Progressive Education Society's

Modern College of Arts, Science and Commerce, Ganeshkhind, Pune-411016 India

(Autonomous)

(Affiliated to Savitribai Phule Pune University)

DBT STAR Status **NAAC Accredited 'A' Grade**

M. Sc. (Organic Chemistry)- Part-II

A Two Year Degree Course

Choice Based Credit System (CBCS)

Implemented from

Academic Year 2023-24

Board of Studies

Department of Chemistry

PROGRAMME OUTCOMES:

After completing M.Sc. Chemistry Programme, students will be able to:

Knowledge Outcomes:

PO1: Demonstrate and apply the fundamental knowledge of the basic principles in various fields of Chemistry

PO2: Create awareness and sense of responsibilities towards environment and apply Knowledge to solve the issues related to Environmental pollution.

PO3: Apply knowledge to build up small scale industry for developing endogenous product.

PO4: Apply various aspects of chemistry in natural products isolations, Pharmaceuticals, dyes, textiles, polymers, petroleum products, forensic etc. and also to develop interdisciplinary approach of the subject.

Skill Outcomes:

It would help students to -

PO5: Collaborate effectively on team-oriented projects in the field of Chemistry or other Related fields.

PO6: Communicate scientific information in a clear and concise manner both orally and in writing.

PO7: Inculcate logical thinking to address a problem and become result oriented with a positive attitude.

PO8: Explain environmental pollution issues and the remedies thereof.

PO9: Apply the knowledge to develop the sustainable and eco-friendly technology in Industrial Chemistry.

Generic Outcomes:

PO10: To develop their critical reasoning, judgment and communication skills.

PO11: To augment the recent developments in the field of green and eco-friendly reactions, pharmaceutical, Bioinorganic Chemistry and relevant fields of research and development.

PO12: To enhance the scientific temperament among the students so as to develop a research culture and implementation of the policies to tackle the burning issues at global and local level.

M.Sc. (II) Organic Chemistry 2023-24

Course Structure

Sr. No.	Course Code	Course Name	Credits
		Semester – III	
1	23-CHO-301	Organic Reaction Mechanism and Pericyclic Chemistry	4
2	23-CHO-302	Spectroscopy of Organic Compounds	4
3	23-CHO-303	Organic Stereochemistry and Asymmetric Synthesis	4
4	23-CHO-304 Theory	CHO-353-A) Protection - De-protection, Chiron Approach and Carbohydrate Chemistry	4
		OR	
		CHO-353B**)** Retrosynthetic Analysis and Advanced Heterocyclic Chemistry	4
5	23-CHO-305	**Practical I**: Ternary Mixture Separation and Convergent Syntheses	4
	23-CS-3	Cyber Security-Module III	1
	23-SKB-3	Compulsory Credit Skill Based Course	2
		Semester – IV	
6	23-CHO-401	Biogenesis and Total Synthesis of Natural Products	4
7	23-CHO-402	Name Reactions in Organometallic Chemistry	4
8	23-CHO-403 Theory	CHO-452 A) Aspects of Medicinal Chemistry **OR** CHO-452 B) Applied Organic Chemistry	4 4
9	23-CHO-404 Practical	**Practical II: Select any two Sections**	4
		Section-I: Solvent Free Green Organic Syntheses	2
		Section-II: Practical Organic Syntheses	2
		Section-III: Project / Industrial Training	2
10	23-CHO-405	**Practical III**: Divergent Organic Syntheses and Isolation of Natural Products.	4
	23-CS-4	Cyber Security-Module IV	1
	23-SKB-4	Compulsory Credit Skill Based Course	2

- **Students must complete one online course based on the above syllabus and submit the certificate as a part of continuous assessment.**

Equivalence of Previous Syllabus

Old Course (2019 Pattern)	New Course – M.Sc. II 2023 Pattern (Autonomous)
Semester III	**Semester III**
CCTP-7 CHO-350: Organic Reaction Mechanism and Biogenesis	**23-CHO-301** Organic Reaction Mechanism and Pericyclic Chemistry
CCTP-8 CHO-351: Structure Determination of Organic Compounds by SpectroscopicMethods	**23-CHO-302** Spectroscopy of Organic Compounds
CCTP-9 CHO-352: Stereochemistry and Asymmetric Synthesis of Organic Compounds.	**23-CHO-303** Organic Stereochemistry and Asymmetric Synthesis
CBOP-3 CHO-353A:Protection -De-protection, Chiron approach and Carbohydrate Chemistry.	**23-CHO-304** CHO-304-A) Protection - De-protection, Chiron Approach and Carbohydrate Chemistry
CBOP-3 CHO-353B: Designing Organic Syntheses and Heterocyclic Chemistry	**23-CHO-304** CHO-304B**)** Retrosynthetic Analysis and Advanced Heterocyclic Chemistry
CCPP-3 CHO-354: **Practical I**: Solvent Free Organic Synthesis	**23-CHO-305** **Practical I**: Ternary Mixture Separation and Convergent Syntheses
Semester IV	**Semester IV**
CCTP-10 CHO-450: Chemistry of Natural Products	**23-CHO-401** Biogenesis and Total Synthesis of Natural Products
CCTP-11 CHO-451: Organometallic Reagents in Organic Synthesis	**23-CHO-402** Name Reactions in Organometallic Chemistry
CBOP-4 CHO-452B: Medicinal Chemistry	**23-CHO-403** 23-CHO-403 A) Aspects of Medicinal Chemistry **OR**
CBOP-4CHO-452B: Applied Organic Chemistry	**23-CHO-403** 23-CHO-403 B) Applied Organic Chemistry
CBOP-5 CHO-453: **Practical III**: **Select any two Sections from I, II, III** Section-I: Ternary Mixture Separation Section-II: Carbohydrates Synthesis and Isolation of Natural Products Section-III: Project / Industrial Training/Internships (including Summer Project)	**23-CHO-404 Practical: Select any two Sections from I, II, III** Section-I: Solvent Free Green Organic Syntheses Section-II: Practical Organic Syntheses Section-III: Project /Industrial Training
CCPP-4 CHO-454: **Practical II**: Convergent and Divergent OrganicSyntheses.	**23-CHO-405**: **Practical III**: Divergent Organic Syntheses and Isolation of Natural Products.

23-CHO-301: Organic Reaction Mechanism and Pericyclic chemistry

[48L + 12T]

Section I: Organic Reaction Mechanism, [24 L + 6 T]

1. **Methods for determining Reaction Mechanisms**
(Kinetic and non-kinetic methods) (***Ref** -1)* **[4 L]**
2. **Free Radicals:** Generation, stability, reactivity, Free radical substitution, addition to multiple bonds, radicals in synthesis, Inter- and intra-molecular bond formation via mercury hydride, tin hydride, thiol donors, cleavage of C-X , C-Sn, C-S, O-O bonds, Oxidative coupling, C-C bond formation in aromatics, SNAr reactions, Free Radicals in Organic Synthesis. *(**Ref**-2, 3, 6, 7).* **[10 L]**
3. **Linear Free Energy Relationships**, *Ref. 3, 4.* **[4 L]**
4. Hammet plots, Hammet equation, substituent constants, reaction constants, use of Hammet plots, calculation of k and K, Deviations from straight line plots, Taft equation, solvent effects. *Ref. 3, 4, 5.* **[6 L]**

Section II: Pericyclic Chemistry [24 L + 6 T]

Analysis by correlation diagrams, FMO approach, Electrocyclic, Cycloaddition reactions Diels alder reactions, concept of secondary orbital overlap, Sigmatropic and ene reactions, 1,3-dipolar additions, Claisen , Cope rearrangement and problem solving.

References:

1. Mechanism and structure in Organic Chemistry E. S. Gould (Holt, Rinehart and Winston)
2. Advanced Organic Chemistry –J. March, 4th edition
3. Advanced Organic Chemistry- Part A: Structure and Mechanism- F. A. Carey and R. J. Sundberg, 5th Edition, Springer 2007)
4. A guidebook to mechanism in Organic Chemistry- Peter Sykes
5. The Hammett Equation by C. D. Johnson
6. Organic Chemistry-J. Clayden, N. Greeves, S. Warren, P. Wothers, Oxford University Press
7. Radical in Organic Synthesis- B. Giese, Pergamon Press (1986)
8. Advanced Organic Chemistry, Part A by F. A. Carey and R. J. Sundberg
9. Conservation of orbital symmetry by R. B. Woodward and R. Hoffmann
10. Pericyclic Reactions By A. P. Marchand, Roland E. Lehr
11. Organic reactions and orbital symmetry, 2nd Ed. T. L. Gilchrist and R. C. Storr
12. Pericyclic Reactions by A Mechanistic and Problem-Solving Approach by Sunil Kumar Vinod Kumar S.P. Singh

Course: 23-CHO-301, Semester III (4 Credits)
Course Outcomes

After successfully completing this course, students will be able to:

CO1: Correlate the Kinetic and non-kinetic methods for the determination of mechanism of any organic reaction.

CO2: Understand the mechanisms of free radical reactions in different processes.

CO3: Study the Linear free energy relationship and extend its applications in many reactions

CO4: Understand MOT and will be able to extend this in predicting reaction mechanism and stereochemistry of pericyclic reactions.

CO5: To understand the concept of Hammett equation in order to determine the mechanisms of various reactions.

23-CHO-302: Spectroscopy of Organic Compounds
[48L +12T]

1.Section-I: NMR Spectroscopy [24 L + 6 T]

NMR in Stereochemistry Determination: Homotopic, enatiotopic and distereotopic protons, Chemical and Magnetic equivalence; First and second order splitting, Complex multiplicity patterns and coupling constants in asymmetric compounds; Simplification of complex spectra, NOE, Diastereomerism, Atropy or axial chirality, % Enantiomeric excess, chiral NMR solvents etc in structure elucidation. **[10 L]**

2. ^{13}C NMR spectroscopy - APT, DEPT and INEPT **[6 L]**

3. ^{15}N, ^{19}F and ^{31}P NMR spectroscopy

Fundamentals and applications in structure elucidation of organic compounds, catalystsand biomolecules. *(**Self learning and for internal assessment only).**

4.2D NMR spectroscopy in structure elucidation: (a)Homonuclear: COSY, TOCSY, 2D-INADEQUATE, 2D- ADEQUATE, NOESY, ROESY

(b) Heteronuclear: HSQC, HMQC, HMBC **[8L]**

Section-II: Mass Spectrometry [24 L + 6 T]

1.Mass Spectrometry: Principle, ionization methods like EI, CI, ES, MALDI and FAB-Fragmentation of typical organic compounds, stability of fragments, Rearrangements, factors affecting fragmentation, ion analysis, ion abundance, High-Resolution mass spectrometry in determination of molecular formula. **[6 L]**

2.Applications of Mass Spectrometry: Determination of the elemental composition, Isotopic Abundance in structure establishment; Analysis of Biomolecules: Proteins and Peptides, Oligonucleotides and Oligosaccharides **[6 L]**

Problems solving: Structure elucidation using UV, IR, (^{1}H and^{13}C) NMR and 2D NMR (COSY /HETCOR only), APT, DEPT and MS data as well as spectra. **[12 L]**

References:

1. Spectrometric Identification of Organic Compounds by R. M. Silverstein, G. C. Basslerand T. C. Morrill, John Wiley.
2. One and Two dimensional NMR Spectroscopy by Atta-Ur-Rehman, Elsevier (1989).
3. Organic Structure Analysis-Phillip Crews, Rodriguez, Jaspars by Oxford University Press (1998).
4. Organic Structural Spectroscopy by Joseph B. Lambert, Shurvell, Lightner, Cooks,Prentice-

Hall (1998).
5. Organic Structures from Spectra by Field L.D. Kalman J.R. and Sternhell S. 4th Ed. John Wiley and Sons Ltd.
6. Mass Spectrometry Basics by Christopher G. Herbert Robert A.W. Johnstone
7. Mass Spectrometry Principles and Applications by Edmond de Hoffmann and Vincent Stroobant.
8. Introduction to Spectroscopy by Pavia

Course: 23-CHO-302, Semester III (4 Credits)

Course Outcomes

After successfully completing this course, students will be able to:

CO1: Identify the structure of a molecule from given spectroscopic data.

CO2: Interpret CMR spectrum

CO3: Interpret mass spectrum and thus identify structure of a molecule and it's molecular weight.

CO4: Predict the structure of an unknown compound when provided with UV, IR, PMR, CMR and 2D spectrum.

CO5: Interpretation of COSY and HETCOR spectrum.

CO6: Learn about nuclei other than ^{13}C and ^{1}H which are NMR active like N15, P.F. Which provide important information for structure determination.

CO7: Determine molecular formula from molecular weight.

23-CHO-303:Organic Stereochemistry and Asymmetric Synthesis [48L +12T]

Section I- Organic Stereochemistry [24L + 6T]

1. Conformations of polysubstituted cyclohexane, six membered rings with SP^2 carbon, heterocycles with N and O, anomeric effect, stereochemical principles involved in reactions of six membered rings and other than six membered rings, concept of I- Strain. *(**Ref.** 1, 2, 3, 4, 5, 6)* **[8 L]**

2. A) Stereochemistry of fused and bridged ring systems: Nomenclature, synthesis; stereochemical aspects of Perhydrophenanthrene, Perhydroanthracene, hydrindane, Steroids; Bridged system (bi, tri and polycyclo system) including heteroatoms, Bredt's Rule. ***(Ref.-1, 2, 3, 4, 5, 6).***

B) Conformations of following compounds with justification of each: cis and trans -1,3- and l,4-di-t-butyl-cyclohexanes; Cis-4-di-t-butyl- cis-2,5-dihydroxycyclohexane; Twistane; bicyclo- [2.2.2]octane; Trans-anti-trans- Perhydro-anthracene and the lactone; cyclohexane-l,4-dione; 1,2,2,6,6-penta-methyl-4- hydroxy-4-phenylpiperidine; ψ-tropine; 2-hydroxy-2-phenyl quinolizidine; 4-t-butyl-4- methyl-l,3-dioxane; cis- and trans-2,5-di-t-butyl-l,3-dithianes;cis-2,5-di-t-butyl-l,3,2-dioxaphosphorinan-2-one ***(Ref.** 1, 7, 8)* **[8 L]**

3. Determination of configuration, Cram's rule, Cram's cycle model, Cram's dipolar model, Felkin-Anh Model; Resolution and analysis of stereomers - formation of racemization and methods of resolution. (***Ref.*** 1, 2, 4), **[8 L]**

Section II- Asymmetric Synthesis [24L + 6T]

1. Introduction of Asymmetric Synthesis, Chirol pool and Chiral auxillaries.
2. Asymmetric Organocatalysis
3. Asymmetric Aldol Reaction, Enantioselective, diastereoselective and double diastereoselective Aldol reactions.
4. Transition Metal-Catalyzed Homogeneous Asymmetric Hydrogenation
5. Transition Metal-Catalyzed Homogeneous Asymmetric Hydroxylation and Epoxidation

Asymmetric Phase-Transfer and Ion Pair Catalysis **(*Self learning)**

Course: 23-CHO-303, Semester III (4 Credits)
Course Outcomes

After successfully completing this course, students will be able to:

CO1: Identify and justify different conformations in substituted cyclohexane rings.

CO2: Understand differential principles that are involved in the reactions of six membered rings and other than six membered rings, heterocyclic rings with nitrogen and oxygen.

CO3: Understand the different concepts involving 6-membered rings like I-strain, anomeric effects

CO4: Understand the nomenclature, synthesis and stereochemical aspects involved in multi-ring systems, Steroids, Bridged and fused ring system (bi, tri and polycyclo system) and also including heteroatoms.

CO5: Give justification for different conformations present. Students will also understand different Methods of resolution and analysis of stereomers. They will also come to know about the Stereochemistry of a polymer chains and their types.

CO6: Identify what is asymmetric synthesis, Chiral pool and auxillaries, asymmetric Organocatalysis

CO7: describe the different types of reactions involving transition metal catalysts.

23-CHO-304:
CHO-304-A) Protection - De-protection, Chiron Approach and Carbohydrate Chemistry [48L + 12T]

Section I: Protection - De-protection, Chiron approach [24L + 6T]

1. Protection and de-protection of functional group in organic synthesis: Hydroxyl group- alkyl ether, benzyl ether,acyl, PMB, Trityl, TMS, TBDMS, THP, MOM, MEM, MIPether; **Diol** - Acetone,Cyclohexanone; **Amines**- Benzyl, Acyl, CBZ, BOC, FMOC, **Carboxyl group**-Ester,

DCCI, DIPCDI; **Ketone and aldehydes**- Glycol, Thioglycol, Ketal, Acetal; Othroesters as protecting groups, Protection de-protection approach - In Solid phase synthesis of polypeptide; polynucleotide, cyclitols, and amino-sugars. ***(Ref. 1, 2, 3, 4)*****[12 L]**

2. Chiron approach: a) Introduction, b) The concept of chiral templates and chirons wherein the carbon skeleton is the chiral precursor, c) Utilization of the basic concepts in synthesis of (S) Propanediol, (R) and (S) – Epichlorohydrin, L (+)-Alanine, (-) Multistratin, (-) Pentenomycin and (-) Shikimic acid (***Ref.*** 2, 5, 6, 7). **[12 L]**

Section - II: Carbohydrate Chemistry [24 L + 6T]

a) Basics of Carbohydrates: Introduction of sugars, structures of monosaccharides, triose, tetrose, pentose, hexose, D/L forms of aldoses and ketoses in Fisher projections, cyclic hemiacetal forms of monosaccharides, representation of monosaccharide structure (Fisher, Zig-zag, Mills, Haworth projection and Chair conformation), The structure of Glucose, the anomeric configuration, mutarotation (D-Glucose), Conformations of monosaccharides, the anomeric effect. Modified monosaccharides, Alditols, Cyclitols, Nomenclature of monosaccharides, Cyclic forms of the α and β-D-aldoses.

b) Synthesis of Glycosides: glycosyldonar acceptor concept, general methods for glycosyl bond formation: Glycosyl halides, Trichloroacetimides, Glycals and Glycal derivatives, Thioglycosides, Phosphites, n-Pentyl glycosides, SulfoxidesDiazarines, Alkylation of reducing sugars

c) Mannosides, Synthesis of 2-Deoxy Sugars, Orthogonal strategy in Oligosaccharide synthesis, Effect of protecting groups on glycosylation stereoselectivity and coupling efficiency, Intramolecular glycosylation, Total synthesis of natural products: Oligosaccharides and Glycoconjugates. (**Ref. 5, 8, 9, 10, 11, 12)** **[24 L]**

1. References:

2. Greene's protective groups in organic synthesis – Peter G. M. Wuts and Theodor R. A. Green 4th Edn. Wiley-India
3. Organic Chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press)
4. Modern organic synthesis-An introduction- George S. Zweifel, Michael H. Nantz.
5. Advanced Organic chemistry, Part B – F. A Carey and R. J. Sundberg, 5th edition (2007)
6. Chiron Approach in organic synthesis – S. Hanessianh
7. Organic Chemistry – R. P. Morrison and R. N. Boyd
8. Organic Chemistry – I. L. Finar, volume II.
9. Essentials of Carbohydrate Chemistry and Biology: Thisbe K. Lindhorst, WILEY-VCH, 2000, Chapter 3.
10. Monosaccharide's: Their Chemistry and their Roles in Natural Products: Peter M. Collins, Robert J. Ferrier: John Wiley & Sons, 1995.
11. Carbohydrate in Chemistry and Biology: Part 1 Chemistry of Saccharides Vol.1.WILEY-VCH, 2000.
12. The Organic Chemistry of Sugars; By: Daniel E. Levy Peter Fugedi Publication: Taylor & Francis, Published on 2006
13. Handbook of Chemical Glycosylation by Alexei V. Demchenko, Wiley VCH, 2008

23-CHO-304
CHO-304B) Retrosynthetic Analysis and Advanced Heterocyclic Chemistry [48 L + 12 T]

Section I: Designing Organic Syntheses [24 L + 6 T]

1. **Concepts of Retrosynthesis:** Retrosynthetic analysis, disconnection approach, Synthons, multiple step synthesis, functional group intercoversion, Illogical two group intercoversion, C-C disconnection, Donor and acceptor Synthons, two group disconnection, 1,3-dicarbonyls, 1,5 related functional group disconnection, Umpolung, convergent synthesis, special methods for small rings, Heteroatom and Heterocyclic compounds, problems, (***Ref***.-1, 2, 4). **[14 L]**
2. **Application of Retrosynthetic Approach:** Retrosynthesis and synthesis of following Molecules: Strychnine, Reserpine, , Asteltoxin, Indolizomycin,**. Ref**-3 **[10 L]**

References:

1. Designing Organic Syntheses by Stuart Warren
2. Organic Chemistry from Retrosynthesis to Asymmetric Synthesis, by Vitomir Sunjic, Springer; 1st ed. 2016 edition
3. Classics in Total Synthesis by K.C. Nicolaou and E.J.Sorensen

Additional Study material: NPTEL Lecture:
A Study Guide in Organic Retrosynthesis: Problem Solving Approach (https://nptel.ac.in/content/syllabus_pdf/104105087.pdf)

Section II: Advanced Heterocyclic Chemistry [24 L + 6 T]

1. Systematic nomenclature (Hantzsch-Widman System) for monocyclic, fused and bridged heterocycles. Tautomerism in aromatic heterocycles. Strain-bond angle, torsional strains and their consequences in small ring heterocycles. **[4 L]**

2. General chemical behaviour of heterocyclic compounds and their applications in: Biological systems (Anthocyanins, Flavones, Neurotransmitters), Natural Products (Alkaloids: Nicotin, Quinine), Drugs and Medicines (Omeprazole, Amlodipine, Cilostazol) **[4 L]**

3. Synthesis, reactions and structural effects of heterocyclic rings [16 L]

a) Common Methods in Ring Synthesis of Aromatic Heterocyclic Systems**:** Typical ring synthesis involving C – Heteroatom, C – C bond formations, Electrocyclic processes in heterocyclic Synthesis: 1,3 -dipolar cycloadditions producing five - membered heterocycles, Nitrenes in heterocyclic synthesis, Palladium catalysis in the synthesis of Benzo - Fused heterocycles, Fischer synthesis, Epoxidation, Use of Sulphur Ylides, Azides for small rings

b) Three and four membered heterocylces: Aziridines, Oxiranes, Thirienes, Azetidines, Oxitanes and Thietanes

c) Five-membered and benzo-fused five memberedheterocycles:Oxazole, Isoxazole, Thiazole, Pyrazole, Imidazole, Benzothiazole and Benzimidazole

d) Six membered and benzo-fused six membered heterocycles:Pyrazine, Pyridazine, Pyrimidine, Quinazoline, Quinoxaline, Aziridines, Quinoline

Self Learning: Isoquinoline, Indoles

References

1. Heterocyclic Chemistry by T. Gilchrist.
2. An Introduction to the Chemistry of Heterocyclic Compounds by RM Acheson.
3. Heterocyclic Chemistry by J A Joule and K. Mills.
4. Principles of Modern Heterocyclic Chemistry by A Paquette.
5. Organic Chemistry by J. Clayden, N. Greeves & S. Warren

Course: CHO-304B) Semester III (4 Credits)
Course Name: Retrosynthetic Analysis and Heterocyclic Chemistry

After successfully completing this course, students will be able to:

CO1: Do retrosynthesis of any organic compound whether it is small or complex molecule.
CO2: Design new synthetic route for particular compound.
CO3: Understand interconversion of functional group.
CO4: Understand logical and Illogical synthesis and retrosynthesis.
CO5: Understand the synthesis and applications of Heterocyclic compounds.
CO6: Learn medicinal applications of Heterocyclic compounds.
CO7: Learn synthesis, reactions and structural effects of heterocyclic rings etc.

23-CHO-305: Practical I: Ternary Mixture Separation and Convergent Syntheses [96 L + 24 T]

Section-I: Ternary Mixture Separation [48 L + 12 T]

Separation of minimum 06 mixtures containing three components. The mixtures should also involve separation of nitrophenols, amino acids, low boiling and water soluble and insoluble compounds solids and liquids with **multifunctional groups**. The mixture separation should be carried out on micro-scale using ether or water.

The students should be able to

A) Understand and employ concept of type determination and separation
B) Meticulously record physical constants
C) Perform micro scale chemical elemental analysis
D) Perform qualitative estimation of functional groups
E) Recrystallize /distill the separated compounds and extend these skills to organic synthesis

Section-II: Convergent Synthesis [48 L + 12 T]

A. Convergent Synthesis 1(Three Stage Synthesis)
Stage I: 2-methoxy naphthalene to 1-formyl-2-methoxy naphthalene(V.H Formylation)
Stage II: o- Anisidine to 2-methoxy-4-nitroaniline
Stage III: Synthesis of Schiff's base from 1-formyl-2-methoxy naphthalene, 2-methoxy-4-nitroaniline (One pot synthesis: MCR)

B. Convergent Synthesis 2(Three Stage Synthesis)
Stage I: 4-Nitro toluene to 4-amino toluene (Reduction by using Sn/HCl)

Stage II: Phenol into 2-hydroxy benzaldehyde (Reimer-Tiemann reaction)
Stage III: Synthesis of amidoalkyl-2-naphthols from β-Naphthol,4-amino toluene andof 2-hydroxy benzaldehyde (One pot synthesis: MCR)

C. Convergent Synthesis 3(Three Stage Synthesis)

Stage I: Benzene to acetophenone (F.C acylation)
Stage II: 4-Nitrochlorobenzene into 4-amino chlorobenzene (Reduction by usinghydrazine)
Stage III: Quinoline synthesis by using acetophenone, 4-amino chloro benzene andstyrene (One pot synthesis: [3 + 2 + 1] cycloaddition reaction)

23-CHO-305: Practical I: Ternary Mixture Separation and Convergent Syntheses

Course Outcomes:

After successfully completing this course, students will be able to:

CO1: Understand different methods to separate given organic mixture.

CO2: Learn to purify solid components on the basis of purification methods

CO3: Identify the presence of functional groups and elements in the given compound.

CO4: Understand the structural properties of the compound on the basis of wet chemical tests.

CO5: Learn the basics of organic transformations.

CO6: Understand various methods to improve practical yield of every step involved in the synthesis.

Semester IV

23-CHO-401: Biogenesis and Total Synthesis of Natural Products [48L +12T]

Section I: Biogenesis and structure determination [24 L + 6 T]

1. Terpenoids: Mono-, Sesqui-, Di-, tri-terpenoids and cholesterol **[6 L]**
2. Alkaloids: Derived from ornithine, lysine, nicotinic acid, tyrosine and tryptophan. **[6L]**

References:

1. Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery by ChristopherT Walsh, Yi Tang
2. From Biosynthesis to Total Synthesis: Strategies and Tactics for Natural Products- Editor Alexandros L. Zografo
3. Medicinal Natural Products: A Biosynthetic Approach, 3rd Edition By Paul M. Dewick

3. Structure Determination of Pinnaic acid **[12L]**

References:

1. Angew. Chem. Int. Ed. 2001, 40 (23), 4450-4452.
2. Angew. Chem. Int. Ed. 2001, 40, (23), 4453-4456.
3. Angew. Chem. Int. Ed. 2007, 46, 5746–5749

Section II : Total synthesis [24 L + 6 T]

Understanding and planning of total synthesis while maintaining the stereochemistry.

a) A case study: Longifolene – (All eight syntheses from Advanced Organic Chemistry Carey, Sundberg; Part B **[12 L]**
b) Hirsutellone B (Angew. Chem. Int. Ed. 2009, 48, 6870 –6874.) **[6 L]**
c) Ribisins A and B : (J. Org. Chem. 2019, 84, 15165−15172) **[6 L]**

Course: 23-CHO-401 Biogenesis and Total Synthesis of Natural Products: Semester IV (4 Credits)

Course Outcomes:

After successfully completing this course, students will be able to:

CO1: Understand the process of biogenesis and the steps involved in it.
CO2: Study the process of total synthesis starting from isolation of natural products.
CO3: Understand the various physical and chemical methods to determine the correct structure of a natural product.
CO4:To reach simple starting materials from the target molecule using the concept of retrosynthesis.
CO5: To design their own total synthesis route of new natural product target molecule.
CO6: Understand mechanism of various oxidizing and reducing agents used in the total synthesis of natural products.

23-CHO-402: Name Reactions in Organometallic Chemistry [48 L+ 12T]

1. Transition metal complexes in organic synthesis; Pd, Ni, Fe, and Cu only (C-C, C- N, C-O bond formation reactions with catalytic cycle, ligand and % mole concepts) **[12 L]**
2. C=C formation reactions: Wittig, Horner-Wordworth-Emmons, Shapiro, Bamford- Stevens, McMurry, Julia-Lythgoe and Peterson olefination reactions. **[8 L]**
3. Multi-component reactions: Ugi, Passerini, Biginelli and Mannich reaction **[3 L]**
4. Ring formation reactions: Pausan-Khand, Bergman and Nazerov cyclization **[3 L]**
5. Click chemistry: criterion for click reaction, Sharpless azides cycloadditions.
6. Click reactions in synthesis of bioconjugates (sugars and proteins) **[4 L]**
7. Metathesis: Schrock and Grubbs catalyst, Olefin cross coupling (OCM), ring closing (RCM) and ring opening (ROM) metathesis, application in polymerization and synthesis of small organic molecules. **[6 L]**
8. Use of Boron and Silicon reagents in organic synthesis. **[8 L]**
9. Other important reactions: Baylis Hilman, Eschenmoser-Tanabe fragmentation, Mitsunobu reaction. **[4L]**

References:

1. C–N bond forming cross-coupling reactions: an overview: by Jitender Bariwalab and Erik Van der Eycken Chem. Soc. Rev., 2013, 42, 9283
2. Iron Catalysis in Organic Synthesis Chem. Rev. 2015, 115, 3170–3387.
3. Recent advances in homogeneous nickel catalysis Nature 2014, Vol 509, Page 299-309.
4. Aerobic Copper-Catalyzed Organic Reactions Chem. Rev. 2013, 113, 6234−6458.
5. Transition Metals for Organic Synthesis Volume 1 *Edited by M. Beller and C. Bolm* WILEY-VCH Verlag GmbH & Co. KGaA ISBN: 3-527-30613-7
6. Multicomponent Reactions Edited by Jieping Zhu, Hugues Bienayme WILEY-VCH Verlag GmbH & Co. KGaA
7. Organic chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press),
8. Some modern methods of organic synthesis – W. Carruthers (Cambridge)
9. Organic synthesis – Michael B. Smith
10. Advanced organic chemistry, Part B – F. A Carey and R. J. Sundberg, 5th edition (2007).
11. Strategic Applications of named reactions in organic synthesis-Laszlo Kurti and Barbara Czako
12. Name Reactions Jie Jack Li (Fourth Expanded Edition), Page No: 1-582.
13. Organic Synthesis Using Transition Metals, by Roderick Bates, Second Edition, AJohn Wiley & Sons, Ltd., Publication.

Course: 23-CHO-402: Name Reactions in Organometallic Chemistry, Semester IV (4 Credits)

Course Outcomes:

After successfully completing this course, students will be able to:

CO1: Understand homogeneous and heterogeneous catalysis.

CO2: Uses of palladium catalyst in synthesis. Cross coupling reactions.

CO3: Uses of transition metals in organic synthesis.
CO4: Double bond formation name reactions.
CO5: Green chemistry multicomponent reactions
CO6: Uses of boron and silicon in synthesis.

23-CHO-403 A) Aspects of Medicinal Chemistry
OR
23-CHO-403 B) Applied Organic Chemistry

23-CHO-403

23-CHO-403 A) Aspects of Medicinal Chemistry [48L + 12T]

1. Introduction to Peptides and proteins, Proteins as biological catalyst Nucleic acids, Metabolism, Chemistry of cofactors/coenzymes, Chemistry of TPP, PLP, Folic Acid and other vitamins, Principle of drug design, Chemistry of diseases and Drug development,Proton pump inhibitors and Problem solving. **[8 L]**
   Additional study material: NPTEL lecture: Organic Chemistry in Biology and Drug Development (full course) https://nptel.ac.in/content/syllabus_pdf/104105120.pdf) https://nptel.ac.in/courses/104/105/104105120/
2. Peptides, sequencing and applications in therapeutics, Solution phase and solid phase peptide synthesis and Modern techniques for biomolecules and disease diagnosis. **[6 L]**
   Additional study material: NPTEL lecture (only 3 topics): Essentials of Biomolecules: Nucleic Acids and Peptides https://nptel.ac.in/content/syllabus_pdf/104103121.pdf https://nptel.ac.in/courses/104/103/104103121/
3. Introduction to medicinal Chemistry. History, drug targets, Drug discovery, design and development, Case Study: Design of Oxamniquine. **[4 L]**
4. Pharmacokinetics and Pharmacodynamics of drug: Drug absorption, distribution, metabolism, elimination and toxicity, drug metabolism, biotransformation, Drug receptor interactions, Hansch Equation and significance of terms involved in it. **[6 L]**

Section II: [24 L + 6 T]

1. Structure and activity Relationship: QSAR, Applications of SAR and QSAR in drug design, physio-chemical parameters lipophilicity, partition coefficient, electronic ionization constant, Case Study: Statins **[10 L]**
2. Introduction, Developments, SAR, Mode of action, limitations and adverse effect of Anti-infective Agents, Beta lactam antibacterial agents (Penicillins, Cephalosporins), Tetracyclins, Macrolides, Chloramphenicol, Polyenes, Amphotericin-B, Azoles, Amantadine, Acyclovir, Quinine, Quinolines, Quinolones, Refamycine, Sulphonamides [**14 L]**

References:

1. Medicinal Chemistry and Drug Discovery by Burger
2. Introduction to Medicinal Chemistry by Grham and Patrick
3. Introduction to Drug Design by J. R. Dimmock and S.S. Pandeya
4. The Organic Chemistry of Drug Design and Drug Action, 3rd Edition, R. B. Silverman, Academic Press, 2014
5. Wilson and Gisvold's Text Book of Organic Medicinal and Pharmaceutical Chemistry, Ed Robert F Dorge, 12th Edition, 2010
6. Chemistry of Heterocycles by T. Eicher and S. Hauptmann, Thieme

Course: 23-CHO-403 A) Aspects of Medicinal Chemistry, Semester - IV (4 Credits)

Course outcomes:

After successfully completing this course, students will be able to:

CO1: Understand the chemistry involved in peptides and proteins, their sequencing and applications in therapeutics. Students will study about chemistry of different vitamins.

CO2: Understand principles of drug discovery and drug design. Students will be able to understand the process of drug discovery.

CO3: Understand different concepts of pharmacokinetics and pharmacodynamics, absorption, distribution, metabolism and excretion of drugs

CO4: Understand about drug targets, drug-receptor interactions, structure activity relationship (SAR) & QSAR.

CO5: Developments, SAR, Mode of action, limitations and adverse effect of different drug families (antimalerials, antibiotics, antivirals, antifungal, anti-infective agents)

23-CHO-403 B) Applied Organic Chemistry

Section-I: [24 L + 6 T]

1. Covalent Organic Frameworks: Structures, Synthesis, and Applications. [12L]

(Ref: Review article by Maria S. Lohse and Thomas Bein ***Adv. Funct. Mater***. 2018, 28(33), 1705553.)

2. Organic Electroluminescent Materials, [12 L]

(Ref: Review article by L.S. Hunga and C. H. Chen ***Materials Science and Engineering*** 2002, R 39, 143–222)

Section II: [24L+6T]

1. Supramolecular Organic Compounds [8 L]

(Ref: Review by Matthew C. T. Fyfe and J. Fraser Stoddart ***Accounts of Chemical*** *Research* 1997, 30 (10), 393-401.)

(Ref: Review article by Wei Chen and et al. ***Chem. Soc. Rev.***, **2015**, *44*, 2998-3022)

2. Single Molecule Switches [8 L]

(Refs: Review article by Wei Chen and et al. ***Chem. Soc. Rev.***, **2015**, *44*, 2998-3022.)

3. Molecular Machines [8 L]

(**References:**

1. Review article by David A. Leigh and et al. *Chem. Rev.* 2015, *115*, 10081−10206.

2. Redox-Gated Tristable Molecular Brakes of Geared Rotation. *J. Org. Chem.*, 2017, 82(10), 5354-5366.
3. Massimo Baroncini, Serena Silvi, Alberto Credi. *Chem. Rev.* 2020, *120* (1), 200-268).

23-CHO-404 Practical: – Practical II [96L + 24T]

Section-I: Solvent Free Green Organic Syntheses (Any 10)

A) Solvent Free Carbon–Carbon Bond Formation

1. Pinacol coupling reaction (Page 36)
2. Knoevenagel condensation (Page 40)
3. Dieckmann condensation (Page 42)
4. Biginelli reaction (Page 46)
5. Claisen reaction(Page 47)
6. Pechmann reaction (Page 50)
7. calix[4]resorcinarene (Page 50)

B) **Solvent-Free C–N Bond Formation**

Azomethine synthesis (Page 213)

C) **Solvent-Free C–X Bond Formation**

Phenol bromination using *N*-bromosuccinimide (Page 320)

E) **Solvent-Free N–N Bond Formation**

Beckmann rearrangement (Page 346)

F) **Other Solvent-Free Reactions**

1. D-mannitol protection using phenylboronic acid (Page 388)
2. Baeyer-Villiger reaction
3. 2-Hydroxybenzaldehyde oxidation using urea-hydrogen peroxide Complex (Page 13)

G) Solvent free supramolecular assembly formation

rac-Bis-beta-naphthol and benzoquinone

Reference:

Solvent-free Organic Synthesis by Koichi Tanaka (Copyright © 2009 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, ISBN: 978-3-527-32264-)

Additional Study Material: https://nptel.ac.in/courses/104/106/104106108/

Section-II : Practical Organic Syntheses (Any 10)

1. Cyclohexanone to Phenyl hydrazone to 1,2,3,4-Tetrahydrocarbazole
2. Hydroquinone to Quinone to 1, 2, 4-Triacetoxy benzene
3. p-Cresol to p-Cresyl benzoate to 2-Hydroxy-5-methyl benzophenone
4. Benzyl cyanide to p-Nitrobenzyl cyanide to p-Nitro phenyl acetic acid
5. Hydroquinone to Hydroquinonediacetate to 2,5 Dihydroxyacetopheneone
6. Resorcinol to 4-methyl-7-hydroxy coumarin to 4-Methyl-7-acetoxy coumarin
7. Hippuric acid to Azalactone to 4-Benzylidene 2-phenyl oxazol-5-one
8. o-Nitroaniline to o-Phenylene diamine to Benzimidazole
9. 4-Nitro toluene to 4-Nitro benzoic acid to 4-Amino benzoic acid
10. Phthalic anhydride to Phthalimide to Anthranilic acid
11. Cyclohexanone to Enamine to 2-Acetyl cyclohexanone

Section-III: Project / Industrial Training

1. Students should carry out a small research project.
2. This should make them familiar with

i. Literature survey, research methodologies
ii. Data Analysis
iii. Column and TLC chromatographic techniques
iv. Characterization of the products by analytical and spectral methods.

3. Project report must be written and submitted in a proper format as follows;

i) Certificate (Signed by Project guide and Head of the Department)
ii) Certificates for Poster/Paper presented in conferences (if any)
iii) Self declaration certificate for plagiarism
iv) Introduction (not more than 6 pages)
v) Results and Discussions
vi) Experimental Section
vii) Conclusion
viii) References (Use ACS format)
ix) Spectroscopic or other relevant supporting data
x) Acknowledgement

4. Interdisciplinary projects shall be encouraged; however there **must be some organic chemistry component**.

5. Students should spend enough time for the project works (**at least** 4 hours per week for **15 weeks**)

6. At least 30% students should undertake projects/summer training/Internships etc.

7. If student is performing project in another institute, for such a student, internal mentor must be allotted and he will be responsible for internal assessment of a student. In this case student has to obtain certificate from both external and internal mentor. ***Systematic record of attendance of project students must be maintained by a mentor.*** Project will be evaluated jointly by three examiners and there will not be any practical performance during the examination. Typically, student has to present his practical work, discuss results and conclusions in details (20-30 min.) which will be followed by question-answer session (10 min). It is open type of examination.

Course: 23-CHO-404: Practical II Semester III (4 Credits)

Course Outcomes:

After successfully completing this course, students will be able to:

CO1: Understand how to do various reactions with the help of green chemistry approach.
CO2: Learn to reduce the pollution and how to do reactions without using solvents.
CO3: Learn and understand green chemistry approach for C-C, C-N, C-X and C-S bond formation reactions.
CO4: Learn multistep synthetic methods
CO5: Develop their research aptitude

23-CHO-405: Practical III:
Divergent Organic Syntheses and Isolation of Natural Products

[96L + 24T]

Section I: Divergent Organic Syntheses (select any 3 sets of any 4 reactions each)

[48L +12T]

SET I:

A). Divergent Synthesis 1(5 Single Stage Synthesis from β-Naphthol)

1. β-Naphthol to Synthetic dye (By diazonium coupling)

2. β-Naphthol to 6-Bromo-2-naphthol (Bromination reaction)
3. β-Naphthol to β-Naphthyl methyl ether (Methylation reaction)
4. β-Naphthol to temperature dependent sulfonation (Sulfonation reaction)
5. β-Naphthol to (±) Binol then Resolution of Binol (Resolution technique)

SET-II

B). Divergent Synthesis 2 (5 Single Stage Synthesis from Aromatic aldehyde)

1. Aromatic aldehyde to phenylhydrazone
2. Aromatic aldehyde with malononitrile to 2-iminochromene by intramolecular cyclization.
3. Aromatic aldehyde to 2-hydroxy-3,5-dinitrobenzaldehyde
4. Aromatic aldehyde to o-Formylphenoxy acetic acid
5. Aromatic aldehyde to catechol

SET-III

B). Divergent Synthesis 3 (5 Single Stage Synthesis from Acetophenone)

1. Acetophenone to Ethyl benzene by Wolf Kishner reduction
2. Acetophenone to m-Nitro acetophenone by nitration
3. Acetophenone to Chalcone using aromatic aldehyde
4. Acetophenone into Schiff base using aromatic amine
5. Acetophenone to Benzoic acid and Iodoform

SET-IV

Divergent Synthesis 4 (5 Single Stage Syntheses from Acetyl acetone):

1. Acetyl acetone to Pyrimidine
2. Acetyl acetone to 2,4-dimethyl-1H-benzo[b][1,4]diazepine
3. Acetyl acetone to Pyrazole
4. Acetyl acetone with 1mmol benzaldehyde to 3-benzylidenepentane-2,4-dione
5. Acetyl acetone with 3 mmol benzaldehyde into 3-benzylidene-6-phenylhex-5-ene-2,4-dione

References

1. Practical organic chemistry by Mann and Saunders
2. Text book of practical organic chemistry –by Vogel
3. The synthesis, identification of organic compounds –Ralph L. Shriner, Christine K.F.
4. Hermann, Terence C. Morrill and David Y. Curtin

Section II: Isolation of Natural products [48L +12T]

Part A: Isolation (Any 4)

1. Caffeine from tea leaves
2. Piperine from pepper
3. Eucalyptus oil from leaves (Steam distillation)
4. Lycopene from tomatoes
5. Trimyristin from nutmeg
6. Cinnamaldehyde from cinnamon
7. Eugenol from clove

Part B: Isolation of pigments from the natural products (Any 3)

1. Orange Marigold
2. Rose
3. Sunflower
4. Hibiscus
5. Any colored flowers/fruits available in the local area **(only one is allowed).**

Note: Students should be able to collect reasonable quantities of color pigments to do the characterization (Physical Constant, Elemental analysis functional group test etc.) and should also form the appropriate derivative. They are encouraged to use these pigments for developing food grade natural colors from lesser known plant sources

23-CHO-405: Practical III: Divergent Organic Syntheses and Isolation of Natural Products:

Course Outcomes:

After successfully completing this course, students will be able to:

CO1: Understand the use of oxidizing and reducing reagents

CO2: Learn various ways to isolate components from naturally occurring substances instead of their synthesis.

CO3: Understand the synthesis of different organic compounds from one starting material.

CO4: Understand the methods to isolate product from reaction mixture by solvent extraction