University of Mumbai

No. AAMS_UGS/ICC/2024-25/143

CIRCULAR:-

Attention of all the Principals of the Affiliated Colleges, Directors of the Recognized Institutions and the Head, University Departments is invited to this office Circular No. AAMS_UGS/ICC/2023-24/23 dated 08th September, 2023 relating to the NEP UG & PG Syllabus.

They are hereby informed that the recommendations made by the **Board of Studies in Chemistry** at its meeting held on 02nd September, 2024 and subsequently passed by the Board of Deans at its meeting held on 3rd September, 2024 **vide** item No. 6.16 (N) have been accepted by the Hon'ble Vice Chancellor as per the power confirmed upon him under section 12(7) of the Maharashtra Public Universities Act, 2016 and that in accordance therewith syllabus for **M.Sc.(Organic Chemistry) Sem – III & IV** is introduced as per appendix (NEP 2020) with effect from the academic year 2024-25.

(The Circular is available on the University's website www.mu.ac.in).

(Dr. Prasad Karande)
REGISTRAR

MUMBAI – 400 032
21st September, 2024

To

All the Principals of the Affiliated Colleges, Directors of the Recognized Institutions and the Head, University Departments.

BOD 6.16(N) 03/09/2024

Copy forwarded with Compliments for information to:-

1) The Chairman, Board of Deans,
2) The Dean, Faculty of Science,
3) The Chairman, **Board of Studies in Chemistry**
4) The Director, Board of Examinations and Evaluation,
5) The Director, Department of Students Development,
6) The Director, Department of Information & Communication Technology,
7) The Director, Centre for Distance and Online Education (CDOE) Vidyanagari,
8) The Deputy Registrar, Admission, Enrolment, Eligibility & Migration Department (AEM),

Copy forwarded for information and necessary action to :-	
1	The Deputy Registrar, (Admissions, Enrolment, Eligibility and Migration Dept)(AEM), dr@eligi.mu.ac.in
2	The Deputy Registrar, Result unit, Vidyanagari drresults@exam.mu.ac.in
3	The Deputy Registrar, Marks and Certificate Unit,. Vidyanagari dr.verification@mu.ac.in
4	The Deputy Registrar, Appointment Unit, Vidyanagari dr.appointment@exam.mu.ac.in
5	The Deputy Registrar, CAP Unit, Vidyanagari cap.exam@mu.ac.in
6	The Deputy Registrar, College Affiliations & Development Department (CAD), deputyregistrar.uni@gmail.com
7	The Deputy Registrar, PRO, Fort, (Publication Section), Pro@mu.ac.in
8	The Deputy Registrar, Executive Authorities Section (EA) eau120@fort.mu.ac.in He is requested to treat this as action taken report on the concerned resolution adopted by the Academic Council referred to the above circular.
9	The Deputy Registrar, Research Administration & Promotion Cell (RAPC), rapc@mu.ac.in
10	The Deputy Registrar, Academic Appointments & Quality Assurance (AAQA) dy.registrar.tau.fort.mu.ac.in ar.tau@fort.mu.ac.in
11	The Deputy Registrar, College Teachers Approval Unit (CTA), concolsection@gmail.com
12	The Deputy Registrars, Finance & Accounts Section, fort draccounts@fort.mu.ac.in
13	The Deputy Registrar, Election Section, Fort drelection@election.mu.ac.in
14	The Assistant Registrar, Administrative Sub-Campus Thane, thanesubcampus@mu.ac.in
15	The Assistant Registrar, School of Engg. & Applied Sciences, Kalyan, ar.seask@mu.ac.in
16	The Assistant Registrar, Ratnagiri Sub-centre, Ratnagiri, ratnagirisubcentar@gmail.com
17	The Director, Centre for Distance and Online Education (CDOE), Vidyanagari, director@idol.mu.ac.in
18	Director, Innovation, Incubation and Linkages, Dr. Sachin Laddha pinkumanno@gmail.com
19	Director, Department of Lifelong Learning and Extension (DLLE), dlleuniversityofmumbai@gmail.com

Copy for information :-	
1	P.A to Hon'ble Vice-Chancellor, vice-chancellor@mu.ac.in
2	P.A to Pro-Vice-Chancellor pvc@fort.mu.ac.in
3	P.A to Registrar, registrar@fort.mu.ac.in
4	P.A to all Deans of all Faculties
5	P.A to Finance & Account Officers, (F & A.O), camu@accounts.mu.ac.in

To,

1	The Chairman, Board of Deans pvc@fort.mu.ac.in
2	**Faculty of Humanities,** **Dean** 1. Prof.Anil Singh Dranilsingh129@gmail.com **Associate Dean** 2. Dr.Suchitra Naik Naiksuchitra27@gmail.com 3.Prof.Manisha Karne mkarne@economics.mu.ac.in
	Faculty of Commerce & Management, **Dean** 1. Dr.Kavita Laghate kavitalaghate@jbims.mu.ac.in **Associate Dean** 2. Dr.Ravikant Balkrishna Sangurde Ravikant.s.@somaiya.edu 3. Prin.Kishori Bhagat kishoribhagat@rediffmail.com

	Faculty of Science & Technology **Dean** 1. Prof. Shivram Garje ssgarje@chem.mu.ac.in **Associate Dean** 2. Dr. Madhav R. Rajwade Madhavr64@gmail.com 3. Prin. Deven Shah sir.deven@gmail.com
	Faculty of Inter-Disciplinary Studies, **Dean** 1.Dr. Anil K. Singh aksingh@trcl.org.in **Associate Dean** 2.Prin.Chadrashekhar Ashok Chakradeo cachakradeo@gmail.com
3	Chairman, Board of Studies,
4	The Director, Board of Examinations and Evaluation, dboee@exam.mu.ac.in
5	The Director, Board of Students Development, dsd@mu.ac.in DSW direcotr@dsw.mu.ac.in
6	The Director, Department of Information & Communication Technology, director.dict@mu.ac.in

BOD – 3/9/2024
12 (7) of M.P.U.A. 2016
Item No. – 6.16 (N)

As per NEP 2020

University of Mumbai

Title of the P.G. program
M.Sc. (Organic Chemistry)

Syllabus for

Semester – SEM III & IV

Ref: GR dated 16th May, 2023 for Credit Structure of PG

(with effect from the academic year 2024-25)

University of Mumbai

Sr. No.	Heading	Particulars
1	**Title of program** **O:_____**	**M. Sc. (Organic Chemistry)**
2	**Scheme of Examination** **R: _____**	**NEP** **50% Internal** **50% External,** **Semester End Examination** **Individual Passing in Internal and External Examination**
3	**Standards of Passing** **R: _____**	**40%**
4	**Credit Structure** **R: SP - 20B**	**Attached herewith**
5	**Semesters**	**Sem. III & IV**
6	**Program Academic Level**	**6.5**
7	**Pattern**	**Semester**
8	**Status**	**New**
9	**To be implemented from Academic Year**	**From the Academic Year 2024-25**

Sign of the BOS Coordinator
Dr. Sunil Patil
BOS in Chemistry
Director, Students' Welfare,
University of Mumbai

Sign of the
Offg. Associate Dean
Dr. Madhav R. Rajwade
Faculty of Science & Technology

Sign of the
Offg. Dean
Prof. Shivram S. Garje
Faculty of Science & Technology

Preamble

1) **Introduction**

This program is designed to provide a comprehensive and in-depth understanding of the fascinating world of Organic chemistry. Through a rigorous academic curriculum and hands-on research experience, we aim to nurture the intellectual curiosity and scientific acumen of our students, preparing them for successful careers in various sectors of the chemical sciences. The M.Sc. (Organic Chemistry) course is structured to equip students with a strong theoretical foundation, practical skills, and critical thinking abilities necessary to address the challenges and opportunities in the diverse fields of chemistry. Our esteemed faculty members are experts in their respective fields, with a passion for both teaching and research. They are committed to providing a nurturing learning environment, encouraging open discussions, and fostering collaborative research endeavors. Through their mentorship, students will have the opportunity to engage in cutting-edge research projects, pushing the boundaries of scientific knowledge and contributing to the advancement of the chemical sciences.

We envision our M.Sc. (Organic Chemistry) postgraduates to act as a catalyst for positive change, equipped to drive innovation, shape industries, and address societal challenges through their expertise in chemistry. Whether your passion lies in research, industry, education, or beyond, our program aims to provide the knowledge and skills necessary to excel in your chosen path.

2) **Aims and Objectives**

The aims and objectives of M.Sc. (Organic Chemistry) course are designed to provide students with a well-rounded and advanced education in the field of Organic chemistry. These goals focus on equipping students with a deep understanding of chemical principles, fostering research and analytical skills, and preparing them for successful careers in various sectors of the chemical sciences. The M.Sc. (Organic Chemistry) course aims to produce skilled and knowledgeable professionals who can contribute to scientific research, industrial innovation, and the betterment of society through their expertise in Organic chemistry.

3) **Learning Outcomes**

The learning outcomes of a M.Sc. (Organic Chemistry) course are designed to equip students with a comprehensive and advanced understanding of the field of chemistry. These learning outcomes reflect the knowledge, skills, and competencies that students are expected to gain upon successful completion of the program.

4) **Any other point (if any):** The skills and knowledge acquired during this master's program will make the students well-equipped for diverse roles.

5) **Credit Structure of the M.Sc. (Organic Chemistry) (Sem I, II, III & IV) (Table as per परिशिष्ट-1 with sign of HOD and Dean)**

R_____

Post Graduate Programs in University Parishishta - 1

Year	Level	Sem	Major				RM	OJT/ FP	RP	Cum. Cr.	Degree
			Mandatory			Electives					
1	6.0	Sem I	3×4+ 2=14			4	4	--	--	22	PG Diploma (after 3 Years Degree)
			Inorganic Chemistry-I (CHEM 502)	TH	4	**Credits 4 (2+2)** **Course 1 :** Physical Chemistry-I + Chemistry Practicals (Physical Chemistry and Inorganic Chemistry) (CHEM 50111) **OR** **Credits 4 (2+2)** **Course 2 :** Physical Chemistry-II + Chemistry Practicals (Physical Chemistry and Inorganic Chemistry) (CHEM 50112)	Research Methodology (CHEM 506)				
			Organic Chemistry-I (CHEM 503)	TH	4						
			Analytical Chemistry-I (CHEM 505)	TH	4						
			Chemistry Practical-I (Organic Chemistry and Analytical Chemistry) (PRCHEMOA 504)	PR	2						
		Sem II	3*4+ 2=14			4	--	4 CHEM 512	--	22	
			Inorganic Chemistry-II (CHEM 508)	TH	4	**Credits 4 (2+2)** **Course 1 :** Physical Chemistry-III + Chemistry Practicals (Physical Chemistry and Inorganic Chemistry) (CHEM 50711) **(OR)** **Credits 4 (2+2)** **Course 2 :** Physical Chemistry-IV + Chemistry Practicals (Physical Chemistry and Inorganic Chemistry) (CHEM 50712)					
			Organic Chemistry -II (CHEM 509)	TH	4						
			Analytical Chemistry -II (CHEM 510)	TH	4						
			Chemistry Practical-II (Organic Chemistry and Analytical Chemistry) (PRCHEMOA 511)	PR	2						

Cum. Cr. For PG Diploma	28	8	4	4		44	
Exit Option: PG Diploma (44 credits) after Three Year UG Degree							

Semester - III and IV

R: SP - 20B

Year	Level	Sem (2yr)	Major				RM	OJT/FP	RP	Cum. Cr.	Degree
2	6.5	Sem III	3*4+ 2=14			4	-	-	4 (CHEM 646)	22	PG Degree after 3-yr UG or PG Degree after 4-yr UG
			Paper –I (Theoretical organic chemistry-I) (CHEM 641)	TH	4	Paper IV (Medicinal Chemistry) + Practical (CHEM 64511) **OR** Paper IV (Biogenesis and green chemistry) + Practical (CHEM 64512)					
			Paper II (Synthetic Organic Chemistry- I) (CHEM 642)	TH	4						
			Paper III (Natural products and Spectroscopy-I) (CHEM 643)	TH	4						
			Organic Chemistry Practical (CHEM 644)	PR	2						
		Sem IV	3*4=12			4	-	-	6 (CHEM 651)	22	
			Paper I (Theoretical organic chemistry-II) (CHEM 647)	TH	4	Paper IV (Bioorganic Chemistry) (CHEM 65011) **(OR)** Intellectual Property Rights and Chemoinformatics (CHEM 65012)					
			Paper II (Synthetic organic chemistry-II) (CHEM 648)	TH	4						
			Paper III (Natural Products and Heterocyclic Chemistry- II)	TH	4						

			(CHEM 649)								
Cum. Cr. For 1 Yr			26			8			10	44	

PG Degree							
Cum. Cr. For 2 Yr PG Degree	54	16	4	4	10	88	

UNIVERSITY OF MUMBAI

Syllabus for M.Sc. (Organic Chemistry)

Semester III and IV

Choice-Based Credit System

Under New Education Policy (NEP) 2020

(To be implemented from the academic year, **2024-2025**)

PROGRAM OUTLINE

MSc Sem III NEP Organic Chemistry

YEAR/SEM	DESCRIPTION		COURSE CODE	COURSE TITLE	CREDITS
MSc Part II Sem III	Mandatory Course - I		CHEM 641	Theoretical Organic Chemistry - I	4
	Mandatory Course - II		CHEM 642	Synthetic Organic Chemistry - I	4
	Mandatory Course - III		CHEM 643	Natural products and Spectroscopy-I	4
	Mandatory Course Practical		(CHEM 644	Organic Chemistry Practical	2
	Elective I	**ANY ONE**	(CHEM 64511	Medicinal) Chemistry + Practical	2+2
	Elective II		(CHEM 64512)	Biogenesis and green chemistry) + Practical	2+2
	RP		(CHEM 646)	Research Project	4
				Total Credits	22

MSc Sem IV NEP Organic Chemistry

YEAR/SEM	DESCRIPTION		COURSE CODE	COURSE TITLE	CREDITS
MSc Part II Sem IV	Mandatory Course - I		CHEM 647	Theoretical Organic Chemistry - II	4
	Mandatory Course - II		CHEM 648	Synthetic Organic Chemistry - II	4
	Mandatory Course -III		CHEM 649	Natural products and heterocyclic Chemistry - II	4
	Elective I	ANY ONE	CHEM 65011	Bioorganic Chemistry	4
	Elective II		CHEM 65012	Intellectual Property Rights and Cheminformatics	4
	RP		CHEM 651	Research Project	6
Total Credits					**22**

PROGRAMME SPECIFIC OUTCOME (PSOs)

1. Gain knowledge of the advanced concepts in the branch of chemistry, scrutinize and accomplish a solution to problems encountered in the field of research and analysis.
2. Apply the basic knowledge of chemistry to perform various tasks assigned to them at theworkplace in industry and academia to meet the global standards.
3. Deduce qualitative and quantitative information of chemical compounds using advanced spectroscopic methods which can further be analyzed using practical skills inculcated in them during the course.
4. Imbibe the attitude as well as aptitude of a scientific approach along with analytical reasoning with respect to the novel techniques actually implemented in the industry.
5. Use the subject knowledge, communication and ICT skills to become an effective team leader/team member in the interdisciplinary fields.
6. Understand, Manage and contribute to solve basic societal issues and environmental concerns ethically based on principles of scientific knowledge gained.
7. Exhibit professional work ethics and norms of scientific development.

PROGRAM - MSc. - II		Semester: III			
Mandatory Course - I **Theory Paper - I**		**CHEM 641** **Theoretical Organic Chemistry - I**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**-**	**04**	**50**	**50**

Prerequisites:

1. Knowledge of molecular orbitals, stereochemistry and basic reaction intermediates and mechanisms.
2. Strains in cycloalkanes and conformational analysis of small rings till cyclohexane.
3. Basics of electronic transitions in organic molecules

Learning Objectives:

1. Describe involvement of reactive intermediates with respect to structure and reactivity through various organic reactions
2. Demonstrate the role of neighboring group participation to generate unexpected reaction outcomes
3. Illustrate the various types of pericyclic reactions and predict their feasibility and stereochemistry under different conditions.
4. Discuss the factors such as strains and steric hindrance that stabilize or destabilize specific conformations of medium size ring compounds
5. Distinguish between cis-trans isomers of decalin, hydrindane and steroids with the factors influencing their stability.
6. Recognize the importance of stereochemistry to explore reaction mechanisms that involve stereochemical changes
7. Discuss the basic principles of photochemistry and reactions given by arenes, olefins and carbonyl compounds.
8. Draw the Jablonski diagram to illustrate different electronic transitions.
9. Illustrate the concept of photoreactivity and factors influencing it, such as the energy of the incident light.

Course Outcomes:

After the successful completion of the unit, the learner will be able to:

1. Identify the intermediate formed, propose the mechanism and predict the product.
2. Analyze the involvement of neighboring groups to determine the mechanism and stereochemistry of the product formed.
3. Identify a reaction as a cycloaddition, electrocyclic reaction, or sigmatropic rearrangement and predict how some organic molecules react with each other under thermal and photochemical conditions in a single step to give important molecules.
4. Estimate the implications of ring size on the stability and strain in medium size ring compounds.
5. Summarize the unusual properties of medium size ring compounds.
6. Analyze the various conformations adopted by fused ring systems, considering factors such as strain and steric interactions.
7. Explain the effect of conformations of reactivity of cyclohexane derivatives.
8. Describe and explain photochemical and photophysical processes using Jablonski diagrams and their quantum yield expressions.
9. Illustrate the regioselectivity and stereoselectivity of aromatic olefins and carbonyl compounds

Semester: III
CHEM 641
Theoretical Organic Chemistry - I

Unit - I: Organic reaction mechanisms

1.1	Organic reactive intermediates, methods of generation, structure, stability and important reactions involving carbocations, nitrenes, carbenes, arynes and ketenes.	5L
1.2	Neighboring group participation: Mechanism and effects of anchimeric assistance, NGP by unshared/ lone pair electrons, π-electrons, aromatic rings, σ-bonds with special reference to norbornyl and bicyclo [2.2.2] octyl cation systems (formation of non-classical carbocation)	3L
1.3	Role of FMOs in organic reactivity: Reactions involving hard and soft electrophiles and nucleophiles, ambident nucleophiles, ambident electrophiles, the α effect.	2L
1.4	Pericyclic reactions: Classification of pericyclic reactions; thermal and photochemical reactions. Three approaches: Evidence for the concertedness of bond making and breaking Symmetry-Allowed and Symmetry-Forbidden Reactions – The Woodward-Hoffmann Rules-Class by Class The generalised Woodward-Hoffmann Rule Explanations for Woodward-Hoffmann rules The Aromatic Transition structures [Huckel and Mobius] Frontier Orbitals Correlation Diagrams, FMO and PMO approach Molecular orbital symmetry, Frontier orbital of ethylene, 1, 3 butadiene, 1, 3, 5 hexatriene and allyl system.	5L

Unit - II: Pericyclic reactions

2.1	Cycloaddition reactions: Supra and antarafacial additions, 4n and 4n+2 systems, 2+2 additions of ketenes. Diels-Alder reactions, 1, 3-Dipolar cycloaddition and cheletropic reactions, ene reaction, retro-Diels-Alder reaction, regioselectivity, periselectivity, torquoselectivity, site selectivity and effect of substituents in Diels-Alder reactions. Other Cycloaddition Reactions- [4+6] Cycloadditions, Ketene Cycloaddition, Allene Cycloadditions, Carbene Cycloaddition, Epoxidation and Related Cycloadditions. Other Pericyclic reactions: Sigmatropic Rearrangements, Electrocyclic Reactions, Alder 'Ene' Reactions.	7L
2.2	Electrocyclic reactions: Conrotatory and disrotatory motions, 4nπ and (4n+2) π electron and allyl systems.	3L
2.3	Sigmatropic rearrangements: H-shifts and C-shifts, supra and antarafacial migrations, retention and inversion of configurations. Cope (including oxy-Cope and aza-Cope) and Claisen rearrangements. Formation of Vitamin D from 7-dehydrocholesterol, synthesis of citral using pericyclic reaction, conversion of Endiandric acid E to Endiandric acid A.	5L

Unit - III:Stereochemistry-I

3.1	Classification of point groups based on symmetry elements with examples (nonmathematical treatment).	2L
3.2	Conformational analysis of medium rings: Eight to ten membered rings and their unusual properties, I-strain, transannular reactions.	3L
3.3	Stereochemistry of fused ring and bridged ring compounds: decalins, hydrindanes, perhydroanthracenes, steroids, and Bredt's rule.	5L
3.4	Anancomeric systems, Effect of conformation on reactivity of cyclohexane derivatives in the following reactions (including mechanism): electrophilic addition, elimination, molecular rearrangements, reduction of cyclohexanones (with $LiAlH_4$, selectride and MPV reduction) and oxidation of cyclohexanols.	5L

Unit - IV: Photochemistry

4.1	Principles of photochemistry:, electronic states and transitions, selection rules, modes of dissipation of energy (Jablonski diagram), electronic energy transfer: photosensitization and quenching process.	3L
4.2	Photochemistry of carbonyl compounds:$\pi \rightarrow^{*} \pi^*$, $n \rightarrow^{*} \pi^*$ transitions, distinctive features of Norrish- I and Norrish-II cleavages, Paterno-Buchi reaction. Photoreduction, calculation of quantum yield, photochemistry of enones, photochemical rearrangements of α, β-unsaturated ketones and cyclohexadienones. Photo Fries rearrangement, Barton reaction.	8L
4.3	Photochemistry of olefins: cis-trans isomerizations, dimerizations, hydrogen abstraction, addition and Di- π- methane rearrangement including aza-di- π -methane. Photochemical Cross-Coupling of Alkenes, Photodimerisation of alkenes.	2L
4.4	Photochemistry of arenes: 1, 2- , 1, 3- and 1, 4 additions. Photocycloadditions of aromatic Rings.	1L
4.5	Singlet oxygen and photo-oxygenation reactions. Photochemically induced Radical Reactions. Chemiluminescence, bioluminescence with 1-2 examples.	1L

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1 March's Advanced Organic Chemistry, Jerry March, sixth edition, 2007, John Wiley and sons.
2 A guide to mechanism in Organic Chemistry, 6th edition, 2009, Peter Sykes, Pearson education, New Delhi.
3 Advanced Organic Chemistry: Reaction Mechanisms, R. Bruckner, Academic Press (2002).
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7 Organic Chemistry, Part A and B, Fifth edition,2007, Francis A. Carey and Richard J. Sundberg, Springer.
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15 Pericyclic Reactions, S. Sankararaman, Wiley VCH, 2005.
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17 Pericyclic reactions, Ian Fleming, Oxford university press, 1999.
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19 Stereochemistry of Carbon Compounds: Principles and Applications, D, Nasipuri, 3rd edition, New Age International Ltd.
20 Stereochemistry of Organic Compounds, Ernest L. Eliel and SamuelH. Wilen, Wiley-India
21 Stereochemistry, P. S. Kalsi, 4th edition, New Age International Ltd
22 Organic Stereochemistry, M. J. T. Robinson, Oxford University Press, New Delhi, India edition, 2005
23 Fundamentals of Photochemistry, K. K. Rohtagi-Mukherji, Wiley- Eastern
24 Essentials of Molecular Photochemistry, A. Gilbert and J. Baggott, Blackwell Scientific Publication.

PROGRAM - MSc. - II		Semester: III			
Mandatory Course - II **Theory Paper - II**		**CHEM 642** **Synthetic Organic Chemistry - I**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**-**	**04**	**50**	**50**

Prerequisites

Knowledge of general methods /strategies for the synthesis of organic molecules, reaction mechanisms, functional group transformations and stereochemistry

Learning Objectives

1. Describe the mechanisms and applications of key name reactions
2. Explain the generation, stability, and reactivity of free radicals
3. Illustrate the formation and utility of enamines in organic synthesis.
4. Describe the applications of enamines, ylides and α C-H functionalization in organic synthesis.
5. Compare the reactivity of enamines with that of enolates, considering factors such as nucleophilicity, stability, and selectivity in various reactions.
6. Outline the utilization of metals and non-metals in organic synthesis

Course Outcomes:

After the successful completion of the module, the learner will be able to:

1. Explain the mechanisms and applications of key name reactions, apply their knowledge to analyse domino and multicomponent reactions, create new synthetic pathways by integrating concepts from click reactions
2. Discuss the generation, stability, and reactivity of free radicals, evaluate characteristic radical reactions including substitutions and additions.
3. Analyse the reactivity of enamines versus enolates and synthesize asymmetric reactions using chiral enamines.
4. Describe and explain the generation of carbanions by strong bases (LDA/n-butyl lithium) and applications in C-C bond formation.
5. Illustrate the methods for synthesizing phosphorus, sulfur, and nitrogen ylides, including the role of nucleophiles and electrophiles in their formation.
6. Apply knowledge of metal and nonmetal reagents for synthesis of organic compounds and design advanced organic transformations using different metal reagents

Semester: III
CHEM 642
Synthetic Organic Chemistry - I

Unit I : Name reactions with mechanism and application [15L]

1.1	Mukaiyama esterification, Mitsonobu reaction, Darzen's Glycidic Ester synthesis, Ritter reaction, Yamaguchi esterification, Peterson olefination.	5L
1.2	Domino reactions: Characteristics; Nazerov cyclization.	3L
1.3	Multicomponent reactions: Strecker reaction,Ugi 4CC, Biginelli synthesis, Hantzsch synthesis, Pictet-Spengler synthesis.	5L
1.4	Click Reactions: Characteristics; Huisgen 1,3-Dipolar Cycloaddition.	2L

UNIT :II Radicals in organic synthesis [15L]

2.1	Free radicals: ● Generation, stability, reactivity, structural and stereochemical properties. ● Persistent and charged radicals, ● Electrophilic and nucleophilic radicals	3L
2.2	Radical Initiators: azobisisobutyronitrile (AIBN) and dibenzoyl peroxide.	1L
2.3	Characteristic reactions: ● Free radical substitution, addition to multiple bonds ● Radical chain reactions ● Radical halogenation of hydrocarbons (Regioselectivity) ● Radical cyclizations, autoxidations: synthesis of cumene hydroperoxide from cumene.	4L
2.4	Radicals in synthesis: ● Inter and intra molecular C-C bond formation via mercuric hydride, tin hydride, thiol donors. ● Cleavage of C-X, C-Sn, C-Co, C-S, O-O bonds. ● Oxidative coupling, C-C bond formation in aromatics: S_NAr reactions.	4L
2.5	Hunsdiecker reaction, Pinacol coupling, McMurry coupling, Sandmeyer reaction, Acyloin condensation.	3L

Unit III : Enamines, Ylides and α-C-H functionalization [15L]

3.1	Enamines: ● Generation & application in organic synthesis with mechanistic pathways. ● Stork enamine reaction. ● Reactivity, comparison between enamines and enolates ● Synthetic reactions of enamines including asymmetric reactions of chiral enamines derived from chiral secondary amines.	4L
3.2	Phosphorus, Sulfur and Nitrogen Ylides: ● Preparation and their synthetic applications along with their stereochemical aspects. ● Wittig reaction, Horner-Wadsworth-Emmons Reaction, Barton-Kellogg olefination.	6L
3.3	α-C-H functionalization: By nitro, sulfoxide, sulfone and phosphonate group: ● Generation of carbanions by strong bases (LDA/n-butyl lithium) and applications in C-C bond formation ● Bamford-Stevens reaction, Julia olefination and its modification, Seyferth–Gilbert homologation, Steven's rearrangement.	5L

Unit IV: Metals / Non-metals in organic synthesis [15L]

4.1	Mercury in organic synthesis: ● Mechanism and regiochemistry of oxymercuration and demercuration of alkenes. ● Mercuration of aromatics. ● Transformation of aryl mercurials to aryl halides. ● Organomercurials as carbene transfer reagents.	3L
4.2	Organoboron compounds: ● Mechanism and regiochemistry of hydroboration of alkenes and alkynes. ● Asymmetric hydroboration using chiral boron reagents. ● 9-BBN hydroboration, oxazaborolidine (CBS catalyst) and functional group reduction by diborane.	3L
4.3	Organosilicons: ● Salient features of silicon governing the reactivity of organosilicons. ● Preparation and important bond-forming reactions of alkyl silanes, alkenyl silanes, aryl silanes and allyl silanes. ● β-silyl cations as intermediates. ● Iodotrimethylsilane in organic synthesis.	3L
4.4	Silyl enol ethers: ● Applications: As nucleophiles (Michael reaction, Mukaiyama aldol reaction) and in ring contraction reactions.	2L
4.5	Organotin compounds:	2L

	• Preparation of alkenyl and allyl tin compounds; • Application in C-C bond formation, in replacement of halogen by H at the same C atom.	
4.6	Selenium in organic synthesis: • Preparation of selenols/ selenoxide. • Selenoxide elimination to create unsaturation. • Selenoxide and seleno acetals as α-C-H activating groups	2L

References:

1. Advanced Organic Chemistry, Part A and Part B: Reaction and Synthesis, Francis A. Carey, Richard J. Sundberg, 5th Edition, Springer Verlag.
2. Modern Methods of Organic Synthesis, 4th Edition, W. Carruthers and Iain Coldham, Cambridge University Press, 2004.
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5. Modern Organic Synthesis: An Introduction, G.S. Zweifel and M.H. Nantz, W.H. Freeman and Company, (2007).
6. Advanced Organic Chemistry: Reaction Mechanism, R.Bruckner, Academic Press (2002).
7. Principles of Organic Synthesis, R.O.C. Norman & J. M. Coxon, 3rd Edn., Nelson Thornes.
8. Strategic Applications of Name Reactions in Organic Synthesis,L. Kurti & B. Czako (2005), Elsevier Academic Press.
9. Advanced Organic Chemistry: Reactions & Mechanisms, 2 Edn., B. Miller & R. Prasad, Pearson
10. Principles of Organic Synthesis, R.O.C. Norman & J. M. Coxon 3rd Edn., Nelson Thornes.
11. Strategic Applications of Name Reactions in Organic Synthesis, L. Kurti & B. Czako (2005), Elsevier Academic Press.
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13. Name Reactions and Reagents in Organic Synthesis, 2nd Edn., Bradford P. Mundy, Michael G. Ellard, and Frank Favoloro, Jr., Wiley-Interscience.
14. Name Reactions, Jie Jack Lie, 3rd Edn., Springer.
15. Organic Electrochemistry, H. Lund, and M. Baizer, 3rd Edn., Marcel Dekker.

PROGRAM - MSc. - II		Semester: III			
Mandatory Course - III **Theory Paper - III**		**CHEM 643** **Natural products and Spectroscopy-I**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**-**	**04**	**50**	**50**

Prerequisites
Structures of simple carbohydrates and their reactions, NMR theory

Learning Objectives

1. Describe properties of natural products such as carbohydrates, pigments, pheromones, alkaloids, prostaglandins, plant and insect growth regulators
2. Outline the analytical steps used in the elucidation of the structures of the above mentioned classes of compounds
3. Write multistep synthesis for these compounds.
4. Grasp the concepts of proton and C13 spectroscopy as well as advanced techniques.
5. Determine structure of molecules given their spectra

Course Outcomes
After completion of this Course, the learner will be able to

1. Identify natural products based on their properties
2. Use analytical evidences to determine structures of natural products
3. Use functional group transformations and reagents to write multistep synthesis of natural products
4. Read and correlate aspects of spectral data to structures
5. Systematically analyze different types of spectra and determine structures of molecules

Semester: III
CHEM 643
Natural products and Spectroscopy-I

Unit - I Natural products-I [15L]

1.1	Carbohydrates - Introduction to naturally occurring sugars: Deoxysugars, aminosugars, branched sugars. Structure elucidation of D- glucosamine (synthesis not expected). Structural features and applications of inositol, starch, cellulose, chitin and heparin	**4L**
1.2	Natural pigments - General structural features, occurrence, biological importance and applications of: carotenoids, anthocyanins, quinones, flavones, pterins and porphyrins (chlorophyll). Synthesis of β-Carotene from β-Ionone and ubiquinone from 3, 4, 5-trimethoxyacetophenone	**4L**
1.3	Insect pheromones - General structural features and importance. Types of pheromones (aggregation, alarm, releaser, primer, territorial, trail, sex	**4L**

	pheromones etc.), advantage of pheromones over conventional pesticides. Synthesis of bombykol from acetylene, disparlure from 6-methylhept-1-ene, grandisol from 2-methyl-1, 3-butadiene	
1.4	Alkaloids - Occurrence and physiological importance of morphine and atropine. Structure elucidation, spectral data and synthesis of Atropine	**3L**

Unit - II Natural products-II [15L]

2.1	Multi-step synthesis of natural products Synthesis of the following natural products with special reference to reagents used, stereochemistry and functional group transformations: a) Woodward synthesis of Reserpine from benzoquinone b) Corey synthesis of Longifoline from resorcinol c) Gilbert-Stork synthesis of Griseofulvin from phloroglucinol d) Corey's Synthesis of Caryophyllene from 2-Cyclohexenone and Isobutylene e) Synthesis of Juvabione from Limonene f) A.V.Ramarao synthesis of 4-demethoxydaunomycin from ethyl acetoacetate	**9L**
2.2	Prostaglandins - Classification, general structure and biological importance. Structure elucidation of **PGE_1**	**2L**
2.3	Insect growth regulators - General idea, structures of JH_2 and JH_3	1L
2.4	Plant growth regulators - Structural features and applications of arylacetic acids, gibberellic acids and triacontanol. Synthesis of triacontanol (synthesis of stearyl magnesium bromide and 12-bromo-1-tetrahydropyranyloxydodecane expected).	**3L**

Unit - III Unit 3: Advanced spectroscopic techniques-I [15L]

3.1	Proton NMR spectroscopy: Recapitulation, chemical and magnetic equivalence of protons, First order and second order spectra, Spin system notations (A_2, AB, AX, AB_2, AX_2, AMX and A_2B_2-A_2X_2 spin systems with suitable examples). Long range coupling (Allylic coupling, 'W' coupling and Coupling in aromatic and heteroaromatic systems), Temperature effects	**7L**
3.2	^{13}C –NMR spectroscopy: Recapitulation, equivalent and non-equivalent carbons (examples of aliphatic and aromatic compounds), ^{13}C- chemical shifts, calculation of ^{13}C- chemical shifts of aromatic carbons, heteronuclear coupling of carbon to ^{19}F and ^{31}P.	**4L**
3.3	Spectral problems based on UV, IR, ^{1}HNMR and ^{13}CNMR and Mass spectroscopy	**4L**

Unit - IV Advanced spectroscopic techniques-II [15L]

4.1	Advanced NMR techniques: Simplification of complex spectra, nuclear magnetic double resonance, chemical shift reagents, DEPT experiment, determining number of attached hydrogens (Methyl/methylene/methine and quaternary carbons), two dimensional spectroscopic techniques, COSY and HETCOR spectra, NOE and NOESY techniques	**11L**
4.2	Spectral problems based on UV, IR, ^{1}HNMR, ^{13}CNMR (Including 2D technique) and Mass spectroscopy	**4L**

References

1. Natural product chemistry, A mechanistic, biosynthetic and ecological approach, Kurt B.G. Torssell, Apotekarsocieteten – Swedish Pharmaceutical Press.

2. Natural products chemistry and applications, Sujata V. Bhat, B.A. Nagasampagi and S. Meenakshi, Narosa Publishing House, 2011.

3. Organic Chemistry Natural Products Volume-II, O. P. Agarwal, Krishna Prakashan, 2011.

4. Chemistry of natural products, F. F. Bentley and F. R. Dollish, 1974

5. Natural Product Chemistry Vol.1 and 2, K. Nakanishi J. Goto. S.Ito Majori and S. Nozoo, Academic Press, 1974.

6. Chemistry of natural products, V.K. Ahluwalia, Vishal Publishing Co. 2008.

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9. Stereoselective Synthesis: A Practical Approach, M. Nogradi, Wiley-VCH, 1995.

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12. Introduction to Flavonoids, B.A. Bohm, Harwood Academic Publishers, 1998.

13. New Trends in Natural Product Chemistry, Atta-ur-Rahman and M.I. Choudhary, Harwood Academic Publishers, 1998.

14. Insecticides of Natural Origin, Sukh Dev, Harwood Academic Publishers.

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19. The Total Synthesis of Reserpine, Woodward, R. B.; Bader, F. E.; Bickel, H., Frey, A. J.; Kierstead, R. W. Tetrahedron 1958, 2, 1-57.

20. Total synthesis of Griseofulvin, Stork, G.; Tomasz, M. J. Am. Chem. Soc. 1962, 84, 310.

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28. The Logic of Chemical Synthesis, E. J. Corey and Xue-Min Cheng, Wiley Interscience.
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30. Applications of Absorption Spectroscopy of Organic compounds, J. R. Dyer, Prentice Hall of India, 1987.
31. Spectrometric Identification of Organic compounds, R.M. Silverstein and others, John Wiley and Sons Inc., 5th ed., 1991
32. Absorption spectroscopy of organic Molecules, V.M. Parikh, 1974.
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36. Introduction to spectroscopy, Donald L. Pavia, Gary M. Lampman, George S. Kriz, James R. Vyvyan, 4th ed., 2009.
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38. Organic Spectroscopy: Principles And Applications, Jag Mohan, Alpha Science International Ltd., 30-Mar-2004
39. Alkaloids, V.K. Ahluwalia, Ane Books Pvt.Ltd.
40. Biotransformations in Organic Chemistry, 5thEdition, Kurt Faber, Springer
41. Structure Determination of Organic Compounds, EPretsch, P. Buhlmann, C.Affolter, Springer

Organic Chemistry Practical

PROGRAM - MSc. - II		**Semester: III**			
Mandatory Course **Practical**		**CHEM 644** **Organic Chemistry Practical**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 25)**	**Semester End Examination (Marks- 25)**
NA	**04**	**-**	**02**	**25**	**25**

Prerequisites

1. Knowledge of the general methods of type detection of binary mixtures of organic compounds
2. Methods of separation of binary mixture of organic compounds
3. Determination of physical constant of organic compounds.

Learning Objectives

1. Demonstrate detection of type of organic compounds in a ternary mixture
2. Separate ternary mixtures into components (including carbohydrates)
3. Determine the physical constants of the three components of the mixture.

Course Outcomes

After completion of this Course, the learner will be able to

1. Detect the type of each component in a ternary mixture (S-S-S, S-S-L, S-L-L and L-L-L) based upon differences in the physical and the chemical properties
2. Separate ternary mixture of organic compounds using chemical methods and microscale techniques
3. Purify the separated compounds (any one) and measure physical constants of all three compounds.
4. Identify the organic compounds(any one)

Semester: III
CHEM 644
Organic Chemistry Practical

List of Experiments

Ternary mixture of organic compounds

1. Separation of a ternary mixture (S-S-S, S-S-L, S-L-L and L-L-L) (for solid mixture: water insoluble/soluble including carbohydrates) based upon differences in the physical and the chemical properties of the components.
2. Purification and determination of physical constant of one of the components (as indicated by examiner)
3. Identification of one component (indicated by the examiner) using micro-scale techniques.

(Minimum 8 experiments)

Note:

1. The candidate is expected to submit a journal certified by the Head of the Department / institution at the time of the practical examination.
2. A candidate will not be allowed to appear for the practical examination unless he / she produces a certified journal or a certificate from the Head

of the institution/department stating that the journal is lost and the candidate has performed the required number of experiments satisfactorily. The list of the experiments performed by the candidate should be attached with such a certificate.

3. Use of non-programmable calculator is allowed both at the theory and the practical examination.

References

1. Systematic Identification of Organic compounds, 6th edition, R. L. Shriner, R. C. Fuson and D.Y. Curtin Wiley, New York.
2. Macro-scale and Micro-scale Organic Experiments, K. L. Williamson, D. C. Heath.
3. Systematic Qualitative Organic Analysis, H. Middleton, Adward Arnold.
4. Handbook of Organic Analysis- Qualitative and Quantitative, H. Clark, Adward Arnold.
5. Vogel's Textbook of Practical Organic Chemistry, Fifth edition,2008, B.S.Furniss, A. J.Hannaford, P. W. G. Smith, A. R. Tatchell, Pearson Education.
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9. Advanced Practical Organic Chemistry – N. K. Vishnoi, Third Addition, Vikas Publishing House PVT Ltd
10. Systematic Laboratory Experiments in Organic Synthesis- A. Sethi, New Age International Publications

Elective I - Medicinal Chemistry Theory

PROGRAM - MSc. - II		Semester: III			
Elective - I Theory		CHEM 64511 Medicinal Chemistry			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks- 25)	Semester End Examination (Marks- 25)
02	NA	-	02	25	25

Prerequisites:
Basic idea of medicinal chemistry terminology, Hammett equation and drug action

Learning Objectives

1. Outline the factors governing bioactivity of drugs
2. Illustrate the procedures in design of drugs
3. List QSAR parameters and correlate to biological activity of drugs
4. Illustrate modern methods of drug design and its use in the synthesis of typical drugs

Course Outcomes

After completion of this Course, the learner will be able to

1. List and explain the terms associated with drug activity and explain factors affecting bioactivity of drugs
2. Explain discovery of drugs without lead molecules and application of modern ideas in design of drugs
3. Explain terms in QSAR parameters and its use in design of drugs
4. Write synthesis of typical drugs using modern methods

Semester: III
CHEM 64511
Medicinal Chemistry

Unit - I: Drug discovery, design and development [15L]

1.1	Introduction, important terms used in medicinal chemistry: receptor, therapeutic index, bioavailability, drug assay and drug potency. General idea of factors affecting bioactivity: Resonance, inductive effect, bioisosterism, spatial considerations. Basic pharmacokinetics: drug absorption, distribution, metabolism (biotransformation) and elimination. Physical and chemical parameters like solubility, lipophilicity, ionization, pH, redox potential, H-bonding, partition coefficient and isomerism in drug distribution and drug-receptor binding.	**7L**
1.2	Procedures in drug design: Drug discovery without a lead: Penicillin, Librium. Lead discovery: random screening, non-random (or targeted) screening. Lead modification: Identification of the pharmacophore, Functional group modification. Structure-activity relationship, Structure modification to increase potency and therapeutic index: Homologation, chain branching, ring-chain transformation, bioisosterism, combinatorial synthesis (basic idea).	**8L**

Unit - II: Drug design, development and synthesis

2.1	Introduction to quantitative structure activity relationship studies. QSAR parameters: - steric effects: The Taft and other equations; Methods used to correlate regression parameters with biological activity: Hansch analysis- A linear multiple regression analysis.	**5L**
2.2	Introduction to modern methods of drug design and synthesis- computer-aided molecular graphics based drug design, drug design via enzyme inhibition (reversible and irreversible), bioinformatics and drug design.	**3L**
2.3	Concept of prodrugs and soft drugs. (a) Prodrugs: Prodrug design, types of prodrugs, functional groups in prodrugs, advantages of prodrug use. (b) Soft drugs: concept and properties.	**3L**
2.4	Synthesis and application of the following drugs: Fluoxetine, cetrizine, esomeprazole, fluconazole, zidovudine, methotrexate, diclofenac, labetalol, fenofibrate.	**4L**

References

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4. Zubay, Godffrey L; Biochemistry; Wm C. Brown publishers.

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Elective I - Medicinal Chemistry Practical

PROGRAM - MSc. - II		Semester: III			
Elective - I Practical		CHEM 64511 Medicinal Chemistry Practical			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks- 25)	Semester End Examination (Marks- 25)
NA	04	-	02	25	25

Prerequisites

Students must have knowledge of Mass spectrometry, NMR spectroscopy, UV-visible spectroscopy, IR spectroscopy.

Learning Objectives

1. Determination of molecular formula from mass spectrometry
2. Analysis of spectral data from various spectra
3. Elucidate structures of organic compounds using combined data from various spectroscopic techniques

Course Outcomes

After completion of this Course, the learner will be able to

1. Use various spectroscopic techniques to elucidate the structure of organic compounds

Semester: III
CHEM 64511
Medicinal Chemistry Practical

List of Experiments

Combined Spectral Identification:

Interpretation of spectral data of organic compounds (UV, IR, PMR, CMR and Mass spectra) (Molecular formula to be determined using rule of 13/elemental composition method).

A student will be given UV, IR, PMR, CMR, and Mass spectra of a compound from which the student is expected to determine molecular formula and preliminary information and report it within the first half an hour of the examination without referring to any book/reference material. The complete structure of the compound may then be elucidated by referring to any standard text-book/reference material etc

(Minimum 10 spectral analysis)

References

Organic structures from spectra, L. D. Field, S. Sternhell, John R. Kalman, Wiley, 4th ed., 2011.

Note:

1. The candidate is expected to submit a journal certified by the Head

of the Department / institution at the time of the practical examination.

2. A candidate will not be allowed to appear for the practical examination unless he / she produces a certified journal or a certificate from the Head of the institution/department Stating that the journal is lost and the candidate has performed the required number of experiments satisfactorily. The list of the experiments performed by the candidate should be attached with such a certificate.
3. Use of non-programmable calculator is allowed both at the theory and the practical examination.

Elective II - Biogenesis and green chemistry Theory

PROGRAM - MSc. - II		**Semester: III**			
Elective – II Theory		**CHEM 64512 Biogenesis and green chemistry**			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks-25)	Semester End Examination (Marks- 25)
02	NA	-	02	25	25

Prerequisites

Basics of biochemistry, Classification and application of biomolecules, Twelve principles of green chemistry with emphasis on atom economy, E-Factor, selectivity

Learning Objectives

1. Describe some of the important pathways related to synthesis of biomolecules and natural products
2. Illustrate the principles of Green Chemistry and their importance in addressing environmental issues
3. Design and evaluate chemical processes that minimize the use of hazardous substances and energy
4. Apply the principles of Green Chemistry to solve real-world problems

Course Outcomes

After completion of this Course, the learner will be able to

1. Explain some of the important pathways related to synthesis of biomolecules and natural products
2. Explain the principles of Green Chemistry and their importance in addressing environmental issues.
3. Design and evaluate chemical processes that minimize the use of hazardous substances and energy.
4. Compare and evaluate the greenness of given synthesis.

Semester: III
CHEM 64512
Biogenesis and green chemistry

Unit - I: Biogenesis and biosynthesis of natural products [15L]

1.1	Primary and secondary metabolites and the building blocks, general pathway of amino acid biosynthesis.	[3L]
1.2	Acetate pathway: Biosynthesis of malonylCoA, saturated fatty acids, prostaglandins from arachidonic acid, aromatic polyketides.	[4L]
1.3	Shikimic Acid pathway: Biosynthesis of shikimic acid, aromatic amino acids, cinnamic acid and its derivatives, lignin and lignans, benzoic acid and its derivatives, flavonoids and isoflavonoids.	[4L]
1.4	Mevalonate pathway: Biosynthesis of mevalonic acid, monoterpenes – geranyl cation and its derivatives, sesquiterpenes – farnesyl cation and its derivatives and diterpenes.	[4L]

Unit - II: Green chemistry [15L]

2.1	Introduction, basic principles of green chemistry. Designing a green synthesis: Green starting materials, green reagents, green solvents and reaction conditions, green catalysts.	[1L]
2.2	Use of the following in green synthesis with suitable examples: a) Green reagents: dimethyl carbonate, polymer supported reagents. b) Green catalysts: Acid catalysts, oxidation catalysts, basic catalysts, phase transfer catalysts [Aliquat 336, benzyl trimethyl ammonium chloride (TMBA), Tetra-n-butyl ammonium chloride, crown ethers], biocatalysts. c) Green solvents: water, ionic liquids, deep eutectic solvents, supercritical carbon dioxide. d) Solid state reactions: solid phase synthesis, solid supported synthesis e) Microwave assisted synthesis: reactions in water, reactions in organic solvents, solvent free reactions. f) Ultrasound assisted reactions.	[9L]
2.3	Comparison of traditional processes versus green processes in the syntheses of ibuprofen, adipic acid, 4-aminodiphenylamine, p-bromotoluene and benzimidazole.	[3L]
2.4	Green Catalysts: Nanocatalyst, Types of nanocatalysts, Advantages and Disadvantages of Nanocatalysts, Idea of Magnetically separable nanocatalysts.	[2L]

References:

1. Enzyme catalysis in organic synthesis, 3rd edition. Edited by Karlheinz Drauz, Harold Groger, and Oliver May, Wiley-VCH Verlag GmbH & Co KgaA, 2012.
2. Biochemistry, Dr U Satyanarayan and Dr U Chakrapani, Books and Allied (P) Ltd.

3. Bioorganic, Bioinorganic and Supramolecular chemistry, P.S. Kalsi and J.P. Kalsi. New Age International Publishers
4. The Organic Chemistry of Enzyme-Catalysed Reactions, Academic Press, By Richard B. Silverman
5. Enzymes: Practical Introduction to structure, mechanism and data analysis, By Robert A. Copeland, Wiley-VCH, Inc.
6. The Organic Chemistry of Biological Pathways By John McMurry, Tadhg Begley by Robert and company publishers
7. Bioorganic Chemistry- A practical approach to Enzyme action, H. Dugas and C. Penny. Springer Verlag, 1931
8. Biochemistry: The chemical reactions in living cells, by E. Metzler. Academic Press.
9. Concepts in biotechnology by D. Balasubrarnanian & others
10. Bioorganic chemistry - A chemical approach to enzyme action by Herman Dugas and Christopher Penney.
11. Medicinal Natural Products: A Biosynthetic Approach by Paul M. Dewick. 3rd Edition, Wiley. 36. Natural product chemistry, A mechanistic, biosynthetic and ecological approach, Kurt B. G. Torssell, Apotekarsocieteten – Swedish pharmaceutical press.
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14. Chemistry of Natural Products, F. F. Bentley and F. R. Dollish, 1974.
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17. Green Chemistry: An Introductory Text, 2nd Edition, Published by Royal Society of Chemistry, Authored by Mike Lancater.
18. Organic synthesis in water. By Paul A. Grieco, Blackie.
19. Organic synthesis in water. By Paul A. Grieco, Blackie.
20. Green chemistry, Theory and Practical, Paul T. Anastas and John C. Warner.
21. New trends in green chemistry By V. K. Ahulwalia and M. Kidwai, 2nd edition, Anamaya Publishers, New Delhi.
22. An introduction to green chemistry, V. Kumar, Vishal Publishing Co.
23. Organic synthesis: Special techniques. V.K.Ahluwalia and Renu Aggarwal

Elective II - Biogenesis and green chemistry Practical

<table>
<tr><td colspan="3">PROGRAM - MSc. - II</td><td colspan="3">Semester: III</td></tr>
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<tr><td colspan="6">Prerequisites
Students must have knowledge of Mass spectrometry, NMR spectroscopy, UV-visible spectroscopy, IR spectroscopy.</td></tr>
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Learning Objectives

1. Determination of molecular formula from mass spectrometry
2. Analysis of spectral data from various spectra
3. Elucidate structures of organic compounds using combined data from various spectroscopic techniques

Course Outcomes

After completion of this Course, the learner will be able to

1. Use various spectroscopic techniques to elucidate the structure of organic compounds

Semester: III
CHEM 64512

Combined Spectral Identification:

Interpretation of spectral data of organic compounds (UV, IR, PMR, CMR and Mass spectra) (Molecular formula to be determined using rule of 13/elemental composition method).

A student will be given UV, IR, PMR, CMR, and Mass spectra of a compound from which the student is expected to determine molecular formula and preliminary information and report it within the first half an hour of the examination without referring to any book/reference material. The complete structure of the compound may then be elucidated by referring to any standard text-book/reference material etc

(Minimum 10 spectral analysis)

References

Organic structures from spectra, L. D. Field, S. Sternhell, John R. Kalman, Wiley, 4th ed., 2011.

Note:

1. The candidate is expected to submit a journal certified by the Head of the Department / institution at the time of the practical examination.
2. A candidate will not be allowed to appear for the practical examination unless he / she produces a certified journal or a certificate from the Head of the institution/department Stating that the journal is lost and the candidate has performed the required number of experiments satisfactorily. The list of the experiments performed by the candidate should be attached with such a certificate.
3. Use of non-programmable calculator is allowed both at the theory and the practical examination.

Semester-III
Course code: CHEM 646
Course title: Research Project

PROGRAM(s): M.Sc-II		SEMESTER: III			
Research Project		Course Title:- Research Project			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
NA	08	–	04	50%	50%

Learning Objectives:

1. To create awareness about the significance of research
2. To identify a research problem
3. To enable the learner to extract information from journals / digital resources and understand how to make a systematic research plan
4. To develop skills in the application of theory to experimental work situations.

Course Outcomes:

Learners will be able to:

1. Select the research topics of interest and create a systematic research plan for a chosen research project.
2. Develop skills in qualitative and quantitative analysis
3. Demonstrate the ability to choose proper synthetic and analytical methods appropriate to research topic.
4. Demonstrate good practices in research.

Course code: CHEM 646

Course title: Research Project

Guidelines:

1. Students are to work on research project individually

2. Research Project is of 4 credits which equals to project working hours of 120.

3. Novelty in research should be the focus when selecting a research topic.

4. The topic of research chosen by the student has to be of their interest, taking in account of its usefulness, social relevance and contribution to the field of chemistry

5. Record of attendance and continuous performance of the student is monitored by the mentor.

6. At the end of the semester, the student has to present the project report in a bound form for external evaluation

7. Participation in national and international conferences and other project competitions is encouraged.

8. Literature survey for the research project is suggested to be from journals of reputed publications and UGC – CARE journals.

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SEMESTER IV

PROGRAM - MSc. - II		Semester: IV			
Mandatory Course –I **Theory Paper - I**		**CHEM 647** **Theoretical Organic Chemistry - II**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**-**	**04**	**50**	**50**

Prerequisites
Understanding of field effect, resonance effect and steric effect,
Basic knowledge of molecular interactions involving kinetic and thermodynamic effects
Fundamentals of Stereochemistry

Learning Objectives:
1. Discuss structural effects, reactivity and applications of Hamett equation.
2. Introduction of important concepts in the field of supramolecular chemistry.
3. Examine the concepts of conformational analysis, racemisation and resolution.
4. Carry out various asymmetric transformations and employ such reactions in asymmetric organic synthesis of important chiral molecules.

Course Outcomes
After completion of this Course, the learner will be able to:
1. Describe the electronic impact of substituents on the rate and equilibrium of reaction
2. Explain the different methods and types of chemical systems used in the assembly of complex molecules and to apply supramolecular chemistry in other areas of biology.
3. Discuss the concepts of conformational analysis, racemisation and resolution.
4. Predict the stereochemical outcome under the conditions of asymmetric synthesis and to apply asymmetric transformations in a logical manner for the synthesis of chiral molecules.

Semester: IV
CHEM 647
Theoretical Organic Chemistry - II

Unit - I Physical organic chemistry

1.1	Structural effects and reactivity: Linear free energy relationship (LFER) in determination of organic reaction mechanism, The Hammett equation, substituent constants, theories of substituent effects, interpretation of σ-values, reaction constants ρ, Yukawa-Tsuno equation	7L
1.2	Uses of Hammett equation, deviations from Hammett equation. Dual parameter correlations, Inductive substituent constants. The Taft model, σ_I and σ_R scales, steric parameters Es and β. Solvent effects, Okamoto-Brown equation, Swain-Scott equation, Edward and Ritchie correlations,	8L

	Grunwald-Winstein equation, Dimroth's E_T parameter, Solvatochromism Z-scale, Spectroscopic correlations, Thermodynamic implications.	

Unit - II Supramolecular chemistry

2.1	Principles of molecular associations and organizations as exemplified in biological macromolecules like nucleic acids, proteins and enzymes.	3L
2.2	Synthetic molecular receptors: receptors with molecular cleft, molecular tweezers, receptors with multiple hydrogen sites.	3L
2.3	Structures and properties of crown ethers, cryptands, cyclophanes, calixarenes, rotaxanes and cyclodextrins. Synthesis of crown ethers, cryptands and calixarenes,	5L
2.4	Molecular recognition and catalysis, molecular self-assembly.Supramolecular Polymers, Gels and Fibres.	4L

Unit - III Stereochemistry- II

3.1	Racemisation and resolution of racemates including conglomerates: Mechanism of racemisation, methods of resolution: mechanical, chemical, kinetic and equilibrium asymmetric transformation and through inclusion compounds.	3L
3.2	Determination of enantiomer and diastereomer composition: enzymatic method, chromatographic methods. Methods based on NMR spectroscopy: use of chiral derivatizing agents (CDA), chiral solvating agents (CSA) and Lanthanide shift reagents (LSR).	3L
3.3	Correlative method for configurational assignment: chemical, optical rotation, and NMR spectroscopy.	4L
3.4	Molecular dissymmetry and chiroptical properties: Linearly and circularly polarized light. Circular birefringence and circular dichroism. ORD and CD curves. Cotton effect and its applications. The octant rule and the axial α–haloketone rule with applications.	5L

Unit - IV Asymmetric synthesis

4.1	Principles of asymmetric synthesis: Introduction, the chiral pool in Nature, methods of asymmetric induction – substrate, reagent and catalyst controlled reactions.	3L
4.2	Synthesis of L-DOPA [Knowles's Mosanto process]. Asymmetric reactions with mechanism: Aldol and related reactions, Cram's rule, Felkin-Anh model, Sharpless enantioselective epoxidation, hydroxylation, aminohydroxylation, Diels-Alder reaction, reduction of prochiral carbonyl compounds and olefins.	9L

4.3	Use of chiral auxiliaries in diastereoselective reductions, asymmetric amplification. Use of chiral BINOLs, BINAPs and chiral oxazolines asymmetric transformations.	3L

References:

1. Modern physical chemistry, Eric V Anslyn, Dennis A. Dougherty, University science books,2006
2. Physical Organic Chemistry, N. S. Isaacs, ELBS/Longman
3. Stereochemistry of Carbon Compounds: Principles and
4. Applications, D, Nasipuri, 3rd edition, New Age International Ltd.
5. Bioorganic, Bioinorganic and Supramolecular chemistry, P.S. Kalsi and J.P. Kalsi. New Age International Publishers
6. Supramolecular Chemistry; Concepts and Perspectives, J. M. Lehn, VCH.
7. Crown ethers and analogous compounds, M. Hiraoka, Elsevier, 1992.
8. Large ring compounds, J.A.Semlyen, Wiley-VCH, 1997.
9. Stereochemistry of Carbon Compounds: Principles and Applications, D, Nasipuri, 3rd edition, New Age International Ltd.
10. Stereochemistry of Organic Compounds, Ernest L. Eliel and Samuel H. Wilen, Wiley-India edit
11. Stereochemistry, P. S. Kalsi, 4th edition, New Age International Ltd.
12. Organic Stereochemistry, M. J. T. Robinson, Oxford University Press, New Delhi, India edition, 2005

PROGRAM - MSc. - II		Semester: IV			
Mandatory Course –II **Theory Paper - II**		**CHEM 648** **Synthetic Organic Chemistry - II**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks- 50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**-**	**04**	**50**	**50**

Prerequisites

Reactive intermediates-Generation, stability and reactions, reactions of the functional groups, reagents in synthesis,

Learning Objectives

1. Apply protection -deprotection protocol for the different functional groups to bring about selective synthetic transformations of groups
2. Generate acyl anion equivalents using different reagents leading to reversal of polarity (umpolung) and use it in synthesis
3. To apply the principles of disconnection approach and break down a complex molecule into simpler starting compounds.
4. To use the principles of selectivity to chemical transformations.
5. To analyze molecules using the principles of retrosynthetic analysis and find suitable starting materials.
6. To write sound synthetic pathways for compounds based on the identified retrosynthetic pathways
7. Employ electroorganic chemistry methods in synthesis
8. Employ transition and rare earth metals in organic synthesis

Course Outcomes

After completion of this Course, the learner will be able to

1. Explain the need for protecting groups in organic synthesis and select appropriate protecting and deprotecting strategies for functional groups such as hydroxyl, carbonyl, amino, and carboxyl groups.
2. Apply the concept of umpolung and generate acyl anion equivalents using various methods
3. Utilize the disconnection approach to identify synthons and synthetic equivalents, perform functional group interconversions (FGI), additions (FGA), and removals (FGR), and execute one- and two-group C-X disconnections for difunctionalized compounds.
4. Develop skills in selectivity control during organic transformations, focusing on chemoselectivity, regioselectivity, stereoselectivity, and enantioselectivity.
5. Formulate a general strategy for designing organic synthesis
6. Demonstrate competence in performing one-group and two group C-C disconnections, incorporate acetylenes and aliphatic nitro compounds in their synthetic strategies and synthesize α, β-unsaturated compounds through appropriate synthetic methods.

7. Explain the various terms in electroorganic chemistry and use electroorganic methods in the synthesis of organic compounds
8. Identify the reactions shown by transition and rare earth metals and use them in different reactions and in synthesis of organic compounds.

Semester: IV
CHEM 648
Synthetic Organic Chemistry - II

Unit 1: Designing Organic Synthesis-I [15L]

1.1	Protecting groups in Organic Synthesis: ● Need for protecting groups, advantages and disadvantages of protection-deprotection protocol and protection and deprotection of the following functional groups with applications ● Hydroxyl including diols (ethers, acetals and esters) ● Carbonyl (acetals) ● Amino (amides, urethanes and phthalimides) ● carboxyl (different types of esters)	[3L]
1.2	Concept of umpolung (Reversal of polarity) ● Generation of acyl anion equivalent using 1,3-dithianes, methyl thiomethyl sulfoxides, protected cyanohydrin ethers, vinyl (enol) ethers and nitroalkanes	[3L]
1.3	Introduction to Retrosynthetic analysis and synthetic planning ● Linear and convergent synthesis ● Disconnection approach: An introduction to synthons, synthetic equivalents, functional group interconversions (FGI), functional group addition (FGA), functional group removal (FGR) ● one and two group C-X disconnections (1,1; 1,2; 1,3 difunctionalized compounds) with suitable examples, ● Selectivity in organic transformations: chemoselectivity, regioselectivity, stereoselectivity, enantioselectivity.	[9L]

Unit 2: Designing Organic Synthesis-II [15L]

2.1	General strategy: ● Order of events in organic synthesis ● choosing a disconnection ● symmetry,	[3L]
2.2	One group C-C Disconnections: ● Alcohols (including stereoselectivity), ● Carbonyl compounds (including regioselectivity), ● Alkene synthesis, ● Use of acetylenes and aliphatic nitro compounds in organic synthesis.	[6L]
2.3	Two group C-C Disconnections: ● 1,2- 1,3- 1,4- 1,5- and 1,6- difunctionalized compounds, ● Diels-Alder reactions, ● α, β-unsaturated compounds,	[6L]

	• control in carbonyl condensations, • Michael addition and Robinson annelation	

Unit-III

Electro-organic chemistry and selected methods of Organic synthesis

3.1	Electro-organic chemistry:	[7L]
3.1.1	Introduction: Electrode potential, cell parameters, electrolyte, supporting electrolytes, working electrode, choice of solvents.	
3.1.2	Cathodic reduction: Reduction of alkyl halides, aldehydes, ketones, nitro compounds, olefins, arenes, electro-dimerization.	
3.1.3	Anodic oxidation: Oxidation of alkylbezene, Kolbe reaction, Non-Kolbe oxidation, Shono oxidation.	
3.2	Selected Methods of Organic synthesis:	[8L]
3.2.1	Applications of Crown ethers, cryptands, micelles, cyclodextrins and catenanes in organic synthesis.	
3.2.2	Organocatalysts: Proline, Imidazolidinone.	
3.2.3	Pd catalysed cycloaddition reactions: Stille reaction, Saeguse-Ito oxidation to enones, Negishi coupling.	
3.2.4	Use of Sc(OTf), and Yb(OTf) as water tolerant Lewis acid catalyst in aldol condensation, Michael reaction, Diels-Alder reaction, Friedel – Crafts reaction.	

Unit - IV

Transition and rare earth metals in organic synthesis [15L]

4.1	Introduction, basic concepts, TS metal complexes, 18 electron rule, oxidation states, ligands, oxidative addition, reduction elimination, migratory insertion.	[3L]
4.2	Palladium in organic synthesis: π-bonding of Pd with olefins, applications in C-C bond formation, carbonylation, alkene isomerisation, cross-coupling of organometallics and halides. Representative examples: Heck reaction, Suzuki-Miayura coupling, Sonogashira reaction and Wacker oxidation. Heteroatom coupling for bond formation between aryl/vinyl groups and N, S, or P atoms.	[5L]
4.3	Olefin metathesis using Grubb's catalyst.	[1L]
4.4	Application of Ni, Co, Fe, Rh, and Cr carbonyls in organic synthesis.	[4L]
4.5	Application of samarium iodide including reduction of organic halides, aldehydes and ketones and nitro compounds.	[1L]
4.6	Application of Ce (IV) in synthesis of heterocyclic quinoxaline derivatives.	[1L]

References

1. Advanced Organic Chemistry, Part A and Part B: Reaction and Synthesis, Francis A. Carey Richard J. Sundberg, 5th Edition,Springer Verlag
2. Modern Methods of Organic Synthesis, 4th Edition, W. Carruthers and Iain Coldham, Cambridge University Press, 2004.

3. Chem.Rev. 2002, 102, 2227-2302, Rare Earth Metal Triflates in Organic Synthesis, S. Kobayashi, M. Sugiura, H. Kitagawa, and W.W.L. Lam.
4. Organic Chemistry, Clayden Greeves Warren and Wothers, Oxford Press (2001).
5. Modern Organic Synthesis: An Introduction, G.S. Zweifel and M.H. Nantz, W.H. Freeman and Company, (2007).
6. Advanced Organic Chemistry: Reaction Mechanism, R.Bruckner, Academic Press (2002).
7. Principles of Organic Synthesis, R.O.C. Norman & J. M. Coxon, 3rd Edn., Nelson Thornes
8. Organic Chemistry, 7th Edn, R. T .Morrison, R. N. Boyd, & S. K.Bhattacharjee, Pearson
9. Strategic Applications of Name Reactions in Organic Synthesis,L. Kurti & B. Czako (2005), Elsevier Academic Press
10. Advanced Organic Chemistry: Reactions & Mechanisms, 2nd Edn., B. Miller & R. Prasad, Pearson
11. Organic reactions and their mechanisms, 3rd revised edition, P.S.Kalsi, New Age International Publishers
12. Organic Synthesis: The Disconnection Approach, Stuart Warren,John Wiley & Sons, 2004
13. Name Reactions and Reagents in Organic Synthesis, 2nd Edn., Bradford P. Mundy, Michael G. Ellard, and Frank Favoloro, Jr.,Wiley-Interscience
14. Name Reactions, Jie Jack Lie, 3rd Edn., Springer
15. Organic Electrochemistry, H. Lund, and M. Baizer, 3rd Edn. Marcel Dekker.
16. Organic Synthesis: Strategy and Control, Paul Wyatt and Stuart Warren, John Wiley & Sons, 2007.

PROGRAM - MSc. - II		Semester: IV			
Mandatory Course –III **Theory Paper III**		**CHEM 649** **Natural Products and Heterocyclic Chemistry**			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks-50)	Semester End Examination (Marks- 50)
04	NA	-	04	50	50

Prerequisites
Introduction to heterocyclic compounds

Learning Objectives

1. Describe properties of steroids and outline the steps in the synthesis of these compounds.
2. Describe classification, structure elucidation and synthesis of vitamins, antibiotics, naturally occurring insecticides and terpenoids.
3. Describe classification and different systems of nomenclature for monocyclic, bicyclic and tricyclic fused heterocycles.
4. Describe structure, reactivity and methods of synthesis of different classes of heterocycles.

Course Outcomes
After completion of this Course, the learner will be able to

1. List structural features of steroids and outline the steps in their synthesis
2. Classify, determine structure based on analytical evidence and write synthesis of vitamins, antibiotics, naturally occurring insecticides and terpenoids
3. Classify and write names using different systems of nomenclature for monocyclic, bicyclic and tricyclic fused heterocycles.
4. Explain structure and reactivity and write synthesis of different classes of heterocycles.

Semester: IV
CHEM 649
Natural products and Heterocyclic Chemistry

Unit 1: Natural products-III **[15L]**

1.1	Steroids: General structure, classification. Occurrence, biological role, important structural and stereochemical features of the following: corticosteroids, steroidal hormones, steroidal alkaloids, sterols and bile acids.	[5L]
1.2	Synthesis of 16-DPA from cholesterol and plant sapogenin.	[2L]
1.3	Synthesis of the following from 16-DPA: androsterone, testosterone, oestrone, oestriol, oestradiol and progesterone.	[5L]

1.4	Synthesis of cinerolone, jasmolone, allethrolone, exaltone and muscone.	[3L]

Unit 2: Natural products-IV **[15L]**

2.1	Vitamins: Classification, sources and biological importance of vitamin B1, B2, B6, folic acid, B12, C, D1, E (α-tocopherol), K1, K2, H (β-biotin). Synthesis of the following: Vitamin A from β-ionone and bromoester moiety. Vitamin B1 including synthesis of pyrimidine and thiazole moieties Vitamin B2 from 3, 4-dimethylaniline and D(-)ribose Vitamin B6 from: 1) ethoxyacetylacetone and cyanoacetamide, 2) ethyl ester of N-formyl-DL-alanine (Harris synthesis) Vitamin E (α-tocopherol) from trimethylquinol and phytyl bromide Vitamin K1 from 2-methyl-1, 4-naphthaquinone and phytol.	[5L]
2.2	Antibiotics: Classification on the basis of activity. Structure elucidation, spectral data of penicillin-G, cephalosporin-C and chloramphenicol. Synthesis of chloramphenicol (from benzaldehyde and β-nitroethanol) penicillin-G and phenoxymethylpenicillin from D-penicillamine and t-butyl phthalimide malonaldehyde (synthesis of D-penicillamine and t-butyl phthalimide malonaldehyde expected).	[5L]
2.3	Naturally occurring insecticides: Sources, structure and biological properties of pyrethrums (pyrethrin I), rotenoids (rotenone). Synthesis of pyrethrin I.	[2L]
2.4	Terpenoids: Occurrence, classification, structure elucidation, stereochemistry, spectral data and synthesis of zingiberene.	[3L]

Unit 3: Heterocyclic compounds-I **[15L]**

3.1	Introduction, classification, Nomenclature of heterocyclic compounds of monocyclic (3-6 membered) (Common, systematic (Hantzsch-Widman) and replacement nomenclature)	[6L]
3.2	Structure, reactivity, synthesis and reactions of pyrazole, imidazole, oxazole, isoxazole, thiazole, isothiazole, pyridazines, pyrimidine, pyrazines and oxazines.	[9L]

Unit 4: Heterocyclic compounds-II **[15L]**

4.1	Nomenclature of heterocyclic compounds of bicyclic/tricyclic (5-6 Membered) fused heterocycles (up to three hetero atoms). (Common, systematic (Hantzsch-Widman) and replacement nomenclature)	[4L]
4.2	Nucleophilic ring opening reactions of oxiranes, aziridines, oxetanes and azetidines.	[3L]
4.3	Structure, reactivity, synthesis and reactions of coumarins, quinoxalines, cinnolines, indole, benzimidazoles, benzoxazoles, benzothiazoles, Purines and acridines	[8L]

References

1. Natural product chemistry, A mechanistic, biosynthetic and ecological approach, Kurt B.G. Torssell, Apotekarsocieteten – Swedish Pharmaceutical Press.
2. Natural products chemistry and applications, Sujata V. Bhat, B.A.Nagasampagi and S. Meenakshi, Narosa Publishing House, 2011.
3. Organic Chemistry Natural Products Volume-II, O. P. Agarwal, Krishna Prakashan, 2011.
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6. Chemistry of natural products, V.K. Ahluwalia, Vishal Publishing Co. 2008.
7. Heterocyclic chemistry, 3rd edition, Thomas L. Gilchrist, Pearson Education, 2007.
8. Heterocyclic Chemistry, Synthesis, Reactions and Mechanisms, R.K. Bansal, Wiley Eastern Ltd., 1990.
9. Heterocyclic Chemistry, J. A. Joule and G. F. Smith, ELBS, 2nd edition, 1982.
10. The Conformational Analysis of Heterocyclic Compounds, F.G.Riddell, Academic Press,1980.
11. Principles of Modern Heterocyclic Chemistry, L.A. Paquette, W.B.Benjamin, Inc., 1978.
12. An Introduction to the Chemistry of Heterocyclic Compounds, 2nd edition, B.M. Acheson, 1975.
13. Natural Products: Chemistry and Biological Significance Interscience, J. Mann, R.S.Davidson, J.B.Hobbs, D.V. Banthrope and J. B. Harborne, Longman,Essex, 1994.
14. Organic Chemistry, Vol 2, I.L. Finar, ELBS, 6th edition, Pearson.
15. Stereoselective Synthesis: A Practical Approach, M. Nogradi, Wiley-VCH, 1995.
16. Rodd's Chemistry of Carbon Compounds, Ed. S. Coffey, Elsevier.
17. Chemistry, Biological and Pharmacological Properties of Medicinal Plants from the Americas, Ed. Kurt Hostettmann, M.P. Gupta and A.Marston, Harwood Academic Publishers.
18. Introduction to Flavonoids, B.A. Bohm, Harwood Academic Publishers, 1998.
19. New Trends in Natural Product Chemistry, Atta-ur-Rahman and M.I. Choudhary, Harwood Academic Publishers, 1998.
20. Insecticides of Natural Origin, Sukh Dev, Harwood Academic Publishers.
21. Total. Synthesis of Longifolene, J. Am. Chem. Soc., E. J. Corey, M.Ohno, R. B. Mitra, and P. A. Vatakencherry. 1964, 86, 478.
22. Total. Synthesis of Longifolene, J. Am. Chem. Soc. 1961, 83, 1251.
23. The structure and total synthesis of 5-Vetivone, J. A. Marshall and P. C. Johnson, J. Org. Chem., 35, 192 (1970).
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25. The Total Synthesis of Reserpine, Woodward, R. B.; Bader, F. E.; Bickel, H., Frey, A. J.; Kierstead, R. W. Tetrahedron 1958, 2, 1-57.
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27. Synthesis of (±)-4-demethoxydaunomycinone,A. V. Rama Rao, G. Venkatswamy , S. M. Javeed M. , V. H. Deshpande, B.Ramamohan Rao, J. Org. Chem., 1983, 48 (9), 1552.
28. The Alkaloids, The fundamental Chemistry A biogenetic approach, Marcel Dekker Inc. New York, 1979.
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30. Medicinal Natural Products, a Biosynthetic Approach, Derick Paul, John Wiley and Sons, 2002.
31. Biosynthesis of Natural Products, Mannitto Paolo, Ellis Horwoocl Limited, 1981.
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Elective –I Bioorganic Chemistry

PROGRAM - MSc. - II		**Semester: IV**			
Elective –I Theory		**CHEM 65011** (Bioorganic Chemistry)			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credits	Continuous Assessment (CA) (Marks-50)	Semester End Examination (Marks- 50)
04	NA	-	04	50	50

Prerequisites
Knowledge of amino acids, Proteins, nucleic acids and enzymes

Learning Objectives

1. Explain the structural features of proteins and nucleic acids and describe properties and synthesis of nucleic acids.
2. Describe properties of enzymes and mechanism of enzyme action.
3. Describe structure and properties of coenzymes
4. Describe role of enzymes in organic synthesis

Course Outcomes
After completion of this Course, the learner will be able to

1. List the structural features of proteins and nucleic acids and outline the properties and synthesis of nucleic acids.
2. Summarize properties of enzymes and illustrate the role of enzymes
3. Examine structure and properties of coenzymes
4. Illustrate the role of enzymes in organic synthesis

Semester: IV
CHEM 65011
Bioorganic Chemistry

Unit 1: Biomolecules-I **[15L]**

1.1	Amino acids, peptides and proteins: Chemical and enzymatic hydrolysis of proteins to peptides, amino acid sequencing. Secondary structure of proteins, forces responsible for holding of secondary structures, α- helix, βsheets, super secondary structure. Tertiary structure of protein: folding and domain structure. Quaternary structure.	[2L]
1.2	Nucleic acids: Structure and function of physiologically important nucleotides (c-AMP, ADP, ATP) and nucleic acids (DNA and RNA), replication, genetic code, protein biosynthesis, mutation.	[3L]
1.3	Structure: Purine & pyrimidine bases, ribose, deoxyribose, nucleosides and nucleotides (ATP, CTP, GTP, TTP, UTP) formation of polynucleotides strand with its shorthand representation.	[3L]

1.4	RNAs (various types in prokaryotes and eukaryotes) m- RNA and r-RNA – general account, t- RNA-clover leaf model, Ribozymes.	[2L]
1.5	DNA: Physical properties – Effect of heat on physical properties of DNA (Viscosity, buoyant density and UV absorption), Hypochromism, Hyperchromism and Denaturation of DNA. Reactions of nucleic acids (withDPA and Orcinol).	[2L]
1.6	Chemical synthesis of oligonucleotides: Phosphodiester, Phosphotriester, Phosphoramidite and H- phosphonate methods including solid phase approach.	[3L]

Unit 2: Biomolecules-II **[15L]**

2.1	Chemistry of enzymes: Introduction, nomenclature, classes and general types of reactions catalyzed by enzymes. Properties of enzymes: a) enzyme efficiency/ catalytic power b) enzyme specificity; Fischer's 'lock and key'and Koshland 'induced fit' hypothesis. Concept and identification of active site.	[6L]
2.2	Factors affecting enzyme kinetics: Substrate concentration, enzyme concentration, temperature, pH, product concentration etc. Reversible and irreversible inhibition.	[4L]
2.3	Mechanism of enzyme action: transition-state theory, orientation and steric effect, acid-base catalysis, covalent catalysis, strain or distortion. Mechanism of chymotrypsin catalyzed hydrolysis of a peptide bond.	[5L]

Unit 3: Biomolecules - III **[15L]**

3.1	Chemistry of coenzymes. Structure, mechanism of action and bio-modeling studies of the following coenzymes: nicotinamide adenine dinucleotide, flavin adenine dinucleotide, thiamine pyrophosphate, pyridoxal phosphate, Vitamin B12, biotin, lipoic acid, Coenzyme A.	[12L]
3.2	Oxidative phosphorylation, chemiosmosis, rotary model for ATP synthesis and role of cytochrome in oxygen activation.	[3L]

Unit 4: Biomolecules – IV **[15L]**

4.1	Role of main enzymes involved in the synthesis and breakdown of glycogen.	[2L]
4.2	Enzyme catalyzed organic reactions: Hydrolysis, hydroxylation, oxidation and reduction.	[6L]
4.3	Enzymes in organic synthesis. Fermentation: Production of drugs/drug intermediates by fermentation. Production of chiral hydroxy acids, vitamins, amino acids, β-lactam antibiotics. Synthesis of chemicals via microbial transformation, synthesis of L-ephedrine. Chemical processes with isolated enzymes in free form (hydrocyanation of m-phenoxybenzaldehyde) and immobilized form (production of 6-aminopenicillanic acid).	[7L]

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Elective -II Intellectual Property Rights and Chemoinformatics

PROGRAM - MSc. - II		**Semester: IV**			
Elective – II Theory		**CHEM 65012 Intellectual Property Rights and Chemoinformatics**			
Teaching Scheme				**Evaluation Scheme**	
Lectures (Hours per week)	**Practical (Hours per week)**	**Tutorial (Hours per week)**	**Credits**	**Continuous Assessment (CA) (Marks-50)**	**Semester End Examination (Marks- 50)**
04	**NA**	**-**	**04**	**50**	**50**

Learning Objectives:

1. To introduce learners to Intellectual Property, Patents, Industrial Designs, Copyrights, Trademarks and Geographical Indications
2. To understand about the Trade Secrets with perspective to IP infringement issue and law of enforcement agencies
3. To give an understanding of the economic value of Intellectual property and different international agreements
4. To introduce learners to cheminformatics and gain knowledge of representation of molecules chemical reaction and also explore chemical structures
5. To give them an insight of different methods of structure elucidation.
6. To enhance their knowledge about tools for drug designing

Course Outcomes

After completion of this Course, the learner will be able to

1. Explain about Intellectual property & its types and importance of protecting IP.
2. Use the knowledge of patents for their research which will be more patent oriented.
3. Describe the knowledge of industrial design, copyright, trademarks and geographical indications
4. Explain the scope, risk and legal aspects of trade secret protection
5. Describe the role of judiciary and law of enforcement agencies in IP Infringement issue.
6. Utilize the knowledge of the economic value of intellectual property in their future research.
7. Describe different international agreements under World Trade organization and Paris convention WIPO AND TRIPS
8. Explain the use and prospects of cheminformatics.
9. Apply the knowledge of molecular modeling and structure elucidation to establish the structure

Semester – IV

CHEM 65012

Intellectual Property Rights and Chemoinformatics

UNIT		Fundamentals of Intellectual Property (15 L)
I	1.1	Introduction to Intellectual Property: Historical Perspective, Different types of IP, Importance of protecting IP.
	1.2	Patents: Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Health care-balancing promoting innovation with public health, Software patents and their importance for India.
	1.3	Industrial Designs: Definition, How to obtain, features, International design registration.
	1.4	Copyrights: Introduction, How to obtain, Differences from Patents.
	1.5	Trade Marks: Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, trade names etc.
	1.6	Geographical Indications: Definition, rules for registration, prevention of illegal exploitation, importance to India.
II		Intellectual Property organizations and enforcement method (15 L)
	2.1	Trade Secrets: Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.
	2.2	IP Infringement issue and enforcement: Role of Judiciary, Role of law enforcement agencies – Police, Customs etc.
	2.3	Economic Value of Intellectual Property: Intangible assests and their valuation, Intellectual Property in the Indian context – Various Laws in India Licensing and Technology transfer.
	2.4	Different International agreements:
		a. World Trade Organization (WTO): (i) General Agreement on Tariffs and Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement (ii) General Agreement on Trade Related Services (GATS) Madrid Protocol. (iii) Berne Convention (iv) Budapest Treaty
		b. Paris Convention WIPO and TRIPS, IPR and Plant Breeders Rights, IPR and Biodiversity.
		Chemoinformatics (15L)
	3.1	Introduction to Chemoinformatics: History and evolution of cheminformatics, Use of Cheminformatics, Prospects of cheminformatics, Molecular modeling and structure elucidation.

III	3.2	Representation of molecules and chemical reactions: Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and Sdfiles, Libraries and toolkits, Different electronic effects, Reaction classification.
	3.3	Searching Chemical Structures: Full structure search, sub-structure search, basic ideas, similarity search, three-dimensional search methods, and basics of computation of physical and chemical data and structure descriptors, data visualization.
IV		Applications of Chemoinformatics (15L)
	4.1	Prediction of Properties of Compound, Linear Free Energy Relations, Quantitative Structure – Property Relations, Descriptor Analysis, Model Building, Modeling Toxicity
	4.2	Structure – Spectra correlations, Prediction NMR, IR and Mass spectra, Computer Assisted Structure elucidations, Computer assisted Synthesis Design
	4.3	Introduction to drug design, Target Identification and Validation, Lead Finding and Optimization, analysis of HTS data, Virtual Screening, Design of Combinatorial Libraries, Ligand-based and Structure based Drug design
	4.4	Application of Cheminformatics in Drug Design.

REFERENCE BOOKS

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Semester-IV
CHEM 651
Course Title: Research Project

PROGRAM(s): M.Sc-II		**SEMESTER: IV**			
Research Project		**Course Title:- Research Project**			
Teaching Scheme				Evaluation Scheme	
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 75)	Semester End Examination (Marks- 75)
NA	12	–	06	75	75

Learning Objectives:

1. To become aware of safe working procedure and ethical handling of chemicals.
2. To understand the use of mathematical and statistical tools to analyse the data, writing and presenting scientific papers
3. To practice ethics in research.
4. To learn to work independently and as part of a team

Course Outcomes:

At the end of the Course the learner will be able to

1. Acquire new knowledge and understanding in a particular field of research.
2. Have the ability to design or perform the new method or techniques developed during research.
3. Interpret and present a report on the research performed.
4. Enhance the ability to use technology.
5. Have insights, ideas in identifying resource selection and collaborate interdepartmental / interfaculty research activities.

Guidelines:

1. Students are to work on research project individually and should be the continuity of the research project selected in the semester 3.
2. Research Project is of 6 credits which equals to project working hours of 180
3. The title of the research project should be descriptive, appropriate and concise as possible.
4. A detailed description of Chemicals, equipment, experimental procedures should be mentioned in the project report.
5. The project report should be well-structured, should present an accurate and complete account of the research performed with data, discussion and conclusions.
6. The publications of earlier work should be cited.
7. Record of attendance and continuous performance of the student is monitored by the mentor.
8. At the end of the semester, the student has to present the project report in a bound form for external evaluation.
9. Participation in national and international conferences and other project competitions is encouraged.

PROPOSED MODALITIES OF ASSESSMENT

Theory Examination Pattern

A. Continuous Assessment: 50% - 50 Marks per paper

Sr.No.	Evaluation Type	Marks
1	Written Objective/Short Answer Examination	**25**
2	Assignment/ industrial visit report / presentation	**25**
	Total	**50**

25 Marks per paper

Sr.No.	Evaluation Type	Marks
1	Written Objective/Short Answer Examination	**15**
2	Assignment/ industrial visit report / presentation	**10**
	Total	**25**

B. External Examination: 50% - 50 Marks per paper

Semester End Theory Examination:

1. Duration - These examinations shall be of **two hours** duration.
2. Theory question paper pattern:
   a. There shall be 04 questions each of 10 marks on each unit and one mix question for 10 marks. (The mix question will have two questions of two marks each from each of the four units)
   b. All questions shall be compulsory with internal choice within the questions.

Paper Pattern for 50 marks

Question	Options	Marks	Questions Based on
Q.1	2 out of 4	10	Unit I
Q.2	2 out of 4	10	Unit II
Q.3	2 out of 4	10	Unit III
Q.4	2 out of 4	10	Unit IV
Q.5	5 out of 8	10	Units (I+II+III+IV)
	TOTAL	50	

Paper Pattern for 25 marks:

25 Marks per paper Semester End Theory Examination:

1. Duration - These examinations shall be of **one hour** duration.
2. Theory question paper pattern:

a. There shall be 02 questions each of 08 marks on each unit and one mix question for 09 marks ((The mix question will have three questions of three marks each from each of the two units)

b. All questions shall be compulsory with internal choice within the questions.

Question	Options	Marks	Questions Based on
Q.1	2 out of 4	08	Unit I
Q.2	2 out of 4	08	Unit II
Q.3	3 out of 6	09	Units (I+II)
	TOTAL	25	

Practical Examination Pattern

A. Internal Assessment: 50% - 25 Marks per paper

Sr.No.	Evaluation Type	Marks
1	Assessment during practicals (Interaction / Performance) Skill, Accuracy, precision of measurement, Record of observation, calculations, graph, result and conclusion. Timely submission of journal	**20**
2	Overall performance (attendance, punctuality, interaction during Practical session throughout semester)	**5**
	Total	**25**

PRACTICAL BOOK/JOURNAL

- The students are required to perform 75% of the Practical for the journal to be duly certified.
- The students are required to present a duly certified journal for appearing at the semester end practical examination, failing which they will not be allowed to appear for the examination.

B. External Examination: 25 Marks per paper

Semester End Practical Examination:

Duration - These examinations shall consist of **one** session of three and half hours.

Particulars	Marks
Experiment performance	15
Viva	05
Journal	05
Total	25

MODALITIES OF ASSESSMENT FOR RESEARCH PROJECT

SEMESTER III

Course: Research Project **Course Code: RPCHEM 646**

A) CONTINUOUS ASSESSMENT- 50%

Sr.No	Evaluation Type	Marks
1	Selection of the project	10
2	Literature survey	15
3	Scheme /Outline of project	10
4	Methodology	15
Total		50

B) SEMESTER END EXAMINATION - 50%

Sr.No	Evaluation Type	Marks
1	Report	**20**
2	Presentation	**30**
Total		**50**

MODALITIES OF ASSESSMENT FOR RESEARCH PROJECT

SEMESTER IV

Course: Research Project **Course Code: RPCHEM 651**

A) CONTINUOUS ASSESSMENT - 50%

Sr.No	Evaluation Type	Marks
1	Experimental work	**30**
2	Characterization & Interpretation	**25**
3	Conclusion	**20**
Total		**75**

B) SEMESTER END EXAMINATION - 50%

Sr. No	Evaluation Type	Marks
1	Report	**25**
2	Presentation	**50**
Total		**75**

Letter Grades and Grade Points:

Semester GPA/ Programme CGPA Semester/ Programme	% of Marks	Alpha-Sign/ Letter Grade Result	Grading Point
9.00 - 10.00	90.0 - 100	O (Outstanding)	10
8.00 - < 9.00	80.0 - < 90.0	A+ (Excellent)	9
7.00 - < 8.00	70.0 - < 80.0	A (Very Good)	8
6.00 - < 7.00	60.0 - < 70.0	B+ (Good)	7
5.50 - < 6.00	55.0 - < 60.0	B (Above Average)	6
5.00 - < 5.50	50.0 - < 55.0	C (Average)	5
4.00 - < 5.00	40.0 - < 50.0	P (Pass)	4
Below 4.00	Below 40.0	F (Fail)	0
Ab (Absent)	-	Ab (Absent)	0

Sign of the BOS Coordinator
Dr. Sunil Patil
BOS in Chemistry
Director, Students' Welfare, University of Mumbai

Sign of the Offg. Associate Dean
Dr. Madhav R. Rajwade
Faculty of Science & Technology

Sign of the Offg. Dean
Prof. Shivram S. Garje
Faculty of Science & Technology