SNDT Women's University, Mumbai

Master of Science (Chemistry)

M. Sc. (Chemistry)

As per NEP-2020

Syllabus Sem III & IV

(2024-25)

Programme template

Programme	Master of Science M. Sc.
Paranthesis	Chemistry
Preamble	To achieve excellence in the academic disciplines, research, and extension activities through an emphasis on "Quality in every activity. This includes providing access to the field of higher education for women, enabling students for research in emerging areas of study, and training and developing scientists and technologists for industries and academics. Additionally, we aim to address the socio-economic demands by offering job-oriented courses, ensuring a comprehensive approach to education and preparing individuals for a dynamic and competitive future. Providing Higher Education for Women, Developing and Research Attitudes in Women Students, Achieving Academic Discipline in Women, Achieving Orientated Courses and Research with Regional Industrial Needs, Developing a Basic Concept of Chemistry Applied in Industries
Programme Outcomes (POs)	After completing this programme, Learner will be able to, 1. Implement practical to enhance women's skills in using advanced instruments. Provide workshops, seminars, and training programs to supplement theoretical knowledge with practical expertise. Create an environment that encourages experimentation, critical thinking, and innovation in the field of chemistry. 2. Conduct regular consultations with local industries to understand their specific needs and challenges. Adapt academic programs to address the skill gaps identified by local industries. 3. Collaborate with industry experts to design and update curriculum to match the requirements of the job market. Provide career counselling and guidance to help women align their skills and aspirations with industry demands. Facilitate internships, co-op programs, and industry-sponsored projects to give women practical exposure to real-world challenges. 4. Integrate entrepreneurship and business skills into the curriculum to encourage women to explore opportunities for self-employment. Provide resources and support for women to start their own ventures or contribute to existing businesses. Develop a mindset of economic independence and financial literacy among women students. 5. Implement outreach programs to bring education and training to rural and backward communities. 6. Encourage faculty and students to engage in applied research that addresses the specific challenges faced by local industries. Enable knowledge transfer between academia and industry to drive innovation and problem solving. By incorporating these considerations into your educational framework.
Programme Specific Outcomes (PSOs)	After completing this programme, Learner will be able to 1. Learn Various Skills, Including Handling Instruments and Advanced Analysis of Chemistry 2. Fulfil the Thrust of Industries in Our Area 3. Develop Women According to the Needs of Industries 4. Empower Women to Become Financially Independent 5. Empower Backward and Rural Women, Connecting Them to Modern Trends and Technical Knowledge

	6. Develop Research in Industry to Meet Local Needs
Eligibility Criteria for Programme	B.Sc. graduate having Chemistry as main subject
Intake	30
Duration	4 semesters (2 years)

Course Structure with Title

Master of Science in Chemistry (M. Sc. Chemistry)

Year I

Subject Code	Courses	Type of Course	Credits	Marks	Int	Ext
	Semester I					
115311	Inorganic Chemistry	Major (Core) Theory	4	100	50	50
115312	Organic Chemistry	Major (Core) Theory	4	100	50	50
115313	Physical Chemistry	Major (Core) Theory	4	100	50	50
145311	Practical (Laboratory Course)	Major (Core) Practical	2	50	50	0
125311	Analytical Chemistry	Major (Elective) Theory	4	100	50	50
125312	Nuclear chemistry	Major (Elective) Theory				
125313	Polymer chemistry	Major (Elective) Theory				
135311	Research Methodology	Minor Stream (RM) Theory	4	100	50	50
			22	**550**	**300**	**250**
	Semester II					
215311	Inorganic Chemistry	Major (Core) Theory	4	100	50	50
215312	Organic Chemistry	Major (Core) Theory	4	100	50	50
215313	Physical Chemistry	Major (Core) Theory	4	100	50	50
245311	Practical (Laboratory Course)	Major (Core) Practical	2	50	0	50
225311	Analytical Chemistry	Major (Elective) Theory	4	100	50	50
225312	Nuclear Chemistry	Major (Elective) Theory				
225313	Polymer Chemistry	Major (Elective) Theory				
255311	Internship/Field Work	OJT	4	100	50	50
			22	**550**	**250**	**300**

Exit option (44 credits):

Year II

Subject code	Courses	Type of Course	Credits	Marks	Int	Ext
	Semester III					
315311	Organic Chemistry - I	Major (Core) Theory	4	100	50	50
315312	Organic Chemistry - II	Major (Core) Theory	4	100	50	50
315313	Organic Chemistry - III	Major (Core) Theory	4	100	50	50
345311	Practical (Laboratory Course)	Major (Core) Practical	2	50	0	50
325311	Medicinal Chemistry	Major (Elective) Theory	4	100	50	50
355311	Research project (Experimental)	RP	4	100	50	50
			22	**550**	**250**	**300**
	Semester IV					
415311	Organic Chemistry - I	Major (Core) Theory	4	100	50	50
415312	In-plant Training	Major (Core) Theory	4	100	50	50
445311	Practical (Laboratory Course)	Major (Core) Practical	4	100	50	50
425311	Organic Retro synthesis	Major (Elective) Theory	4	100	50	50
455311	Research Project (Dissertation, presentation and Seminar)	RP	6	150	100	50
			22	**550**	**300**	**250**

Semester III

3.1 Major (Core)

Course Title	**Organic Chemistry - I (315311)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the principles of Frontier Molecular Orbitals (FMOs) to predict the outcomes of chemical reactions and interpret the significance of HOMO-LUMO interactions in organic reactions and spectroscopy. 2) **Analyze**: Analyze various oxidation and reduction methods for functional group transformations, including the use of specific reagents and conditions for selective oxidation and reduction of alcohols, aldehydes, ketones, and other organic compounds. 3) **Evaluate**: Evaluate the mechanisms and outcomes of pericyclic reactions based on symmetry properties, phase, and nodal characteristics of molecular orbitals, and apply Woodward-Hoffmann rules to predict the products of electrocyclic and cycloaddition reactions. 4) **Design**: Design and propose synthetic routes for complex organic molecules using knowledge of enzyme chemistry and bioorganic principles, including enzyme-catalyzed transformations, enzyme specificity, and applications in synthetic organic chemistry.
Module 1 (Credit 1) - Introduction to FMOs	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the concepts of HOMO and LUMO, including their significance and the HOMO-LUMO gap, to interpret absorption spectra and predict chemical reactivity in organic molecules. 2) **Analyze**: Analyze the effect of electronegativity perturbation and orbital polarization on the molecular orbitals (MOs) of formaldehyde, and describe how these factors influence its chemical behavior. 3) **Evaluate**: Evaluate the role of HOMO and LUMO (π and π* orbitals) in nucleophilic and electrophilic reactions, including the identification of hard and soft reactive sites based on molecular orbital theory. 4) **Design**: Design and rationalize nucleophilic addition reactions on formaldehyde using the concept of 'donor-acceptor' interactions, and connect this with the use of curved arrows in reaction mechanisms to predict and explain reaction pathways.
Content Outline	HOMO and LUMO and significance of HOMO-LUMO gap in absorption spectra as well as chemical reactions. MOs offormaldehyde: The effect of electronegativity perturbation and orbitalpolarization in formaldehyde. HOMO and LUMO (π and π* orbitals) offormaldehyde.Abrief descriptionofMOsof nucleophiles and electrophiles. Concept of 'donor-acceptor' interactions in nucleophilicaddition reactions on formaldehyde. Connection of this HOMO-LUMOinteractionwith'curved arrows'used inreactionmechanisms.The concept of hardness and softness and its application to electrophiles andnucleophiles.Examplesofhardandsoft nucleophiles/electrophiles. Identificationof hardandsoft reactivesitesonthe basis ofMOs
Module 2 (Credit 1) – Oxidation Synthesis	

<table>
<tr><td>Learning Outcom es</td><td>After going through the module, learners will be able to

1) Apply: Apply various oxidation methods, such as using Jones reagent, Swern oxidation, and PCC, to convert alcohols into aldehydes, ketones, or acids. Utilize oxidative cleavage reagents like KMnO4 and O3 to analyze carbon-carbon double bonds.
2) Analyze: Analyze the effectiveness and selectivity of different oxidizing agents and conditions (e.g., Swern oxidation, Moffatt oxidation) in achieving desired oxidation states and transformations of organic compounds.
3) Evaluate: Evaluate the outcomes of different reduction techniques, such as catalytic hydrogenation and metal hydride reductions (LiBH4, DIBAL-H), in converting various functional groups (e.g., nitriles, oximes) to their corresponding reduced forms.
4) Design: Design synthetic pathways utilizing specific oxidation and reduction methods to achieve complex transformations, such as the selective cleavage of glycols with IO4 or the reduction of esters with DIBAL-H, optimizing conditions for targeted organic synthesis.</td></tr>
<tr><td>Content Outline</td><td>(a) Oxidation of alcohol to aldehyde, ketone or acid: Jones reagent,Swern oxidation, Collins reagent, Fetizones reagent, PCC, PDC, PFC,IBX, Activated MnO2, Chromyl chloride (Etard reaction), TEMPO,CAN, NMO, Moffatt oxidation (b) Oxidative cleavage of Carbon-Carbon double bonds: KMnO4, Ozonolysis. (c) Oxidations usingSeO2, PhSeBr. (d) Selective cleavages at functional groups: Cleavageofglycols,IO4, Pb(OAc)4.
(b) Reductions (a) Catalytic Hydrogenation; (b) Reduction of nitriles,oximes and nitro compounds; (c) Reduction of acids and Esters; (d)Reduction with metal hydride- Sodium cyanoborohydride, Diborane,L- & K-Selectrides, LiBH4, DIBAL-H; (e) Birch reduction and relatedreactions,(h)Luchereagent, Wolf-Kishnerreduction,Clemmenson reduction,Wilkinsoncatalyst,TBTH.</td></tr>
<tr><td colspan="2">Module 3 (Credit 1) – Pericyclic Reactions</td></tr>
<tr><td>Learning Outcomes</td><td>After going through the module, learners will be able to

1) Apply: Apply the Woodward-Hoffmann selection rules to predict the outcomes of electrocyclic reactions based on the symmetry properties and phase relationships of molecular orbitals in compounds such as ethylene, 1,3-butadiene, and 1,3,5-hexatriene.
2) Analyze: Analyze the symmetry properties of molecular orbitals in key intermediates (allyl cation, allyl radical, pentadienyl cation, and pentadienyl radical) to understand their role in thermal and photochemical pericyclic reactions.
3) Evaluate: Evaluate reaction mechanisms by using the conservation of orbital symmetry and correlation diagrams to determine the feasibility and regioselectivity of electrocyclic reactions.
4) Design: Design synthetic strategies utilizing pericyclic reactions by leveraging the Huckel-Mobius aromatic and antiaromatic transition state methods to control reaction outcomes and optimize reaction conditions.</td></tr>
<tr><td>Content Outline</td><td>Features and classification of pericyclic reactions, Phases, nodes andsymmetry properties of molecular orbital in ethylene, 1,3-butadiene,1,3,5-hexatriene. Allyl cation, allyl radical, pentadienyl cation andpentadienylradical.Thermal andphotochemicalreactions.

Electrocyclic reactions: Woodward-Hoffmann selection rules forelectrocyclic reactions. Explanation for the mechanism of electrocyclicreactionsby:(i)Symmetrypropertiesof HOMOofopenchainpartner;
(ii) Conservation of orbital symmetry and orbital symmetry correlationdiagram and (iii) Huckel-Mobius aromatic and antiaromatic transitionstatemethod.</td></tr>
</table>

Module 4 (Credit 1) – Bio organic chemistry introduction	
Learning Outcom es	After going through the module, learners will be able to 1) **Apply**: Apply the concepts of molecular recognition and proximity effects to explain the mechanisms of enzyme catalysis and its influence on reaction rates and selectivity. 2) **Analyze**: Analyze the mechanisms of enzyme action and enzyme specificity through Michaelis-Menten and Lineweaver-Burk plots, understanding how factors like enzyme structure and environmental conditions affect enzyme activity. 3) **Evaluate**: Evaluate enzyme inhibition types (reversible and irreversible) and their impact on enzyme function, using case studies involving α-Chymotrypsin, Ribo nuclease, Lysozyme, and Carbopeptidase-A to illustrate practical applications in synthetic organic chemistry. 4) **Design**: Design experimental approaches for studying enzyme kinetics and mechanisms, and propose synthetic pathways utilizing enzyme-catalyzed reactions for various organic transformations, including additions, eliminations, substitutions, and rearrangements.
Content Outline	Basic concepts, Proximity effects in organic chemistry, Molecular adaptation, Molecular recognition. Enzyme Chemistry :-Introduction, Nomenclature, Classification and Extraction of enzymes, Introduction to catalysis and enzymes; Multifunctional catalysis, Intramolecular Catalysis, Mechanism of enzyme action, Factors responsible for enzyme specificity, Enzyme activity and kinetics (Michaelis Menten and Lineweaver–Burk plots),Enzyme Inhibitions (Reversible and irreversible), Structure, Mechanism of action and applications of α-Chymotrypsin, Ribonuclease, lysozymeand Carbopeptidase-A. Enzymes in synthetic organic chemistry.[Additions, eliminations, substitutions, condensations,cyclocondensations,oxidations,reductionsandrearrangementreactions areto becovered]

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1 (Introduction to FMOs),** students could work on a project analyzing the HOMO-LUMO interactions in various organic molecules. They would predict the reactivity and absorption spectra of these molecules based on their molecular orbital theory. This project could involve using computational chemistry software to visualize molecular orbitals and calculate HOMO-LUMO gaps. Alternatively, students could interpret experimental UV-Vis spectra and correlate them with FMO theory. The project would emphasize understanding and applying the concept of donor-acceptor interactions in nucleophilic addition reactions.

- **Module 2 (Oxidation Synthesis),** students could undertake a project involving the selective oxidation and reduction of organic compounds. They would use various reagents and conditions to convert alcohols to aldehydes or ketones and apply oxidative cleavage reagents to analyze carbon-carbon double bonds. The project could include designing synthetic routes that incorporate specific oxidation or reduction methods, optimizing reaction conditions, and evaluating the effectiveness of different reagents. This could be performed in a chemistry lab or simulated using online tools.

- **Module 3 (Pericyclic Reactions),** students could design and predict the outcomes of pericyclic reactions using Woodward-Hoffmann rules. The project would involve applying these rules to predict products of electrocyclic and cycloaddition reactions. Students would analyze symmetry properties and phase relationships of molecular orbitals in various compounds, such as 1,3-butadiene and 1,3,5-hexatriene. They could use molecular modeling software to visualize transition states and reaction mechanisms, or analyze experimental data if available.

- **Module 4 (Bioorganic Chemistry Introduction),** students could explore enzyme-catalyzed reactions by designing experiments that investigate enzyme kinetics and mechanisms. The project might involve using Michaelis-Menten and Lineweaver-Burk plots to analyze enzyme activity and specificity. Students could study specific enzymes, such as α-Chymotrypsin or Lysozyme, and apply enzyme-catalyzed reactions to synthesize organic compounds. The project would emphasize experimental design and the application of enzyme chemistry to organic synthesis.

References-

1. Dugas, H. (1996). *Bioorganic chemistry: A chemical approach to enzyme action*. Springer.
2. Faber, K. (2000). *Biotransformations in organic chemistry*. Springer.
3. Fersht, A. (1999). *Enzyme structure and mechanism* (2nd ed.). W. H. Freeman.
4. Drauz, K., & Waldmann, H. (2002). *Enzyme catalysis in organic synthesis* (Vol. 1). Wiley-VCH.
5. Kalsi, P. S., & Kalsi, J. P. (2008). *Bioorganic, bioinorganic, and supramolecular chemistry*. Wiley.
6. Clayden, J., Greeves, N., Warren, S., & Wothers, P. (2012). *Organic chemistry* (2nd ed.). Oxford University Press.
7. Carey, F. A., & Sundberg, R. J. (2007). *Advanced organic chemistry* (Part A, pp. 713-769; Part B). Springer.
8. Smith, M. B., & March, J. (2007). *March's advanced organic chemistry: Reactions, mechanisms, and structure* (6th ed.). Wiley.
9. Morrison, R. T., Boyd, R. N., & Bhattacharjee, S. K. (2011). *Organic chemistry* (7th ed.). Pearson.

3.2 Major (Core)

Course Title	**Organic Chemistry – II (315312)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) Apply: Apply concepts of carbanion chemistry and neighboring group participation to predict and design synthetic pathways, including reactions such as Aldol, Mannich, and Claisen condensations, as well as intramolecular displacements and rearrangements. 2) Analyze: Analyze spectral data from NMR, MS, and other spectroscopic methods to elucidate the structure of complex organic compounds, including natural products and synthetic molecules, considering their chemical shifts, coupling constants, and fragmentation patterns. 3) Evaluate: Evaluate the stereochemical aspects of acyclic and cyclic compounds, including conformational effects and stereoisomerism, to understand their reactivity and stability in various organic reactions and applications. 4) Design: Design and implement green chemistry strategies to improve the sustainability of chemical processes, analyzing their environmental impact and comparing their "greenness" to traditional methods in terms of efficiency, waste reduction, and resource use.
Module 1 (Credit 1) - Carbanions in organic Chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) Apply: Apply the principles of carbanion chemistry to predict the outcomes of reactions involving carbanions, such as in the Aldol, Mannich, and Claisen reactions, and understand their stereochemical implications. 2) Analyze: Analyze the effects of neighboring group participation and the role of carbanions in organic reactions, including intramolecular displacements and rearrangements, by evaluating reaction mechanisms and experimental data. 3) Evaluate: Evaluate the impact of carbanion character on reaction rates and product distribution in various organic transformations, including enolate alkylation and conjugate additions, considering factors like geometry and reaction conditions. 4) Design: Design synthetic pathways utilizing carbanions and neighboring group participation to achieve specific chemical transformations, incorporating knowledge of reaction mechanisms and stereochemistry.
Content Outline	Ionization of carbon hydrogen bond and prototopy, Base and acid catalysed halogenation of ketones, keto-enolequilibria, structure and rate in enolisation, concerted and carbanion mechanism for tautomerism,carbanion character in phenoxide and pyrrolyl anions, geometry of carbanions, hydrolysis of haloforms, Aldol, Mannich, Cannizzaro, Darzens, Dieckmann, ClaisenBaylis-Hillman reactions, Knoevenagel, benzoin condensation, alkylation of enolates and stereochemistry thereof, Conjugate additions. Enamines and imine anions in organic synthesis etc. **Neighboring Group Participation** Concept of neighboring group participation (anchimeric assistance) with mechanism, neighboring group participation by π & σ bonds, classical and non classicalcarbocations, Intramolecular displacement by hydrogen, Oxygen,

	nitrogen, sulphur and halogen. Alkyl, cycloalkyl, Aryl participation, participation in bicyclic system, migartory aptitude, intimate and solvent separted ion-pair, transannular, pinacole and carbocation rearrangements and related rearrangements in neighboring group participation, NGP in elimination and addition
Module 2 (Credit 1) - Structural elucidation by spectral methods	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply spectral methods, including NMR, MS, ESR, and Mossbauer spectroscopy, to determine the structure of organic compounds, both natural and synthetic, by interpreting spectral data and using appropriate analytical techniques. 2) **Analyze**: Analyze the chemical shifts, coupling constants, and spectral patterns to elucidate the structure of complex molecules, with a focus on terpenes, alkaloids, and steroids. 3) **Evaluate**: Evaluate the effectiveness of various spectral techniques in structural elucidation, considering their applications, limitations, and the types of information they provide about molecular structures. 4) **Design**: Design and implement experimental procedures for the structural determination of organic compounds using a combination of spectral methods, ensuring accurate and comprehensive analysis.
Content Outline	Describe the concept of structural elucidation. 2. Describe spectral methods. 3. Apply the knowledge of the chemistry of terpenes, alkaloids and steroids. 4. Implement structure elucidation of new compound natural or synthetic 5. To explain the Nuclear magnetic resonance spectroscopy. Proton chemical shift, spin spin coupling, coupling constants and applications to organic structures 13C resonance spectroscopy 6. To define the Mass, ESR, Mossbauer spectroscopy and its applications and handling
Module 3 (Credit 1) - Advanced Stereochemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply advanced stereochemical concepts to understand and predict the conformation, reactivity, and stereochemistry of acyclic and cyclic compounds, including complex systems like fused and bridged rings. 2) **Analyze**: Analyze the stereochemical effects of conformation on reactivity and stability in various ring systems, including cyclohexanes, five-membered rings, and polycyclic systems. 3) **Evaluate**: Evaluate different methods of resolution and asymmetric transformation to determine optical purity and stereochemical configurations, using techniques like ORD and CD. 4) **Design**: Design strategies for the synthesis and resolution of chiral molecules, incorporating knowledge of stereochemical principles and resolution methods to achieve specific optical properties and configurations.
Content Outline	Conformation and reactivity in acyclic compounds (06) Meaning of conformation and physical properties, conformational effects on the stability and reactivity Stereochemistry of six membered rings (12) Shape of cyclohexane ring, monsubstuted and disubstited cyclohexane, physical properties, conformation and chemical reactivity in cyclohexanes, conformational effects in six membered rings containing unsaturation. Six membered heterocyclic ring The shapes of rings other than six membered rings (06) five membered, rings larger than 6-membered medium rings, conformational effects in medium rings, transannular effects, concept of I strain Fused rings and bridged rings (14) Bicyclic and polycyclic, Occerence, availbility, sterochemical restrictions and reactions of norbornyl system Allenes, spiranes and biphenyls (06) Enantiomerism in allenes, alkylidene cycloalkane, spiranes-configurationalnomencalture, correlation of axial dissymmtry and

	centrodissymmetry. Resolution methods (04) Resolution by mechanical separtion of crystals, resolution by formation of diasteremers, second order asymmtric transformation, resolution by equilibrium asymmtric transformation, biochemical asymmtrictransformation, criteria of optcal purity ORD and CD (08) Stereochemistry of natural products, strychnine, podophyllotixin
Module 4 (Credit 1) - Green Chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply principles of green chemistry to design and develop sustainable chemical processes that address societal and environmental concerns, considering factors such as waste reduction and resource efficiency. 2) **Analyze**: Analyze existing chemical and industrial processes to identify their environmental impact and sustainability parameters, determining their relative "greenness" and areas for improvement. 3) **Evaluate**: Evaluate the effectiveness of green chemistry advancements and sustainability developments in terms of their impact on society, the environment, and economic development, making informed judgments on their benefits and limitations. 4) **Create**: Create comprehensive solutions that integrate science and technology with societal needs, proposing innovative approaches to enhance the sustainability of chemical processes and addressing broader interdisciplinary issues.
Content Outline	1. Explain Green chemistry and sustainability which relates to problems of societal concern. 2. Describe Green chemistry and sustainability developments that affect society, the environment and economic development. 3. Analyze a process and identify parameters that make environmentally friendly/sustainable/green. 4. Integrate, synthesize, and apply knowledge of the relationship between science and technology and societal issues in both focused and broad interdisciplinary contexts. 5. Demonstrate the ability to effectively communicate to others the concepts learned in the course. 6. Analyze and compare chemical/industrial processes based on their relative "greenness"

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1:** Carbanions in Organic Chemistry, students can investigate the reactivity of carbanions in simple organic reactions using common household or easily accessible chemicals. For instance, they can explore the Aldol condensation reaction using acetone and a variety of aldehydes to form β-hydroxy ketones or α,β-unsaturated carbonyl compounds. They can perform this experiment in a home or local lab setting, using basic laboratory equipment such as beakers, stirrers, and heating sources. The objective is to observe reaction conditions that influence product formation and stereochemistry, and to analyze the results by thin-layer chromatography or simple purification techniques.

- **Module 2:** Structural Elucidation by Spectral Methods, students can work on determining the structure of common organic compounds using spectral data. They can select a natural product or an easily synthesized compound, such as essential oils or flavor compounds from household items, and use NMR spectroscopy (if available) to analyze their structures. If NMR is not accessible, students can use literature data and online spectral databases for practice. The project involves applying spectral techniques to identify functional groups, chemical shifts, and coupling patterns, and interpreting this data to deduce the structure.

- **Module 3:** Advanced Stereochemistry, students could focus on the stereochemistry of readily available compounds, such as simple sugars or amino acids. They could design a project to explore conformational analysis by modeling these compounds using software tools or physical models. The project would involve constructing models of various ring systems, such as cyclohexane or cyclopentane, and analyzing their conformations and stereoisomerism. Students can use online molecular modeling resources or kits that are often available in educational laboratories.

- **Module 4:** Green Chemistry, students could undertake a project to assess the environmental impact of household or common industrial cleaning products by comparing their ingredients and processes to greener alternatives. They can collect data on the chemical composition and environmental impact of these products using available resources, such as product labels and safety data sheets. The project would involve analyzing and comparing the sustainability of different products, proposing greener alternatives, and discussing the potential benefits of these alternatives in terms of waste reduction and resource efficiency.

References-

1. Carey, F. A., & Sundberg, R. J. (2007). *Advanced organic chemistry* (5th ed., Part A). Springer.
2. Giese, B. (1986). *Radicals in organic synthesis*. Pergamon Press.
3. Kopecky, J. (1992). *Organic photochemistry: A visual approach*. VCH Publishers.
4. Barltrop, J. A., & Coyle, J. D. (Eds.). (1987). *Excited states in organic chemistry*. John Wiley & Sons.
5. Kan, O. (2004). *Organic photochemistry*. Elsevier.
6. Woodward, R. B., & Hoffmann, R. (1970). *Conservation of orbital symmetry*. Verlag Chemie.
7. Nasipuri, D. (1994). *Stereochemistry of organic compounds: Principles and applications*. Wiley.
8. Eliel, E. L. (1994). *Stereochemistry of carbon compounds*. Wiley.
9. Sharma, Y. R. (2005). *Organic spectroscopy*. S. Chand & Company.

3.3 Major (Core)

Course Title	**Organic Chemistry – III (315313)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) Apply: Apply principles of photochemistry to analyze and predict the outcomes of photochemical reactions, including the mechanisms of excitation and deactivation, and the effects of electronic transitions on carbonyl compounds and unsaturated systems. 2) Evaluate: Evaluate the reactivity and synthetic applications of various heterocyclic compounds, including mono- and bicyclic systems, using IUPAC naming conventions and understanding their general methods of synthesis and reactivity patterns. 3) Analyze: Analyze the properties and catalytic behaviors of metallic clusters, including their preparation methods, physical and chemical properties, and their role in catalysis and synthetic applications. 4) Create: Design and propose new synthetic routes involving free radicals, incorporating the formation, stability, and reactivity of long and short-lived radicals, and applying radical cyclizations in innovative organic synthesis.
Module 1 (Credit 1) - Photochemistry	
Learning Outcomes	After going through the module, learners will be able to 1) Apply: Apply the principles of photochemistry to understand and predict the behavior of various photochemical processes, including the mechanisms of absorption and the deactivation of photochemically relevant radiation. This includes analyzing electronic transitions and states, as well as the selection rules and notations that describe these transitions. 2) Analyze: Analyze the photochemistry of carbonyl compounds, including $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$ transitions, and interpret the mechanisms of Norrish type-I and type-II cleavages, Patterno-Buchhi reactions, and photoreductions. Evaluate the effects of these processes on enones, cyclohexadienones, and α,β-unsaturated ketones. 3) Evaluate: Evaluate the impact of photochemical reactions in unsaturated systems, including olefins and their cis-trans isomerizations, as well as the Di-π-methane rearrangement. Assess the significance of photochemical reactions in arenes, such as 1,2; 1,3; and 1,4-additions. 4) Design: Design experiments to study photochemical mechanisms using emission (fluorescence and phosphorescence) and absorption spectroscopy. This includes determining the energy and lifetime of singlet and triplet states, and studying quantum yields, including primary and product quantum yields, to assess the efficiency and outcomes of photochemical reactions.
Content Outline	General Principles-Importance and applications of photochemical processes, Mechanism of absorption of photochemically relevant radiation, Excitation and deactivation of molecules, Electronic transitions and states, Selection rules, notations, types and characteristics, Electron energy transfer, photosensitization and quenching processes. 1.2 Photochemistry of carbonyl compounds, $\pi \rightarrow \pi^*$, n $\rightarrow \pi^*$ transitions, Norrish type-I and Norrish type-II cleavages, Patterno-Buchhi reactions, photoreductions, photochemistry of enones, cyclohexadienones, rearrangements of α, β-unstaurated ketones. 1.3 Photochemistry of unsaturated system-olefins, cis-trans isomerizations and, Di-π methane rearrangement. 1.4 Photochemistry of arenes, 1, 2; 1,3 and 1,4

	additions. 1.5 Singlet oxygen and photooxygenation reactions. 1.6 Intramolecular Rearrangements: Rearrangements with trimesityl compound to enol ether, o-nitrobenzaldehyde to o-Nitrosobenzoic acid. Determination of photochemical mechanisms: Use of emission (fluorescence and phosphorescence) and absorption spectroscopy. Energy and life time of singlet and triplet states. The study of quantum yields: primary quantum yields, product quantum yields.
Module 2 (Credit 1) - Heterocyclic chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the principles of heterocyclic chemistry to classify and name both mono- and bicyclic fused heteroaromatic compounds using IUPAC and common nomenclature systems. This includes understanding their structure, classification, and reactivity. 2) **Analyze**: Analyze the reactivity and synthesis of various heterocycles, such as pyrazole, imidazole, oxazole, isoxazole, thiazole, benzimidazole, benzoxazole, benzthiazole, pyridine, and pyridine N-oxide. Evaluate their synthesis methods and applications, as well as their chemical behavior and reactivity. 3) **Evaluate**: Evaluate the methods of synthesis and applications of advanced heterocycles including pyridazine, pyrimidine, pyrazine, oxazine, quinoline, isoquinoline, coumarin, indole, purine, s-triazine, benzodiazepine, piperidine, and morpholine. Assess how their unique properties influence their uses in chemical and pharmaceutical applications. 4) **Design**: Design synthetic routes for the preparation of various heterocyclic compounds and propose their potential applications based on their chemical reactivity and properties. This includes creating strategies for the synthesis of both basic and complex heterocycles, and suggesting how they could be used in different fields such as medicinal chemistry and materials science.
Content Outline	Introduction, Classification, IUPAC and common names of mono-and bicyclic fused Heteroaromatic compounds. 1.2Reactivity, important general methods of synthesis and selected applications of the following heterocycles: Pyrazole, imidazole, oxazole, isoxazole, thiazole, benzimidazole, benzoxazole, benzthiazole,pyridine and pyridine N-oxide. Unit-IIHETEROCYCLIC CHEMISTRY-II [15L] Reactivity, important general methods of synthesis and selected applications of the following Heterocycles: Pyridazine, pyrimidine, pyrazine, oxazine, quinoline, isoquinoline, coumarin, indole, purine, s-triazine, benzodiazepine,piperidine, morpholine.
Module 3 (Credit 1) - Properties of Metallic clusters	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply knowledge of supported metallic clusters to describe their preparation methods and physical and chemical properties. This includes understanding the techniques used to create and stabilize these clusters, as well as their behavior under various conditions. 2) **Analyze**: Analyze the catalytic mechanisms of metallic clusters, including how they facilitate chemical reactions. Evaluate the effectiveness of different catalysts and their roles in various synthetic applications, considering factors such as reactivity, selectivity, and stability.

	3) **Evaluate**: Evaluate the performance of metallic clusters in catalytic processes by examining their efficiency and effectiveness in real-world applications. This involves assessing their impact on reaction outcomes, including yield, selectivity, and overall process optimization. 4) **Design**: Design new catalytic systems using metallic clusters by integrating knowledge of their properties and mechanisms. Create innovative approaches for utilizing these clusters in synthetic chemistry, aiming to enhance catalytic performance and address specific challenges in industrial and laboratory settings.
Content Outline	Supported metallic clusters, Catalysts preparation method, physical and chemical properties. Catalysis mechanism uses and synthetic applications
Module 4 (Credit 1) - Free Radicals	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply principles of radical chemistry to understand the formation, stability, and detection of both long-lived and short-lived radicals. Utilize methods for generating and identifying these radicals in various chemical contexts. 2) **Analyze**: Analyze the processes of homolysis and free radical displacements. Evaluate the mechanisms of radical reactions, including how radicals interact and influence chemical transformations in different environments. 3) **Evaluate**: Evaluate the outcomes of radical addition and rearrangement reactions. Assess the effectiveness and selectivity of these radical reactions in synthetic chemistry, including their impact on the overall reaction efficiency and product formation. 4) **Design**: Design synthetic pathways using radical cyclizations to create complex molecules. Utilize knowledge of radical behavior to develop innovative approaches for constructing target compounds, optimizing reaction conditions, and achieving specific synthetic goals.
Content Outline	Formation, stability and detection of long and short lived radicals, homolysis and free radical displacements, addition and rearrangement of free radicals, radical cyclizations and their applications in synthesis

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1:** Photochemistry, students can investigate the photochemical behavior of common compounds such as essential oils or simple organic dyes. Using household items like lemon juice or tea, students can study the effects of UV light on these substances to observe changes in color or chemical composition. They can design experiments to measure the photo-degradation or isomerization of these compounds, using UV lamps or sunlight, and analyze the results using basic spectroscopic techniques such as colorimetry. This project involves applying photochemical principles to real-world substances and understanding their practical implications.

- **Module 2:** Heterocyclic Chemistry, students could synthesize and study simple heterocyclic compounds like pyridine or imidazole derivatives using readily available chemicals. They can use standard laboratory techniques to prepare these compounds and then analyze their reactivity and properties. For example, they could perform reactions to test their nucleophilicity or electrophilicity and explore how these properties affect their reactivity. The project could involve synthesizing these compounds from common precursors and characterizing them using methods such as melting point determination and thin-layer chromatography.

- **Module 3:** Properties of Metallic Clusters, students could focus on the catalytic properties of common metallic materials, such as those found in household catalysts or automotive catalysts. They can perform simple experiments to test the catalytic activity of these materials in reactions like hydrogenation or oxidation. By using household or easily accessible chemicals, students can design experiments to evaluate the efficiency of these catalysts and analyze their performance. This project involves applying knowledge of metallic clusters to practical catalytic processes and understanding their impact on reaction outcomes.

- **Module 4:** Free Radicals, students can investigate radical reactions using simple organic compounds like styrene or methyl methacrylate. They can design experiments to generate and observe free radicals using initiation methods such as heat or UV light. By performing radical polymerization or addition reactions, students can study the formation and stability of radicals and analyze the impact of different conditions on the reaction outcomes. This project allows students to explore radical chemistry in a hands-on manner and understand its applications in organic synthesis.

References-

1. Sykes, P. (1986). *Organic reaction mechanism* (3rd ed.). Longman.
2. Morrison, R. T., & Boyd, R. N. (2011). *Organic chemistry* (7th ed.). Pearson.
3. Clayden, J., Greeves, N., Warren, S., & Wothers, P. (2012). *Organic chemistry* (2nd ed.). Oxford University Press.
4. Gould, E. S. (1991). *Mechanism and structure in organic chemistry*. Holt, Rinehart & Winston.

3.4 Major (Core)

Course Title	**Practical (Laboratory Course) (345311)**
Course Credits	**2**
Course Outcomes	After going through the module, learners will be able to 1) Analyze: Analyze the qualitative composition of ternary mixtures containing at least one liquid and one water-soluble compound. Develop skills to systematically identify and separate the components of complex mixtures through qualitative analysis techniques. 2) Apply: Apply laboratory techniques to carry out multi-step syntheses involving name reactions, condensations, cyclocondensations, and rearrangements. Perform and demonstrate proficiency in the preparation of compounds such as Phthalimide from Phthalic anhydride and Anthranilic acid, and the synthesis of Acetanilide from acetophenone. 3) Evaluate: Evaluate the efficiency and purity of synthesized products through column chromatography. Assess the effectiveness of separation techniques in isolating pure products from reaction mixtures, and identify any issues in the purification process. 4) Design: Design and execute synthetic routes for complex organic molecules, including phthalic anhydride derivatives and chlorobenzene transformations. Develop strategies for optimizing reaction conditions, and implement effective separation and purification methods to achieve high-quality products.
Module 1 (Credit 1) - Qualitative analysis techniques	
Learning Outcomes	After going through the module, learners will be able to 1) Apply: Apply qualitative analysis techniques to identify and separate components of ternary mixtures, ensuring accurate detection of at least one liquid and one water-soluble compound within the mixture. 2) Analyze: Analyze the results of qualitative tests on ternary mixtures to determine the presence and concentration of different components, utilizing methods such as solvent extraction and chemical reactions. 3) Evaluate: Evaluate the effectiveness of various separation and purification methods, including column chromatography, in achieving the desired purity and yield of the target compounds from complex mixtures. 4) Design: Design and conduct experiments involving multi-step syntheses and reactions, such as name reactions and condensations, to prepare and purify organic compounds, demonstrating proficiency in practical organic chemistry techniques.
Content Outline	Qualitative analysis of ternary mixtures. In a mixture at least one liquid one water soluble compound be given
Module 2 (Credit 1) - Separation Techniques	

Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply practical skills to execute multi-step organic synthesis reactions, such as the preparation of anthranilic acid from phthalic anhydride and phthalimide, demonstrating proficiency in handling name reactions and condensations. 2) **Analyze**: Analyze the results of column chromatography and other purification techniques to assess the purity and yield of synthesized products, such as acetanilide from acetophenone and oxime, ensuring effective separation of complex mixtures. 3) **Evaluate**: Evaluate the effectiveness of various reagents and methods used in cyclocondensation and rearrangement reactions, such as the synthesis of anthraquinone from phthalic anhydride and o-benzoyl benzoic acid, to optimize reaction conditions and product quality. 4) **Design**: Design and implement experimental procedures for the synthesis and purification of organic compounds, including the conversion of chlorobenzene to 2,4-dinitrophenol, incorporating appropriate techniques for separation and purification to achieve high-quality
Content Outline	Preparations involving at least two stage based on name reactions, condensations, cyclocondensations, reagents and rearrangements (as covered under the theory). Separation purification of the product by column is desired. 1. Phthallic anhydride – Phthallimide – Anthranillic acid. 2. cetophenone – Oxime – Acetanillide. 3. Phthalic anhydride – o – benzoyl benzoic acid anthraquinone. 4. Chlorobenzene – 2, 4 – dinitrochlorobenzene – 2,4- dinitrophenol

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1:** Qualitative Analysis Techniques, students can work on the analysis of a ternary mixture that includes a common liquid, such as ethanol, and a water-soluble compound, like sodium chloride. They will use qualitative tests to identify and separate these components. The project involves systematically applying techniques such as solvent extraction, precipitation, and specific chemical reactions to isolate each component. Students can then use qualitative analysis to confirm the identity of each component by performing characteristic tests and recording their results. This project helps develop skills in identifying and analyzing complex mixtures through practical laboratory techniques.

- **Module 2:** Separation Techniques, students can undertake a project involving the synthesis and purification of organic compounds. For example, they could synthesize acetanilide from acetophenone and oxime, followed by purification using column chromatography. The project would require students to carefully plan and execute the multi-step synthesis, then apply column chromatography to separate and purify the product. They would analyze the effectiveness of their purification process by comparing the yield and purity of the final product against theoretical expectations. This project emphasizes the practical application of synthetic techniques and purification methods in organic chemistry.

References-

1. Vogel, A. I. (1986). *Vogel's textbook of practical organic chemistry* (4th ed.). Longman.
2. Carey, F. A., & Sundberg, R. J. (2007). *Advanced organic chemistry: Part A and Part B* (5th ed.). Springer.
3. Zweifel, G. S., & Nantz, M. H. (2011). *Modern organic synthesis: An introduction*. W.H. Freeman.
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6. Hoffmann, R. V. (1989). *Organic chemistry: An intermediate text*. Springer.

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8. Norman, R. O. C., & Coxan, J. (2004). *Organic synthesis*. Oxford University Press.
9. Li, J. J. (2006). *Name reactions: A collection of detailed reaction mechanisms*. Springer.

3.5 A. Major (Elective)

Course Title	**Medicinal Chemistry (325311)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply concepts of pharmacodynamics to elucidate the mechanisms of drug action, including enzyme stimulation, enzyme inhibition, and membrane activity, to understand their therapeutic effects and limitations. 2) **Analyze**: Analyze the factors affecting drug metabolism and inactivation, including Phase I and Phase II reactions, to evaluate how these processes influence drug efficacy and safety. 3) **Evaluate**: Evaluate the pharmacokinetics of various drug classes by examining their absorption, distribution, metabolism, and excretion to assess their bioavailability and therapeutic outcomes. 4) **Design**/Create: Design and create synthetic pathways for key drug molecules such as anti-inflammatory agents, anti-hypertensives, CNS drugs, anesthetics, antibiotics, anti-diabetics, and anti-neoplastic drugs, and apply this knowledge to solve real-world medicinal chemistry problems.
Module 1 (Credit 1) - Basic consideration of drug activity	
Learning Outcomes	After going through the module, learners will be able to 1) Apply: Apply the definitions and concepts of drugs, prodrugs, agonists, antagonists, and other key terms to real-world examples to understand their roles in drug development and therapeutic applications. 2) Analyze: Analyze the factors affecting drug bioactivity, including affinity, efficacy, potency, and pharmacophores, to determine how these factors influence drug-receptor interactions and overall drug effectiveness. 3) Evaluate: Evaluate different theories of drug activity and structure-activity relationships (SAR) by examining case studies and drug design examples to assess their impact on drug development and efficacy. 4) Design: Design a drug development project incorporating QSAR (2D and 3D methods) and the Hantzsch equation to predict the activity and optimize the pharmacological properties of new drug candidates.
Content Outline	Definition and Introduction of following terms-Drug, Prodrug, Hard and Soft drugs, agonists, antagonists, affinity, efficacy, potency, isosterism, bioisosterism, pharmacophores, lead molecule, lethal dose (LD50) and effective dose (ED50) (i) Factors affecting bioactivity, (ii)Theories of drug activity, (iii) Structure activity relationship (SAR), QSAR (2D and 3D method) and Hantzsch equation (iv) Drug receptor mechanism. Classification of Drugs
Module 2 (Credit 1) – Pharmacodynamics	

Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the concepts of enzyme stimulation, enzyme inhibition, antimetabolites, membrane-active drugs, and chelation to understand their mechanisms of action and their effects on biological systems. 2) **Analyze**: Analyze the factors affecting drug metabolism and inactivation, including metabolic (Phase I) and conjugation (Phase II) reactions, to evaluate their impact on drug efficacy and safety. 3) **Evaluate**: Evaluate the effectiveness and potential side effects of drugs by assessing how different mechanisms of drug action and metabolism influence pharmacokinetics and pharmacodynamics. 4) **Design**: Design experimental protocols to investigate the impact of drug metabolism and inactivation on drug interactions and therapeutic outcomes, incorporating both Phase I and Phase II metabolic pathways.
Content Outline	1. Mechanism of drug action: Enzyme stimulation and enzyme inhibition, anti-metabolites, membrane active drugs, chelation; 2. Drug metabolism and inactivation: Factors affecting drug metabolism, pathways of drug metabolism [Metabolic reaction (Phase I) and conjugation reaction (Phase II)]
Module 3 (Credit 1) – Pharmacokinetics	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply knowledge of drug absorption, distribution, and deposition to predict the pharmacokinetic behavior of new drug formulations in different physiological conditions. 2) **Analyze**: Analyze the processes of drug excretion and elimination to determine their impact on drug dosing regimens and therapeutic efficacy. 3) **Evaluate**: Evaluate the bioavailability of drugs through comparative studies of various drug delivery methods and their influence on therapeutic outcomes. 4) **Design**: Design a study to investigate the pharmacokinetic profile of a new drug, including its absorption, distribution, metabolism, and excretion, to optimize its clinical application and dosing strategy.
Content Outline	1. Drug absorption, Distribution and deposition of drugs. 2. Excretion and elimination of drugs, Bioavailability.
Module 4 (Credit 1) - Synthesis and applications of the drug molecules	
Learning Outcomes	After going through the module, learners will be able to 1. **Apply**: Apply the knowledge of anti-inflammatory and anti-hypertensive drugs to recommend appropriate treatment plans for conditions such as chronic pain and hypertension. 2. **Analyze**: Analyze the pharmacological effects of drugs acting on the central nervous system (CNS), including stimulants, depressants, and anesthetics, to determine their therapeutic and adverse effects. 3. **Evaluate**: Evaluate the effectiveness of various antibiotics and antiviral drugs by comparing their mechanisms of action, resistance patterns, and clinical outcomes in the treatment of infectious diseases. 4. **Design**: Design a synthesis pathway for selected antidiabetic or antineoplastic drugs, incorporating key reactions and mechanisms covered in the course, to optimize drug efficacy and minimize side effects.

Content Outline	1. Anti inflammatory Drugs: (a) Naproxen (b) Ibuprofen (c) Oxaprozin (d) Diclofenac Sodium (e) Rofecoxib (f) Celecoxib. 2. Anti-hypertensive Drugs: (a) Verapamil (b) Captopril (c) d-sotalol (d) Atenolol (e) Diltiazem (f) Semotiadil fumarate. 3. Drugs acting on CNS: (a) CNS Stimulant : Dextro-amphetamine (b) Respiratory Stimulant : Doxapram (c) CNS anti-depressant : (i) Chlorpromazine (Antipsychotic) (ii) Diazepam (Anxiolytic) (iii) Phenobarbitol (Antiepileptic) 120 4. Anesthetic Drugs (a) General : Ketamine (b) Local : (i) Lidocaine (ii) Procaine 5. Antibiotics: (a) Chloramphenicol (b) Ampicillin (c) Amoxycillin (d) Cefepime (e) Cefpirome (f) Antimycobactrial: Ethambutol (g) Antiviral: Acyclovir (h) Antimicrobial: Sulfamethoxazole 6. Antidiabetics : (a) Troglitazone (b) Chlorpropamide (c) Tolbutamide VII. Antineopastic Drugs: (a) Antagonist: Fluorouracil (b) Alkylating agents: i) Chlorambucil

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1: Basic Consideration of Drug Activity**
  For this project, students will explore the concept of prodrugs by designing and testing simple prodrug models using readily available substances. The objective is to understand how prodrugs are converted into active forms within the body and their potential therapeutic applications. Students can use common kitchen chemicals and over-the-counter medications for their experiments. They will prepare prodrug samples, simulate biological conditions (e.g., acidic or basic solutions), and observe the conversion to active forms using simple analytical techniques such as pH measurement or color change indicators. This project can be conducted at home or in a community lab with basic equipment.

- **Module 2: Pharmacodynamics**
  Students will investigate the effects of enzyme inhibitors on a common biological reaction, such as the breakdown of hydrogen peroxide using catalase. The objective is to understand enzyme inhibition and its impact on drug action. They will use hydrogen peroxide, a source of catalase (e.g., raw liver or potato), and potential enzyme inhibitors (e.g., specific acids or salts). The experiment involves measuring the rate of reaction with and without inhibitors, using simple equipment like test tubes and a stopwatch. This project can be done at home with basic lab supplies or in a local laboratory.

- **Module 3:Pharmacokinetics**
  Students will study the effect of different substances on the absorption of a model drug by creating a simulated gastrointestinal environment. The objective is to understand how factors such as pH and the presence of food affect drug absorption. Students will use a common over-the-counter medication, various food items (e.g., acidic or fatty foods), and pH indicators. They will dissolve the drug in simulated gastric fluids, add different food substances, and measure changes in drug solubility or absorption using simple filtration and measurement techniques. This project can be done at home with basic supplies or in a community lab.

- **Module 4:Synthesis and Applications of Drug Molecules**
  Students will design a simple synthetic pathway for a common anti-inflammatory drug, such as ibuprofen, using household chemicals and reagents. The objective is to understand the basic principles of drug synthesis and the key reactions involved. They will create a step-by-step synthesis plan, conduct small-scale reactions using safe and accessible chemicals, and analyze the products using simple techniques like colorimetry or pH testing. This project can be performed at home with careful safety measures or in a local lab with access to basic chemical supplies.

References-

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2. Gringuage, A. (2004). *Introduction to medicinal chemistry*. Wiley-VCH.
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6. Korolkovas, A. (2004). *Essentials of medicinal chemistry* (2nd ed.). Wiley-VCH.

3.5 B. Major (Elective)

Course Title	**Organic Synthesis (325312)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) Apply: Apply the principles of radical chemistry to execute organic syntheses involving C-C bond formation, radical trapping, and functional group transformations using various radical-generating reagents. 2) Analyze: Analyze the reactivity and synthetic utility of organolithium, organosilicon, and organotin reagents in forming carbon-carbon and carbon-heteroatom bonds in complex organic molecules. 3) Evaluate: Evaluate the role of transition metals, particularly palladium and rhodium, in facilitating key organic transformations such as C-C bond formation, olefin metathesis, and carbonylation reactions, following the 18-electron rule and related concepts. 4) Design: Design synthetic pathways incorporating rare-earth metals like Samarium iodide and Cerium (IV) as catalysts to achieve selective and efficient organic reactions, including aldol condensations and Diels-Alder reactions.
Module 1 (Credit 1) - Radicals in organic synthesis	
Learning Outcomes	After going through the module, learners will be able to 1) Apply: Apply knowledge of electrophilic and nucleophilic radicals to predict and execute C-C bond formation in aliphatic and aromatic compounds using appropriate radical-generating reagents. 2) Analyze: Analyze the mechanisms underlying radical-mediated processes such as Barton's radical decarboxylation and Hunsdiecker halodecarboxylation to understand the cleavage of C-X, C-Sn, C-Co, and C-S bonds. 3) Evaluate: Evaluate the effectiveness of radical-radical coupling reactions, including oxidative couplings and single electron oxidation of carbanions, in synthesizing complex organic molecules. 4) Design: Design synthetic strategies involving radical reactions on π-rich and π-deficient olefins, leveraging electron transfer reactions and radical trapping methods to achieve desired organic transformations.
Content Outline	General aspects: Electrophilic and nucleophilic radicals and their reactivities with π-rich/deficient olefins. .Inter- and intramolecular aliphatic C-C bond formation via mercury hydride, tin hydride, carbon hydride, thio donor (Barton's radical decarboxylation reaction). .Cleavage of C-X, C-Sn, C-Co and C-S bonds in the generation of radicals. Trapping by electron transfer reactions using Mn(OAc)3. Radical–Radical processes: oxidative couplings, single electron oxidation of Carbanions to generate radicals, dehydrodimerization and Reductive couplings. C-C bond formation in aromatics: Introduction, radical reactions on aromatics, electrophilic radical reactions, nucleophilic radicals, Radical reactions on heteroaromatics–alkylations and acylations. .Hunsdieckerhalode carboxylation, Barton-McCombie alcohol deoxygenation, Kuivila Beckwith and Stork radical
Module 2 (Credit 1) - Metals/Non-Metals In Organic Synthesis	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the principles of organolithium and organocuprate chemistry to synthesize organic compounds, including the use of directed metallation techniques. 2) **Analyze**: Analyze the mechanisms and regiochemistry of hydroboration and

	oxymercuration-demercuration reactions, particularly focusing on asymmetric hydroboration and solvomercuration processes. 3) **Evaluate**: Evaluate the reactivity and synthetic applications of organosilicon and organotin compounds, with emphasis on their roles in C-C bond formation and functional group transformations. 4) **Design**: Design synthetic pathways involving the use of selenium-based reagents for the generation of unsaturated compounds and the activation of ɑ-C-H bonds through selenoxide elimination and seleno-acetals.
Content Outline	Organolithium reagents, Prep and synthetic applications, including directed metallation. Organocupurate reagents. Applications of boron: generation of diborane, hydroboration/oxidation of alkenes, alkynes – mechanism, regiochemistry and stereochemistry. Asymmetric hydroboration using chiral borane reagents, functional groups reduction by diborane.Mercury in organic synthesis: Oxymercuration-demercuration of alkenes, mechanism and regiochemistry, solvomercuration and intramolecularmercuration. Mercuration of aromatics and transformation of aryl-mercurals to aryl halides. Organosilicons: Important features of silicon governing the reactivity of C-Si compounds: Preparation and important C-C bond forming reactions of alkyl silanes, alkenylsilanes, aryl silanes and allylsilanes. Silylenol ethers as enolate precursors. Iodotrialkylsilane and tralkylsilylcyanide in organic synthesis.Organotin compounds: Preparation of alkenyl/aryl and allyl tin compounds and their acylation and Michael reactions. Selenium in organic synthesis: preparation of selenols/selenoxide, selenoxide elimination to create unsaturation, selenoxide and seleno-acetals as α-C-H activating groups
Module 3 (Credit 1) - Transition metals In Orgainc Synthesis	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the 18-electron rule to predict the stability and reactivity of organometallic complexes in organic synthesis. 2) **Analyze**: Analyze the mechanisms of key organometallic reactions such as oxidative addition, reductive elimination, and substitution, with a focus on Pd and Rh catalysts. 3) **Evaluate**: Evaluate the effectiveness of Pd and Rh catalyzed C-C bond formation reactions, including the Wacker process, Heck reaction, and Negishi coupling, in synthesizing complex organic molecules. 4) **Design**: Design synthetic strategies involving olefin metathesis and the use of nickel, cobalt, iron, and chromium carbonyls for the formation of carbon-carbon and carbon-heteroatom bonds in organic synthesis.
Content Outline	Basic concepts, 18 electron rule, oxidative addition, reductive elimination, substitution. Pd and Rh in organic synthesis: π-bonding of Pd and Rh with olefins, applications in C-C bond formations including Wacker process, Heck reaction, Negishi coupling reactions, Carbonylation, hydroformylation, decarbonylation, olefin isomerism, aryl amination using Pd reagents. Olefin metathesis (RCM) using catalysis. Applications of nickel, cobalt, iron and chromium carbonyls in organic synthesis
Module 4 (Credit 1) - Rare-Earth Metals in organic synthesis	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the use of Samarium iodide and Cerium (IV) in reducing functional groups and facilitating challenging organic transformations. 2) **Analyze**: Analyze the catalytic efficiency and water tolerance of $Eu(OTf)_3$ and $Sc(OTf)_3$ in various organic reactions, including aldol condensation and Michael reactions. 3) **Evaluate**: Evaluate the role of rare-earth metals, particularly $Eu(OTf)_3$ and $Sc(OTf)_3$, in promoting Diels-Alder and aza-Diels-Alder reactions, comparing their performance to traditional catalysts. 4) **Design**: Design synthetic routes incorporating rare-earth metal catalysts

	for complex acylation reactions, leveraging their unique reactivity and selectivity.
Content Outline	Selected applications of Samarium iodide, and Cerium (IV), in organic synthesis. 4.5.Eu(OTf)3 and Sc(OTf)3 as efficient, water tolerant Lewis acid catalysts in aldol condensation, Micheal reactions, Diels-Alder and aza-Diels-Alder reactions, acylation reactions .

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1: Radicals in Organic Synthesis**
  Students will undertake a project to synthesize and characterize a simple radical-initiated reaction, such as the coupling of aliphatic radicals using tin hydride. The goal is to understand radical mechanisms and their application in organic synthesis. Students will use readily available chemicals like acetone and tin hydride or other common radical initiators, along with standard laboratory glassware and techniques. They will perform the radical coupling reaction, analyze the products using basic methods such as thin-layer chromatography (TLC) or simple spectroscopic techniques, and discuss the reaction mechanism and efficiency. This project can be carried out at home with proper safety precautions or in a community laboratory.

- **Module 2: Metals/Non-Metals in Organic Synthesis**
  For this project, students will explore the use of organolithium reagents in a model reaction, such as the synthesis of a simple ~~alcohol~~ from an aldehyde. The objective is to apply organolithium chemistry in organic synthesis and understand its reactivity. Students will use commercially available organolithium reagents and aldehydes, along with basic lab equipment. They will perform the reaction, monitor it using TLC, and analyze the products by simple techniques like melting point determination or NMR if available. The project can be completed at home or in a local lab with the necessary safety measures and equipment.

- **Module 3: Transition Metals in Organic Synthesis**
  Students will design a project to investigate a palladium-catalyzed coupling reaction, such as the Heck reaction, using accessible materials. The goal is to apply the principles of transition metal catalysis in organic synthesis. Students will use palladium catalysts, common olefins, and aryl halides, with basic laboratory setups for reaction and analysis. They will perform the Heck reaction, monitor the progress using TLC, and evaluate the products' yield and purity. The project can be conducted at home with safety precautions or in a community lab with necessary reagents and equipment.

- **Module 4: Rare-Earth Metals in Organic Synthesis**
  In this project, students will explore the use of Samarium iodide in a reduction reaction, such as the reduction of a ketone to an alcohol. The objective is to understand the role of rare-earth metals in organic transformations. Students will use Samarium iodide, ketones, and standard reduction conditions, along with basic laboratory equipment. They will perform the reduction reaction, analyze the product using TLC or simple spectroscopic techniques, and discuss the efficiency and selectivity of Samarium iodide. This project can be carried out at home with appropriate safety measures or in a local laboratory with access to the necessary materials.

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3.5 C. Major (Elective)

Course Title	**Natural Products (325313)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) Apply: Apply knowledge of the structure and stereochemistry of steroids, alkaloids, terpenoids, carotenoids, anthocyanins, and flavones in understanding their physiological roles and synthesis. 2) Analyze: Analyze the structure elucidation methods for various natural products, including bile acids, alkaloids, and terpenoids, to determine their chemical and biological properties. 3) Evaluate: Evaluate the synthesis routes and stereochemical aspects of key natural products such as testosterone, nicotine, menthol, and quercetin, considering their industrial and pharmacological significance. 4) Design: Design synthetic strategies for complex natural products, utilizing key principles from the study of steroids, alkaloids, terpenoids, and flavones to achieve desired structural and stereochemical outcomes.
Module 1 (Credit 1) - Steroids	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the principles of steroid chemistry to identify and classify the basic skeleton and stereochemistry of various steroid molecules, including bile acids, androsterone, testosterone, estrone, and progesterone. 2) **Analyze**: Analyze the occurrence and nomenclature of steroids, correlating their structural features with their biological functions and chemical properties. 3) **Evaluate**: Evaluate the methods used for the isolation and structure determination of steroids, assessing their effectiveness in elucidating the detailed structure of bile acids and hormones like testosterone and progesterone. 4) **Design**: Design synthetic pathways for the laboratory synthesis of key steroid molecules such as bile acids, androsterone, and estrone, incorporating stereochemical considerations and advanced synthetic techniques.
Content Outline	Occurrence, nomenclature, basic skeleton, Diel's hydrocarbon and stereochemistry. Isolation, structure determination and synthesis of Bile acids, Androsterone, Testosterone, Estrone, Progestron
Module 2 (Credit 1) – Alkaloids	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the principles of alkaloid chemistry to determine the physiological actions and roles of various alkaloids in plants, including ephedrine, (+)-coniine, nicotine, atropine, quinine, and morphine. 2) **Analyze**: Analyze the structure and stereochemistry of alkaloids, using general methods of structure elucidation to identify and classify their nitrogen heterocyclic rings and degradation pathways. 3) **Evaluate**: Evaluate the effectiveness of different isolation and structure elucidation techniques for alkaloids, comparing their impact on understanding the chemical properties and physiological effects of compounds such as quinine and morphine.

	4) **Design**: Design synthetic strategies for the preparation of key alkaloids, including ephedrine and atropine, incorporating considerations of stereochemistry and structure-activity relationships.
Content Outline	Definition, nomenclature and physiological action, occurrence, isolation, general methods of structure elucidation, degradation, classification based on nitrogen heterocyclic ring, role of alkaloids in plants. Structure, stereochemistry and synthesis of the following: Ephedrine, (+)- coniine, nicotine, atropine, Quinine and Morphine.
Module 3 (Credit 1) - Terpenoids & Carotenoids	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply the isoprene rule to classify and name various terpenoids and carotenoids, such as citral, geraniol, and β-carotene, and describe their occurrence and isolation techniques. 2) **Analyze**: Analyze the structure and stereochemistry of representative molecules like α-terpineol, menthol, and abietic acid using general methods of structure determination to understand their chemical properties and functions. 3) **Evaluate**: Evaluate different synthesis methods for terpenoids and carotenoids, including citral and farnesol, assessing their efficiency and effectiveness in producing these compounds with the desired stereochemistry. 4) **Design**: Design a synthetic route for the preparation of complex terpenoids and carotenoids, such as zingiberene and phytol, incorporating considerations of molecular structure, stereochemistry, and reactivity.
Content Outline	Classification, Nomenclature, occurrence, isolation, general methods of structure determination, isoprene rule, Structure determination, stereochemistry, and synthesis of the following representative molecules: Citral, Geraniol, α-Terpineol, Menthol, Farnesol, Zingiberene, Phytol, Abietic acid and β- Carotene.
Module 4 (Credit 1) - Anthocyanins and Flavones	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply**: Apply general methods of structure determination to identify and characterize anthocyanins and flavones, including cyanidin chloride, cyanin, and hirsutidin chloride, based on their occurrence and nomenclature. 2) **Analyze**: Analyze the synthesis processes of flavonoids, such as flavones (using Kostanecki and Baker-Venkataraman approaches) and flavonols, to understand their chemical transformations and the influence of different synthetic methods on their final structure. 3) **Evaluate**: Evaluate the chemical properties and physiological effects of anthocyanins like cyanidin chloride and cyanin by comparing their synthesis and structural features with those of flavones and flavonols. 4) **Design**: Design a synthetic strategy for the preparation of complex flavonoid compounds, including isoflavones and quercetin, taking into account the principles of structure determination, stereochemistry, and reactivity.
Content Outline	Occurrence, nomenclature and general methods of structure determination. Synthesis of cyanidin chloride, cyanin, Hirsutidin chloride, Flavones (Kostanecki and Baker-Venkataraman approaches), Flavonols, Qurcetin, and Isoflavones

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1: Steroids**
  Students will conduct a project to synthesize a simple steroid derivative, such as cholesterol, from commercially available starting materials. The objective is to understand the basic principles of steroid chemistry and synthesis. Students will use available reagents and simple laboratory equipment to carry out the synthesis, such as the oxidation of cholesterol to form its derivative. They will analyze the product using techniques like TLC or melting point determination and compare it to known steroid structures. This project can be completed at home with basic safety measures or in a community laboratory with access to necessary chemicals and equipment.

- **Module 2: Alkaloids**
  In this project, students will focus on the extraction and preliminary characterization of an alkaloid from a common plant source, such as nicotine from tobacco leaves. The objective is to apply extraction techniques and understand the basic structure and physiological roles of alkaloids. Students will use simple extraction methods, such as solvent extraction, and perform basic tests to confirm the presence of nicotine. They will analyze the alkaloid using simple methods like TLC or basic color reactions. This project can be conducted at home with careful handling of materials or in a community lab.

- **Module 3: Terpenoids & Carotenoids**
  Students will design a project to synthesize a common terpenoid, such as limonene, using accessible starting materials and reagents. The goal is to understand the application of the isoprene rule in terpenoid synthesis. Students will use readily available chemicals and perform the synthesis in a controlled environment. They will analyze the product using techniques such as GC-MS or TLC to confirm the structure and purity. This project can be done at home with safety precautions or in a local laboratory with necessary reagents and equipment.

- **Module 4: Anthocyanins and Flavones**
  For this project, students will synthesize a simple flavonoid, such as flavone, using basic organic chemistry techniques. The objective is to apply structure determination and synthesis methods to flavonoids. Students will use commercially available starting materials and perform the synthesis using standard organic reactions. They will analyze the product using simple methods like UV-Vis spectroscopy or TLC and compare it to known flavonoid structures. This project can be carried out at home with appropriate safety measures or in a community lab with access to necessary materials and equipment.

References-

1. Silverman, R. B. (2004). *The organic chemistry of drug design and drug action*. Academic Press.
2. Mann, J., Davidson, R. S., Hobbs, J. B., Banthrope, D. V., & Harborne, J. B. (1994). *Natural products: Chemistry and biological significance*. Longman.
3. Finar, I. L. (1975). *Organic chemistry: Vol. II* (5th ed.). ELBS.
4. Bohm, B. A. (1998). *Introduction to flavonoids*. Harwood Academic Publishers.
5. Atta-ur-Rahman, & Choudhary, M. I. (2001). *New trends in natural product chemistry*. Harwood Academic Publishers.
6. Kumar, B., & Chopra, H. (1994). *Biogenesis of natural products*. Springer.

3.6 Research Project

Course Title	**Research Project Part – I (355311)**
Course Credits	**4**
Course Outcomes	After this course, the students will be able to, 1) **Apply** advanced analytical techniques to investigate complex research questions 2) **Design** and execute experiments to collect and analyze data in analytical chemistry.
Module 1 (Credit 1) - Research Proposal Development	
Learning Outcome	1) **Identify** research gaps specific to analytical chemistry and formulate clear research objectives and hypotheses. 2) **Design** robust experimental methodologies to effectively address the identified research questions.
Content Outline	**Guidelines for Students:** • **Tasks:** Engage in an extensive literature review focusing on analytical chemistry to identify gaps and emerging research areas. • **Approach:** Develop clear research objectives and hypotheses based on identified gaps. Discuss potential experimental designs with faculty for feasibility and relevance.
Module 2 (Credit 1) - Experimental Setup and Data Collection	
Learning Outcome	1) **Implement** experimental protocols meticulously to ensure accuracy and reliability in data collection. 2) **Maintain** detailed records of experimental procedures to facilitate reproducibility and comprehensive analysis.
Content Outline	**Guidelines for Students:** • **Tasks:** Implement designed experimental protocols with meticulous attention to detail and accuracy. • **Approach:** Record experimental procedures comprehensively, including variables, controls, and data collection methods. Use standardized techniques and equipment under supervision.
Module 3 (Credit 1) - Data Analysis and Interpretation	
Learning Outcomes	1) **Perform** preliminary data analysis using appropriate statistical tools to validate experimental methods and ensure robustness. 2) **Interpret** initial findings and integrate results with existing knowledge to refine research hypotheses in analytical chemistry.

Content Outline	**Guidelines for Students:** ● **Tasks:** Conduct preliminary data analysis using statistical software to validate experimental results. ● **Approach:** Interpret findings in the context of existing literature. Discuss with peers and faculty to refine interpretations and implications for further experimentation.
Module 4 (Credit 1) - Interim Report and Presentation Preparation	
Learning Outcome	1) Compile an interim report summarizing research progress, including challenges encountered and preliminary conclusions. 2) Prepare and deliver a structured presentation outlining research objectives, methodologies, and initial findings to solicit constructive feedback.
Content Outline	**Guidelines for Students:** ● **Tasks:** Compile a comprehensive interim report documenting research progress, challenges, and preliminary conclusions. ● **Approach:** Develop a structured presentation highlighting research objectives, methodologies, and initial findings. Practice presentation skills and incorporate feedback for clarity and coherence

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

Module 1 (Credit 1) - Research Proposal Development
Assessment Components:

1. **Literature Review (30%):**
    - **Task:** Submit a comprehensive literature review identifying gaps and emerging areas in analytical chemistry.
    - **Evaluation Criteria:** Depth of research, clarity in identifying research gaps, relevance to current trends, and integration of sources.
2. **Research Objectives and Hypotheses (20%):**
    - **Task:** Develop and submit clear research objectives and hypotheses based on the literature review.
    - **Evaluation Criteria:** Clarity, feasibility, alignment with identified research gaps, and potential impact.
3. **Experimental Design Discussion (20%):**
    - **Task:** Present potential experimental designs to faculty for feedback and feasibility assessment.
    - **Evaluation Criteria:** Robustness of experimental design, feasibility, alignment with research objectives, and thoroughness of preparation.
4. **Participation and Engagement (10%):**
    - **Task:** Actively participate in discussions with faculty and peers.
    - **Evaluation Criteria:** Contribution to discussions, receptiveness to feedback, and collaborative engagement.

Module 2 (Credit 1) - Experimental Setup and Data Collection
Assessment Components:

1. **Experimental Protocol Implementation (30%):**
    - **Task:** Submit a detailed report on the implementation of experimental protocols.

    - **Evaluation Criteria:** Accuracy, attention to detail, adherence to protocols, and thorough documentation.
2. **Record Keeping (20%):**
    - **Task:** Maintain and submit detailed records of experimental procedures.
    - **Evaluation Criteria:** Completeness, clarity, reproducibility, and thoroughness.
3. **Standardized Techniques Usage (20%):**
    - **Task:** Demonstrate proper usage of standardized techniques and equipment under supervision.
    - **Evaluation Criteria:** Proper usage, adherence to standards, accuracy, and compliance with supervision.
4. **Participation and Engagement (10%):**
    - **Task:** Actively participate in experimental activities and discussions.
    - **Evaluation Criteria:** Contribution to team efforts, engagement in the process, and responsiveness to supervision.

Module 3 (Credit 1) - Data Analysis and Interpretation
Assessment Components:

1. **Preliminary Data Analysis (30%):**
    - **Task:** Submit a preliminary data analysis report using appropriate statistical tools.
    - **Evaluation Criteria:** Correctness, application of statistical methods, validation of results, and thoroughness.
2. **Interpretation of Findings (20%):**
    - **Task:** Submit a report interpreting initial findings in the context of existing literature.
    - **Evaluation Criteria:** Depth of analysis, integration with existing knowledge, clarity of interpretation, and alignment with research hypotheses.
3. **Peer and Faculty Discussion (20%):**
    - **Task:** Participate in discussions with peers and faculty to refine interpretations.
    - **Evaluation Criteria:** Constructive engagement, openness to feedback, and ability to refine hypotheses.
4. **Participation and Engagement (10%):**
    - **Task:** Actively participate in data analysis activities and discussions.
    - **Evaluation Criteria:** Contribution to team efforts, engagement in the process, and responsiveness to feedback.

Module 4 (Credit 1) - Interim Report and Presentation Preparation
Assessment Components:

1. **Interim Report (30%):**
    - **Task:** Submit a comprehensive interim report documenting research progress, challenges, and preliminary conclusions.
    - **Evaluation Criteria:** Completeness, clarity, thoroughness, and organization.
2. **Structured Presentation (20%):**
    - **Task:** Prepare and deliver a structured presentation outlining research objectives, methodologies, and initial findings.
    - **Evaluation Criteria:** Structure, clarity, coherence, and effectiveness of communication.
3. **Feedback Incorporation (20%):**
    - **Task:** Incorporate feedback from the presentation into the research process.
    - **Evaluation Criteria:** Responsiveness to feedback, clarity of revisions, and improvement in presentation skills.
4. **Participation and Engagement (10%):**
    - **Task:** Actively participate in presentation preparation and delivery.

- **Evaluation Criteria:** Contribution to team efforts, engagement in the process, and responsiveness to feedback

References-

1) Harris, D. C. (1982). Quantitative chemical analysis. W Freeman.
2) Skoog, D. A. (n.d). Fundamentals of analytical chemistry. Saunders College Publishing.
3) Christian, G. D. (n.d). Analytical chemistry. John Wiley & Sons.
4) Hage, D. (n.d). Analytical chemistry and quantitative analysis. Cengage Learning.
5) Fifield, F. W., & Kealey, D. (n.d). Principles and practice of analytical chemistry. Blackwell Science.
6) Harvey, D. (2016). Analytical chemistry 2.1. Lulu Press

Semester IV

4.1 Major (Core)

Course Title	**Organic Chemistry – I (415311)**
Course Credits	**4**
Course Outcomes	After going through the module, learners will be able to 1) **Apply** the principles of drug design and discovery to predict potential lead compounds by analyzing disease targets, bioassays, and drug-receptor interactions. 2) **Analyze** the structure and reactivity of various heterocyclic compounds, classifying them based on ring size and aromaticity to determine their roles in organic synthesis. 3) **Evaluate** different synthetic routes and reaction mechanisms, applying name reactions and spectral analysis to the synthesis of complex heterocyclic compounds. 4) **Design** environmentally friendly organic synthesis processes by integrating the twelve principles of green chemistry, selecting alternative reagents, catalysts, and solvents.
Module 1 (Credit 1) – Principles of Drug design and drug discovery	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the stages of drug discovery to identify and develop potential lead compounds by screening natural products and synthetic libraries, considering pharmacokinetics and pharmacodynamics principles. 2) **Analyze** the nature of drug-receptor interactions and evaluate various theoretical models (e.g., Occupancy theory, Induced-fit theory) to understand the mechanisms of drug action and receptor activation. 3) **Evaluate** the role of natural products, hormones, and neurotransmitters in drug discovery, assessing their potential as lead structures for the design of new therapeutic agents. 4) **Design** specific agonists, antagonists, and enzyme inhibitors by applying principles of structure pruning and pharmacophore modeling, aiming to optimize drug-receptor interactions for improved therapeutic outcomes.
Content Outline	Introduction to drug discovery, Folklore drugs, stages involved in drug discovery- disease, drug targets, bioassay. Discovery of a lead, screening of natural products and synthetic compound libraries. Pharmacokinetics (ADME), pharmacodynamics, Nature of drug-receptor interactions and their theories-Occupancy theory, Induced-fit theory, Macromolecular purturbation theory and Two-state model of receptor activation. Natural products as lead structures in drug discovery, Pharmacophore, structurepruning technique e.g. morphine. Discovery of lead structure from natural hormones and neurotransmitters, Principle of design of agonists (e.g.Salbutamol),antagonists(e.g.cimitidine) and enzyme inhibitors
Module 2 (Credit 1) – Heterocyclic compounds	

Learning Outcomes	After going through the module, learners will be able to 1) **Apply** the rules of chemical nomenclature to correctly name a wide range of heterocyclic compounds, ensuring accurate communication of molecular structures. 2) **Analyze** various heterocyclic ring systems by classifying them based on ring size, aromaticity, and electronic properties to determine their chemical behavior and potential applications. 3) **Evaluate** the significance of different heterocyclic structures in organic chemistry, comparing their stability and reactivity to predict their roles in synthetic reactions and pharmaceutical applications. 4) **Design** systematic approaches for the synthesis and functionalization of heterocyclic compounds by utilizing knowledge of their classification and nomenclature, tailoring properties for specific chemical or biological functions.
Content Outline	Nomenclatures of all types of heterocycles, Classification of heterocycles: as aromatics based upon various memberedring systems
Module 3 (Credit 1) – OrganicSynthesis	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** knowledge of name reactions to synthesize various four-, five-, and six-membered heterocyclic compounds, such as Azitidines, Thiazoles, Pyridines, and Pyrimidines, considering their reactivity and utility in organic synthesis. 2) **Analyze** the reactivity and functional properties of fused heterocyclic systems like Flavones, Chromones, and Indoles, by examining their synthetic routes and comparing spectral data for structure confirmation. 3) **Evaluate** the efficiency and applicability of different synthetic routes for the production of complex heterocyclic compounds, such as Benzodiazepines and Phenothiazines, to optimize reaction conditions and yield. 4) **Design** advanced synthetic strategies for constructing diverse heterocyclic frameworks, integrating name reactions and spectral analysis to achieve targeted chemical transformations for specific applications.
Content Outline	General synthetic routes based on name reactions, reactivities, utilitiesand wherever possible spectral analyses of the following class ofheterocycles. Four-membered: Azitidines,includingβ-lactums. Five membered: Thiazoles, Oxazoles, Pyrazoles and Imidazoles Six membered: Pyridines, Pyrimidines. Fused heterocycles: Flavones, Chromones, Coumarines,Indoles, Quinolines, Benzodiazepines, and Phenothiazines
Module 4 (Credit 1) – Introduction to Green Chemistry	
Learning Outcomes	After going through the module, learners will be able to 1) **Apply** Anastas' twelve principles of green chemistry to various chemical processes, selecting alternative starting materials, reagents, and catalysts to minimize environmental impact. 2) **Analyze** the relevance and effectiveness of green chemistry tools, such as eco-friendly solvents and sustainable processes, by comparing them with traditional chemical methods. 3) **Evaluate** the environmental and economic benefits of implementing green chemistry principles in industrial and laboratory settings, assessing their potential to reduce waste and energy consumption. 4) **Design** innovative green chemical processes by integrating alternative materials and catalysts, aiming to create more sustainable and less

	hazardous chemical syntheses.
Content Outline	Green chemistry, relevance and goals, Anastas' twelve principles of green chemistry-Tools of green chemistry: alternative starting materials, reagents, catalysts, solvents and processes with suitable examples.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

- **Module 1: Principles of Drug Design and Drug Discovery** Design a project to screen common household or garden plants for potential bioactive compounds using simple extraction methods. The objective is to identify plants that may have therapeutic properties by performing basic tests for antioxidant activity or preliminary phytochemical screening. Resources can include solvents like ethanol or water, simple laboratory glassware, and available plant material. The project can be done at home or in a local community lab. Methodology involves extracting plant materials, testing the extracts using basic assays, and analyzing the results to suggest potential leads for further study.

- **Module 2:Heterocyclic Compounds** Conduct a project to synthesize and analyze simple heterocyclic compounds from commercially available chemicals or household substances. For example, students can prepare pyridine or imidazole derivatives using readily accessible starting materials and simple reaction setups. The project involves designing the synthesis route, performing the reactions, and characterizing the products using basic techniques like melting point determination or UV-Vis spectroscopy, which can be done in a local lab. The goal is to understand the synthesis and properties of heterocycles through hands-on experience.

- **Module 3:Organic Synthesis** Design a project to synthesize a specific heterocyclic compound such as a benzodiazepine or a flavone using simple organic reactions. Students can use household chemicals or easily obtained laboratory reagents to carry out the synthesis. The project should include a step-by-step synthesis plan, including reaction setup and purification techniques such as re-crystallization. Characterization can be done using basic tools like thin-layer chromatography (TLC) or melting point apparatus. This project can be executed in a home lab or a nearby community lab, with an emphasis on understanding synthetic routes and evaluating the product.

- **Module 4:Introduction to Green Chemistry** Develop a project to redesign a traditional chemical process using green chemistry principles. Students can choose a simple chemical reaction or process (e.g., esterification) and explore ways to make it more environmentally friendly by selecting alternative, less toxic reagents or solvents. The project involves conducting the reaction using conventional and green approaches, comparing the efficiency, safety, and waste produced. Resources include readily available reagents and solvents, with the work potentially conducted at home or in a community lab. The focus is on understanding and applying green chemistry principles to real-world chemical processes.

References-

1. Wolf, M. E. (Ed.). (2009). *Burger's medicinal chemistry and drug discovery* (6th ed.). Wiley.
2. Patrick, G. L. (2008). *Introduction to medicinal chemistry* (3rd ed.). Oxford University Press.
3. Silverman, R. B. (2004). *Introduction to drug design*. CRC Press.
4. Gupta, R. R., Kumar, M., & Gupta, M. (Eds.). (2009). *Heterocyclic chemistry* (Vols. I-III). Elsevier.
5. Joules, J. A., & Mills, K. (2000). *Heterocyclic chemistry*. Wiley.
6. Paquette, L. A. (Ed.). (2003). *Modern heterocyclic chemistry*. Wiley.
7. Ahluwalia, V. K. (2008). *Green chemistry: Environmentally benign reactions*. Ane Books India.

8. Anastas, P. T., & Williamson, T. C. (1998). *Green chemistry: Designing chemistry for the environment*. Wiley.
9. Sanghi, R., & Srivastava, M. M. (2009). *Green chemistry: Environmentally friendly alternatives*. Springer.

4.2 Major (Core)

<table>
<tr><td>Course Title</td><td>In-Plant Training (415312)</td></tr>
<tr><td>Course Credits</td><td>4</td></tr>
<tr><td>Course Outcomes</td><td>An orientation program for the In-Plant Training for aspiring students should be planned before students proceed for training. This program is essential in preparing students for real-world industrial environments, ensuring they gain valuable practical experience and develop problem-solving skills. As a faculty advisor, your role is critical in facilitating this training. You will:

● Identify suitable plants for student training.
● Liaise with plant authorities to establish and sign MOUs.
● Ensure students understand and commit to safety protocols through a signed undertaking.
● Coordinate with industry mentors assigned to the students.
● Conduct surprise visits to review student performance.
● Assist students with any issues they encounter during training.
● Help students make the most of their training experience, fostering a problem-solving aptitude.

For students, this orientation will outline the skills and competencies you need to develop during your training. You will learn about the technical, safety, and professional expectations from your in-plant training, and how to identify and propose improvements within the plant.

After going through the course, learners will be able to:

1) Analyze proficiency in laboratory techniques, instrumentation, and data analysis relevant to the analytical chemistry industry.
2) Apply knowledge to solve problems, optimize processes, and develop innovative solutions in an industrial setting.
3) Discuss communicate with colleagues, supervisors, and clients, both verbally and in writing, while collaborating with cross-functional teams to achieve common goals.
4) Assess industry-specific safety protocols and regulations to ensure a safe working environment</td></tr>
<tr><td colspan="2">Module 1 (Credit) - Introduction to Analytical Chemistry in the Plant</td></tr>
<tr><td>Learning Outcomes</td><td>1) Assess proficiency in using advanced analytical instruments such as mass spectrometers and chromatographs, applying theoretical knowledge to practical scenarios.
2) Apply and execute experiments independently, analyze experimental data using statistical methods, and interpret results effectively.</td></tr>
<tr><td>Content Outline</td><td>● Technical Skills: Demonstrate proficiency in laboratory techniques, instrumentation, and data analysis relevant to the industry.
● Safety and Regulations: Ensure students understand industry-specific safety protocols and regulations, such as OSHA guidelines, and have signed an undertaking acknowledging their responsibility.
● Communication: Stress the importance of effective communication with colleagues, supervisors, and mentors, both verbally and in writing.

Tasks for Students:

● Participate in a detailed tour of the plant's analytical laboratories and facilities.
● Observe and document safety procedures and protocols.</td></tr>
</table>

	• Engage with plant staff to understand daily operations and communication practices. **Identifying Areas for Improvement:** • Encourage students to note any inefficiencies or safety concerns during their tour and suggest practical improvements, such as better equipment organization or enhanced safety signage.
Module 2 (Credit 1) - Problem-Solving and Process Optimization	
Learning Outcomes	1) **Apply** chemical knowledge to identify problems in industrial processes, propose innovative solutions, and optimize processes to enhance efficiency and quality. 2) **Analyze** complex chemical problems, troubleshoot experimental setups, and adapt methodologies for optimal outcomes in real-world applications.
Content Outline	• **Technical Skills:** Provide an overview of key analytical instruments (HPLC, GC, UV-Vis, IR spectroscopy) and their applications. • **Problem-Solving:** Teach students how to apply their chemical knowledge to develop and optimize analytical methods. • **Adaptability:** Encourage students to be flexible and willing to learn new skills, procedures, and technologies. **Tasks for Students:** • Participate in hands-on training sessions with key analytical instruments. • Conduct experiments and analyze data, documenting their processes and results. • Review current analytical methods used in the plant, identifying potential improvements. **Identifying Areas for Improvement:** • Guide students to propose new or modified analytical methods to enhance accuracy and efficiency, such as optimizing reagent usage or improving calibration techniques.
Module 3 Credit 1) - Safety and Regulatory Compliance	
Learning Outcomes	1) **Analyze** of industry-specific safety protocols and regulations, ensuring compliance with standards such as OSHA guidelines and environmental regulations. 2) **Assess** safety measures effectively in laboratory and industrial settings, contributing to a safe working environment while mitigating risks associated with chemical handling and experimentation.
Content Outline	• **Quality Control:** Explain the role of quality control in ensuring product safety and compliance with regulatory standards. • **Teamwork:** Highlight the importance of collaborating with cross-functional teams, including scientists, engineers, and technicians. • **Professionalism:** Emphasize the need for punctuality, responsibility, and a strong work ethic in a professional setting. **Tasks for Students:** • Perform quality tests on production samples and review quality assurance documentation. • Participate in a simulated quality audit to identify gaps or inconsistencies. • Collaborate with team members to discuss quality control challenges and

	solutions. **Identifying Areas for Improvement:** ● Encourage students to suggest improvements in documentation practices or testing procedures, such as implementing digital records or refining test protocols.
Module 4 (Credit 1) - Research and Development in Analytical Chemistry	
Learning Outcomes	1) **Analyze** communicate scientific findings and experimental results clearly and concisely, both orally and in written reports, tailored to technical and non-technical audiences. 2) **Assess** effectively with interdisciplinary teams, including scientists, engineers, and technicians, to achieve project goals, solve complex problems, and deliver high-quality analytical solutions.
Content Outline	● **Industry-Specific Knowledge:** Introduce students to ongoing research projects and the significance of R&D in the plant. ● **Report Writing and Presentation Skills:** Teach students how to prepare clear, concise reports and present scientific data to both technical and non-technical audiences. ● **Time Management:** Emphasize the importance of prioritizing tasks and managing time efficiently. **Tasks for Students:** ● Design and conduct their own experiments, applying advanced analytical techniques. ● Collaborate with R&D teams and participate in problem-solving sessions. ● Present their research findings to the plant's R&D team and prepare detailed reports. **Identifying Areas for Improvement:** Guide students to review ongoing R&D projects, identify challenges, and propose innovative solutions or collaborations, such as new research methodologies or cross-functional team projects.

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

Module 1 - Introduction to Analytical Chemistry in the Plant

Assessment Strategy:

1. **Plant Laboratory Tour Assessment:**
   - Students will submit a reflective report detailing their observations during the plant's analytical laboratory tour, focusing on equipment, safety protocols, and communication practices.
   - Assessment Criteria: Accuracy of observations, understanding of safety procedures, and clarity in communication.
2. **Safety and Regulations Understanding:**
   - Students will take a safety quiz to assess their understanding of industry-specific safety protocols and regulations discussed during the orientation.
   - Assessment Criteria: Knowledge retention of safety guidelines and compliance with regulatory standards.
3. **Communication Skills Assessment:**
   - Students will prepare a mock email or report addressing a hypothetical safety concern or procedural suggestion observed during the tour.

   - Assessment Criteria: Clarity, professionalism, and effectiveness in communicating ideas.

Module 2 - Problem-Solving and Process Optimization

Assessment Strategy:

1. **Hands-on Instrumentation Skills:**
   - Students will conduct practical sessions using HPLC, GC, UV-Vis, and IR spectroscopy.
   - Assessment Criteria: Ability to operate instruments accurately, collect data, and troubleshoot basic issues.
2. **Experimental Design and Analysis:**
   - Students will submit a detailed experimental report on a selected analytical method, including data analysis and interpretation.
   - Assessment Criteria: Experimental design, data accuracy, statistical analysis, and interpretation of results.
3. **Process Optimization Proposal:**
   - Students will propose a process improvement related to analytical methods used in the plant, supported by data and feasibility analysis.
   - Assessment Criteria: Innovation, practicality, and potential impact of the proposed improvement.

Module 3 - Safety and Regulatory Compliance

Assessment Strategy:

1. **Quality Control Simulation:**
   - Students will participate in a simulated quality control exercise, analyzing samples and reviewing quality assurance documentation.
   - Assessment Criteria: Accuracy of analysis, adherence to quality control procedures, and identification of potential improvements.

2. **Safety Implementation Project:**
   - Students will develop a safety enhancement plan for a specific laboratory process, emphasizing risk mitigation and compliance with regulations.
   - Assessment Criteria: Clarity of safety measures proposed, feasibility of implementation, and alignment with industry standards.
3. **Team Collaboration Assessment:**
   - Students will work in teams to solve a safety or regulatory compliance challenge, presenting their solutions and rationale.
   - Assessment Criteria: Collaboration skills, problem-solving approach, and effectiveness in presenting solutions

Module 4 - Research and Development in Analytical Chemistry

Assessment Strategy:

1. **Experimental Research Report:**
   - Students will prepare a comprehensive research report on their independent experiment, including methodology, results, and discussion.
   - Assessment Criteria: Scientific rigor, data interpretation, critical analysis, and clarity of presentation.
2. **Team Collaboration and Presentation:**
   - Students will collaborate with R&D teams to solve a complex analytical problem and present their findings to the R&D department.
   - Assessment Criteria: Teamwork, contribution to problem-solving, presentation skills, and ability to engage with interdisciplinary teams.
3. **Innovation Proposal:**

- Students will propose an innovative research project or improvement initiative based on current R&D activities in the plant.
- Assessment Criteria: Originality, feasibility, potential impact, and alignment with plant objectives.

References:

1. Green, D. W., & Southard, M. Z. (2018). Perry's chemical engineers' handbook (9th ed.). McGraw-Hill Education.
2. Seider, W. D., Lewin, D. R., Seader, J. D., Widagdo, S., Gani, R., & Ng, K. M. (2016). Product and process design principles: Synthesis, analysis, and evaluation (4th ed.). Wiley.
3. McCabe, W. L., Smith, J. C., & Harriott, P. (2004). Unit operations of chemical engineering (7th ed.). McGraw-Hill Education.
4. Sinnott, R., & Towler, G. (2019). Chemical engineering design: Principles, practice and economics of plant and process design (6th ed.). Butterworth-Heinemann.
5. Crowl, D. A., & Louvar, J. F. (2018). Chemical process safety: Fundamentals with applications (4th ed.). Pearson.
6. Kletz, T., & Amyotte, P. (2010). Process plants: A handbook for inherently safer design (2nd ed.). CRC Press.
7. Turton, R., Bailie, R. C., Whiting, W. B., Shaeiwitz, J. A., & Bhattacharyya, D. (2018). Analysis, synthesis, and design of chemical processes (5th ed.). Prentice Hall.
8. Smith, R. (2016). Chemical process design and integration (2nd ed.). Wiley.
9. Biegler, L. T., Grossmann, I. E., & Westerberg, A. W. (1997). Systematic methods of chemical process design. Prentice Hall.
10. Marlin, T. E. (2000). Process control: Designing processes and control systems for dynamic performance (2nd ed.). McGraw-Hill Education.

4.3 Major (Core)

<table>
<tr><td>Course Title</td><td>Practical (Laboratory Course) (445311)</td></tr>
<tr><td>Course Credits</td><td>4</td></tr>
<tr><td>Course Outcomes</td><td>After going through the module, learners will be able to

Develop proficiency in fundamental separation methods
Assess the principles behind different separation techniques
Assess the principles of chromatography and spectroscopy
Develop skills in handling complex mixtures and natural products</td></tr>
<tr><td colspan="2">Module 1 (Credit 1) - Fundamental Separation Techniques.</td></tr>
<tr><td>Learning Outcomes</td><td>After going through the module, learners will be able to

- Apply basic separation techniques to various types of mixtures
- Analyze melting point determinations and interpret the results
- Assess and interpret simple spectroscopic analyses
- Execute chemical tests to identify components in mixtures</td></tr>
<tr><td>Content Outline</td><td>Separation and Analysis of a Water-Soluble and Water-Insoluble Solid Mixture
Fractional Crystallization and Melting Point Determination of a Binary Solid Mixture
Liquid-Liquid Extraction and Spectroscopic Analysis of Organic Compounds
Steam Distillation and Chemical Tests for Mixture Component Identification</td></tr>
<tr><td colspan="2">Module 2 (Credit 1) - Advanced Separation and Chromatography</td></tr>
<tr><td>Learning Outcomes</td><td>After going through the module, learners will be able to
- Perform various chromatographic techniques
- Prepare derivatives for compound identification
- Conduct UV-Vis spectroscopy and interpret spectra
- Analyze Soxhlet extraction and analyze results using TLC</td></tr>
<tr><td>Content Outline</td><td>Chromatographic Separation and Derivative Preparation of Binary Mixtures
Column Chromatography and UV-Vis Spectroscopy of Colored Compounds
Soxhlet Extraction and TLC Analysis of Natural Product Mixtures
Fractional Distillation and Refractive Index Measurement of Liquid Mixtures</td></tr>
<tr><td colspan="2">Module 3 (Credit 1) - Spectroscopic and Mass Analysis Techniques</td></tr>
<tr><td>Learning Outcomes</td><td>After going through the module, learners will be able to
Perform re-crystallization and interpret IR spectra
Conduct NMR analysis and interpret the results
Assess sublimation and analyze mass spectra
Execute GC-MS analysis and interpret chromatograms and mass spectra</td></tr>
<tr><td>Content Outline</td><td>Recrystallization and IR Spectroscopy of Separated Organic Solids
Solvent Extraction and NMR Analysis of Non-Volatile Liquid Mixtures
Sublimation and Mass Spectrometry of Solid Organic Compounds
Azeotropic Distillation and GC-MS Analysis of Volatile Organic Mixtures</td></tr>
<tr><td colspan="2">Module 4 (Credit 1) - Specialized Extraction and Analysis Methods</td></tr>
</table>

Learning Outcomes	After going through the module, learners will be able to - **Characterize** non-volatile liquid components in mixtures - **Isolate** and identify organic compounds from solid-liquid mixtures - **Perform** acid-base extractions and titrations - **Execute** salting-out separations and determine boiling points
Content Outline	• Characterization of Non-Volatile Liquid Components in a Binary Mixture • Isolation and Identification of Organic Compounds from a Solid-Liquid Mixture • Acid-Base Extraction and Titration Analysis of Organic Mixtures • Salting-Out Separation and Boiling Point Determination of Aqueous Solutions

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

Module 1: Fundamental Separation Techniques
Project Idea: Mystery Mixture Analysis
- **Description**: Students are given an unknown mixture containing a water-soluble and a water-insoluble solid. They must separate the components, identify them through melting point determination and chemical tests, and prepare a comprehensive lab report detailing their methodology and findings.
- **Assessment**: Evaluation based on separation efficiency, accuracy of component identification, quality of lab report, and presentation of results.

Module 2: Advanced Separation and Chromatography
Project Idea: Natural Product Isolation and Characterization
- **Description**: Students are provided with a plant extract and tasked with isolating a specific compound using column chromatography. They must then characterize the isolated compound using TLC and UV-Vis spectroscopy, comparing their results with literature values.
- **Assessment**: Grading based on chromatographic technique, purity of isolated compound, accuracy of spectroscopic analysis, and interpretation of results.

Module 3: Spectroscopic and Mass Analysis Techniques
Project Idea: Structural Elucidation Challenge
- **Description**: Students receive a purified organic compound and must determine its structure using a combination of IR, NMR, and mass spectrometry. They are required to interpret the spectra, propose a structure, and defend their conclusion in a short presentation.
- **Assessment**: Evaluation of spectral interpretation skills, logical reasoning in structure determination, quality of presentation, and ability to answer questions about their analysis.

Module 4: Specialized Extraction and Analysis Methods
Project Idea: Industrial Process Simulation
- **Description**: Students are given a complex mixture mimicking an industrial process stream. They must design and execute a multi-step separation and analysis protocol, including acid-base extraction, salting-out, and titration. The final product must meet specified purity criteria.
- **Assessment**: Grading based on the effectiveness of the separation strategy, accuracy of quantitative analysis, purity of final product, and a written report detailing the process optimization and results.

References-

1. Middleton, H. (Year). *Systematic qualitative organic analysis*. Orient Longman.
2. Clark, H. T. (Year). *A handbook of organic analysis*. Orient Longman.
3. Shriner, R. L., Fuson, R. C., & Curtin, D. Y. (Year). *The systematic identification of organic compounds*. John Wiley & Sons.
4. Mann, J., & Saunders, B. C. (Year). *Practical organic chemistry*. Pearson.
5. Mohrig, J. R., Hammond, C. N., & Schatz, P. F. (2018). Techniques in organic chemistry: Miniscale, standard taper microscale, and Williamson microscale (4^{th} ed.). W. H. Freeman.
6. Harwood, L. M., Moody, C. J., & Percy, J. M. (1999). Experimental organic chemistry: Standard and microscale (2^{nd} ed.). Wiley-Blackwell.

7. Jarrett, R. M. (2013). A lab manual of experiments in physical chemistry (2nd ed.). CRC Press.
8. Gilbert, J. C., & Martin, S. F. (2015). Experimental organic chemistry: A miniscale and microscale approach (6th ed.). Cengage Learning.
9. Palleros, D. R. (2000). Experimental organic chemistry. John Wiley & Sons.
10. Roberts, R. M., Gilbert, J. C., Rodewald, L. B., &Wingrove, A. S. (2009). Modern experimental organic chemistry (4th ed.). Saunders College Publishing.
11. Furniss, B. S., Hannaford, A. J., Smith, P. W. G., & Tatchell, A. R. (1989). Vogel's textbook of practical organic chemistry (5th ed.). Longman Scientific & Technical.

4.4 Major (Elective)

<table>
<tr><td>Course Title</td><td>Organic Retro synthesis (425311)</td></tr>
<tr><td>Course Credits</td><td>4</td></tr>
<tr><td>Course Outcomes</td><td>After going through the Course, learners will be able to
Apply retrosynthetic analysis to challenging synthetic problems.
Assess the basic concepts of retrosynthetic analysis.
Apply retrosynthetic analysis to simple organic molecules.
Design efficient and practical synthetic routes for complex molecules.
Assess advanced research in organic synthesis</td></tr>
<tr><td colspan="2">Module 1 (Credit 1) - Introduction to Retrosynthetic Analysis</td></tr>
<tr><td>Learning Outcomes</td><td>After going through the module, learners will be able to,
Define and explain the principles of retrosynthetic analysis.
Assess key disconnections and functional group transformations in organic molecules.
Analyze retrosynthetic analysis to devise simple synthetic routes.</td></tr>
<tr><td>Content Outline</td><td>• Definition and principles of retrosynthetic analysis
• Disconnection approach: functional group transformations
• Key disconnections: carbonyl compounds, alcohols, alkenes, and alkynes
• Protecting groups: introduction and applications</td></tr>
<tr><td colspan="2">Module 2 (Credit 1) - Retrosynthetic Analysis of Carbon-Carbon Bond Formation</td></tr>
<tr><td>Learning Outcomes</td><td>After going through the module, learners will be able to,
Apply key reactions for carbon-carbon bond formation, such as Grignard reactions, aldol condensations, and Diels-Alder reactions.
Analyze the stereochemistry of products formed in carbon-carbon bond formation reactions.
Design synthetic routes involving carbon-carbon bond formation</td></tr>
<tr><td>Content Outline</td><td>• Grignard reactions and organolithium reagents
• Aldol condensations and Claisen condensations
• Michael additions and Robinson annulation
• Diels-Alder reactions
• Wittig reactions and Horner-Wadsworth-Emmons reactions</td></tr>
<tr><td colspan="2">Module 3 (Credit 1) - Retrosynthetic Analysis of Functional Group Transformations</td></tr>
<tr><td>Learning Outcomes</td><td>After going through the module, learners will be able to
Apply key reactions for functional group transformations, such as oxidation, reduction, substitution, and elimination reactions.
Analyze protecting groups to selectively modify functional groups.
Design synthetic routes involving multiple functional group transformations.</td></tr>
<tr><td>Content Outline</td><td>• Oxidation and reduction reactions
• Nucleophilic substitution reactions
• Electrophilic aromatic substitution reactions
• Elimination reactions</td></tr>
</table>

Module 4 (Credit 1) - Complex Molecules and Strategies	
Learning Outcomes	After going through the module, learners will be able to **Apply** retrosynthetic analysis to complex natural products and bioactive molecules. **Develop** multi-step synthetic routes, considering convergent and divergent strategies. **Design** synthetic routes that incorporate stereo-selective and stereo-specific reactions.
Content Outline	• Retrosynthetic analysis of natural products and bioactive molecules • Multi-step syntheses and convergent strategies • Protecting group strategies for complex molecules • Stereo selective and stereo-specific reactions in retrosynthetic analysis

Assignments/Activities towards Comprehensive Continuous Evaluation (CCE)-

Module 1: Introduction to Retrosynthetic Analysis
Activity 1: Retrosynthetic Analysis Puzzle
Description: Students will be given a target molecule and asked to work in pairs or small groups to devise a retrosynthetic route. They will present their solutions to the class, discussing the key disconnections and functional group transformations involved.
Assessment: The quality and accuracy of the retrosynthetic routes, as well as the ability to explain the reasoning behind the disconnections, will be assessed.
Activity 2: Literature Search and Analysis
Description: Students will research a specific class of organic compounds (e.g., alkaloids, terpenes) and identify key retrosynthetic strategies used in their synthesis. They will present their findings in a short report or presentation.
Assessment: The depth of research, understanding of retrosynthetic principles, and quality of presentation will be assessed.

Module 2: Retrosynthetic Analysis of Carbon-Carbon Bond Formation
Activity 1: Reaction Mechanism Analysis
Description: Students will be given reaction schemes involving carbon-carbon bond formation and asked to propose detailed mechanisms. They will discuss the mechanisms with their peers and the instructor.
Assessment: The accuracy of the proposed mechanisms and the ability to explain the driving forces and stereochemistry will be assessed.
Activity 2: Retrosynthetic Analysis Challenge
Description: Students will compete in a timed retrosynthetic analysis challenge, where they will be given a target molecule and asked to devise a route as quickly as possible. The fastest and most accurate solutions will be rewarded.
Assessment: The speed and accuracy of the retrosynthetic routes will be assessed.

Module 3: Retrosynthetic Analysis of Functional Group Transformations
Activity 1: Functional Group Interconversion
Description: Students will be given a starting material and a target functional group and asked to propose a series of reactions to achieve the transformation. They will present their solutions to the class and discuss the advantages and disadvantages of different routes.
Assessment: The creativity and efficiency of the proposed routes, as well as the understanding of functional group transformations, will be assessed.
Activity 2: Protecting Group Strategy Design
Description: Students will be given a complex molecule with multiple reactive functional groups and asked to design a protecting group strategy for selective functionalization. They will justify their choices and discuss potential challenges.
Assessment: The understanding of protecting group chemistry and the ability to design a practical strategy will be assessed.

Module 4: Complex Molecules and Strategies
Project Idea: Retrosynthetic Analysis of a Natural Product
Description: Students will choose a complex natural product and devise a retrosynthetic route for its synthesis. They will research the literature to identify potential starting materials and reactions, and present their findings in a detailed report or presentation.
Assessment: The depth of research, creativity of the retrosynthetic route, and quality of presentation will be assessed.

References-

1. Warren, S. (2006). Organic synthesis: The disconnection approach. Wiley-Interscience.
2. Carey, F. A., & Sundberg, R. J. (2007). Advanced organic chemistry: Reactions, mechanisms, and structure. Springer Science & Business Media.
3. Corey, E. J., & Trost, B. M. (1981). Retrosynthetic analysis: A guide to thinking backward in organic synthesis. Academic Press.

4.5 Research Project

Course Title	**Research Project Part – II (455311)**
Course Credits	**6**
Course Outcomes	After this course, the students will be able to, 1) **Analyze** advanced proficiency in experimental design, data analysis, and scholarly communication in analytical chemistry. **2) Evaluate** a comprehensive research report and a concise research article suitable for publication.
Module 1 (Credit 1) - Experimental Work	
Learning Outcome	1) **Analyze** and Expand experimental protocols based on insights gained from Semester III findings, incorporating necessary methodological refinements. 2) **Assess** rigorous data collection practices and document experimental details comprehensively to support robust analysis.
Content Outline	**Guidelines for Students:** ● **Tasks:** Extend experimental protocols based on Semester III outcomes, addressing identified limitations or refining methodologies. ● **Approach:** Document all experimental procedures meticulously, ensuring reproducibility and reliability. Seek guidance from faculty on protocol adjustments and experimental setups.
Module 2 (Credit 1) - Advanced Data Analysis	
Learning Outcome	1) **Analyze** advanced statistical techniques to analyze complex datasets thoroughly, extracting meaningful insights relevant to research objectives. 2) **Discuss** data trends, patterns, and correlations, ensuring alignment with research hypotheses in analytical chemistry.
Content Outline	**Guidelines for Students:** ● **Tasks:** Apply advanced statistical methods to analyze collected data comprehensively. ● **Approach:** Interpret data trends and correlations to derive meaningful conclusions. Discuss findings with faculty and peers to validate interpretations and refine analytical approaches
Module 3 (Credit 1) - Final Results Compilation	
Learning Outcomes	1) **Analyze** experimental results into a coherent narrative that aligns with research hypotheses and objectives in analytical chemistry. 2) **Discuss** findings with existing literature to contextualize contributions and demonstrate the significance of the research outcomes
Content Outline	**Guidelines for Students:** ● **Tasks:** Compile experimental results into a cohesive narrative that supports research hypotheses. ● **Approach:** Conduct a thorough review of literature to contextualize findings. Discuss implications of results with faculty to ensure completeness and relevance to the field.
Module 4 (Credit 1) - Research Article Preparation	

Learning Outcome	1) **Analyze** a concise research article following journal-specific guidelines, ensuring clarity, adherence to formatting requirements, and incorporation of appropriate references. 2) **Apply** research findings effectively, preparing the manuscript for submission to a peer-reviewed scientific journal in analytical chemistry.
Content Outline	**Guidelines for Students:** ● **Tasks:** Draft a concise research article suitable for submission to a peer-reviewed journal. ● **Approach:** Follow journal-specific formatting guidelines and incorporate feedback received from faculty. Emphasize clarity, coherence, and adherence to scholarly writing conventions.
Module 5 (Credit 1) - Research Report Finalization	
Learning Outcomes	1) **Analyze** the comprehensive research report documenting all stages of the study, from initial proposal through to final experimental outcomes. 2) **Assess** and refine content based on feedback received to ensure completeness, coherence, and scholarly rigor in analytical chemistry.
Content Outline	**Guidelines for Students:** ● **Tasks:** Finalize the research report, incorporating all stages of the study and addressing feedback received. ● **Approach:** Revise content for clarity, coherence, and academic rigor. Seek guidance from faculty on structuring and presenting findings effectively in the final report.
Module 6 (Credit 1) - Final Presentation and Defense	
Learning Outcome	1) **Analyze** a professional presentation summarizing key research findings, methodologies employed, and implications for the field of analytical chemistry. 2) **Apply** mastery of analytical concepts and research methodologies during the defense session before an academic panel, showcasing the depth of understanding and contributions to analytical chemistry research.
Content Outline	**Guidelines for Students:** ● **Tasks:** Prepare a professional presentation summarizing research findings and methodologies. ● **Approach:** Practice presentation skills and anticipate questions from the academic panel. Demonstrate comprehensive understanding of research outcomes and their implications for analytical chemistry.