DETAILED SYLLABUS FOR THE POST OF ANALYST IN KERAFED (Cat No.244/2024)

Total marks : 100)

Module 1 : Atomic structure and Chemical bonding (10 marks)

Bohr's theory, atomic spectrum of hydrogen atom, de Broglie equation, Heisenberg's uncertainty principle, Schrödinger's wave equation, Quantum numbers and their significance, Shapes of s, p, d and f orbitals. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle, Variation of orbital energy with atomic number, s, p, d, f block elements and their properties. Shielding effect, Slater rules, variation of effective nuclear charge in periodic table. Ionization enthalpy, factors affecting ionization energy, applications of ionization enthalpy. Electron gain enthalpy, trends of electron gain enthalpy. Electronegativity, hybridization, Inert pair effect, relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group.

Ionic bond – nature of ionic bond, radius ratio, Lattice energy, Born-Haber cycle and its applications, solvation enthalpy and solubility of ionic compounds.

Covalent bond – valence bond theory and its limitations, concept of resonance, resonance energy, hybridisation and shapes of simple molecules (BeF_2, PCl_3, SF_6, CH_4, Ethane, ethene and ethyne) VSEPR theory, shapes of molecules and ions (NH_3, XeF_6, H_2O).

Molecular orbital theory – LCAO method, molecular orbital energy diagram and properties of homo and hetero diatomic molecules (N_2, O_2, CO and NO), bond strength and bond energy.

Intermolecular Forces - Hydrogen bond: Intra and intermolecular hydrogen bonds - Effect on physical properties. Induction forces and dispersion forces: van der Waals forces, ion-dipole, dipole-dipole, ion-induced dipole and dipole-induced dipole interactions.

Module 2 : Coordination chemistry, organometallic and bioinorganic compounds (10 marks)

Werner's theory, IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Chelate effect, valence bond theory (inner and outer orbital complexes), back bonding. Crystal field theory, CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δo, Δt). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry.

Classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. Preparation and properties of carbonyls (Fe, Ni, Mn, Cr), Vibrational frequency of CO bond in metal carbonyls. Bonding in

organometallic compounds like ferrocene, dibenzene chromium, Ziese's salt.

Bioinorganic chemistry- Role of metal ions in biological systems- Biochemistry of iron haemoglobin and myoglobin. Electron transport proteins: Cytochromes, Iron-Sulphur proteins- storage and transport of iron. Photosynthesis, Sodium-Potassium pump, Biochemistry of magnesium and calcium.

Module 3 : Stereochemistry and Reaction mechanism (10 marks)

Classification and nomenclature of organic compounds, hybridization, Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications.

Organic acids and bases; their relative strength. Homolytic and heterolytic fission, electrophiles and nucleophiles; Types, shape and their relative stability of carbocations, carbanions, free radicals and carbenes. Introduction to types of organic reactions and their mechanism: Addition, Elimination and Substitution reactions. Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with C.I.P rules. Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixture and resolution. Relative and absolute configuration: D/L and R/S designations.

Module 4 : Hydrocarbons, aromatic compounds, alkyl halides, alcohols, phenols, and carbonyl compounds (10 marks)

Formation of **alkanes**, Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation-relative reactivity and selectivity. Formation of alkenes and alkynes by elimination reactions. Reactions of **alkenes**: Electrophilic additions their mechanisms, Diels-Alder reaction, Reactions of **alkynes**: Acidity, Electrophilic and Nucleophilic additions. Hydration to form carbonyl compounds, Alkylation of terminal alkynes.

Aromaticity: Hückel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of the groups. Preparation and reactions of naphthalene, phenanthrene and anthracene.

Alkyl halides: Methods of preparation, nucleophilic substitution reactions

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouveault-Blanc reduction

Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism.

Ethers and Epoxides: Preparation and reactions with acids.

Structure, reactivity and preparation of **carbonyl compounds**. Nucleophilic additions, Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisan-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α- substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV), Michael addition. Preparation, physical properties and reactions of monocarboxylic acids.

Module 5 : Natural products and biomolecules (10 marks)

Alkaloids: Extraction. Classification based on structure of heterocyclic ring. Physiological actions of nicotine, quinine, morphine.

Terpenes: Classification – Isoprene rule – Essential oils – Isolation of essential oils by steam distillation – Uses of lemongrass oil, eucalyptus oil – Isolation of terpenes from essential oils (elementary idea) – Source, structure and uses of citral, geraniol, limonene and menthol.

Lipids: Classification – Fats and oils – Hydrogenation – Analysis of fats and oils – Acid
value, Saponification value and Iodine value. Phospholipids: Structure of Lecithin. Biological functions of lipids.

Steroids: Classification – Structure and biological functions of cholesterol, testosterone, estradiol and progesterone – Elementary idea of HDL and LDL.

Hormones: Definition, examples and functions of steroid, peptide and amine hormones.

Vitamins: Classification – Sources and deficiency diseases – Structure of vitamin A, B_1, C.

Module 6 : States of matter (10 marks)

Gaseous state – Gas laws – The general gas equation – Mixture of gases – Dalton's Law – Mole fraction and partial pressure – calculation of partial pressure – The Kinetic model of gases – Molecular Speeds – Maxwell's distribution of molecular speeds – Calculation of most probable velocity, average velocity and root mean square velocity – Average kinetic energy – Degrees of freedom of a gaseous molecule. Law of equipartition of energy, degrees of freedom and molecular basis of heat capacities. Collision number - Mean free path - Collision diameter - Deviation from ideal behavior - Compressibility factor – van der Waals equation of state (derivation required) – Virial equation - Expression of van der Waals equation in virial form and calculation of Boyle temperature.

Liquid state – Properties of liquids – vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases.

Solid state – Amorphous and crystalline solids – Laws of crystallography – Crystal lattices – Unit cells – seven crystallographic systems – Bravais lattices – Spacing of lattice planes in simple cubic, body centred and face centred cubic systems – Number of particles per unit cell in each of these. Direct and reciprocal lattice (Miller indices). Determination of internal structure of crystals by X-ray diffraction methods – derivation of Bragg's equation – Bragg's rotating crystal method and Debye Scherrer Powder diffraction method – Crystal structure of NaCl and CsCl.

Module 7 : Colloids, adsorption, chemical kinetics and equilibrium (10 marks)

Colloids : Classification – preparation – electrical double layer – *zeta* potential – Properties of Colloids – Tyndall effect – Brownian movement – Coagulation – Hardy – Schulz rule – Flocculation value – Electro kinetic properties – Electrophoresis – Electro-osmosis – Protective colloids – Gold number – Emulsion – Oil in water emulsion and water in oil emulsion – Emulsifying agents – Gels –Syneresis – Micelles – Critical micelle concentration.

Adsorption : Physical and chemical adsorption, factors affecting adsorption. Adsorption isotherms: Freundlich and Langmuir isotherms – Multilayer adsorption – BET equation and its applications to surface area measurements. Applications of adsorption.

Chemical Kinetics : The rates of chemical reactions – Factors affecting the rate of reactions – rate laws and rate constant – Order and molecularity of reactions – Methods of determining the rate of reaction – Integrated rate laws of first order, second order and third order reactions – Half life – kinetics of consecutive parallel and opposing reactions (first order only), rate constants for first, second, third and zero order reactions with examples. Temperature dependence of reaction rates – Arrhenius equation – Effect of temperature on reaction rates. Determination and significance of Arrhenius parameters – Theories of reaction rates – Collision theory – Derivation of rate equation for bimolecular reactions using collision theory.

Chemical equilibrium : Law of mass action, thermodynamic derivation of law of chemical equilibrium. Relation between Gibbs free energy of reaction and reaction quotient. Equilibrium constants and their quantitative dependence on temperature, pressure and thermodynamic derivation of relations between the various equilibrium constants Kp, Kc and Kx (using chemical potential). Van't Hoff's equation - Le Chatelier principle. Homogeneous and heterogenous equilibria.

Module 8 : Analytical Principles and techniques (10 marks)

Errors in Quantitative analysis –Units, significant digits, rounding – Precision and accuracy – Types of errors – classification and minimization of errors. Statistical treatment of analytical data – population and samples –

Mean and standard deviation – distribution of random errors – confidence limits – tests of significance – Correlation and regression – linear regression analysis

Qualitative Analysis: Applications of solubility product and common ion effect in the precipitation of cations – Interfering acid radicals and their elimination (oxalate, fluoride, borate, phosphate, chromate, arsenite and arsenate) – Preparation of Na_2CO_3 extract for inorganic qualitative analysis and its advantages.

Gravimetric analysis – Mechanism of precipitate formation. Factors affecting stability of precipitates. Co-precipitation and post precipitation. Effects of digestion, washing, drying and ignition of precipitates.

Titrimetric analysis : Fundamental concepts – mole, molarity, molality, ppm and ppb primary standard – secondary standard, quantitative dilution – problems. Acid base titrations – titration curves – pH indicators. Redox titrations – titration curve – redox indicators. Complexometric titrations – EDTA titrations – titration curves – Indicators acid-base, redox and metal – ion indicators.

Module 9 : Spectroscopy (10 marks)

Electromagnetic spectrum- wavelength, frequency and energy relation.

UV-Visible Spectroscopy: Electronic transitions in molecules ($\sigma \rightarrow \sigma^*$, $n \rightarrow \sigma^*$, $\pi \rightarrow \pi^*$ and
$n \rightarrow \pi^*$) – Chromophore and auxochrome. Study of the UV spectra of butadiene, acetone,
methyl vinyl ketone and benzene. λmax calculation for dienes and α,β-unsaturated carbonyl compounds.

IR Spectroscopy: Concept of group frequencies – fingerprint region – IR spectra of alcohols, phenols, amines, ethers, aldehydes, ketones, carboxylic acids, esters and amides. Factors influencing carbonyl stretching frequency. Comparison of carbonyl stretching frequency in compounds containing carbonyl group.

^{1}H NMR: Chemical shift – delta and tau scales - Spin-spin splitting – Interpretation of 1H NMR spectra of simple organic molecules such as ethyl bromide, ethanol, acetaldehyde, acetone, 1, 1, 2-tribromoethane, propanoic acid, ethyl acetate, toluene and acetophenone.

Structure elucidation of simple organic compounds using UV, IR and ^{1}H NMR spectroscopic techniques (ethanol, acetone, acetophenone, acetaldehyde, acetic acid, propanoic acid and ethyl acetate).

Module 10 : Instrumental methods of analysis (10 marks)

Principle and applications of – Conductometric titrations, potentiometric titrations, Atomic Absorption Spectroscopy (AAS), flame emission spectroscopy, Colorimetry, Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM),

Thermogravimetry (TG), Differential thermal analysis (DTA), Differential Scanning Calorimetry (DSC).

Chromatography : Types of Chromatography – Adsorption and Partition Chromatography, Column, Thin Layer and paper Chromatography – Rf value, HPLC, Ion Exchange Chromatography – Gas chromatography.

Mass spectrometry – mass spectrum, base peak and molecular ion peak, types of fragmentation, McLafferty rearrangement, isotopic effect.

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