding | Electrovalent/Ionic Bonding<br><br>Covalent Bonding<br><br>Intermolecular Forces<br><br>Metallic Bonding<br><br>Bonding and Physical Properties | Describe ionic bonding using some ionic compounds e.g. NaCl, energy considerations of ionic bonding, definition of lattice energy (no derivation), properties of ionic compounds.<br><br>Describe covalent bonding using simple covalent compounds e,g, $CO_2$, coordinate/dative covalent bonding e.g. in ammonium ion ($NH_4^+$), $Al_2Cl_6$ molecule, bond energy, bond length and bond polarity(Fajan's rule), properties of covalent compounds, hybridisation concept (sp, $sp^2$, $sp^3$), shapes of simple molecules using the valence shell electron-pair repulsion theory e,g. $H_2O$, $NH_3$, $CH_4$, etc.<br><br>Van der waals forces, permanent and induced dipoles, hydrogen bonding.<br><br>Describe metallic bonding in terms of a lattice of positive ions surrounded by delocalised electrons.<br><br>The effect of different types of bonding on the physical properties |

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| | | | of substances (e.g. unusual high boiling point of water, miscibility of water and ethanol, nylon, polyester). |

## CHM 001 Practicals

1. Sensitivity of weighing equipment, Graduation of measuring equipment, and determination of significant figures in readings;
2. Preparation of standard solutions: Serial dilution;
3. Volumetric analysis: Practice in volumetric analysis, acid-base, redox, precipitation titrations. Acid base titrimetry involving NaOH, oxalic acid, HCl and $Na_2CO_3$, Determination of percentage composition of iron using $KMnO_4$ (redox Titrimetry), Titrimetric analysis of mixtures, $NaOH/NaHCO_3$ and $Na_2CO_3/NaHCO_3$; and
4. Introduction to the statistical analysis of data: Use of supplied data to illustrate elements of simple statistics.

## CHM 002: Physical Chemistry (3 units)

***Specific Objectives***

At the end of this course, candidates should be able to:

1. state the assumptions of the kinetic theory for ideal gases;
2. state and derive equation for Raoult's law;
3. use of colligative properties of solution to obtain experimentally determined molar masses;
4. apply Hess' Law to construct simple energy cycles and carry out calculations involving such cycles;
5. define the terms, standard electrode potential, and standard cell potential.
6. use redox equation to construct an electrochemical cells using relevant half equations;
7. construct and use rate equations to deduce order of reactions.
8. define acids and bases in terms of Arrhenius, Bronsted-Lowry and Lewis concept; and
9. identify acids/bases in chemical reaction, giving the basis for the classification.

## Course Content



| S/N | Topic | Sub-Topic | Detail |
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| 1. | Kinetic Molecular Theory of Gases | Gas Laws | Statement of and calculations involving Boyle's, Charles', Dalton's, Graham's laws and Avogadro's hypothesis. |
| | | Ideal and Real Gases | Ideal gas equations, Kinetic theory of gases (assumptions only), real gases deviation from ideal gas behaviour, Van der Waal's equation. Use of the general gas equation. PV=nRT in calculations, including relative molecular mass determination. |
| 2. | Solutions | Phase and Phase Diagram | Interpretation of phase diagram for one component system. |
| | | Ideal and Non-Ideal Solutions | Definition of ideal and non-ideal solutions, Raoult's Law |
| | | Colligative Properties | Lowering of vapour pressure, depression of freezing, elevation of boiling point and osmotic pressure. Determination of molar mass using osmotic pressure. (The derivation not required). |
| 3 | Thermochemistry | Enthalpy Change | Exothermic and endothermic changes, Definition of enthalpy changes for processes (combustion, neutralization, hydration, formation, solution, atomization) under standard condition. |
| | | Hess' Law | State Hess' law and construct energy cycles based on Hess' law and carry out calculations based on Hess' law<br>Use of bond energy to calculate energy changes. |

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| | | Introduction to Chemical Thermodynamics | Definition of entropy and Gibb's free energy Calculation of entropy change for reactions. Calculation of Gibb's free energy change for reactions using $\Delta G \approx \Delta H - T\Delta S$. Predicting the spontaneity of reactions |
| 4 | Electrochemistry | Electrolysis<br><br>Electrochemical Cells<br><br>Fuel Cells and Batteries | Faraday's first and second laws of electrolysis and calculations based on them. Identify the substances liberated during electrolysis based on the state of electrolyte, position in electrochemical series, concentration of electrolyte and nature of electrodes. Definitions of electrode potential, standard electrode potential, cell potential. Calculations of e.m.f of a cell. Application of Nernst equation. Use of cell potential to predict the feasibility of reactions. Industrial uses of electrolysis.<br><br>$H_2/O_2$ fuel cell, rechargeable batteries. |
| 5 | Chemical Kinetics | Rate Equations<br><br>Activation Energy<br>Catalysis | Definition of rate of reaction and reaction mechanism. Factors affecting rate of reaction. Orders of reaction, rate constants and molecularity. Calculations of order of reaction from experimental data. Simple collision theory. Definition of activation energy. Arrhenius equation.<br>Homogeneous and Heterogeneous catalysis. |
| 6 | Equilibrium State | Mass Action | Equilibrium changes, reaction quotient (Q), equilibrium expressions (homogenous and heterogeneous equilibra).Calculations of equilibrium constants in terms of |

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| | | | concentration ($K_c$) and partial pressure ($K_p$). Relationship between $K_c$ and $K_p$. |
| | | Le-Chatelier's Principle | Statement and Application of Le-Chatelier's principle to deduce the effects of changes in temperature, pressure and concentration on a system at equilibrium. |
| | | Acid-Base Equilibra | Definitions of acid and base in terms of; Arrhenius, Bronsted-Lowry and Lewis concept. Auto-ionisation of water. Acid strengths, pH of acids, buffer solution. Indicator theory. |
| | | Ionic Equilibra in Aqueous System | Solubility product, common ion effect. Selective precipitation of ions. |
| 7 | Nuclear Chemistry | Radioactivity | History of Radioactivity. Types of radiations. Radioactive disintegration. Nuclear equations, half-life, radioactive carbon dating. Detectors and applications of radioactivity. |

## CHM 002 Practicals

1. Experiments to calculate enthalpy changes.
2. Determination of molecular mass using freezing point depression.

## CHM 003: Inorganic Chemistry (3 units)

***Specific Objectives***

At the end of this course, candidates should be able to:

1. describe the extraction of groups 1,2 and 13 metals;
2. describe physical properties of elements and variation down a Group;
3. discuss gradation in properties across the period from metal through metalloid to non-metals;
4. describe and explain the relative stability of oxides, hydrides and chloride of Group 14 elements;
5. explain what a transition element is in terms of d – block elements;

and

6. describe the tendency of transition metals to form variable oxidation states and write their electronic configuration.

## Course Content

| S/N | Topic | Sub-Topic | Detail |
|---|---|---|---|
| 1. | Periodicity of Elements | General Trends in Properties of Elements | Nature of elements, trends in physical and chemical properties of elements. |
| 2. | Chemistry of Hydrogen | Hydrogen | Occurrence, isotopes, preparation and reactions, hydrides. |
| 3. | s-block elements | Group 1 | Physical and chemical properties, extraction of group 1 metals e.g Sodium, trends in properties of their compounds. Uses of group 1 metals. |
| | | Group 2 | Physical and chemical properties, extraction of group 2 metals e.g Calcium, trends in properties of their compounds. Uses of group 2 metals |
| 4. | p-block elements | Group 13 | Boron and Aluminium. Occurrence and extraction, trends in properties of their compounds with oxygen, chlorine and hydrogen. |
| | | Group 14 | Occurrence, allotropic forms, physical and chemical properties, trends in properties of oxides, hydrides, halides. Greenhouse effect, Uses of group 14 elements. |
| | | Group 15 | Occurrence, allotropic forms, physical and chemical properties, simple oxides and nitrides, environmental impacts of $NO_X$. uses of group 15 elements. |
| | | Group 16 | Occurrence, allotropic forms, physical and chemical properties, |

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| | | Group 17 | trends in properties of oxides, hydrides and halides. Environmental impact of $SO_X$. Uses of group 16 elements.<br>Occurrence, physical and chemical properties, hydrogen halides, metal halides and inter-halogen compounds. Uses of group 17 elements. |
| 5. | d-block elements | First Row Transition Elements<br><br>Introduction to Coordination Chemistry | Definition of transition element, electronic configuration, atomic radii, ionization potential, variable oxidation states, formation of metal complex.<br>Definition of metal complex and ligands, types of ligands. Bonding in metal complexes (chain theory and its limitations, Werner's theory). Valence bond theory and hybridization concept. Study of structure and magnetic properties of octahedral and tetrahedral complexes. Nomenclature of coordination compounds. |

## CHM 003 Practicals

### Qualitative Inorganic Practical

1. Flame tests and systematic analysis of mixtures containing two salts.
2. Identification of anions: preliminary tests for anions, preparation of $Na_2CO_3$ extracts and confirmatory tests.
3. Identification of cations group I – VI: Group separation and analysis of ions within a group (group analysis).

## CHM 004: Organic Chemistry (3 Units)

### Specific Objectives

At the end of this course, candidates should be able to:

1. interpret and use nomenclature and general formulae of alkanes, alkenes, alkynes, arenes, aldehydes, ketones, alcohols, alkyl

halides and carboxylic acids and their derivatives;
2. describe the synthetic routes to simple organic compounds and the reactions of the above classes of compounds;
3. describe the formation of polymer by addition and condensation polymerization;
4. identify the monomer present in a given section of a polymer molecule.
5. relate chemical principles to industrial processes; and
6. explain the various types of isomerism exhibited by organic compounds.

## Course Content

| S/N | Topic | Sub-Topic | Details |
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| 1. | Structure and Bonding in Organic Compounds | Hybridization | Tetravalency and hybridization of carbon |
| | | Classes of Organic Compounds | Functional groups, homologous series, determination of molecular formula from empirical formula. |
| | | Nomenclature | Naming of organic compounds: alkanes, alkenes, alkynes, aldehydes, ketones, alcohols, alkyl halides, arenes, carboxylic acids, amines. |
| 2. | Purification | Purification of Organic Compounds | Determination of melting point, crystallization and recrystallization, simple distillation, liquid extraction, sublimation |
| | | Determination of Elements | Various methods of determining C,H, N, S and halogens in organic compounds. Sodium fusion test. |

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| 3 | Organic Reactions | Covalent Bond Cleavage | Homolytic and heterolytic fission, free radical reaction Nucleophiles and electrophiles |
| | | Types of Reactions | Addition, Substitution, Elimination, Hydrolysis, Condensation. |
| | | Electronic Concepts in Organic Chemistry | Inductive, steric and electrometric effects. |
| 4. | Isomerism in Organic Compounds | Isomerism in Organic Compounds | Constitutional, chain, position and functional group isomerism. Tautomerism, stereoisomerism, geometrical and optical isomerism. |
| 5. | Organic Compounds | Alkanes, Alkenes and Alkynes Alcohols | Nomenclature, structure, synthesis, properties and reactions Nomenclature, structure, synthesis, properties and reactions(combustion, substitution to give halogenoalkanes, reaction with Na, oxidation to carbonyl compounds and carboxylic acids, dehydration to alkenes, formation of esters by esterification with carboxylic acids and acyl chlorides). Classes of alcohols. Distinguishing tests for |
| | | Alkylhalides | |
| | | Carbonyl Compounds (Aliphatic and Aromatic) | |

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| | | | alcohols(Lucas and Jones reagents) |
| | | Carboxylic Compounds and their Derivatives | Nomenclature, structure, synthesis, properties and reactions. |
| | | Primary Amines | Nomenclature, structure, synthesis, properties and reactions (reduction, reaction with HCN, NaCN, reaction with aqueous $I_2$). Tests for aldehydes and ketones using 2,4-dinitrophenylhydrazine. |
| | | Introduction to Aromatic Compounds | Nomenclature, properties, preparation from alcohols, aldehydes and nitriles. Reactions of carboxylic acids with reactive metals, reduction to alcohols using $LiAlH_4$. Hydrolysis of esters by acid and base. Hydrolysis of acylchlorides Preparation of alkylamines. Basicity of amines in terms of their structure. Reactions of amines (formation of diazonium salt) Aromaticity, Kekule structures. |
| 6. | Macromolecules | Carbohydrates | Classes of carbohydrates. Simple tests |
| | | Proteins | Amino acids, formation of peptide bonds in peptides. Simple |

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| | | Polymers | description of electrophoresis. Types of polymerization reactions and their differences. Simple structures of polymers. Uses of polymers. |
| 7. | Biotechnology | Biotechnology | Biotechnology and its application in food and drugs. |
| 8. | Petroleum Industry | Petrochemicals | Constituents of crude oil, refining, cracking. Chemicals derived from crude oil. |

**CHM 004 Practicals**

1. Reactions of simple functional groups: Simple organic tests, solubility, sodium fusion test, functional group identification( with emphasis on ketones aldehydes and carboxylic acids).
2. Re-crystallisation and determination of melting point of organic compounds.

**RECOMMENDED TEXTS**


1. E. N. Ramsden: *A-Level Chemistry,* 4th Edition (2000). Stanley Thornes (Pub) Ltd. ISBN 0748752994.
2. Phillips Mathews: *Advanced Level Chemistry.*
3. *Basic Organic Chemistry* by B. A. Osuntogun, O. B. Familoni and B.I. Alo; 3rd Edition (2012) University to Lagos Press.
4. *AQA Chemistry* by Ted Lister and Janet Renshaw (2009)Nelson Thornes Ltd. (Pub).
5. *Understanding Advanced Physical Inorganic Chemistry: The Learner's Approach.* by Jeanne Tan, Kim Seng Chan (2009) World Scientific (Pub).

6. *Chemistry: The Central Science* by Theodore E. Brown, Theodore Lawrence Brown, H. Eugene H. LeMay, Bruce E. Bursten, Catherine Murphy, Patrick Woodward 12th Edition (2012) Pearson Education (Pub.).
7. Martins S. Silverberg (2010). *Principles of General Chemistry*. Second edition. McGraw Hill Publishers. New York.
8. *University General Chemistry, Inorganic and Physical.* Y.C. Wong, C.T. Wong, S.O. Onyiruka and L.E.S Akpanisi. Afrcana – FEP Publishers Ltd (2002).