SEMESTER I

24PCH101: Structure and Mechanism in Organic Chemistry

Unit 1: Methods of Determination of Reaction Mechanism

Reaction intermediates, Transition state, Reaction coordinate diagrams, Thermodynamic and kinetic requirements of reactions: Hammond postulate. Methods of determining mechanism: non-kinetic methods - product analysis, determination of intermediates-isolation, detection, and trapping. Cross-over experiments, isotopic labelling, isotope effects and stereo chemical evidences. Kinetic methods - relation of rate and mechanism. Effect of structure on reactivity: Hammett and Taft equations. Linear free energy relationship, partial rate factor, substituent and reaction constants.

Unit 2: Aromaticity

Aromatic character: Five-, six-, seven-, and eight-membered rings-other systems with aromatic sextets – Huckel's theory of aromaticity,Craig's rule- concept of homoaromaticity and antiaromaticity. – NMR concept of aromaticity and antiaromaticitynon benzeniod aromatic compounds- systems with 2,4,8 and 10 electrons, systems of more than 10 electrons (annulenes), Mobius aromaticity. alternant and non-alternant hydrocarbons (azulene type) – aromaticity in heteroaromatic molecules, sydnones and fullerenes.

Unit 3: Aromatic and Aliphatic Electrophilic Substitution

Aromatic electrophilic substitution: Orientation and reactivity of di- and polysubstituted phenol, nitrobenzene and halobenzene. Reactions involving nitrogen electrophiles: nitration, nitrosation and diazonium coupling; Sulphur electrophiles: sulphonation; Halogen electrophiles: chlorination and bromination; Carbon electrophiles: Friedel-Crafts alkylation, acylation and arylation reactions. Aliphatic electrophilic substitution Mechanisms: SE2 and SEi, SE1- Mechanism and evidences.

Unit 4: Stereochemistry

Stereoisomerism – symmetry – enantiomers and diastereomers – *R* and *S* nomenclature – optical activity and chirality – types of molecules exhibiting optical activity – absolute

configuration – chirality in molecules with non carbon stereocenters (N, S and P) – molecules with more than one chiral centre – atropisomerism.Molecular chirality – allenes, spiranes, biphenyls, helicenes and cyclophanes – methods of determining configuration – *E* and *Z* nomenclature – determination of configuration of geometrical isomers – stereochemistry of addition and elimination reactions – stereospecific and stereoselective synthesis [elementary examples]. Basic concepts of conformational analysis – conformations of cyclopentane, cyclohexane, cyclohexene and fused (decalin) and bridged (norbornane type) ring systems – anomeric effect in cyclic compounds.

Unit 5: Aliphatic and Aromatic Nucleophilic Substitution:

S_N1, ion pair, S_N2 mechanisms and evidences. Aliphatic nucleophilic substitutions at an allylic carbon, aliphatic trigonal carbon and vinyl carbon.S_N1, S_N2, S_Ni, and S_E1 mechanism and evidences, Swain- Scott, Grunwald-Winstein relationship - Ambident nucleophiles. Aromatic nucleophilic substitution: Mechanisms - S_NAr, S_N1 and Benzyne mechanisms - Evidences - Reactivity, Effect of structure, leaving group and attackingnucleophile. Reactions: Oxygen and Sulphur-nucleophiles, Bucherer and Rosenmund reactions, von Richter, Sommelet- Hauser and Smiles rearrangements.

Text Books:

Units 1, 2, 3 & 5

1. J. March and M. Smith, Advanced Organic Chemistry, 5th edition, John-Wiley and Sons.2001.
2. S. H. Pine and J. B. Hendrickson, D. J. Cram and G. S. Hammond, Organic Chemistry; 5th Ed., McGraw Hill, Noida, 1987..

Unit 4

1. P. S. Kalsi, Stereochemistry of carbon compounds, 8th edition, New Age International Publishers, 2015.

24PCH102: Structure and Bonding in Inorganic Compounds

Unit 1: Structure of main group compounds and clusters

VB theory – Effect of lone pair and electronegativity of atoms (Bent's rule) on the geometry of the molecules; Structure of silicates - applications of Paulings rule of electrovalence - isomorphous replacements in silicates – ortho, meta and pyro silicates – one dimensional, two dimensional and three-dimensional silicates. Structure of silicones, Structural and bonding features of B-N, S-N and P-N compounds; Poly acids – types, examples and structures; Borane cluster: Structural features of closo, nido, arachano and klado; carboranes, hetero and metalloboranes; Wade's rule to predict the structure of borane cluster; main group clusters –zintl ions and mno rule.

Unit 2: Solid state chemistry – I

Ionic crystals: Packing of ions in simple, hexagonal and cubic close packing, voids in crystal lattice, Radius ratio, Crystal systems and Bravis lattices, Symmetry operations in crystals, glide planes and screw axis; point group and space group; Solid state energetics: Lattice energy – Born-Lande equation - Kapustinski equation, Madelung constant.

Unit 3: Solid state chemistry – II

Structural features of the crystal systems: Rock salt, zinc blende & wurtzite, fluorite and anti-fluorite, rutile and anatase, cadmium iodide and nickel arsenide; Spinels -normal and inverse types and perovskite structures. Crystal Growth methods: From melt and solution (hydrothermal, sol-gel methods) – principles and examples.

Unit 4: Techniques in solid state chemistry

X-ray diffraction technique: Bragg's law, Powder diffraction method – Principle and Instrumentation; Interpretation of XRD data – JCPDS files, Phase purity, Scherrer formula, lattice constants calculation; Systematic absence of reflections; Electron diffraction technique – principle, instrumentation and application. Electron microscopy – difference between optical and electron microscopy, theory, principle, instrumentation, sampling methods and applications of SEM and TEM.

Unit 5: Band theory and defects in solids

Band theory – features and its application of conductors, insulators and semiconductors, Intrinsic and extrinsic semiconductors; Defects in crystals – point defects (Schottky, Frenkel, metal excess and metal deficient) and their effect on the electrical and optical property, laser and phosphors; Linear defects and its effects due to dislocations.

Text Books:

Units 1 to 5

1. A R West, Solid state Chemistry and its applications, 2nd Edition (Students Edition), John Wiley & Sons Ltd., 2014.
2. J D Lee, Concise Inorganic Chemistry, 5th Edition, Wiley India Edition, 2008.
3. B.R. Puri, L.R. Sharma, K.K. Kalia, Principles of Inorganic Chemistry, 33rd edition, New Delhi, ShobanLalNagin Chand & Co., (2020).
4. R Mukhopadhyay Wiley Engineering Chemistry, Second edition, 2013.

24PCH103: Thermodynamics and Kinetics

Unit 1: Classical Thermodynamics:

Partial molar properties-Chemical potential, Gibb's- Duhem equation-binary and ternary systems. Determination of partial molar quantities. Thermodynamics of real gases - Fugacity-determination of fugacity by graphical and equation of state methods-dependence of temperature, pressure and composition. Thermodynamics of ideal and non-ideal binary mixtures, Duhem - Margulus equation applications of ideal and non-ideal mixtures. Activity and activity coefficients-standard states - determination-vapour pressure, EMF and freezing point methods.

Unit 2: Statistical thermodynamics:

Introduction of statistical thermodynamics concepts of thermodynamic and mathematical probabilities-distribution of distinguishable and non-distinguishable particles. Assemblies, ensembles, canonical particles. Maxwell - Boltzmann, Fermi Dirac & Bose-Einstein Statistics- comparison and applications. Partition functions-evaluation of translational, vibrational and rotational partition functions for monoatomic, diatomic and polyatomic ideal gases.

Unit 3: Irreversible Thermodynamics

Theories of conservation of mass and energy, entropy production in open systems by heat, matter and current flow, force and flux concepts. Onsager theory-validity and verification-Onsager reciprocal relationships. Electro kinetic and thermo mechanical effects-Application of irreversible thermodynamics to biological systems.

Unit 4: Kinetics of Reactions

Theories of reactions-effect of temperature on reaction rates, collision theory of reaction rates, Unimolecular reactions -Lindeman and Christiansen hypothesis- molecular beams, collision cross sections, effectiveness of collisions, Potential energy surfaces. Transition state theory-evaluation of thermodynamic parameters of activation-applications of ARRT to reactions between atoms and molecules, time and true order-kinetic parameter evaluation. Factors

determine the reaction rates in solution - primary salt effect and secondary salt effect, Homogeneous catalysis- acid- base catalysis-mechanism of acid base catalyzed reactions-Bronsted catalysis law, enzyme catalysis-Michelis-Menton catalysis.

Unit 5: Kinetics of complex and fast reactions

Kinetics of complex reactions, reversible reactions, consecutive reactions, parallel reactions, chain reactions. Chain reactions-chain length, kinetics of H_2 – Cl_2 & H_2 – Br_2 reactions (Thermal and Photochemical reactions) - Rice Herzfeld mechanism. Study of fast reactions-relaxation methods- temperature and pressure jump methods electric and magnetic field jump methods -stopped flow flash photolysis methods and pulse radiolysis. Kinetics of polymerization-free radical, cationic, anionic polymerization - Polycondensation.

Text Books:

Units 1, 2 & 3

1. J. Rajaram and J.C. Kuriacose, Thermodynamics for Students of Chemistry, 2nd edition, S.L.N.Chand and Co., Jalandhar, 1986.
2. M.C. Gupta, Statistical Thermodynamics, New Age International, Pvt. Ltd., New Delhi, 1995.

Units 4 & 5

3. K.J. Laidler, Chemical Kinetics, 3rd edition, Pearson, Reprint - 2013.
4. J. Rajaram and J.C. Kuriokose, Kinetics and Mechanisms of chemical transformation, Macmillan India Ltd, Reprint - 2011.

24PCH201: Nanotechnology

Unit 1: Introduction to Nanotechnology

Definition and history of nanotechnology - unique properties due to nanosize, quantum dots, classification of nanomaterials. . Fundamentals of crystal structures – nucleation, crystal growth and material parameters – Basics of Quantum confinement

Unit 2: Synthesis of Nanomaterials

General methods of synthesis of nanomaterials – hydrothermal synthesis, solvothermal synthesis – microwave irradiation– sol-gel and precipitation technologies – combustion flame – chemical vapour condensation process – gas-phase condensation synthesis – reverse micelle synthesis – polymer-mediated synthesis – protein microtubule-mediated synthesis – synthesis of nanomaterials using microorganisms and other biological agents – sonochemical synthesis – hydrodynamic cavitation.

Unit 3: Characterization Techniques

Principles of Atomic Force Microscopy (AFM) – Transmission Electron Microscopy (TEM) Resolution and Scanning Transmission Electron Microscopy (STEM) – Scanning Tunneling Microscopy (STM) – Scanning Nearfield Optical Microscopy (SNOM). Scanning probe microscopes – X-ray Diffraction

Unit 4: Properties of Nanomaterials

Optical properties - quantum dots, surface plasmon resonance. Electrical properties - conductivity, semiconductors. Mechanical properties - strength, flexibility. Magnetic properties - superparamagnetism, ferromagnetism.

Unit 5: Applications of Nanotechnology

Nanomedicine - drug delivery, imaging, diagnostics. Nanoelectronics - transistors, sensors, quantum computing. Environmental applications - water purification, air filtration. Energy applications - solar cells, batteries, fuel cells.

Text Books:

Unit 1

1. Phani Kumar, Principles of Nanotechnology, Scitech Publications, 2010.

Unit 2

2. T Pradeep, Nano: The Essentials – Understanding Nanoscience and Nanotechnology, Mc-Graw-Hill Education, 2017.

Unit 3 & 5

3. Er. Rakesh Rathi, Nanotechnology (Technology Revolution of 21st Century, S. Chand, 2010.

Unit 3 & 4

4. Thomas Varghese, K. M. Balakrishna, Nanotechnology: An Introduction to synthesis, Properties and Applications of Nanomaterials, Atlantic Publishers and Distributors, 2012.

Unit 5

5. Manoj Bhatia, Nanotechnology, Anmol Publications PVT. Ltd., 2010.

24PCH213: Principles of Green Chemistry

Unit 1: Introduction

Introduction- Need for Green Chemistry. Goals of Green Chemistry. Limitations of Green Chemistry. Chemical accidents, terminologies, International green chemistry organizations and Twelve principles of Green Chemistry with examples.

Unit 2: Designing a Green Reaction

Choice of starting materials, reagents, catalysts and solvents in detail, Green chemistry in day today life. Designing green synthesis-green reagents: dimethyl carbonate. Green solvents: Water, Ionic liquids-criteria, general methods of preparation, effect on organic reaction. Supercritical carbon dioxide- properties, advantages, drawbacks and a few examples of organic reactions in $scCO_2$. Green synthesis-adipic acid and catechol.

Unit 3: Green Catalysts

Environmental pollution, Green Catalysis-Acid catalysts, Oxidation catalysts, Basic catalysts, Polymer supported catalysts-Poly styrene aluminum chloride, polymeric super acid catalysts, Poly supported photosensitizers.

Unit 4: Green Reactions

Phase transfer catalysis in green synthesis-oxidation using hydrogen peroxide, crown ethers-esterification, saponification, anhydride formation, Elimination reaction, Displacement reaction. Applications in organic synthesis.

Unit 5: Microwave Assisted and Sonication

Micro wave induced green synthesis-Introduction, Instrumentation, Principle and applications. Sonochemistry – Instrumentation, Cavitation theory - Ultra sound assisted green synthesis and Applications.

Text Books:

Units 1 - 5

1. V.K. Ahluwalia, Green Chemistry; 2nd Ed., Ane Books Pvt Ltd., New Delhi, 2016.

2. Ahluwalia, V.K. and Kidwai, M.R. New Trends in Green Chemistry, Anamalaya Publishers, 2005.

24PCH301: Inorganic Qualitative Analysis and Estimation of Metal ions Lab

Experiments:

1. Analysis of two common and two rare earth elements in a given inorganic mixture

   Common: Pb, Cu, Bi, Cd, Zn, Co, Ni, Ca, Ba, Sr

   Rare: W, Se, Te, Mo, Ce, Zr, Th, V, Li

2. Colorimetric Estimation: Cu, Fe, Mn, Ni, Cr

References:

1. V. V. Ramanujam, Inorganic Semimicro Qualitative Analysis; 3rd Ed., National Pubs, London, 1988.
2. G. Svehla, Text Book of Macro and Semimicro Qualitative Inorganic Analysis; 5th Ed., Longman group Ltd, London, 1987.
3. A. I. Vogel, Text Book of Quantitative Inorganic Analysis; 6th Ed., Longman, New Delhi, 2000.

24PCH104: Organic Chemistry II

Unit 1: Addition Reactions

Addition to carbon-carbon multiple bonds – electrophilic, nucleophilic and free radical additions – stereochemical factors influencing the addition of bromine and hydrogen bromide, hydroxylation, 1,2-dihydroxylation – hydroboration leading to formation of alcohols – oxidation and ozonolysis. Addition to carbonyl and conjugated carbonyl systems – mechanism – Grignard reagents – 1,2- and 1,4-additions (lithium dimethylcuprate).

Unit 2: Elimination Reactions

Elimination reactions – mechanisms; E1, E2, E1cB – stereochemistry of elimination, Hofmann's and Zaitsev's rules – Competition between elimination and substitution – pyrolytic *cis*-elimination, Hofmann degradation, Cope elimination – Bredt's rule with examples.

Unit 3: Oxidation Reactions

Mechanism of oxidation reactions: Dehydrogenation by quinones, selenium dioxides, ferricyanide, mercuric acetate, lead tetra acetate, permanganate, manganese dioxide, osmium tetroxide, oxidation of saturated hydrocarbons, alkyl groups, alcohols, halides and amines. Reactions involving cleavage of C-C bonds - cleavage of double bonds, oxidative decarboxylation, allylic oxidation, oxidation by chromium trioxide - pyridine, Swern oxidation, Corey-Kim oxidation and Moffatt Oxidation

Unit 4: Reduction Reactions

Mechanism of reduction reactions: Wolff-Kishner, Clemmenson, Rosenmund, reduction with Trialkyl and triphenyltin hydrides, McFadyen-Steven's reduction, Homogeneous hydrogenation, Hydroboration with cyclic systems, MPV and Bouveault-Blanc reduction.

Unit 5 Rearrangements:

Rearrangements to electron deficient carbon: Pinacol-pinacolone and semi-pinacolone rearrangements, Wagner-Meerwein, Dienone-phenol, Baker-Venkataraman, Benzilic acid and Wolff rearrangements.

Rearrangements to electron deficient nitrogen: Hofmann, Curtius, Schmidt, Lossen, Beckmann rearrangements. Rearrangements to electron deficient oxygen: Baeyer-Villiger oxidation and Dakin rearrangements.

Rearrangements to electron rich atom: Favorskii, Quasi-Favorskii, Stevens, [1,2]-Wittig and [2,3]-Wittig rearrangements. Intramolecular rearrangements – Claisen, Cope, oxy-Cope and Benzidine rearrangements.

Text Books:

1. S. H. Pine and J. B. Hendrickson, D. J. Cram and G. S. Hammond, Organic Chemistry; Special Ed., McGraw Hill, Noida, 2006.
2. R. T. Morrison, R. N. Boyd, S. K. Bhattacharjee, Organic Chemistry, 7th Ed., Pearson Education, 2010.
3. Jie Jack Li, Name Reactions – A Collection of Detailed Reaction Mechanism; 6th Ed., Springer, 2021.

Reference Books:

1. T. H. E. Lowry and K. S. Richardson, Mechanism and Theory in Organic Chemistry; 3rd Ed., Benjamin - Cummings Publishing, USA, 1997.
2. J. March and M. B. Smith, Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 6th Ed., Wiley, New York, 2007.
3. R. K. Bansal, Reaction Mechanism in Organic Chemistry; Tata McGraw Hill, Noida, 1990.
4. J. Clayden, N. Greeves, S. Warren, and P. Wothers, Organic Chemistry, 2nd Ed., Oxford University Press, UK, 2012.
5. F. A. Carey, and R. J. Sundberg, Advanced Organic Chemistry, Parts A and B, 5th Ed., Springer, Germany, 2007.

24PCH105: Coordination Chemistry and Organometallics

Unit 1: Modern theories of coordination compounds

Crystal field theory; CFT for octahedral, tetrahedral and square planner complexes; measurement of 10Dq - factors affecting 10Dq; John-Teller effect and its consequences, spectro chemical series, limitation of crystal field theory; Molecular orbital theory for octahedral, tetrahedral complexes, Ligand field theory.

Unit 2: Spectral characteristics of complexes

Term states for d ions - characteristics of d-d transitions - charge transfer spectra - selection rules for electronic spectra - Orgel correlation diagrams - Sugano-Tanabe energy level diagrams - nephelauxetic series - Racha parameter and calculation of inter-electronic repulsion parameter

Unit 3: Electron Transfer reactions.

Outer sphere electron transfer reactions and Marcus-Hush theory; inner sphere electron transfer reactions; nature of the bridging ligand in inner sphere electron transfer reactions. Photo-redox, photo-substitution and photo-isomerisation reactions in complexes and their applications.

Unit 4: Organometallics

Hapticity - The 18 electron rule – applications and limitations – preparation, properties, structure and bonding in metal carbonyls, metal nitrosyls – metal alkenes (Zeise salt)- metal alkyne – metallocene (Ferrocene)- metal arenes- dinitrogen complexes – fluxional molecules.Isolobal concept and its applications.

Unit 5: Catalysis in Organometallics

Organometallic reactions – ligand association and dissociation – oxidative addition and reductive elimination – insertion reactions- reactions of coordinated ligands. Hydrogenation of olefins (Wilkinson’s catalyst), hydroformylation(Oxo process), olefin oxidation (Wacker process) and carbonylation of methanol (acetic acid synthesis)- epoxidation of olefin, polymerization of olefins (Ziegler Natta catalyst)- olefin metathesis.

Text Books:

1. Ajai Kumar, Coordination Chemistry , 7th Edition, 2020. – Unit – I, II, III.
2. R.C. Mehrotra & A. Singh, Organometallic Chemistry: A Unified Approach, 2nd Edition, 2020. Unit – IV, V.

Reference Books:

1. Huheey J. E., Keiter E. A. and Keiter R. L. and Medhi O. K., Inorganic Chemistry - Principles of Structure and Reactivity, 4th edition, Pearson Education, 2006.
2. Atkins, P. W.; Paula, J.; Physical Chemistry, Oxford Publications, 8th edition, 2009.
3. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, ed., Wiley-Eastern Company, New Delhi, 1990.
4. Day, M. C., and Selbin, J., Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd. 2nd edition, 1985.
5. Kettle, S. F. A., Physical Inorganic Chemistry – A Coordination Chemistry Approach, Spectrum Academic Publishers, Oxford University Press, 1996.

24PCH106: Physical Chemistry II

Unit 1: Basic Quantum Mechanics

Inadequacy of classical mechanics – black body radiation – photoelectric effect – Bohr's theory of hydrogen atom – hydrogen spectra – wave-particle dualism – uncertainty principle ,Schrödinger equation – postulates of quantum mechanics – operator algebra: linear operator, Hermitian operators, eigenfunctions and eigen values, Applications of wave mechanics to simple systems – particle in a box, one and three dimensional,.

Unit 2: Quantum Chemistry – Applications

Applications of wave mechanics – the harmonic oscillator, rigid rotator – hydrogen like atoms – perturbation method systems. Electron spin – many electron atoms – Pauli's principle – Slater determinant spin-orbit interaction. Molecular Quantum Mechanics: Born-Oppenheimer approximation-MO and VB treatments of hydrogen molecule comparison– hybridization, solving wave equation for sp, sp2 and sp3 hybrid orbitals – Huckel's molecular orbital theory .

Unit 3: Group Theory I

Symmetry and group theory: Symmetry elements and operations – point groups –assignment of point groups to molecules – group postulates and types of groups –group multiplication tables, sub groups, similarity transformations – conjugate elements and classes. Matrix representation of symmetry operations and point groups – reducible and irreducible representations – properties of irreducible representation.

Unit 4: Group Theory II

The great orthogonality theorem – construction of character table (C2V & C3V)– direct product – projection operators – symmetry of hybrid orbitals. Applications: vibrational spectra – election rules for fundamental vibrational transition – IR and Raman activity of fundamentals in CO2, HO,N2F2–the rule of mutual exclusion and Fermi resonance.

Unit 5: Surface Chemistry

Adsorption of gases on solids – Langmuir theory-BET theory of multilayer adsorption-derivation of BET equation-surface area determination-adsorption from solutions-Gibbs adsorption isotherm – solid-liquid interfaces – contact angle and wetting. Homogeneous catalysis---General catalytic mechanism-Equilibrium and steady state treatments-acid-base catalysis

Text Books:

1. Levine, I. N.; Physical Chemistry, McGraw-Hill Science/Engineering/Math, 6^{th} edition, 2008.

Reference Books:

1. Jaffe, H. H.; Orchin, M.; Symmetry in Chemistry, John Wiley & Sons Inc., 2002
2. Atkins, P. W.; Paula, J.; Physical Chemistry, Oxford Publications, 8th edition, 2009.
3. Raff, L. M.; Principles of Physical Chemistry, Prentice Hall, 2001.
4. Lowe, J. P., Peterson, K.A., Quantum Chemistry, Academic press, 2011.

24PCH202: Carbon Nanomaterials

Unit 1: Introduction

Introduction – Carbon molecules, nature of the carbon bond, new carbon structures, discovery of C60-structure of C60 and its crystal, from a Graphene Sheet to a Nanotube, Single wall and Multi walled Nanotubes, Zigzag and Armchair Nanotubes, Nomenclature, Euler's Theorem.

Unit 2: Structure of Higher Fullerenes

Structure of Higher Fullerenes, Growth Mechanisms; Production and Purification- Fullerene Preparation by Pyrolysis of Hydrocarbons, Partial Combustion of Hydrocarbons, Arc Discharge Methods, Physical Properties.

Unit 3: Spectroscopic Properties of Carbon Nanotubes

Spectroscopic Properties of Carbon Nanotubes- Raman and Infrared Spectroscopy of Carbon Nanotubes, Absorption and Emission Spectroscopy of Carbon Nanotubes.

Unit 4: Graphenes

Structure of graphene; Preparation of graphene – synthesis of graphene by various physical and chemical methods and Purification; Electronic Properties Band Structure of Graphene - Mobility and Density of Carriers, Spectroscopic Properties of graphene - Raman, Application of Fullerene, CNT, Graphene.

Unit 5: Assessment of Nanomaterial Toxicity

Assessment of nanomaterial toxicity: In vitro toxicity assessment-cell viability, reactive oxygen species generation. In vivo toxicity assessment: inflammatory response, acute toxicity studies, LD50 determination.

Textbooks

1. Swathi Sharma, Carbon for Micro and Nano Devices De Gruyter; 1st edition (18 March 2024)

References:

1. Handbook of Endofullerenes and Carbon Nanocapsules (In 2 Volumes)
2. Handbook of Polymer Structures of Nanocarbon: Formation and Applications (In 2 Volumes)
3. Handbook of Carbon Nano-Based Energy Conversion and Storage (In 2 Volumes)
4. Handbook of Carbon Nano-Based Devices and Sensors (In 2 Volumes)
5. Handbook of Chemical Functionalization in Carbon Nanoscience (In 2 Volumes)

24PCH214: Renewable Feedstock and Biomass Conversion

Unit 1: Introduction

Primary energy sources, renewable vs. non-renewable primary energy sources, renewable energy resources in India, Current usage of renewable energy sources in India, future potential of renewable energy in power production and development of renewable energy technologies.

Unit 2: Solar Energy

Solar Radiation and its measurements, Solar Thermal Energy Conversion from plate Solar Collectors, Concentrating Collectors and its Types, Efficiency and performance of collectors, Direct Solar Electricity Conversion from Photovoltaic, types of solar cells and its application of battery charger, domestic lighting, street lighting, and water pumping, power generation schemes. Recent Advances in PV Applications: Building Integrated PV, Grid Connected PV Systems

Unit 3: Wind Energy

Wind energy principles, wind site and its resource assessment, wind assessment, Factors influencing wind, wind turbine components, wind energy conversion systems (WECS), Classification of WECS devices, wind electric generating and control systems, characteristics and applications.

Unit 4: Bio-Energy

Energy from biomass, Principle of biomass conversion technologies/process and their classification, Bio gas generation, types of biogas plants, selection of site for biogas plant, classification of biogas plants, Advantage and disadvantages of biogas generation, thermal gasification of biomass, biomass gasifies, Application of biomass and biogas plants and their economics.

Unit 5: Other Types of Energy

Energy conversion from Hydrogen and Fuel cells, Geo thermal energy Resources, types of wells, methods of harnessing the energy, potential in India. OTEC, Principles utilization, setting of

OTEC plants, thermodynamic cycles. Tidal and wave energy: Potential and conversion techniques, mini-hydel power plants and their economics.

References

1. Twidell & Wier,'Renewable Energy Resources' CRC Press(Taylor & Francis).
2. Tiwari and Ghosal/ Narosa,'Renewable energy resources'.
3. D.P.Kothari, K.C.Singhal,'Renewable energy sources and emerging technologies', P.H.I.
4. D.S.Chauhan, S.K. Srivastava, 'Non – Conventional Energy Resources', New Age Publishers, 2006.
5. B.H.Khan, 'Non – Conventional Energy Resources', Tata Mc Graw Hill, 2006.8. K. Bagavathi Sundari (2006), Applied Chemistry, MJP Publishers.

Semester III

24PCH107: Organic Synthesis and Photochemistry

Unit – 1: Retro Synthetic Analysis I

Introduction to disconnections – Synthons and Synthetic Equivalents – electron donors (Nucleophiles) – electron acceptors (Electrophiles). Introduction of functional groups – Umpolung reactions – one group disconnections: alcohols, olefins, ketones, acids – two group disconnections: 1,2 -, 1,3 -, 1,4 -, and 1,5 – difunctional compounds – convergent syntheses

Unit – 2: Retro Synthetic Analysis II

Functional group Interconversion – functional group addition – carbon hetero atom bonds – methods for 3- and 4- membered rings – synthesis of mono and difunctional open chain molecules – mono and bicyclic molecules with substituents

Unit – 3: Pericyclic Reactions:

Concerted reactions- stereochemistry- orbital symmetry and correlation diagram Frontier molecular orbital approach- Woodward- Hoffmann rules- electrocyclic reactions, cycloaddition reactions- selection rules- sigmatropic rearrangements- selection rules with examples- 1,3 and 1,5 hydrogen shifts- Cope and Claisen rearrangements.

Unit – 4: Organic Photochemistry – I

Photochemical excitation: Experimental techniques; electronic transitions; Jablonskii diagrams; intersystem crossings; energy transfer processes; Stern Volmer equation. Reactions of electronically excited ketones; $\pi \rightarrow \pi^*$ triplets; Norrish type-I and type-II cleavage reactions; photo reductions; Paterno-Buchi reactions;

Unit – 5: Organic Photochemistry – II

Photochemistry of α,β - unsaturated ketones; cis-trans somerization. Photon energy transfer reactions, Photo cycloadditions, Photochemistry of aromatic compounds; photochemical rearrangements; di-π-methane rearrangement; Reaction of conjugated cyclohexadienone to 3,4-diphenyl phenols; Barton's reaction.

Reference Books:

1. S. Warren, Designing Organic Synthesis: The Disconnection Approach; 2nd Ed., Wiley, New York, 2008.
2. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Parts A and B, 5th Ed., Springer, Germany, 2007.
3. S. Sankararaman, Pericyclic Reactions - A Textbook: Reactions, Applications and Theory; Wiley-VCH, New York, 2005.
4. J. D. Coyle, Organic Photochemistry; Wiley, New York, 1998.
5. J. M. Coxon, and B. Halton, Organic Photochemistry; 2nd Ed., Cambridge, University Press, UK, 1987.

24PCH108: Advanced Coordination Chemistry

Unit 1: General Principles of Bioinorganic Chemistry

Occurrence and availability of inorganic elements in biological systems – bio mineralization – control and assembly of advanced materials in biology – nucleation and crystal growth – various bio minerals – calcium phosphate – calcium carbonate and iron bio minerals – Function and transport of alkali and alkaline earth metal ions: characterization of Ca^{2+} and Mg^{2+} – complexes of alkali and alkaline earth metal ions with macro cycles – ion channels – ion pumps, catalysis and regulation of bio energetic processes by the alkaline earth metal ions – Mg^{2+} and Ca^{2+}.

Unit 2: Heme and Non-Heme Proteins and Enzymes

Heme and non-heme proteins – haemoglobin and myoglobin – oxygen transport and storage – electron transfer and oxygen activation – cytochromes, ferredoxins and rubredoxin – model systems, mononuclear non-heme iron enzymes. Copper containing proteins – classification and examples – electron transfer – oxygen transport-oxygenation – oxidases and reductases – cytochrome oxidase – superoxide dismutase (Cu, Zn) – nickel containing enzyme: urease.

Unit 3: Medicinal Bioinorganic Chemistry

Bioinorganic chemistry of essentially toxic metals – lead, aluminium and chromium – detoxification by metal chelation – drugs that act by binding at the metal sites of metalloenzymes. Chemotherapy – chemotherapy with compounds of certain non-essential elements – platinum complexes in cancer therapy – cisplatin and its mode of action – cytotoxic compounds of other metals. Gold containing drugs as anti-rheumatic agents and their mode of action - radiopharmaceuticals – technetium.

Unit 4: Principles of Photochemistry

Absorption, excitation, photochemical laws, quantum yield. Absorption and emission for complexes with different ground state /excited state for ML_6 complexes. Potential energy function and energy levels for ML_6 complexes. Flash photolysis, stopped flow techniques. Energy dissipation by radiative and non-radiative processes, absorption

spectra. Frank-Codon principle, photochemical stages – primary and secondary processes. Jablonski diagram for photochemical process.

Unit 5: Photochemical Properties of Transition Metal Complex

Photo physical process, Photochemical process, Photo rearrangement reaction, Prompt and Delayed Photochemical reactions, Photolysis rules and ligand field theory. Photo chemistry of Cr (III) complex – Photo Substitution, Photo aquation reactions, Photo isomersation, Photo Racemization Photochemistry of Co (III) complex – Energy level diagram, Co (III) Cyanide Complex.

Text Books:

1.S.J, Lippard and J.M Berg,Principles of Bioinorganic Chemistry 1994

2.Ferraudi, G.J Elements of Inorganic Photochemistry,Wiley 2000

3.Williams, D.R-Introduction to Bioinorganic Chemistry 2019

Reference Books:

1. Huheey J. E., Keiter E. A. and Keiter R. L. and Medhi O. K., Inorganic Chemistry - Principles of Structure and Reactivity, 4th edition, Pearson Education, 2006.

2. Atkins, P. W.; Paula, J.; Physical Chemistry, Oxford Publications, 8th edition, 2009.

3. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, ed., Wiley-Eastern Company, New Delhi, 1990.

4. Day, M. C., and Selbin, J., Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd. 2nd edition, 1985.

5. Kettle, S. F. A., Physical Inorganic Chemistry – A Coordination Chemistry Approach, Spectrum Academic Publishers, Oxford University Press, 19

24PCH109: Electrochemistry and Spectroscopy

Unit 1: Electrochemistry I

Ion transport in solution – migration, convection and diffusion – Fick's laws of diffusion conduction – Debye-Huckel theory – ionic atmosphere – Debye- HuckelOnsager equation – verification and extension – Debye-Falkenhagen effect and Wien effect, Debye-Huckel limiting law – activity coefficients and ionic strength – Bjerrum model. The electrode – electrolyte interface – electrical double layer and multi layers – theories – electrocapillary curves – Lipmann equation and Lipmann potentialstructure of semiconductor interface-Garrett-Brattain space charge model. Electrokinetic phenomena -classification – Tiselius method of separation of proteins — electrocatalysis.

Unit 2: Electrochemistry II

Dynamics of electron transfer – Marcus theory – tunneling – the rate of charge transfer – current density – Butler-Volmer equation – Taft equation –Polarization and overvoltage – mechanism of hydrogen evolution and oxygen evolution reactions. Principles of electrode position of metals – corrosion and passivity – Pourbaix and Evans diagrams – methods of protection of metals from corrosion. Power storage systems – fuel cells – construction and functioning – applications– photovoltaic cells.

Unit 3: Spectroscopy I

Interaction of electromagnetic radiation with molecular systems – time evolution of the systems under radiation – Einstein transition probability for induced absorption and spontaneous and stimulated emission – absorption coeffients transition moment and oscillator strength. Microwave spectroscopy – rotational spectra of diatomic molecules, rigid and nonrigid rotors – intensity of spectral lines – effects of isotopic substitution – microwave spectra of polyatomic molecules – linear and symmetric top molecules –Stark effect

Unit 4: Spectroscopy II

Infrared spectra – diatomic molecules, simple harmonic and anharmonic oscillators – diatomic vibrating rotator rotation – vibration spectrum of carbon monoxide – interaction of rotation and vibration (breakdown of Born Oppenheimer approximation) – influence of the rotation on the spectrum of polyatomic molecules, linear and symmetric top molecules, parallel and perpendicular vibrations – influence of nuclear spin. Raman spectra - rotational Raman spectra of linear and symmetric top molecules – vibrational Raman spectra – rotational fine structure-polarization of light and Raman effect. Laser Raman spectroscopy- principle-applications.

Unit 5: Spectroscopy III

Electronic spectra of diatomic molecules- vibrational coarse structure – intensity of vibrational lines in electronic spectra – Franck-Condon principle predissociation-rotational fine structure- Fortratdiagram. Electronic spectra of poly atomic molecules. Photoelectron Spectroscopy: Basic Principles – Koopman's theorem – UPES, XPES (ESCA and Auger Spectroscopy) – valence and core binding analysis, examples and applications of ESCA with two examples.

TEXTBOOKS:

1. Allen J. Bard & Larry R. Faulkner Electrochemical Methods: Fundamentals and Applications, 2nd Edition (2001)
2. Peter Atkins & Julio de PaulaBahl**, Physical Chemistry** 11th Edition, (2018) Oxford University
3. Peter Atkins & Ronald Friedman Molecular Quantum Mechanics , 5th Edition 2011 Oxford University Press.
4. C.N. Banwell & E.M. McCash **Fundamentals of Molecular Spectroscopy**, 5th Edition 2017 McGraw-Hill Education

REFERENCE BOOKS:

1. Glasstone, Introduction to Electrochemistry; Maurice Press, Philadelphia, 2008.
2. L. Antropov, Theoretical Electrochemistry; University Press of the Pacific, USA, 2001.

3. S. Glasstone, An Introduction to Electrochemistry; Read Books, New Delhi, 2007.4.
4. J. O'M Bockris and A. K. N. Reddy, Modern Electrochemistry; Vol. 1 and 2, 2nd Ed., Plenum Press, New York, 1998.
5. W. Kemp, Organic Spectroscopy; 3rd Ed., Palgrave, New York, 2011.
6. J. R. Dyer, Applications of Absorption Spectroscopy of Organic Compounds, PHI Learning, New Delhi, 2009.
7. Y. R. Sharma, Elementary Organic Spectroscopy – Principles and Chemical Applications; S. Chand and Co., New Delhi, 1992.
8. P. S. Kalsi, Spectroscopy of Organic Compounds; 6th Ed., New Age International Publishers, New Delhi, 2004.

24PCH110: Analytical Chemistry

Unit 1: Data And Error Analysis

Various types of error – accuracy, precision, significant figures - Hypothesis testing, levels of confidence and significance, test for an outlier, testing variances, means t-Test, paired t-Test – analysis of variance (ANOVA) – correlation and regression. Curve fitting, fitting of linear equations, simple linear cases, weighted linear case, analysis of residuals – general polynomial equation fitting, linearizing transformations, exponential function fit – r and its abuse – multiple linear regression analysis, elementary aspects.

Unit 2: Instrumental Methods of Analysis

Principles and applications of extended X-ray absorption fine structure (EXAFS) – surface extended X-ray absorption (SEXAFS) – atomic absorption spectroscopy (AAS) – flame emission spectroscopy (FES) – turbidimetry – theory and applications. Instrumentation and sampling techniques in UV-visible and IR spectroscopy.

Unit 3: Chromatography

Solvent extraction – principles of ion exchange, paper, thin-layer and column chromatography techniques – columns, adsorbents, methods, Rfvalues, McReynold's constants and their uses – HPTLC, HPLC techniques – adsorbents, columns, detection methods, estimations, preparative column – GC-MS techniques – methods, principles and uses.

Unit 4: Thermoanalytical Methods and Fluorescence Spectroscopy

Principles – instrumentations and applications of thermogravimetry analysis (TGA), Differential Thermal Analysis (DTA) and Differential Scanning Calorimetry (DSC) – thermometric titrations – types – advantages. Basic aspects of synchronous fluorescence spectroscopy – spectral hole burning – flow cytometry – fluorometers (quantization) – instrumentation – applications.

Unit 5: Electroanalytical Techniques:

Electrochemical sensors, ion-sensitive electrodes, glass – membrane electrodes, solid liquid membrane electrodes – ion-selective field effect transistors (ISFETs) – sensors for the analysis of gases in solution. Polarography – principles and instrumentation – dropping mercury electrode – advantages –Illogic equation – applications of polarography – polarographic maxima – oscillographic polarography, AC polarography – cyclic voltammetry – advantages over polarographic techniques – chronopotentiometry – advantages – controlled potential coulometry – amperometric titrations: principles – techniques – applications – estimation of lead.

TEXTBOOKS:

1. "Principles of Instrumental Analysis" by Douglas A. Skoog, F. James Holler, and Stanley R. Crouch
2. "Instrumental Methods of Analysis" by Willard, Merritt, Dean, and Settle
3. "Modern Methods of Analytical Chemistry" by David C. Harris
4. "Analytical Chemistry: A Chemist's Companion" by Jack C. Dybowski, Mark S. Schure
5. Introduction to Instrumental Analysis" by Robert D. Braun

REFERENCE BOOKS:

1. "Statistics for Analytical Chemistry" by Jane C. Miller
2. "Chemometrics: A Textbook" by Richard G. Brereton
3. "Introduction to Modern Liquid Chromatography" by Lloyd R. Snyder, Joseph L. Glajch, and Julian L. Kirkland
4. "Fluorescence Spectroscopy: New Applications in Chemical and Biological Sciences" by Jose R. Lakowicz
5. "Electrochemical Methods: Fundamentals and Applications" by Allen J. Bard and Larry R. Faulkner
6. "Principles of Instrumental Analysis" by Douglas A. Skoog

7. "Introduction to Thermal Analysis: Techniques and Applications" by Michael E. Brown
8. "Chromatography: Concepts and Contrasts" by James M. Miller

24PCH303: Physical Chemistry Lab

EXPERIMENTS

a. Kinetics-acid hydrolysis of ester–comparison of strengths of acids.

b. Kinetics-persulfate-iodine reaction –determination of order, effective of ionic strength on rate constant.

c. Determination of molecular weight of substances by Rast method.

d. Determination of Critical Solution Temperature (CST) of phenol-water system and effect of impurity on CST.

e. Study of phase diagram of two components forming a simple eutectic.

f. Three component system

g. Conductometry – Acid-alkali titrations-Mixture of acids

h. Conductometry – precipitation titrations.

i. Conductometry – solubility product of sparingly soluble salts (PbSO4/BaSO4/PbCrO4/BaCrO4) and verification of Onsager equation

j. Potentiometric titrations – acid alkali titrations.

k. Potentiometry – determination of dissociation constant of weak acids.

References Books:

1. B.P. Levitt, Findlay's Practical Physical Chemistry; 9th Ed., Longman, 1985.
2. J.N. Gurtu and R. Kapoor, Advanced Experimental Chemistry; Vol. 1-Physical, S. Chand and Co., New Delhi, 1987.
3. J.B. Yadav, Advanced Practical Physical Chemistry; 20thEd., GOEL Publishing House, Krishna Prakashan Media Ltd., Chennai, 2001.

Text Books:

1 . Experiments in Physical Chemistry" by Carl W. Garland, Joseph W. Nibler, and David P. Shoemaker(8th or 9th edition)

2. Physical Chemistry: A Laboratory Manual" by Renu Bala, Bhupinder Mehta, and Manju Arora: S. Chand Publishing

24PCH304: Analytical Chemistry Lab

1. Preparation of organic compounds (double stage)

1. p-Bromoacetanilide from aniline (acetylation and bromination)
2. Acetylsalicylic acid from methyl salicylate (hydrolysis and acetylation)
3. 1,3,5-Tribromobenzene from aniline (bromination, diazotization and hydrolysis
4. Benzilic acid from benzoin (rearrangement)
5. *p*-Aminobenzoic acid from p-nitrotoluene (oxidation and reduction)

2. Preparation of complexes

1. Tris(thiourea)copper(I) chloride
2. Tetraamminecopper(II) sulphate
3. Potassium trioxalatoferrate
4. Potassium trioxalatochromate(III)
5. Hexamminecobalt(III) chloride

Techniques for Separation and Purification: (Not for Exam)

1. Purification of organic compounds by crystallization using the following solvents:
   a. Water b. Alcohol c. Alcohol-Water
2. Distillation - Simple
3. Soxhlet extraction
4. Chromatographic techniques:
   a. Column b. Thin layer Chromatography

Text Books:

1. Venkateswaran V, Veeraswamy R., Kulandaively A.R., Basic principles of practical chemistry, 2nd edition, New Delhi, sultan chand & sons, (1997)
2. 3. N. S. Gnanaprakasam and G. Ramamurthy, Organic Chemistry Lab Manual; S. V. Printers, 1987.

References Books:

1. J. Mohan, Organic Analytical Chemistry, Theory and Practice; Narosa, 2003.
2. V. K. Ahluwalia, P. Bhagat and R. Agarwal, Laboratory Techniques in Organic Chemistry; I. K. International, 2005.
3. A. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford and P. W. G. Smith, Vogel's Textbook of Practical Organic Chemistry; 5th Ed., Prentice Hall, 1989.
4. Vogel, Text Book of Quantitative Inorganic Analysis; 6th Ed., Longman, New Delhi, 2000

24PCH401: Scientific Ethics and Professionalism

Unit 1: Introduction to Scientific Ethics

Definition and importance of ethics in science - Historical cases of scientific misconduct - Core values of science: honesty, objectivity, integrity, carefulness - Ethical theories and their relevance to scientific practice - Ethical concerns in chemical research

Unit 2: Research Ethics and Integrity

Responsible Conduct of Research (RCR) - Plagiarism: types, detection, and prevention - Data fabrication, falsification, and misrepresentation - Ethical approval and protocols (IEC, IRB) - Intellectual Property Rights (IPR) and Patents - Reproducibility and transparency in scientific research

Unit 3: Professionalism in Scientific Practice

Professional behavior in laboratory and academic settings - Code of conduct for chemists (ACS, RSC standards) - Mentorship and collaboration ethics - Authorship and publication ethics - Conflict of interest and bias in research and publication - Peer review process: responsibilities and ethics

Unit 4: Environmental and Social Responsibilities

Chemists' role in environmental protection and sustainability - Ethics in handling hazardous chemicals and waste disposal - Social accountability and the impact of chemical research on society - Science communication and public engagement - Case studies on ethical dilemmas in chemistry applications

Unit 5: Contemporary Issues and Case Studies

Case studies of recent scientific misconduct and lessons learned - Ethics in computational and AI-assisted chemical research - Ethical issues in funding, patents, and commercialization of research - Global and cultural perspectives in scientific ethics - Seminar presentations and group discussions on selected topics

Textbooks:

1. SA Iqbal, M Liviu, Textbook of Forensic Chemistry, Discovery Publishing House Private Limited, 2011.
2. B. M. Patel, Research Methodology and Scientific Writing, CRC Press, 2022.
3. Rakesh Kumar Parashar, Scientific Ethics and Research Methodology, Pathfinder Publications, 2020.
4. P. B. Sharma, Scientific Research Methodology, CBS Publishers & Distributors Pvt. Ltd., 2018.

Reference Books:

1. Robert M. Anderson, Ethics for Chemists, Springer, 2020.
2. Nicholas H. Steneck, ORI Introduction to the Responsible Conduct of Research, U.S. Department of Health and Human Services, 2007.
3. Francis L. Macrina, Scientific Integrity: Text and Cases in Responsible Conduct of Research, ASM Press, 2020.
4. American Chemical Society (ACS), The Chemical Professional's Code of Conduct, ACS Publications, 2022.

SEMESTER IV

24PCH203: NANOMATERIALS IN ENERGY TECHNOLOGY

Unit 1: Introduction

Nanotechnology for sustainable energy- energy conversion process, indirect and direct energy conversion, use of nano scale catalysts to save energy and increase the productivity in industry.

Unit 2: Hydrogen Energy

Hydrogen production methods: from fossil fuels, electrolysis, thermal decomposition, photochemical, photo catalytic, hybrid; Hydrogen storage methods: metal hydrides, metallic alloy hydrides, carbon nanotubes etc.

Unit 3: Bio energy

Nano catalyst in biofuel production –Nanomaterial for Microbial fuel cells and biosensors-Immobilization of enzymes and microbes using Nano materials-Algal bio fuel

Unit 4: Energy Conversion Systems

Functional Nanostructured Materials for electrochemical Energy Conversion Systems, Fuel Cells, Principles and nanomaterials design for: Proton exchange membrane fuel cells (PEMFC); Direct methanol fuel cells (DMFC); Solid-oxide fuel cells (SOFC), Current status and future trends

Unit 5: Energy Storage Systems

Functional Nanostructured materials for electrochemical Energy Storage Systems - Primary and Secondary Batteries (Lithium ion Batteries), Cathode and anode materials, Capacitor Electrochemical supercapacitors, electrical double layer model, Principles and materials design. Basic concept about Redox-flow battery

Text Books:

1. Qiang Li, Nanomaterials for Sustainable Energy, Springer, 2016

2. B. S. Gurunathan & M. U. M. Patel, Energy Storage Devices for Renewable Energy-Based Systems, Elsevier, 2018

Reference Books:

1. Guozhong Cao & Ying Wang, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, World Scientific, 2nd Edition, 2017
2. Bent Sørensen, Hydrogen and Fuel Cells: Emerging Technologies and Applications, Academic Press, 2017
3. B. E. Conway, Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications, Springer, Updated Edition, 2018

24PCH215: Sustainable Synthesis

Unit 1: Green Chemistry

Green metrics: Atom economy, E-factor, Process Mass Intensity (PMI). Examples of green chemistry, Designing a green synthesis, Rearrangements reaction, Addition reaction, substitution, elimination reaction. Synthesis involving basic principles of green chemistry, some examples. Synthesis of styrene, Synthesis of urethane, Free radical bromination, Synthesis of paracetamol, Synthesis of Ibuprofen.

Unit 2: Greener Reactions

Phase transfer catalysis in green synthesis-oxidation using hydrogen peroxide, crown ethers - esterification, saponification, anhydride formation, Displacement reaction. Phase transfer catalysis (PTC) in green synthesis – mechanism and applications.

Unit 3: Green Techniques

Micro wave induced green synthesis - Introduction, Instrumentation, Principle and applications. Sonochemistry – Instrumentation, Cavitation theory - Ultra sound assisted green synthesis and Applications in organic synthesis.

Unit 4: Sustainable And Environmental Benign Technologies

Reactions on solid supports. Reduction in materials usage, energy consumption, waste generation, use of nonrenewable resources, cost, and hazard risks. Carbon management strategies: carbon capture, carbon sequestration, carbon footprint evaluation, and carbon trading mechanisms.

Unit 5: Utilization of Green Energy Sources

Renewable chemicals from biomass and sustainable polymers (polylactide). Ultrasound assisted reactions: esterification, reduction, coupling reactions.Synthesis and applications of sustainable polymers: polylactide (PLA), polyhydroxyalkanoates (PHA), and polyethylene furanoate (PEF).

Text Books:

1. B. M. Trost and T. C. Bruice, Green Chemistry: Frontiers in Benign Chemical Syntheses and Processes, Oxford University Press, 2010.
2. V. K. Ahluwalia and R. Kidwai, New Trends in Green Chemistry, Anamaya Publishers, 2004.
3. S. S. Bhagwat, Green Chemistry: Environmentally Benign Reactions, Wiley-Blackwell, 2012.
4. M. Lancaster, Green Chemistry: An Introductory Text, Royal Society of Chemistry, 2010.

Reference Books:

1. J. Collins and J. M. Lupton, *Microwave Methods in Organic Synthesis*, Blackwell Publishing, 2010.
2. J. K. Varma, *Sonochemistry and its Applications in Green Synthesis*, CRC Press, 2015.
3. R. A. Sheldon, *Green and Sustainable Manufacture of Chemicals*, Wiley-VCH, 2012.