

# CHEMISTRY

## General topics

Concept of atoms and molecules; Dalton's atomic theory; Mole concept; Chemical formulae; Balanced chemical equations; Calculations (based on mole concept and stoichiometry) involving common oxidation-reduction, neutralisation, and displacement reactions; Concentration in terms of mole fraction, molarity, molality and normality.

## States of Matter: Gases and Liquids

Gas laws and ideal gas equation, absolute scale of temperature; Deviation from ideality, van der Waals equation; Kinetic theory of gases, average, root mean square and most probable velocities and their relation with temperature; Law of partial pressures; Diffusion of gases. Intermolecular interactions: types, distance dependence, and their effect on properties; Liquids: vapour pressure, surface tension, viscosity.

## Atomic Structure

Bohr model, spectrum of hydrogen atom; Wave-particle duality, de Broglie hypothesis; Uncertainty principle; Qualitative quantum mechanical picture of hydrogen atom: Energies, quantum numbers, wave function and probability density (plots only), shapes of *s*, *p* and *d* orbitals; Aufbau principle; Pauli's exclusion principle and Hund's rule.

## Chemical Bonding and Molecular Structure

Orbital overlap and covalent bond; Hybridisation involving *s*, *p* and *d* orbitals only; Molecular orbital energy diagrams for homonuclear diatomic species (up to  $\text{Ne}_2$ ); Hydrogen bond; Polarity in molecules, dipole moment; VSEPR model and shapes of molecules (linear, angular, triangular, square planar, pyramidal, square pyramidal, trigonal bipyramidal, tetrahedral and octahedral).

### **Chemical Thermodynamics**

Intensive and extensive properties, state functions, First law of thermodynamics; Internal energy, work (pressure-volume only) and heat; Enthalpy, heat capacity, standard state, Hess's law; Enthalpy of reaction, fusion and vapourization, and lattice enthalpy; Second law of thermodynamics; Entropy; Gibbs energy; Criteria of equilibrium and spontaneity.

### **Chemical and Ionic Equilibrium**

Law of mass action; Significance of  $\Delta G$  and  $\Delta G^\ominus$  in chemical equilibrium; Equilibrium constant ( $K_p$  and  $K_c$ ) and reaction quotient, Le Chatelier's principle (effect of concentration, temperature and pressure); Solubility product and its applications, common ion effect, pH and buffer solutions;

Acids and bases (Brønsted and Lewis concepts); Hydrolysis of salts.

### **Electrochemistry**

Electrochemical cells and cell reactions; Standard electrode potentials; Electrochemical work, Nernst equation; Electrochemical series, emf of galvanic cells; Faraday's laws of electrolysis; Electrolytic conductance, specific, equivalent and molar conductivity, Kohlrausch's law; Batteries: Primary and Secondary, fuel cells; Corrosion.

### **Chemical Kinetics**

Rates of chemical reactions; Order and molecularity of reactions; Rate law, rate constant, half-life; Differential and integrated rate expressions for zero and first order reactions; Temperature dependence of rate constant (Arrhenius equation and activation energy); Catalysis: Homogeneous and heterogeneous, activity and selectivity of solid catalysts, enzyme catalysis and its mechanism.

### **Solid State**

Classification of solids, crystalline state, seven crystal systems (cell parameters  $a, b, c, \alpha, \beta, \gamma$ ), close packed structure of solids (cubic and hexagonal), packing

in fcc, bcc and hcp lattices; Nearest neighbours, ionic radii and radius ratio, point defects.

### **Solutions**

Henry's law; Raoult's law; Ideal solutions; Colligative properties: lowering of vapour pressure, elevation of boiling point, depression of freezing point, and osmotic pressure; van't Hoff factor.

### **Surface Chemistry**

Elementary concepts of adsorption: Physisorption and Chemisorption, Freundlich adsorption isotherm; Colloids: types, methods of preparation and general properties; Elementary ideas of emulsions, surfactants and micelles (only definitions and examples).

### **Classification of Elements and Periodicity in Properties**

Modern periodic law and the present form of periodic table; electronic configuration of elements; periodic trends in atomic radius, ionic radius, ionization enthalpy, electron gain enthalpy, valence, oxidation states, electronegativity, and chemical reactivity.

### **Hydrogen**

Position of hydrogen in 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, use and structure; hydrogen as a fuel.

### **s-Block Elements**

Alkali and alkaline earth metals-reactivity towards air, water, dihydrogen, halogens, acids; their reducing nature including solutions in liquid ammonia; uses of these elements; general characteristics of their oxides, hydroxides, halides, salts of oxoacids; anomalous behaviour of lithium and beryllium; preparation, properties, and uses of compounds of sodium (sodium carbonate, sodium chloride, sodium hydroxide, sodium hydrogen carbonate) and calcium (calcium oxide, calcium hydroxide, calcium carbonate, calcium sulphate).

### ***p*-Block Elements**

Oxidation state and trends in chemical reactivity of elements of groups 13-17; anomalous properties of boron, carbon, nitrogen, oxygen, and fluorine with respect to other elements in their respective groups.

*Group 13:* Reactivity towards acids, alkalis, and halogens; preparation, properties, and uses of borax, orthoboric acid, diborane, boron trifluoride, aluminium chloride, and alums; uses of boron and aluminium.

*Group 14:* Reactivity towards water and halogen; allotropes of carbon and uses of carbon; preparation, properties, and uses of carbon monoxide, carbon dioxide, silicon dioxide, silicones, silicates, zeolites.

*Group 15:* Reactivity towards hydrogen, oxygen, and halogen; allotropes of phosphorous; preparation, properties, and uses of dinitrogen, ammonia, nitric acid, phosphine, phosphorus trichloride, phosphorus pentachloride; oxides of nitrogen and oxoacids of phosphorus.

*Group 16:* Reactivity towards hydrogen, oxygen, and halogen; simple oxides; allotropes of sulfur; preparation/manufacture, properties, and uses of dioxygen, ozone, sulfur dioxide, sulfuric acid; oxoacids of sulfur.

*Group 17:* Reactivity towards hydrogen, oxygen, and metals; preparation/manufacture, properties, and uses of chlorine, hydrogen chloride and interhalogen compounds; oxoacids of halogens, bleaching powder.

*Group 18:* Chemical properties and uses; compounds of xenon with fluorine and oxygen.

### ***d*-Block Elements**

Oxidation states and their stability; standard electrode potentials; interstitial compounds; alloys; catalytic properties; applications; preparation, structure, and reactions of oxoanions of chromium and manganese.

### ***f*-Block Elements**

Lanthanoid and actinoid contractions; oxidation states; general characteristics.

## **Coordination Compounds**

Werner's theory; Nomenclature, *cis-trans* and ionization isomerism, hybridization and geometries (linear, tetrahedral, square planar and octahedral) of mononuclear coordination compounds; Bonding [VBT and CFT (octahedral and tetrahedral fields)]; Magnetic properties (spin-only) and colour of *3d*-series coordination compounds; Ligands and spectrochemical series; Stability; Importance and applications; Metal carbonyls.

## **Isolation of Metals**

Metal ores and their concentration; extraction of crude metal from concentrated ores: thermodynamic (iron, copper, zinc) and electrochemical (aluminium) principles of metallurgy; cyanide process (silver and gold); refining.

## **Principles of Qualitative Analysis**

Groups I to V (only  $\text{Ag}^+$ ,  $\text{Hg}^{2+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Pb}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Al}^{3+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Mn}^{2+}$  and  $\text{Mg}^{2+}$ ); Nitrate, halides (excluding fluoride), carbonate and bicarbonate, sulphate and sulphide.

## **Environmental Chemistry**

Atmospheric pollution; water pollution; soil pollution; industrial waste; strategies to control environmental pollution; green chemistry.

## **Basic Principles of Organic Chemistry**

Hybridisation of carbon;  $\sigma$  and  $\pi$ -bonds; Shapes of simple organic molecules; aromaticity; Structural and geometrical isomerism; Stereoisomers and stereochemical relationship (enantiomers, diastereomers, meso) of compounds containing only up to two asymmetric centres (*R,S* and *E,Z* configurations excluded); Determination of empirical and molecular formulae of simple compounds by combustion method only; IUPAC nomenclature of organic molecules (hydrocarbons, including simple cyclic hydrocarbons and their mono-functional and bi-functional derivatives only); Hydrogen bonding effects; Inductive, Resonance and Hyperconjugative effects; Acidity and basicity of organic compounds; Reactive intermediates produced during homolytic and

heterolytic bond cleavage; Formation, structure and stability of carbocations, carbanions and free radicals.

### **Alkanes**

Homologous series; Physical properties (melting points, boiling points and density) and effect of branching on them; Conformations of ethane and butane (Newman projections only); Preparation from alkyl halides and aliphatic carboxylic acids; Reactions: combustion, halogenation (including allylic and benzylic halogenation) and oxidation.

### **Alkenes and Alkynes**

Physical properties (boiling points, density and dipole moments); Preparation by elimination reactions; Acid catalysed hydration (excluding the stereochemistry of addition and elimination); Metal acetylides; Reactions of alkenes with  $\text{KMnO}_4$  and ozone; Reduction of alkenes and alkynes; Electrophilic addition reactions of alkenes with  $\text{X}_2$ ,  $\text{HX}$ ,  $\text{HOX}$ , ( $\text{X}=\text{halogen}$ ); Effect of peroxide on addition reactions; cyclic polymerization reaction of alkynes.

### **Benzene**

Structure; Electrophilic substitution reactions: halogenation, nitration, sulphonation, Friedel-Crafts alkylation and acylation; Effect of directing groups (monosubstituted benzene) in these reactions.

### **Phenols**

Physical properties; Preparation, Electrophilic substitution reactions of phenol (halogenation, nitration, sulphonation); Reimer-Tiemann reaction, Kolbe reaction; Esterification; Etherification; Aspirin synthesis; Oxidation and reduction reactions of phenol.

### **Alkyl Halides**

Rearrangement reactions of alkyl carbocation; Grignard reactions; Nucleophilic substitution reactions and their stereochemical aspects.

### **Alcohols**

Physical properties; Reactions: esterification, dehydration (formation of alkenes and ethers); Reactions with: sodium, phosphorus halides,  $\text{ZnCl}_2/\text{concentrated HCl}$ , thionyl chloride; Conversion of alcohols into aldehydes, ketones and carboxylic acids.

### **Ethers**

Preparation by Williamson's synthesis; C-O bond cleavage reactions.

### **Aldehydes and Ketones**

Preparation of: aldehydes and ketones from acid chlorides and nitriles; aldehydes from esters; benzaldehyde from toluene and benzene; Reactions: oxidation, reduction, oxime and hydrazone formation; Aldol condensation, Cannizzaro reaction; Haloform reaction; Nucleophilic addition reaction with  $\text{RMgX}$ ,  $\text{NaHSO}_3$ , HCN, alcohol, amine.

### **Carboxylic Acids**

Physical properties; Preparation: from nitriles, Grignard reagents, hydrolysis of esters and amides; Preparation of benzoic acid from alkylbenzenes; Reactions: reduction, halogenation, formation of esters, acid chlorides and amides.

### **Amines**

Preparation from nitro compounds, nitriles and amides; Reactions: Hoffmann bromamide degradation, Gabriel phthalimide synthesis; Reaction with nitrous acid, Azo coupling reaction of diazonium salts of aromatic amines; Sandmeyer and related reactions of diazonium salts; Carbylamine reaction, Hinsberg test, Alkylation and acylation reactions.

### **Haloarenes**

Reactions: Fittig, Wurtz-Fittig; Nucleophilic aromatic substitution in haloarenes and substituted haloarenes (excluding benzyne mechanism and cine substitution).

## **Biomolecules**

*Carbohydrates*: Classification; Mono- and di-saccharides (glucose and sucrose); Oxidation; Reduction; Glycoside formation and hydrolysis of disaccharides (sucrose, maltose, lactose); Anomers.

*Proteins*: Amino acids; Peptide linkage; Structure of peptides (primary and secondary); Types of proteins (fibrous and globular).

*Nucleic acids*: Chemical composition and structure of DNA and RNA.

## **Polymers**

Types of polymerization (addition, condensation); Homo and copolymers; Natural rubber; Cellulose; Nylon; Teflon; Bakelite; PVC; Bio-degradable polymers; Applications of polymers.

## **Chemistry in Everyday Life**

Drug-target interaction; Therapeutic action, and examples (excluding structures), of antacids, antihistamines, tranquilizers, analgesics, antimicrobials, and antifertility drugs; Artificial sweeteners (names only); Soaps, detergents, and cleansing action.

## **Practical Organic Chemistry**

Detection of elements (N, S, halogens); Detection and identification of the following functional groups: hydroxyl (alcoholic and phenolic), carbonyl (aldehyde and ketone), carboxyl, amino and nitro.