CHEMISTRY (HONS./PG) [CODE -06]

Unit. 1: Physical Chemistry (1)
Physical States of Matter, Physical Properties & Molecular Structure:


SECTION C: (i) Elementary ideas of crystallography—Laws of crystallography, crystal lattice, simple crystal system, ionic and covalent crystals, Bragg’s method of crystal analysis with illustration of NaCl and KCl crystal faces, Born-Haber cycle. (ii) Heat capacity of solids, Einstein’s specific heat equations, Debye’s $T^3$-Law (detailed deduction not required).

SECTION D: Colloidal system:
(i) Properties of colloids; optical, kinetic and electrical (ii) Electro kinetic phenomena; charge and stability of colloids, mechanism of coagulation (iii) Determination of Avogadro’s number from Perrin distribution equation and Einstein’s diffusion equation, (iv) Ultracentrifuge, Determination of size of colloid particles and molecular weights of macro-molecules, (v) Colloidal electrolytes and their properties (soaps and detergents, Critical micellization concentration).proteins.

SECTION E: Physical properties and molecular structure:
(i) Polar molecules and dipole moment (derivations of equations not required). (ii) Elementary ideas on molecular spectra, potential energy curves and Raman Spectra, with applications.

Unit. 2: Physical Chemistry (2)
Thermodynamics & Its Applications to Equilibrium processes:

SECTION A: Thermodynamics:
(i) Heats of solution and dilution, heats of neutralization from bond enthalpies, Kerchief’s equation. (ii) Carnot’s theorem, thermodynamic scale of temperature, refrigeration cycle. (iii) Detailed treatment of entropy, free energy, Gibbs-Helmholtz
equation, Partial molal quantities, Gibb’s potential, Gibbs-potential, Gibbs-Duhere equation, Maxwell’s relations. Thermodynamic equation of state. Elementary idea of entropy and probability.

(iv) Applications of thermodynamics: Clausius-Clapeyron equation, Nernst distribution law, Joule-Thomson effect, expression for \( (C_p - C_v) \) for van der Waals gases.

(v) Elements of statistical thermodynamics, Boltzman distribution, partition functions and their relations with thermodynamic state functions.

SECTION B:
(i) Chemical equilibria: homogeneous equilibria.

Experimental determination of equilibrium constants. Thermodynamic derivation of the law of mass action. The reaction isotherm & temperatur dependence of equilibrium constants (van't Hoff equation).


SECTION C: Electromotive force — Different types of electrodes, glass and quinhydrone electrodes, important reference electrodes. Thermodynamics of a reversible chemical cell, standard electrode potentials and standard emf of Chemical cell (Nernst equation); Concentration cells, liquid junction potential, salt bridge. Redox potential, Redox series, Redox indicators (Theory and applications). Decomposition potentials, polarization, overvoltage, Dry cells (Leclanche cell), accumulators (acid and alkali). Applications of e.m.f. measurements-Thermodynamic parameters of electrochemical reactions (enthalpy, entropy and free energy), determination of solubility products, transport numbers, pH, Kw, valencies of ions and dissociation constants of weak electrolytes. Potentiometric titrations.

SECTION D: Colligative properties: Thermodynamic derivation of Raoult law for lowering of vapour pressure, elevation of boiling point and depression of freezing point, van’t Hoff’s osmotic pressure equation, interrelationships; between the different colligative properties, abnormal colligative properties. SECTION E: Equilibrium in heterogeneous systems & phase equilibria.

(i) Derivation of phase rule; its significance. Duhem Margules equation.

(ii) One component system. carbon dioxide, water, sulfur.

Unit 3: Physical Chemistry (3)
Transport Phenomenon: Kinetics & Catalysis: Photochemistry Adsorption & Surface Phenomenon:

SECTION A: Viscosity of gases and liquids, viscosity co-efficients, and their dependence on temperature. Stoke’s Law and terminal velocity, diffusion of gases and solutes in solution (Fick’s law).
SECTION B: Electrochemistry:
(i) Electrolytic conductance, Transport numbers and their interpretations; hydration of ions. Determination of ionic speeds. Qualitative treatment of Onsager equation and Debye-Huckel theory.

SECTION C: Chemical Kinetics:

SECTION D: Adsorption and surface chemistry:

SECTION E: Catalysis:

SECTION F: Photochemistry:

Unit 4: Inorganic Chemistry (1) Atomic Structure; Radioactivity & Nuclear Chemistry; Chemical Bonding:
SECTION B: Radioactive decay, α-β Y-rays; half life and average life of radioelements. Characteristics of radioactive decay series (different types) and Uranium decay series, Group displacement Law, radioactive equilibrium, Nuclear binding energy (including determining factors), stability of nuclei. Nuclear reactions, (different common types); projectiles, target nuclei, compound nuclei, spallation reaction, Nuclear energy. Elementary ideas on Nuclear fission and fusion reactions. Radio carbon dating, Age of mineral (elementary principle only), Isotope exchange. Separation and uses of isotopes.

SECTION C: Nature of chemical bond, Ionic bond, Lattice energy, Solvation energy, Born-Haber cycle (including mathematical calculation), Concepts of polarization, Fajan’s rule. Ionic potential and its applications. Inert pair effect, Covalent bond and coordinate bond, σ - and π- bonds valence bond theory (simple mathematical treatment), assumptions, defects, Resonance. Molecular orbital theory (non-mathematical treatment), application to homonuclear diatomic molecules: H₂ to F₂ and heteronuclear diatomic molecules. NO, CO and HF and H₂O, BeF₂, CO₂. Bond orders; Hybridization, Bent's rule, shapes of molecules, VSEPR theory. Hydrogen bond and its effects on physical properties, Intermolecular forces (elementary idea), Metallic bond, (qualitative bond theory), conductors, semiconductors, superconductors, insulators. Unit 5: Inorganic Chemistry (5) Chemical Periodicity; Acid-Base, Solvents & Redox Systems: s- & p- Block Elements & Their Compounds :

SECTION A: Periodic classification of elements on the basis of electronic configuration and periodic variation of properties; atomic radii, ionic radii, ionization energy; Slater’s rule; electron affinity, electronegativity concept (Pauling & Allred-Rochow scales).

SECTION B: Modern concept of acids and bases including SHAB principle, strengths of acids and bases (qualitative idea). Non-aqueous solvents; Liquid ammonia & liquid SO₂ as solvents, Redox potentials. Formal potentials, applications of redox potentials, variation of redox potentials, under the influence of pH, precipitation and complex formation; dismutation. Choice of indicators in redox titrations. Redox potential diagrams and their applications.

SECTION C: Noble gases; isolation properties and structure of compounds of noble gases.

SECTION D: B, Al, Ga, In, Ti- General group comparison. Boric acid, Borax, Boron nitrides, Borazine, Diborane, Borohydrides.

SECTION E: C, Si, Ge, Sn, Pb-General group comparison. Carbides, silicides, silicon halides, silicic acids, silicones, silicates.

SECTION F: N, P, As, Sb, Bi-General group comparison, Elemental states of P, As, Sb, Bi; Oxides and Oxyacids of Nitrogen and Phosphorus, Hydrazine, Hydroxylamine, Hydrazoic acid, Halides of nitrogen and phosphorus, Nitrides, condensed phosphorus, Phosphonitride compounds.

SECTION G: O, S, Se, Te - General group comparison. Hybrids, Halides, Elemental states of S, Se, Te: Oxides and Oxyacids of Sulphur, Selenium and
Tellurium. Thionic acids, sodium thiosulfate, polysulphides, hydrogen peroxide, ozone, peroxycids of sulphur.


Unit. 6: Inorganic Chemistry
- d- Block Elements & Their Compounds: Coordination Chemistry & Organometallics:
  - SECTION A: Terristrial abundance of the metals; elementary idea of mineral formation; General methods of isolation of metals from their natural sources of occurrence (technical details omitted) Availability in India and the chemistry of isolation of the following metals: Li, Rb, Cs, Ag, Au, Ti, V, Cr, Mn, Co, Ni, Pt, Ra, U.
  - SECTION B: Study of the elements of Group IA, IB, IIA and IIB with reference to their chemical reactions and properties (specially redox and coordination)
  - SECTION C: General characteristics of first now transition metals with reference to electronic configuration, oxidation states, redox properties, colour of the ions. Magnetic properties of first transition metal ions and their complexes. Determination of magnetic susceptibility and its application to complex compounds, Polyvanadates.
  - SECTION D: Introduction to coordination compounds. Werner's theory, Nomenclature of coordination compounds upto two metal atoms, Types of ligands, Chelates and inner-metallic complexes and their applications in chemical analyses. Isomerism of coordination compounds: different types; geometrical and optical isomerisms for coordinations numbers 4 and 6. Trans effect. Study of complexes in solution: detection, composition (Job's, slope ratio and mole ration methods), stability-potentionmetric method, Metal-ligand interactions: Valence Bond and Crystal Field Theories. Application of VB and CFT approaches in explaining stereochemistry, magnetic and spectral features (d¹-d⁹), systems) of coordination compounds (coord. No. upto six) Introduction of ligand field theory (qualitative treatment only). Metal legand bonding, mo concept, σ- and π- bondings in complexes.
  - SECTION E: Metal complexes-of π acids ligans: carbonyls, nitrosoyls and cyanides. Introduction of o bonded and non-classically bonded organometallics, metal (mono) olefins-Zeise's salt; Metallocenes; Ferrocene, Metal-metal bonded complexex; inorganic rings, cages and clusters; boron cage compounds, carboranes and metalloocene carboranes. Catalysis by organometallic complexes: substitution, oxidative addition, reductive elimination, insertion reactions, hydrogenation, hydroformylation and polymerization of alkenes; fluxional molecules.

Unit. 7: Organic Chemistry
- SECTION A: Nature of bonds in organic compounds: Atomic orbitals, Molecular orbitals: bonding, non-bonding and antibonding. Hybridisation of atomic orbitals with reference of C, N, Cl, Br, I, O; Sigma and Pi-bonds;
electronegativity; Dipole moment (bond moment, group moment, polarization and polarisability of covalent bond). Inductive and effectromeric effects. Energetics of bond cleavage and bond formation; Bond energies and bond distances; Carbocations, carbanions, Free radicals, ambident ions (definitions, examples). Conjugation, Resonance, Hyperconnugation; Tautomerism with reference to the following systems only Ketone-Enol, Nitro-Acinin, Nitroso-Oximino. Strength of organic acids and bases.


SECTION C: Investigation of reaction mechanisms: Rate law of a reaction; Activation energy, Transition state, Reaction intermediates, energy profile diagrams involving two transition states. Idea of a reversibility of a reaction, Kinetically and Thermodynamically controlled products: Primary kinetic isotope effects; classification of reagents and reactions; steric inhibition and steric strain in organic molecules. Pericyclic reactions, electrocyclic opening and closure.

SECTION D: Mechanism of organic reactions- What and Why? Addition reactions: Electrophilic, Nucleophilic and Radical. Classical and non-classical carbonium ion. Comparative study of (i) electrophilic addition at C=C; (ii) Nucleophilic addition at C=O group of aldehydes and ketons; (iii) Nucleophilic substitution at C=O group of acids and their derivatives; Substitution reaction at the saturated carbon atom (SN$_1$, SN$_2$, SNi); and the aromatic system (SE$_2$), Elimination reactions: beta elimination (E$_1$, E$_2$ and E$_1$eB) and alpha elimination carbenes; polymerization reactions: Ionic and Free radical mechnisms.


SECTION G: Elementary idea of the applications of U. VIR and H-NMR spectroscopy for simple organic molecules.

Unit 8: Organic Chemistry (2)

SECTION A: Aliphatic Compounds: Nomenclature and general methods of preparation, properties and reactions with mechanism in respect of the following: (i) Hydrocarbons. Alkanes, Alkenes, Alkaienes, Alkynes and their halogen derivatives, (ii) Monohydric alcohols; (iii) Ethers and thioethers; (iv) Carbonyl compounds;
(v) Saturated monocarboxylic acids and their derivatives;
(vi) Alkynitriles, Nitroalkanes, Nitriles, Isonitriles, Amines, Urea, Diazomethane, Diazoacetic ester.
(vii) Amino acids and proteins: Definition and Classification; Syntheses (by Gabriel phthalimide method, Strecker's method and Azlactone method), properties and reactions of Glycine and Alanine; Tests, peptide linkage and its geometry.
(viii) Carbanion Chemistry with reference to acetoacetic ester, malonic ester and cyanoacetic ester.

SECTION B:
Alicyclic Compounds: General methods of preparation, properties and reactions with mechanism of alicyclic compounds (one ring only) with up to six carbon atoms; Bayer Strain theory; Conformational aspects boat, half-chair and chair forms; axial and equatorial bonds, Conformation, reactions of mono-and di-substituted derivatives only. SECTION C: General methods of preparation, properties, reactions, structure and synthetic used of Grignard reagents; preparation of uses of Li and Zn alkyls. SECTION D: Carbohydrates: Nomenclature: Classification; Reactions and structure elucidation of Glucose and Fructose: Ascending and descending in sugar series. Aldopentoses. Aldohexoses; Ketopentoses and Ketohexoses; Interconversion of aldohexose to ketohexose and vice versa; Configuration of Arabinose, Glucose, Fructose; Conformation of Glucose; Inversion of Sucrose; Ring-chain tautomerism.

Unit 9: Organic Chemistry (3)

SECTION A: Aromatic Compounds:
(i) Idea of aromatic compounds upto-pi-electron system; Aromaticity and Aromatic character;
(ii) Benzene: Modern idea of structure, Electrophilic substitution; preparation properties and important reactions with mechanism of homologues of benzene, halogen derivatives; Nucleophilic and cine substitution: Benzyne intermediates; Orientation and reactivity—mechanistic approach.
(iii) Aromatic nitro compounds: General methods of preparation, properties, reactions with mechanism.
(v) Aromatic diazo compounds: preparation, properties and reactions with mechanism.
(vi) General methods of preparation, properties and reactions with mechanism of the following classes of compounds: Phenols, Aromatic alcohols, Aromatic aldehydes, Aromatic Ketones, Aromatic carboxylic acids and their derivatives, Phenolic aldehydes and ketones, Phenolic acids, Nitro phenols, Benzoquinones and aromatic sulphonic acids.
(vii) General methods of preparation properties, reactions with mechanism of the following bi-functional compounds: Diols, Hydroxy ketons, Hydroxy aldehydes, Dicarbonyl compounds (alpha, beta and gamma) keto acids, unsaturated aldehydes, Unsaturated ketones, Unsaturated acids, Lactons.

SECTION B: Polynuclear hydrocarbons: Synthesis, reactions and structures of Naphthalene and Anthracene; Synthesis (only) of Phenanthrene.

SECTION C: Heterocyclic Compounds: General methods of synthesis, properties and important reactions of the following compounds. Pyrrole, Furan, Thiophene, Pyridine, Quinoline and Indole and derivatives of Pyrrole and Pyridine.

SECTION D: Dyes: Classification, Elementary idea of colour and constitution; Preparation and uses of Phenolphthalein, Methyl orange, Congo red, Malachite green, Alizarin and Indigo.

SECTION E: Problems incorporating reactions including in the syllabus. Unit. 10: Advanced Level Chemistry & Application Oriented Chemistry:

SECTION A: Bioinorganic Chemistry
   Essential and trace elements of life, role of metal ions (Na+, K+, Mg²⁺, Ca²⁺, Fe²⁺/³⁺, Cu²⁺/¹⁺, Zn²⁺) in biology. Basic reactions in the biological systems. Transport of ion across biological membrane, Na⁺ ion pump. Transport and storage of metabolic energy, ATP-ADP interconversion. O₂ - uptake proteins: hemoglobin and myoglobin; electron transport proteins: cytochromes and ferredoxins; redox metalloenzymes: catalase, peroxidase, super oxide dismutase, ascorbate oxidase. Bioinorganic chemistry of nitrogen fixation, respiratory electron transport chair, photosynthesis. Toxic effects of metal ions, Chelation therapy, metal dependent diseases, metal complexes as drugs.

SECTION B: Chemical Analysis: Principles & Applications: Gravimetric and titrimetric (acid-base, redox, complexometric EDTA) estimations of common cations and anions (single & in mixtures). Chemical separation techniques: chromatography, ion exchange, solvent extraction; Instrumental methods of analysis: conductometry, potentionmetry, polarography, amperometry, UV-VIS spectrophotometry, flame photometry, AAS and AES spectrometry, neutron activation analysis. IR, NMR and ESR spectroscopy applications to simple inorganic and organic systems. Analysis of complex materials; ores, alloys, drugs, Pharmaceuticals, air and water samples. Error analysis.

SECTION C: Chemistry on Materials:
   Production and uses of stainless steels and alloy steels, glass and ceramic materials, Port-land cement (composition and setting). Chemical and biofertilizers, natural and synthetic rubbers, synthetic fibres, biopolymers and biodegradable polymes; common drugs and Pharmaceuticals, common pesticides (applications and residual toxicity). Solid, liquid and gaseous fuels, coal based chemicals and petrochemicals (C₁ to C₃ compounds): oils, soaps and detergents, hydrogenation of oils, production of vanaspati and margarine. Constituents and
formulations of paints and varnishes, common cosmetics and perfumes, food additives and preservatives. SECTION D: Environmental chemistry