



SYLLABUS

Ph. D. Entrance Exam - Chemistry

2021-2022

**PT. RAVISHANKAR SHUKLA UNIVERSITY
RAIPUR
CHHATTISGARH**

FIRST SEMESTER

PAPER NO 1. CH -101

GROUP THEORY AND CHEMISTRY OF METAL COMPLEXES

Max. Marks 80

UNIT - I

SYMMETRY AND GROUP THEORY IN CHEMISTRY: Symmetry elements and symmetry operation, definitions of group, subgroup, relation between orders of a finite group and its subgroup. Conjugacy relation and classes. Point symmetry group. Schoenflies symbols, representations of groups by matrices (representation for the C_n , C_{nv} , C_{nh} , D_{nh} , etc. groups to be worked out explicitly). Character of a representation. The great orthogonality theorem (without proof) and its importance. Character tables and their use in spectroscopy.

UNIT - II

- A. **METAL-LIGAND BONDING:** Limitation of crystal field theory, molecular orbital theory, octahedral, tetrahedral and square planar complexes, bonding and molecular orbital theory.
- B. **METAL-COMPLEXES:** Metal carbonyls, structure and bonding, vibrational spectra of metal carbonyls for bonding and structural elucidation, important reactions of metal carbonyls; preparation, bonding, structure and important reactions of transition metal nitrosyl, dinitrogen and dioxygen complexes; tertiary phosphine as ligand.

UNIT -III

- A. **METAL-LIGAND EQUILIBRA IN SOLUTION:** Stepwise and overall formation constants and their interaction, trends in stepwise constants, factors affecting the stability of metal complexes with reference to the nature of metal ion and ligand, chelate effect and its thermodynamic origin, determination of binary formation constants by pH-metry and spectrophotometry.
- B. **ISOPOLY ACID AND HETEROPOLYACID:** Isopoly and heteropoly acids of Mo and W. Preparation, properties and structure. Classification, Preparation, properties and structures of borides, carbides, nitrides and silicides. Silicates- classification and Structure, Silicones- preparation, properties and application.

UNIT - IV

- A. **METAL CLUSTERS:** Higher boranes, carboranes, metalloboranes and metallocarboranes. Metal carbonyl and halide cluster, compounds with metal-metal multiple bonds.
- B. **CHAINS:** catenation, heterocatenation, intercatenation.
- C. **RINGS:** Borazines, phosphazines.

BOOK SUGGESTED:

1. Advanced Inorganic Chemistry, F.A. Cotton and Wilkinson, John Wiley.
2. Inorganic Chemistry, J.E. Huhey, Harpes and Row.
3. Chemistry of the Elements, N.N. Greenwood and A. Earnshaw, Pergamon.
4. Comprehensive Coordination Chemistry Eds. G. Wilkinson, R.D. Gillars and J.A. McCleverty, Pergamon.

PAPER NO 2. CH –102

CONCEPTS IN ORGANIC CHEMISTRY

Max. Marks 80

UNIT - I

- A. NATURE OF BONDING IN ORGANIC MOLECULES:** Localized and Delocalized chemical bond, conjugation and cross-conjugation, Bonding in Fullerenes, Bonds weaker than covalent, addition compounds,
Crown ether complexes and cryptands. Inclusion compounds, Cyclodextrins, Catenanes and Rotaxanes.
- B. AROMATICITY:** Aromaticity in benzenoid and non-benzenoid compounds, Huckel anti-aromaticity, homo-aromaticity. PMO approach for Aromaticity, Annulenes.

UNIT - II

- A. CONFORMATIONAL ANALYSIS:** Conformational analysis of cycloalkanes, decalins, effect of conformation on reactivity, conformation of sugars, steric strain due to unavoidable crowding.
- B. STEREOCHEMISTRY:** Elements of symmetry, chirality, molecules with more than one chiral center, methods of resolution, optical purity, stereospecific and stereoselective synthesis. Asymmetric synthesis. Optical activity in the absence of chiral carbon - Biphenyls, allenes and spiranes, chirality due to helical shape.

UNIT - III

- A. REACTION INTERMEDIATES:** Generation, structure, stability and reactivity of carbocations, carbanions, free radicals, carbenes and nitrenes. Sandmeyer reaction, Free radical rearrangement and Hunsdiecker reaction.
- B. ELIMINATION REACTIONS:** The E₂, E₁ and E_{1cB} mechanisms. Orientation of the double bond. Reactivity, effects of substrate structures, attacking base, the leaving group and the medium.

UNIT - IV

PERICYCLIC REACTIONS: Classification of pericyclic reactions. Woodward-Hoffmann correlation diagrams. FMO and PMO approach. Electrocyclic reactions - conrotatory and disrotatory motions, 4n, 4n+2 and allyl systems. Cycloadditions - antarafacial and suprafacial additions, 4n and 4n+2 system, 2+2 addition of ketenes, 1,3 dipolar cycloadditions and cheletropic reactions. Sigmatropic rearrangements - suprafacial and antarafacial shifts of H, sigmatropic shifts involving carbon moieties, 3,3- and 5,5- sigmatropic rearrangements. Claisen, Cope and Aza-Cope rearrangements. Ene reaction.

BOOKS SUGGESTED:

1. Advanced Organic Chemistry, F. A. Carey and R. J. Sundberg, Plenum.
2. A Guide Book to Mechanism in Organic Chemistry, Peter Sykes, Longman.
3. Structures and Mechanism in Organic Chemistry, C. K. Ingold, Cornell University Press.
4. Organic Chemistry, R. T. Morrison and R. N. Boyd, Prentice-Hall.
5. Modern Organic Reactions, H. O. House, Benjamin.
6. Principles of Organic Synthesis, R. O. C. Norman and J. M. Coxon, Blackie Academic and Professional.
7. Pericyclic Reactions, S. M. Mukherji, Macmillan, India.
8. Reaction Mechanism in Organic Chemistry, S. M. Mukherji and S. P. Singh, Macmillan.
9. Stereochemistry of Organic Compounds, D. Nasipuri, New Age International.
10. Some Modern Methods of Organic Synthesis, W. Carruthers, Cambridge Univ. Press.
11. Rodd's Chemistry of Carbon Compounds, Ed. S. Coff
12. Organic Chemistry, Vol 2, I. L. Finar, ELBS.
13. Stereo selective Synthesis: A Practical Approach, M. Nogradi, and VCH.
14. Organic Chemistry, Paula Yurkanis Bruice, Pearson Education.

PAPER NO 3. CH –103

QUANTUM CHEMISTRY, THERMODYNAMICS AND CHEMICAL DYNAMICS - I

Max. Marks 80

UNIT - I

A. MATHEMATICAL CONCEPTS IN QUANTUM CHEMISTRY:

Vector quantities and their properties. Complex numbers and Coordinate transformation. Differential and Integral Calculus, Basic rules of differentiation and Integration applications.

- B. The Schrodinger equation and postulates of quantum mechanics. Discussion of solutions of the Schrodinger equation to some model systems viz Particle in a box, the harmonic oscillator, the rigid rotator, the hydrogen atom.

UNIT –II

BASICS OF THERMODYNAMICS: Maxwell's thermodynamic relations, Vant's Hoff hypothesis. Partial molar volume and partial molar heat content. Chemical potential, Gibbs-Duhem equation, variation of chemical potential with temperature and pressure. Chemical potential of ideal gases, pure solids, liquids and mixture of ideal gases. Activity and Fugacity, Determination of Fugacity, Variation of Fugacity with Temperature and Pressure.

UNIT –III

ELECTROCHEMISTRY–I: Electrochemistry of solution. Debye-Huckel Onsager treatment and its extension, ion solvent interactions. Debye-Huckel Limiting Law. Debye-Huckel theory for activity coefficient of electrolytic solutions. Determination of activity and activity coefficient, ionic strength, Thermodynamics of electrified interface equations. Derivation of electro-capillarity, Lippmann equation (surface excess), methods of determination.

UNIT –IV

CHEMICAL DYNAMICS –I: Methods of determining rate laws, consecutive reactions, collision theory of reaction rates, steric factor, Activated complex theory, kinetic salt effects, steady state kinetics, and thermodynamic and kinetic control of reactions. Dynamic chain (Hydrogen-bromine and Hydrogen-chlorine reactions) and Oscillatory reactions (Belousov-Zhabotinsky reaction etc.)

BOOKS SUGGESTED :

1. Physical Chemistry, P.W. Atkins, ELBS.
 2. Coulson's Valence, R. McWeeny, ELBS.
 3. Chemical Kinetics, K. J. Laidler, Pearson.
 4. Kinetics and Mechanism of Chemical Transformations, J. Rajaraman and J. Kuriacose, McMillan.
 5. Modern Electrochemistry Vol. I and Vol. II, J.O.M. Bockris and A.K.N. Reddy, Plenum.
 6. Thermodynamics for Chemists, S. Glasstone EWP.
 7. An Introduction to Electrochemistry S. Glasstone EWP.
 8. Organic Chemist's Book of Orbitals. L. Salem and W.L. Jorgensen, Academic Press
 9. The Physical Basis of Organic Chemistry, H. Maskill, Oxford University Press
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PAPER NO 4. CH - 104

THEORY AND APPLICATIONS OF SPECTROSCOPY- I

Max. Marks 80

UNIT - I

UNIFYING PRINCIPLES:

Electromagnetic radiation, interaction of electromagnetic radiation with matter-absorption, emission transmission, reflection, dispersion, polarization and scattering, Uncertainty relation and natural line width and natural line broadening, transition probability, selection rules, intensity of spectral lines, Born-Oppenheimer approximation, rotational, vibrational and electronic energy levels. Region of spectrum, representation of spectra, F.T. spectroscopy, computer averaging, lasers.

UNIT- II

MICROWAVE SPECTROSCOPY:

Classification of molecules in term of their internal rotation mechanism, determination of rotation energy of diatomic and polyatomic molecules, intensities of rotational spectral lines, effect of isotopic substitution on diatomic and polyatomic molecules, intensities of rotational spectral lines and parameters of rotational energy of linear and the transition frequencies, non-rigid rotators, spectral lines and parameters of rotational energy of linear and symmetric top polyatomic molecules. Application in determination of bond length.

UNIT- III

INFRA RED SPECTROSCOPY:

Introduction, simple and anharmonic oscillators in vibrational spectroscopy, diatomic-vibrating rotator, Modes of vibration in polyatomic molecules, vibration-coupling, Fourier Transform IR spectroscopy: instrumentation, interferometric spectrophotometer, sample handling, Factors influencing vibrational frequencies, Application of IR spectroscopy: Interpretation of IR spectra of normal alkanes, aromatic hydrocarbons, alcohols, phenols, aldehydes, ketones, ethers, esters, carboxylic acids, amines and amides.

UNIT- IV

RAMAN SPECTROSCOPY:

Classical and quantum theories of Raman effect, pure rotational, vibrational and vibrational-rotational Raman spectra, selection rules, mutual exclusion principle, Resonance Raman spectroscopy, Coherent anti Stokes Raman spectroscopy (CARS), Instrumentation, Application of Raman effect in molecular structures, Raman activity of molecular vibration, structure of CO₂, H₂O, N₂O, SO₂, NO₃⁻, ClF₃.

BOOKS SUGGESTED

1. Modern Spectroscopy, J.M. Hollas, John Wiley.
2. Fundamentals of Molecular Spectroscopy, C.N. Banwell.
3. Spectroscopy, B.K. Sharma, Goel Publication.
4. Organic Spectroscopy: Principles and Applications, Jag Mohan, Narosa Publication.
5. Spectroscopy Methods in Organic Chemistry, D.H. Williams & I. Fleming, Tata Mcgraw-Hill Publication.
6. Spectrophometric Identification of Organic Compounds, R.M. Silverstein & F. X. Webster, John Wiley Publication.

SECOND SEMESTER

PAPER NO1 . CH - 201

TRANSITION METAL COMPLEXES

Max. Marks 80

UNIT - I

REACTION MECHANISM OF TRANSITION METAL COMPLEXES: Energy profile of a reaction, reactivity of metal complexes, inert and labile complexes, kinetic application of valence bond and crystal field theories, kinetics of octahedral substitution, anation reactions, reactions without metal ligand bond cleavage. Substitution reactions in square planar complexes, the trans effect. Redox reactions, electron transfer reactions, mechanism of one electron transfer reactions, outer sphere type reactions, cross reactions and Marcus-Hush theory, inner sphere type reactions.

UNIT - II

ELECTRONIC SPECTRA AND MAGNETIC PROPERTIES OF TRANSITION METAL COMPLEXES:

Spectroscopic ground states, Correlation, Orgel and Tanabe-Sugano diagrams for transition metal complexes (d^1 - d^9 states), Selection rules, mechanism for break down of the selection rules, intensity of absorption, band width, spectra of d-d metal complexes of the type $[M(H_2O)]^{n+}$, spin free and spin paired ML_6 complexes of other geometries, Calculations of Dq , B and parameters, spin forbidden transitions, effect of spin-orbit coupling, Spectrochemical and Nephelauxetic series. Magnetic properties of complexes of various geometries based on crystal field model, spin free-spin paired equilibria in octahedral stereochemistry.

UNIT - III

- A. TRANSITION METAL COMPLEXES:** Transition metal complexes with unsaturated organic molecules, alkanes, allyl, diene dienyl, arene and trienyl complex, preparations, properties, nature of bonding and structure features. Important reaction relating to nucleophilic and electrophilic attack on ligands and organic synthesis.
- B. TRANSITION METALS COMPOUND WITH BOND TO HYDROGEN:** Transition Metals Compounds with Bond to Hydrogen.

UNIT-IV

- A. ALKYL AND ARYL OF TRANSITION METALS:** Types, routes of synthesis, stability and decomposition pathways, organocopper in organic synthesis.
- B. COMPOUNDS OF TRANSITION METAL - CARBON MULTIPLE BONDS :** Alkylidenes, low valent carbenes, nature of bond and Structural characteristics.
- C. FLUXIONAL ORGANOMETALLIC COMPOUNDS:** Fluxionality and dynamic equilibria in compounds such as olefin, -allyl and dienyl complexes.

BOOKS SUGGESTED :

1. Principles and applications of organotransition metal chemistry, J.P.Collman, L.S.Hegsdus, J. R. Norton and R.G. Finke, University Science Books.
2. The Organometallic chemistry of the Transition metals, R. H. Crabtree, John Wiley.
3. Metallo - organic chemistry, A.J. Pearson, Wiley.
4. Organometallic chemistry, R.C. Mehrotra and A. Singh, New age International.

PAPER NO 2. CH - 202

REACTION MECHANISMS

Max. Marks 80

UNIT - I

- A. **ALIPHATIC NUCLEOPHILIC SUBSTITUTION:** The S_N^2 , S_N^1 , mechanisms. The neighbouring group mechanism, neighbouring group participation by π and σ bonds, anchimeric assistance. Reactivity effects of substrate structure, attacking nucleophile, leaving group and reaction medium, ambident nucleophile and regioselectivity.
- B. **AROMATIC NUCLEOPHILIC SUBSTITUTION:** The S_N^1 , S_N^2 mechanisms. Reactivity effect of substrate structure, leaving group and attacking nucleophile. The von Richter, Sommelet-Hauser, and Smiles rearrangements.

UNIT - II

- A. **ALIPHATIC ELECTROPHILIC SUBSTITUTION:** Mechanisms of S_E^2 , S_E^1 , electrophilic substitution accompanied by double bond shifts. Effect of substrates, leaving group and the solvent polarity on the reactivity.
- B. **AROMATIC ELECTROPHILIC SUBSTITUTION:** The arenium ion mechanism, orientation and reactivity. The ortho/para ratio, ipso attack, orientation in other ring systems. Reactivity-Effect of substrates and electrophiles. Vilsmeier reaction and Gattermann-Koch reaction.

UNIT - III

ADDITION TO CARBON-CARBON MULTIPLE BONDS: Mechanistic and stereochemical aspects of addition reactions involving electrophiles, nucleophiles and free radicals, regio- and chemoselectivity. Addition to cyclopropane ring. Hydrogenation of double and triple bonds, hydrogenation of aromatic rings Hydroboration, Michael reaction. Sharpless asymmetric epoxidation.

UNIT - IV

ADDITION TO CARBON-HETERO MULTIPLE BONDS: Mechanism of metal hydride reduction of saturated and unsaturated carbonyl compounds, acids esters and nitriles. Addition of Grignard Reagents, Organo-Zinc and Organo-lithium to carbonyls and unsaturated carbonyl compounds, Wittig reaction.

Mechanism of condensation reactions involving enolates - Aldol, Knoevenagel and Stobbe reactions. Hydrolysis of esters and amides, ammonolysis of esters.

BOOKS SUGGESTED :

1. Advanced Organic Chemistry-Reactions, Mechanism and Structure, Jerry March, John Wiley.
 2. Modern Organic Reactions, H. O. House, Benjamin.
 3. Principles of Organic Synthesis, R. O. C. Norman and J. M. Coxon, Blackie Academic & Professional.
 4. A Guide Book to Mechanism in Organic Chemistry, Peter Sykes, Longman.
 5. Structures and Mechanism in Organic Chemistry, C. K. Ingold, Cornell University Press.
 6. Reaction Mechanism in Organic Chemistry, S. M. Mukherji and S. P. Singh, Macmillan
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PAPER NO 3. CH –203

QUANTUM CHEMISTRY, THERMODYNAMICS AND CHEMICAL DYNAMICS - II

Max. Marks 80

UNIT –I

- A. **APPLICATION OF MATRICES IN QUANTUM CHEMISTRY:** Addition and multiplication, inverse and transpose of matrices. Determinants, in quantum Chemistry.
- B. **ANGULAR MOMENTUM IN QUANTUM CHEMISTRY:** Angular momentum, angular momentum Operators. Eigen functions and Eigen values Angular momentum, ladder operators.
- C. **APPROXIMATE METHODS:** The variation theorem, linear variation principle. Perturbation theory (first order and non-degenerate). Applications of variation method and perturbation theory to the Helium atom.

UNIT –II

STATISTICAL THERMODYNAMICS: Probability, permutations and combinations concepts of probability, Maxwell Boltzmann distribution. Different ensembles and Partition functions translational, rotational, vibrational and Electronic. Thermodynamic function using appropriate Partition function. Fermi-Dirac and Bose-Einstein Statistics and statistical basis of entropy. Heat capacity of solids, Debye and Einstein Models.

UNIT –III

ELECTROCHEMISTRY –II: Structure of electrified interfaces. Gouy-Chapman, Stern, Over potentials and exchange current density, Derivation of Butler –Volmer equation, Tafel plot. Semiconductor interfaces, Theory of double layer at semiconductor, electrolyte solution interfaces, structure of double layer interfaces. Effect of light at semiconductor solution interfaces. Electro catalysis influence of various parameters. Hydrogen electrode.

UNIT –IV

CHEMICAL DYNAMICS –II: General features of fast reactions by flow method, relaxation method, flash photolysis and the nuclear magnetic resonance method. Molecular reaction dynamics, Dynamics of molecular motions, probing the transition state, dynamics of barrierless chemical reactions in solutions, dynamics of unimolecular reaction. [Lindemann –Hinshelwood , RRK and Rice-Ramsperger-Kassel-Marcus {RRKM}] theories of unimolecular reactions.

BOOKS SUGGESTED :

1. The Chemistry Mathematics Book, E. Steiner, Oxford University Press.
2. Mathematics for Chemistry, Doggett and Sutcliffe, Longman.
3. Mathematical Preparation for Physical Chemistry, F. Daniels, McGraw Hill.
4. Chemical Mathematics, D.M, Hirst, Longman.
5. Applied Mathematics for Physical Chemistry, J.R. Barrante, Prentice Hall.
6. Basic Mathematics for Chemists, Tebbutt, Wiley.
7. Physical Chemistry, P.W. Atkins, ELBS.
8. Introduction to Quantum Chemistry, A.K. Chandra, Tata McGraw Hill.
9. Quantum Chemistry, Ira N. Levine, Prentice Hall.
10. Coulson's Valence, R. McWeeny, ELBS.
11. Chemical Kinetics, K. J. Laidler, Pearson.
12. Kinetics and Mechanism of Chemical Transformations, J. Rajaraman and J. Kuriacose, McMillan.
13. Modern Electrochemistry Vol. I and Vol. II, J.O.M. Bockris and A.K.N. Reddy, Plenum.
14. Thermodynamics for Chemists, S. Glasstone EWP.
15. An Introduction to Electrochemistry S. Glasstone EWP.
16. Physical Chemistry, Ira N. Levine McGraw Hill.
17. Physical Chemistry, Silbey, Alberty, Bawendi, John-Wiley.

PAPER NO 4 . CH - 204

THEORY AND APPLICATIONS OF SPECTROSCOPY –II

Max. Marks 80

UNIT - I

ULTRAVIOLET AND VISIBLE SPECTROSCOPY:

Introduction, intensity of vibrational-electronic spectra and Frank-Condon principle for dissociation energy, rotational fine structure of electronic-vibrational spectra, Shape of some molecular orbitals viz., H₂, He₂, N₂, O₂. Electronic spectra of organic molecules, chromophores, application of electronic spectroscopy: spectrophotometric studies of complex ions, determination of ligand/metal ratio in a complex, identification of compounds, determination of stability constants.

UNIT -II

SCATTERING SPECTROSCOPY:

Principle, instrumentations and application of Auger spectroscopy, Scanning Electron Microscopy, Electron diffraction of gases and vapours, The Wierl equation and co-related method.

Theory, instrumentation and application of turbidimetry, nephelometry, fluorometry. Fluorescence and phosphorescence and factors affecting them.

UNIT - III

MASS SPECTROMETRY:

Introduction, basic principles, separation of the ions in the analyzer, resolution, molecular ion peak, mass spectral fragmentation of organic compounds, factors affecting fragmentation, McLafferty rearrangement. Instrumentation, Characteristics of mass spectra of Alkanes, Alkenes, Aromatic hydrocarbons, Alcohols, Amines. Nitrogen rule, ring rule, Molecular weight and formula determination, Gas chromatography-Mass spectrometry.

UNIT - IV

NUCLEAR RESONANCE SPECTROPHOTOMETRY:

Theory of NMR spectroscopy, interaction of nuclear spin and magnetic moment, chemical shift, precessional motion of nuclear particles in magnetic field, spin-spin splitting, coupling constants, factor affecting the chemical shift, shielding effect, effect of chemical exchange, hydrogen bonding, instrumentation of Fourier transform NMR spectrophotometer, structure determination of organic compounds, Carbon-13 NMR spectroscopy, Multiplicity-proton (¹H) decoupling-noise decoupling, off resonance decoupling, selective proton decoupling, chemical shift.

BOOKS SUGGESTED

1. Modern Spectroscopy, J.M. Hollas, John Wiley.
 2. Fundamentals of Molecular Spectroscopy, C.N. Banwell.
 3. Spectroscopy, B.K. Sharma, Goel Publication.
 4. Organic Spectroscopy : Principles and Application, Jag Mohan, Narosa Publication.
 5. Spectroscopic Methods in Organic Chemistry, D.H. Williams & I. Fleming, Tata Mcgraw-Hill Publication.
 6. Spectrophometric Identification of Organic Compounds, R.M. Silverstein & F.X. Webster, John Wiley Publications.
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THIRD SEMESTER

PAPER NO 1. CH - 301

RESONANCE SPECTROSCOPY, PHOTOCHEMISTRY AND ORGANOCATALYSIS

Max. Marks 80

UNIT –I

- A. **ELECTRON SPIN RESONANCE SPECTROSCOPY:** Hyperfine coupling, spin polarization for atoms and transition metal ions, spin-orbit coupling and significance of g-tensors, application to transition metal complexes (having one unpaired electron).
- B. **NUCLEAR QUADRUPOLE RESONANCE SPECTROSCOPY:** Quadrupole nuclei, quadrupole moments, electric field gradient, coupling constant, splitting, applications.

UNIT –II

- A. **PHOTOELECTRON SPECTROSCOPY:** Basic principle both for atoms and molecules; Photo-electric effect, ionization process, Koopman's theorem, Spectra of simple molecules, Auger electron spectroscopy, Determination of Dipole moment.
- B. **PHOTOACOUSTIC SPECTROSCOPY:** Basic principle of Photo acoustic Spectroscopy (PAS), PAS – gases and condensed system Chemical and Surface application.

UNIT –III

- A. **PHOTOCHEMICAL REACTIONS :** Interaction of electromagnetic radiation with matter, Photophysical processes , Stern Volmer equation, types of excitations, fate of excited molecule, quantum yield, transfer of excitation energy, Actinometry.
- B. **DETERMINATION OF REACTION MECHANISM:** Classification, rate constants and life times of reactive energy states –determination of rate constants of reactions. Effect of light intensity on the rate of photochemical reactions.
- C. **MISCELLANEOUS PHOTOCHEMICAL REACTIONS:** Photo-Fries reactions of anilides, Photo-Fries rearrangement. Barton reaction. Singlet molecular oxygen reactions. Photochemical formation of smog. Photodegradation of polymers, Photochemistry of vision.

UNIT –IV

- A. **ORGANOCATALYSIS**
General Principles: Energetic, Catalytic cycles, catalytic efficiency and life time, selectivity. Type of organometallic reaction: Ligand substitution, Oxidative addition, reductive elimination and insertion and deinsertion. Homogeneous catalysis: Hydrogenation of alkenes, Hydroformylation, Monsanto acetic acid synthesis, Wacker oxidation of alkenes, Alkenes metathesis, Palladium-Catalysed C-C bond forming reactions, asymmetric oxidation. Heterogenous catalysis: The nature of heterogenous catalysts, Fischer- Tropsch synthesis, alkene polymerization.

BOOK SUGGESTED:

1. Infrared and Raman Spectra: Inorganic and Coordination Compounds, K. Nakamoto, Wiley.
2. Fundamentals of Photochemistry, K.K. Rohtagi-Mukherji, Wiley-Eastern.
3. Essentials of Molecular Photochemistry, A. Gilbert and J. Baggott, Blackwell Scientific Publications.
4. Molecular Photochemistry, N.J. Turro, W.A. Benjamin.
5. Introductory Photochemistry, A. Cox and T. Camp, McGraw-Hill.
6. Photochemistry, R.P. Kundall and A. Gilbert, Thomson Nelson.
7. Application of Spectroscopy of Organic Compounds, J.R. Dyer, Prentice Hall.
8. Photochemistry, R.P. Kundall and A. Gilbert, Thomson Nelson.
9. Organic Photochemistry, J. Coxon and B. Halton, Cambridge University Press.
10. Shriver & Atkins Inorganic Chemistry: P. Atkins, T.Overtone, J. Rourke, M. Weller, F. Armstrong, Oxford University Press
11. Inorganic Chemistry: C.E. Housecraft, A.G. Sharpe, Pearson Education Limited.
12. Inorganic Chemistry: Principles of Structure and Reactivity: J.E. Huheey, E.A. Keiter, R.L.Keiter, O.K. Medhi, Pearson Education
13. Organometallic Chemistry: A Unified Approach: R.C. Mehrotra, A.Singh, New Age International Publishers.

PAPER NO 2. CH - 302

CHEMISTRY OF BIOMOLECULES

Max. Marks 80

UNIT –I

- A. **BIOENERGETICS:** Standard free energy change in biochemical reactions, exergonic, endergonic. Hydrolysis of ATP, synthesis of ATP from ADP.
- B. **ELECTRON TRANSFER IN BIOLOGY:** Structure and function of metalloproteins in electron transport processes –cytochromes and iron-sulphur proteins, synthetic models.
- C. **TRANSPORT AND STORAGE OF DIOXYGEN:** Heme proteins and oxygen uptake, structure and function of haemoglobin, myoglobin, haemocyanins and haemerythrin, model synthetic complexes of iron, cobalt and copper.

UNIT –II

- A. **METALLOENZYMES:** Zinc enzymes –carboxypeptidase and carbonic anhydrase. Iron enzymes – catalase, peroxidase and cytochrome P-450. copper enzymes- superoxide dismutase. Molybdenum oxatransferase enzymes –xanthine oxidase.
- B. **ENZYME MODELS:** Host-guest chemistry, chiral recognition and catalysis, molecular recognition, molecular asymmetry and prochirality. Biomimetic chemistry, Cyclodextrin-based enzyme models, calixarenes, ionophores, synthetic enzymes or synzymes.

UNIT –III

- A. **ENZYMES :** Nomenclature and classification of Enzyme. Induced fit hypothesis, concept and identification of active site by the use of inhibitors.
- B. **CO-ENZYME CHEMISTRY:** Structure and biological functions of coenzyme A, thiamine pyrophosphate, pyridoxal phosphate, NAD⁺, NADP⁺, FMN, FAD, lipoic acid, vitamin B₁₂.
- C. **BIOTECHNOLOGICAL APPLICATIONS OF ENZYMES:** Techniques and methods of immobilization of enzymes, effect of immobilization on enzyme activity, application of immobilization enzymes in medicine and industry. Enzymes and Recombinant DNA Technology.

UNIT –IV

- A. **BIOPOLYMER INTERACTIONS:** forces involved in biopolymer interaction. Electrostatic charges and molecular expansion, hydrophobic forces, dispersion force interactions. Multiple equilibria and various types of binding processes in biological systems. Hydrogen ion titration curves.
- B. **THERMODYNAMICS OF BIOPOLYMER SOLUTIONS:** Thermodynamics of biopolymer solution, osmotic pressure, membrane equilibrium, muscular contraction and energy generation in mechanochemical system.
- C. **CELL MEMBRANE AND TRANSPORT OF IONS:** Structure and functions of cell membrane, ion transport through cell membrane, irreversible thermodynamic treatment of membrane transport and Nerve conduction.

BOOK SUGGESTED:

1. Principles of Bioinorganic Chemistry, S.J. Lippard and J.M. Berg, University Science Books.
 2. Bioinorganic Chemistry, I. Bertini, H.B. Gray, S.L. Lippard and J.S. Valentine, University Science Books.
 3. Inorganic Biochemistry vols II and I. Ed G.L. Eichhorn, Elsevier.
 4. Principles of Bioinorganic Chemistry, S.J. Lippard and J.M. Berg, University Science Books.
 5. Bioinorganic Chemistry, I. Bertini, H.B. Gary, S.J. Lippard and J.S. Valentine, University Science.
 6. Inorganic Biochemistry vols I and II ed. G.L. Eichhorn, Elsevier.
 7. Bioorganic Chemistry: A Chemical Approach to Enzyme Action, Hermann Dugas and C. Penny, Springer-verlag.
 8. Understanding Enzymes, Trevor palmer, Prentice Hall.
 9. Enzyme Chemistry : Impact and Applications, Ed. Collin J Suckling, Chapman and Hall.
 10. Enzyme Mechanisms Ed, M.I. Page and A. Williams, Royal Society of Chemistry.
 11. Fundamentals of Enzymology, N.C. Price and L. Stevens, Oxford University Press.
 12. Immobilized Enzymes: An Introduction and Applications in Biotechnology, Michael D. Trevan, and John Wiley.
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13. Enzymatic Reaction Mechanisms, C. Walsh, W.H. Freeman.
14. Enzyme Structure and Mechanisms, A Fersht, W.H. Freeman.
15. Biochemistry: The Chemical Reactions of Living Cells, D.E. Metzler, Academic Press.
16. Principles of Biochemistry, A.L. Lehninger, Wroth Publishers.
17. Biochemistry, L. Stryer, W.H. Freeman.
18. Biochemistry, J. David Rawn, Neil Patterson.
19. Biochemistry, Voet and Voet, John Wiley.
20. Outlines of Biochemistry, E.E. Conn and P.K. Stumpf, John Wiley.
21. Bioorganic Chemistry : A Chemistry Approach to Enzyme Action, H. Dugas and C. Penny, Springer-Verlag.
22. Biochemistry and Molecular Biology of Plants, Buchanan, Grissem and Jones, I.K. International Pvt. Ltd.

PAPER NO 3. CH –303

CATALYSIS, SOLID STATE AND SURFACE CHEMISTRY

Max. Marks 80

UNIT –I

ACIDS, BASES, ELECTROPHILES, NUCLEOPHILES AND CATALYSIS:

Acid-base dissociation, Electronic and structural effects, acidity and basicity. Acidity function and their applications. Hard and soft acids and bases. Nucleophilicity scales. Nucleofugacity. The alpha effect. Ambivalent Nucleophilies. Acid base catalysis-specific and general catalysis. Bronsted catalysis, Enzyme Catalysis.

UNIT –II

MICELLES AND ADSORPTION :

Micelles : Classification of surface active agents, micellization, hydrophobic interaction, critical micellar concentration (CMC), factors affecting the CMC of Surfactants. Thermodynamics of micellization - phase separation and mass action models. Reverse micelles, micro-emulsion. Micellar Catalysis, Surface tension capillary action, pressure difference across curved surface (Laplace equation), vapor pressure of droplets (Kelvin equation), Gibbs adsorption isotherm.

UNIT –III

SOLID STATE CHEMISTRY - I :

Crystal defects and Non-stoichiometry - Perfect and imperfect crystals, intrinsic and extrinsic defects - point defect, line and plane defects, vacancies - Schottky defects and Frankel defects. Thermodynamics of Schottky and Frenkel defect, formation of color centres, non-stoichiometry and defects. Electronic properties and Band theory of semiconductors.

UNIT –IV

MACROMOLECULES :

Polymer - Definition types of polymers, electrically conducting, fire resistant, liquid crystal polymers, kinetics of polymerization, mechanism of polymerization.

Molecular mass and average molecular mass. Molecular mass determination (Osmometry, Viscometry, diffusion and light scattering methods), Sedimentation, chain configuration of macromolecules, calculation of average dimensions of various chain structures.

BOOK SUGGESTED :

1. G.W. Castellan, "Physical Chemistry", Addison- Lesley Publishing Co.
2. E.A. Moelwyn Hughes, "Physical Chemistry", Pergamon Press.
3. Denbigh, "Chemical Equilibria", D. Van Nostrand.
4. J. Rose, "Dynamic Physical Chemistry" Sir Issac Pitman and Sons.
5. Solid state "Chemistry and its Applications, A.R. West, Plenum.
6. Principle of Solid State H.V. Kar, Wiley Eastern.
7. Solid State Chemists, D.K. Chakrabarty, New Age International (P) Ltd.
8. Micelles, Theoretical and Applied Aspects, V. Moral Plenum.
9. The Chemistry Mathematics Book, E. Steiner, Oxford University Press.
10. Mathematics for Chemistry, Doggett and Sutcliffe, Longman.
11. Mathematical Preparation for Physical Chemistry, F. Daniels, McGraw Hill.
12. Chemical Mathematics, D.M. Hirst, Longman.
13. Applied Mathematics for Physical Chemistry, J.R. Barrante, Prentice Hall.
14. Basic Mathematics for Chemists, Tebbutt, Wiley.
15. Quantum Chemistry, Ira N. Levine, Prentice Hall.
16. Introduction to Quantum Chemistry, A.K. Chandra, Tata McGraw Hill.

PAPER NO 4. CH –304

ANALYTICAL TECHNIQUES AND DATA ANALYSIS

Max. Marks 80

UNIT –I

SAMPLE PREPARATION, DEGESTION AND STATISTICAL ANALYSIS

- A. Sampling - Collection, Preservation and preparation of sample, Techniques of sampling of solid, liquid and gaseous samples, Operation of drying and preparing a solution of the analyte.
Principle, methodology and application of different types of digestions such as acid digestion, base digestion, enzymatic and microwave digestion for liquid and solid materials.
- B. Evolution and procession of Analytical Data, Precision and Accuracy, Types of Errors, Propagation of errors, Normal Distribution Curve, Standard deviation, Confidence limit, Graphical presentation of result-method of average, Method of Linear least square, Significant figures, Statistical aid to hypothesis of testing- t-test, F-test, Correlation coefficient, Rejection of data.

UNIT –II

SEPARATION TECHNIQUES

- A. Principle of Solvent Extraction, Methods of Extraction, Efficiency of extraction, Selectivity of extraction, applications.
- B. Principle, classification of chromatographic techniques, Technique and applications of paper chromatography, Thin-layer chromatography, HPTLC, Column chromatography.

UNIT –III

THERMAL AND AUTOMATED METHODS

- A. Principle, Instrumentation, Applications of TGA, DTA and DSC methods.
- B. Automated methods, Principle, instrumentation and application of flow injection analysis.

UNIT –IV

ELECTROCHEMISTRY

- A. Principles and instrumentation of pH potentiometry, coulometry and conductometry.
- B. Basic principles, Diffusion current, polarized electrode, Micro electrode, Dropping Mercury Electrode Ilkovic equation, Polarographic wave, Qualitative analysis Stripping methods, Cyclic Voltammetry, Amperometric titration :-curves, Differential pulse polarography and Square wave polarography.

BOOK SUGGESTED :

1. Fundamental of Analytical Chemistry- Skoog D.A. and West D.M.
2. Saunders, College Publication.
3. Textbook of Quantitative Inorganic Analysis-Vogel A.I.
4. Principles and Practice of Analytical Chemistry-Fifield F.W and Kealey
5. D. Black well Science
6. Instrumental Analysis R. Braun, McGraw Hill, International Edition.
7. Analytical Chemistry, Christian, G.D., WSE/Wiley.
8. Instrumental Analysis, Willard Meritt Dean, CBS.
9. Chemical Analysis, Brawn, McGraw Hill.
10. Fundamental of Analytical Chemistry-Skoog D.A. and West D.M.
11. Principles of instrumental analysis, Skoog Holler - Niemann.
12. Instrumental analysis, Wizard Dean and Merit.
13. Principle and PRACTICAL analytical chemistry, Fifield and Kealey.

FOURTH SEMESTER

PAPER NO 1. CH - 401

INSTRUMENTAL METHODS OF ANALYSIS

Max. Marks 80

UNIT –I

ADVANCED CHROMATOGRAPHY:

- A. Ion chromatography: Ion exchange equilibrium, Ion-exchange packing and Inorganic Applications.
- B. Size exclusion chromatography: Column packing, Theory of size of exclusion chromatography and applications.
- C. Supercritical fluid chromatography: Properties of supercritical fluid SFC-Instrumentation and operating variables, comparison with other types of chromatography, applications.
- D. Capillary Electrophoresis and capillary electro chromatography : overviews and applications

UNIT –II

X-RAY AND PROTON INDUCED SPECTROSCOPY:

- A. X-Ray fluorescent method: Principles-Characteristics x-ray emission. Instrumentation x-ray tube, Radioactive sources. Wavelength dispersive instruments. Energy dispersive instruments. Analytical Applications-Qualitative Analysis.
- B. Proton Induced X-Ray Spectroscopy : Theory, instrumentation and application.

UNIT –III

ATOMIC EMISSION SPECTROSCOPY

- A. Selectivity, sensitivity and interferences of atomic spectroscopy.
- B. Theory, instrumentation and application of flame photometer, AES, ICP-AES and AFS.

UNIT –IV

ATOMIC ABSORPTION SPECTROSCOPY AND HYPHENATED TECHNIQUES

- A. Theory instrumentation and application of flame and graphite furnace AAS, cold-vapor and hydride generation AAS.
- B. Theory, instrumentation and application of hyphenated techniques i.e. GC/HPLC/-MS, GC/IC/HPLC-ICP-MS.

BOOK SUGGESTED:

1. Instrumental methods of analysis, Willard, Meritt and Dean.
2. Basic concepts of analytical chemistry, S.M. Khopkar, John Wiley & Sons.
3. Metallurgical analysis, S.C. Jain.
4. Material Science and Engineering. An Introduction, W.D. Callister, Wiley.
5. Material Science, J.C. Anderson, K.D. Leaver, J.M. Alexander and R.D. Rawlings, ELBS.
6. Fundamentals of Analytical Chemistry, Skoog, Welt, Holler and Crouch Thomson Learning Inc.

PAPER NO 2. CH - 402
NATURAL PRODUCT AND MEDICINAL CHEMISTRY

Max. Marks 80

UNIT-I

- A. **Terpenoids and Carotenoids:** Classification, nomenclature, occurrence, isolation, general methods of structure determination of Citral, Geraniol, α -Terpeneol, Menthol, Farnesol, Zingiberene, Santonin, Phytol, Abietic acid and β – Carotene.
- B. **Alkaloids:** Definition, nomenclature and physiological action, occurrence, isolation, general methods of structure elucidation, degradation, classification based on Nitrogen heterocyclic ring, role of alkaloids in plant. Synthesis and biosynthesis of the following: Ephedrine, (+)- Coline, Nicotine, Atropine, Quinine and Morphine.

UNIT-II

- A. **Steroids:** Isolation, structure determination and synthesis of Cholesterol, Bile acids, Androsterone, Testosterone, Esterone, Progesterone, Aldosterone and Biosynthesis of cholesterol.
- B. **Plant Pigments:** Occurrence, nomenclature and general method of structure determination. Isolation and synthesis of Apigenin, Luteolin, Quercetin, Myrcetin, Quercetin-3-glucoside, Vitexin, Diadzin, Butein, Aureusin, Cyanidin-7-arebinoside, Cyanidin, Hirsutidin.

UNIT- III

Drug Design

- A. Development of new drugs procedures followed in drug design, concepts of lead compound and lead modification, concepts of prodrugs and soft drugs, Structure-Activity Relationship (SAR), Factors affecting bioactivity, resonance, inductive effect. Theories of drug activity: occupancy theory, rate theory, induced fit theory. Quantitative Structure Activity Relationship (QSAR).
- B. Concepts of drug receptors, lipophilicity, pharmacophore, pharmacological activity and typical range of parameters related to drug likeness.
- C. General introduction of pharmacokinetics and pharmacodynamics.

UNIT – IV

- A. **Anteoplastic Agents:** Introduction, Alkylating agents, antimetabolites, carcinolytic antibiotics, mitotic inhibitors.
- B. **Antibiotics:** Constitution and synthesis of penicillins, chloramphenicol, tetracycline and streptomycin.
- C. **Antimalarials:** Synthesis and properties of the following Antimalarial: 8-amino quinolone derivatives-Pamaquine, Primapune, Pentaquinr, Isopentaquine, 4- amino quinolone derivatives- Santoquine, Camaquine, Acridine derivatives-Mepracrine, Azacrin, Pyrimidine and Biguanid derivatives- Paludrine Pyremethamine.

Book Suggested:

1. Natural Products: Chemistry and Biological Significance, J. Mann, R. S. Davidson, J. B. Hobbs.
2. D. V. Banthrope and J. B. Harbrone, Longman, Essex., Organic Chemistry, Vol. 2, I. L. Finar, ELBS.
3. Chemistry, Biological and Pharmacological properties of Medicinal Plants from the Americans, Ed. Kurt Hostettmann, M. P. Gupta and A. Marston, Harwood Academic Publishers.
4. Introduction to Flavonoids, B. A. Bhom, Harwood Academic Publishers.
5. New Trends in Natural Product Chemistry, Att-ur-Rahman and M. I. Choudhary, Harwood, Academic Publishers.

6. Insecticides of Natural Origin, Sukh Dev, Harwood Academic Publishers.
7. Introduction to medicinal Chemistry, A Gringuage, Wiley-VCH.
8. Burger's Medicinal Chemistry-1 (Chapter-9 and Ch- 14), Drug Ed. M. E. Discovery, Wolff, John Wiley.

PAPER NO 3. CH - 403

MATERIAL AND NUCLEAR CHEMISTRY

Max.Marks 80

UNIT-I

NON EQUILIBRIUM THERMODYNAMICS: Fundamental concepts, Forces and Fluxes, Entropy production, Phenomenological Laws and Onsager's r for biological systems, coupled reactions.

UNIT-II

MATERIAL CHEMISTRY:

Preparation and Properties of Nanoparticles, Materials-Metals, Ceramics (Oxide, carbides, sulphides, nitrides). Physical and chemical Methods, Size and Shape controlled Synthesis, Sol-gel methods, Optical Properties, Electrical and Magnetic Properties, Application of Nanoparticles. Characterization of Nanoparticles (SEM, TEM etc.)

UNIT-III

SUPRAMOLECULAR CHEMISTRY:

Properties of covalent bonds, bond length, inter bond angles, Force constant, bond and molecular dipole moment, molecular and bond polarizability.

Intermolecular Forces, hydrophobic effects, Electro static, induction, dispersion and resonance energy, Hydrogen bond, Magnetic interactions. Principles of molecular association and organization Biological macromolecules, Molecular receptors and design principal, cryptands, Cyclophanes, calixerenes and cyclodextrins. Supramolecular reactivity and catalysis.

UNIT-IV

NUCLEAR AND RADIOCHEMISTRY

NUCLEAR THEORY :

Nuclear cross section and nuclear radii, nuclear shells and magic numbers, theory of nuclear shell model, nuclear potentials, square well and simple harmonic oscillator potentials, application, liquid drop model, semi-empirical mass equation, application and limitations.

NUCLEAR FISSION :

Mass, energy and charge distribution of fission products, decay chains, prompt and neutrons, liquid drop model of nuclear fission.

NUCLEAR ENERGY :

Nuclear fission, chain reaction, multiplication factor, nuclear reactors

APPLIED RADIOCHEMISTRY :

Radioactive isotopes, purity and strength of radioisotopes. Radiochemical principle in the use of tracers, Application of Tracers in Chemical investigations, Physico-chemical methods, Analytical applications, Age determinations, Medical applications, Agricultural application.

BOOKS SUGGESTED:

1. Nuclear and Radiochemistry by G. Friedlander, J.W. Kennedy & J.M. Miller, John Willey and Sons, New York.
2. Source Book an Atomic Energy – S. Glasstone, Affiliated East –West Press Pvt. Ltd. New Delhi.
3. Nuclear Physics by I. Kaplan, Addison –Willey Publishing company, London.
4. Nuclear Chemistry and its applications, M. Haissinsky, Addison –Welsley, Publishing Company, London.
5. Essentials of Nuclear chemistry, H.J. Arnikar, Wiley Eastern Ltd, New Delhi.
6. Molecular Mechanics, U. Burkert and N.L. Allinger, ACS Monograph 177, 1982.
7. Mechanism and Theory in Organic Chemistry, T.H. Lowry and K.C. Richardson, Harper and Row.
8. Introduction to Theoretical Organic Chemistry and Molecular Modelling, W.B. Smith, VCH, Weinheim.
9. Physical Organic Chemistry, N.S. Isaacs, ELBS./ Longman.
10. Supramolecular Chemistry: concept and Perspectives, J.M. Lehn, VCH.
11. The Chemistry Mathematics Book, E. Steiner, Oxford University Press.
12. Chemical Mathematics, D.M, Hirst, Longman.
13. Applied Mathematics for Physical Chemistry, J.R. Barrante, Prentice Hall.
14. Quantum Chemistry, Ira N. Levine, Prentice Hall.
15. Introduction to Quantum Chemistry, A.K. Chandra, Tata McGraw Hill.

PAPER NO 4. CH - 404

ENVIRONMENTAL & APPLIED CHEMICAL ANALYSIS

Max. Marks 80

UNIT –I

AIR POLLUTION MONITORING AND ANALYSIS

Classification of air pollution monitoring levels, air quality, standards and index, monitoring and analysis of selected air borne pollutants: SO₂, NO_x, SPM, VOC's, Pb, CO₂, POP's, Hg, carbon and ozone. Air pollution control devices Viz ESP, scrubber technique, baghouse filters etc. Atmospheric chemistry of acid rains, photochemical smog, green house effect, global warming, ozone hole.

UNIT –II

SOIL AND WATER POLLUTION

Soil and water quality standards, monitoring and analysis of selected soil water contaminants: COD, pesticides, heavy metals, POPs, fluoride, cyanide, nitrate, phosphate, oil & grease, Geobiochemical impact of municipal solid waste, steel plants effluent, domestic sewage. Control devices of water pollutants.

UNIT –III

FOOD ANALYSIS

- A. Introduction to general Constituents of food, Proximate Constituents and their analysis, Additives-Introduction -Types - Study of preservatives colors and Antioxidants and method of estimation, adulteration - Introduction, Types, Test for adulterants.
- B. Introduction standards composition and analysis of following foods : Wheat, Bread, Biscuits, Jam, Jelly, Honey, Milk, Ice Cream, Butter, Cheese, Milk Powder, Oils and Fats, Tea, Coffee, Soft drinks, Alcoholic beverages, Cereal and pulses, Confectionery, Fruits, Vegetables, Egg, Fish, Meat.

UNIT –IV

COSMETICS, CLINICAL AND DRUG ANALYSIS

- A. Introduction of Cosmetics, evaluation of cosmetics materials, raw material and additives, Cosmetics colors, Perfumes in cosmetics, Cosmetics formulating, introduction, standards and methods of analysis, Creams, face powders, Make-up, Shaving preparations, Bath preparations.
- B. Concepts and principles of analytic methods commonly used in the clinical species: i.e. ammonia, blood urea Nitrogen, Ca, Cl, CO₂, Fe, K, Li, Mg, Na, P, urea, glucose.
Method for analysis of proteins (i.e. albumin, bilirubin, creatinine, cholesterol, HDL-cholesterol, triglycerides, creatinine) and Enzymes (i.e. Alanine Aminotransferase, acid phosphatase, alkaline phosphatase, amylase, aspartate, aminotransferase, cholinesterase, lactate, and lipase).

BOOK SUGGESTED :

1. Environmental Chemistry, S.E. Manahan, Lewis Publishers.
 2. Environmental chemistry, Sharma and Kaur, Krishna Publishers.
 3. Environmental Chemistry, A.K. De, Wiley Eastern.
 4. Environmental Chemistry, Analysis, S.M. Khopkar, Wiley Eastern.
 5. Standard Method of Chemical Analysis, F.J. Welcher Vol. III, Van Nostrand Reinhold Co.
 6. Environmental Toxicology, Ed. J. Rose, Gordon and Breach Science Publication.
 7. Environmental Chemistry, C. Baird, W.H. Freeman.
 8. Analytical chemistry, G.D. Christian, J. Wiley.
 9. Fundamentals of Analytical Chemistry, D.A. Skoog, D.m. West and F.J. Holler, W.B. Saunders.
 10. Analytical Chemistry - Principles, J.H. Kennedy, W. Saunders.
 11. Analytical Chemistry-Principles, and Techniques, L.G. Hargis, Prentice Hall.
 12. Principles of Instrumental Analysis, D.A. Skoog and J.L. Loary, W.B. Saunders.
 13. Principles of Instrumental Analysis, D.A. Skoog, W.B. Saunders.
 14. Quantitative Analysis, R.A. Day, Jr. and A.L. Underwood, Prentice Hall.
 15. Environmental Solution Analysis, S.M. Khopkar, Wiley Eastern.
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16. Basic Concepts of Analytical Chemistry, S.M. Khopkar, Wiley Eastern.
17. Handbook of Instrumental Techniques for Analytical Chemistry, F. Settle, Prentice Hall.
18. Environmental Biotechnology, Indushekar Thakur, I.K. International Pvt. Ltd.
19. Fundamental of Analytical Chemistry, D.A. Skoog, D.M. West, F.J. Holler and S.R. Crouch, Thompson Learning Inc.
20. APHA, 1977, "Methods of Analysis of air, water and soil" Washington US.