

INDIAN INSTITUTE OF TECHNOLOGY

DEPARTMENT OF CHEMISTRY

PLO: Program Learning Objectives and Learning Outcomes

Academic Program: **Ph.D.**

Proposing Department: **Chemistry**

Program Learning Objectives:	Program Learning Outcomes:
Program Goal 1: Fundamental Understanding: To impart an advanced level theoretical and practical knowledge in the major fields of Chemistry	Program Learning Outcome 1a: Students will learn the basic concepts of Physical, Inorganic, Organic, Computational, Biochemistry, Polymer, and Solid State Chemistry, Quantum Chemistry etc. Program Learning Outcome 1b: Students will have comprehensive practical knowledge in chemistry.
Program Goal 2: Basic Training for Research: To provide quality training for conducting fundamental and advanced research in Chemistry.	Program Learning Outcome 2a: Students will be acquainted with different research techniques, such as synthetic organic chemistry, inorganic chemistry, biochemistry, solid-state chemistry, material design, ab-initio calculation, semi-empirical methods, molecular dynamics simulation, and analytical equation solving approach, etc. Program Learning Outcome 2b: Students will learn to run different advanced instruments, to write research articles for publication, and to work collaboratively with other Ph.D. students.

Program Goal 3: Skill Enhancement: To focus on skill enhancement in the core chemistry with practical expert hands which will make students employable in academia and industries.	Program Learning Outcome 3: Students will get good skills in core chemistry suitable for getting employed in academia, industries, and encourage entrepreneurship.
Program Goal 4: Communication Skill: To develop various communication skills such as reading, listening, speaking, etc., which will help in expressing ideas and views clearly and effectively.	Program Learning Outcome 4: Students will learn how to read and understand research papers, make technical presentations, and communicate with a large audience.
Program Goal 5: Social Awareness: To make understand the environmental issues (especially in Indian context), such as global warming, climate change, acid rain, ozone depletion and will create awareness in society.	Program Learning Outcome 5a: Students will have awareness and appreciation on various global problems related to chemistry, such as global warming, climate change, environmental sustenance, energy crisis, waste-to-wealth, and toxicological implications of chemicals in societies, etc. Program Learning Outcome 5b: Students will learn to fundamentally apply themselves for social outreach at local and global levels.

Sl. No.	Subject Code	Course Name	L	T	P	C
1.	CH7101/CH7201	Sustainable Chemistry	3	1	0	4
2.	CH7102/CH7202	Solid State Chemistry	3	1	0	4
3.	CH7103/CH7203	Nanotechnology for Biomedical Applications	3	1	0	4
4.	CH7104/CH7204	Bioanalytical Techniques	3	1	0	4
5.	CH7105/CH7205	Advanced Medicinal Chemistry	3	1	0	4
6.	CH7106/CH7206	Organic and Organometallic Catalysis	3	1	0	4
7.	CH7107/CH7207	Advanced Optical Spectroscopy	3	1	0	4
8.	CH7108/CH7208	Chemistry of Heterocycles	3	1	0	4
9.	CH7109/CH7209	Syntheses and Applications of Industrial Polymers	3	1	0	4
10.	CH7110/CH7210	Chemistry and Applications of Nanostructured Materials	3	1	0	4
11.	CH7111/CH7211	Art in Organic Synthesis	3	1	0	4
12.	CH7112/CH7212	Spectroscopic Techniques in Chemistry	3	1	0	4
13.	CH7113/CH7213	Supramolecular Chemistry	3	1	0	4
14.	CH7114/CH7214	Reagents for Organic Synthesis	3	1	0	4
15.	CH7115/CH7215	Introduction to Computational Chemistry	3	0	2	4
16.	CH7116/CH7216	Application of Glycochemistry in Modern Technology	3	1	0	4

Course Number	CH7102 /CH7202
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Solid State Chemistry
Learning Mode	Offline
Learning Objectives	The aim of the Course is to enable students to understand the basics of solid-state structure, their characterization and understanding of the structure-property correlation. Additionally, this course will be helpful for students who desire to do research in solids or work in an area related to crystallography or structural chemistry.
Course Description	This course introduces solid-state chemistry, emphasising symmetry, structure and properties. The Course will help students understand the basic synthetic techniques of solid-state chemistry, the basics of symmetry and space group, X-ray crystallography, descriptive crystal chemistry and defects. Also, the students will be introduced to the band theory of solids and their electric and magnetic properties.
Course Outline	Module 1: Preparative solid-state chemistry: Hydrothermal techniques, high throughput synthesis, high-temperature ceramic techniques, sol-gel, chalcogel synthesis by metathesis route, pyrolysis, air sensitive synthesis; Module 2: Characterization of inorganic solids. Module 3: Crystal chemistry: Lattices, unit cells, symmetry, point groups, space groups, CCP, HCP, voids, radius ratio rules. Methods of crystallography: powder, single crystals, X-ray, neutron and electron diffraction. Module 4: Descriptive crystal chemistry: AB, AB₂, AB₃ (ReO₃, spinels, pyrochlores, perovskites, K₂NiF₄ etc.). Module 5: Defects: Origin of defects in crystals, equilibrium, non-equilibrium, point, line, planar defects; Non Stoichiometry: evolution of point defects in non-stoichiometric solids, Wadsley defect, crystallographic shear, Magneli phases, defect perovskite oxides. Solid Solutions. Statistical distribution of defects. Module 6: Electronic properties and band theory: Metals, Semiconductors, Inorganic Solids. Electric and magnetic properties of solids: insulators, semiconductors, conductors and Fermi surfaces;

	superconductivity; dielectrics and ferroelectrics; pyroelectrics and piezoelectrics, diamagnetism and paramagnetism; ferromagnetism, ferrimagnetism and antiferromagnetism. Free electron model, color centers (V & H), trap, non-linear optical properties, p-n junctions and diodes. Quantum statistic, superconductivity and Bose-Einstein condensate.
Learning Outcome	Students will be able to 1. Propose and design synthesis of new inorganic solids. 2. Will be able to interpret X-ray diffraction data along with other microscopic, thermogravimetric characterizations of solids. 3. Understand structures of various inorganic solids. 4. Understand defects chemistry in Solids 5. Understand the electric and magnetic behavior of solids.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. A.R. West, Solid State Chemistry and its applications, 2nd Ed., Wiley, 2014.
2. L.E. Smart and Moore, Solid State Chemistry: An Introduction, 3rd Ed., CRC Press, 2005.
3. C. Kittel, Introduction to Solid State Physics, 8th Ed., Wiley, 2012.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X		X			X		
CLO-2	X		X			X		
CLO-3	X		X			X		
CLO-4	X		X			X	X	
CLO-5	X		X			X	X	

Course Number	CH7103/CH7203
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Nanotechnology for Biomedical Applications
Learning Mode	Offline
Learning Objectives	To introduce basic concepts of nanotechnology and various applications of Biomedical Science including biomaterials, nanomedicine, drug delivery and biomedical devices.
Course Description	The course instills the concept of Nanotechnology and nanotechnological advances related to the three main aspects of Biomedical applications, viz. Disease diagnostics, drug delivery and theranostics.
Course Outline	Module 1: Nanotechnology for Disease Diagnostics: Nanotechnology in immunoassay, working principles of bionanosensors, nanoparticle conjugation strategies with DNA, protein and antibody for biosensing, FRET/BRET based assays for cancer, AIDS, tuberculosis and other disease diagnostics; Nanoparticle assisted multiplexed diagnostic assays (Bio-barcode amplification assay, sandwich DNA assay etc.) and point-of care diagnostics (lateral flow assay), nanotechnology in imaging (MRI, CT, PET, Terahertz imaging). Module 2: Nanotechnology for Drug Delivery: Lipid, polymeric, polysaccharide, dendrimer based nanoparticle as drug delivery vehicles; Carbon nanotube-based vectors for delivering immunotherapeutics and drugs; Hydrogels for drug delivery, nanoparticle induced gene delivery for gene therapy. Module 3: Nanotechnology for Therapy: Nanodrugs for treatment of cancer (Doxil, Depocyt, Abraxane and other drugs); Concept of nanodrug-encapsulation, self-assembly, controlled release with nanoparticles (targeted and triggered release), nanoparticle recovery; modified Ag-nanoparticle for Photodynamic therapy of cancer; nanoparticle assisted vaccine development; nanoshells for surgical procedures; nanotechnology in 3D-organ printing.

Learning Outcome	Students will be able to 1. Gain basic concept of Nanotechnology and nanomaterials relevant to Biomedical science and research. 2. Relate nanotechnology to recent advances in disease diagnostics 3. Know various nanomaterials for drug delivery and nanoformulations of drugs. 4. Relate and interpret nanotechnology related to theranostics and futuristic medicine.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. Mauro Ferrari, BiOMEMS and Biomedical Nanotechnology, Springer, 2007.
2. Neelina H. Malsch, Biomedical Nanotechnology, CRC press, 2019.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X	X	X					
CLO-2	X	X	X					
CLO-3	X				X		X	X
CLO-4	X				X	X	X	X

Course Number	CH7104/ CH7204
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Bioanalytical Techniques
Learning Mode	Offline
Learning Objectives	To develop the skills of the application of basic and advanced techniques employed in quantitative and qualitative analysis of biomolecules
Course Description	The course describes various basic and advanced analytical techniques to intercept biomolecules including DNA, RNA, Protein etc. relevant to pharmaceutical industry, forensics, biomedical research

Course Outline	Module 1: Protein Analysis & Techniques: Protein purification methods: (ion-exchange, gel filtration and affinity chromatography), protein estimation, peptide mapping, epitope analysis and mapping, basics of molecular docking, automated peptide sequencing and synthesis, dynamic light scattering. Module 2: Immunological Analysis: Antibody production – Hybridoma technology, Western blot and immunoprecipitation, immunohistochemistry, immuno-electrophoresis, immuno-diffusion techniques, immunofluorescence & flow cytometry, immunoassay: radioimmunoassay (RIA); enzyme-multiplied immunoassay technique (EMIT); fluorescence polarisation immunoassay (FPIA); closed enzyme donor immunoassay (CEDIA); enzyme-linked immunosorbent assay (ELISA), applications of immunoassays in diagnosis centers and screening of drugs. Module 3: Recombinant DNA Techniques: Automated DNA sequencing and synthesis, FISH (Fluorescent in-situ Hybridization), DNA fingerprinting (VNTR and micro satellite mapping), Gene cloning and expression: cloning strategies, production of recombinant proteins, PCR methodology and applications, micro arrays. Module 4: Spectroscopic and Spectrometric Applications: Elementary applications of spectroscopic (optical, FTIR, NMR), and mass spectrometric (LC-HRMS, MALDI-TOF) detection of biomolecules. Module 5: Electron Microscopy in Bioscience: Scanning Electron Microscopy (SEM), Transmission electron microscopy (TEM), Scanning Transmission electron microscopy (STEM), AFM – basic technique and application in biomaterials characterization. Module 6: Pharmacodynamics: Pharmacology, biopharmaceutics, pharmacokinetics, pharmacodynamics, and toxicology. Module 7: Electrophoresis Applications: Separation of proteins, DNA, RNA (Agarose, PAGE, SDS-Page), gradient.
Learning Outcome	Students will be able to 1. Explain basic conceptual framework to use analytical tools to intercept biomolecules 2. Explain mechanistically isolation, purification, quantification techniques of biomolecules. 3. Perform a procedure to characterize various types of biomolecules. 4. Gain concepts to perform characterization of cells and cellular components using microscopy, flow cytometry and other analytical

	techniques
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. A. Hoffman and S. Cloakie, Wilson and Walkers Principles and Techniques of Biochemistry and Molecular Biology, 8th Ed., Cambridge University Press, 2018.

References:

1. M. L. Srivastava, Bioanalytical Techniques, Narosa Publishers, 2008.

2. Jeanette M. Van Emon, Immunoassay and other Bioanalytical Techniques, 1st Ed., CRC Press, 2006.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X	X	X					
CLO-2	X	X	X		X			
CLO-3	X				X	X	X	X
CLO-4	X				X	X	X	X

Course Number	CH7105/CH7205
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Advanced Medicinal Chemistry
Learning Mode	Offline
Learning Objectives	The main objective of this course is to familiarize students with the fundamental concepts of drug discovery and development, to train students on various aspects of new drug discovery/development, drug screening, target identification, lead discovery, optimization and the molecular basis of drug design and drug action.
Course Description	This course introduces different classes of drug molecules based on therapeutic aspects. The course further emphasizes the reaction mechanism, use of different reagents, and catalysts in organic transformations leading to the synthesis of different classes of life-saving drug molecules.
Course Outline	Module 1: Introduction to different classes of drugs, relation between structure of a drug molecule and corresponding biological activity. Module 2: Drugs based on a substituted benzene ring: Chloramphenicol, Salmeterol, Tolazamide, Diclophenac, Tiapamil and Intryptyline. Drugs based on heterocycles fused to two benzene rings: Quinacrine and Tacrine. Module 3: Drugs based on five-membered heterocycles: Tolmetin, Spiralpril, Oxaprozine, Sulconazole, Nizatidine, Imolamine, Isobuzole. Drugs based on six-membered heterocycles: Warfarin, Quinine, Norfloxacin, Ciprofloxacin, Methylclothiazide, Citrine, Terfenadine. Module 4: Drugs based on five-membered heterocycles fused with six-membered rings: Acyclovir, Methotrexate. Module 5: Drugs based on seven-membered heterocyclic rings fused with benzene: Chlordiazepoxide, Diazepam, Diltiazem. Module 6: β-Lactam antibiotics: Penicillin, cephalosporin.
Learning Outcome	Students will be able to 1. Correlate pharmacology of a disease and its mitigation or cure through medicinal chemistry. 2. To understand the drug metabolic pathways, adverse effects and therapeutic value of drugs. 3. To know the structural activity relationship of different classes of drugs. 4. Students will be acquainted with the synthesis of various important classes of drugs on a large scale.

	5. Knowledge about the mechanistic pathways of different class of medicinal compounds based on their interactions with various receptors of human beings.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested Readings:

Text Books:

1. W. O. Foye, T. L. Lemke, and D. A. Williams, Foye's Principles of Medicinal Chemistry, 6th Ed., USA, 2008.
2. D. Lednicer, Strategies for Organic Drug Synthesis and Design, John Wiley & Sons Inc., New York, 2nd Ed., 2008.
3. A. Burger, Medicinal Chemistry, Vol. I-III, Wiley Interscience Publications, New York, 1995.
4. W. O. Foye, Principles of Medicinal Chemistry, 3rd Ed., Lea & Febiger/Varghese Publishing House, Bombay, 1989.

Reference Books:

1. D. Lednicer and L. A. Mitscher, The Organic Chemistry of Drug Synthesis, Vol. III, Wiley Interscience, 1977.
2. A. Kar, Medicinal Chemistry, Wiley Eastern Ltd., New Delhi, 1993.
3. N. K. Terrett, Combinatorial Chemistry, Oxford Univ. Press, 1998.
4. D. Lednicer, Strategies for organic drug synthesis and design, John Wiley & Sons, New York, 2009.
5. G. L. Patrick, Introduction to Medicinal Chemistry, Oxford University Press, 2001.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X	X						X
CLO-2	X	X			X			
CLO-3			X		X		X	
CLO-4					X	X	X	

Course Number	CH7106/CH7206
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Organic and Organometallic Catalysis
Learning Mode	Offline
Learning Objectives	The aim is to inculcate the concept of catalysis using organic molecules and organometallic complexes. This course will build a strong foundation of synthesis, characterization and applications of various homogeneous catalysts that are either organic molecules or organometallic complexes.
Course Description	This course introduces molecular catalysts that are either purely organic molecules or organometallic complexes derived from organic molecules and an appropriate metal. This course will describe the synthesis and characterization of various catalysts and their applicability in various chemical reactions. The course will also highlight the importance of such catalysts in various industries including the pharmaceutical industry.
Course Outline	Module 1: Introduction to catalysis: the importance of catalysis (homogeneous and heterogeneous), thermodynamics and kinetics involving catalytic pathways, and terminologies used in catalysis, including TOF and TON. Module 2: Organocatalysis: Enamine and iminium catalysis, Asymmetric proton catalysis, ammonium ions as chiral templates, chiral Lewis bases as catalysts. Asymmetric acyl transfer reactions, Ylide-based reactions. Module 3: Transition metal-catalyzed reactions: Design and development of various transition metal catalysts, Importance, and application in C-H/N-H activation reactions. Module 4: N-heterocyclic carbenes (NHCs) based catalysts: Recent developments in the field of homogeneous catalysts derived from (NHCs). Synthesis and characterizations, Applications of NHC based catalysts in organic synthesis.
Learning Outcome	Students will be able to: 1. Understand the thermodynamic and kinetic benefits of the use of catalysts for efficient conversion of reactants to desired products. 2. Identify organic molecules that are used as organocatalysts. 3. Design, synthesize, and characterize new organometallic catalysts for specific organic transformations.

	4. Relate and interpret technology related to organo- and organometallic catalysts often used in fine chemical, pharmaceutical, polymer and other related biochemical industries.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. M. C. Kozlowski and P. J. Walsh, Fundamentals of Asymmetric Catalysis, University Science Books, U.S., 2009.
2. R. B. Crabtree, The Organometallic Chemistry of the Transition Metals, 7th Ed., Wiley, 2019.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X							
CLO-2	X		X		X			
CLO-3	X		X					
CLO-4	X							X

Course Number	CH7107/CH7207
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Advanced Optical Spectroscopy
Learning Mode	Offline
Learning Objectives	On successful completion of the course, students will be able to explain the different advance level phenomenon that takes place due to the interaction of light with matter in the area of optical spectroscopy. Students will be able to learn different advanced level instrumental techniques in the area of optical spectroscopy.
Course Description	This course introduces different advance level phenomena that take place in the optical spectroscopy. Fundamental theories behind different light induced phenomena in the optical spectroscopy such as dynamics of solvent relaxation, resonance energy transfer, excimer and exciplex formation etc. will be discussed. This course also describes different instrumentation techniques in the area of optical spectroscopy.
Course Outline	Module 1: Overview of basic concepts: Light-matter interaction, introduction to lasers, transition dipole moment, and selection rules for electronic transitions, Jablonski diagram, fluorescence and phosphorescence. Module 2: Advanced concepts: Theory of nonradiative transitions, effect of solvents on the fluorescence emission spectra, spin-orbit coupling and singlet-triplet transitions, polarized light absorption and emission, fluorescence anisotropy, Dynamics of solvent relaxation, energetics and dynamics of bimolecular processes like excimer and exciplex formation, fluorescence resonance energy transfer and its applications, mechanisms of fluorescence quenching. Non-adiabatic transitions, conical intersection. Module 3: Techniques and instrumentation: UV-Vis spectrophotometry, steady-state fluorimetry, time-resolved fluorimetry, transient absorption spectroscopy, multiphoton spectroscopy, single-molecule spectroscopy, fluorescence correlation spectroscopy.

Learning Outcome	1. Overview of factors involved in transition in optical spectroscopy, such as transition probability, selection rules, etc. 2. Description of different light induced phenomena in optical spectroscopy. 3. Description of different instruments used in optical spectroscopy. 4. Description of different advanced techniques used in the optical spectroscopy to solve global problems related to chemistry.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. W. W. Parson, Modern Optical Spectroscopy, Springer, Student Ed., 2009.
2. K. K. Rohatgi-Mukhejee, Fundamentals of Photochemistry, Wiley Eastern Ltd, 1992.
3. J. R. Lakowicz, Principles of Fluorescence Spectroscopy, Springer, 3rd Ed., 2006.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X				X			X
CLO-2	X	X			X			X
CLO-3	X			X	X			
CLO-4	X	X		X	X		X	X

Course Number	CH7108/CH7208
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Chemistry of Heterocycles
Learning Mode	Offline
Learning Objectives	The main objective of this course is to make students acquainted with the different types of heterocyclic organic molecules and their use in day today life and also emphasize on synthesis.
Course Description	This course introduces different classes of heterocyclic organic molecules. This further depict the use of different reagents, catalysts, and also emphasize on reaction mechanisms involved in synthesis of various heterocycles.
Course Outline	Module 1: Introduction to heterocycles with special emphasis on nomenclature, acidity, basicity, reactivity and aromaticity. Synthesis and application of three and four membered heterocycles (aziridine, azirine, azetidine, oxiranes, thiarines, oxetenes and thietanes). Module 2: Five- and Six-membered heterocyclic rings having two heteroatoms: Pyrazole, imidazole, oxazole, iso-oxazole, thiazole and isothiazole, Thymine, Uracil and Cytosine. Module 3: Benzofused five- and six-membered heterocycles: Indole, benzofuran, benzothiophene. Synthesis and application of Benzofused six membered rings with one, two and three heteroatoms: Benzopyrans, quinolines, isoquinolines, quinoxalines, acridines, phenoxazines, phenothiazines, benzotriazines, pteridines. Purines: Adenine and Guanine, Module 4: Seven and larger membered ring heterocycles: Azepines, oxepines, thiepinines. Chemistry of porphyrins and spiro heterocycles. Module 5: Importance of heterocycles in medicinal and commercial applications.
Learning Outcome	Students will be able to 1. To understand the structural-activity relationship of different heterocycles. 2. To understand the event of synthesis various important heterocycles. 3. Understand the evolution of drug discovery. 4. To understand how derivatives of different heterocycles do have potential application as drug molecules. 5. Knowledge about the different classes of heterocycles and their physicochemical relevance to the pharmaceutical industry.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. J. A. Joule, and K. Mills, Heterocyclic Chemistry, 5th Ed., Wiley, 2010.
2. T. L. Gilchrist, Heterocyclic Chemistry, 3rd Ed., Addison-Wesley Longman, Ltd., 1998.
3. R. M. Acheson, An Introduction to the Chemistry of Heterocyclic Compounds, 3rd Ed., Wiley India Pvt Ltd, 2008.
4. T. Eicher, and S. Hauptmann, The chemistry of Heterocycles, Wiley-VCH, Weinheim, 2003.
5. R. K. Bansal, Heterocyclic Chemistry: Syntheses, Reactions and Mechanisms, 3rd Ed., New Age International, Publisher, New Delhi, 1999.
6. A. R. Katritzky, C. A. Ramsden, J. A. Joule and V. V. Zhdankin, Handbook of Heterocyclic Chemistry, 3rd Ed., Elsevier, Oxford, UK, 2010.
7. R. R. Gupta, M. Kumar, V. Gupta, Heterocyclic Chemistry, Vol-III, 1st Ed., Springer Verlag, Berlin Heidelberg Publication, 2005.
8. D. T. Davies, Aromatic Heterocyclic Chemistry, Oxford University Press, 1992.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X	X			X			X
CLO-2	X	X			X		X	
CLO-3			X		X		X	X
CLO-4					X		X	X
CLO - 5	X	X			X		X	X

Course Number	CH7109/CH7209
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Syntheses and Applications of Industrial Polymers
Learning Mode	Offline
Learning Objectives	This course gives a detailed overview of polymer synthesis and applications of various industrial polymers. This course will be helpful for students, who desire to do research in the area and aim for a career related to a polymer and chemical industry.
Course Description	This course deals with the detailed synthesis and applications of different industrially relevant polymers. In the few introductory classes basic properties of polymers will be discussed in brief. In the next stages synthesis and applications of relevant industrial polymers will be discussed in detail in light of their different synthetic techniques. This course also outlines an important discussion about emulsion polymerizations and applications of polymer dispersion. Finally few examples will be illustrated in the light of advanced polymer applications such as liquid crystalline polymers, conductive polymers polymer adhesives and biomedical applications of degradable polymers.

Course Outline	Module 1: Basics- Definitions, nomenclature, classifications, environmental assessment, brief overview of basic properties of polymers such as molecular weight, polymer morphology, polymer solution property/solubility aspects, thermal properties, mechanical properties and rheology, polymer degradation and weathering Module 2: Kinetics and examples of step growth polymerizations, Synthesis and applications of different industrially relevant condensation polymers: polyesters, polyamides, polyurea, polyurethanes, polyethers, polybenzimidazoles, formaldehyde resins, silicones etc. Module 3: Chain growth polymerization: kinetics, mechanisms of different controlled radical polymerizations. Synthesis and applications of different industrially relevant addition polymers, such as polyolefins, polyacrylates and vinyl polymers and their copolymers. Module 4: Polymer dispersions and their industrial applications: Synthesis of polymer dispersions including emulsion polymerization, few exemplary industrial applications of polymer dispersions and coatings. Module 5: Few special applications of polymers – Liquid crystalline polymers, electroactive/conductive polymers, polymers in photoresist applications, polymer adhesives, applications of degradable polymers in packaging and biomedical applications.
Learning Outcome	1. Basic definitions, classifications and properties of polymers. 2. Details of step growth polymerization kinetics and synthesis and applications of industrially important condensation polymers. 3. Details of chain growth polymerization kinetics and synthesis and applications of industrially important addition polymers. Thermal and mechanical properties of polymers. 4. Polymer dispersion and their applications. Few advanced applications of polymers in the light of liquid crystalline polymers, conductive polymers etc.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. W. R. Ashcroft, Industrial Polymer Applications Essential Chemistry and Technology, Royal Society of Chemistry, 2017.
2. M. Chanda and S. K. Roy, Industrial Polymers, Specialty Polymers, and Their Applications, 1st Ed., CRC press, 2008.

3. Dieter Urban and Koichi Takamura, Polymer Dispersions and Their Industrial Applications, Wiley-VCH, 2002.

4. G. Odian, Principles of Polymerization, 4th Ed., Wiley-India, Reprint, 2012.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X		X		X	X		
CLO-2	X		X		X	X		
CLO-3	X		X		X	X		
CLO-4	X		X		X	X		
CLO-5	X		X		X	X		
CLO-6	X		X		X		X	

Course Number	CH7111/CH7211
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Art in Organic Synthesis
Learning Mode	Offline
Learning Objectives	To learn various organic reactions and reagents used in them as tools applied in the art of organic synthesis. To learn a retrosynthetic approach towards organic synthesis.
Course Description	This course will cover the concept of retrosynthesis and its applications in the fields of complex organic molecules.
Course Outline	Module 1: Retrosynthetic analysis: basics for retrosynthetic analysis, transforms and retrons, types of transforms, Biomimetic approach to retrosynthesis, Chemical degradation as a tool for retrosynthesis, Chiron approach, Protection/Deprotection strategies. Module 2: Transform-based strategies: transform-guided retrosynthetic search, Diels-Alder cycloaddition as a T-goal, retrosynthetic analysis by computer under T-goal guidance, enantioselective transforms as T-goals. Module 3: Structure and topological-based strategies: Structure-goal (S-goal) strategies, acyclic and cyclic ring-bond disconnections strategies, disconnection of fused-ring systems, disconnection of bridged-ring systems. Module 4: Stereochemical strategies: stereochemical simplification-transform stereoselectivity, stereochemical complexity-clearable stereocenters, stereochemical strategies-acyclic and polycyclic systems. Module 5: Functional group-based transformations: Disconnection using tactical sets of functional group-keyed transforms, strategies use of functional group equivalents, acyclic core group equivalents of cyclic functional groups, functional group and appendages as keys for connective transforms. Multistrategic retrosynthetic analysis of longifolene, parontherine, perhydrohistrionicotoxin, Gibberellic acid, Picrotoxinin. Module 5: A newer synthetic approach for complex organic molecules: Multicomponent reactions, cascade/tandem reactions, C-H activation/functionalizations and umpolung strategy.

Learning Outcome	At the end of the course, the students should be able to 1. use retrosynthetic method for the logical dissection of complex organic molecules and devise synthetic methods. Demonstrate an understanding of advanced retrosynthetic analysis including synthetic strategies and selectivity associated with synthesis. 2. use various reagents and organic reactions in a logical manner in organic synthesis. 3. comprehend the strategies involved in the protection and deprotection of functional groups in organic synthesis. 4. employ problem solving approach to describe various reactions, reagents and catalysts in organic synthesis.
Assessment Method	Class test, quiz and assignment (20%), Mid sem (30%), End sem examination(50%)

Suggested Readings:

Text Books:

1. K. C. Nicolaou, E. J. Sorensen, Classics in Total Synthesis: Targets, Strategies, Methods, 1st Edition, Wiley-VCH, 1996.
2. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, 1st Edition, Oxford University Press, 2001

Reference Books:

1. E. J. Corey, X.-M. Cheng, The Logic of Chemical Synthesis, John Wiley & Sons Ltd, 1989
2. M. B. Smith, Organic Synthesis, McGraw-Hill Inc., New York, 1994.
3. S. Warren, P. Wyatt, Organic Synthesis: The DiSc.onnection Approach, 2nd Edition, John Wiley & Sons Ltd, 2009.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X		X		X			
CLO-2	X				X			
CLO-3	X				X			
CLO-4	X		X		X			
CLO-5								

Course Number	CH7112/CH7212
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Spectroscopic Techniques in Chemistry
Learning Mode	Offline
Learning Objectives	The aim of this course is to enlighten students about the basic principles of various common spectroscopic techniques and their applications in different aspects, to understand molecular details of various molecules and materials.
Course Description	This course gives an overview of UV-Vis spectroscopy, Fluorescence spectroscopy, IR spectroscopy, Raman spectroscopy, NMR spectroscopy, Mass spectrometry and Mössbauer Spectroscopy.
Course Outline	Module - 1: Electronic Spectroscopy: Interaction of radiation with matters. Electronic states, Jablonski diagram, General principles, Electronic absorption by molecules, absorption peaks and molar absorptivity, absorption and intensity shifts. Selection rules and their implications, Instrumentations, analytical applications: qualitative and quantitative analyses. Electronic spectra of inorganic and organic compounds. Introduction to fluorescence, effects of solvents on fluorescence spectra, polarization of emission, measurements of fluorescence polarization. Time resolved fluorescence Spectroscopy. Time dependent decays of fluorescence anisotropy. Module 2: Infrared Spectroscopy: principles, factors influencing Vibrational frequencies, preparation of samples, the range of IR radiation, selection rules. Instrumentation: representation of spectra, dispersive and Fourier- transform IR- Spectroscopies. Application of IR Spectroscopy to inorganic and organic compounds. Raman Spectroscopy: principles, normal, resonance and laser Raman Spectroscopies. Structure determination by symmetry selection rules (normal coordinate analysis). Application of Raman Spectroscopy to structural chemistry; Module 3: Nuclear magnetic resonance Spectroscopy: General principles, sensitivity of the method, CW and FT-NMR, Instrumentation. Application in chemical analysis (with special reference to ^1H – NMR): Chemical shift, spin-spin splitting, hyperfine interaction, area of peak, shift reagents, off-resonance decoupling, Nuclear Overhauser Effect, solid state and gas phase NMR spectra. 2D NMR. Module 4: Mass spectrometry: Principles, advantages and limitations of Mass Spectrometry. Instrumentation, Methods of ionization, Metastable ions. Theory of Mass Spectrometry; Structure elucidation of inorganic and organic compounds, Module 5: Mössbauer Spectroscopy: The Mössbauer Effect, the

	Mössbauer nuclei, chemical isomer shift, quadrupole splitting, magnetic hyperfine interaction. Elucidation of electronic structure of ^{57}Fe , ^{119}Sn compounds using Mössbauer data, Mössbauer of biological systems.
Learning Outcome	At the end of this course the students will have understanding on 1. principles and applications of electronic spectroscopic techniques. 2. comparative understanding of IR and Raman spectroscopy and their applications. 3. principles and applications of NMR spectroscopy. 4. analysis and instrumentation details of Mass spectroscopy. 5. principles and few applications of Mossbauer spectroscopy.
Assessment Method	Class test & quiz(20%), Mid sem (30%), End Term examination(50%)

Suggested Readings:

Text book

1. B. P. Lever, Inorganic Electronic Spectroscopy, 2nd Edition, Elsevier, 1984
2. Willard, Merritt, Dean, & Settle, Instrumental Methods of Analysis, 7th Edition 1986
3. R. M. Silverstein, G. C. Bassler, C. Morrill, Spectrometric Identification of Organic Compounds, 5th edition, John Wiley & Sons, 1991
4. C. N. Banwell, Fundamentals of Molecular Spectroscopy, 4th Edition, Tata Magraw Hill, 1994
5. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, 3rd Edition, Thomson Brooks/Cole, 2000
6. J. R. Dyer, Application of absorption Spectroscopy of organic compounds, Prentice Hall of India Pvt. Ltd. 2004
7. J. R. Lakowicz, Principles of Fluorescence Spectroscopy, 3rd Edition 2006

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X		X		X	X		
CLO-2	X		X		X	X		
CLO-3	X		X		X	X		
CLO-4	X		X		X	X		
CLO-5	X		X		X	X		

Course Number	CH7113/CH7213
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Supramolecular Chemistry
Learning Mode	Offline
Learning Objectives	To introduce students, the relatively new but rapidly emerging topic of supramolecular chemistry. Students will be exposed to the various facets of supramolecular chemistry and will learn the important groups of compounds that are classified as supramolecules. After course completion, students will also know synthetic techniques to obtain a myriad of supramolecular structures, their characterization (using analytical tools) techniques as well as fascinating applications of such supramolecules.
Course Description	The course begins with an introduction and in-depth meaning of technical jargons used in supramolecular chemistry such as self-organization, self-assembly, preorganization, host-guest chemistry. Syntheses and characterizations of various types of supramolecules will be taught. Examples of exciting applications of supramolecules will be showcased from contemporary literature. Recent developments of supramolecular polymers will be introduced.
Course Outline	Module 1: Introduction to supramolecular chemistry (concepts and definitions), non-covalent forces and interactions in supramolecules Module 2: Syntheses of macrocycles and supramolecules (crown ethers, cryptates, cryptands, carcerands, calixarenes, cyclodextrins, fullerenes, dendrimers, rotaxanes, cucurbiturils, porphyrins) Module 3: Self-assembly and preorganization, self-assembly strategies for supramolecular metallacycles/metallacages and their applications in host-guest chemistry Module 4: Molecular devices, molecular machines and functional supramolecular structures, nano-scalar supramolecular reactors (small molecule activation and confinement assisted catalysts), metal-organic frameworks (MOFs) and their applications, therapeutic applications of supramolecular coordination constructs Module 5: Supramolecular polymers and their applications, Selected examples from recent literature related to developments in supramolecular chemistry.
Learning Outcome	Students will be able to: 1. identify supramolecular entities and the supramolecular interaction

	involved in them. 2. propose a synthetic route to new supramolecular frameworks. 3. propose analytical techniques to structurally characterize the supramolecular frameworks and analyze relevant experimental data. 4. design new supramolecules with practical applications such as their use as molecular hosts, molecular reactors, sensors, therapeutic agents and others. 5. to identify uses of supramolecular materials in practical applications related to environmental remediation.
Assessment Method	Class test & quiz (20%), Mid sem (30%), End Term examination (50%)

Suggested Readings:

Text books

1. J. W. Steed, J. L. Atwood, Supramolecular Chemistry, 3rd Edition, John Wiley & Sons Ltd. 2022.

Reference Books

1. J. W. Steed, D. R. Turner, K. Wallace, Core Concepts in Supramolecular Chemistry and Nanochemistry, 1st Edition, Wiley, 2007

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X							
CLO-2	X	X			X			
CLO-3	X		X					X
CLO-4	X					X		
CLO-5	X						X	

Course Number	CH7114/CH7214
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Reagents for Organic Synthesis
Learning Mode	Offline
Learning Objectives	To impart knowledge of oxidation and reduction, coupling reactions and potential role of different reagents in modern organic synthesis.
Course Description	This course illustrates the reactivity and sensitivity potential of different metallic and non-metallic-based reagents towards gamut of organic molecules. This course further provides a platform to learn fundamental aspects of reaction mechanisms associated with respective reagents.
Course Outline	Module 1: Uses of Magnesium, Lithium, Copper, Boron, Zinc, Phosphorous, Sulfur, Tin and Silicon-based reagents in organic synthesis. Module 2: Carbon-carbon bond formation through coupling reactions: Heck, Suzuki, Stille, Sonogoshira, Negishi, Kumada, Hiyama, Tsuji-Trost, olefin metathesis and McMurry. Module 3: Reagents developed from Titanium, Chromium, Iron, Rhodium, Nickel and Palladium. Lanthanides in Organic Synthesis: General properties and use of Lanthanide metal compounds in different oxidation states ((i) Cerium (ii) Samarium (iii) Ytterbium). Introduction to non-metal reagents: Module 4: Oxidizing reagents: Pyridinium Chlorochromate (PCC), Pyridinium Fluorochromate (PFC), Swern oxidation, DCC oxidation, Tetrapropyl ammonium peruthenate and other oxidizing agents. Reducing agents: Reductions involving NaBH₄, LiAlH₄, NaBH₃CN, DIBAL and Red-Al. Module 5: New approach using organo-catalyst/metal-catalyst/hydrogen atom transfer (HAT)/electron coupled proton transfer (ECPT).
Learning Outcome	1. Understand the reactivity pattern and underlying reaction mechanism of different oxidizing and reducing reagents. 2. Understand the judicious use of reagents in organic synthesis. 3. Acquire the knowledge of chemoselectivity in corroboration with regioselectivity and stereoselectivity. 4. Apply the knowledge in synthesizing organic molecules with highest order of complexity.
Assessment Method	Class test & quiz (20%), Mid sem (30%), End sem examination (50%)

Suggested Readings:

Text book:

1. T. Imamoto, Lanthanides in Organic Synthesis, Academic Press, 1994.
2. J. Tsuji, Transition Metal Reagents and Catalysts: Innovations in Organic Synthesis, John Wiley & Sons Ltd., 2000
3. W. Carruthers, I. Coldham, Modern Methods of Organic Synthesis, 4th Edition, Cambridge University Press, 2006
4. R. O. C Norman, J. M. Coxon, Principles of Organic Synthesis, 3rd Edition, CRC Press, 2009

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X				X			
CLO-2	X	X			X		X	
CLO-3	X		X		X			X
CLO-4	X		X		X		X	

Course Number	CH7115/CH7215
Course Credit	L-T-P-C: 3-0-2-4
Course Title	Introduction of Computational Chemistry
Learning Mode	Offline
Learning Objectives	After completion of this course successfully, the students will be able to understand the computational methods implemented in different computational and molecular dynamics packages. This course will provide them with practical implementation of quantum and statistical methods. This will demonstrate practical implementation of solving scientific problems in computational methods by the end of the course.
Course Description	The course introduces the advanced computational concepts, and methods in theoretical chemistry. The course further looks at implementation of quantum and statistical mechanics in standard computational packages.
Course Outline	Module 1: Molecular Mechanics / Force Field Methods: Introduction to molecular mechanics; comparison of popular force fields; performance of molecular mechanics, review of postulates of quantum chemistry, The Born-Oppenheimer approximation, potential energy surfaces, local and global minima, transition states, Module 2: Hartree-Fock molecular orbital theory: Slater determinants, antisymmetry principle, Hartree-Fock energy expressions for arbitrary spin-orbital configurations spin integration, restricted and unrestricted references, self-consistent- field (SC.F) procedure, Basis sets: Slater and Gaussian functions, contractions, polarization and diffuse functions, split-valence sets, correlation-consistent sets, core-valence sets, general contractions, basis set exchange, types of integrals, Gaussian product theorem, permutational symmetry of integrals, The Hartree-Fock algorithm, Semiempirical methods, Electron Correlation. Module 3: Vibrational frequency analysis: symmetry analysis, harmonic vs. fundamental frequencies, zero-point vibrational energies (ZPVE's), Hessian index, distinguishing minima from transition states. Intrinsic reaction coordinates (IRC) analysis, analytic gradient theory, Geometry optimization. Machine Learning Techniques Module 4: Electronic structure calculation: variational method and principle, atomic charges, dipole moment, polarizability, hyperpolarizability, Transition state theory, statistical mechanics, and thermodynamic properties, electron correlation, Configuration interaction, Many-body perturbation theory, Useful approximations: resolution of the identity (density fitting) and local correlation, Coupled-cluster theory, Density-functional theory, Non Dynamical correlation and

	multiconfigurational self-consistent- field (MCSC.F) theory, Comparison of the performance of electronic structure theories. Module 5: Numerical methods and computation. Module 6: Practical Component: Geometry Optimization and Frequency Calculation.
Learning Outcome	This course will enable students 1. to understand the basics of Molecular Dynamics. 2. to understand the basics of Ab initio methods. 3. to understand the implementation of different approximation methods. 4. to understand the applications of computational chemistry. 5. to understand the use of computational and molecular dynamics packages.
Assessment Method	Class test & quiz (20%), Mid sem (30%), End sem examination (50%)

Suggested Readings:

Text Books:

1. A. Szabo and N. S. Ostlund, Modern Quantum Chemistry, Introduction to Advanced Electronic Structure Theory, 1st Edition, revised, Dover, 1989.
2. F. Jensen, Introduction to Computational Chemistry, 2nd Edition, Wiley, New York, 2006.

Reference Books:

1. D. A. McQuarrie, Quantum Chemistry, University Science Books, Mill Valley, CA, 1983.
2. P.W. Atkins and R.S. Friedman, Molecular Quantum Mechanics, 5th Edition, Oxford University Press, 2010.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X	X						
CLO-2	X	X						
CLO-3			X		X			
CLO-4			X		X	X		
CLO-5					X			X

Course Number	CH7116/CH7216
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Application of Glycochemistry in Modern Technology Glycochemistry and its applications
Learning Mode	Offline
Learning Objectives	Aim of this course is to provide the advance knowledge of carbohydrate chemistry and their role and importance in survival of human life, renewable source of energy and key synthetic precursors.
Course Description	The course describes various basic and advanced concept of carbohydrate chemistry, analytical techniques to interpret the oligosaccharides. Application of carbohydrates to pharmaceutical industry, biomedical research.
Course Outline	Module 1: Structure, reactivity and reactions: monosaccharides, disaccharides, oligosaccharides and polysaccharides, anomeric effect, reaction of hydroxyl group, protection/deprotection/orthogonal protection strategies classical and modern techniques for glycosylation reactions.. Module 2: Biosynthesis and their function: Key enzymes involved in biosynthesis of glycoproteins, glycolipids and glycopeptides and biodegradation of carbohydrates and altering the glycosylations. Module 3: Glycotechnology: Mechanistic aspects, interaction of carbohydrates with other biomolecules, and glycoengineering. carbohydrate based drug design: modified sugars as antibiotics, anti-inflammatory, natural products in medicinal chemistry (Nojirimycin, swainsonine, heparin), sugar in the food and paper industries and renewable source for bio-fuels production (from carbohydrates to hydrocarbons).
Learning Outcome	Students will be able to 1. identify various classes of carbohydrates and their building blocks. 2. understand the role of carbohydrates in a biological system. 3. understand the role of carbohydrates and their derivatives in the pharmaceutical industry. 4. apply the advanced knowledge of glycochemistry in an existing and emerging problem in basic science along with their application in the synthesis of drug molecules/ immunology.
Assessment Method	Class test & quiz (20%), Mid sem (30%), End sem examination (50%)

Suggested Readings:

Text Books:

1. P.Collins R.Ferrier, Monosaccharides, Their Chemistry and Their Roles in Natural Products, Wiley, 1995.
2. G.-J. Boons, Carbohydrate Chemistry, Blackie Academic & Professional, 1997.
3. Peng George Wang and Carolyn R. Bertozzi, Glycochemistry: Principles: Synthesis, and Applications, CRC Press, 2001.

Reference Books:

1. Zhongwu Guo and Geert-Jan Boons, Carbohydrate-Based Vaccines and Immunotherapies (Wiley Series in Drug Discovery and Development), 2009.
2. Ryouichi Ito and Youta Matsuo, Handbook of Carbohydrate Polymers: Development, Properties and Applications, Nova Science Pub Inc., 2010.
3. Ravin Narain, Engineered Carbohydrate-Based Materials for Biomedical Applications: Polymers, Surfaces, Dendrimers, Nanoparticles, and Hydrogels, Wiley, 2011.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X							
CLO-2	X		X		X			
CLO-3	X		X				X	X
CLO-4			X		X	X	X	X