

CHEMISTRY

Atoms, Molecules and Chemical Arithmetic:

Dalton's atomic theory; Gay Lussac's law of gaseous volume; Avogadro's Hypothesis and its applications. Atomic mass; Molecular mass; Equivalent weight; Valency; Gram atomic weight; Gram molecular weight; Gram equivalent weight and mole concept; Chemical formulae; Balanced chemical equations; Calculations (based on mole concept) involving common oxidation-reduction, neutralization, and displacement reactions; Concentration in terms of mole fraction, molarity, molality and normality. Percentage composition, empirical formula and molecular formula; Numerical problems.

Atomic Structure:

Concept of Nuclear Atom – electron, proton and neutron (charge and mass), atomic number, Rutherford's model and its limitations; Extra nuclear structure; Line spectra of hydrogen atom. Quantization of energy (Planck's equation $E = h\nu$); Bohr's model of the hydrogen atom and its limitations, Sommerfeld's modifications (elementary idea); The four quantum numbers, ground state electronic configurations of many-electron atoms and monoatomic ions; The Aufbau Principle; Pauli's Exclusion Principle and Hund's Rule. Dual nature of matter and light, de Broglie's relationship, Uncertainty principle; The concept of atomic orbitals, shapes of s, p and d orbitals (pictorial approach).

Radioactivity and Nuclear Chemistry:

Radioactivity α -, β -, γ rays and their properties; Artificial transmutation; Rate of radioactive decay, decay constant, half-life and average age life period of radio-elements; Units of radioactivity; Numerical problems. Stability of the atomic nucleus – effect of neutron-proton (n/p) ratio on the modes of decay, group displacement law, radioisotopes and their uses (C, P, Co and I as examples) isobars and isotones (definition and examples), elementary idea of nuclear fission and fusion reactions.

The Periodic Table and Chemical Families:

Modern periodic law (based on atomic number); Modern periodic table based on electronic configurations, groups (Gr. 1-18) and periods. Types of elements – representative (s-block and p-block), transition (d-block) elements and inner transition (f-block/lanthanides and actinides) and their general characteristics. Periodic trends in physical and chemical properties – atomic radii, valency, ionization energy, electron affinity, electronegativity, metallic character, acidic and basic characters of oxides and hydrides of the representative elements (up to $Z = 36$). Position of hydrogen and the noble gases in the periodic table; Diagonal relationships.

Chemical Bonding and Molecular Structure:

Valence electrons, the Octet rule, electrovalent, covalent and coordinate covalent bonds with examples; Properties of electrovalent and covalent compounds. Limitations of Octet rule (examples); Fajans Rule. Directionality of covalent bonds, shapes of polyatomic molecules (examples); Concept of hybridization of atomic orbitals (qualitative pictorial approach): sp, sp², sp³ and dsp². Molecular orbital energy diagrams for homonuclear diatomic species – bond order and magnetic properties. Valence Shell Electron Pair Repulsion (VSEPR) concept (elementary idea) – shapes of molecules. Concept of resonance (elementary idea), resonance structures (examples). Elementary idea about electronegativity, bond polarity and dipole moment, inter- and intra-molecular hydrogen bonding and its effects on physical properties (mp, bp and solubility); Hydrogen bridge bonds in diborane.

Coordination Compounds:

Introduction, Double salts and complex salts, coordination compounds (examples only), Werner's theory, coordination number (examples of coordination numbers 4 and 6 only),

colour, magnetic properties and shapes, IUPAC nomenclature of mononuclear coordination compounds.

Solid State:

Classification of solids based on different binding forces: molecular, ionic, covalent and metallic solids, amorphous and crystalline solids (elementary idea). Unit cell in two-dimensional and three-dimensional lattices, calculation of density of unit cell, packing in solids, packing efficiency, voids, number of atoms per unit cell in a cubic unit cell, point defects, electrical and magnetic properties. Band theory of metals, conductors, semiconductors and insulators and n & p type semiconductors.

Liquid State:

Vapour pressure, viscosity and surface tension (qualitative idea only, no mathematical derivations).

Gaseous State:

Measurable properties of gases. Boyle's Law and Charles Law, absolute scale of temperature, kinetic theory of gases, ideal gas equation – average, root mean square and most probable velocities and their relationship with temperature. Dalton's Law of partial pressure, and Graham's Law of gaseous diffusion. Deviations from ideal behaviour. Liquefaction of gases, real gases, van der Waals equation; Numerical problems.

Chemical Energetics and Chemical Dynamics:

Chemical Energetics – Conservation of energy principle, energy changes in physical and chemical transformations. The first law of thermodynamics; Internal energy, work and heat, pressure – volume work; Enthalpy. Internal energy change (ΔE) and Enthalpy change (ΔH) in a chemical reaction. Hess Law and its applications (Numerical problems). The heat of reaction, fusion and vapourization; Second law of thermodynamics; Entropy; Free energy; Criterion of spontaneity. Third law of thermodynamics (brief introduction).

Chemical Equilibria – The Law of mass action, dynamic nature of chemical equilibria. Equilibrium constants, Le Chateliers Principle. Equilibrium constants of gaseous reactions (K_p and K_c) and the relation between them (examples). Significance of ΔG and ΔG° .

Chemical Dynamics – Factors affecting the rate of chemical reactions (concentration, pressure, temperature, catalyst), Concept of collision theory. Arrhenius equation and concept of activation energy.

Order and molecularity (determination excluded); First-order reactions, rate constant, half-life (numerical problems), examples of first-order and second-order reactions.

Physical Chemistry of Solutions:

Colloidal Solutions – Differences from true solutions; Hydrophobic and hydrophilic colloids (examples and uses); Coagulation and peptization of colloids; Dialysis and its applications; Brownian motion; Tyndall effect and its applications; Elementary idea of emulsion, surfactant and micelle.

Electrolytic Solutions – Specific conductance, equivalent conductance, ionic conductance, Kohlrausch's law, Faraday's laws of electrolysis, applications. Numerical problems.

Non-electrolytic Solutions – Types of solution, vapour pressure of solutions. Raoult's Law; Colligative properties – lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmotic pressure and their relationships with molecular mass (without derivations); Numerical problems.

Ionic and Redox Equilibria:

Ionic equilibria – ionization of weak electrolytes, Ostwald's dilution law. Ionization constants of weak acids and bases, ionic product of water, the pH – scale, pH of aqueous solutions of acids and bases; Buffer solutions, buffer action and Henderson equation.

Acid-base titrations and acid-base indicators (structures not required). Hydrolysis of salts (elementary idea), solubility product, common ion effect (no numerical problems).

Redox Equilibria: Oxidation – Reduction reactions as electron transfer processes, oxidation numbers, balancing of redox reactions by oxidation number and ion-electron methods. Standard electrode potentials (E°), Electrochemical series, feasibility of a redox reaction. Significance of Gibb's equation: $\Delta G^\circ = -nF\Delta E^\circ$ (without derivation), no numerical problems. Redox titrations with (examples); Nernst equations (Numerical problems).

Hydrogen:

Position of hydrogen in the periodic table, occurrence, isotopes, preparation, properties and uses of hydrogen, hydrides-ionic covalent and interstitial; physical and chemical properties of water, heavy water, hydrogen peroxide – preparation, reactions and structure and use; hydrogen as a fuel.

Chemistry of Non-Metallic Elements and their Compounds:

Carbon – occurrence, isotopes, allotropes (graphite, diamond, fullerene); CO and CO₂ production, properties and uses. Nitrogen and Phosphorus – occurrence, isotopes, allotropes, isolation from natural sources and purification, reactivity of the free elements. Preparation, properties, reactions of NH₃, PH₃, NO, NO₂, HNO₂, HNO₃, P₄O₁₀, H₃PO₃ and H₃PO₄.

Oxygen and Sulphur – Occurrence, isotopes, allotropic forms, isolation from natural sources and purification, properties and reactions of the free elements. Water, unusual properties of water, heavy water (production and uses). Hydrogen peroxide and ozone (production, purification, properties and uses).

Halogens – a comparative study, occurrence, physical states and chemical reactivities of the free elements, peculiarities of fluorine and iodine; Hydracids of halogens (preparation, properties, reactions and uses), inter-halogen compounds (examples); Oxyacids of chlorine.

Chemistry of Metals:

General principles of metallurgy – occurrence, concentration of ores, production and purification of metals, mineral wealth of India. Typical metals (Na, Ca, Al, Fe, Cu and Zn) – occurrence, extraction, purification (where applicable), properties and reactions with air, water, acids and non-metals. Manufacture of steels and alloy steel (Bessemer, Open-Hearth and L.D. process).

Principles of chemistry involved in electroplating, anodizing and galvanizing. Preparation and properties of K₂Cr₂O₇ and KMnO₄.

Lanthanoids – Electronic configuration, oxidation states, chemical reactivity and lanthanoid contraction and its consequences.

Actinoids – Electronic configuration, oxidation states and comparison with lanthanoids.

Chemistry in Industry:

Large-scale production (including physicochemical principles where applicable, omitting technical details) and uses of Sulphuric acid (contact process), Ammonia (Haber's process), Nitric acid (Ostwald's process), sodium bicarbonate and sodium carbonate (Solvey process).

Polymers: Natural and synthetic polymers, methods of polymerization (addition and condensation), copolymerization, some important polymers – natural and synthetic like polythene, nylon polyesters, bakelite, rubber. Biodegradable and non-biodegradable polymers.

Surface Chemistry:

Adsorption – physisorption and chemisorption, factors affecting adsorption of gases on solids, catalysis, homogenous and heterogenous activity and selectivity; enzyme catalysis colloidal state distinction between true solutions, colloids and suspension; lyophilic, lyophobic multimolecular and macromolecular colloids; properties of colloids; Tyndall effect, Brownian movement, electrophoresis, coagulation, emulsion – types of emulsions.

Environmental Chemistry:

Common modes of pollution of air, water and soil. Ozone layer, ozone hole – important chemical reactions in the atmosphere, Smog; major atmospheric pollutants; Green House effect; Global warming pollution due to industrial wastes, green chemistry as an alternative tool for reducing pollution, strategies for control of environment pollution.

Chemistry of Carbon Compounds:

Hybridization of carbon: σ – and π – bonds. Isomerism – constitutional and stereoisomerism; Geometrical and optical isomerism of compounds containing up to two asymmetric carbon atoms. IUPAC nomenclature of simple organic compounds – hydrocarbons, mono and bifunctional molecules only (alicyclic and heterocyclic compounds excluded).

Conformations of ethane and n-butane (Newman projection only). Electronic Effects: Inductive, resonance and hyperconjugation. Stability of carbocation, carbanion and free radicals; Rearrangement of carbocation; Electrophiles and nucleophiles, tautomerism in β -dicarbonyl compounds, acidity and basicity of simple organic compounds.

Compounds:

Alkanes – Preparation from alkyl halides and carboxylic acids; Reactions — halogenation and combustion.

Alkenes and Alkynes – Preparation from alcohols; Formation of Grignard reagents and their synthetic applications for the preparation of alkanes, alcohols, aldehydes, ketones and acids; S_N1 and S_N2 reactions (preliminary concept). Markownikoff's and anti-Markownikoff's additions; Hydroboration;

Oxymercuration-demercation, reduction of alkenes and alkynes (H_2 /Lindler catalyst and Na in liquid NH_3), metal acetylides.

Haloalkanes and Haloarenes:

Haloalkanes – Preparation from alcohols; Nomenclature, nature of C -X bond, physical and chemical properties, mechanism of substitution reactions, optical rotation. Formation of Grignard reagents and their synthetic applications for the preparation of alkanes, alcohols, aldehydes, ketones and acids; S_N1 and S_N2 reactions (preliminary concept). Uses and environmental effects of - dichloromethane, trichloromethane, tetrachloromethane, iodoform, freons, DDT.

Alcohols:

Preparation of alcohols from carbonyl compounds and esters. Reaction – dehydration, oxidation, esterification, reaction with sodium, $ZnCl_2/HCl$, phosphorous halides.

Ethers – Preparation by Williamson's synthesis; Cleavage with HCl and HI . Aldehydes and Ketones – Preparation from esters, acid chlorides, gem-dihalides, and Ca-salt of carboxylic acids. Reaction – Nucleophilic addition with HCN , hydrazine, hydroxyl amines, semi carbazides, alcohols; Aldol condensation, Clemmensen and Wolff – Kishner reduction, haloform, Cannizzaro and Wittig reactions.

Carboxylic Acids – Hydrolysis of esters (mechanism excluded) and cyanides; Hunsdicker and HVZ reactions.

Aliphatic Amines – Preparation from nitro, cyano and amido compounds. Distinction of 1° , 2° and 3° amines (Hinsberg method); Reaction with HNO_2 ; Carbyl amine reaction.

Aromatic Compounds: Benzene – Kekule structure, aromaticity and Hückel rule. Electrophilic substitution – halogenation, sulfonation, nitration, Friedel Crafts reaction, ozonolysis. Directive influence of substituents in monosubstituted benzenes. Carcinogenicity and toxicity.

Amines – Preparation from a reduction of nitro compounds; Formation of diazonium salts and their stability; Replacement of diazonium group with H , OH , X (halogen), CN and NO_2 , diazo coupling and reduction.

Haloarenes – Nature of C -X bond, substitution reactions; Nucleophilic substitution, cine substitution (excluding mechanism, Directive influence of halogen in monosubstituted compounds only).

Phenols – halogenation, sulfonation, nitration, Reimer – Tiemann and Kolbe reactions. Aromatic Aldehydes – Preparation by Gattermann, Gattermann-Koch, Rosenmund and Stephen's method. Reactions – Perkin, Benzoin and Cannizzaro.

Application Oriented chemistry:

Main ingredients, their chemical natures (structures excluded) and their side effects, if any, of common antiseptics, analgesics, antacids, and vitamin C.

Introduction to Bio-Molecules:

Carbohydrates – Pentoses and hexoses. Distinctive chemical reactions of glucose. Amino acids – glycine, alanine, aspartic acid, cysteine (structures). Zwitterion structures of amino acids, peptide bond.

ADP and ATP – structures and role in bioenergetics; Nucleic acids – DNA and RNA skeleton structures. Names of essential elements in biological systems.

Principles of Qualitative Analysis:

Detection of water-soluble non-interfering Acid and Basic Radicals by dry and wet tests from among:

Acid Radicals: Cl^- , S^{2-} , SO_4^{2-} , NO_3^- , CO_3^{2-} . Basic Radicals: Cu^{2+} , Al^{3+} , Fe^{3+} , Fe^{2+} , Zn^{2+} , Ca^{2+} , Mg^{2+} , Na^+ , NH_4^+ .

Detection of special elements (N, Cl, Br, I and S) in organic compounds by chemical tests. Identification of functional groups in phenols, aromatic amines, aldehydes, ketones and carboxylic acids.