# Course Curriculum under

**National Education Policies**

SYLLABUS

**FOR**

BACHELOR OF SCIENCE IN CHEMISTRY

Department of Chemistry

**ADAMAS UNIVERSITY**

**2026**

Barasat, Kolkata-700 126

## VISION OF THE DEPARTMENT

The Vision of the Department of Chemistry is to generate and disseminate Chemistry education among its pupils such that at individual level, a Chemistry graduate should be inspired with a sense of curiosity and wonder about the fundamental nature of the world around the student; be empowered with the ability to make decisions about their own lives and critically evaluate scientific and technological developments that impact society and lastly be equipped them with the knowledge and skills to pursue further study and rewarding careers in the chemical sciences and a wide range of related fields.

## MISSION STATEMENTS OF THE DEPARTMENT

M.S 01: To represent a clear framework or narrative that gives a coherent 'big picture' of chemistry as a subject, explains why it matters, and shows how different areas of content are connected.

M.S 02: To prepare competitive and professional graduates within an innovative and intellectually stimulating environment, support other academic programs at Adamas University by offering quality chemistry learning experiences, conduct basic and applied research of national and international impact.

M.S 03: To advance knowledge platform that supports an invent-and-design culture in graduate and undergraduate chemistry education and that empowers students to address and solve challenges of global significance.

M.S 04: To reach out to our future thought leaders—students of all backgrounds from pre- college to doctoral candidates—to share the power of chemistry to create new knowledge directed at the major unmet needs of our time.

**DEPARTMENT OF CHEMISTRY**
**School of Basic and Applied Sciences**
**Adamas University**
**PROGRAMME NAME: B.Sc. (Hons.) CHEMISTRY**
**Four Year degree course**
**FULL SYLLABUS**
**Effective from: 2026-27**

## (Semester 1)

## Fundamental Chemistry-I

**Unit-1: Gaseous state-** Arguments of Kinetic Theory of gas, Maxwell's distribution of speeds & energy. average, root mean square and most probable speed and energy, principle of equipartition of energy and molar heat capacity of gases, Collision of gas molecules and viscosity. Deviation of gases from ideal behaviour. Critical temperature and Boyle temperature. van der Waals equation of state; the law of corresponding states; virial equation. Continuity of state.

**Unit-2: Liquid State-** Vapour Pressure. Surface tension, surface energy, capillary rise. Spreading of liquid over surface. Viscosity: General features of fluid flow, Newton's equation, viscosity coefficient, Poiseuille equation, temperature dependence of viscosity coefficient and surface tension. Experimental determination of viscosity and surface tension.

**Unit-3: Atomic structure-** Bohr's atomic model and its limitation, wave mechanical model: de Broglie hypothesis and matter waves, Schrodinger's wave equation, wave function and the concept of probability, radial and angular probability distributions, shapes of *s*, *p*, *d* and *f* orbitals, Concept of quantum numbers and their significance, Aufbau principle, Hund's rule and Pauli's exclusion principle for determining electronic configuration of multielectronic systems. Concept of exchange energy**,** L-S coupling, Ground state Term symbols of atoms.

**Unit-4: Bonding feature in organic molecules-** IUPAC nomenclature, Valance Bond Theory (VBT), DBE/IHD calculation, hybridisation, representation the gross structural formulae, factors influencing electron availability, intermolecular forces explaining physical properties (Dispersion Forces (also called London Forces), Dipole-Dipole Force, Hydrogen Bonds, Ion-Dipole Force, van der Waals forces, noncovalent interaction), aromaticity.

**Unit-5: Reaction intermediates-** carbocations, carbanions, carbon radicals, carbenes: structure using orbital picture, electrophilic/nucleophilic behaviour, stability, generation and fate (elementary idea).

**Unit-6: Lab**

1. Determine the surface tension by (i) drop number (ii) drop weight method.
2. Study the variation of surface tension of detergent solutions with concentration.
3. Study of viscosity of unknown liquid (glycerol, sugar) with respect to water.
4. Study of the variation of viscosity with the concentration of the solution.
5. *Qualitative analysis of acid radicals*

$Cl^-$, $Br^-$, $I^-$, $NO_3^-$, $SCN^-$,$S^{2-}$,$SO_4^{2-}$, $NO_2^-$, $PO_4^{3-}$, $[Fe(CN)_6]^{4-}$, $[Fe(CN)_6]^{3-}$.

6. Detection of special elements (N, Cl, S) in organic molecules by Lassaigne's test.

**Reference books:**


1. Huheey, Keiter and Keiter, Principles of Inorganic Chemistry,
2. R. Sarkar, Vol. 1 Inorganic Chemistry,
3. Concise Inorganic Chemistry by J. D. Lee,
4. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education),
5. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988),
6. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, Oxford University Press,
7. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry 10th Ed., Oxford UniversityPress (2014),
8. P.C. Rakshit, Physical Chemistry 7th Edition (2004),
9. Chatterjee, H. Physical Chemistry, Vol-1, Edition, Platinum publishers,
10. Das, S.C. Advanced Practical Chemistry, Sixth edition.


## Fundamental Chemistry-II

**Unit-1: Thermodynamics I**

**a)** *Introduction to Thermodynamics*- Importance and scope, definition of system and surroundings: type of systems; extensive and intensive properties; Thermodynamic equilibrium. The zeroth law of thermodynamics.

b) *1st law of thermodynamics and consequences*- Isothermal reversible and irreversible workdone. 1st law of thermodynamics, state functions and path functions. Concept of heat capacity. Joule's Experiment. Joule coefficient for vander Waal gas. Adiabatic process.

**c)** *Thermochemistry*- Heat changes during physicochemical processes at constant pressure and constant volume; Kirchhoff's relations; bond dissociation energies; changes of thermodynamic properties in different chemical changes.

**Unit-2: Chemical Kinetics-I-** Differential rate law, idea of elementary and multistep reactions, order and molecularity, integrated rate law for zero, 1st and 2nd order reaction Arrhenius equation, energy of activation.

**Unit-3: Periodic properties-** Effective nuclear charge and Slater's rule, atomic, ionic and covalent radii and their group and periodic trends for *s, p* and *d* block elements, ionization potential, electron affinity and electronegativity and their group and periodic variation for *s* and *p* block elements. Relativistic and inert pair effect.

**Unit-4: Radioactivity-** Radioactivity, radioactive displacement law, half-life and average life of radioactive elements, *n/p* ratio, nuclear binding energy. Liquid drop model, fission, fusion, spallation, and artificial transmutation reactions. Nuclear power generation and its application.

**Unit-5: Stereochemistry-** Symmetry elements, representation of molecules in different conformations and their inter-conversions, molecular chirality, stereogenicity, chirotopicity, Configurations, Optical activity (specific rotation,

optical purity (enantiomeric excess), racemic compounds, racemisation, resolution), topicity of ligands and faces, Conformational analysis: nomenclature, dihedral angle, torsion angle, energy barrier of rotation, relative stability, dipole-dipole interaction, H-bonding, classification and stability, conformational analysis of small aliphatic acyclic (ethane, propane, n-butane, haloethane, 1,2-haloethane, 1,2- glycol, 1,2-halohydrin etc.) and cyclic molecules (3, 4, 5, 6-membered rings; mono- and di-substituted cyclohexane).

**Unit-6: Lab**

1. Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system,
2. Determination of heat of neutralization of a strong acid by a strong base,
3. Detection of the following functional groups in organic molecules: Aromatic -$NH_2$, aromatic -$NO_2$, -$CONH_2$, Phenolic –OH, -COOH, >C=O.
4. Qualitative analysis of basic radicals: $Na^+$, $K^+$, $Ca^{2+}$, $Sr^{2+}$, $Ba^{2+}$, $Al^{3+}$,$Mn^{2+}Fe^{3+}$, $Co^{2+}$, $Ni^{2+}$, $Cu^{2+}$, $Zn^{2+}$, $NH_4^+$, $Mg^{2+}$.

## Reference books:


1. Huheey, Keiter and Keiter, Principles of Inorganic Chemistry,
2. R. Sarkar, Vol. 1 Inorganic Chemistry,
3. Concise Inorganic Chemistry by J. D. Lee,
4. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education),
5. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988),
6. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, Oxford University Press,
7. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry 10th Ed., Oxford University Press (2014),
8. P.C. Rakshit, Physical Chemistry 7th Edition (2004),
9. Chatterjee, H. Physical Chemistry, Vol-1, Edition, Platinum publishers,
10. Das, S.C. Advanced Practical Chemistry, Sixth edition.


## (Semester 2)

## General Chemistry I

**Unit-1: Thermodynamics II**

a) *Second law of Thermodynamics & entropy*- Second law of thermodynamics: need for a second law, Clausius and Kelvin-Planck statements and their equivalence; Carnot's theorem, thermodynamic scale of temperature, concept of heat engine, Carnot cycle and refrigerator. Clausius inequality, entropy as a state function, calculation of entropy change for various transformation; auxiliary state function (G and A) Gibbs-Helmholtz equation; Maxwell's relation, thermodynamic equation of state.

b) *Joule-Thomson Experiment*- Joule-Thomson cooling, co-efficient of Joule-Thomson process$(\mu_{JT})$, evaluation of $\mu_{JT}$ for van der Waal's gases.

c) *Open system*- Chemical potential and activity. Variation of with temperature and pressure, Gibbs-Duhem equation; Euler's theorem; expression for ideal gas. Non-ideal system: idea of fugacity and activity; standard states.

**Unit-2: Ionic bonding-** Radius ratio rule and its applications; Packing of ions in crystals. Lattice energy and Born-Lande equation, Born-Haber cycle and its application.

**Unit-3: Covalent bonding-** a) Fajan's rule and its application, Valence Bond Theory, VSEPR theory, Bent's rule, hybridization, resonance. b) Concept of molecular orbitals in bonding through LCAO approach. MO diagrams of homonuclear diatomic molecules ($H_2$, $B_2$, $C_2$, $N_2$, $O_2$ , $F_2$) and heteronuclear diatomic molecules (CO, NO, $NO^+$, $CN^-$, HF, HCl).

**Unit-4: Molecular Orbital Theory-** Concept of molecular orbitals in bonding through LCAO approach. MO diagrams of homonuclear diatomic molecules and heteronuclear diatomic molecules.

**Unit-5: Nucleophilic substitution reactions and elimination reactions:** a) Nucleophilic substitution reaction: Classification ($SN^1$, $SN^2$, $SN^{2\square}$, $SN^i$, NGP), mechanism, Stereo-chemical features, effects of different parameter on reaction rate. b) Elimination reaction: Classification **(**E1, E1cB, E2, Syn, Anti), mechanism, geometrical features, effects of different parameter on reaction rate, Saytzeff and Hofmann products, stereoselectivity; substitution *vs* elimination.

**Unit-6: Lab**

1. Study of kinetics of decomposition of $H_2O_{2.}$
2. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate.
3. Determination of specific rotation of optically active compound.
4. Inversion of cane-sugar.
5. Verify the Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.

## Reference books:


1. Huheey, Keiter and Keiter, Principles of Inorganic Chemistry,
2. R. Sarkar, Vol. 1 Inorganic Chemistry,
3. Concise Inorganic Chemistry by J. D. Lee,
4. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education),
5. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988),
6. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, Oxford University Press,
7. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry 10th Ed., Oxford University Press (2014),
8. P.C. Rakshit, Physical Chemistry 7th Edition (2004),
9. Chatterjee, H. Physical Chemistry, Vol-1, Edition, Platinum publishers,
10. Das, S.C. Advanced Practical Chemistry, Sixth edition.
11. Mukherjee, G.N. University handbook of undergraduate chemistry experiments.


## General Chemistry II

**Unit-1: Chemical Kinetics-II -** Opposing, parallel and consecutive reactions, kinetic and thermodynamic control of reaction; idea of rate determining step; steady-state approximation. Collision theory, Outline of transition state theory; primary kinetic salt effect. Lindeman theory of unimolecular reaction. Basic concept of different reactors (CSTR, PFR, Batch etc.).

**Unit-2: Catalysed reactions**

a) *Homogeneous catalysis:* Mechanism of catalytic action, acid-base catalysis, autocatalysis, chain reaction; enzyme catalysis - Michaelis-Menten equation, turnover number, Lineweaver-Burk plot; influence of temperature and pH.
b) *Heterogeneous catalysis:* Adsorption- Surface dynamics: physical and chemical adsorption, Freundlich and Langmuir adsorption isotherm, multilayer and BET isotherm (outline) and applications, Gibbs adsorption isotherm and surface excess. Heterogeneous catalysis.

**Unit-3: Theories of Acid-Base Chemistry-** Different theories of acid-base including solvent system, Bronsted-Lowry's concept, Lux-Flood concept and Lewis concept. HSAB principle,
gas phase acidity, leveling effects of solvents. Superacids, Pauling's rule.

**Unit-4: s and p block elements-** Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses: diborane, boron nitrides, borazine, oxo- and peroxo acids of sulphur, sulphur-nitrogen compounds, polyhalides, pseudohalogens, fluorocarbons.

**Unit-5: Reactions of alkenes and alkynes-** a) Alkenes: mechanism of addition, reactivity, regioselectivity, stereoselectivity, halogenations, oxymercuration-demercuration, hydroboration, hydrogenation, epoxidation, hydroxylation, ozonolysis, addition. b) alkynes- Electrophilic and nucleophilic additions; dissolving metal, hydration, terminal alkylation.

**Unit-6: Lab:** Acid base titration:

1. Standardization of sodium hydroxide solution
2. Standardization of HCl solution.
3. Standardization of acetic acid solution.
4. Estimation of carbonate and hydroxide present together in mixture.
5. Estimation of carbonate and bicarbonate present together in a mixture.
6. Estimation of acetic acid available in vinegar sample.
7. Estimation of alkali content of antacid tablet.

**Reference books:**


1. Huheey, Keiter and Keiter, Principles of Inorganic Chemistry,
2. R. Sarkar, Vol. 1 Inorganic Chemistry,
3. Concise Inorganic Chemistry by J. D. Lee,
4. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education),
5. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988),
6. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, Oxford University Press,
7. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry 10$^{th}$ Ed., Oxford University Press (2014),
8. P.C. Rakshit, Physical Chemistry 7$^{th}$ Edition (2004),
9. Chatterjee, H. Physical Chemistry, Vol-1, Edition, Platinum publishers,

10. Das, S.C. Advanced Practical Chemistry, Sixth edition.
11. Mukherjee, G.N. University handbook of undergraduate chemistry experiments.

**(Semester 3)**

**General Chemistry III**

**Unit-1: Transport Phenomena-** Concept of electrolyte, electrolytic conduction: Electronic versus electrolytic conduction. Cell constant; specific, equivalent and molar conductance. Kohlrausch's law, equivalent conductance at infinite dilution. Debye-Huckel theory of Ion atmosphere, asymmetric effect, relaxation effect and electrophoretic effect. Ostwald dilution law and determination of ionization constants for weak electrolytes from conductance measurements. Conductometric titration; transport number, Hittorf's rule, determination of transport number by the moving boundary method.

**Unit-2: Colloids-** Lyophobic and lyophilic sols, Schultz-Hardy rule, electrokinetic phenomenon. Surfactants and micelles and reverse micelles: applications

**Unit-3: Chemistry of redox reactions-** Ion electron method and elementary idea on standard redox potentials with sign conventions. Concept of electrochemical cells and different types of electrodes, standard redox potentials, Concept of formal potential and influence of different factors on formal potential. Latimer and Frost diagrams. Feasibility of redox titration and the significance of redox potential at the equivalence point, Use of redox indicators.

**Unit-4: Electrophilic and nucleophilic aromatic substitution:** a) Electrophilic substitution reaction: Mechanisms, kinetics, reactivity, effect of substitution on arenes Reactivity and ortho-para ratio for arenes, different reactions (chloromethylation, Gatterman-Koch, Gatterman, Hoesch, Vilsmeier-Haack reaction, Reimer-Tiemann, Kolbe-Schmidt), diazonium salt, b) nucleophilic substitution reactions: mechanisms, kinetics, reactivity, benzyne.

**Unit-5: Lab:**

**A. Derivatization of organic compounds:**

1. Nitration of aromatic compounds (methyl salisylate, phenol, nitrobenzene etc.),
2. Hydrolysis of amides (benzamide) and esters (methyl or ethyl benzoate derivatives)
3. Acetylation of aromatic alcohols (phenol, $\beta$-naphthol etc.) / aromatic amines (aniline derivatives),
4. Benzoylation of aromatic alcohols (phenol, $\beta$-naphthol etc.)/ aromatic amines (aniline derivatives),
5. Iodoform synthesis from acetone and ethanol.

**B. Purification of the crude product by crystallization method and melting Point determination of the purified product.**

**C. Redox titration:**

1. Estimation of Fe(II) present in Mohr's salt by permanganometric and dichromatometric titration.
2. Estimation of Fe(III) present in a sample by permanganometric and dichromatometric titration.
3. Estimation of Fe(II) and Fe(III) in a given mixture by permanganometric and dichromatometric titration.
4. Estimation of Fe(III) and Ca(II) in a given mixture by permanganometric method.

**Reference books:**

1. Huheey, Keiter and Keiter, Principles of Inorganic Chemistry,

2. R. Sarkar, Vol. 1 Inorganic Chemistry,
3. Concise Inorganic Chemistry by J. D. Lee,
4. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education),
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9. Chatterjee, H. Physical Chemistry, Vol-1, Edition, Platinum publishers,
10. Das, S.C. Advanced Practical Chemistry, Sixth edition.
11. Mukherjee, G.N. University handbook of undergraduate chemistry experiments.

## General Chemistry IV

**Unit-1: Chemical equilibrium & Ionic Equilibrium –** Criteria for spontaneity and equilibrium**.** Equilibrium constant and standard Gibbs free energy change; definition of $K_p$, $K_c$, $K_x$ Van't Hoff's reaction isobar and isochore. Le Chatelier principle and its application, Nernst's distribution law; Application. Concept of pH, Acid and base hydrolysis. Hydrolysis of salts, Buffer solution. Acid-base indicators, titration curve. Solubility equilibria and influence of common and indifferent ions there on.

**Unit-2: Introduction to Coordination Compounds-** Werner's theory and applications, types of ligands, chelate effect and macrocyclic effect, IUPAC nomenclature of coordination complexes and Isomerism.

**Unit-3: Noble gases-** Preparation, properties and nature of bonding in $XeF_2$, $XeF_4$, $XeF_6$, $XeOF_4$ and $XeO_2F_2$.

**Unit-4: Chemistry of alcohols-** Classification, nomenclature, monohydric alcohols-nomenclature, synthesis, chemical reaction of vicinal glycols, oxidation, oxidative cleavage, trihydric alcohols: nomenclature and synthesis, glycerols: reactivity and mechanism.

**Unit-5: Nitrogen compounds-** amines: preparation, separation and identification, E. Clarke reaction, enamines, diazomethane, diazoacetic ester, aromatic nitro compounds, aromatic diazonium salts, nitrile and isonitrile.

**Unit-6: Lab-**

**A. Physico-chemical experiments:**

1. Find out the pH of an unknown solution by colorimetric method.
2. Determination of solubility product for sparingly soluble salt.
3. Determination of partition coefficient of iodine between water and organic solvent.
4. Equilibrium Constant determination of $KI + I_2 \rightleftharpoons KI_3$ system.

**B. Permangometric, Dichromatometric and Iodometric titration:**

1. Estimation of Fe(III) and Mn(II) in a mixture using standardized $KMnO_4$solution
2. Estimation of Fe(III) and Cr(III) in a mixture using $K_2Cr_2O_7$.
3. Standardization of sodium thiosulfate solution

4. Estimation of Cu(II) by standardized sodium thiosulphate solution.

**Reference books:**


1. Huheey, Keiter and Keiter, Principles of Inorganic Chemistry,
2. R. Sarkar, Vol. 1 Inorganic Chemistry,
3. Concise Inorganic Chemistry by J. D. Lee,
4. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education),
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6. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry 10th Ed., Oxford UniversityPress (2014),
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8. Chatterjee, H. Physical Chemistry, Vol-1, Edition, Platinum publishers,
9. Das, S.C. Advanced Practical Chemistry, Sixth edition.
10. Mukherjee, G.N. University handbook of undergraduate chemistry experiments.


**(Semester 4)**

**Organic Chemistry-I**

**Unit 1: Chemistry of carbonyl compounds:** Synthesis, mechanism, reactivity, reactions with alcohols, amines, thiols, HCN, bisulfate, Wittig reaction, hydride addition, Wolff-Kishner reduction, Bouveault-Blanc reduction, Clemmensen reduction, reduction with metal hydrides.

**Unit-2: Characteristic reactions of carbonyl compounds-** Cannizzaro reaction, Tischenko reaction, aldol condensation, benzoin condensation, acyloin Condensation, Mannich reaction, oxidation, michael addition and robinson annulation.

**Unit-3: Carboxylic Acids and their Derivatives-** Preparation, physical properties and reactions of monocarboxylic acids; acid derivatives, mechanism of ester group hydrolysis.

**Unit-4: Rearrangement reactions:** Wagner-Meerwein, pinacol, Dienone-phenol, Wolff, benzil-benzilic acid rearrangement, Beckmann, Schmidt, Hofmann, Lossen, Curtius, Baeyer-Villiger oxidation, Dakin, Fries, Claisen, dienone-phenol, Hofmann-Martius, Fischer-Hepp, Bamberger, Orton, Benzidine, Radical coupling: pinacol, acyloin, McMurry etc.

**Unit-5: Biomolecules:** Carbohydrates, amino acids, peptides (synthesis and degradation), proteins (elementary idea), nucleic acids (Basic introduction to the structure and properties of DNA and RNA).

**Reference Books:**


1. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988).
2. Norman &Coxon Principles of Organic Synthesis (CRC Press)
3. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; Organic Chemistry, Oxford University Press.
6. March, J. Advanced Organic Chemistry.

**Unit-6: Lab**- Synthesis, purification and Identification of the following molecules

**Drug molecules:**

1. Paracetamol from p-amino phenol,
2. Aspirin synthesis from salicylic acid,
3. Phenytoin from benzil and urea,
4. Hippuric acid from glycine,
5. Cholesterol benzoate from cholesterol (liquid crystal),
6. P-Methoxy benzamide (mosquito repellent) from p-methoxy benzyl chloride etc.

**Dye derivatives:**

7. Azo dye from aniline and β-naphtol,
8. Azo dye from sulphanilic acid and β-naphtol,
9. Extended azo dye and their photophysical study etc.

**Others:**

10. Benzoic acid from benzaldehyde,
11. p-Iodo nitrobenzene from p-nitro aniline,
12. Synthesis of dibenzalacetone from benzaldehyde etc.

## Reference books:


1. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009)
2. Das, S.C. Advanced Practical Chemistry, Sixth edition.
3. Mukherjee, G.N. University handbook of undergraduate chemistry experiments.


## Physical Chemistry-I

**Unit-1: Quantum Mechanics -I**

**a)** Origin of quantum mechanics- Black body radiation, de Broglie hypothesis, wave-particle duality, Uncertainty principle. Photoelectric effect, Compton effect.

**b)** Time-dependent and time -independent Schrödinger equation; probabilistic interpretation of the wave function, stationary state. Elementary idea of operator, operator algebra, eigen value equation, expectation value. Postulates of quantum mechanics. Commutation relation.

c) Application to Particle in a box problem- Construction of Schrödinger equation for 1 D box problem and its solution. Evaluation of expectation values of x, $x^2$, $p_x$, $p_x^2$ for 1-D box and their significance. Extension of the particle in one-dimensional box to two- and three- dimensional cases, idea of degenerate energy states. Free particle.

**d)** Simple harmonic Oscillator- Schrödinger equation, series solutions of differential equation: Hermite equation. Expressions for energy and wave functions. Connection with the uncertainty principle, classical turning points. Limitation, introduction of anharmonicity.

**Unit-2: Phase Rule and colligative properties-**

**a)** Definition of phase, number of components and degrees of freedom, Derivation of phase rule and its applications. One component system and its phase diagram. First order phase transition and Clapeyron equation. Clausius-Clapeyron equation: derivation and its use; liquid vapor equilibrium for two component systems.

**b)** Colligative property- Ideal solutions, ideally dilute solutions and Raoult's law, Colligative properties of solution: Lowering of vapor pressure, elevation of boiling point, depression of freezing point, osmotic pressure. Abnormal colligative properties, van't Hoff factor; biomedical application: osmosis and dialysis.

**c)** Phase diagram for two and three component system- Liquid vapor equilibrium for two component systems, Fractional distillation. Phenol-water system. Three component systems, water-chloroform-acetic acid system, triangular plots.

**Unit-3: Thermodynamics of electrochemical cell-** Electrochemical cells: representation, EMF and relation of $\Delta G$, $\Delta H$ and $\Delta S$ with EMF. Thermodynamic derivation of Nernst equation. Standard cells, different types of electrode, standard electrode potential and principle of its determination; concentration cells. Activity coefficient, Debye-Hückel model limiting law, applications. Determination of transport number by EMF method, glass electrode and determination of pH, applications of EMF measurement: potentiometric titrations: acid-base, redox and precipitation.

**Unit-4: Lab-** Conductometric method

1. Conductometric titration of an acid (strong, weak/ monobasic, dibasic, and acid mixture) against strong base.
2. Study of saponification of ester conductometrically
3. Oswald dilution law
4. Study the equilibrium of at least one of the following reactions by the distribution method:

$$\text{(i) } I_2(aq) + I^-(aq) \rightarrow I_3^-(aq)$$

$$\text{(ii) } Cu^{2+}(aq) + n NH_3 \rightarrow Cu(NH_3)_n$$

## Reference books:


1. Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 10th Ed., Oxford University
2. Ball, D. W. *Physical Chemistry* Thomson Press, India (2007).
3. Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).
4. McQuarrie, D. A & Simon, J. D, Physical Chemistry: A molecular approach, University Science Books, Sausalito, California.
5. N. K. Bera, Physical Chemistry, 1st Edition, Techno World Pub.
6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
7. University Hand Book of Undergraduate Chemistry Experiments, University of Calcutta.


## Inorganic Chemistry I

**Unit-1: Bonding in Coordination complexes-** Valence bond theory and its limitations, Concept of crystal field theory, Effect of weak and strong field ligands in crystal field splitting, J-T distortion and OSSE and its application.

**Unit-2: Modified Ligand Field Theory of Coordination Complexes-** □□□energy diagram for $ML_6$ and $ML_4$ complexes, Nephelauxetic effect.

**Unit-3: Electronic Spectra of Coordination Complexes-** Selection rules for electronic spectral transitions, L-S coupling, hole formalism principle, Orgel diagrams for $d^1 - d^9$ ions, Charge transfer spectra.

**Unit-4: Magnetic property of coordination complexes-** Magnetism and magnetic moments, Spin only magnetic moments and their correlation with effective magnetic moments, Orbital contribution towards

magnetic moment and its quenching in crystal field, Exchange interaction in metal complexes, Spin-orbit coupling.

**Unit-5: Chemistry of *d* and *f* block elements-** General comparison of chemistry of 3d, 4d and 5d elements in term of electronic configuration, atomization energy, oxidation states, redox properties, coordination chemistry, spectral and magnetic properties. Spectral and magnetic properties of *f*-block elements and comparison between lanthanides and actinides.

**Unit-6: Lab Iodometric and Complexometric titration**

1. Estimation of Zn(II) by complexometric titration.
2. Estimation of Fe(III) and Cu(II) in a mixture.
3. Estimation of Cu(II) and Zn(II) present in a mixture by iodometric titration.
4. Estimation of Ca(II) by EDTA complexometry.
5. Estimation of Ca(II) and Mg(II) in a given mixture.
6. Estimation of permanent and temporary hardness of water

## Reference books:


1. Huheey, Keiter and Keiter, *Principles of Inorganic Chemistry*
2. R. Sarkar, Vol. 2 *Inorganic Chemistry*
3. Chemistry of elements by Greenwood and Earnshaw
4. Handbook of Practical Chemistry by Subhas C Das.


**(Semester 5)**

**Organic Chemistry-II**

**Unit-1: Carbocycles:** Thermodynamic and kinetic factors, Baldwin rules, Synthesis of carbocycles through alkylation, condensation, cycloaddition, rearrangement and their reactivity, synthesis of polycyclic aromatics (naphthalene, anthracene and phenanthrene).

**Unit-2: Heterocycles:** Classification, nomenclature**,** aromaticity**,** reactivity and synthesis (Pyrrole, pyridine, indole, furan, thiophene, quinolone etc.)

**Unit-3: Enolate chemistry:** Alkylation, acylation and conjugate addition at of carbonyls, di-carbolyl derivative synthesis, strategies of ring synthesis.

**Unit-4: Retrosynthetic analysis:** Disconnections, synthons, synthetic equivalents, functional group interconversion, bond disconnection (C-hetero atom and C-C), protection-deprotection strategy, **s**ynthesis through rearrangement reactions, synthesis of large rings (high dilution technique), application to illustrate the disconnection approach to organic synthesis.

**Unit-5: Lab: Chromatographic methods**

1. Theory and application of chromatography in sample analysis (TLC, column chromatography),
2. Synthesis of small molecules and their purification thorugh chromatographic techniques,
3. Theory and application of rotatory evaporator.

**Reference Books:**

1. Joule and Mills, Heterocyclic Chemistry- 4th edition (Wiley)
2. Gilchrist, T.L. Heterocyclic Chemistry (Pearson),
3. Organic Synthesis - The Disconnection Approach – S. Warren,
4. Designing Organic Synthesis – S. Warren,
5. Tactics of Organic Synthesis - T.-L. Ho,
6. Das, S.C. Advanced Practical Chemistry, Sixth edition,
7. Mukherjee, G.N. University handbook of undergraduate chemistry experiments.

## Physical Chemistry-II

**Unit-1: Quantum Mechanics-II**

*Angular Momentum and H-atom*- Commutation rules; Ladder operator method to solve Schrödinger equation; Rigid rotator model. Hydrogen atom: Schrödinger equation in spherical polar coordinates. Separation of variables; Spherical harmonics. Quantum numbers, degenerate states, orbital, radial density distributions.
*Approximation methods*: Variation method: Basis and applicability. Linear variation method- secular determinant; Rayleigh-Schrodinger perturbation theory for non-degenerate states. simple applications.

**Unit 2: Covalent bonding-** Born-Oppenheimer approximation; LCAO-MO treatment of $H_2^+$; Bonding and antibonding orbitals; Qualitative extension to $H_2$ ; Comparison of LCAOMO and VB treatments of $H_2$ and their limitations; Covalent bonding, valence bond and molecular orbital approaches.

**Unit-3: Statistical Thermodynamics and its Application-** Concept of probability. Microscopic and microstates, thermodynamic probability. Entropy Derivation of Maxwell-Boltzmann distribution. Concept of partition function (PF). Relevance to thermodynamics.
Rotational, Translational, Vibrational and Electronic PF for diatomic molecules, Calculation of equilibrium constants in term of partition function. Application to chemical/ionization equilibrium, heat capacity of solid, Equipartition principle. Gibbs paradox, and quantum statistics.

**Unit 4**: **Third Law of thermodynamics-** Nerst Heat theorem, Third law, absolute entropy, and residual entropy. Adiabatic demagnetization.

**Unit-5: Lab-** pH-metric and potentiometric titration:

1. Study the effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.
2. pH metric titration of i) strong acid vs. strong base ii) weak acid vs. strong base
3. Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$ solution.
4. Determination of $K_{sp}$ for AgCl by potentiometric titration of $AgNO_3$ solution against standard KCl solution.

## Reference books:

1. Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 10th Ed., Oxford University
2. Ball, D. W. *Physical Chemistry* Thomson Press, India (2007).
3. Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).
4. McQuarrie, D. A & Simon, J. D, Physical Chemistry: A molecular approach, University Science Books, Sausalito, California.
5. N. K. Bera, Physical Chemistry, 1st Edition, Techno World Pub.
6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.

7. University Hand Book of Undergraduate Chemistry Experiments, University of Calcutta.

## Inorganic Chemistry II

**Unit-1: Roles of metal ions in biological systems-** Basic chemical reactions in biological system and roles of metal ions, $Na^+$-$K^+$ ion pump and ionophores.

**Unit-2: Oxygen transport and electron transport protein-** Biological functions of haemoglobin, myoglobin, hemocyanin and hemerythrin. Cytochromes and ferredoxins, Chlorophyll: PS-I and PS-II, Z-scheme of electron transport, Cytochrome C oxidase and its function in mammalian respiratory chain. Biological nitrogen fixation by Nitrogenase.

**Unit-3: Functions of Metal Enzymes-** Metal containing enzymes (carbonic anhydrase, carboxypeptidase, catalase, peroxidase) and their roles in biological system.

**Unit-4: Toxicity of metal ions-** Toxicity of metal ions, Chelation therapy and its applications, use of Gd-complex as MRI contrast reagent, uses of metal complexes as various drugs (Pt and Au complexes as drugs).

**Unit-5: Errors, accuracy and precision-** Errors**,** accuracy and precision, methods of their expression and normal law of distribution if indeterminate errors.

**Unit-6: Absorption Spectroscopy-** Chemical interferences and sources of chemical interferences and their method of removal. Techniques for quantitative estimation of trace level of metal ions from different samples.

**Unit-7: Chromatographic techniques-**Classification, principle and efficiency of different chromatographic techniques, Qualitative and quantitative aspects of chromatographic methods.

**Unit-7: Lab-Inorganic synthesis and characterization**

Inorganic Preparations:

1. Tetraamminecopper (II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$
2. *Cis* and *trans* $K[Cr(C_2O_4)_2.(H_2O)_2]$ Potassium dioxalatodiaquachromate (III)
3. Tetraamminecarbonatocobalt (III) ion
4. Potassium tris(oxalate) ferrate(III) and its photochemistry
5. Synthesis of porphyrin and complexation with Zn metal.
6. Synthesis of Schiff bases and its complexation.

## Reference books:


1. Bioinorganic Chemistry by G. N. Mukherjee and A. Das
2. Bioinorganic Chemistry by Stephen J Lippard
3. Bioinorganic Chemistry by Asim K Das
4. Analytical Chemistry by Daniel C Harris
5. Analytical Chemistry by G. D. Christian
6. Analytical Chemistry by Skoog


## (Semester 6)

## Spectroscopy

**Unit-1: Molecular Spectroscopy**

Light matter interaction. Characteristic features of spectral lines: intensity, broadening

Rotational spectroscopy of diatom: rigid rotor model, selection rules, characteristic features of spectral lines (spacing and intensity); determination of bond length, effect of isotopic. Substitution Concept of non-rigid rotor.

Vibrational spectroscopy- SHO approximation. selection rules, spectral analysis, fundamental line, overtones, hot bands; anharmonicity.

Raman effect- Characteristic features, and conditions of Raman activity. Rotational and vibrational Raman spectra, the rule of mutual exclusion with examples.

**Unit-2: Electronic Spectroscopy:**

The Franck Condon principle, Photophysical processes, Jablonski diagram. Absorption and emission spectra, Beer-Lambert law. Difference between thermal and photochemical processes, photochemical reaction. Laws of photochemistry: Grotthuss - Draper law, Stark - Einstein law, Quantum yield. Fluorescence Quenching (static and Dynamics), Fluorescence lifetime measurement

**Unit 3: Laser:** Principles of laser action, laser characteristics, pulsed lasers, laser cavity modes, Q-switching, mode locking, non-linear effects, harmonic generation, examples of lasers: He-Ne, Nd-YAG, titanium-sapphire, dye lasers.

**Unit-4: Group Theory and application-** Introduction to group theory, symmetry elements, point group. Reducible and irreducible representations of point group. Classes and character, statement of grand orthogonality theorem, character tables, concept of character projection operator. Selection rules in molecular spectroscopy. Normal modes, their symmetry properties, IR and Raman activity. Electronic spectroscopy. Crystal field theory. SALC – Hückel theory ( butadiene, benzene, napthalene), Hybridization, Vibronic coupling.

**Unit 5: Lab**

i)Verification of Lambert-Beer's law
ii) Absorbance spectrum study by UV-Vis spectrophotometer.
iii) Emission spectrum study by Fluorimeter, Fluorescence quenching.

### Reference books:


1. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, McGraw Hill Education, 4th Edition 2016
2. Molecular structure and spectroscopy, G. Aruldhas, 2nd Edition, Practice – Hall of India, Pvt Ltd., New Delhi – 110001, 2007.
3. Introduction to Spectroscopy, D. L. Pavia, G. L. Lampman, G. S. Kriz, Thompson Learning Inc, 5th Ed 2015.


## Organometallics and reaction kinetics

**Unit-1: Introduction to Organometallic compounds-** Basic idea of organometallic compounds, 18 electron and 16 electron rules for organometallic complexes.

**Unit-2: Structure and bonding of organometallic compounds-** Structures and bonding of metal carbonyls, IR spectra of metal carbonyls, metal nitrosyls, stereochemical control of valence of metal nitrosyls, metal cyanides, Zeise's salt, fluxional molecule.

**Unit-3: Structure and reactivity of Ferrocene-** Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation).

**Unit-4: Organometallic Reactions** - Reactions of organometallic complexes. Homogeneous catalysis by organometallic compounds: hydrogenation, hydroformylation and polymerization of alkenes.

**Unit-5: Introduction to reaction kinetics-** Thermodynamic and Kinetic aspects of reactions.

**Unit-6: Reactions in square planar complexes-** Mechanism of nucleophilic substitution in square planar complexes. Solvent exchange, aquation, anation, base hydrolysis, acid catalyzed hydrolysis.

**Unit-7: Electron Transfer Reactions-** Mechanism of electron transfer reactions, applications of Marcus expression (simple form).

## Reference books:


1. F. Basolo and R.C. Pearson, *Mechanisms of Inorganic Chemistry*
2. B. D. Gupta and A. J . Elias, *Organometallic Chemistry*
3. Greenwood, N.N. &Earnshaw. *Chemistry of the Elements*, Butterworth-Heinemann. 1997.
4. Cotton, F.A. & Wilkinson, G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.
5. Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. *Concepts & Models of Inorganic Chemistry*


## Advanced Special Chemistry -1

## Solid State Chemistry

**Unit-1: Chemical crystallography**- Space lattice, Crystal point groups, space group, Stereographic projections, Packing in solids, Crystal structures of representative systems, Silicates and Zeolites, Cements, Glasses, Quasicrystals, Nanostructures. Crystal classifications, Crystal energetics. Madelung constant and Lattice energy.

**Unit-2: Characterization techniques for solids-** X-ray diffraction, Electron microscopy (SEM, TEM, AFM), Thermal techniques (TG, DTA, DSC), Spectroscopic techniques (Mossbauer, IR, UV-VIS) and Physical property measurement techniques (Magnetic moments-VSM /SQUID, Electrical resistivity – Two / Four probe methods and thermal conductivity, Optical band gap, XPES, XAS).

**Unit-3: Electronic properties and defects:**
Free electron model, Metals, semiconductors and insulators, doped semiconductors Solid state Ionics. Point defects, Dislocations, Extended defects, Clusters and aggregates, Color centres, Non-stoichiometry of compounds, Diffusion mechanisms, Fick's law, Kirkenall effect.

**Unit-4: Phase transitions-** Critical phenomena, variety of phase transitions (Ordered- disorder, Martensite-austenite,

Spinoidal decompositions etc), Liquid crystals, Structure-property relations (magnetic, electrical, superconductivity, optical and thermal).

**Unit-5: Preparative techniques-** Powder synthesis by conventional and modern chemical methods, Reactivity of solids, Decomposition mechanisms, Powder processing (sintering and diffusion processes), Tailoring of solids, Special methods for single crystal growth and thin films depositions.

**Unit 6: Lab**

1. Synthesis of metal nanomaterials and determine their plasmon band
2. Synthesis of semiconductor materials and check the effect of size.
3. X-ray data analysis and determine the phase of the material
4. Estimation of lattice strain (Williamson-Hall Effect) on doping nanomaterials from the powder x-ray data.
5. Different techniques to grow single crystals.
6. Band gap calculation of materials from UV-VIS data.
7. Metal based nano-thin film preparation.
8. Single crystal structure determination by different software packages.

## Reference books:


1. West, A. R., Solid State Chemistry and Its Applications, John Wiley & Sons, 1984
2. Chakrabarty, K., Solid State Chemistry, New Age Publishers, 1996.
3. Introduction to Solid State Physics, C. Kittle. Wiley India.


## Materials of Industrial Importance

**Unit-1: Glass and Ceramics-** Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass and bio-glass. Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fibre.

**Unit-2: Pesticides**

a) Pesticides Residues in the Atmosphere: Pesticides into the atmosphere and their fate, Transport of vapours, Precipitation, effect of residues on human life, b) Pesticides residues in Water system: Nature and origin of pollution of aquatic systems, Point and Non-Point pollution. Dynamics of pesticides in aquatic environment. b) Pesticides residues in the Soil: Absorption, Retention, Transport and Degradation of pesticides in the soil, Effect on microorganisms and Consequent effect on the soil condition, Fertility, Interaction in the soil, c) Effect of pesticide residues on the quality of human life. Model ecosystem, In general and consequent effect on human life. The Cases of & affected societies and starving populations facing problems of health and nutrition, Traditional wisdom and Food security

**Unit-3: Battery technology-** Primary and secondary batteries, battery components and their role, Characteristics of Battery. Working of following batteries: Li-Battery, Solid state electrolyte battery &Fuel cells, Solar cell, dye sensitized solar cell, polymer cell.

**Unit-4: Catalysis-** General principles and properties of catalysts, homogenous catalysis and heterogenous catalysis and their industrial applications, Deactivation or regeneration of catalysts. Phase transfer catalysts, application of zeolites as catalysts. Leaching and soxlet washing. Catalytic process design and optimization: reactor type and configuration, kinetic modelling and reactor design.

**References Books:**


1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. R. M. Felder, R. W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: *Introduction to Ceramics,* Wiley Publishers, New Delhi.
4. J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.


**Unit 10: Materials of industrial importance lab-**

1. Metallic coatings on ceramic and plastic material.
2. Preparation of bio glasses.
3. Identification of pesticides by different spectroscopic techniques
4. Preparation of dye.

**References Books:**


1. P. C. Jain, M. Jain: *Engineering Chemistry*, Dhanpat Rai& Sons, Delhi.
2. R. Gopalan, D. Venkappayya, S. Nagarajan: *Engineering Chemistry*, Vikas Publications, New Delhi.
3. B. K. Sharma: *Engineering Chemistry*, Goel Publishing House, Meerut.


**Organic Spectroscopy (3-1-0-4)**

**1. Module 1: Introduction to Spectroscopy (3 Lectures)**

Definition and scope of spectroscopy, Interaction of electromagnetic radiation with matter, Regions of electromagnetic spectrum, Basic principles: absorption, emission, Energy transitions (electronic, vibrational, rotational), Chromophores and auxochromes, Overview of major techniques: UV-Visible, IR, NMR, Mass spectrometry, Comparison and applications

2. **Module 2: UV-Visible Spectroscopy (7 Lectures)**

Principles of UV-Vis spectroscopy, Beer-Lambert Law and its limitations, Types of electronic transitions ($\sigma \rightarrow \sigma^*$, $n \rightarrow \sigma^*$, $\pi \rightarrow \pi^*$, $n \rightarrow \pi^*$), Chromophores and conjugation, Effect of conjugation on absorption, Auxochromes and solvent effects, Bathochromic and hypsochromic shifts, Woodward-Fieser rules for: Conjugated dienes, α,β-unsaturated carbonyl compounds, Applications in structure determination

3. **Module 3: Infrared (IR) Spectroscopy (12 Lectures)**

Principles of IR spectroscopy, Molecular vibrations (stretching, bending), IR active vs inactive vibrations, Selection rules, Characteristic IR absorption: Alkanes, alkenes, alkynes, Functional groups: Alcohols, ethers, amines, Carbonyl compounds: Aldehydes, ketones, acids, esters, Fingerprint region and its significance, Effect of hydrogen bonding and conjugation

4. **Module 4: Nuclear Magnetic Resonance (NMR) Spectroscopy (15 Lectures)**

Basic principles of NMR, Nuclear spin and magnetic properties, Chemical shift and shielding/deshielding, Factors affecting chemical shift, Spin-spin coupling and splitting patterns, Coupling constant (J-value), Integration and proton counting, Interpretation of simple $^{1}H$ NMR spectra, Advanced splitting patterns, $^{13}C$ NMR spectroscopy basics, DEPT techniques (introductory level), NMR of common functional groups, Solvent effects and exchangeable protons, Introduction to 2D NMR (COSY, HSQC – basic idea).

5. **Module 5: Mass Spectrometry (8 Lectures)**

Principles of mass spectrometry, Ionization methods (EI concept), Mass analyzer and detection, Molecular ion peak and base peak, Fragmentation patterns: Alkanes, alcohols, Fragmentation of carbonyl compounds, Isotope patterns and nitrogen rule, McLafferty rearrangement, Applications and spectral interpretation

## Stereo Chemistry and Heterocyclic Chemistry-II

Unit-I: Stereochemistry (20L)

Symmetry properties, point group, configuration – acyclic and cyclic systems; conformation – cyclic systems (Cyclopropane, Cyclobutane, Cyclopentane, substituted cyclopentanes and cyclopentanones, Cyclohexane, cyclohexene, cyclohexanone, medium rings, decalin, hydrindane systems, perhydrophenanthrenes, perhydroanthracenes). Conformation and reactivity with reference to substitution, elimination, addition, rearrangement reactions, cyclisation reactions, Baldwin‘s Rules with example; Curtin-Hammett Principle, Zimmerman Traxler model for Aldol reaction. Diastereoselective synthesis: Asymmetric synthesis with chiral substrates (Cram’s rule, Felkin Anh model, Prelog’s rule, Stereochemistry of reactions– nucleophilic additions to cyclic ketones, Cieplak model. Chiroptical properties of organic molecules, CD, ORD-principles and applications, haloketone rules, sector rules.

Unit-II: Heterocyclic Chemistry (25L)

Systematic nomenclature (Hantzsch–Widman system) for monocycle and fused heterocycles. General approach to heterocyclic synthesis–cyclisation and cycloadditionroutes. Heterocycles in organic synthesis – masked functionalities, umpolung, Stork annulation reaction and applications. Synthesis and reactivity of pyrrole, pyridine, quinoline, isoquinoline, indole, pyrazole, imidazole, oxazole, thiazole and their applications in organic synthesis. Rearrangement and ring transformation involving 5-and 6-membered heterocycles with one heteroatom. (synthesis of testosterone, estrone, progesterone, ranitidine, lansoprazole and/or recently discovered molecules etc.). Nomenclature of normal and fused heterocycles. Reactivity and synthesis of pyrimidine, pyridazines, pyrazines, purines, pteridines with and without oxygen and/or sulfur atoms, and their role in biological systems. Introduction to chemistry of azepins, oxepins, thiepins and their analogues; phosphorous and selenium containing heterocycles with the use of modern reagents. ANRORC and Vicarious nucleophilic substitutions in heterocycles.

**(Semester 7)**

## Advanced Special Chemistry -2

### Fundamentals of Nano-materials

**Unit-1:** Historical development of nanomaterials, organization of matter-atoms, molecules, clusters and supramolecules.

**Unit-2:** Quantum Confinement, Structure and Bonding, Intermolecular forces, Molecular and crystalline structures- Bulk to surface transition, density of states, bandgap and dimensionality of nanomaterials, surface reconstruction.

**Unit-3:** Synthesis of Nanomaterials. Physical methods, Chemical methods and Bio inspired methods—1D-2D nanomaterials, carbon based materials, aerogels, zeolites, self-assembled nanomaterials, core shell particles, Metal, Metal Oxide, semiconductor nanoparticles, Carbon Nanotubes.

**Unit-4**: Structure, function and properties of nanomaterials: mechanical, magnetic, electrical, optical, biocompatibility, toxicity and emergent quantum properties.

**Unit-5**: Characterization of nanomaterials: Size and Surface Characterization using powder XRD analysis, dynamic Light Scattering, zeta Potential Analysis, FT-IR, SEM, UV-Vis, photoluminescence, TEM, FESEM and AFM studies.

**Unit-6: lab-**

1. Synthesis of Copper/ Silver/ Gold nanoparticles by simple chemical reduction method and confirm the synthesis of size dependent nanomaterial by surface plasmon resonance analysis.
2. Synthesis of Iron oxide nanoparticles by wet chemical method and confirm the synthesis by band gap analysis.
3. Synthesis of mixed ferrite nanoparticles by co-precipitation method and characterize the product by FTIR analysis.
4. Synthesis of CdS nanoparticles by simple wet chemical method and demonstrate the size variation.
5. Synthesis of ZnO quantum dots by simple solvothermal synthesis and confirm the size dependent variation in band gap.
2. Bio-inspired synthesis of nanoparticles from plant materials.

### Reference Books:


1. Fundamentals of Molecular Spectroscopy by C. N. Banwell, McGraw-Hill
2. Handbook of Thin Film Deposition, Hartmut Frey, Hamid. R. Khan Editors.
3. Elements of X-ray diffraction, B. D. Cullity, Creative Media Partners, LLC.


**or**

### Polymer and paints:

**Unit-1: Introduction to polymeric materials, its functionality-** Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers. Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bifunctional systems, Poly-functional systems.

**Unit-2: Kinetics and thermodynamical aspects of Polymerization-** Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization, polymerization techniques. - Determination of molecular weight of polymers ($M_n$, $M_w$, etc) by end

group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index. Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point. Glass transition temperature ($T_g$) and determination of $T_g$, Ceiling temperature, free volume theory, WLF equation, factors affecting glass transition temperature ($T_g$). Recycling of 3D printing materials.

**Unit-3: Preparation of Polymers**

Nomenclature - Classification of Polymers - Homo and hetero chain polymers - Addition polymerization - Condensation polymerization. Mechanism of Addition Polymerization - Cationic - Anionic polymerization - Free radical and Co-ordination or Ziegler-Natta polymerization.

**Unit-4: Application: Rubbers and Plastics**

Commodity and general purpose thermoplastics: Polyethylene, Polypropylene, Polystyrene, Polyvinyl Chloride, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, Polycarbonate, Polyphenylene oxide. Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex, Styrene Butadiene rubber, Polychloroprene rubber, Nitrile rubber, Butyl rubber, Ethylene-propylene-Diene Terpolymer, Silicone, Thermoplastic Elastomer.

**Unit-5: Paint & Dye-**Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints. Pigments, toners and lakes pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints, Dyes, Wax polishing, additives, Metallic coatings, metal spraying and anodizing. Origin of colour in organic molecules, chromatic and achromatic colours, solvatochromism, halochromism; Chromophores, auxochromes, chromogens, basic fluorophores; organic pigments (Anthraquinone, Benzimidazolone-dioxazines, Diazo lakes).

**References:**


1. Malcohm P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed.
2. Harry R. Allcock, Frederick W. Lampe and James E. Mark, Contemporary PolymerChemistry, 3rd ed. Prentice-Hall (2003).
3. Fred W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984)
4. Joel R. Fried, Polymer Science and Technology, 2nd ed. Prentice-Hall (2003).
5. PetrMunk and Tejraj M. Aminabhavi, Introduction to Macromolecular Science, 2nd ed. John Wiley & Sons (2002).


**Unit-6: Lab-**

**A. Polymer synthesis:**

1. Free radical solution polymerization of styrene (St)
2. Preparation of nylon 6,6,
3. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC)and phenolphthalein
4. Preparation of urea-formaldehyde resin,

**B. Polymer characterization:**

1. Determination of molecular weight by viscometry:
2. Testing of mechanical properties of polymers.

**C. Polymer analysis**

1. Instrumental Techniques,
2. IR studies of polymers,

**Reference Books:**


1. L. H. Sperling, Introduction to Physical Polymer Science, 4th ed. John Wiley &Sons(2005)
2. Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3rd ed. Oxford UniversityPress (2005)
3. Seymour/ Carraher's Polymer Chemistry, 9th ed. by Charles E. Carraher, Jr. (2013).
4. 1. K.J. Saunders: Organic Polymer Chemistry, Chapmann & Hall, London.
5. P.J. Flory: Principles of Polymer Chemistry, Cornell University Press, NY.
6. G. Odian: Principles of Polymerization, John Wiley & Sons Inc, NY.
7. James E. Mark, Hary Allcock, Robert West, Inorganic Polymers, Prentice Hall Englewood


Or

**Chemical Systems Biology CHM440 L-T-P: 3-1-0**

**Unit I: Introduction (15L)**

Background and definition of chemical biology, overview of chemical biology and its' importance, allied fields and their link with chemical biology, Proteins and Amino Acids: alpha-Amino Acids, other amino acids and their importance, isoelectric point, preparation of amino acids, reactions of AA, peptide bond formation, reagents-reactions, solid phase peptide synthesis, peptides and proteins, overview of protein structure, protein-protein interactions, its's application in biology.

**Unit II: Biomolecular-drug interaction (15L)**

Key discoveries in the field of chemical biology, few examples and journey through those discoveries, the use of unusual amino acids to probe biomolecular conformation, the use of novel fluorescence probe and applications, small molecule kinase inhibitors, GTP analogues as potential regulators for microtubule dynamics.

**Unit III: Bioorthogonal reaction and its' application in Chemical Biology (15L)**

Foundational Concepts of Bioorthogonal reaction; Click Chemistry Principles Reaction Mechanism, Reaction Conditions; Bioorthogonal Reaction Types, Applications of Bioorthogonal Reactions; Biomolecule Labeling, Protein Modification, Cell Imaging, Techniques for Application in Live Cells and In Vitro; In Vitro Labeling, In Vivo Labeling, Cell-Based Assays.

**Textbook:**

1. Chemical Biology: From Small Molecules to Systems Biology and Drug Design (Willey), Editor(s): Profs. Stuart L. Schreiber, Tarun M. Kapoor and Günther Wess, Nature Chemical Biology, 2010, 6, 847-853.

## Inorganic Cluster and Spectroscopic application

**Unit-1: Borane Chemistry-** Metallaboranes, Metallacarboranes, Applications of PSEPT over heteroboranes. Principle of Isolobility: Development and formulation of the concept of isolobility and its applications in the understanding of structure and bonding of heteroboranes.

**Unit-2: Inorganic Rings and Clusters-** Metal-metal bonding (MO approach), metal-metal single and multiple bonded compounds. Bonding in dimolybdenum and dirhenium complexes, carbonyl clusters.

**Unit-3: Advanced inorganic catalysis:** Catalysis and photocatalysis by inorganic metal complexes

**Unit-4: EPR spectroscopy and its applications-** Advanced EPR spectroscopy and its applications in different inorganic molecules.

**Unit-5: NMR:**
Nuclear spin, NMR active nuclei, principle of nuclear magnetic resonance,equivalent and non-equivalent carbons and protons, chemical shift δ), shielding / deshielding, upfield and downfield shifts. NMR peak area (integration for PMR), diamagnetic anisotropy, relative peak positions of different kinds of protons (alkyl halides, olefins, alkynes, aldehyde, acid, alcohol, amine etc.), substituted benzene derivatives, first order coupling (splitting of the signals: ordinary ethanol, bromoehane, dibromoehanes), coupling constants, elementary idea of 13C, splitting pattern in presence of heteroatoms (P, F), structure analysis. $^{1}$H-NMR spectra of coordination compounds of paramagnetic metal ions.

**Unit-6: NQR spectroscopy-** Principle, nuclear quadrupole coupling constant, structural information from NQR spectra.

**Unit-7: Lab-Spectrophotometric Analysis of Metal Ions**

1. Spectrophotometric estimation of Fe in alloy.
2. Determination of coordination number of complexes by Job's method
3. Spectrophotometric estimation of Mn as $MnO_4^-$
4. Spectrophotometric estimation of Cr as $CrO_4^{2-}$
5. Spectrophotometric estimation of Fe in multivitamin tablets.
6. Spectrophotometric estimation of Mn and Cr in a mixture.

Reference Books:


1. Greenwood, N.N. & Earnshaw. *Chemistry of the Elements*, Butterworth-Heinemann. 1997.
2. Cotton, F.A. & Wilkinson, G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.
3. Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. *Concepts & Models of Inorganic Chemistry*.
4. Sathyanarayana, D. N., *Handbook of Molecular Spectroscopy*

5. Das, A. K., Vol. 7. *Inorganic Chemistry*.

## Photochemical and Pericyclic reactions

**Unit-1: Photochemical reaction-** Photolysis of carbonyl compounds and nitrites: Norrish Type I, Norrish Type II, α-cleavage, Barton reaction, photoreduction, photoexcitation, photorearrangement reactions (Photorearrangemnt reaction of cyclohexanones, cyclohexadienone and α-tropolone methyl, Di-π-methane, photoisomerisation and photodimerisation), cycloadditions of benzene and its derivatives.

**Unit-2: Radical Chemistry:** Generation and detection of radicals, radical initiators, reactivity pattern of radicals, radical reaction intermediates, single electron transfer reactions

**Unit-3: Pericyclic reactions:** Frontier Molecular Orbital (FMO) approach and concept of aromaticity of transition states). Symmetry principles in pericyclic reactions, Orbital and state correlation diagram for $4n\pi$, $(4n+2)\pi$ systems, selection rules (Woodward-Hoffmann selection rules and general rules), Classification (Cycloaddition reactions, Electrocyclic reactions, Sigmatropic rearrangements, Ene reactions), application in synthesis.

Reference Books:

3. Stereochemistry of Organic Compounds - E. L. Eliel and S. H. Wilen,
4. Stereochemistry of Organic Compounds - D. Nasipuri,
5. Organic Photochemistry - J. W. Coxon& B. Halton,
6. Elements of Organic Photochemistry - D. O. Cowan & K. L. Drisco,
7. Pericyclic Chemistry – S. M. Mukherjee.
8. Frontier Orbitals and Organic Chemical Reactions – I. Fleming

**Unit-4: Lab- Extraction, small heterocycle Synthesis:**

1. Natural product extraction (caffeine, nicotine, casein etc.) etc.
2. Heterocycle Synthesis:
    - **a)** Synthesis of benz-oxazole from o-amino phenol derivatives,
    - **b)** Synthesis of phthalazine derivative from phthalic anhydride,
    - **c)** Synthesis of pyrazolone derivative from phenyl hydrazine,
    - **d)** Synthesis of coumarin derivative from resorcinol,
    - **e)** Synthesis of indole and carbazole derivative from phenyl hydrazine,
    - **f)** Synthesis of barbituric acid etc.

**Reference Books:**

1. Das, S.C. Advanced Practical Chemistry, Sixth edition,
2. Mukherjee, G.N. University handbook of undergraduate chemistry experiments.

## Research Methodology

**Or**

## Supramolecular Chemistry and Its Application

**Unit-1: Basic concept and principles**- Molecular recognition and self-assembly, Hydrogen Bonds: Definition, Structure and Stability, strength, Secondary Electrostatic Interactions in Hydrogen Bonding Arrays.

**Unit-2: Non-covalent interactions**- Ion pairing, Ion-Dipole Interactions, Dipole-Dipole interactions, Dipole-Induced Dipole and Ion-Induced Dipole interactions, Van der Waals or Dispersion Interactions, Closed shell interactions, Aromatic-Aromatic Interactions.

**Unit-3: Biological supramolecular systems-** Ionophores, Porphyrin and other Tetrapyrrolic Macrocycles, Coenzymes, Neurotransmitters, DNA and Biochemical Self-assembly.

**Unit-4: Biomimetic systems and Artificial receptors-**

(i) Cation Binding Hosts - Podand, Corand, Cryptand, Spherand; Nomenclature, Selectivity and Solution Behaviour;
(ii) Anion binding hosts - Challenges and Concepts, Biological Receptors, Conversion of Cation Hosts to Anion Hosts, Neutral Receptors, Metal-Containing Receptors,
(ii ) Co-receptors –Zwitter ionic, Cascade Complexes, Ion-pair, remote anion and cation binding sites,
(iv) Hosts for Neutral Receptors: Clathrates, Inclusion Compounds, Zeolites, Intercalates, Coordination Polymers, Cavitands, Clathrands, resorcicarene, Cyclodextrins and cucurbituril.

**Unit-5: Dynamics of supramolecular chemistry**- Transport processes, Dynamic Combinatorial chemistry, Supramolecular chirality and chirality imprinting, molecular extraction

**Unit-6: Solid-State Chemistry-** Catenation, poly-catenation, Rotaxane, molecular knots, molecular rotors, Organic Crystal Structures, Metal Organic Frameworks (MOFs), Covalent Organic Frameworks.

**Unit-7: Crystal Engineering & Supramolecular devices**- Supramolecular Synthons, Structure-Property Correlation, structure directing agents, design of Solids, phase transformations, Chemonics and semiochemistry, pH induced molecular devices, light induces molecular devices, energy converting molecular devices, supra-molecular logic gates.

**Reference Books:**


1. Lehn, J.-M. *Supramolecular Chemistry: Concepts and Perspectives.*
2. Das, A. K., *An Introduction to Supramolecular Chemistry.*


## (Semester 8)

## Advanced Special Chemistry -3

### Medical Nanotechnology

**Unit-1: Medical Nanotechnology-** Concept of a living cell; Unicellular and multicellular organisms; Types of tissues; Microorganisms (Structure, types and clinical significance); Viruses (structure, types and clinical significance).

**Unit-2:** Preparation, Characterization of biocompatible nanomaterials—nanospheres, nano shells, nano capsules, nanomicelles and their potential use in therapy (Antibiotics, photodynamic therapy).

**Unit-3:** Magnetic nanoparticles and their applications in magnetic hyperthermia as MRI contrasting agents.

**Unit-4:** Nanoparticle-Based Drug Delivery using Inorganic Nanoparticles and organic nanoparticles (e.g., cyclodextrin, polymer, dendrimers etc) for targeted- site specific, and non-targeted drug delivery, nanoencapsulation of water-insoluble drugs for intracellular drug delivery.

**Unit-5:** Application of biomimetic hydroxyapatite nanocrystals or bioactive polymer nanoparticles in bone substitutes and dentistry.

**Unit-6:** Application of inorganic nanoparticles for detection of various pollutants and biomaterials.

**Reference Books:**


1. Yoseph Bar Cohen, Biomimetics: Biologically Inspired Technologies‖, CRC Press, Boca Raton,
2. Reza Arshady and Kenji Kono, ―Smart Nanoparticles in Nanomedicine‖, MML series volume 8, Knetus Books, London, 2006
3. Ramakrishna S, MuruganRamalingam, and Kumar T. S. S., ―Biomaterials: A Nano Approach‖, CRCPress, London, 2010.
4. BikramjitBasu and Ashok Kumar K., ―Advanced Biomaterials: Processing and Applications‖, John Wiley, New Jersey, 2009.
5. Hari Singh Nalwa, ―Handbook of Nanostructured Biomaterials and Their Applications In Nanobiotechnology‖, American Scientific Publishers,2005.
6. Cato T. Laurencin, Temenoff J. S. and Mikos A. G., ―Biomaterials: The Intersection of Biology and Materials Science‖, Pearson, New Delhi, 2009.
7. Astrid Sigel, Helmut Sigel and Roland K. O. Sigel, ―Bi


**Unit-7: Lab-**

1. To identify an analyse the given nanomaterial by FTIR spectroscopy.
2. To analyse and confirm the crystal structure of given sample by X-ray diffraction technique. 3. To perform the time resolved photoluminescence study on nanoparticles/ quantum dots.
3. To carryout Photoluminescence study of the given nanoparticles.

## Reference books:


1. Instrumental Methods of Analysis, Hobart H. Willard, John A. Dean, Lynne L. Merritt D. Van Nostrand Company.
2. Fundamentals of Molecular Spectroscopy by C. N. Banwell, McGraw-Hill.


**or**

## Analytical methods in Industry

**Unit-1: Physical Methods of Separation:**

Boiling and distillation, vapor-liquid equilibria, Rault's law & Henry's law, relative volatility, azeotropic mixtures. Different distillation processes. Classification of filters, Sand filters, filter press, plates & frame press, filter aids, principles of leaf filters. General Principles (Significance, moisture content), Rate of drying (Constant & falling rate period, factors affecting drying), Types of evaporators, jacketed, horizontal and vertical tube evaporators, forced circulation evaporations, entrainment separators (upturned, deflector type, tangential type).

**Unit 2: Thermal Methods of Analysis:**

Thermal Gravimetric Analysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetery (DSC), Thermal Mechanical Analysis (TMA). Flow of Heat- Introduction, Conduction (Fourier law, Thermal conductivity, thermal diffusivity thermal insulation & problems), Heat Exchange Equipment.

**Unit 3: Electro Analytical Techniques:**

Theory and application of Potentiometery, Voltametry, Polarography, Amperometry, Coulometry and Conductometry.

**Unit 4: Analytical Separation techniques:**

Definition and importance. Different type of separation technique, Solvent extraction. Distillation (simple, fractional and vacuum distillation), Crystallization. Chromatographic separation: Thin layer chromatography (TLC), Column chromatography, Paper chromatography; principle, methodology and application.

**Unit 5: Advance method of separation and analysis:**

Principle methodology and application of High-performance thin layer chromatography (HPTLC), High-performance liquid chromatography (HPLC), Liquid chromatography-mass-spectrometry (LC-MS), Gas chromatography (GC), Gas chromatography-mass-spectrometry (GC-MS), Inductively coupled plasma mass spectrometry (ICP-MS), Lyophilizer, X-ray fluorescence (XRF), Single crystal X-ray diffraction (SCXRD), Super conducting quantum interference device (SQUID).

**Unit 6: Lab**

i) Separation with ion-exchange chromatography
ii) Gravimetric analysis
iii) Experiment with Gas chromatography

**Reference:**


1. H.H. Willard, L.L. Merrit, J.A. Dean, F. A. Settle*: Instrumental Methods of Chemical Analysis*, Wadsworth Publishing Company, California.
2. G. D. Christian: *Analytical Chemistry*, John Wiley
3. N. Y. S.M. Khopkar: *Basic Concepts of Analytical Chemistry*, Wiley Eastern Ltd, New Delhi.
4. F. A. Henglein: Chemical Technology (Pergamon).
5. R.N. Shrove: The Chemical Process Industries (MGH).
6. W.L. Badger and J.T. Bandchero: Introduction to Chemical Engineering (MGH).
7. G.H. Morrison & H. Freiser: Solvent extraction in Analytical Chemistry (John Wiley)


Or

## Medicinal Chemistry

**Unit I: Medicinal Chemistry-I (20L)**

An overview of drugs and drug targets at the molecular level; intermolecular binding forces. Classification of drugs. Pharmacodynamic (PD) studies: Enzymes as drug targets, Receptors as drug targets, Nucleic acid as drug targets, Miscellaneous drug targets (biosynthetic building blocks, transport proteins etc as drug targets). Pharmacokinetics (PK) studies: Drug ADME, Drug administration, Drug dosing, Drug delivery. Prodrugs and use of prodrug systems (prodrugs for stability, solubility and slow release), overview of drug delivery; Synthetic methods in medicinal chemistry: Combinatorial and parallel synthesis: solid phase techniques, mix and split method in combinatorial synthesis; dynamic combinatorial synthesis; solid phase synthesis; diversity-oriented synthesis. Lead discovery; Bioassays; drug targets; Lead Modification; optimization;

pharmacophore. Quantiative-structure activity relationships (QSAR). Toxicological studies for drugs: Therapeutic index and therapeutic window, ED-values, LD-values. drug synergy.

**Unit-II: Physical Organic Chemistry (10L)**

**Physical Organic Chemistry**: MO treatment of acyclic and cyclic conjugated systems; Huckel's rule and concept of aromaticty, annulenes, heteroannulenes, fullerenes (C60), alternate and non-alternate hydrocarbons, antiaromaticity, pseudo-aromaticity, homo-aromaticity; graphical methods Frost diagram. Huckel treatment – applications to ethylene, allyl, cyclopropenyl, butadiene, cyclobutadiene, Hammett equation and its modifications.

**Unit-III: Medicinal Chemistry-II**: **(15L)**

Anti-bacterial drugs: Discovery of penicillin, Mechanism of action, Structure-activity relationship, Drug resistance, Role of clavulinic acid, New generation antibiotics. Anti-viral drugs: Discovery, Mechanism of action, Structure-activity relationship, Anti-cancer drugs: Introduction, examples and mechanism of action, PDT. Drugs working on cholinergic receptors: Introduction, examples and mechanism of action. Drugs working on adrenergic nervous system: Introduction, examples and mechanism of action. Opoid analegesics. Ant-ulcer drugs.

## Reagent Chemistry (CC-Without Research)

**Unit-1: Modern Reagents in Organic Synthesis-** Complex metal hydrides, Gilman's reagent, Li-reagents, 1,3-dithiane, trimethylsilyl iodide, tri-n-butyltin hydride, Woodward and Prevost hydroxylation, $OsO_4$, $NaIO_4$, DDQ, $SeO_2$, $SmI_2$, coupling reagents (DCC, HOBT, EDC.HCl, HATU etc.), phase transfer catalysts, crown ethers, Merrifield resin, Peterson's synthesis, Wilkinson's catalyst, Baker yeast, Lipase, organo-boron reagents, organo-phosphorus reagents, organo-silicon reagents, organo-sulphur reagents, ylides.

**Unit-2: Cross-coupling reactions:** Cross coupling reactions (Heck, Suzuki, Sonogashira, Kumada, Negeshi, Stille, Hiyama coupling reactions) and their application in synthesis.

**Unit-3: Translational Metal Reagents in Organic Synthesis-** Application of organotransition metals in organic synthesis, Structural and mechanistic aspects (with special thrust on Pd), Davies rule., cross-coupling reactions, Ziegler Naata reaction, Olefin metathesis, Grubbs reagent, Tebbe's reagent, Pauson-Khand reactions, Volhardt co-trimerisation, nontransition metal reagents.

**Unit-4: C-H bond activation-** Basic introduction (ortho-, meta-, para-C-H bond activation) and its application in organic synthesis.

Reference Books:


1. Hydroboration - H. C. Brown

2. Borane Reagents - H. C. Brown, A. Pelter, K. Smith.
3. Relevant parts from Advanced Organic Chemistry - F.A. Carey and R.J. Sandberg; Vols. I & II.
4. Relevant parts from Comprehensive Organic Synthesis - B. M.Trost& I. Fleming
5. Principles of Organic Synthesis - RO.C. Norman and J. M. Coxon-Blackie.
6. C-H Bond Activation in Organic Synthesis - Jie. J. Lee

## Natural Products and Bio-organic Chemistry (CC-Without Research)

**Unit-1: Basic introduction to Natural Products-** Familiarity with methods of structure elucidation, biosynthesis, synthesis and biological activity of alkaloids, terpenoids and steroids.

**Unit-2: Total synthesis of few of the natural products-** Strychnine, Strychnine, Penicillin V, Reserpine, Vitamin B12, Progesterone, Prostaglandins F2-alpha and E2, Prostaglandins A2 and F2-alpha, Carpanone, Biotin, Periplanone B etc.

**Unit-3: Basic Introduction to Bio-organic Chemistry-** Molecular models of biological receptors, biomimetic chemistry, design, chemistry behind coagulation, vision, electron transport, biological decarboxylation, biological methylation, synthesis and binding studies of synthetic receptors.

**Unit-4: Chemistry of enzymatic activity-** Enzyme catalyzed reactions (examples of nucleophilic displacement on a phosphorus atom), enzymatic action of some common enzymes (chymotrypsin, lysozyme, ribonuclease, carboxypeptidase etc.), coupling of ATP cleavage to endergonic processes.

**Unit-5: Application of enzymes-** Use of enzymes in organic synthesis (biocatalysis), biotechnological applications of enzymes: Enzyme purification, immobilization of enzymes, enzyme therapy, enzyme and recombinant DNA technology.

Reference Books:


1. Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery- Christopher T. Walsh
2. The Organic Chemistry of Biological Pathways (2nd Edition)- John E. McMurry; Tadhg P. Begley
3. Bioorganic Chemistry- Dugas
4. Classics in Total Synthesis: Targets, Strategies, Methods (1st Edition)-Nicolaou, Sorensen.


## Project/Dissertation

## Skill Enhancement Courses (SECs)

### Green Methods in Chemistry

**Unit-1: Introduction to Green Chemistry**- What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry

**Unit-2: Principles of Green Chemistry and Designing a Chemical synthesis**

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following:

a) Designing a Green Synthesis using these principles; Prevention of Waste/ by products; maximum incorporation of the materials used in the process into the final products, Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.
b) Prevention/ minimization of hazardous/ toxic products reducing toxicity.risk = (function) hazard × exposure; waste or pollution prevention hierarchy.
c) Green solvents– supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents and how to compare greenness of solvents.
d) Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy.
e) Prevention of chemical accidents designing greener processes, inherent safer design, principle of ISD "What you don't have cannot harm you", greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation.
f) Strengthening/ development of analytical techniques to prevent and minimize thegeneration of hazardous substances in chemical processes.

**Unit-3: Examples of Green Synthesis and some real world cases**

a) Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis).
b) Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoicacid, oxidation of toluene and alcohols; microwave assisted reactions in organic solvents Diels-Alder reaction and Decarboxylation reaction.
c) Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine).
d) A green synthesis of ibuprofen which creates less waste and fewer byproducts (Atom economy).
e) Surfactants for Carbon Dioxide – replacing smog producing and ozone depleting solvents with $CO_2$ for precision cleaning and dry cleaning of garments.
f) Environmentally safe antifoulant.
g) $CO_2$ as an environmentally friendly blowing agent for the polystyrene foam sheet packaging market.
h) Using a catalyst to improve the delignifying (bleaching) activity of hydrogen peroxide.
i) A new generation of environmentally advanced preservative: getting the chromium and arsenic out of pressure treated wood.
j) Right fit pigment: synthetic azopigments to replace toxic organic and inorganic pigments.
k) Development of a fully recyclable carpet: cradle to cradle carpeting.

**Reference Books**:


1. Manahan S.E. (2005) Environmental Chemistry, CRC Press.
2. Miller, G.T. (2006) Environmental Science 11th edition. Brooks/Cole.
3. Mishra, A. (2005) Environmental Studies. Selective and Scientific Books, New.
4. Ahluwalia, V.K. &Kidwai, M.R.*New Trends in Green Chemistry*, Anamalaya Publishers (2005).
5. Anastas, P.T. & Warner, J.K.: *Green Chemistry - Theory and Practical*, Oxford University Press (1998).
6. Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
7. Cann, M.C. &Connely, M.E. *Real-World cases in Green Chemistry*, American Chemical Society, Washington (2000).
8. Ryan, M.A. &Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, Washington (2002).
9. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition,2010.


## Fuel Chemistry

**Unit-1: Review of energy sources (renewable and non-renewable):** Classification of fuels and their calorific values. *Coal:* Uses of coal (fuel and nonfuel) in various industries, its composition, carbonization of coal. Coal gas, producer gas and water gas—composition and uses. Coal gasification (Hydro gasification and Catalytic gasification), Coal liquefaction and Solvent Refining.

**Unit-2: Petroleum and Petrochemical Industry:** Composition of crude petroleum, Refining and different types of petroleum products and their applications. Fractional Distillation, Cracking, Reforming Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels.

**Unit-3: Petrochemicals:** Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and Xylene its derivatives.

**Unit-4: Lubricants:** Classification of lubricants, lubricating oils (conducting and non-conducting) Solid and semisolid lubricants, synthetic lubricants. Properties of lubricants (viscosity index, cloud point, pore point) and their determination.

**Reference Books:**


1. Stocchi, E. *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK (1990).
2. Jain, P.C. & Jain, M. *Engineering Chemistry* DhanpatRai& Sons, Delhi.
3. Sharma, B.K. & Gaur, H. *Industrial Chemistry*, Goel Publishing House, Meerut(1996).


## Pharmaceutical Chemistry

**Unit-1: Drugs & Pharmaceuticals**

Drug discovery, design and development; Basic Retrosynthetic approach. Synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti-inflammatory agents (Aspirin, paracetamol, lbuprofen); antibiotics (Chloramphenicol);

**Unit-2: Types of drugs**

Antibacterial and antifungal agents (Sulphonamides; Sulphanethoxazol, Sulphacetamide, Trimethoprim); antiviral agents (Acyclovir), Central Nervous System agents (Phenobarbital, Diazepam),Cardiovascular (Glyceryltrinitrate), antilaprosy (Dapsone), HIV-AIDS relateddrugs (AZT- Zidovudine), 7-Fluoroquinoline based drugs, Remdesivir, Tamiflu etc.

**Unit-3: Fermentation**

Aerobic and anaerobic fermentation. Production of (i) Ethyl alcohol and citric acid, (ii) Antibiotics; Penicillin, Cephalosporin, Chloromycetinand Streptomycin, (iii) Lysine, Glutamic acid, Vitamin B2, Vitamin B12 and Vitamin C.

**Reference Books:**


• G.L. Patrick: Introduction to *Medicinal Chemistry, Oxford University* Press, UK.

• Hakishan, V.K. Kapoor: *Medicinal and Pharmaceutical Chemistry*, VallabhPrakashan, Pitampura, New Delhi.

• William O. Foye, Thomas L., Lemke, David A. William: *Principles of Medicinal Chemistry*, B.I. Waverly Pvt. Ltd. New Delhi.


## Mathematical and Computation in Chemistry

**Unit-1: Programming Languages (FORTRAN/C++, Python)**

Syntax for formula translation, Decision making statement, loop, array, subroutine.

**Unit-2: Numerical Analysis:**

Numerical techniques for roots of equations, numerical differentiation, numerical integration, simultaneous equations, interpolation, extrapolation, differential equation, partial differential equation.

### Unit-3. Lab

Application in general and chemical problem:

1. Sum of series
2. Conversion of decimal number to binary number and vice versa
3. Matrix multiplication, check the associative characteristic of the operation.
4. To check the non-commutative nature of Pauli matrices.
5. To check the normalization and orthogonality of functions.
6. Getting x, $x^2$, $p_x$, $p_x^2$ for particle in 1D box and SHO system.
7. Getting the most probable speed of gas obeying Maxwell speed distribution.
8. Getting titration curve for acid base titration and evaluating equivalence point.
9. Solving kinetic equation for one step and two steps problem

**Reference books:**

1. C Xavier, Fortran77 and Numerical Methods, New Age International (P) Ltd.
2. Markus, Modern Fortran in Practice, Cambridge Univrsity Press (2012).
3. S. A. Teukolsky, W. T. Vetterling, B. P. Flannery, Numerical Recipe in Fortran77, The art of scientific computing. W. H. Press, 2nd Edition, Cambridge University Press.
4. Mathematics for Chemists, N. K. Bera, S. Ghosh, P. Ghosh. Techno World.
5. B. Stroustrup, The C++ Programming Language, 4th Edition.

**AI in Chemistry**

Unit 1: Introduction to Artificial intelligence (AI): (7L)

Definition of AI. Scope and overview. Historical background. Evolutionary algorithms, Machine learning: supervised, unsupervised, reinforcement learning, Artificial Neural network, Natural language processing (NLP).

Unit 2: Chemical structure representation (8L)

Concept of force field, Chemical structure representation and molecular descriptors. Preliminary concept of quantum chemistry and its computation. Molecular modelling. Predicting molecular structure using evolutionary algorithms.

Unit 3: Data Science in Chemistry: (6L)
Importance of data in AI application, Source of chemical data, data processing: cleaning normalization, feature extraction, linear regression, decision trees.

Unit 4: Application of AI in chemistry (qualitative description): (7L)
Drug Discovery: Predictive modelling for drug design, Virtual screening and ligand-based drug- discovery, De novo drug design using generative models. Molecular Modeling and Simulation: Protein-ligand docking, Quantum mechanics/molecular mechanics (QM/MM) methods. Chemical Process Optimization: Optimization of chemical processes using AI techniques, Predictive maintenance, Real-time process control and optimization. Chemical Synthesis, Molecular Property Prediction, Spectroscopy Analysis and Materials Characterization.

Unit 5: Ethical and Societal Implications Ethical guidelines (2L)

Ethical considerations in the use of AI in chemistry. Impact of AI on the practice of chemistry and scientific research. Societal implications of AI-driven chemical technologies. Impact of AI on employment and the workforce.

References:

1. Amit Konar, Artificial intelligence and soft-computing, CRC press, 2000.
2. Russell / Norvig , ARTIFICIAL INTELLIGENCE: A MODERN APPROACH , 4th Edition , Pearson Education, 2022.
3. 8. Schneider, G., & Fechner, U. (2005). Computer-based de novo design of drug-like molecules. Nature Reviews Drug Discovery, 4(8), 649-663.

**BASIC CYBER SECURITY AND THE INTERNET OF THINGS (IoT) GEN104**

**Course Code:** (To be assigned)

**Credits:** 4 (Theory)

**Semester:** II

**Contact Hours:** 60 Hours (4 Hours per Week)

**Course Description**

The rapid growth of digital technologies has transformed every aspect of modern life, including education, business, governance, healthcare, communication, and entertainment. Alongside these developments, cyber threats and security concerns have emerged as major challenges for individuals and organizations. Simultaneously, the Internet of Things (IoT) has enabled interconnected smart devices and systems that are reshaping industries and everyday living.

This course introduces undergraduate students from all disciplines to the fundamentals of cyber security and the Internet of Things. It emphasizes cyber awareness, safe digital practices, ethical and legal aspects of technology use, and the principles and applications of IoT. The course is designed to develop informed, responsible, and digitally competent citizens capable of navigating an increasingly connected world.

**Course Objectives**

The course aims to:

1. Introduce students to the concepts of cyberspace, digital systems, and cyber security.
2. Develop awareness of cyber threats, cybercrime, and preventive measures.
3. Familiarize students with cyber ethics, privacy, and relevant cyber laws.
4. Introduce the architecture, technologies, and components of IoT systems.
5. Explain real-world applications of IoT across various sectors.
6. Understand security and privacy challenges in interconnected digital environments.

**Course Outcomes (COs)**

Upon successful completion of the course, students will be able to:

**CO1:** Explain the concepts of cyberspace, digital assets, and cyber security fundamentals.

**CO2:** Identify common cyber threats, cybercrimes, and appropriate security measures.

**CO3:** Demonstrate awareness of cyber ethics, privacy concerns, and cyber laws.

**CO4:** Describe the architecture, components, and communication technologies used in IoT systems.

**CO5:** Explain the applications of IoT in various sectors and emerging smart environments.

**CO6:** Evaluate security, privacy, and ethical challenges associated with IoT-enabled systems.

**Unit I: Introduction to Cyber Security and Cyberspace - (12 Hours)**

**Topics**

1. Digital Revolution and Information Society
2. Cyberspace and Digital Ecosystems
3. Data, Information, and Digital Assets
4. Fundamentals of Cyber Security
5. Importance of Information Security
6. Principles of Cyber Security:
    - Confidentiality
    - Integrity
    - Availability
7. Security Threat Landscape
8. Cyber Attacks and Their Consequences
9. National and Global Cyber Security Challenges
10. Emerging Trends in Cyber Security

**Unit II: Cyber Threats, Cybercrime and Protection Mechanisms - (12 Hours)**

**Topics**

1. Malware:
    - Virus
    - Worm
    - Trojan Horse
    - Spyware
    - Adware
    - Ransomware

2. Social Engineering Attacks
3. Phishing, Smishing and Vishing
4. Identity Theft and Financial Fraud
5. Cyberbullying and Online Harassment
6. Password Security and Authentication
7. Multi-Factor Authentication
8. Secure Internet Browsing
9. Email Security
10. Mobile Device Security
11. Social Media Security
12. Personal Cyber Hygiene Practices

**Unit III: Cyber Ethics, Privacy and Cyber Laws - (12 Hours)**

**Topics**

1. Cyber Ethics and Responsible Use of Technology
2. Digital Citizenship
3. Privacy in the Digital Age
4. Personal Data Protection
5. Intellectual Property Rights
6. Copyright and Plagiarism
7. Cybercrime: Concepts and Categories
8. Digital Evidence and Digital Forensics (Overview)
9. Information Technology Act, 2000
10. Cyber Laws and Regulations in India
11. National Cyber Security Policies and Initiatives
12. Ethical Issues in Emerging Technologies

**Unit IV: Fundamentals of Internet of Things (IoT) - (12 Hours)**

**Topics**

1. Introduction to IoT
2. Evolution of Connected Systems
3. Characteristics of IoT
4. IoT Ecosystem and Architecture
5. Sensors and Actuators
6. Embedded Systems and Smart Devices
7. Data Acquisition and Processing
8. Communication Technologies:
    - Wi-Fi
    - Bluetooth
    - RFID
    - NFC
    - Cellular Communication
9. Cloud Computing in IoT
10. Edge Computing Concepts
11. IoT Platforms and Frameworks
12. Challenges in IoT Deployment

**Unit V: IoT Applications, Challenges and Security - (12 Hours)**

**Topics**

1. Smart Homes
2. Smart Cities
3. Smart Healthcare Systems
4. Smart Agriculture
5. Industrial IoT (IIoT)
6. Smart Transportation and Logistics
7. Wearable Technologies
8. Environmental Monitoring Systems
9. Security Challenges in IoT

10. Privacy Issues in Connected Devices
11. Ethical Concerns in Smart Systems
12. Future Trends:
    - Artificial Intelligence and IoT (AIoT)
    - Digital Twins
    - Industry 5.0
    - Sustainable Smart Ecosystems

**Text Books**


1. Nina Godbole and Sunit Belapure, *Cyber Security: Understanding Cyber Crimes, Computer Forensics and Legal Perspectives*.
2. Arshdeep Bahga and Vijay Madisetti, *Internet of Things: A Hands-On Approach*.
3. Charles J. Brooks et al., *Cyber Security Essentials*.


**Reference Books**


1. Michael Miller, *The Internet of Things*.
2. Rajkumar Buyya and Amir Vahid Dastjerdi, *Internet of Things: Principles and Paradigms*.
3. William Stallings, *Effective Cyber Security*.
4. Pethuru Raj and Anupama Raman, *The Internet of Things: Enabling Technologies, Platforms and Use Cases*.

**Paper Name:** Introduction to IKS **Paper Code:** (IKS101)
**Credit:** 4
**LTP:** 4–0–0

## Course Objectives:

1. To introduce the fundamental concepts and sources of Indian Knowledge Systems.
2. To explore scientific and technological developments in ancient India.
3. To examine architectural, engineering, and ecological knowledge systems.
4. To analyze philosophical traditions contributing to scientific thought.
5. To relate traditional knowledge systems with modern scientific advancements.

## Course Description:

This course provides a comprehensive overview of Indian Knowledge Systems with emphasis on scientific, technological, and intellectual developments of ancient India. It includes foundational texts, mathematical and astronomical advancements, metallurgical excellence, architectural achievements, and traditional medical knowledge. The course also highlights ecological sustainability and philosophical reasoning while establishing connections with modern science and innovation.

## Course Outcomes:

**CO1** Explain the historical development, fundamental concepts, educational traditions, and philosophical foundations of Indian Knowledge Systems, including major schools of Indian thought.

**CO2** Describe the contributions of ancient India in polity, economy, mathematics, astronomy, Ayurveda, and other scientific disciplines, with reference to classical texts and scholars.

**CO3** Interpret the principles of traditional Indian engineering, metallurgy, materials science, architecture, urban planning, and technological innovations developed in ancient India.

**CO4** Analyze indigenous ecological knowledge, environmental ethics, water management systems, and sustainable agricultural practices in the context of present-day sustainability challenges.

**CO5** Evaluate the significance and contemporary relevance of Indian Knowledge Systems in modern education, scientific research, innovation, technology development, and societal well-being.

## Course Content:

**Module I** Foundations of Indian Knowledge Systems: Philosophy and Scientific Thoughts [14 lecture hours]

a. Introduction to Indian Knowledge Systems with historical evolution. Ancient Indian Literature and Scriptures (*Vedas, Vedanga, Puranas*, the maha-kavya— Ramayana and Mahabharata).
b. Oral traditions in Ancient Indian Education- Preservation of culture, tradition and Dharma through education*: Guru-Shishya Parampara*, Gurukulas, Six philosophical Schools-*Samkhya, Yoga, Nyaya, Vaisheshika, Purva-Mimamsa, Advaita (Uttara-Mimamsa)*
c. Indian philosophy: Concept of Pancha-bhuta. Conscious Awakening through Mindfulness, Breath Control, Meditation, Philosophical debates-Buddhism and Jainism- The role of ancient Indian Universities- *Nalanda* and *Takshashila.*

**Module II** Ancient Indian polity and economy [6 lecture hours]

a. Introduction to Ancient Indian Political and Economic System. The notion of Bharartavarsha as a Chakravarti-Kshetra and important attributes of Chakravartin.
b. Concept of Kingship: Duties and Responsibilities of a king in ancient India.
c. Ancient Indian economy- taxation, Savings and Expenditure

**Module III** Mathematics, Astronomy, Ayurveda and Life Sciences in Ancient India [12 lecture hours]

a. The development of mathematical and astronomical knowledge in ancient India, evolution of the number system, decimal representation, and the concept of zero and infinity. Contributions of Aryabhata, Brahmagupta, and Bhaskara II..
b. Early astronomical concepts and Astronomical Instruments (*Yantras*)
Application of Physics and Chemistry
c. The fundamental concepts of Ayurveda as a holistic system of medicine. Ayurvedic view of cause of deceases.
d. References to classical texts such as Surya Siddhanta, *Charaka Samhita* and *Sushruta Samhita.*

**Module IV** Metallurgy, Materials, architecture and Civil Engineering [14 lecture hours]

a. The advancements in metallurgy and materials science in ancient India, traditional metallurgical practices and early innovations in materials : the Iron Pillar of Delhi-example of advanced materials engineering.
b. Nanomaterials and nanotechnology in ancient India.

c. The architecture and civil engineering in ancient India-Temple architecture- *Nagara* and *Dravida* styles
d. Urban planning concepts- the cities of Harappa and Mohenjo-Daro, drainage systems and spatial organization. Ancient cities of Indus -Saraswati region. Cave and monolithic architecture.

## **Module V** Environmental Ecology and Agricultural Sustainability [8 lecture hours]

a. Traditional ecological knowledge and sustainable practices, biodiversity preservation. Ancient Indian water harvesting techniques. The concept of Pancha-bhuta and its relation to environmental balance.
b. Sustainable agricultural practices and their relevance in the context of present-day environmental challenges.

## **Module VI** Modern Relevance of IKS [6 lecture hours]

a. Relevance of IKS in contemporary contexts. Ancient, traditional practices such as textile weaving, pottery, and shipbuilding as examples of applied knowledge systems.
b. The role of Indian Knowledge Systems in modern research, innovation, contemporary education and scientific development.

**References-**


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2.Bag, A K, *Mathematics in Ancient and Medieval India*, Chaukhamba Orientalia, New Delhi, 1979

3.Banerjee, P*, Public Administration in Ancient India,* Macmillan, London, 1916

4.Chatterjee, Satishchandra, *An Introduction to Indian Philosophy*, Rupa & Co. Calcutta

5. Kapoor, kapil, Singh, Avadesh, *Indian Knowledge Systems* Vol. 1-2, D.K print World Ltd, New Delhi 2021

6. Debiprasad Chattopadhyaya, Science in Ancient India

7. Dharampal, Indian Science and Technology in the Eighteenth Century

8. A.L. Basham, The Wonder That Was India