Course Curriculum for PG PROGRAMME
2 Year M.Sc. in CHEMISTRY

Name Program	**M.Sc. in CHEMISTRY**
Department offering the Program	**CHEMISTRY**

Distribution of Total Credits		
Departmental Core (DC)	**Electives (DE/OE)**	**Total Credits**
154	**36**	**190**

Distribution of credits: Semester-wise				
Semester I	**Semester II**	**Semester III**	**Semester IV**	**Total**
51	**52**	**51**	**36**	**190**

Course Structure for PG PROGRAMME
2 Year M.Sc. in CHEMISTRY

Course No.	Course Name	L	T	P	C
Semester 1					
CYC 501	Quantum Chemistry	3	0	0	9
CYC 502	Organic reactions and stereochemistry	3	0	0	9
CYC 503	Mathematics for chemists	3	0	0	9
CYC 504	Application of Spectroscopic methods	3	0	0	9
CYC 505	Coordination Chemistry	3	0	0	9
CYC 506	Inorganic Chemistry lab	0	0	3	3
CYC 507	Organic Chemistry lab - I	0	0	3	3
	Total	**15**	**0**	**6**	**51**

Course No.	Course Name	L	T	P	C
Semester 2					
CYC 508	Kinetics and Thermodynamics	3	0	0	9
CYC 509	Methods in Organic Synthesis	3	0	0	9
CYC 510	Organometallic Chemistry	3	0	0	9
CYC 511	Group Theory & Electronic Spectroscopy	3	1	0	10
CYO 5XX	Open elective 1	3	0	0	9
CYC 512	Physical Chemistry lab -I	0	0	3	3
CYC 513	Organic Chemistry lab -II	0	0	3	3
	Total	**15**	**1**	**6**	**52**

Course No.	Course Name	L	T	P	C
Semester 3					
CYC 514	Photochemistry & Pericyclic reactions	3	0	0	9
CYC 515	Molecular spectroscopy	3	0	0	9
CYC 516	Strategies in organic synthesis	3	0	0	9
CYO 5XX	Open elective -2	3	0	0	9
CYC 519	Thesis Unit -1	0	0	0	9
CYC 517	Physical Chemistry lab -II	0	0	3	3
CYC 518	Analytical Chemistry lab	0	0	3	3
	Total	**12**	**0**	**0**	**51**

Course No.	Course Name	L	T	P	C
Semester 4					
CYD 5XX/CYO 5XX	Departmental elective -1/open elective - 3	3	0	0	9
CYD 5XX /CYO 5XX	Departmental elective -2/open elective - 4	3	0	0	9
CYC 520	Thesis Unit -2	0	0	0	9
CYC 521	Thesis Unit -3	0	0	0	9
	Total	**0**	**0**	**0**	**36**

List of Electives

A.	**Open Electives**		**L-T-P**
	CYO 501	Instrumental Techniques for Material Characterization	3-0-0
	CYO 502	Material Sciences and Technology	3-0-0
	CYO 506	Electrochemical Strategies in Energy Systems	3-0-0
	CYO 507	Nuclear & Radiation Chemistry	3-0-0
	CYO 508	Surface Science & Catalysis	3-0-0

B.	**Departmental Electives**		**L-T-P**
	Course No.	**Course Name**	3-0-0
1	CYD 501	Medicinal Chemistry	3-0-0
2	CYD 502	Polymer Chemistry	3-0-0
3	CYD 503	Cluster Chemistry	3-0-0
4	CYD 504	Symmetry in Bonding	3-0-0
5	CYD 505	Asymmetric Synthesis	3-0-0
6	CYD 506	Computational Chemistry	3-0-0
7	CYD 507	Bio-inorganic Chemistry	3-0-0
8	CYD 508	Chemistry of *f*–Block Elements	3-0-0
9	CYD 509	Modern Terpyridine Chemistry	3-0-0
10	CYD 510	Chemistry of Nanostructured Materials	3-0-0
11	CYD 511	Advanced Methods in Organic Synthesis	3-0-0
12	CYD 512	Modern aspects of Catalysis and Surface science	3-0-0
13	CYD 513	Electroanalytical methods	3-0-0
14	CYD 514	Single crystal X-ray diffraction	3-0-0
15	CYD 515	Advances in Nonconventional Energy Systems	3-0-0
16	CYD 516	Advanced heterocyclic chemistry	3-0-0
17	CYD 517	Oligosaccharide synthesis	3-0-0
18	CYD 518	Metalloenzymes-Special Topics	3-0-0
19	CYD 519	Characterization Techniques for inorganic chemists	3-0-0
20	CYD 520	Advanced Fluorescence Spectroscopy	3-0-0
21	CYD 521	Nanomaterials for Advanced Applications	3-0-0
22	CYD 522	Advanced Biocatalysis	3-0-0
23	CYD 523	Supramolecular chemistry & Molecular recognition	3-0-0
24	CYD 532	Solid State Materials: Chemistry& Engineering	3-0-0
25	CYD 533	Advanced Electrochemistry	3-0-0
26	CYD 534	Heterocyclic Chemistry	3-0-0
27	CYD 535	Main Group Chemistry	3-0-0
28	CYD 536	Science of Corrosion & Corrosion Control	3-0-0

Course Content for PG PROGRAMME
2 Year M.Sc. CHEMISTRY
SEMESTER-I

CYC 501	Quantum Chemistry	(3-0-0)

- **Course Philosophy:**
  - Background of origin of Quantum Mechanics
  - Distinctive features of Quantum Mechanics with respect to Classical Mechanics and its application in Chemistry
- **Learning Outcomes:**
  - Understanding the fundamentals as well to have an insight of the microscopic world (sub-atomic particles, atoms and molecules)
  - Rationalization of experimentally observed phenomena, which could not be explained by Classical Mechanics
  - Application to solve atomic and molecular energetics and structure

UNIT-I **[14 L]**

Operator algebra, Wave Particle Duality, Standing waves, Path integrals and Schrödinger equation, Postulates, Separating variables and particle in 1D box, Time dependent states and expectation values, Particle in a 3D box, Finite well, delta and step function, Tunneling, Schrödinger equation for Harmonic Oscillator, Series solution, orthogonality of Eigen functions, Theorem of Hermitian operator

UNIT-II **[15L]**

Hydrogen atom (separating centre of mass, polar coordinates, separation of variables, theta and phi functions, finding R(r)), Atomic orbitals, Hermitian operators, Generalized uncertainty principle, Angular momentum and spin, Spin Statics Theorem, Boson and Fermion

UNIT-III **[13L]**

Perturbation theory, Variation method, He atom and Pauli's principle, Hydrogen molecular ion-Linear variation method, MO and VB theory, MO of diatoms, Hückel theory, Introduction to many electron atoms

Reference Books:

1. Quantum Chemistry, I. N. Levine. 7th Edition, Pearson, 2014.
2. Molecular Quantum Mechanics, P. W. Atkins and Ronald S. Friedman, 4th Edition, Oxford University Press, 2010.
3. Quantum Chemistry, R. K. Prasad, 4th Edition, New Age International Publication, 2010.

CYC 502	Organic reactions and stereochemistry	(3-0-0)

- **Course Philosophy:**
  - Fundamental aspects of a reaction and their applications in chemical transformations
  - Mechanism of organic reactions
  - Idea for visualizing molecules in three dimensional projection
  - Introduction to the concept of chirality and chiral centre
  - Resolves the molecular complexity present in organic molecules through stereochemical analysis
- **LearningOutcomes:**
  - Understanding of the basic stereochemical requirement of a chemical reaction
  - Estimate the stability of various conformers of organic molecules by correlating steric, electronic and stereoelectronic effects
  - Prediction of the reaction outcome in a stereoselective reaction by establishing a preferred relative stereochemistry
  - Design of synthetic route towards generation of asymmetric centre in molecular framework

UNIT -I **[6 L]**

Reaction Mechanism: Structure and Reactivity. Types of mechanism, types, of reaction, thermodynamic and kinetic requirements, kinetic and thermodynamic control, Hammond's postulate, Curtin-Hammett principle, potential energy diagrams, transition states and intermediates, methods of determining mechanisms, isotope effects.

UNIT -II **[18 L]**

Conformation analysis of cycloalkanes, cycloalkenes, decalines, hydrindanes, fused polycyclic systems, bridged ring systems. Effect of conformation on reactivity, threo and erythro isomers, methods of resolution, optical purity, enatiotopic and diastereotopicatoms, groups & faces.

UNIT-III **[10 L]**

Steric and Stereoelectronic effect in addition and ring-closure reactions: Baldwin's Rule and Dunitz's angle of attack, Cieplak Model. Stereoselectivity and stereospecificity–1,2-induction and 1,3-induction – Cram's rule and beyond – chelation-control and non-chelation-control. Sterospecific and stereoselective synthesis.

UNIT -IV **[8 L]**

Optical activity in absence of chiral carbon (biphenyls, allenes and spirans), chirality due to helical shape. Stereochemistry of organo nitrogen-, sulfur- and phosphorus-compounds. Optical rotatory dispersion, circular dichroism, Cotton effect, axial haloketone rule, octant rule. Aromaticity in benzenoid and non-benzenoid compounds.

Reference Books:

1. Advanced Organic Chemistry, J. March, 4th Edition, JohnWileyand Sons, 1992.
2. Stereochemistry of Organic Compounds, D. Nasipuri, 2nd Edition, New AgeInternational, 1994.
3. Stereochemistry of Organic Compounds, P.S. Kalsi, 6th Edition, New Age International,2004.

CYC 503	Mathematics for Chemists	(3-0-0)

Course Philosophy:

- Revision of the mathematical concepts of complex number, vectors and tensors to chemical systems by solving eigenvalue and eigenvector problems. Solving first and second order differential equations that are used for solving elementary model problems in physical chemistry; quantum mechanics (e.g., particle in a potential-free box, particle on a ring, harmonic oscillator, etc.) as well spectroscopy, thermodynamics, statistical thermodynamics, and kinetics. Developing advanced mathematical skills (series solutions, numerical analysis) which are used in computational chemistry and spectroscopy.

Learning Outcomes:

- At the end of the course, the learners should be able to:
- Use mathematical techniques in linear algebra for eigenvalues and eigenvectors and first and second order differential equations with series solutions not only in quantum chemistry and spectroscopy but in other areas of physical and theoretical chemistry that will be offered during the whole programme.
- The students should be able to solve all the model problems in physical chemistry (quantum mechanics, statistical thermodynamics, kinetics, spectroscopy, etc.) for which exact analytical methods and solutions are available. Using the solutions to analyse the basis behind the philosophy of the method developments and also the limitation of each methods if any.

UNIT -I [13 L]

Error Analysis: Error, precision, accuracy, significant figures, mean, standard deviation, propagation of errors. Complex Number: Modulus and Conjugate, Argand Plane and Polar representation. Vectors: Dot product, cross product, gradient, divergence, continuity equation, curl. Vector integration: Stokes' and Gauss' theorems. Determinants and Matrices: coordinate transformation, Jacobian, system of linear equations, inverse of a matrix, Cramer's rule, Gaussian elimination and its variants, eigenvalues and eigenvectors.

UNIT -II [15 L]

Differential Equations: General and particular solutions of a differential equation. Partial Differential equations.First order equations and their applications. Separation of variables, equations reducible to separable form. Exact differential equations, non-homogeneous differential equations, integrating factors. Second order linear differential equations: homogeneous with constant coefficients, characteristic equation, general solution, particular solution. Special functions such as Lagrange, Legendre and Hermite polynomials.

UNIT -III [14 L]

Fourier series and transform, basic theorems, convolution. Laplace transform and its properties, Applications of Fourier and Laplace transforms. Introduction to Numerical Methods: Numerical differentiation and interpolation, Newton-Raphson method, Numerov Method, Numerical solution of differential equations.

Reference Books:

1. Mathematical Methods for Physicists, G. B. Arfken and H.J. Weber, Academic Press (2001).
2. Mathematical Methods in the Physical Sciences, M. L. Boas, John Wiley, India (2007).
3. Advanced Engineering Mathematics, E. Kreyszig, John Wiley, New York (1999).

CYC 504	Application of Spectroscopic methods for chemists	(3-0-0)

- **Course Philosophy:**
  - The subject offers the readers a fundamental understanding of the spectroscopic techniques and their application for structure elucidation of organic molecules
- **Learning Outcomes:** At the end of the course the student will be able to
  - Interpret spectral data
  - Qualify National level Entrance Examinations

UNIT -I [10 L]

Electronic spectroscopy: Types of electronic transitions in organic compounds, solvent effects, effect of extended conjugation, Woodward-Fieser rules,

Infrared spectroscopy: Frequencies of organic functionality, factors affecting the frequencies. Vibrational spectra of ionic, coordination and metal carbonyl compounds. Introduction to Raman spectroscopy.

UNIT -II [22L]

Nuclear Magnetic Resonance Spectroscopy: Principle and theory of NMR spectroscopy. Chemical shift, shielding and deshielding mechanism, spin-spin interaction, coupling and multiplicity, Karplus relationship, First order splitting patterns and structure correlation. Off-resonance decoupling, chemical shift reagents, restricted rotation (DMF, biphenyls, annulenes), long range coupling, NOE effects. Hetero-nuclear coupling, ^{13}C-NMR: Natural abundance and sensitivity, Calculation of ^{13}C. 2D NMR: COSY, NOISY, HETCOR, DEPT.

UNIT -III [10L]

Mass spectrometry: Basic principle, base peak, metastable peak, fragmentation processes of organic molecules and deduction of structural information. Cleavage of bonds, Different techniques like CSI, EI, FAB and MALDI etc. for identification of compounds.

Structure elucidation by spectroscopic techniques.

Reference Books:

1. Introduction to Spectroscopy – D. L. Pavia, G.M. Lampman, G. S. Kriz, 4th Edition, Cengage Learning, 2008.
2. Spectrometric identification of organic compounds, Robert M. Silverstein, Francis X. Webster, David Kiemle, 7th Edition. Wiley, 2005.
3. Spectroscopic methods in organic chemistry - D. H. Williams and I. Flemming, 6th Edition, McGraw Hill, 2011.
4. Organic structure Analysis- Phillip Crews, Rodriguez, Jaspars, Oxford University Press, 1998.

CYC 505	Coordination Chemistry	(3-0-0)

- **Course Philosophy:**
  - This course will impart
  - The basic understanding of various theories used in coordination chemistry of transition metal complexes and their properties.
  - Reaction mechanism and electron transfer reactions
- **Learning Outcome:**
  - After studying this course, students should be able to:
  - Understand the basic theories related to the bonding in transition metal complexes.
  - Interpret the reaction kinetics and the electron transfer mechanism in the complexes.
  - Understand origin and the interpretation of magnetic properties in the coordination complexes.

UNIT -I [15 L]

CFT and its limitations, LFT, MOT. Classification of ligands by donor atoms, stability, reactivity, bond types, geometry and coordination compounds. Spectroscopic method of assignment of absolute configuration of metal chelates and their stereochemical conformations.

UNIT -II [15L]

Kinetics and mechanism of reactions of transition metal complexes: The trans effect, substitution reactions, electron transfer redox processes, acid base hydrolysis. The template effect and Macrocyclic ligands. Inorganic photochemistry of coordination compounds.

UNIT III [12L]

Definition of magnetic properties, Sources of paramagnetism, Diamagnetism and Pascal Constants, Derivation of Curie Equation, Curie and Curie-Weiss Law, Determination of Magnetic Susceptibility, Orbital and spin contribution to magnetic susceptibility, Introduction to magnetic properties of lanthanides, Magnetic exchange coupling, Spin cross over phenomena.

Reference Books:

1. Shriver & Atkins: Inorganic Chemistry, P.W. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong; 5th Edition, Oxford University Press, 2013.
2. Advanced Inorganic Chemistry, F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann; 6th Edition, Wiley, 1999.
3. Inorganic chemistry, K. F. Purcell and J. C. Kotz, Holt Saunders international, 1980.

CYC 506	Inorganic Chemistry Lab	(0-0-3)

- **Course Philosophy:**
  - The course is intended to impart:
  - Fundamental understanding about the principles involved in quantitative analysis
  - Develop idea about inorganic preparations
  - Develop understanding of electronic and magnetic properties of complex compounds
  - Develop understanding about the kinetics of formation and redox properties of compounds
- **Learning Outcomes:** At the end of the course the students will be able to:
  - Plan and conduct an experiment for quantitative analysis using various methods
  - Understand the role of accuracy and precision in various methods adopted
  - Learn methods for preparation, separation and purification of inorganic compounds

1. Volumetric Experiments:
   (a) Estimation of alkali present in Antacid Tablet.
   (b) Estimation of calcium in milk powder by complexometry.
2. Inorganic Preparations: Preparation of complexes of Copper and Nickel using a variety of ligands.
3. Determination of ligand field strength of series of transition metal complexes using UV-visible spectroscopy
4. Synthesis and magnetic moment determination of series of transition metal complexes.
5. Preparation and catalytic study of transition metal complexes.
6. Determination of Composition and stability constant by Job's Method.
7. Synthesis of $[Co(NH_3)_5Cl]Cl_2$ and study of its reducing properties.
8. Estimation of phosphoric acid in cold drinks by molybdenum blue method.

Reference Books:

1. Collection of Interesting General Chemistry Experiments, Anil J Elias, Universities Press, 2008.
2. Integrated Approach to Coordination Chemistry: An Inorganic Laboratory Guide, R. A. Marusak, Kate Doan, S. D. Cummins, 2007, Wiley, NY.
3. Vogels Textbook Of Quantitative Chemical Analysis, J. Mendham, R. C. Denney, J. D. Barnes, M. J. K. Thomas, 6thedition, Pearson, 2006.

CYC 507	Organic Chemistry Lab-I	(0-0-3)

- **CoursePhilosophy:**
  - Practically validate the theoretical knowledge acquired from the theory
- **Learning Outcomes:**
  - Plan and Perform experiments and Interpret experimental results by correlation with theory

1. Separation& Purification of organic mixture by extraction techniques. (3 expts.)
2. Separation& Purification of binary organic mixture by Column chromatography.
3. Extraction & Separation of Organic compounds from plants: Marigold leaves, Spinach, etc. (2 expts.)
4. Organic quantitative analysis: Estimation of i) acetone/ethylalcohol & ii) phenol/aniline. (2 expts.)
5. Separation& Purification of organic compounds by crystallization/sublimation techniques. (2 expts.)

Reference Books:

1. Systematic Identification of Organic Compounds, A laboratory Manual, R.L. Shriner, R.C. Fuson and D.Y. Curtin, 6th edition Wiley, New York.
2. Vogel's Textbook of Practical Organic Chemistry revised-B. S. Furniss, A.J. Hannaford, P.W. G.Smith, A.R. Tatchell, 5thEdition, Addison Wesley Longman Limited, UK, 1997.
3. A Handbook of Quantitative & Qualitative Analysis- Arnold Heinemann, Clarke, H. T (1975).

SEMESTER-II

CYC 508	Kinetics and Thermodynamics	(3-0-0)

- **Course Philosophy:**
  - Thermodynamics and Kinetics are the foundation of chemistry and it is needed for organic, inorganic and medicinal chemistry. The syllabus was focussed for all branches of thermodynamics irreversible thermodynamics, statistical thermodynamics apart from classical thermodynamics. The Kinetics part consists of application of basic kinetics concept to the rate of the reaction.
- **Learning Outcomes:**
  - **Calculate** change in thermodynamic properties, equilibrium constants, partial molar quantities, chemical potential.
  - **Predict** heat capacity of an ideal gas of linear and non-linear molecules from the number of degrees of freedom, rotational and vibrational wave numbers.
  - **Calculate** transport properties of gases, liquids and solids

UNIT -I [10 L]

Classical Thermodynamics: Concept of entropy, reversible and irreversible processes, Clausius inequality, Free energies, Criteria of spontaneity. Fundamental equations for open systems, Partial molar quantities and chemical potential, Gibbs-Duhem equation, Real gases and fugacity.

UNIT -II [14L]

Non-equilibrium Thermodynamic: criteria for non-equilibrium states, entropy production, flow, irreversible processes, Electrokinetic phenomena, Diffusion, Electric conduction, Coupled reactions. Theory of electrolytes, Ionic strength, Derivation of Debye Hückel limiting law.

UNIT -III [12L]

Statistical Thermodynamics: Concept of ensembles, Canonical ensemble, Boltzmann distribution, Thermodynamic quantities and canonical partition function. Grand canonical ensemble, Fermi-Dirac and Bose-Einstein distributions. Molecular partition functions, thermodynamic properties, Equipartition theorem, Chemical equilibrium. Real gases, intermolecular potential and virial coefficients. Debye and Einstein theory of heat capacity of solids. Structure and thermal properties of liquids, Pair correlation functions.

UNIT -IV [6L]

Chemical kinetics and applications: Theories of chemical reaction rates. Rate theories based on thermodynamics, Rate theory based on Statistical Mechanics. Conventional Transition State Theory and Applications. Thermodynamics of Adsorption.

Reference Books:

1. P. Atkins and J. Paula, Physical Chemistry, 8th Edition, Oxford University Press, Oxford 2006.
2. D. A. McQuarrie and J. D. Simon, Molecular Thermodynamics, University Science Books, California 2011.
3. D. A. McQuarrie, Statistical Mechanics, University Science Books, California 2005.

CYC 509	Methods in Organic Synthesis	(3-0-0)

- **Course Philosophy:**
  - Knowledge on various organic reactions by Functional Group transformation.
  - Gather information about various name reactions.
  - New synthetic tools applied in organic synthesis.
  - Chasing the synthesis of complex molecular architecture by means of developing new synthetic methods.
- **Learning Outcomes:**
  - Knowing various reagents for task specific organic transformations.
  - Logical utilization of reagent based chemistry in organic synthesis.
  - Strategic application of catalysis in organic synthesis.
  - Design of green organic synthesis by using environmentally benign reagents.

UNIT -I [17 L]

Oxidation: Different oxidative processes, Oxidation of hydrocarbons, alcohols, carbonyl compounds and amines. Asymmetric Epoxydation and Dihydroxylation (Sharpless, Shi, Jacobsen-Katsuki), Hypervalent iodine reagents, Wacker oxidation. Reduction: Different reductive processes, Reduction of hydrocarbons, carbonyl compounds, nitro compounds. Reduction with hydride and modified hydride transfer reagents, Asymmetric Reduction (CBS Reduction), Reduction with SET reagent (Birch reductions, Titanocene dichloride, Samarium(II) Iodide, Photoredox Catalysis).

UNIT -II [8 L]

Coupling Reactions for C-C and C-Nbondformations: Heck cross coupling; Sonogashira cross coupling; Suzuki reaction; Suzuki–Miyaura cross-coupling, Negishi cross coupling;Hiyama coupling; Stille cross coupling; Buchwald-Hartwig amination.

UNIT –III [11 L]

Organoboron chemistry: hydroboration, Synthesis and reactions of organoboranes, unsaturated hydrocarbon synthesis, allylboranes, allylenolates. Organosilicon chemistry: α- and β- effects, hydrosilylation, synthesis and reactivity of vinylsilanes, allylsilanes.

UNIT –IV [6 L]

Organophosphorous chemistry: phosphorus ylides- Wittig reaction and its modifications; phosphine oxides and its applications. Organosulfur chemistry: sulfur-stabilization of anions and cations, sulfur ylides, sulfoxides and sulfones.

Reference Books:

1. Strategic Applications of Named Reactions in Organic Synthesis, L. Kürti and B.Czakó Elsevier Academic Press, 2005.
2. Name Reactions and Reagents in Organic Synthesis, B.P.Mundy, M.G.Ellerd and Jr. F. G.Favaloro, Wiley- Interscience, 2nd Edition, 2005.
3. Advanced Organic Chemistry Part B, F.A. Carey and R.J. Sundberg, 5th Edition, Springer,2008.

CYC 510	Organometallic Chemistry	(3-0-0)

- **Course Philosophy:**
  - With this course students will learn the concepts involved in the syntheses, structure, physical and chemical properties organometallic compounds along with their application in catalysis.
- **Learning Outcomes:**
  - General synthetic procedures and characterization of organometallic compounds.
  - Structure, binding and reactivity.
  - Application in catalysis and biology.

UNIT –I [16 L]

Basic Concept of organometallic chemistry, 18-electron rule, phosphines, alkenes, alkynes, and allyl complexes, carbenes, carbynesmetallocenes, metal arene complexes, fluxionality in organometallic compounds

UNIT –II [12 L]

Homogeneous & Heterogeneous Catalysis: Oxidative addition and reductive elimination, insertion reactions. Agostic interaction, Hydroformylation, Ziegler-Natta catalyst, Wilkinson's catalyst, Synthesis gas, Monsanto process, and Wacker process.

UNIT –III [10 L]

Organometallic enzymes and coenzymes, Vitamin B_{12} coenzyme, model compounds, heavy metal toxicity, organometallic compounds as drugs, organometallic radiopharmaceuticals, tracers, ionophores and sensors.

Reference Books:

1. Basic Organometallic Chemistry: Concepts, Syntheses and Applications, Dr. B.D. Gupta, Dr. Anil J. Elias, 2nd Edition, University Press, 2013.
2. Inorganic Chemistry Principles of structure and reactivity, J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, 4th Edition, Pearson, 2013.
3. Organometallic Chemistry, A Unified Approach, R. C. Mehrotra and A. Singh, New Age International, 2009.

CYC 511	Group Theory & Electronic Spectroscopy	(3-1-0)

- **Course Philosophy:**
  - This course will impart
  - The fundamental understanding of symmetry elements and operations
  - Basic principles of group theory
  - Applications of group theory in spectroscopy.
- **Learning Outcome:**
  - After studying this course, students should be able to:
  - Symmetry of the molecules and the symmetry operations therein.
  - Interpret whether a given group is Cyclic, Abelian and/or given a finite Cyclic group.
  - Understand the construction and use of character tables in electronic and vibrational spectroscopy.
  - Understand the techniques in group theory to interpret electronic spectra in transition metal complexes.

UNIT -I [12L + 4T]

Symmetry elements and symmetry operations, Algebraic Operators, Point groups and its determination in various molecules. Matrix mathematics & Matrix representation symmetry operations, Eigenvalues and eigenvectors, Similarity transformation of matrices, Diagonalization of matrices.

UNIT -II [15 L + 5T]

Definition of a Group, Subgroup, Abelian group, Cyclic group. Rearrangement Theorem, Group multiplication Tables, Lagrange's Theorem. Classes, Direct Products, Reducible & Irreducible representations. The Great Orthogonality Theorem and its consequences. Character table & its construction, Standard reduction formula, Symmetry of Translations and rotations. Symmetry of p and d orbitals.

UNIT -III [15L + 5T]

Classification & Determination of normal vibrational modes. Free ion Terms, Mülliken symbols. Electronic Spectra of transition metal complexes: Orgel, Tanabe-Sugano, Correlation diagram, Charge transfer spectra, Selection rules and its relaxations.

Reference Books:

1. Chemical Applications of Group Theory, F. A. Cotton, 3rd Edition, John Wiley & Sons, 2008.
2. Symmetry, orbitals, and spectra (S.O.S.), M. Orchin and H. H. Jaffé, John Wiley & Sons Ltd., 1971.
3. Symmetry and Group Theory in Chemistry, S. K. Dogra and H. S. Randhawa, 1st Edition, New Age International Publishers, 2014.

CYC 512	Physical Chemistry Lab -I	(0-0-3)

- **Course Philosophy:**
  - The idea of practical classes is to provide students an exposure to experimental laboratory, where they will experience how to perform an experiment properly based on their theoretical understanding.
  - The practical syllabus is pertinent to the theoretical subjects the students are taught, viz. Thermodynamics, Quantum Chemistry and its application, Spectroscopy and Kinetics, so to provide students a correlation between theoretical knowledge and experiments.
- **Learning Outcomes:**
  - The students will have a hands on experience with different instruments and learn the 'what is what' of that particular equipment. In this way the learning will be more effective.

1. Determination of the critical solution temperature of the phenol-water system and construction of phenol-water phase diagram
2. Determination of Thermodynamic Parameters for Micellization of SDS in aqueous solution
3. Determination of the Molecular Weight of Polystyrene from Viscosity Measurements
4. Determination of the heat of neutralization
5. Determination of activation energy and entropy of activation for acid catalyzed ester
6. Conjugated Bonding in Cyanine Dyes: A "Particle in a box" Model
7. Kinetics of salt effect and ionic strength (persulfate-iodine reaction)
8. Determine the critical micelle concentration of a surfactant (SLS) by conductivity method at concentration.
9. Study the adsorption of acetic acid by activated charcoal from aqueous solution.
10. Verify the Walden's Rule, $\lambda_0\eta_0$ = constant.
11. Determine the concentrations of a strong acid and a weak acid present in a mixture by potentiometric titration.
12. Verification of Beer Lamberts Law by colourimeter.
13. Determine the concentrations of a strong acid and a weak acid present in a mixture by conductometric titration.
14. Determination of Surface area and porosity through BET method.

Reference Books:

1. Practical Physical Chemistry by B. Viswanathan and P.S. Raghavan, Viva Books, 2014.

CYC 513	Organic Chemistry Lab-II	(0-0-3)

- **Course Philosophy:**
  - Practically validate the theoretical knowledge acquired from the theory
- **Learning Outcomes:**
  - Multistep organicsynthesis: Characterization and identification oftheproductsof the individual steps byphysicalandspectroscopic means.

1. Synthesis of cyclohexanoneoxime.
2. Synthesis of Caprolactam.
3. Synthesis of Nylon-6.
4. Synthesis of Tetrahydrocarbazole.
5. Synthesis of β-Nitrostyrene.
6. Thermal cycloaddition reaction.
7. Preparation of Pyridiniumchlorochromate (PCC) reagent.
8. Oxidation of alcohol by PCC.
9. Synthesis of amphoteric polymer.
10. Synthesis of Poly(methyl methacrylate).
11. Synthesis of Marketed Drugs: Paracetamol, Aspirin, etc.

Reference Books:

1. Experimental Organic Chemistry- L.M. Harwood and C.J.Moody, Blackwell Scientific, London, 1989.
2. Practical Organic Chemistry – W.Kemp, McGraw Hill, London, 1962.
3. Reagents in Organic Synthesis, Fieser and Fieser, Wiley, 2006.

SEMESTER-III

CYC 514	Photochemistry & Pericyclic reactions	(3-0-0)

- **Course Philosophy:**
  - Introduction to pericyclic reactions.
  - Understanding the theory and stereochemical implications of different categories pericyclic reactions of pericyclic reactions.
  - Introduction to and applications of pericyclic reactions as a synthetic tool.
  - Introduction to the concept of chromophores and their photochemical reactions as individual chromophores and in juxtaposition with each other.
  - Contemporary research in the organic syntheses involving photochemical reactions.
  - Applications of the photochemical reactions for synthesis of different molecules.
- **Learning Outcomes:**
  - Prediction of the modes of the pericyclic reactions and the sterochemical implications using the theories of pericyclic reactions.
  - Design of synthetic routes towards small molecules based on pericyclic reactions as key step.
  - Understanding of the fundamental aspects of photochemical reactions.
  - Designing of moderately complex molecular frameworks and functionalizations based on photochemical reactions.

UNIT -I: **[14 L]**

Pericyclic Reaction: Definition and classification of pericyclic reactions; Theory of pericyclic reactions; FMO approach, OCD, Aromatic TS concept. Electrocyclic reactions: stereochemical aspects and applications in organic synthesis. Sigmatropic reactions: stereochemical aspects and application in organic reactions.

UNIT -II: **[12 L]**

Cycloaddition reactions: 4n and 4n+2 systems, ketenes and allenes; stereochemical aspects and application in organic synthesis. Group transfer and chelatropic reactions.

UNIT -III: **[10 L]**

Photochemistry: Photochemical reactions; determination of reaction mechanism; photochemistry of alkenes, carbonyl compounds, enonesand aromatic compounds. Reactions of anilides.

UNIT- IV: **[6 L]**

Photochemical Rearrangements, Lumiketone rearrangement, Type A and Type B rearrangement, Di-pi-methane rearrangement, Oxa-di-pi-methane rearrangement, Barton reaction, reaction of hypohalites, Photo-Fries rearrangement. Photoinduced electron transfer (PET) reactions. Photoredox catalysis.

Reference Books:

1. Organic chemistry– J. Clayden, N. Greeves, S.Warren and P.Wothers 2nd Edition Oxford Press, 2012.
2. Frontier Orbitals and Organic Chemical Reactions, I. Flemming, Wiley, London, 1976.
3. Photochemistry of organic compounds, PetrKlan, Jakob Wirz, 1st Edition, Wiley, 2009.

CYC 515	Molecular Spectroscopy	(3-0-0)

- **Course Philosophy:**
  - Application of Quantum Chemistry in order to elucidate different types of molecular spectra (rotational, vibrational, electronic)
  - Exposure to LASER and modern spectroscopic techniques
- **Learning Outcomes:**
  - Understanding the fundamentals of molecular spectroscopy
  - Learning the analysis of simple and complex spectra
  - Theoretical knowledge of different types of LASERS and modern day spectroscopic techniques

UNIT -I **[12 L]**

Introduction to spectral energy domains and measurement of spectra, Implications of discrete energy levels, Population of States – Boltzman Distribution, Interaction of radiation with matter, Transition dipole moment, Transition moment integral, Electronic transition, selection rule

UNIT -II **[22 L]**

Rotational (Microwave) spectroscopy: The rigid diatomic rotor, intensity of rotational transitions, degeneracy, allowed rotational energy levels. Classification of polyatomic rotors and the non- rigid rotor, symmetric and asymmetric tops, Molecular vibrations - Infrared spectroscopy, harmonic and anharmonic oscillators, Morse potential, IR selection rules, Raman spectroscopy, polarizability and Raman selection rules Molecular electronic spectra, Electronic transitions, Franck-Condon principle. Polarization of transitions, origin of line widths in molecular spectra

UNIT –III **[8 L]**

Photophysical processes, Non-Linear Spectroscopy, Lasers and Masers

Reference Books:

1. Spectra of Atoms and Molecules, P. F. Bernath, 2nd Edition, Oxford University Press, 2005.
2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, 4th Edition, Tata McGraw-Hill Education, 1994.
3. Molecular Vibrations: The Theory of Infrared and Raman Spectra, E. B. Wilson, Jr., J. C. Decius and P. C. Cross, Dover Publications, 1980.

CYC 516	Strategies in organic synthesis	(3-0-0)

- **Course Philosophy:**
  - With this course student will learn the techniques involves the synthetic strategies and total synthesis of various organic molecules
- **Learning Outcome:**
  - By the end of this course, each student should be able to learn-
  - The concept of disconnection and retrosynthetic approaches and basics of umpolung.
  - New techniques of organic synthesis like one pot domino, cascade and tandem reactions.
  - Various approaches of C-H activation and its application in affordable synthesis.
  - The application of protection and deprotection of functional groups.

UNIT -I [10L]

Disconnection approach: basic principles, one-group, two-group disconnections. Selectivity aspects: Chemoselectivity, regioselectivity, stereoselectivity, Retrosynthesis, Umpolung concepts; uses of aliphatic nitro, amines; radical reactions in synthesis- FGA, FGI and its reverse.

UNIT -II [10L]

Synthetic strategies and total synthesis of complex organic molecules with biological interest.

UNIT -III [8L]

Linear and convergent synthesis, Multi-component reactions, One-pot reactions, Domino, Cascade and tandem reactions, Modular Synthesis.

UNIT -IV [8L]

Directed ortho-metallation, Metathesis reactions, C-H activation and functionalization, Organometallic reagents, formation of C-X bond. Common catalysts and reagents (organic, inorganic and enzymatic).

UNIT -V [6L]

Protection and deprotection of active functional groups: alcohol, carbonyl and carboxyl groups, amine and amino acids.

Reference Books:

1. Organic Synthesis: The Disconnection Approach, S. Warren, 2nd Edition, Wiley, 2008.
2. Advanced Organic Chemistry, Part B, F.A. Carey and R.J. Sundberg, 5th Edition, Springer, 2008.
3. The Logic of Chemical Synthesis, E.J. Corey and X-M. Cheng, Wiley, 1995.

CYC 517	Physical Chemistry Lab -II	(0-0-3)

- **Course Philosophy:**
  - With this course student will learn the hands-on laboratory experience to operate the different instruments and analysis of results.
- **Learning Outcomes:**
  - Hands on experience of operations and applications of FTIR spectrophotometer, UV-vis spectrophotometer, Cylic voltammeter, photoluminescence spectrophotometer, BET surface area for both qualitative and quantitative analysis.
  - **Write and execute** simple programs in FORTRAN and C++ .

1. Spectroscopic determination of Critical Micelle Concentration
2. Precipitation Titration and Determination of Solubility of a Sparingly Soluble Salt
3. Determination of the surface area of silica by N_2 adsorption at 77 K
4. Study on the effect of extended conjugation on the wavelength of maximum absorption (λ_{max}) of organic compounds
5. Determination of thermodynamic parameters of a reaction from EMF measurement
6. Functional group (-OH, -COOH, -$CONH_2$, etc) determination of surface modified nanoparticles using IR spectroscopy.
7. Estimation of band-gap for Cu nanoparticles using absorption spectroscopy.
8. Effect of solvent polarity on CMC determined by tensiometric method
9. Determination of fluorescence quantum yield of dye(s).
10. Determination of Activation energy for the photoisomerisation of *cis*/*trans* stilbene
11. Synthesis of Fluorescent Carbon Quantum Dots from Lemon Juice and study of its optical property.
12. Determination of the concentration of a given solution using Cyclic Voltametry.
13. Computer-Aided Drug Discovery: Molecular Docking of Diminazene Ligands to DNA Minor Groove
14. Dissociation of the Ethyl Radical: An Exercise in Computational Chemistry

Reference Books:

1. Experiments in physical chemistry, C W Garland, J W nibler and D P Shoemaker, 8th edition, Mcgraw-Hill International Edition.
2. Programming: Principles and Practice Using C++, B. Stroustroup, Addison Wesley, 2014.
3. Principles of Instrumental Analysis, Douglas A. Skoog, ISBN-13: 978-8131525579

CYC 518	Analytical Chemistry Lab	(0-0-3)

- **Course Philosophy:**
  - The purpose of this course is to provide in-depth practical training in laboratory techniques with a diverse toolbox in analytical sciences and instrumentation.
  - Also it will enhance student-centered activity and inquiry-based learning to strengthen the connections to real-life.
- **Learning Outcome:**
  - Students gain hands-on practical experience with a range of equipment in the field of analytical sciences which can intensify the fundamental understanding of instruments and its background theory.
  - Students should able to apply the analytical instruments confidently and accurately in order to address their needs.

1. IR spectrophotometry: Sample preparation for liquid and solid samples, identification of functional groups.
2. UV-Vis spectrophotometry: Simultaneous analysis of two component systems.
3. UV-Vis spectrophotometry: Determination of pKa and isosbestic points.
4. Titrimetric: Estimation of phosphoric acid content in cold drinks.
5. Titrimetric: Estimation of acetic acid content in vinegar.
6. Estimation of paracetamol content in analgesic tablets.
7. Cyclic voltammetry: Study the redox property of a series of transition metal complexes.
8. SEM-EDX: Sample preparation and study of SEM and EDX data of a series of samples.
9. Gas-Chromatography: Determination of hydrocarbons in a sample.
10. Mass spectrometry: Separation and determination of organic compounds in a mixture.
11. NMR Spectroscopy: Identification of samples using NMR spectroscopy.

Reference Books:

4. Fundamentals of analytical chemistry, Douglas Skoog, Donald West, F. Holler, Stanley Crouch, 9thEdition, Cengage Learning, 2013.
5. Advanced Practical Inorganic Chemistry, Gurdeep Raj, 22nd Edition, Krishna Prakasan M. (Pvt.) Ltd., 2010.
6. Atkins' Physical Chemistry, P. Atkins and J. de Paula, 8th Ed., Oxford University Press, New Delhi, 2008.

SEMESTER-IV
DEPARTMENTAL ELECTIVES

CYD 501	Medicinal Chemistry	(3-0-0)

Course Philosophy:

- With this course student will learn the basics of medicinal chemistry and fundamental of drug discovery

Learning Outcome: By the end of this course, each student should be able to learn:

- Knowledge on the fundamental principles of medicinal chemistry and, drug design.
- Acquiring knowledge on the strategy of computer aided drug design and their application in modern drug discovery.
- Apply the pharmacodynamic and pharmacokinetic principles that describe drug actions.
- Basics of Intellectual property (IP) and Regulatory affairs.
- Learning the art of synthesis of FDA approved drugs.

UNIT -I **[12L]**

Basics of Drug Action– Enzymes, proteins, antagonist, agonist, Drug-receptor interactions, Drug action through enzyme inhibition, Examples based on kinase inhibition, Drug likeness, Pharmacokinetics, ADME, bioavailability and bioequivalence.Drug metabolism and elimination, Chirality and drug action.

UNIT -II **[12 L]**

Drug Design-Ligand based drug design,Structure Activity Relationships studies from Hit identification to lead optimization,De Novo drug design techniques: Receptor/enzyme cavity size prediction. Pharmacophore concept: Pharmacophore mapping. Molecular docking, quantitative structure and relationship (QSAR). Informatics methods in drug design, bioinformatics, chemoinformatics.

UNIT –III **[12 L]**

Classification of drugs-
Basedonstructureorpharmacologicalbasiswithexamples.antibacterials, antivirals, antifungal, anticancer agents, statins, antidiabetic drugs, cardiovascular drugs

UNIT-IV **[6L]**

Synthesis of Marketed Drugs. Introduction to Clinical trials, Fundamentals of Intellectual Property (IP) and regulatory affairs.

Reference Books:

1. Medicinal Chemistry-An Introduction, Gareth Thomas, 2nd edition, 2007,Wiley, NY.
2. An introduction to medicinal Chemistry, Graham L. Patrick, 4th Edition,Oxford,2009.
3. The Organic Chemistry of Drug Design and Drug Action, R.B. Silverman, Academic Press.

CYD 502	Polymer Chemistry	(3-0-0)

Course Philosophy:

- With this course students will learn synthesis, structure, properties of polymers and mechanism of polymerizations along their processing and

characterizations.

- **Learning Outcome:**
  - Classify different polymers based on their sources and properties.
  - Establish mechanism and kinetics of polymerizations along with molecular weight property relationship.
  - Identify the importance of polymers in field of Biomedical, electronics and advanced applications.
  - Utilize the concept of polymerization for copolymer and stereo regular polymers synthesis.

UNIT -I **[14L]**

Introduction and common applications of polymers. Classification of polymers. Kinetics and mechanism of chain growth and step growth polymerization. Polymerization processes (Bulk, Solution, Emulsion and Suspension). Molecular weight, molecular weight distribution and degree of polymerization. Significance of Molecular weight and distribution, Experimental methods for determination of molecular weight. Structure-property relationship of polymers. Commercial thermoplastic and thermosetting polymers- Synthesis, properties and applications.

UNIT -II **[14L]**

Copolymers: Classification, synthesis and application. Stereochemistry of Polymerization. Polymer synthesis procedures – FRP, ATRP, RAFT, ROMP, MP, ROP. Synthesis and applications of biodegradable, biomedical polymers. Conducting Polymers. Inorganic Polymers, Vulcanization of Rubbers.

UNIT -III **[14L]**

Polymer processing, Glass transition temperature: significance and determination. Analysis and Testing of Polymers. Advanced Polymers: Smart Polymers, Shape Memory Polymers, Self-Healing Polymers, LCP, Branched polymers (star, dendritic and hyper branched polymers).

Reference Books:

1. Principles of polymerization, George G. Odian, 4th Edition, A John Wiley &Sons, Inc., Publication, 2004.
2. Textbook of Polymer Science, W. F. Billmeyer, 3 rd Edition, A John Wiley & Sons, Inc., Publication, 2007.
3. Polymer Science & Technology–Plastics, Rubbers, Blends and Composites. Premamoy Ghosh. 3rd Edition, McGraw Hill Education (India) Private Limited, 2010.

CYD 503	Cluster Chemistry	(3-0-0)

- **Course Philosophy:**
  - The course is intended to provide students the chemistry behind formation of various types of cluster compounds, develop understanding about the

bonding involved and predict their structures. It also intended to introduce the role of cluster compound as catalysts.

- **Learning outcome:** At the end of the course students should be able to-
  - Construct the valence bond scheme of boron clusters
  - Predict the structure of the clusters
  - Rationalise structure of clusters

UNIT -I [10 L]

Clusters: Definition, Clusters of Main Group elements, Clusters of Alkali and Alkaline earth metals, Preparation, structure and bonding, Reactivity of clusters.

UNIT -II [15 L]

Higher Boranes: Preparation structure, bonding and reactivity of Higher Boranes and carboranes, Naming of Boranes and carboranes, styx numbers, Wades rules. Clusters of early and late main group elements. Role of ligands in cluster formation, design methodology

UNIT -III [17L]

Transition Metal carbonyl clusters, early and late transition metal clusters, Mingo's Rules, Jemmi's '*mno'* rule. Metal-metal multiple bonded systems, structure, bonding and reactivity, Isopoly &h eteropoly acids & salts, PSEP Theory, violations, capping principle, Metal carbonyl hydride clusters, Electron precise molecules, Catalysis by clusters

Reference Books:

1. Basic Organometallic Chemistry: Concepts, Syntheses and Applications, B.D. Gupta, Anil J. Elias, 2nd Edition, University Press, 2013.
2. Inorganic and Organometallic Polymers, V. Chandrasekhar, Springer India, 2005.
3. Concepts and Models of Inorganic Chemistry, Bodie E. Douglas, Darl H. McDaniel and John J. Alexander, 3rd Edition, John Wiley and Sons, 1994.

CYD 504	Symmetry in Bonding	(3-0-0)

- **Course Philosophy:**
  - This course will communicate the fundamental understanding of the applications of group theory related to:
  - The hybrid orbitals,
  - Molecular orbitals and
  - Chemical bonding.
- **Learning Outcome:**
  - After studying this course, students should be able to:
  - Bring into fore the molecular orbital theory
  - The techniques in group theory to interpret bonding in organic molecules as well as transition metal complexes.
  - Use of symmetry in vibrational spectra and structural interpretation.

UNIT -I [12 L]

Hybrid orbitals and their symmetries, Hybrid orbitals for σ and π-bonding, Hybrid

orbitals as linear combination of atomic orbitals, descending symmetry in Jahn-Teller distortion. The Projection operator, Application of Projection operator method in multi-dimensional representations.

UNIT -II [20 L]

Molecular orbitals and hybrid orbitals: Criteria of LCAO Approximation, Construction of SALCs for different geometry of molecules. Designation and symmetry of molecular orbitals. Molecular orbitals of sandwich complexes. Hückel π-orbital method and applications, 1,3 butadiene, Carbocyclic systems. Three centre bonding.

UNIT -III [10 L]

Application of normal mode analysis: Geometrical isomer prediction, Structure determination and Linkage isomer prediction, Denticity of anionic ligands, Coordinate bond vibrations, and bonding mode in metal carbonyls.

Reference Books:

1. Chemical Applications of Group Theory, F. A. Cotton, 3rd Edition, John Wiley & Sons, 2008.
2. Group Theory and Chemistry, D. M. Bishop, 1st edition, Dover Publications; Una Rev Edition, 1993.
3. Introduction to Ligand Fields, B. N. Figgis**,** John Wiley & Sons Ltd., London and New York 1966.

CYD 505	Asymmetric Synthesis	(3-0-0)

- **Course Philosophy:**
  - Why asymmetric synthesis is required?
  - History and progress of asymmetric synthesis.
  - Understanding the major strategies, techniques and tools for asymmetric synthesis.
- **Learning Outcome:**
  - Grasp of the fundamentals of asymmetric synthesis.
  - Understanding the current tools of asymmetric synthesis.
  - Designing an asymmetric synthesis

UNIT I [10L]

Introduction –Introduction to and recapitulation of terminologies associated to stereochemistry and asymmetric synthesis. Concepts and necessity for asymmetric synthesis.

Chiral induction – Concepts of substrate and reagent controlled asymmetric induction; Concepts of diastereoselective synthesis and double diastereoselective synthesis; Concepts of catalytic asymmetric synthesis, Chiral Pool approach: Advantages and Limitations

"Chirons"– terpenes and carbohydrates as chiral source material – Steven‟s steroid intermediate synthesis, Syntheses of biologically relevant compounds, Chiral auxiliary based asymmetric synthesis: Introduction, advantages and disadvantages.

Basic requirements of a chiral auxiliary popular and generally adaptable chiral auxiliaries (Oppolzer, Evans, Enders, Davies, 8-phenyl-menthol, BINOL, etc.)

UNIT II [14L]

Chiral diasteroselective and catalytic reactions involving - Asymmetric alkylations of enolates and azaenolates based on organolithiums. Asymmetric 1,2 and 1,4 addition to C=X; Asymmetric aldol and related reactions.

UNIT III [18L]

Chiral diasteroselective and catalytic reactions involving - Asymmetric Pericyclic reactions, Asymmetric hydroborations and other reductions.

Asymmetric oxidations. Asymmetric organocatalysis: Chiral amine catalysis.

Reference Books:

1. Principles of Asymmetric Synthesis – R. E. Gawley and J. Aube, Pergamon, 2nd Edition, Elsevier, 2012.
2. Catalytic Asymmetric Synthesis, I. Ojima (ed.), 3rd Edition, Wiley, 2010.
3. Principles and Applications of asymmetric synthesis - Guo-Qiang Lin, Yue-Ming Li, Albert S.C. Chan, John Wiley & Sons, 2001.

CYD 506	Computational Chemistry	(3-0-0)

Course Philosophy:

- The course is aimed at developing elementary programming skills in C++ to enable them write short programs for performing scientific calculations. Introducing the basics of theoretical and numerical methods for computer simulation of model systems. Introducing various simulation techniques using standard softwares based on time and length scales of various phenomena.

Learning Outcome:

- At the end of the course, the learners should be able to:
- Write short simple programs in C++ and be able to compile and execute them in a host of machines. Using TeraChem software the students should be able to do basic electronic structure calculations. Use standard software tools such as NAMD, AMBER to perform molecular dynamics simulation of various phenomena. The student should be also able to interpret the simulated data (with its limitations) and correlate with experimental observations.

UNIT –I [10 L]

Programming languages (C++) : C++ basics, loop and decision making, functions, classes and objects, pointer and references, overloading and type conversions; inheritance and polymorphism;

UNIT -II: **[8 L]**

Review of postulates of quantum chemistry, The Born-Oppenheimer approximation, variational method and principle, Hartree-Fock method, restricted and unrestricted references, selfconsistent- field (SCF) procedure, Geometry optimization, basis set, semiempirical methods, geometry optimization, vibrational frequency analysis,

Density-functional theory.

UNIT -III **[12 L]**

Molecular Mechanics / Force Field Methods: Introduction to molecular mechanics; review of basic Concepts; comparison of popular force fields; performance of molecular mechanics, Lagrangian, Hamiltonian, and Newtonian equations of motions, integration algorithms, Periodic boundary conditions, force calculations, methods for long range interactions calculation.

UNIT -IV **[12 L]**

Modelling of macromolecules: all atom and ab-initio molecular dynamics, Coarse-Graining and Multiscale Simulations for Nanoscale Systems, Quantum mechanics/molecular mechanics (QM/MM) approaches, study of self-organized assemblies, biomolecules like peptides, proteins, membranes and ion channels. Dynamical and structural studies of molecules using molecular dynamics simulations.

Reference Books:

1. Programming: Principles and Practice Using C++, B. Stroustroup, Addison Wesley, 2014.
2. Introduction to Computational Chemistry, F. Jensen, Wiley Publishers, 2007.Let Us C++, Y. P. Kanetkar, BPB Publications, 2003.
3. Understanding Molecular Simulations: From Algorithms to Applications, D. Frenkel and B. Smit, Academic Press, 2002.

CYD 507	**Bio-inorganic Chemistry**	**(3-0-0)**

- **Course Philosophy:**
  - The course in intended to impart knowledge and understanding about the role of various metal ions in biology, either as part of enzymes or as a participant various biological processes. The provide information about the structure and mechanistic aspect of various metallo-enzymes.
- **Learning outcome:** At the end of the course students should be able to-
  - Develop understanding about how metal ions are transported and stored in biological systems
  - Explain how the active site structure of the enzyme and protein folding influence the activity of the enzymes
  - Develop understanding about the interaction of metal with proteins/nucleic acids and their implication in biological processes.

UNIT -I **[18L]**

Essential and trace elements in biological processes, Metal Storage and Transport: Ferritin, transferrin, and siderophores, ionophores. Biological role of alkali and alkaline earth metal ions, transport and regulation, molecular aspects of intramolecular processes,.Metalloenzymes, Iron enzymes, Mn, Ni, Zn and Cu containing Enzymes, SODs, Molybdenum/Tungsten containing enzymes, Coenzyme vitamin B_{12}, Zinc in transcription and regulation.

UNIT -II **[12 L]**

Photosynthesis, Oxygen Evolution Complex (OEC), Oxygen Binding and transport: Biological Dioxygen carriers: Hemoglobin, hemerythrin, hemocyanin, allosteric regulation, artificial dioxygen carriers, metallo-porphyrins, Electron-transfer proteins, long distance electron transfer.

UNIT -III **[11 L]**

Metal-Nucleic Acid Interactions: Metals in Medicine, Metal deficiency and disease, toxic effects of metals, metals used for diagnosis and chemotherapy with particular reference to anticancer drugs

Reference Books:

1. Bioinorganic Chemistry: A Survey, Ei-Ichiro Ochiai, academic press, 2008.
2. Bio-inorganic Chemistry: A short course, Rossette M. Roat –Malone, 2nd edition, Wiley, NY, 2007.
3. Bioinorganic Chemistry, Ivano Bertini, Harry B. Gray, Stephen J. Lippard, Joan Silverstone Valentine, University Science Books, 1994.

CYD 508	Chemistry of f-block elements	(3-0-0)

- **Course Philosophy:**
  - This course contains the chemistry of f-block elements, extraction, fundamental properties and their application. Electronic, magnetic properties, organometallic chemistry f-block elements are explored. Applicability of these elements in organic synthesis, material chemistry are also included.
- **Learning Outcome:**
  - General synthetic procedures and characterization of f-block elements.
  - Structure, binding and reactivity
  - Application in multidisciplinary areas.

UNIT -I [22 L]

Introduction of Lanthanides, abundance, ores, extraction, electron configuration, f-orbitals, periodic properties, redox properties, energetics, coordination chemistry, electronic and magnetic properties, lanthanide meta-organic frameworks, organometallic chemistry of lanthanides, lanthanide in organic synthesis.

UNIT -II **[20 L]**

Introduction of actinides, occurrence, extraction, characteristics, redox behaviour, binary compounds, coordination chemistry, electronic and magnetic properties, organometallic chemistry, Transactinides.

Reference Books:

1. The Rare Earth Elements: Fundamentals and Application, David A. Atwood, Wiley-Blackwell, 2012.
2. Lanthanide and Actinide Chemistry, Simon Cotton, Wiley & Sons Ltd, 2006.
3. Principles in Organolanthanide Chemistry, Reiner Anwander, Springer, 2001.

CYD 509	Modern Terpyridine Chemistry	(3-0-0)

- **Course Philosophy:** This course will impart
  - Fundamental understanding of the synthesis and applications of Terpyridine and corresponding metal complexes
- **Learning Outcome:** After studying this course, students should be able to:
  - Understand the basic techniques used in synthesis of Terpyridine and its derivatives along with corresponding metal complexes.
  - Study the models of supramolecular and photophysical properties of Terpyridine complexes.
    Study the homogeneous and surface anchored catalysis by Terpyridine complexes.

UNIT I: (14L)

Basic synthetic strategies, Ring assembly, Cross coupling methods, synthesis of 2,2':6',2''-Terpyridine derivatives, Unsymmetrically terminally substituted 2,2':6',2''-Terpyridines, Multi-functional 2,2':6',2''-Terpyridine with variable substituents.

UNIT II: (14 L)

Synthetic strategies for mono- and bis-chelate Terpyridine based transition metal complexes, Ruthenium Terpyridine complexes, luminescent and chiral properties of the complexes. Dyads, Triads, Helicates Rotaxanes and Catenanes in supramolecular Terpyridine architectures. Fullerene Terpyridine complexes.

UNIT III: (14L)

Homogeneous and Surface anchored catalysis by Terpyridine complexes: Oxidation and Reduction reactions by chemical, photochemical and electrochemical methods.

Reference Books:

1. Modern Terpyridine Chemistry, G. R. Newkome, H. Hofmeier, and U. S. Schubert WILEY - VCH Verlag GmbH & Co. KGaA, Weinheim, 2003, ISBN-3-527-30630-7.
2. Terpyridine-based Materials: For Catalytic, Optoelectronic and Life Science Applications, A. Winter, G. R. Newkome, and U. S. Schubert WILEY -VCH Verlag GmbH & Co. KGaA, Weinheim, 2012, ISBN- 978-3-527-63963-2.
3. Ruthenium Complexes: Photochemical and Biomedical Applications, Edited by A. A. Holder, L. Lilge, W. R. Browne, M. A.W. Lawrence, J. L. Bullock Jr., WILEY -VCH Verlag GmbH & Co. KGaA, Weinheim, 2018, ISBN: 978-3-527-33957-0.

CYD 510	Chemistry of Nanostructured Materials	(3-0-0)

- **Course Philosophy:**

  - With this course student will learn various strategy for control synthesis of nanomaterials, their characterization and applications in various fields.

Learning Outcome: At the end of this course the student will able to:

- Identify special properties of nanomaterials.
- Conceptualize various synthetic routes for nanomaterial synthesis.
- Characterize nanomaterials by various analytic tools and identify their potential area of application.

UNIT –I [19L]

Introduction; fundamentals of nanomaterials science, surface science for nanomaterials, colloidal chemistry; Classical methods of Synthesis, preparation and fabrication of nanomaterials;

UNIT –II [19L]

Shape and size control synthesis of nanomaterials. Recent advancement in Sonochemistry and Other Novel Methods for Nanoparticle synthesis. Characterization of Nanomaterials. Potential applications of nanomaterials in various fields.

Reference Books:

1. Solid State Chemistry – An Introduction, L. Smart and E. Moore, Taylor & Francis Group, 4th Edition, 2012.
2. Principles of the Solid State, H. V. Keer, 1st Edition, New Age International Publishers, 2005.
3. The Chemistry of Nanomaterials: Synthesis, Properties and Applications, C. N. R. Rao, Achim Muller, Anthony K. Cheetham, Wiley, 2004.

CYD 511	Advanced Methods in Organic Synthesis	(3-0-0)

Course Philosophy:

- Knowledge on various organic reactions in organic synthesis.
- Acquire advanced synthetic tools applied in organic synthesis.
- Chasing the synthesis of complex molecular architecture by means of developing new synthetic methods.

Learning Outcome:

- Gather the information about various modern synthetic methods.
- Conceptualize various synthetic methods for organic synthesis.
- Update to current trends of organic research

UNIT –I [19L]

Olefin Metathesis Reaction; Photoredox Catalysis; Metal-Free Iodinane Catalysis; C-H activation; Cross-Dehydrogenative Coupling (CDC); Counter ion Directed Catalysis;

UNIT- II [19L]

Remote Functionalization; Electrochemical Reaction; "On water" Reaction; Chiral Amine Catalysis; Memory of chirality; Relay Catalysis; Concept of Dual Catalysis; Ball-Milling Reaction;

Frustrated Lewis pair (FLP) chemistry.

Reference Books:

1. Visible Light Photocatalysis in Organic Chemistry, Edited by Corey R. J. Stephenson, Tehshik P. Yoon, and David W. C. MacMillan, 1st Edition, © 2018 Wiley-VCH Verlag GmbH & Co. ISBN: 978-3-527-33560-2.
2. Hypervalent Iodine Chemistry: Preparation, Structure and Synthetic Applications of Polyvalent Iodine Compounds; Viktor V. Zhdankin; © 2014 John Wiley & Sons, ISBN:9781118341032.
3. From C-H to C-C Bonds: Cross-Dehydrogenative-Coupling, Chao-Jun Li; © 2015 The Royal Society of Chemistry; ISBN: 978-1-84973-797-5.
4. Chiral Amine Synthesis: Methods, Developments and Applications; edited by Thomas C. Nugent; © 2010 Wiley-VCH Verlag GmbH & Co. ISBN: 978-3-527-32509-2.

CYD 512	**Modern aspects of Catalysis and Surface science**	**(3-0-0)**

Course Philosophy:

- Catalysis is an interdisciplinary area which covers materials science, green chemistry and development of sustainable energy.
- The course is aimed to encourage student for understanding the correlation between different segment of chemistry along with chemical engineering as well as modern nanostructured materials.

Learning Outcome:

- At the end of the course students will be comfortable to do research in fine chemicals synthesis in gas phase as well as liquid phase
- Students will also be able to do research in hydrocarbon sector as well as in sustainable energy

UNIT –I [14L]

Kinetics of Gas-solid reaction; LH and LR Mechanism, Adsorption and adsorption isotherm; Physisorption and Chemisorption of gas molecules to the solid surface; determination of particle size from chemisorptions measurement, TPR/TPD/TPO techniques;

UNIT –II [16L]

Elementary gas phase reaction, spillover effect, multiplet theory brief overview of catalytic reactor, fixed bed and batch reactor, mass transfer and heat transfer on the catalyst surface; promotional and poisoning effect on catalyst surface; selected organic reaction e,g selective oxidation, hydrogenation, dehydrogenation, dehydration, alkylation, aromatization etc. and their mechanism in gas phase,

UNIT –III [8L]

Energy related catalysis, petroleum refining, hydrotreating, methane decomposition, steam

reforming, cracking and isomerization reaction; Fischer-Tropsch synthesis; bio-fuel.

Reference Books:

1. Current Trends of Surface Science and Catalysis, Jeong Young (Ed.) Park (Author), Jeong Young Park(editor), 1st Edition, Springer, 2013.
2. Handbook of Heterogenous Catalysis, G. Ertl, H. Knozinger, F. Schuth, J. Weitkamp, WILEY-VCH Verlag GmbH & Co. KGaA, ISBN 978-3-527-31241-2
3. Nanotechnology in Catalysis, Spinger,; ISBN-0387-34687-2; Edited by G A Somorjai Vol-1-3

CYD 513	Electroanalytical methods	(3-0-0)

Course Philosophy:

- Electroanalytical techniques offer a unique access to information on chemical, biochemical, and physical systems.
- The purpose of this course is to provide both the instrumental basis and the theoretical fundamentals of electrochemical techniques, commonly used in recent time, so that an interest can be develop among the students to easily apply these techniques for real-time applications.

Learning Outcome:

This course is rigorous examination of theory and applications of electro-analytical methods. Students completing this course will be:

- Knowledgeable of the current electroanalytical techniques,
- Comprehend the factors that must be controlled to obtain reliable and reproducible data during their electroanalytical experiments,
- Capable of selecting the most appropriate electroanalytical technique for a specific analysis,
- Adept at evaluating the electrode reaction mechanism from data obtained from various electroanalytical techniques.

UNIT –I [18L]

Polarographic methods, Dropping Mercury Electrode, Current-voltage relationship, Voltammetry: Cyclic voltammetry, linear sweep voltammetry, pulse voltammetry, stripping voltammetry.

UNIT-II [20L]

Potentiometric techniques. Theory of electro-gravimetric analysis, electrode reactions, overpotential, completeness of deposition, and electrolytic separation of metals by controlled potential electrolysis/electrodeposition. Rotating disc and ring disc electrodes, concepts and applications of AC impedance techniques. Spectro-

electrochemistry
Reference Books: 1. Fundamentals of analytical chemistry, Douglas Skoog, Donald West, F. Holler, Stanley Crouch, 9th Edition, Cengage Learning, 2013. 2. Electroanalytical Methods, F. Scholz, 2nd Edition, Springer, 2010.

CYD 514	**Single crystal X-ray diffraction**	**(3-0-0)**

- **Course Philosophy:**

  - This course contains the theory and application of single crystal X-ray diffraction technique.
  - With this course students will learn the concepts behind the technique and how to solve the structures of small molecules.

- **Learning Outcome:** At the end of the course students will be able to-

  - Gain knowledge about X-ray diffraction technique
  - Solve structure of small molecules from diffraction data

UNIT-I [18L]

Unit cell, Bravais lattice, symmetry elements and space groups, examples, Hermann-Mauguin Symbolism, Reciprocal lattice concept, determination of space groups, Laue pattern, Ehwald's sphere, convolution, phase problem,

UNIT –II [20L]

Structure factor and its significance, Patterson Fourier synthesis, Direct methods, Isomorphous replacement, Harkar-Kasper inequalities, refinement of crystal structures. R factor, Difference fourier maps. Treatment of disorder.

Reference Books:

1. Crystal Structure Determination, Werner Massa, Robert O. Gould, 2nd Edition, Springer; 2004. Corr. 5th printing 2010 edition, 2010.
2. Introduction to macromolecular crystallography, Alexander McPhearson, Wiley-Liss, 2003.
3. Crystal structure analysis- A primer, 3rd edn. J. P. Glusker, K. N. Trueblood, Oxford Science Publications, 2010

CYD 515	Advances in Non-conventional Energy Systems	(3-0-0)

- **Course Philosophy:** This course will impart
  - Electrochemical techniques related to conversion and storage energy.
  - Fundamental understanding of the Chemical, Electrochemical and Photochemical processes in Energy generation, storage and Utilization.
- **Learning Outcome:** After studying this course, students should be able to:
  - Understand the basic electrochemical techniques used in energy conversion and storage systems.
  - Advantage and disadvantages in the Industrial methods for generation of Fuels.
  - Use concepts towards the mimicking systems in artificial photosynthesis.

UNIT-I [15L]

Electrochemical Techniques and their application to Real Systems, Electrochemical Cells: Batteries, Supercapacitors.

UNIT –II [13L]

Fuels through industrial reforming, Fischer-Tropsch process, and Water-gas shift reactions, Multi electronic reservoirs for Electrochemical energy storage.

UNIT –II [14L]

Recent advances in Fuel Cells, Synthesis, Characterization and Application Energy Materials: Electrochemical, photochemical and chemical methods for HER and OER catalysis,

Reference Books:

1. Energy Production and Storage: Inorganic Chemical Strategies for a Warming World (Inorganic Chemical Strategies for a Warming World), edited by Robert H. Crabtree ISBN: 978-0-470-74986-9, Wiley Publications.
2. Molecular Water Oxidation Catalysis, edited by Antoni Llobet ISBN: 978-1-118-41337-1, Wiley Publications.
3. Electrochemical and Electrocatalytic Reactions of Carbon Dioxide; Edited by: B.P. Sullivan, K. Krist and H.E. Guard; ISBN: 978-0-444-88316-2.

CYD 516	Advanced Heterocyclic Chemistry	(3-0-0)

Course Philosophy:

- The subject offers the readers a fundamental understanding of the basics of heterocyclic chemistry and their occurrence in bioactive molecules in advanced level.

Learning Outcome:

- Acquire knowledge about importance of heterocyclic molecules relevant to pharmaceutical chemistry.

UNIT –I [10L]

Different types of strains, interactions and conformational aspects of non-aromatic 3-and 4-membered heterocycles: Synthesis, reactivity, and importance of the following ring systems. Azirines, Oxaranes, Thiiranes, Diazirenes, Diaziridines, Azetidines and Oxetanes.

UNIT-II [12L]

5- and 6-Membered heterocyles containing two hetero atoms: Synthesis, reactivity, aromatic character and importance of the following heterocycles: Pyrazole, Imidazole, Oxazole, Thiazole, Isoxazole, Isothiazole, Pyridazine, Pyrimidine, Pyrazine, Oxazine, thiazine, benzimidazole, benzoxazole and benzthiazole.

UNIT –III [10L]

Heterocyles with Nitrogen-ring-junction: Synthesis and reactivity of Quinolizines, Indolizines and Imidazopyridines. Heterocycles with Dipolar structures: synthesis and reactivity of pyridine-*N*-oxides and pyridinium imides.

UNIT –IV [8L]

Synthesis of Drugs: Ranitidine, Lansoprazole and/or recently discovered molecules containing multiple hetero atoms and rings. Synthesis of few heterocyclic novel natural products.

Reference Books:

1. Heterocyclic Chemistry J. A. Joule and K. Mills, 5th Edition, Wiley-Blackwell publishing, 2010.
2. Heterocyclic Chemistry T. Gilchrist 3rd edition, Prentice Hall, 1997.
3. Modern Heterocyclic Chemistry, Julio Alvarez-Builla, Juan Jose Vaquero, José Barluenga, Wiley-VCH, 2011.

CYD 517	Oligosaccharide synthesis	(3-0-0)

Course Philosophy:

- Introduction to important carbohydrate polymers in natural systems.
- Introduction to some of the most important methods in carbohydrate synthesis

Learning Outcome:

- Biologically important carbohydrate polymers - their structural and repeating units.
- Synthetic tools and methodologies in carbohydrate synthesis.
- Knowledge of the synthetic routes to repeating units of some biologically interesting carbohydrates.

UNIT –I [21L]

Monosaccharides; Protecting group strategies – one-pot orthogonal protection; Glycosyl

donors and glycosylation - glycosylation methods, photochemical glycosylation, substituent effects on glycosylation.

UNIT –II [21L]

Oligosaccharide synthesis – one pot glycosylation, iterative glycosylation, solid phase and automated synthesis. Structure, relevance and synthesis of some important oligosaccharides such as glycosaminoglycans, capsular polysaccharides of pathogens, etc.

References:

1. Carbohydrates- the sweet molecules of life R. V Stick, Academic press, 2001.
2. Essentials of Carbohydrate Chemistry and Biochemistry, T. K. Lindhorst, Wiley VCH, 2000.
3. Recent Primary literature

CYD 518	Metalloenzymes- Special Topics	(3-0-0)

Course Philosophy:

- The course is intended to impart basic understanding about the structure and function of metal containing enzymes and its model

Learning Outcome: At the end of the course the student is able to-

- Know the difference in the structure and function of various metalloenzymes
- Develop understanding about the role of metal ions and the mechanism of action
- Understand the design aspects of metalloenzyme model compounds

UNIT-I [8L]

Introduction to metalloenzymes: Coordination chemistry and basic characterization techniques, suggested mechanism of selected enzymes and synthetic analogues

UNIT –II [16L]

Vanadium: haloperoxidases; Cobalt: cobalamine based enzymes; Zinc: hydrolases, peptidases, ligases, transferases, lyases, oxido-reductases; Iron: heme and non-heme enzymes- Phosphatases, Mono oxygenases, dioxygenases, peroxidase, catalase, super-oxide dismutase, reductases;

UNIT –III [14L]

Manganese: Oxygen Evolving Complex in PS-II, super-oxide dismutase, catalase; Copper: Mono oxygenases, dioxygenases, super-oxide dismutase, catecholase and tyrosinase; Nickel: urease, hydrogenase, super-oxide dismutase; Molybdenum: Oxido-reductases.

References:

1. Bio-inorganic chemistry- A survey by Ei-ichiro Ochiai, 2006, Associated Press, Elsevier

2. Chemical Reviews 1996, Vol. 96 and other recent litterature.
3. Biological Inorganic Chemistry: Structure and reactivity by I. Bertini, H. B. Gray, E. I. Stiefel, J. S. Valentine, 2007, Abe Books
4. Physical Methods in Bio-inorganic Chemistry by Lawrence Que, 2000, University Science Books

CYD 519	Characterization Techniques for Inorganic Chemists	(3-0-0)

Course Philosophy: The course intended to provide

- Basic understanding about various techniques such as, infrared spectroscopy, electronic spectroscopy, EPR spectroscopy, voltammetric techniques, CD, ORD and Mossbauer Spectroscopy

Learning Outcome: At the end of the course the student will be able to-

- Develop understand the principle involved in various techniques used by inorganic chemists
- Interpret data such as IR, UV-visible, EPR, Cyclic voltammogram, CD, ORD and Mossbauer Spectra

UNIT –I [8L]

Interpretation of UV-visible and IR spectra of inorganic and organometallic compounds, case studies. Characterization methods for paramagnetic compounds:

UNIT –II [8L]

EPR: Fundamental principles of continuous wave EPR (CW-EPR), X, Q and W band modes, case studies- interpretation, ENDOR. HYSCORE, methods for simulation, specific examples.

UNIT –III [12L]

Solution studies: Cyclic voltammetry, basic principles and applications, interpretation of redox peaks, case studies. Circular Dichorism (CD) and optical rotatory dispersion (ORD): Principles and application in inorganic and organometallic compounds.

UNIT –IV [10L]

Mossbauer Spectroscopy: Introduction and basic principles, selected examples, interpretation of data.

Reference Books:

1. Infrared and Raman spectra of Inorganic and coordination compounds: Part A & B, Kazuo Nakamoto, Wiley, 2009
2. Applications of Physical Methods to Inorganic and Bioinorganic Chemistry by Robert A. Scott, Charles M. Lukehart, 2007, Wiley –Blackwell.
3. Electron Paramagnetic Resonance: Elementary Theory and Practical Applications, John A. Weil, James R. Bolton, 2nd Edition, Wiley, 2007.
4. Physical Methods for Chemists, R. S. Drago, 2nd Edition, Saunders (W.B.) Co Ltd, 1992.

CYD 520	Advanced Fluorescence Spectroscopy	(3-0-0)

Course Philosophy:

- This course will give an introduction to modern spectroscopic techniques including time-resolved laser methods and dynamic properties of materials.

Learning Outcome:

- Understanding the fundamentals as well to have an insight of the many photo-physical processes and every possible deactivation pathways of the excited systems including organic, inorganic and nanoscales materials.

UNIT –I [18L]

Jablonski diagram, Fluorescence quantum yields and lifetimes, radiative and non-radiative rates, steady state and time-resolved fluorescence, quenching of fluorescence, Fluorescence anisotropy, Resonance energy transfer, Solvatochromism, TRES.

UNIT –II [20L]

Light sources, LASER, monochromator, optical filters, PMT, polarizers, corrected emission spectra, TCSPC, Fluorescence upconversion, transient recording, data analysis. Different examples correlating data recording and data analysis and information found.

Reference Books:

1. Principles of fluorescence spectroscopy by J.R.Lakowicz, *3rd ed., Springer, 2006*
2. Fundamentals of Photochemistry, K. K. Rohatgi-Mukherjee, John Wiley & Sons, 1978.
3. Molecular spectroscopy by Jeanne L. McHale, CRC Press, 2017.

CYD 521	Nanomaterials for Advanced Applications	(3-0-0)

Course Philosophy:

- With this course student will learn various strategy for control synthesis of nanomaterials and their applications in biotechnology.

Learning Outcome:

- Students will learn shape and size control synthesis of metallic, inorganic and magnetic nanomaterials.
- Applications of these nanomaterials in the field of biotechnology, photonics, imaging and sensors will be introduced to the students.

UNIT –I [21L]

The interface of bioscience, nanotechnology and photonics, Quantum dots for bioimaging, Metallic nanoparticles and nanorods for biosensing, Upconverting nanophores and Inorganic nanoparticles for nanosensors for In vitro bioanalysis and optical diagnostics.

UNIT –II [21L]

Magnetic targeting, magnetic separation and detection, Magnetic tweezers, Chemo therapy, MRI, Magnetic contrast agents, Hyperthermia, Application of various nanomagnetic

materials in biotechnology, core-shell structures and their applications. Nanoelectronics, Micro and nano electromechanical systems. Nanophotonics.

Reference Books:

1. Introduction to Nanophotonics, Sergey V. Gaponenko, Cambridge University Press, New York, (2010)
2. Nanofabrication towards Biomedical Applications, Techniques, Tools, Applications, and Impact. C. S. S. R. Kumar, J. Hormes, C. Leuschner, 2005, WILEY -VCH Verlag GmbH & Co. KGaA, Weinheim, ISBN-13 978-3-527-31115-6.
3. Nanoscale Technology in Biological Systems, Edited by Ralph S. Greco, Fritz B. Prinz, R. Lane Smith, CRC PRESS, Boca Raton London New York Washington,

CYD 522	Advanced Biocatalysis	(3-0-0)

Course Philosophy:

- Biochemical studies for the metalloenzyme provide a useful starting point for the development of academically as well as industrially important synthetic analogues of bio-enzymes.

Learning Outcome:

- Students will be familiar with some of the important enzymatic action.
- Students will be able to model the active site of the bio-enzyme of their interest.
- Students will understand the advantage of synthetic model over active enzymes.
- They will be able to develop a non-toxic, green, economic and energy-efficient synthetic method for the preparation of synthetically/industrially important chemicals.

UNIT –I [18L]

Introduction: potential of enzyme-catalysed processes in biology; Introduction to model complexes: Impact in catalysis; Structure and probable enzymatic action of galactose oxidase, catechol oxidase, tyrosinase, vanadium haloperoxidase, etc.;

UNIT –II [20L]

Immobilization on solid supports: Novel concepts, use of nano-, meso- and magnetic materials and characterization, limitations of catalysts, Plots and parameters for Michaelis-Menten kinetics, effect of local environment in catalysis, Supported catalysts, Effect and application in fine Chemicals Industry.

References:

1. Recent review articles/ Journals
2. Enzyme Kinetics and Mechanism; Paul F. Cook, W. W. Cleland. ISBN-13: 978-0815341406
3. Enzyme Kinetics and Mechanisms; Taylor, Kenneth B. ISBN 978-0-306-48025-6

CYD 523	Supramolecular Chemistry & Molecular recognition	(3-0-0)

- **Course Philosophy:** The course aims to:-
  - Demonstrate the importance of supramolecular forces for the assembly of complex nanomaterials
  - Give an understanding of how the properties of ligands can be tuned in order to optimise the performance of metal complexes in their various applications.
  - Examine the relevance of such Supramolecular systems to catalytic, biological, chemi-architectural, industrial processes and applications
- **Learning Outcome:** By the end of the course the student will be able to:-
  - Develop an understanding of the importance of intermolecular forces to define the "chemistry beyond the molecules"
  - Use the basic understanding of such forces to rationalise the formation of complex nanomaterials
  - Understand the importance of the bottom-up approach to prepare complex systems.
  - Recognize the main types of supramolecular assemblies and suggest synthetic strategies for their preparation.

UNIT –I [14L]

Supramolecules: Supramolecular Chemistry and Molecular Recognition. Concepts, Definitions, Language, Receptor Design Principles. Supramolecular Interactions. Ion-ion interactions; Ion-dipole interactions; dipole-dipole -interactions; van der Wall interactions, π-π-interactions; cation-π interactions; hydrogen bonding; hydrophobic effect; metal-coordination bonds. Self-assembly processes in organic systems. Catenanes, rotaxanes, pseudorotaxanes. Synthetic strategies for their preparation. Examples of each type.

UNIT –II [20L]

Self-assembly processes in metal-containing compounds. Using the coordination bond to prepare large supramolecular assemblies. Cages, macrocycles and catenanes. Polymeric materials and grids. Nano-capsules and containers. Synthetic strategies for their preparation. Examples of each type. Potential uses of such assemblies as nano-reactors and for transport. Host-Guest Chemistry. Hosts for Cation Binding; Host for Anion Binding; Hosts for the Binding of Neutral Guests; Synthetic consideration; Templation; Kinetic and Thermodynamic Aspects of Binding Selectivity. Kinetic and Thermodynamic Considerations; Helicates. Supramolecular Chirality. Supramolecular Reactivity and Catalysis. Supramolecular Catalysts; Enzyme Models. Self-Replicating Systems. Kinetic Models; Self-replication in nature; Artifical Self Replicating Systems.

UNIT –III [8L]

Molecular switches and machines. Use of supramolecular forces to assemble components that respond (on-off) to external stimuli. Molecular shuttles, abacus and muscles. Assembling such components into surfaces for molecular electronics. Supramolecular Aggregates and Assemblies.

Reference Books:

1. Supramolecular Chemistry, J. W. Steed and J. L. Atwood, J. Wiley and Sons; 1st Ed. 2000.
2. Principles and Methods in Supramolecular Chemistry, Hans-Joerg Schneider & A. Yatsimirsky, J. Wiley & Sons, 1st Ed. 2000.
3. Control of Reactivity in Aggregates of Amphiphilic Molecules. P. Scrimin, in "Supramolecular control of Structure and Reactivity," John Wiley and Sons, 1996, Vol. 3, pp. 101-153.

CYD 532	Solid State Materials: Chemistry and Engineering	(3-0-0)

- **Course Philosophy:**
  - With this course students will learn the concepts involved in the syntheses, structure and physical properties of crystalline solids along with their characterizations and applications.
- **Learning Outcome:**
  - Identify and apply suitable strategies for synthesizing crystalline solids in polycrystalline and single crystal forms.
  - Correlate and Predict structure composition-properties (magnetic, electrical and optical) in crystalline solids.
  - Characterize solids with X-Ray, microscopic and thermal techniques.

Unit -I [14L]

Crystal Structures and Crystal Chemistry, Bonding in Solids, Defect Chemistry and its applications in various fields. Electrical, Magnetic and Optical Properties of solids, Structure Property Relationship, Superconductors.

Unit -II [14L]

Synthesis, Processing and Fabrication Methods of solids, Nucleation and Growth in Solution, Solid State Reaction, ChimieDouce Methods, Gas-Phase Methods, Crystal Growth, Recent advances in solid state materials.

Unit -III [14L]

Characterization of Solids: Crystallography and Diffraction Techniques, Optical and Electron Microscopy Techniques, Spectroscopic Techniques, Thermal Techniques.

Reference Books:

1. Solid State Chemistry and its Applications, Second Edition, Anthony R. West, 2014, Wiley.
2. Metallic Nanostructures: From Controlled Synthesis to Applications, YujieXiong, Xianmao Lu, 2015, Springer.
3. Materials Science and Engineering: An Introduction, William D. Callister, Jr. David G. Rethwisch, 2013, Wiley.

CYD 533	Advanced Electrochemistry	(3-0-0)

- **Course Philosophy:**
  - The learners should be able to apply theories in electrochemistry to analyze electrode kinetics.
- **Learning Outcome**: At the end of the course, the learners should be able to:
  - **Write** equations representing electrochemical cell, **explain** various overpotential involved during the operation of the cell.
  - **Calculate** electrochemical cell parameters, electrochemical active surface area, current and overpotential under given condition, **Plot** potential vs current, surface coverage vs. potential, potential vs. pH, concentration profile

vs. distance from the electrode.

- **Understand** the basics of electrocatalysis and industrial applications of electrochemistry

UNIT -I [10 L]

Ionics: Electrochemistry of solutions, Ion-solvent interactions, ion-ion interactions, ionic migration and diffusion. Phenomenological description of transport processes. Electrodics: Equilibrium electrode potentials, Thermodynamics of electrochemical cells and applications.Theories of Double-Layer structure, diffuse-double-layer theory of Gouy and Chapman, the Stern Model, Adsorption of ions and neutral compounds

UNIT -II [16L]

Electrode kinetics: Current-potential relationship (derivation of Butler-Volmer and Tafel equations). Adsorption isotherms for intermediates formed by charge transfer (Langmuir adsorption and its limitations, relating bulk concentration to surface coverage), Electrocaplillary and differential capacitance measurements; Influence of double layer on charge transfer processes.potential of zero charge, pzc of solid electrodes, polarization: types of polarization, the charge transfer resistance Types of overpotentials: origin and minimization

UNIT-III [14L]

Electro-catalysis, Bio-electrochemistry, Electron transfer in homogeneous system and in heterogeneous system. Electrosynthesis: electroorganic and electroinorganic syntheses, mechanism of electro-organic reactions; hydrogen evolution and oxygen reduction reactions, Industrial processes: electroplating, anodization, Al production, electrosynthesis of selected industrial chemicals.

Reference Books:

1. Atkins' physical chemistry, P. Atkins and J. de Paula, 8th Edition, Oxford University Press, New Delhi, 2008.
2. E. Gileadi, Physical Electrochemistry, Fundamental, Techniques and Applications, Wiley-VCH, 2011
3. A. J. Bard and L. R Faulkner Electrochemical Methods: Fundamentals and Applications, 2nd Edition, Wiley, 2001

CYD 534	Heterocyclic chemistry	3-0-0

Course Philosophy:

- The subject offers the readers a fundamental understanding of the basics of heterocyclic chemistry and their occurrence in bioactive molecules in advanced level.

Learning Outcome:

- Acquire knowledge about importance of heterocyclic molecules relevant to pharmaceutical chemistry

Unit-I **[12 L]**

Synthesis and reactions of heteroaromatics containing one hetero atom. General

approaches to heterocycle synthesis – cyclisation and cycloaddition routes.

Unit -II **[18 L]**

Synthesis, reactions and their mechanisms of aziridine, azetidine; pyrazines and their analogues; Synthesis of oxazole, thiazole, imidazole, iso-oxazole, isothiazole and corresponding fused systems; imidazopyridine, pteridines, folic acid. Synthesis of drugs like Nevirapine.

Unit III **[12 L]**

Nomenclature of bicyclic and tricyclic fused system. Synthesis of uracil, thymine and cytosine. Synthesis of adenine and guanine. Synthesis of uric acid, caffeine, pyrazine, synthesis of Triazole and tetrazole.

References Books:

2. I .L. Finar, Organic Chemistry, Vol.II, 5th Edition, ELBS, 1975.
3. Heterocyclic Chemistry J. A. Joule and K. Mills, 5th Edition, Wiley-Blackwell publishing, 2010.
4. Heterocyclic Chemistry T. Gilchrist 3rd edition, Prentice Hall, 1997.
5. Modern Heterocyclic Chemistry, Julio Alvarez-Builla, Juan Jose Vaquero, José Barluenga, Wiley-VCH, 2011.

CYD 535	Main Group Chemistry	(3-0-0)

Course Philosophy:

- This course contains the chemistry of s- and p-block elements, synthesis, structure and bonding and their chemical reactivity. Organometallic chemistry of main group elements is included with a special focus on their applications in organic synthesis. Various applications of main group elements in catalysis and material chemistry will be explored.
- With this course students will learn the concepts involved in the syntheses, structure, physical and chemical properties of main group elements along with their application in various field

Learning Outcome:

- General synthetic procedures and characterization for inorganic and organometallic compounds
- Structure, binding and reactivity
- Application in multidisciplinary areas.

UNIT -I [12 L]

s-block elements: Organometallic compounds of alkali and alkaline earth metals, synthetic methods, structure, bonding and reactivity, application catalysis, organometallic compounds of zinc, cadmium and mercury, application

UNIT -II [12 L]

p-block elements: General properties, synthesis, structure, bonding of organoelements compounds, spectroscopic characterization and application. Multiple bonding in main group elements, Hypervalency in p-block elements, heavier carbene analogues, small

molecule activation, and unusual oxidation states of main group elements.

UNIT -III [18L]

Inorganic rings, cages and polymers: boron, carbon, silicon, germanium, tin, nitrogen, phosphorus and arsenic, sulfur and selenium compounds, synthesis, structures, bonding, nomenclature, application in catalysis and material chemistry.

Reference Books:

1. Inorganic Rings and Polymers of the p-Block Elements: From Fundamentals to Applications, Tristram Chivers and Ian Manners, RSC, 2009.
2. Organometallics, A concise introduction, C. Elschenbroich, A. Salzer 3rdedition, 2006, Wiley-VCH Verlag GmbH& Co, KGaA,Weinheim, Germany.
3. Inorganic and Organometallic Polymers, V. Chandrasekhar, Springer India, 2005.

CYD 536	Science of Corrosion & corrosion control	(3-0-0)

- **Course Philosophy:**
  - Most of the industries such as chemical, mining and petroleum industries are facing the corrosion problems. In a recent survey made in India it was estimated that the annual loss due to corrosion is approximately 3 – 4% loss of the GDP. We teach corrosion to paper to B. Tech students of Petroleum Engineering, Mechanical Engineering and Chemical Engineering students. Therefore we have floated this course as open elective.
  - The course is offered to impart: Knowledge about the problem faced by industries
  - Develop understanding about the mechanism and process of corrosion
  - Knowledge about various methods for protection against corrosion
- **Learning Outcome:**
  - Knowledge of corrosion and corrosion control to engineering students will help in their working in industries.

UNIT -I [14L]

Definition of corrosion, consequences of corrosion and economic aspects of corrosion. Types of corrosion: Chemical and electrochemical corrosion, Pilling Bedworth rule, Forms of corrosion, Theories of corrosion. Factors affecting corrosion. Kinetics of corrosion: Evan's diagram. Thermodynamics of corrosion- Pourbaix diagram.

UNIT-II [16L]

Measurement of corrosion: Weight loss, potentiodynamic polarization and electrochemical impedance spectroscopy methods. Corrosion prevention: modification of materials, modification of environment, modification in design, corrosion inhibitors, protective coatings, cathodic and anodic protection.

UNIT-III [12L]

Application of FTIR, SEM-EDX, XPS and AFM in corrosion inhibition studies. Corrosion problems in Chemical, Mining and petroleum industries.

Reference Books:

1. Corrosion Engineering, Mars. G. Fontana, 3rd Edition, McGraw-Hill, Inc. 1987.
2. Principles and prevention of corrosion, Denny A. Jones, 2nd Edition, Prentice Hall, 1995.
3. An Introduction to Science of Corrosion and Its Inhibition, S. N. Banerjee, Oxonian Press, 1985.

OPEN ELECTIVES

CYO 501	Instrumental Techniques for Materials Characterization	(L-T-P)

- **Course Philosophy:**
  - With this course students will learn Principle, instrumentation and applications of various X-Ray, Microscopic and Thermal techniques for materials characterizations.
- **Learning Outcome:**
  - Characterize materials using advanced characterization techniques.
  - Select and interpret analysis results.
  - Design experiments with improved sample preparation, new measurement procedures and tools
  - Utilize the concept of different materials characterization techniques for qualitative and quantitative analysis.

UNIT -I: **X-Ray Techniques [14L]**

Principle, Instrumentation and applications of XRD, XRF (EDS, WDS) and XPS. Crystal Structure determination by XRD. Qualitative and Quantitative elemental analysis by XRF. Surface chemical analysis by XPS. Neutron Diffraction for materials characterization.

UNIT -II: **Microscopic Techniques [20L]**

Resolution, magnification, depth of field, Imaging – theory and concepts. Principle, Instrumentation and applications of Scanning electron microscopy, Transmission electron microscopy, Scanning Tunnelling Microscopy, Atomic Force Microscopy. Sample Preparation Techniques for microscopic analysis. Elemental analysis by EPMA. Electron energy loss spectroscopy (EELS) and selected area electron diffraction (SAED) in TEM.

UNIT -III: **Thermal Techniques [8L]**

Principle, Instrumentation and applications of TGA, DSC and DTA. Factors affecting thermal analysis. Determination of degradation and cure kinetics by TGA and DSC.

Reference Books:

1. Elements of X-Ray Diffraction, B.D. Cullity, S.R. Stock, Third Edition, Pearson, 2014.
2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Y.Leng, Wiley, 2008.
3. Thermal Analysis, W. M. Wandlandt, Third Edition, Wiley, 1986.

CYO 502	Materials Science and Technology	(3-0-0)

- **Course Philosophy:**
  - With this course students will be introduced to the concepts related to materials science and technologies, their classifications and relation between processing, structure, and physical properties
- **Learning Outcome:**
  - Classify materials based on their properties and establish structure properties relationship.
  - Correlate effect of crystal structure, defects and imperfections on materials properties.
  - Identify the causes of failures and characterize materials with Thermal, spectroscopic and mechanical methods.
  - Identify importance of composites, their processing, and characterization.

Unit -I **[14 L]**

Introduction to Materials Science, Classification of Materials, Modern Materials Needs, Processing/Structure/Properties/ Performance Correlations. Structure of Crystalline Solids, Geometry of crystals- the Bravais lattices, Crystal directions and Planes- Miller indices, Structure determination-X-ray diffraction, Braggs Law, the power method. Imperfections in Solids: Point Imperfections, Line imperfections- edge and screw dislocations, Surface imperfections. Phase Diagrams.

Unit -II **[14L]**

Mechanical Properties, Failure: Fracture, Creep, Fatigue. Electrical, Magnetic, Thermal and optical properties of materials. Characterization of Materials: Mechanical, Thermal and Spectroscopic techniques. Properties of Selected Engineering Materials.

Unit -III **[14L]**

Polymer Structures. Characteristics, Applications, and Processing of Polymers, Composites: Significance and Classification. Processing, Characterization and Applications of Composites. Advanced Materials: Smart materials, Biomaterials, Nanomaterial and Nanocomposites.

Reference Books:

1. Materials Science and Engineering: An Introduction, William D. Callister, Jr. David G. Rethwisch, 2013, Wiley.
2. Solid State Chemistry and its Applications, Second Edition, Anthony R. West, 2014, Wiley.
3. Polymer Science & Technology – Plastics, Rubbers, Blends and Composites. Premamoy Ghosh. 3rd Edition, McGraw Hill Education (India) Private Limited, 2010.

CYO 506	Electrochemical Strategies in energy systems	(3-0-0)

- **Course Philosophy:** This course will impart
  - Fundamental understanding of the applications of electrochemistry
  - Electrochemical techniques related to conversion and storage energy.
- **Learning Outcome:** After studying this course, students should be able to:
  - Understand the basic electrochemical techniques used in energy systems.
  - Study the stability limits and the interpretation of E_H-P_H (Pourbaix) diagram.
  - Use concepts and models of mimicking systems in artificial photosynthesis.
  - Understand the basic principles and advances in Fuel-Cell and its technology.

UNIT -I [18 L]

Voltammetric, Amperometric, Potentiometric and Coulometric methods in energy systems. Stability limits of water,Pourbaix diagram and its features, Difference in Pourbaix diagram of $[Ru(tpy)(bpy)(OH_2)]^{2+}$ and $[Ru(tpy)(bpm)(OH_2)]^{2+}$. Understanding and case studies of Pourbaix diagram.

UNIT -II [14 L]

NAD^+/NADH as a model redox system: Reaction path and case studies. Electrochemical, chemical and photochemical oxidation of Water, reduction of CO_2, Proton Reduction. Case Studies of each system. Electrochemical analogues of Water-gas shift (WGS) reaction and WGS in homogeneous systems; Syn Gas, Fischer-Tropsch process.

UNIT -III [10 L]

Fuel Cells Technology: alkaline fuel cells, phosphoric acid fuel cell, molten carbonate fuel cells, solid oxide fuel cells, polymer electrolyte fuel cells; cell components, thermodynamics and kinetics, operation and performance, applications.

Reference Books:

1. Electrochemical Methods: Fundamentals and Applications 2nd Edition, Allen J. Bard and L. R. Faulkner, 2001.
2. Modern Analytical Chemistry, D. Harvey,1st Edition, 2000.
3. Hydrogen and Fuel Cells. Emerging Technologies and Applications. B. Sørensen. 2nd Edition, 2011.

CYO 507	Nuclear & Radiation Chemistry	(3-0-0)

- **Course Philosophy:**
  - The course is meant to develop a better understanding of nuclear structure, various nuclear reactions and their implication in harvesting of nuclear energy. The course also introduces important information on nuclear reactor, theory involved and reactor design. It also enhance the knowledge of various applications of radiation chemistry and tracers in various fields.
- **Learning outcome:** At the end of the course the students should be able to:
  - The develop an understanding of the nuclear structure, explain the origin of nuclear reactions
  - Differentiate different nuclear energy harvesting technologies, and identify

the conditions and parameters for optimum function of nuclear reactor

- Solve problems involving nuclear reactions, reactors, and those related application of nuclear radiations/tracers
- Develop understanding of various application of tracers and nuclear radiation in various fields

UNIT -I **[10L]**

Structure of Nucleus, Shell Model, liquid drop model, Collective model, optical model, merits and demerits. Radioactivity: Decay kinetics, α, β decay, γ emission, Parent – daughter decay –growth relationship, secular and transient equilibrium, Theory of α, β and γ decay, selection rules. Artificial radioactivity.

UNIT -II **[15L]**

Nuclear Reactions: Elastic, inelastic, Photonuclear, radiative capture, evaporation, spallation, Fragmentation, and Transfer reactions. Nuclear fission and fusion; Theory of Nuclear fission, fission energy and fission cross-section, Nuclear Reactors: Classification of reactors, reactor power, critical size, Breeder reactor.

UNIT -III **[17L]**

Application of radioactivity: Tracers in medicine, agriculture, chemical investigations; Analytical applications, Industry and in age determinations. Neutron Activation Analysis, advantages and applications. Radiation detectors, Radiolysis of water, Dosimeters

Reference Books:

1. Essentials of Nuclear Chemistry H. J. Arnikar, 4th edition, New Age Publishers, 1995.
2. Nuclear and Radiochemistry, G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller, John Wiley & Sons, 1985.
3. Nuclear and Radiochemistry: Fundamentals and Applications, Karl H. Lieser, 2nd edition, 2001, Wiley, NY.

CYO 508	Surface Science and Catalysis	(3-0-0)

Course Philosophy:

- The course Surface Science and Catalysis has been designed for the students who willpursue their research in the area of heterogeneous catalysis which is related to oil industry, petrochemical industry, and fine chemical synthesis.
- Apart from catalysis thin film, several techniques for its preparation will be taught.

Learning Outcome:

- Student will come out with a thorough understanding of catalyst preparation, characterization by different techniques, surface chemistry associated with different reactions which will be useful for them to join in different R&D as well as industry.
- The thin film, molecular beam epitaxy as well as other topics can be useful for several interdisciplinary researches.

UNIT -I [12 L]

Elementary gas phase reaction, Kinetics of diffusion controlled reaction, spill-over effect, multiplet theory, Kinetics of Gas-solid reaction, LH and LR Mechanism Promotional and poisoning effect on catalyst surface, Physisorption and adsorption isotherm, Langmuir and BET isotherm, Hysteresis loop, Chemisorption of gas molecules to the solid surface, Determination of particle size from chemisorption measurement, TPR/TPD/TPO techniques,

UNIT -II [12L]

Brief overview of catalytic reactor, fixed bed and batch reactor, mass transfer and heat transfer on the catalyst surface**,** selective oxidation reaction, Hydrogenation reaction, Dehydrogenation reaction Dehydration reaction, Alkylation reaction

UNIT -III [11L]

Energy related Catalysis, Oil refining, Hydro treating, Hydrodesulfurization, Hydrodenitrogenation reactions, methane decomposition, steam reforming, cracking and isomerisation reaction Fischer-Troph synthesis, Bio-fuel

UNIT -IV [7L]

Mesoporous material, Organic-inorganic hybrid material, Thin film, PVD, CVD, Molecular beam epitaxy techniques, Langmuir-blodget thin film , self-assembled monolayers

Reference Books:

1. Chemical Kinetics, K. J. Laidler, 3rd Edition, Pearson Education India, 1987.
2. Handbook of Heterogeneous Catalysis Vol 1-8, Edited by Gerhard Ertl, HelmuthKnözinger, FerdiSchüth, Jens Weitkamp Wiley-VCH Verlag GmbH& Co. KGaA, Weinheim, Germany, ISBN: 978-3-527-31241-2, 2008
3. The Surface Science of Metal Oxides, Victor E. Henrich, P. A. Cox, Cambridge University Press; New Ed edition, 1996. 2. Current Trends of Surface Science and Catalysis, Jeong Young (Ed.) Park (Author), Jeong Young Park(editor), 1st Edition, Springer, 2013.