

Revised Course / Curriculum / Syllabus in compliance of NEP-2020 (M. Sc.)

M. Sc. in 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 Physical, Inorganic, and Organic chemistry, etc.
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, polymer chemistry, solid-state chemistry, material design, ab-initio calculation, semi-empirical methods, molecular dynamics simulation, and analytical equation solving approach, determining reaction kinetics etc. Program Learning Outcome 2b: Students will learn to run different advanced instruments, to write research articles for publication, and to work collaboratively with 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.
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Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	CH4101	Quantum Chemistry	3	1	0	4
2.	CH4102	Organic Chemistry-I	3	1	0	4
3.	CH4103	Inorganic Chemistry-I	3	1	0	4
4.	CH4104	Principles of Molecular Spectroscopy	3	0	0	3
5.	CH4105	Symmetry & Group Theory	3	0	0	3
6.	CH4106	Organic Chemistry Lab	0	0	6	3
7.	HS4111	Soft Skills for Employability	1	2	0	3
		TOTAL	16	5	6	24

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CH4201	Thermodynamics	3	1	0	4
2.	CH4202	Organic Chemistry-II	3	0	0	3
3.	CH4203	Inorganic Chemistry-II	3	0	0	3
4.	CH4204	Chemical Kinetics	3	0	0	3
5.	CH4205	Modern Methods of Analysis	3	1	0	4
6.	CH4206	Inorganic Chemistry Lab	0	0	6	3
		TOTAL	15	2	6	20

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	CH5101	Physical Chemistry Lab	0	0	6	3
2.	CH5102	Inorganic Chemistry-III	3	0	0	3
3.	CH5103	Organic Chemistry-III	3	0	0	3
4.	CH5199	Project-I	0	0	12	6
5.	CH51XX/ CH61XX	Department Elective-I	3	0	0	3
6.	XX61PQ	IDE-I	3	0	0	3
		TOTAL	12	0	18	21

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	CH6201	Computer Programming for Chemists	2	0	2	3
2.	CH5299	Project-II	0	0	16	8
3.	CH62XX	Department Elective - II	3	0	0	3
4.	XX62PQ	IDE-II	3	0	0	3
5.	IK5201	Indian Knowledge System	2	0	0	2
		TOTAL	10	0	18	19

Total Credits = 84

Elective Groups

Sl. No.	Course Code	Department Elective - I	L	T	P	C
1.	CH5104	Biochemistry	3	0	0	3
2.	CH5105	Basic Polymer Chemistry	3	0	0	3
3.	CH5106	Consumer Chemistry	3	0	0	3
4.	CH5107	Non-Equilibrium Statistical Mechanics	3	0	0	3

Sl. No.	Course Code	Department Elective - II	L	T	P	C
1.	CH6202	Solid State Chemistry	3	0	0	3
2.	CH6203	Nanotechnology for Biomedical Applications	3	0	0	3
3.	CH6204	Bioanalytical Techniques	3	0	0	3
4.	CH6205	Advanced Medicinal Chemistry	3	0	0	3
5.	CH6206	Organic and Organometallic Catalysis	3	0	0	3
6.	CH6207	Advanced Optical Spectroscopy	3	0	0	3
7.	CH6208	Chemistry of Heterocycles	3	0	0	3
8.	CH6209	Syntheses and Applications of Industrial Polymers	3	0	0	3

*An upgraded version of M. Sc. 5/6 level electives need to be essentially upgraded for PhD students with additional contents comprising additional lectures / assignments / tutorials / miniproject making the total credit : 3-1-0-4 / 3-0-2-4. Such course proposals with an advanced level (6/7 level course number) are listed separately for PhD students.

IDE for M. Sc. students (Other than Dept. of Chemistry)

Sl. No.	Course Code	Department Elective - II	L	T	P	C
1.	CH6101	Sustainable Chemistry	3	0	0	3
2.	CH6210	Chemistry and Applications of Nanostructured Materials	3	0	0	3

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	CH4101	Quantum Chemistry	3	1	0	4
2.	CH4102	Organic Chemistry-I	3	1	0	4
3.	CH4103	Inorganic Chemistry-I	3	1	0	4
4.	CH4104	Principles of Molecular Spectroscopy	3	0	0	3
5.	CH4105	Symmetry & Group Theory	3	0	0	3
6.	CH4106	Organic Chemistry Lab	0	0	6	3
7.	HS4111	Soft Skills for Employability	1	2	0	3
		TOTAL	16	5	6	24

Course Number	CH4101
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Quantum Chemistry
Learning Mode	Offline
Learning Objectives	The objective of the course is to understand the postulates of quantum mechanics and apply them to obtain the physical attributes of the model systems like a particle in an infinite potential well, harmonic oscillator, particle on a ring, particle on a sphere and rigid rotor. In addition, the course aims to apply quantum mechanics to solve real systems like a hydrogen atom, ground and excited states of a He atom, and molecules like H_2^+ and H_2 . Further, this course uses semi-empirical methods like Hückel molecular orbital theory to solve for pi molecular orbitals of conjugated polyenes like benzene, 1,3-Butadiene, etc.
Course Description	This course lays down a strong foundation in quantum mechanics and its application in chemistry.
Course Outline	Module 1: Basic Principles of Quantum Mechanics: Postulates, wave functions and probabilities, Uncertainty principle, matrix representation of operator in a given basis set, solution of matrix eigenvalue-eigenvector relationship, commutation relationships, coordinate and momentum space representation of operators, Hermitian operators, commutators and results of measurements in Quantum Mechanics. Eigenfunctions and eigenvalues of operators and superposition principle. Properties of eigenstates – single-valuedness, double differentiability, continuity, boundedness / square integrability. States as probability distributions and expectation values. The expansion of arbitrary states in terms of complete sets. The time dependent Schrödinger equation. Module 2: Solution of the Schrödinger equation for exactly solvable problems: Particle-in-a-box, particle-in-a-ring, harmonic oscillator and rigid rotor. Tunneling, one dimensional potential barriers and wells. Module 3: Angular momentum: Commutation relationships, commutation between Hamiltonian and permutation operator, basis functions and representation of angular momentum operators, coupling (addition) of angular momenta, Clebsch-Gordan coefficients. Introduction of quantum statistics, Pauli antisymmetry principle. Module 4: Hydrogen atom: Solution of the Schrödinger equation for the hydrogen atom, radial and angular probability distributions, atomic orbitals and electron spin. Module 5: Approximation methods: Time-independent perturbation theory, degenerate states, variational method. Comparison between variation and perturbation methods, for example, anharmonic oscillator and helium atom. Module 6: Multi-electron atom: Spectra and structure of helium atom, term symbols for atoms. Pauli's exclusion principle and Aufbau principle. RS/jj coupling & Zeeman effect. Module 7: Molecular structure and chemical bonding: Born-Oppenheimer approximation, elementary concepts of molecular orbital

	(MO) and valence bond (VB) theories, and their application to di-atomic molecules. Hückel theory for conjugated π -electron systems. Aromaticity, drawbacks of MO and VB theories, remedy (electron correlation for MOT, ion-covalent resonance for VBT), Hartree Fock theory, and electron correlation.
Learning Outcome	After successful completion of the course, students will be able 1. To understand the origin and postulates of quantum mechanics. 2. To solve for model systems' energies and wave functions (particle in a box, harmonic oscillator, etc.). 3. To add angular momentum in coupled and uncoupled representations. 4. To find the energies and eigenfunctions of a hydrogen atom. 5. To apply the approximation methods (variation and perturbation) on model systems. 6. To solve for the energies and wave functions of the He atom (both ground and excited states) using approximation methods. 7. To find the energies and molecular orbitals of a few simple molecules using molecular orbital theory, valence bond theory and Hückel molecular orbital theory.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

Text Books:

1. P. W. Atkins, Molecular Quantum Mechanics, 5th Edition, Oxford University Press, 2010.
2. I. N. Levine, Quantum Chemistry, 7th Edition, Pearson Education India, 2014.

Reference Books:

1. J. P. Lowe, Quantum Chemistry, K. A. Peterson, 3rd Edition, Academic Press, 2006.

	PLO-1a	PLO-1b	PLO-2a	PLO-2b	PLO-3	PLO-4	PLO-5a	PLO-5b
CLO-1	X							
CLO-2	X							
CLO-3	X							
CLO-4	X							
CLO-5	X							
CLO-6	X				X			
CLO-7	X		X		X			

Course Number	CH4102
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Organic Chemistry-I
Learning Mode	Offline
Learning Objectives	This course aims at acquainting students with the concept of acid, base, aromaticity, stereochemistry as well as reactive intermediates. Learn the concept of asymmetric synthesis and employ such reactions in asymmetric organic synthesis of important chiral molecules.
Course Description	In this course, students will learn about concepts of acid, base, aromaticity, reaction intermediates, methods for determining the reaction mechanisms, stereochemistry as well as asymmetric synthesis.
Course Outline	Module 1: Introduction of acid base concepts, pH and Brönsted relationship, HSAB theory, aromaticity and antiaromaticity, y-aromaticity, homo-aromaticity, annulenes, heteroannulenes and fullerenes. Module 2: Reactive intermediates: carbocations, carbanions, radicals, carbenes, benzyne and nitrenes. Electrophiles and nucleophiles: Reactivity, stability, and mechanisms. Energy surfaces and transition states: Hammond Postulate, Isotope effects and Hammett plot. Steric and electronic effects of solvents. Module 3: Stereochemistry: Newman, Fischer and Sawhorse projection, erythro/threo, syn/anti configurations, meso configuration. Conformational and configurational isomers, analysis of cycloalkanes, the effect of conformation on reactivity. Symmetry elements, chiral molecules with one stereogenic center: optical activity, sequence rules, absolute configuration, enantiomeric excess. Molecules with two (or more) stereogenic centers: diastereomers, stereochemistry of fused, bridged, and caged ring systems, resolution of enantiomers. Module 4: Chirality without stereogenic center: allenes, biphenyls, adamantoids, catenanes, spiranes, alkylidene cycloalkane/hemispiranes, transcycloalkene, metallocenes, cyclophanes, helicenes, atropisomerism. Prochirality, enantiotopic and diastereotopic constitutionally heterotopic atoms, groups and faces. Stereospecific and stereoselective reactions. Introduction to asymmetric synthesis.
Learning Outcome	On successful completion of this course, students will learn 1. The concept of acidity, basicity and aromaticity and their application in organic chemistry. 2. Preparation, stability and analysis of the role of reactive intermediates such as carbocations, carbanions, nonclassical carbocations, free radicals, benzyne as well and nitrenes in the chemical reactions. 3. Demonstrate chirality in organic molecules using units such as center, axial, planar and helicity. Predict E/Z and R/S configuration in organic molecules by applying concepts of stereochemistry. 4. The concept of asymmetric synthesis and its applications.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested readings:**Text Books:**

1. M. B. Smith, March's Advanced Organic Chemistry 8th Edition, Wiley, 2020.
2. E. L. Eliel and S. H. Wilen, Stereochemistry of Organic Compounds, John Wiley & Sons, New York, 2008.
3. D. Nasipuri, Stereochemistry of Organic Compounds. Principles and Applications, 4th Edition, New Age International Private Limited, 2020.
4. T. H. Lowry and K. S. Richardson, Mechanism and Theory in Organic Chemistry, 3rd Edition Harper & Row, New York, 1997.

Reference Books:

1. D. G. Morris, Stereochemistry, RSC Tutorial Chemistry Text 1, 2001.
2. F. A. Carey and R. A. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, 5th Edition, Springer, New York, 2007.
3. F. A. Carey and R. A. Sundberg, Advanced Organic Chemistry: Part B: Reaction and Synthesis 5th Edition, Springer, New York, 2007.
4. S. S. Gupta, Basic Stereochemistry of Organic molecules, 2nd Edition, Oxford University Press, 2018.
5. P. Y. Bruice, Organic Chemistry, 8th Edition, Pearson, 2020

	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					X	
CLO-4	X	X				X		
CLO-5	X							

Course Number	CH4103
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Inorganic Chemistry-I
Learning Mode	Offline
Learning Objectives	The course aims to learn the aqueous, non-aqueous, and organometallic chemistry of s- and p-block elements and to understand their industrial importance.
Course Description	This course introduces the chemistry of s and p- block elements along with its industrial importance.
Course Outline	Module 1: s-block elements: aqueous solution chemistry including macrocyclic complexes, non-aqueous coordination chemistry and non-aqueous solvents and their organometallic compounds. Module 2: p-block elements: halides, oxides, oxo acids and oxo anions, boranes, carboranes and other metal clusters, metallocarboranes, nitrides, phosphides, and arsenides, phosphazenes, sulfides and selenides, Interhalogen compounds and polyhalogen ions, compounds of xenon, krypton and radon. Organometallic compounds of p-block elements. Module 3: Industrial importance of s- and p-block compounds.
Learning Outcome	At the end of this course, the students will be able 1. To learn the aqueous and non-aqueous chemistry of s-block elements. 2. To understand the application of organometallic compounds of s-block elements. 3. To learn the chemistry of different oxides, halides, nitrides, phosphides, sulfides and selenides of p- p-block elements. 4. To learn the chemistry of interhalogen, polyhalogens and noble gas compounds. 5. To learn the industrial importance of s and p-block elements.
Assessment Method	Class test, assignment & quiz (20%), Mid Semester examination (30%), End Semester examination (50%)

Suggested readings:

Text Books:

1. J. D. Lee, Concise Inorganic Chemistry, 5th Edition, Oxford University Press, 2008.
2. C. Housecroft and Alan G. Sharpe, 5th Edition, Inorganic Chemistry, Pearson, 2018.

Reference Books:

1. F. A. Cotton, G. Wilkinson, C. A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, An Indian Adaptation, Wiley, 2021.
2. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, Elsevier (Butterworth-Heinemann); 2nd Edition, 1997 (Reprint 2005).

	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							
CLO-5	X				X			

Course Number	CH4104
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Principles of Molecular Spectroscopy
Learning Mode	Offline
Learning Objectives	The objectives of this course are on successful completion of the course, students will be able to explain the different phenomenon that takes place due to the interaction of light with matter. Students will get basic knowledge about different spectroscopic techniques such as rotational, vibrational, Raman, electronic, nuclear magnetic resonance, and Mössbauer. Fundamental theories behind these techniques, selection rules, and factors affecting the spectra will be covered in this course.
Course Description	This course introduces different phenomena that take place due to the interaction of light with matter, fundamental theories, selection rules, and factors that control spectral line width and line shape. This course describes the fundamental theories for different spectroscopic techniques such as rotational, vibrational, Raman, electronic, nuclear magnetic resonance, and Mössbauer spectroscopy.
Course Outline	Module 1: Introduction: Interaction of radiation with matter, Einstein coefficients, transition probability, transition dipole moments and selection rules, factors that control spectral line width and line shape. Beer-Lambert law. Module 2: Rotational spectroscopy: The rigid diatomic rotor, selection rules, intensity of rotational transitions, rotational level degeneracy, and the role of nuclear spin in determining allowed rotational energy levels. Classification of polyatomic rotors and the non-rigid rotor. Module 3: Vibrational spectroscopy: Harmonic and anharmonic oscillators, Morse potential, mechanical and electrical anharmonicity, selection rules. The determination of anharmonicity constant and equilibrium vibrational frequency from fundamental and overtones. Normal modes of vibration, G and F matrices, internal and symmetry coordinates. Fermi resonance, rotation-vibration coupling. Module 4: Electronic spectroscopy: Franck-Condon principle, vertical transitions, selection rules, parity, symmetry and spin selection rules. Polarization of transitions, fluorescence and phosphorescence. factor affecting the emission spectra of molecules. Vibronic coupling, Jahn-Teller effect, and conical intersection, non-adiabatic transitions, predissociation, hot-atom Chemistry. Module 5: Raman spectroscopy: Polarizability and selection rules for rotation and vibrational Raman spectra. Module 6: Nuclear magnetic resonance spectroscopy: Introduction, general principles, chemical shift, spin-spin splitting, area of peak, shift reagents. Hyperfine interaction. Module 7: Mössbauer spectroscopy: Principle, chemical shift, quadrupole effects, the effect of magnetic field
Learning Outcome	1. Description of factors involved in the spectroscopic transition, such as transition probability, selection rules, spectral line width, line shape, etc.

	2. Description of spectroscopy in the microwave region, rotational spectra of rigid diatomic molecules, selection rules, and non-rigid rotor. 3. Study of vibrating diatomic molecule, energy levels of a diatomic molecule, simple harmonic and anharmonic oscillator, selection rule. 4. Understand the concepts of Raman spectroscopy, the concept of polarizability, and rotational and vibrational Raman Spectra. 5. Understand the concepts of electronic spectroscopy. 6. Understand the concepts of nuclear magnetic resonance spectroscopy. 7. Understand the principles of Mössbauer spectroscopy.
Assessment Method	Class test, assignment & quiz (20%), Mid Semester examination (30%), End Semester examination (50%)

Suggested readings:

Text Books:

1. P. W. Atkins, Molecular Quantum Mechanics, 5th Edition, Oxford University Press, 2012.
2. P. F. Bernath, Spectra of Atoms and Molecules, 4th Edition, Oxford University Press, 2020.
3. E. B. Wilson, Jr., J. C. Decius and P. C. Cross, Molecular Vibrations: The Theory of Infrared and Raman Spectra, Dover Publications, 2003.
4. C. N. Banwell, Fundamentals of Molecular Spectroscopy, 4th Edition, McGraw Hill Education, 2017.

	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
CLO-4	X				X	X		X
CLO-5	X				X			X
CLO-6	X	X			X	X		X
CLO-7	X	X			X			

Course Number	CH4105
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Symmetry and Group Theory
Learning Mode	Offline
Learning Objectives	The student should be able to: Recognize symmetry elements in a molecule; State the point group a molecule belongs to; Understand degenerate and non-degenerate representations; Combine matrices and set up matrices for transformations; Apply this to polyatomic systems (e.g. square planar, octahedral) to find symmetry species of normal modes of vibrations; deduce which modes are IR/Raman active. Students will learn how to predict orbitals involved in hybridization, σ , π bonding etc, based on the symmetry of the molecules.
Course Description	This course introduces the concept of group, different symmetry elements in a molecule, and the application of group theory to predict different molecular properties, vibrational transitions, and orbitals involved in hybridization, σ , π bonding etc, based on the symmetry of the molecules
Course Outline	Module 1: The concept of groups, symmetry operations and symmetry elements in molecules, matrix representations of symmetry operations, point groups, and stereographic projection. Module 2: Irreducible representations and construction of character tables. Great orthogonality theorem. Module 3: Application of group theory: molecular orbitals, hybridization. vibrational and Raman spectroscopy, classification of normal vibrational modes, and selection rules in vibrational and electronic spectroscopy. Commutator between Hamiltonian and symmetry operators. Simultaneous eigenfunctions, symmetry adapted linear combination, symmetry, and Fermi resonance. Conservation of orbital symmetry and pericyclic reactions.
Learning Outcome	Students will be able 1. Categorize molecules based on their symmetry properties, which allows them to predict many molecular properties. 2. to guess the molecular properties by applying group theoretical methods. 3. to determine which vibrational transitions are allowed or forbidden based on symmetry. What is Transition probability? 4. to predict orbitals involved in hybridization, σ , π bonding, etc, based on the symmetry of the molecules.
Assessment Method	Class test, assignment & quiz (20%), Mid Semester examination (30%), End Semester examination (50%)

Suggested Readings:

1. F. A. Cotton, Chemical Applications of Group Theory, 3rd Edition, Wiley, 2008
2. D. M. Bishop, Group theory and Chemistry, Dover Publications, 1993.
3. R. L. Carter, Molecular Symmetry and Group Theory, Wiley, 2005.
4. A. Vincent, Molecular Symmetry and Group Theory, 2nd Edition, Wiley, 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	X		X		X	
CLO-3	X	X			X		X	
CLO-4	X	X			X			X

Course Number	CH4106
Course Credit	L-T-P-C: 0-0-6-3
Course Title	Organic Chemistry Lab
Learning Mode	Offline
Learning Objectives	This course aims to provide the detailed experimental knowledge and demonstrate the application/importance of organic experiments for various organic transformation/product formation, isolation, characterization with their elaborated reaction mechanism. Students will learn different instrumental techniques to analyze the complex organic molecules structure, stereochemistry, etc.
Course Description	This course contains experiments based on the concept of Organic Chemistry. Students will do experiments based on synthetic analysis, functional group transformation, and computational methods in Physical Chemistry.
Course Outline	Separation of two-component mixtures of organic compounds. Synthesis and isolation of organic compounds with an emphasis on different techniques of reaction set-up (air-sensitive, moisture-sensitive etc.), separation/purification (extraction, Soxhlet extraction, recrystallization, distillation, column chromatography) and monitoring of reaction by TLC. Structure determination of the isolated pure compounds by NMR spectroscopy, IR Spectroscopy and Mass spectrometry.
Learning Outcome	1. Apply organic chemistry concepts by doing experiments and purifying impure organic compounds by recrystallization or sublimation/column chromatography. 2. Development of skills to solve them by doing experimental organic chemistry. Verify the purity of organic compounds/identify the number of organic compounds in a mixture employing thin-layer chromatography 3. Demonstrate procedures and methods applied in organic Chemistry 4. To learn different instrumental techniques, and to explain and analyze the core structure. 5. Ability to solve independently the concepts of organic chemistry
Assessment Method	Viva (20%), Lab experiment (40%), End Semester examination (40%)

Suggested readings:

1. A. I. Vogel, A. R. Tatchell, B. S. Furnis, Vogel's Text Book of Practical Organic Chemistry, 5th Edition, Pearson, 2003.
2. J. R. Mohrig, D. G. Alberg, G. E. Hofmeister, P. F. Schatz, C. N. Hammond, Laboratory Techniques in Organic Chemistry. 4th Edition, W. H. Freeman and Company, 2014.
3. J. J. Li, C. Limberakis, D. A. Pflum, Modern Organic Synthesis in the Laboratory, Oxford University Press, 2007.
4. A. Ault, Techniques and Experiments for Organic Chemistry, 6th Edition, University Science Book, 1998.
5. J. Leonard, B. Lygo and G. Procter, Advanced Practical Organic Chemistry, 3rd Edition, CRC Press, 2013.

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

Course Code	HS4111
Course Credit	L-T-P-C: 1-2-0-3
Course Title	Soft Skills for Professional Development
Learning Mode	Lectures and Tutorials
Learning Objectives	Soft Skills. These are the traits, characteristics, habits, and skills needed to survive and thrive in the modern work world. This soft skills course will teach you how to develop the skills that can make the difference between a lackluster career that tops out at middle management versus one that lands you in the executive suite or wherever you define career success. This course aims to help the students (a) gain a comprehensive understanding of communication skills for work place interaction; (b) attain proficiency in written and oral language; (c) develop team work skills; (d) foster decision making; (e) strengthen analytical and thinking skills; (f) develop leadership skills; (g) acquire techniques for time management, problem solving and emotional intelligence.
Course Description	This academic course on soft skills aims to equip students with skills necessary for the professional world. By focusing on essential principles and providing practical experiences, students develop their soft skills. Through interactive discussions and exercises, students enhance critical thinking and adaptability in diverse contexts. Upon completion, students will excel in formal presentations, group discussions, and persuasive writing, enhancing their verbal and non-verbal proficiency.
Course Outline	Section A: Theoretical Component Unit 1: Communication skills Barriers to communication – Verbal communication (oral and written) – Non-Verbal Communication – interpersonal communication – email etiquette – power to listen – ethical considerations in communication – intercultural communication – comprehension – creative and critical writing (included in section B-below) Unit 2: Team Building Conflict resolution – Mediation – Accountability – Collaboration – Empathy - building rapport – cultural awareness – Dealing with people - group and teams, group formation, group decision making, types of teams and the models of team effectiveness – Negotiation techniques Unit 3: Leadership Leader vs Managers – Core values of leadership - leadership styles – Theories of Leadership – Leadership models - Vision and its articulation and implementation – goal setting and performance management – Ethical leadership – Power -power bases -power tactics Unit 4: Personality Development and Stress Management Theories of Personality development (Freud, Jung, Eysenck, Carl Rogers and Maslow), Personality frameworks such as MBTI, Big Five and personality assessment - Reasons and Remedies of Stress. Unit 5: Thinking

	Critical Thinking - Reasoning: Deductive and Inductive – Analytical skills – brainstorming – strategic thinking – creative thinking – Lateral Thinking – EQ and IQ Unit 6: Problem Solving What is a problem? Identifying a problem – data collection methods and tools – 5 Whys – drill down technique – case and effect diagram Prioritizing problem – pareto’s principle Generating solutions – making decisions - Implementing solutions Evaluating solutions Unit 7: Time Management What is Time Management? Time Management Strategies Stumbling Blocks in Time Management Task Prioritization and Delegation Technology and Time Management Section B: Tutorial Component Unit I: Group Discussion Unit II: Oral presentation Unit III: Designing and Using PPTs – solo and group presentation Unit IV: Critical writing practise Unit V: Analytical writing practise
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Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	CH4201	Thermodynamics	3	1	0	4
2.	CH4202	Organic Chemistry-II	3	0	0	3
3.	CH4203	Inorganic Chemistry-II	3	0	0	3
4.	CH4204	Chemical Kinetics	3	0	0	3
5.	CH4205	Modern Methods of Analysis	3	1	0	4
6.	CH4206	Inorganic Chemistry Lab	0	0	6	3
		TOTAL	15	2	6	20

Course Number	CH4201
Course Credit	L-T-P-C: 3-1-0-4
Course Title	Thermodynamics
Learning Mode	Offline
Learning Objectives	An in-depth study of classical and statistical thermodynamics and apply it to existing and emerging problems in basic science.
Course Description	This course demonstrates the physical and statistical basis of thermodynamics relevant for chemists.
Course Outline	Module 1: Classical Thermodynamics: Review of the laws of thermodynamics, reversible and irreversible processes, Carnot Cycle, concept of entropy, 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. Module 2: Thermodynamics of ideal and non-ideal solutions: Liquid-liquid solutions, liquid-solid solutions, multicomponent systems and excess thermodynamic properties, activity of ideal, regular and ionic solutions. Thermodynamic equation of state. Phase behaviour of one and two-component systems, Ehrenfest classification of phase transitions. Electrochemical equilibrium Module 3: Statistical thermodynamics: Maxwell-Boltzmann statistics for non-interacting systems, Concept of ensembles: Concept of ensembles, partition functions and distributions, microcanonical, canonical and grand canonical ensembles, canonical and grand canonical partition functions, Boltzmann, Fermi-Dirac and Bose-Einstein distributions. Module 4: Ideal gases: Canonical partition function in terms of molecular partition function of non-interacting particles, translational, rotational and vibrational partition functions. Absolute thermodynamic quantities for ideal monoatomic and diatomic gases, the heat capacity of an ideal gas of linear and nonlinear molecules, and chemical equilibrium. Coupling between rotation and nuclear spin statistics Module 5: Real gasses and weakly interacting liquids: Canonical partition function for interacting particles, intermolecular potential (Lennard-Jones, hard-sphere and square-well) and virial coefficients. Temperature dependence of the second virial coefficient. Distribution function of liquids. Introduction to molecular dynamics and Monte Carlo simulations. Module 6: Solids: Thermodynamics of solids – Einstein and Debye models. Metals: Fermi function, Fermi energy, free electron model and density of states, chemical potential of conduction electrons.
Learning Outcome	1. Understand the fundamentals of classical and statistical thermodynamics 2. Develop problem-solving ability in classical and statistical thermodynamics 3. Understand and develop tools of statistical mechanics for systems under different conditions

	4. Apply the fundamental knowledge in classical and statistical thermodynamics to an existing and emerging problem in basic science and problems related to some global challenges. 5. Apply tools and methods of equilibrium statistical mechanics to understand and analyze various thermodynamic properties.
Assessment Method	Class test, assignment & quiz (20%), Mid Semester examination (30%), End Semester examination (50%)

Suggested readings:

1. Atkins' Physical Chemistry, Peter Atkins, Julio de Paula, James Keeler, 12th Edition, Oxford University Press, 2022.
2. D. A. McQuarrie, Statistical Mechanics, Viva Books Private Limited, 2008.
3. M. Tuckerman, Statistical Mechanics: Theory and Molecular Simulation, Oxford Publishers, 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	X
CLO-5		X	X		X	X		X

Course Number	CH4202
Course Credit	L-T-P-W: 3-0-0-3
Course Title	Organic Chemistry-II
Learning Mode	Offline
Learning Objectives	This course aims to provide a detailed concept and demonstrate the importance of organic reagents for various organic transformation reactions with their elaborated reaction mechanism.
Course Description	This course elaborates on the utility of various organic reagents for functional group transformation strategies, cross-coupling reactions, C-H bond functionalization, asymmetric synthesis and its application in pharmaceutical industries.
Course Outline	Module 1: C-C Bond Formation: a) via carbanion chemistry (carbonyl group, esters, -NO₂, -SO₂Ph, -CN, etc.) b) via Boron and Silcone enolates c) via imines chemistry d) Michael additions. e) via allyl boron, allyl tin, allyl and vinyl silanes. f) Metal-catalyzed cyclopropanation reactions (including Simmons Smith reaction). g) Fischer carbenes, Schrock carbenes, Olefin metathesis: various types of metathesis and application to organic synthesis. Dotz Benzoannulation. h) Cross-coupling strategies (Heck, Suzuki, Stille, Negishi, Kumada, Hiyama, Sonogashira). i) C-H bond activation strategies. j) via organocatalyst with specific examples. Module 2: Oxidation: Oxidation involving organosulfur and organoselenium compounds (selected examples); Dess-Martin, IBX and related hypervalent iodine based oxidations, Ag₂CO₃/celite Prevost, photosensitised oxidation, RuO₄, 2-sulfonyl oxaziridine, transition metal catalysed oxidation, and Fleming-Tamao oxidation. Module 3: Reduction: Using silanes, Aluminium and Boron based reagents (e.g. DIBAL, L-selectride, K-selectride, Red-Al etc.), low valent Ti species. Module 4: Asymmetric Synthesis: Concise introduction to asymmetric synthesis, Sharpless epoxidation and dihydroxylation, Jacobsen's epoxidation, Corey's oxazaborolidine catalyzed reduction, Noyori's BINAP reduction, SAMP, RAMP, Evans oxazoline and Oppolzer sultams, Aldol reaction (in brief: only principles using models).
Learning Outcome	At the end of the course, the students will be able to 1. understand the fundamentals of organic chemistry, organic reagents for synthetic transformation. 2. understand the oxidation, reduction, cross-coupling reaction of organic chemistry 3. develop problem-solving ability in organic chemistry 4. understand and develop synthetic tools for the synthesis of various important and blockbuster drugs 5. apply the fundamental knowledge in an existing and emerging problem in basic science along with their application in several industries.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested Readings:

Text Books:

1. W. Carruthers, I. Coldham, Some Modern Methods of Organic Synthesis, 4th Edition, Cambridge University Press 2008.
2. Michael B. Smith, Organic Synthesis, 4th Edition, Academic Press, 2016.
3. Carreira, E. M.; Kvaerno, Classics in Stereoselective Synthesis, Wiley -VCH, 2009.

Reference Books:

1. Ji-Jack Li, C-H Bond Activation in Organic Synthesis, CRC Press, 2015.
2. M. B. Smith, March's Advanced Organic Chemistry 8th Edition, Wiley, 2020.
3. M. C. Kozlowski and P. J. Walsh, Fundamentals of Asymmetric Catalysis, University Science Books, U.S., 2009.
4. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Edition, Oxford University Press India, 2023.

	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			
CLO-3	X		X	X	X		X	X
CLO-4				X	X		X	X
CLO-5				X	X		X	X

Course Number	CH4203
Course Credit	L-T-P-W: 3-0-0-3
Course Title	Inorganic Chemistry-II
Learning Mode	Offline
Learning Objectives	The aim of the Course is to enable students to understand the basics of coordination chemistry and bonding in complexes. This course will help to build the foundation for understanding inorganic complexes in general, which will be helpful for any detailed study or future research in inorganic chemistry.
Course Description	This course elaborates on various theories to understand the bonding in transition and inner transition metal complexes. The Course will help students understand the electronic spectra, color and magnetism of transition, and inner transition metal complexes. Also, the students will be introduced to the reaction mechanism of transition metal complexes.
Course Outline	Chemistry of Transition Metals: Module 1: Transition metal chemistry: Introduction (Periodic trends and Electronic configurations). Module 2: Bonding in coordination complexes: Crystal-Field theory and Ligand Field theory, Molecular Orbital Theory, Jahn-Teller effect, Spectrochemical series, nephelauxetic series. Module 3: Electronic Spectra: d-d transitions, Orgel and Tanabe-Sugano diagrams, charge-transfer spectra. Magnetic properties. Module 4: Reaction mechanisms of d-Block metal complexes: Aspects of Ligand substitutions in square planar and octahedral complexes; Ray-Dutt and Bailar twists mechanism, Electron-transfer processes: inner sphere and outer sphere mechanism; Metal-metal multiple bonds. Module 5: Inner transition metals: Introduction (f-orbitals and oxidation states, atomic and ionic sizes), spectroscopic and magnetic properties, Inorganic/organometallic compounds and coordination complexes. analytical applications.
Learning Outcome	Students will be able to understand 1. Periodic trends of basic properties and electronic configuration of transition and inner transition metals. 2. Structure and bonding of various transition metal complexes. 3. Electronic spectra and magnetic properties. 4. Reaction mechanism of metal complexes.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested readings:

Text Books:

1. F. A. Cotton, G. Wilkinson, C. A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, An Indian Adaptation, Wiley, ISBN-13: 978-9354245701, 2021.
2. J. D. Lee, Concise Inorganic Chemistry, 5th Edition, Oxford University Press, 2008.

Reference Book:

1. C. Housecroft and A. G. Sharpe, Inorganic Chemistry, 4th Edition, Pearson, 2012.

	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			X		
CLO-4	X		X			X		

Course Number	CH4204
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Chemical Kinetics
Learning Mode	Offline
Learning Objectives	The objective of the course is to enable the students to determine the rate of reactions and the rate laws using the steady-state approximation. Further, the course aims to enable the students to understand the factors affecting the rates in gas phase reactions, liquid phase reactions, and electrochemical reactions.
Course Description	This course will introduce the basics of chemical kinetics
Course Outline	Module 1: Review of basic concepts in kinetics: Overview of rate laws and determining rates and orders of reactions. Temperature dependence and Arrhenius law, steady state approximation; determination of reaction mechanisms, Kinetics of polymerization. Chain reaction. Module 2: Fast Reaction Kinetics: Relaxation methods, Stopped flow method, Laser Flash Photolysis, flow tube methods. Module 3: Theories of reaction rates: Potential energy surfaces-adiabatic and non-adiabatic curve crossing Processes- transition state theory-activation/thermodynamic parameters. Various theories of Unimolecular reactions, RRKM theory, statistical mechanical interpretation of reaction rate theory. Module 4: Homogeneous and heterogeneous catalysis: Catalysis concepts, enzyme catalysis. Kinetic isotope effects, salt effects. Module 5: Reactions in solutions: Influence of solvent properties on rate. Different types of molecular interactions in solution. Diffusion and activation controlled reactions. Module 6: Kinetics in the Excited State: Jablonski diagram. Kinetics of unimolecular and bimolecular photophysical and photochemical processes. Resonance energy transfer rates-Fluorescence quenching kinetics in solution and gas phase. Stern-Volmer equation. Module 7: Electrode Kinetics: Metal/solution interface- Dependence of electrochemical reaction rate on overpotential-current density for single step and multi-step processes, influence of electrical double layer on rate constants. Activation and diffusion controlled processes- Marcus kinetics and quadratic dependence of Gibbs free energies-electron transfer processes involving organic and inorganic compounds. Different types of overpotentials. Experimental methods for elucidation of reaction mechanisms.
Learning Outcome	After completing the course, students will be able 1. to understand the basic concepts of chemical kinetics like rate laws and how they are determined. 2. to know the techniques to measure the rate of fast reactions. 3. to apply different theories that could explain the rate of gas phase reactions. 4. to understand the role of catalyst in enhancing the rate of reaction.

	5. to understand the influence of solvent properties on rate of a reaction in solutions. 6. to understand the role of excited electronic states in the kinetics of photophysical and photochemical processes. 7. to understand the electrochemical reactions.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested Readings:

1. J. I Steinfeld, J. S. Francisco and William L. Hase, Chemical Kinetics and Dynamics; Prentice Hall, 2nd Edition, 1998.
2. K. J. Laidler,; "Chemical Kinetics", 3rd Edition 1997 , Benjamin-Cummings. Indian reprint Pearson, 2009.
3. K. K. Rohatgi - Mukkerjee, "Fundamentals of Photochemistry", 3rd edition, Wiley Eastern Ltd., 2014.
4. C.H. Banford and R.G. Compton (ed) Comprehensive chemical kinetics, Vol 26 Electrode kinetics – principles and methodology, Elsevier science publishers 1986.

	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	
CLO-5	X		X				X	
CLO-6	X	X	X			X		X
CLO-7	X		X					

Course Number	CH4205
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Modern Methods of Analysis
Learning Mode	Offline
Learning Objectives	This course will enable students to establish the structure and configuration of known or unknown compounds using spectrophotometric, spectrometric and thermal techniques.
Course Description	This course introduces applications UV-vis, IR, NMR spectroscopies, CD and ORD and Mass spectrometry analysis for structural determination of organic and inorganic compounds:
Course Outline	Application of UV, IR, NMR, CD, ORD, Mass, and Thermal analysis for structure determination of organic and inorganic compounds: Module 1: UV-Vis Spectroscopy: Woodward rule for conjugated dienes and carbonyl compounds; Application in quantitative titrations. Module 2: IR Spectroscopy: Characteristic vibrational frequencies of different functional groups, hydrogen bonding and solvent effect on vibrational frequencies, overtones, combination and Fermi resonance bands. Module 3: Nuclear Magnetic Resonance: An overview of NMR of nuclides (^1H, ^{13}C, ^{19}F, ^{31}P and metal nuclides). Chemical shift, spin-spin interaction, shielding mechanism, complex spin-spin interaction, coupling constant, shift reagent, nuclear over Hauser effect (NOE), resonance of other nuclei. ^{13}C NMR: Chemical shift, ^{13}C coupling constants, two-dimensional NMR spectroscopy, NOISY, DEPT, INEPT terminology. Module 4: Mass Spectrometry: Instrumentation, McLafferty rearrangement; Examples of mass spectral fragmentation of organic and inorganic compounds with respect to their structure determination. Module 5: CD & ORD: Definition, deduction of absolute configuration, octant rule for ketones. Module 6: Chromatography methods, including GC and HPLC
Learning Outcome	At the end of this course, the students will be able to 1. understand the theories and applications of different spectroscopic techniques (UV, Mass, IR and NMR, CD, ORD, etc.). 2. elucidate specialized and advanced spectroscopic techniques for the structural elucidation of organic /inorganic compounds. 3. solve structures of unknown organic and inorganic compounds using combined spectral data 4. design different spectroscopic experiments to address the quality control of industrial products 5. use the spectroscopic techniques to address different societal needs.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested Readings:
Text Books:

1. R. S. Drago, Physical Methods for Chemist, 2nd Edition, Affiliated East West Press Pvt. Ltd., 2016
2. A. B. P. Lever, Inorganic Electronic Spectroscopy, 2nd Edition, Elsevier, 1984,.
3. R. M. Silverstein, Spectrometric Identification of Organic Compounds, 8th Edition, Wiley, 2022.
3. D.L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, 5th Edition, Harcourt College Publisher, NY, 2015.

Reference Book:

1. W. Kemp, Organic Spectroscopy, 3rd Ed., Macmillan Education UK, 2017
2. Willard, Merritt, Dean, Settle, Instrumental Methods of Analysis 7Ed (Pb 1986) Paperback – 1 December 2004

	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	
CLO-5							X	

Course Number	CH4206
Course Credit	L-T-P-C: 0-0-6-3
Course Title	Inorganic Chemistry Lab
Learning Mode	Offline
Learning Objectives	The aim of this course is to provide detailed experimental knowledge and demonstrate the application/importance of inorganic experiments for the synthesis and study of various inorganic complexes. Students will learn different instrumental techniques to analyze inorganic complexes.
Course Description	This course contains experiments based on the concept of inorganic Chemistry. Students will do experiments for the synthesis of inorganic complexes, qualitative identification and quantitative estimation of inorganic compounds.
Course Outline	Synthetic methods: solution chemistry, solid-state synthesis, sol-gel methods, multi-step synthesis, preparation of isomers, synthesis under an inert atmosphere. Characterization: quantitative and qualitative determination of ligand and metal, use of spectral techniques (UV-Visible, IR, NMR, analytical methods (conductance, TG, DSC, cyclic voltammetry). Structural elucidation of crystal and powder sample via SCXRD and PXRD. Experiments: i. Synthesis of paramagnetic metal acetylacetonate complex of Fe^{3+}. ii. Preparation of bis(N,N-disalicylidene ethylenediamine)-μ- aquadichloro cobalt (II). Estimation of cobalt in the complex. iii. Synthesis of hexammine cobalt(III) chloride. Estimation of chloride in the complex. iv. Solid-phase synthesis of trans-bis glycinate copper(II). v. Preparation of bis-chloro bis-triphenylphosphine nickel (II). Estimation of nickel in the complex. vi. Preparation of potassium bis(peroxo)-oxo- (1, 10-phenanthroline) vanadium (V) trihydrate. Estimation of vanadium and peroxide in the complex. vii. Synthesis of Tetrabutylammonium Tribromide, TBATB viii. Simultaneous determination of chromium and manganese in a solution by visible Spectroscopy: ix. Synthesis of an organometallic compound: Ferrocene x. Synthesis of nanomaterial. Other similar experiments may be included as and when required to substitute the ones listed above. This practical course's core concepts and learning objectives will remain the same.
Learning Outcome	After completion of this course successfully, students will be able to - 1. apply the concepts of inorganic chemistry by doing experiments, synthesizing inorganic compounds by precipitation, recrystallization or etc. 2. use various qualitative and quantitative methods for identification and estimations of inorganic ions and common anions. 3. interpret IR, UV-vis spectra of inorganic compounds and have some basic idea about functioning of these equipment. 4. demonstrate procedures and methods applied in Inorganic Chemistry.

	5. able to solve independently the concepts of Inorganic Chemistry.
Assessment Method	Viva (20%), Lab experiment (30%), End sem examination (50%)

Suggested Readings:

1. J Mendham, R C Denney, J D Barnes, M Thomas, B Shivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Edition, Pearson, 2020.
2. G Shevla, B Shivasankar, Vogel's Qualitative Inorganic Analysis, 7th Edition, Pearson, 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			
CLO-5		X	X		X			

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	CH5101	Physical Chemistry Lab	0	0	6	3
2.	CH5102	Inorganic Chemistry-III	3	0	0	3
3.	CH5103	Organic Chemistry-III	3	0	0	3
4.	CH5199	Project-I	0	0	12	6
5.	CH51XX/ CH61XX	Department Elective-I	3	0	0	3
6.	XX61PG	IDE-I	3	0	0	3
		TOTAL	12	0	18	21

Course Number	CH5101
Course Credit	L-T-P-W: 0-0-6-0 = 3
Course Title	Physical Chemistry Lab
Learning Mode	Offline
Learning Objectives	Apply the concepts of physical chemistry by doing experiments; Development of skill to solve problems through experimental physical chemistry. To learn different instrumental techniques, and computational methods to explain the fundamentals of physical chemistry.
Course Description	This course contains experiments based on the concept of Physical Chemistry. Students will do experiments based on instrumentation methods, volumetric methods, and computational methods on Physical Chemistry.
Course Outline	Experiments based on adsorption, conductometry, potentiometry, surface chemistry, kinetics, spectroscopy, Quantum chemistry, theoretical calculation. i. Adsorption of an organic dye on activated charcoal. ii. Kinetics of chemical reactions. iii. Potentiometric titration (redox/precipitation). v. High Resolution FTIR spectra based experiment. vi. Quantum models determination of different systems such as Free-electron on a 1D box or particle on a ring. vii. Determination of critical micelle concentration of any surfactant using surface tensiometer and conductivity meter. viii. Thermodynamics of a charge transfer system, conductometric titration of a charge transfer system. ix. Thermodynamics of chemical mediated denaturation of protein. x. Spectrophotometric determination of pK_a. xi. Determination of fluorescence quantum yield of an unknown molecule. Determination of fluorescence Stern-Volmer quenching constant for any fluorophore. xii. Construction of Walsh Diagram. xiii. Calculation of equilibrium constant.
Learning Outcome	After completion of this course successfully:

	1. The students will be able to understand the concepts of physical chemistry by doing experiments. 2. Students will learn different instrumental techniques used to explain the fundamentals of physical chemistry. This will give them experience in solving existing and emerging problems in basic science. 3. They will be able to demonstrate some instrumental techniques, and computational methods at the end of the course. 4. Demonstrate procedures and methods applied in physical chemistry. 5. Ability to solve independently the concepts of physical chemistry.
Assessment Method	Viva (20%), Lab experiment (30%), End sem examination (50%)

Suggested Readings:

1. B. Viswanathan, P. S. Raghavan, Practical Physical Chemistry, Viva Books, 2010.
2. A. M. Halpern, G. C. McBane, Experimental Physical Chemistry: A Laboratory Text Book, 3rd Edition.; W. H. Freeman, 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
CLO-3		X	X					X
CLO-4		X	X					X
CLO-5		X	X					X

Course Number	CH5102
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Inorganic Chemistry-III
Learning Mode	Offline
Learning Objectives	To highlight the importance of organometallic chemistry that bridges organic and inorganic sub-disciplines in chemistry. To enthuse interest among students by discussing rich chemistry and important applications of transition-metal-based organometallic molecules in catalysis and their relevance in the industry. To show how selected metal ions are important in the biological environment, highlight the role of the metal ions in the catalysis of biochemical reactions and their importance in sustaining life processes.
Course Description	The course describes ligands, molecular models and reaction types relevant to describing the organometallic chemistry of transition metals. Early and recent examples of transition-metal-based catalysis are of industrial importance in the present context. The course describes the biological significance of s- and d-block elements, including their storage, transport, and bio-mineralization. It also highlights the course of action of various metal-based proteins and enzymes under physiological conditions and their important roles in sustaining life.
Course Outline	Organometallics: Module 1: 18-Electron rule, organometallic complexes with ligands such as hydrides, alkyl, carbonyl, nitrosyl, olefin and phosphines. Metal-carbene complexes and metallocenes. Fluxionality in organometallic complexes. Types of organometallic reactions. Module 2: Homogeneous catalysis including C-C coupling, metathesis and olefin oxidation, alkene isomerization, alkene hydrogenation, alkene hydroformylation, hydrocyanation of butadiene, alkene hydrosilylation and hydroboration Module 3: Heterogeneous catalysis, including Fischer-Tropsch reaction and Ziegler-Natta polymerization. Bioinorganic Chemistry: Module 4: Role of metal ions in biological systems, alkali and alkaline earth cations in biological systems and ionophores Module 5: Non-redox metalloenzymes, including Carboxypeptidases, Carbonic Anhydrase, and Alcohol Dehydrogenase Module 6: Redox-proteins: Iron proteins, including Siderophores, Iron Storage and Transfer Proteins, Iron-Sulfur Proteins, Haem and non-haem proteins, and electron transfer proteins. Copper proteins including Plastocyanin, Azurin, Superoxide Dismutase, and Hemocyanin, Module 7: storage and transport of Zn, Mo, Co, Cr, V, and Ni; Biomineralization of Iron, xanthine oxidase, nitrogenase, vitamin B12 coenzyme, photosystem I and II
Learning Outcome	Students will be able to 1. understand scientific reports describing use of transition metal based organometallics.

	2. propose mechanisms and identify intermediates for reactions catalyzed by transition metal based organometallics. 3. propose design and syntheses of new catalysts based on transition metals. 4. understand and explain the reaction pathways of various metal based enzymes, understand the importance of trace metals in physiological systems 5. explain the application of transition metal based molecules as catalysts in organic transformation
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested readings:

Text books:

1. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, 7th Edition, Wiley, 2019.
2. H. B. Gray, E. I. Stiefel, J. S. Valentine, I. Bertini, Biological Inorganic Chemistry: Structure and Reactivity, 1st Edition, University Science Book, 2006.

Reference Book:

1. W. Kaim, B. Schwederski, A. Klein, Bioinorganic Chemistry - Inorganic Elements in the Chemistry of Life: An Introduction and Guide, 2nd Edition, Wiley, 2013.

	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	
CLO-4					X	X		
CLO-5	X						X	

Course Number	CH5103
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Organic Chemistry-III
Learning Mode	Offline
Learning Objectives	The aim of this course is to provide the basic details of pericyclic reaction, photochemical reaction, utility to natural products and heterocyclic derivatives as key synthetic precursors in organic reaction. This course will eventually enable students to understand the different reaction outcomes in thermal and photochemical conditions.
Course Description	This course elaborates on the different types of organic reactions, their outcome and structural elucidation of natural products and their application in pharmaceutical/agrochemical-based industries.
Course Outline	Module 1: Pericyclic Reactions: Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene and allyl system. Classification of pericyclic reactions. Woodward-Hoffmann correlation diagrams. FMO and PMO approach. Electrocyclic reaction; conrotatory and disrotatory motions $4n$, $4n+2$ and allyl systems. Cycloaddition; interfacial and suprafacial addition; $4n$ and $4n+2$ systems; $2+2$ addition of ketenes; 1,3 dipolar cycloadditions and heliotropic reactions. Sigmatropic Rearrangements; suprafacial and antarafacial shifts of H, sigmatropic shifts involving carbon moieties, 3,3- and 5,5- sigmatropic rearrangements, Claisen, Cope and Aza-Cope rearrangements, Ene reaction. Module 2: Photochemistry: Quantum yields, intersystem crossing, photosensitization and energy transfer reactions. Photochemistry of olefins and carbonyl compounds, photo oxygenation and photo fragmentation, Photochemistry of aromatic compounds: isomerisation, additions and substitutions. Singlet molecular oxygen reactions. Paterno-Buchi reaction, Di-pimethane rearrangement, Barton's reaction and Photo-Fries rearrangement. Module 3: Chemistry of Natural Products: Structure elucidation and biosynthesis of Alkaloids, Terpenoids, Steroids and their application with specific examples. Total synthesis of Morphine, Camphor, Longifoline, Cortisone, Reserpine, Juvabione, Aphidicolin, Fredericamycin A, Taxol and Prostaglandin.
Learning Outcome	1. Understand the detailed pericyclic reaction under thermal as well as photochemical conditions and cyclization process. 2. Understand the impact of heterocycles in organic synthesis. 3. Understand the impact of natural product in survival of human life. 4. Identify various classes of natural products and their building blocks. 5. Apply the advanced knowledge of organic reaction in an existing and emerging problem in basic science along with their application in several industries.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested Readings:**Text Books:**

1. I. L. Finar, Organic Chemistry, Vol II, 5th edition, ELBS, 2002.
2. T. R. Gilchrist, Longman, Heterocyclic Chemistry, 3rd edition, 2005.
3. Ward, Selectivity in Organic Synthesis, Wiley-VCH, 1999.
4. I. Fleming, Molecular Orbitals and Organic Chemical Reactions, Student Edition Wiley, 2009.
5. S. Sankararaman, Pericyclic Reactions – A textbook. Wiley-VCH, 2005.
6. K. C. Nicolaou, E. J. Sorensen, Classics in Total Synthesis: Targets, Strategies, Methods, 1st Ed., Wiley-VCH, 1996.
7. Advanced Organic Chemistry: Structure and Mechanisms (Part A and B), F. A. Carey and R. J. Sundberg, 5th Ed., Springer, 2008.

	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
CLO-5								X

Course Number	CH5199 and CH5299
Course Credit	CH5199: L-T-P-C: 0-0-12-6 and CH5299: L-T-P-C: 0-0-16-8
Course Title	Project-I and II
Learning Mode	Offline
Learning Objectives	Apply the concepts of chemistry by doing experiments/theoretical and computational studies for a particular research project under the supervision of a faculty member; Development of skill to solve problems through hands-on experience on a research problem. To learn different instrumental techniques, and computational methods to interpret and present data
Course Description	This course is aimed at exposing students to research through hands-on learning skills in laboratory set up. Students will do experiments based on research goals as pre decided and floated by faculty members, learn data curation, interpretation, writing reports and present data.
Course Outline	Research in laboratory set up
Learning Outcome	1. Demonstrate planning, time and enhance experimental skills. 2. Demonstrate leadership skills. Undertake research independently. 3. Demonstrate a capacity to communicate research results clearly, comprehensively and persuasively.
Assessment Method	Research report and presentation

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

Elective Groups

Sl. No.	Course Code	Department Elective - I	L	T	P	C
1.	CH5104	Biochemistry	3	0	0	3
2.	CH5105	Basic Polymer Chemistry	3	0	0	3
3.	CH5106	Consumer Chemistry	3	0	0	3
4.	CH5107	Non-Equilibrium Statistical Mechanics	3	0	0	3

Course Number	CH5105
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Biochemistry
Learning Mode	Offline
Learning Objectives	The aim is to inculcate the concept of Biomolecules and related metabolic processes in organisms; to lay down a strong foundation of biochemical aspects of life and modern technology to enable the students to interrogate biomedical problems.
Course Description	This course introduces molecular structure and interactions of biomolecules that help in functioning and organization of organisms including vital metabolic processes, disease states and therapeutic avenues.
Course Outline	Module 1: Introduction to biomolecules: a. Proteins: physico-chemical properties of amino acids, primary, secondary, tertiary, quaternary structure, function, conformation of peptides and proteins, protein folding and stability, chemical synthesis of peptides, chemical structure determination of peptides and proteins, protein purification and estimation. b. Carbohydrates: Structure, properties, and reactions of mono- and disaccharides, carbohydrate conformers, function, estimation, and tests of carbohydrates, storage polysaccharides-linkage, variety and uses. c. Lipids & membranes: nomenclature, structure of various biologically relevant lipids, membrane structure and fluid mosaic model, membrane fluidity and lipid rafts. d. Nucleic acids: Building blocks, Structure and characteristics of DNA/RNA, transcription, translation Module 2: Molecular mechanisms of fundamental processes: Metabolism of proteins (transamination, deamination, decarboxylation), carbohydrates (glycolysis, TCA cycle, electron transport and phosphorylation, gluconeogenesis) and lipids (beta oxidation). Module 3: Biochemistry of enzymes: Basics of enzyme, nomenclature, enzymatic catalysis, enzyme kinetics and drug-enzyme interactions, Enzymatic reaction mechanisms, Allosteric regulation of enzymes, vitamins and coenzymes Module 4: Biochemistry of metabolites: Steroids, terpenoids, carotenoids, alkaloids, classification, structure and biological roles, biosynthetic pathways and applications

Learning Outcome	Students will be able to 1. interpret molecular structure and interactions of essential biomolecules like proteins, nucleic acids, carbohydrates and lipids 2. elucidate important metabolic pathways related to biomolecules 3. explain the working and mode of action of enzymes, enzyme-drugs interaction along with the importance of metabolites in plant and animals. 4. relate and interpret technology related to modern pharmaceuticals, forensics and other related biochemical industries.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested readings:

1. D. L. Nelson, M. M. Cox, Lehninger Principle of Biochemistry, 8th Edition, W. H. Freeman Co. Ltd., 2021.
2. J. M. Berg, L. Stryer, J. L. Tymoczko, G. Gatto, Biochemistry, 9th Edition, , W H Freeman Co. Ltd., 2019.

	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			
CLO-3	X				X	X	X	
CLO-4	X				X	X	X	X

Course Number	CH5106
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Basic Polymer Chemistry
Learning Mode	Offline
Learning Objectives	The aim of the course is to learn the fundamentals of polymer chemistry, which will include synthesis and kinetics, basic characterization, properties of polymers and fundamentals of their degradation.
Course Description	This course content includes understanding various common synthetic methodologies of polymers, their classification, properties, characterization and degradation. Thus it aims to establish a solid foundation for further research in the relevant area, which includes polymers and material chemistry.
Course Outline	Module 1: Introduction to polymers- Basic definitions and classifications of polymers based on their basic properties Module 2: Polymer synthesis- Step growth polymerizations, chain growth polymerizations, the kinetics of both cases, the mechanistic outline of various living Polymerization techniques (anionic, cationic, ring-opening metathesis, reversible-deactivation radical polymerizations), a few examples of post-polymer modifications. Module 3: Polymer properties – Molecular weight, glass transition temperature, polymer conformation (end-to-end distance for three different basic chain models, the radius of gyration), thermodynamics of polymer solutions (Flory-Huggins theory, concept of good and bad solvent), a brief introduction to the mechanical properties of polymers. Module 4: Characterization of polymers - molecular weight characterization via SEC, thermal analysis using DSC and TGA. Module 5: Degradation of polymers – Weathering and biodegradation.
Learning Outcome	After successful completion of the course, students will be able 1. Basic definitions, classifications of polymers. 2. Outline of various polymerization reaction techniques which include, detail discussions and kinetics of step growth and chain growth polymerizations. 3. Various common properties of polymers including polymer solution properties, thermal and mechanical properties. 4. Basic characterizations of polymers via different techniques. 5. Understand various mechanism of polymer degradation, which includes, weathering and biodegradation.

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

Text Books:

1. Timothy P. Lodge, Paul C. Hiemenz, Polymer Chemistry, 3rd Edition, CRC Press, 2020.
2. Fred W. Billmeyer, Jr., Textbook of Polymer Science, 3rd Edition, Wiley, 2008.
3. Paul J. Flory, Principles of Polymer Chemistry (1st Indian Edition, Asian Books Private Limited), 2007.
4. George Odian, Principles of Polymerization, 4th Edition, John Wiley & Sons, 2004.

	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
CLO-5								X

Course Number	CH5106
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Consumer Chemistry
Learning Mode	Offline
Learning Objectives	To introduce advanced concepts of chemistry related to consumer products used in our daily life including but not limited to pharmaceuticals, food industry, cosmetics, apparel and textiles etc. The course examines the role of chemistry in both consumer products and the environment.
Course Description	The course instills the use of chemistry to products related to our daily usage, their industrial production and relevant chemical transformation happening during their use. Chemistry of consumer products used in laundry, food, gardening, apparel, cosmetics, pharmaceuticals etc. will be covered.
Course Outline	Module 1: Chemistry in the laundry: Soaps, domestic laundry detergents, other household cleaning agents, dry clean, chemistry of washings, ISI certifications, AOS foam boosters. Hardness of water and its removal. Module 2: Chemistry in the kitchen: Butter, margarine and other fats, oils and waxes, body fat, fish oils, chocolate, cholesterol, prostaglandins, antioxidants, the chemistry of cooking, Food additives, adulterations, alcoholic products, caffeine, nutrition, digestion, allergens. Module 3: Chemistry in the boudoir: Chemistry of cosmetics, lipsticks, toothpaste, deodorants, perfumes, sunglasses, and baby care products. Module 4: Chemistry in the garden: Pesticides and alternatives, fertilizers, insect repellents, Herbicides, swimming pool chemistry. Module 5: Chemistry in the medicine cabinet: Medicinal chemistry of drugs, drugs action, tranquilizers, anesthetic drugs, Packing regulations. Marketing. Licensing – drug license -legal aspects.
Learning Outcome	Students will be able to: 1. Gain basic concepts of consumer chemistry and chemical products relevant to daily household uses and society. 2. Gain an understanding of the vocabulary of chemistry, which permeates society on food and product labels, in regards to pollution and climate change, and in the discussion of sustainable energy 3. Know various chemical transformations to create consumer products 4. Relate and interpret consumer product with their industrial production
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. Consumer Chemistry, S. B. Ransom, J. Chiocca and R.V. Reen, 2005
2. Experimental Cosmetics, W. Sawyer, Dover publishers, New York, 2000.

	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	X

Course Number	CH5107
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Non-Equilibrium Statistical Mechanics
Learning Mode	Offline
Learning Objectives	To connect the Brownian motion and reaction rate law in solution phase chemistry
Course Description	This course focuses on the topics of Brownian motion in the light of non-equilibrium statistical mechanics. Important equations such as Einstein's theory, Langevin description, Smoluchowski equation will be derived and discussed. The rate law in the context of reaction in the solution phase, such as Kramers' theory and Grote-Hynes's theory, will be discussed.
Course Outline	Module 1: Einstein's theory of Brownian motion: Brown's experiment, introduction to Einstein's theory, the irregular movement of particles suspended in a liquid and its relation to diffusion, the relation between diffusion and mobility, determination of Avogadro number, Perrin's experimental verification of Einstein's theory, theoretical observations on Brownian motion and the existence of a random force. Module 2: Langevin description of Brownian motion: General expression of mean square displacement, relation between random and viscous force: the fluctuation-dissipation theorem, Langevin dynamics in a trapping potential; Brownian motion in velocity space: Fokker-Planck equation, calculation of $M_1(v)$, calculation of $M_2(v)$. Module 3: Brownian motion in phase space (motion in a force field) and the application in reaction rate theory in solution phase: Kramers' equation, Kramers equation as a generalization of Liouville equation and connection to equilibrium statistical mechanics, Kramers' theory of activated processes, a simple connection to Transition State Theory, Grote-Hynes theory of reaction rate in solution phase, entropy production, flux-force concept, bilinear relation, Onsager reciprocity relationship, Module 4: Overdamped motion: Smoluchowski equation and diffusion over a barrier: Smoluchowski equation, diffusion of particles over the barrier.

Learning Outcome	Students will be able to learn 1. Einstein's theory of Brownian motion, which provides the concept of diffusion in solution important for understanding physico-chemical processes in solution. 2. The Langevin description of Brownian motion which is a more detailed understanding of the molecular dynamics. 3. The concept of Brownian motion during free-energetically uphill and downhill processes. These are important for understanding chemical reaction from molecular perspective. 4. The connection between Brownian motion and chemical reaction rate. 5. To understand about the mathematical equations involved and how to solve them analytically.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. M. Tuckerman, Statistical Mechanics: Theory and Molecular Simulation, Oxford Publishers, 2010.
2. D. A. McQuarrie, Statistical Mechanics, University Science Books, California, 2005
3. Investigations on the Theory of the Brownian Movement, A. Einstein, Dover Publications Inc., 1956.

	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	X		
CLO-5	X		X		X			

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	CH6201	Computer Programming for Chemists	2	0	2	3
2.	CH5299	Project-II	0	0	16	8
3.	CH62XX	Department Elective - II	3	0	0	3
4.	XX62PQ	IDE-II	3	0	0	3
5.	IK5201	Indian Knowledge System	2	0	0	2
		TOTAL	10	0	18	19

Course Number	CH6201
Course Credit	L-T-P-C: 2-0-2-3
Course Title	Computer Programming for Chemists
Learning Mode	Offline
Learning Objectives	The objective of the course is to enable the students to understand the implementation of computational methods using programming. This course will provide them with programming experience at a higher level and will demonstrate the background involved in computational methods at the end of the course.
Course Description	The course introduces the basics of computer, computer programming, and methods of theoretical chemistry, incorporated into computer programs, to calculate the structures and properties of molecules.
Course Outline	Module 1: Programming: Numerical methods with a basic understanding of theoretical and computational chemistry, methodologies and terminology using C or FORTRAN, JAVA or Python programming. Module 2: Interpolation: Numerical interpolation, polynomial and cubic spline interpolation, regression analysis and least square fit, linear, polynomial, and non-linear regression analysis, extrapolation of data. Curve fitting and introduction to QSAR. Introduction to AI/ML. Module 3: Solution of linear and nonlinear equations: Numerical methods: roots of equations – bisection and Newton-Raphson methods, system of linear equations, Gaussian, Gauss-Jordan elimination, nonlinear system of equations, eigenvalues and eigenvectors. Matrix inversion and solution of Schrödinger equation Module 4: Differentiation and integration: Numerical differentiation and integration, differential equations, numerical solution of Schrödinger equation for H atom and comparison with analytical results. Module 5: Applications to chemistry: statistical thermodynamics, chemical kinetics, curve fitting, Gaussian and Lorentzian deconvolution, software packages such as visualization, and semi-empirical methods.
Learning Outcome	This course will enable students 1. to understand the basics of computers and computer programming. 2. to fit the experimental data using numerical interpolation. 3. to solve linear and nonlinear equations numerically and apply it to theoretical and computational chemistry. 4. to implement numerical integration and differentiation and apply it to theoretical and computational chemistry. 5. to understand the applications of computational chemistry using software packages.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%)

Suggested Readings:

Text Books:

1. S. S. M. Wong, Computational Methods in Physics and Engineering, 2nd Edition, WSPC, 1997.
2. Tao Pang, An Introduction to Computational Physics, Cambridge University Press; 2nd edition, 2006.

Reference Books:

1. Mark Pilgrim, “Dive Into Python,” <http://diveintopython.org>, 2004.
2. Press, W. H., Teukolsky, S.A. Vetterling W.T. and Flannery, B.P., Numerical Recipes; The Art of scientific Computing, Cambridge University Press, New York, 2007.
3. C. Lanczos, Applied Analysis, Dover New York, 2010.
4. S.E. Koonin, and D.C. Meredith, Computational Physics, Fortran Version, Westview Press, U.S.A., 1998
5. B.W. Kernighan and D.M. Ritchie, The C Programming Language, 2nd Edition, Pearson, 2015.

	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			
CLO-3	X	X	X		X			
CLO-4			X	X	X	X		X
CLO-5			X	X	X	X		X

Course Number	CH5199 and CH5299
Course Credit	CH5199: L-T-P-C: 0-0-12-6 and CH5299: L-T-P-C: 0-0-16-8
Course Title	Project-I and II
Learning Mode	Offline
Learning Objectives	Apply the concepts of chemistry by doing experiments/theoretical and computational studies for a particular research project under the supervision of a faculty member; Development of skill to solve problems through hands-on experience on a research problem. To learn different instrumental techniques, and computational methods to interpret and present data
Course Description	This course is aimed at exposing students to research through hands-on learning skills in laboratory set up. Students will do experiments based on research goals as pre decided and floated by faculty members, learn data curation, interpretation, writing reports and present data.
Course Outline	Research in laboratory set up
Learning Outcome	1. Demonstrate planning, time and enhance experimental skills. 2. Demonstrate leadership skills. Undertake research independently. 3. Demonstrate a capacity to communicate research results clearly, comprehensively and persuasively.
Assessment Method	Research report and presentation

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

Sl. No.	Course Code	Department Elective - II	L	T	P	C
1.	CH6202	Solid State Chemistry	3	0	0	3
2.	CH6203	Nanotechnology for Biomedical Applications	3	0	0	3
3.	CH6204	Bioanalytical Techniques	3	0	0	3
4.	CH6205	Advanced Medicinal Chemistry	3	0	0	3
5.	CH6206	Organic and Organometallic Catalysis	3	0	0	3
6.	CH6207	Advanced Optical Spectroscopy	3	0	0	3
7.	CH6208	Chemistry of Heterocycles	3	0	0	3
8.	CH6209	Syntheses and Applications of Industrial Polymers	3	0	0	3

*An upgraded version of M. Sc. 5/6 level electives need to be essentially upgraded for PhD students with additional contents comprising additional lectures / assignments / tutorials / miniproject making the total credit : 3-1-0-4 / 3-0-2-4. Such course proposals with an advanced level (6/7 level course number) are listed separately for PhD students.

Course Number	CH6202
Course Credit	L-T-P-C: 3-0-0-3
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	CH6203
Course Credit	L-T-P-C: 3-0-0-3
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	CH6204
Course Credit	L-T-P-C: 3-0-0-3
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: Pharmacanalytics: 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	CH6205
Course Credit	L-T-P-C: 3-0-0-3
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	CH6206
Course Credit	L-T-P-C: 3-0-0-3
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	CH6207
Course Credit	L-T-P-C: 3-0-0-3
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	CH6208
Course Credit	L-T-P-C: 3-0-0-3
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	CH6209
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	

IDE for M. Sc. students (Other than Dept. of Chemistry)

Sl. No.	Course Code	Department Elective - II	L	T	P	C
1.	CH6101	Sustainable Chemistry	3	0	0	3
2.	CH6210	Chemistry and Applications of Nanostructured Materials	3	0	0	3

Course Number	CH6101
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Sustainable Chemistry
Learning Mode	Offline
Learning Objectives	Learn the importance of use of non-toxic chemical entities, minimizing waste, saving power and doing organic synthesis according to the principles of green chemistry.
Course Description	This course illustrates different Green strategies and techniques for organic synthesis. Further courses depict the use of different non-toxic chemical entities (metals, non-metals, solvents, light source) for Green organic synthesis.
Course Outline	Module 1. Principles of Green Chemistry. Classification of organic reactions under Green chemistry principles: a) Atom economic and non-toxic byproduct reactions: rearrangements, addition reaction, condensations, cascade strategies under catalysis, b) atom uneconomic reactions: substitutions, eliminations, Wittig reactions, degradation reactions Module 2. Green Strategies and techniques for Organic Synthesis: use of Microwave, Sonochemistry, Ball mill technique, electrochemical reactions, photochemical reactions, Module 3. Catalysis: Principles of various catalysis techniques in terms of Green Organic Synthesis: homogeneous, heterogeneous, bio (enzyme) catalysis, catalysis with non-toxic metals (Ca, Fe, Co, etc.), solid supported catalysis, metal free/organocatalysis, Visible light catalysis, phase transfer catalysis; Alternative/Green solvents for organic synthesis: water, ionic liquids, supercritical liquids (SC.L), poly(ethylene glycol) (PEG), fluorous biphasic Solvents Module 4. Comparison of greenness of solvents, understanding the role/effect of these solvents on organic reactions, solvent free organic synthesis, reactions at room temperature, applications of the Green strategies in organic synthesis, comparing various organic reactions under classical conditions and Green conditions.
Learning Outcome	Students will be able to: 1. understand the concept of Green organic synthesis. 2. realize the environmental benign way of organic synthesis. 3. understand the way to reduce waste, minimize energy consumption in organic synthesis. 4. spread awareness of an environmentally friendly way of living in society.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

1. P. T. Anastas and J. C. Warner, Green Chemistry: Theory and Practice, Oxford University

Press, Oxford, 1998.

2. R. Sanghi and M. M. Srivastava, Green Chemistry: Environment Friendly Alternatives, Narosa Publishing House, Delhi, 2003.
3. M. Lancaster, Green Chemistry: An introductory text, RSC Publishing, 2nd Edition, 2010.
4. V. K. Ahulwalia, Strategies for Green Organic Synthesis, Ane Books Pvt. Ltd., 1st Edition, 2012.
5. A. Stolle, B. Ranu, Ball Milling Towards Green Synthesis: Applications, Projects, Challenges, Royal Society of Chemistry, 2014.

	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

Course Number	CH6210
Course Credit	L-T-P-C: 3-0-0-3
Course Title	Chemistry and Applications of Nanostructured Materials
Learning Mode	Offline
Learning Objectives	To introduce basic concepts of nanomaterial science with emphasis on the role of chemistry in nanoparticle synthesis and controlling the size in order to apply them for various applications.
Course Description	The course provides the concept of nanoscience and technology. It will enable students learn about surface science, colloidal chemistry and size dependent optical, electronic properties and applications of nanomaterials.
Course Outline	Module 1: Introduction; fundamentals of nanomaterial science, surface science for nanomaterials, colloidal chemistry Module 2: Synthesis, preparation and fabrication: chemical routes, Top-down and bottom-up approaches, self-assembly methods, biomimetic and electrochemical approaches. Module 3: Size controls properties (optical, electronic and magnetic properties of materials) Module 4: Applications (metal nanoparticles, carbon nanotubes and nanoporous zeolites; Quantum dots, basic ideas of nanodevices). Module 5: Application in OLED, QLED
Learning Outcome	Students will be able to 1. gain basic concept of nanoscience and technology relevant to research. 2. gain concept of fabrication of nanomaterials and also about the chemistry of size and shape control. 3. relate nanotechnology to recent advances in terms of optical, electronic, and magnetic properties of materials. 4. relate and interpret nanotechnology related to the application to various emerging fields.
Assessment Method	Class test, assignment & quiz (20%), Mid sem examination (30%), End sem examination (50%).

Suggested readings:

Text Book

1. G. Schmid, Nanoparticles, Wiley-VCH, 2006.
2. F. J. Owens, and C. P. Poole Jr., The Physics and Chemistry of Nanosolids, Wiley-Interscience Publication, 2008.
3. Z. Guo and L. Tan, Fundamentals and Applications of Nanomaterials, Artec House publication, 2009.
4. G. Cao, and Y. Wang, Nanostructures and Nanomaterials, World Scientific, 2011.

	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