Savitribai Phule Pune University

(Formerly University of Pune)

Syllabus of

M.Sc. II Organic Chemistry

(According to NEP-2020)

for

Colleges Affiliated to Savitribai Phule Pune University

Approved by

Board of Studies in Chemistry

Implementation from Academic Year 2024 - 2025

M.Sc. II Organic Chemistry Course Structure

Sr. No.	Course Name	Course Code	Major Core/ Major elective	Credits
Semester III				
1.	Organic Reaction Mechanism and Stereochemistry	CHO-601 MJ	Major Core	4T
2.	Advanced Spectroscopic Methods in Structure Determination	CHO-602 MJ	Major Core	4T
3.	Heterocyclic Chemistry	CHO-603 MJ	Major Core	2T
4.	Organic Synthesis Experiments	CHO-604 MJP	Major Core	2P
5.	Ternary Mixture Separation	CHO-605 MJP	Major Core	2P
6.	Synthetic methods in Organic Chemistry	CHO-610 (A) MJ	Major elective (Any Two)	4T (2 credits for each course)
	Carbohydrates and Chiron approach	CHO-610 (B) MJ		
	Medicinal Chemistry	CHO-610 (C) MJ		
7.	Research Project (RP)	CHO-631 RP	Research Project	4
Semester IV				
1.	Chemistry of Natural Products	CHO-651 MJ	Major Core	4T
2.	Advanced Synthetic Organic Chemistry	CHO-652 MJ	Major Core	4T
3.	Convergent and Divergent Organic Synthesis	CHO-653 MJP	Major Core	2P
4.	Green Chemistry Experiments	CHO-654 MJP	Major Core	2P
5.	Asymmetric Synthesis	CHO-660 (A) MJ	Major elective (Any Two)	4T (2 credits for each course
	Applied Organic Chemistry	CHO-660 (B) MJ		
	Industrial Organic Chemistry	CHO-660 (C) MJ		
6.	Research Project (RP)	CHO-681 RP	Research Project	6

1. Teaching Hours

a) Theory – Each credit of theory is equivalent to 15 teaching hours. For 1 credit of theory there will be 1 lecture of 1 hour per week. In case of theory paper consisting of sections, each section is of 2 credits and time allotted will be 30 hours teaching.

b) Practical – Each credit of practical is equivalent to 30 teaching hours. Each experiment will be allotted 5 h time.

2. Examination

Theory and practical courses carry 50 marks equivalent to 2 credits and 100 marks equivalent to 4 credits. Each course will be evaluated with Continuous Internal Evaluation (CIE) and University Assessment (UA) mechanism. Continuous Internal Evaluation shall be of 30% while university Evaluation shall be of 70%. To pass the course, a student has to secure 40% mark in CIE as well as university assessment. For CIE teacher must select variety of procedures for examination such as: i) Written test / Mid Semester test (not more than one for each course), ii) Term paper, iii) Viva-Voce, Project / survey / field visits iv) Tutorials v) Group discussion vi) Journal / Lecture / Library notes vii) Seminar presentation, viii) Short quiz ix) assignment x) research project by individual student or group of student xi) An open book test, etc. Each practical course will be extended over one semester and practical examination will be conducted at the end of every semester. The practical examination should involve one internal and two external examiners. All three examiners will evaluate the all practical courses.

Guidelines for Practicals and Project

- All experiments should be carried out on micro-scale and by considering stoichiometric quantities of reactants and reagents with the proper understanding of the mechanism.
- Post graduate departments should arrange at least **one study visit to relevant industry/national research laboratory/premier academic institute**.
- Students must read MSDS and should handle chemicals and reactions accordingly.

- The necessary reactions should be carried out in fume hood and appropriate safety measures should be taken during the laboratory experiments and projects.
- All reactions should be **monitored using alumina coated TLC plates**.
- Certified journals should be presented at the time of final examination.
- Students should choose a research project topic that aligns with their interests and career goals, but also consider its feasibility within the available resources and time frame.
- Consult with faculty members, advisors, or mentors to identify a research area that has potential for contribution to the field of chemistry.
- Students opting for the projects are encouraged to participate in AVISHKAR, national and international conferences and other project competitions.
- Teachers are encouraged to give the project ideas based on the societal needs.

PROGRAM OUTCOMES (POs)

PO No.	**PO Statement** After completing the Programme Master of Science in Organic Chemistry, students will be able to	Knowledge and Skill
PO-1	Learn the terms, theories, assumptions, methods, principles, theory statements, and classification.	Disciplinary knowledge
PO-2	Fixed out the problem and resolved it using theories and practical knowledge.	Critical thinking & Problem-solving
PO-3	Inculcate his knowledge for carrying projects and advanced research-related skills.	Research related skill
PO-4	Actively participate in the team on case studies and field-based situations.	Cooperation/Teamwork
PO-5	Analyse and interpret ideas, evidence, and experiences with learned scientific reasoning	Scientific reasoning
PO-6	Aware and implement the subject facts that can be applied to personal and social development	Reflective thinking
PO-7	Use digital literacy to retrieve and evaluate subject-related information	Information/Digitally literacy:
PO-8	Get moral and ethical values for society as well as in research	Moral and ethical awareness
PO-9	Give analytical reasoning to interpret research data.	Analytical Reasoning
PO-10	Improve their managerial skills and abilities in subject-related activities.	Leadership readiness/qualities
PO-11	Inculcate continuous learning habits through all available resources.	Lifelong readiness/qualities

PROGRAM SPECIFIC OUTCOMES (PSOs)

PO No.	PSO Statement After completing the Programme Master of Science in Organic Chemistry, students will be able to
PSO-1	Demonstrate proficiency in advanced terms, theories, principles, and techniques of chemistry through different courses, laboratory experiments, and research projects.
PSO-2	Develop a foundational understanding of research methodologies, including literature review, hypothesis formulation, experimental design, data analysis, and interpretation.
PSO-3	Acquire hands-on experience with advanced chemistry-related equipment.
PSO-4	Apply modern research techniques to investigate complex chemical phenomena and solve practical problems.
PSO-5	Demonstrate competence in quality assurance and quality control practices essential for industry.

Semester-III

CHO-601 MJ: Organic Reaction Mechanism and Stereochemistry

Course type: Major Core (Theory) **No. of Credits: 4**

Course Outcomes

After completion of this course, the student will student will be able to

CO-1: Acquire familiarity with fundamental organic reaction mechanisms and stereochemistry principles.

CO-2: Gain a comprehensive understanding of Theoretical Concepts to Predict Reactivity and Selectivity.

CO-3: Apply concepts of reaction mechanisms and stereochemistry.

CO-4: Design Synthetic Routes and Strategies.

CO-5: Analyze the products of different organic reactions.

CO-6: Solve Complex Organic Chemistry Problems based on Organic Reaction Mechanism and Stereochemistry.

Course Content

Chapter No.	Title with Contents	No. of hours
	Section-I: Organic Reaction Mechanism	
1	**Non-kinetic Methods for determining Reaction Mechanisms** Reaction mechanism, energy profile diagram, Product analysis, Testing & Trapping of intermediate, use of isotopes (Kinetic isotope effect – primary and secondary kinetic isotope effect), crossover experiments and stereochemical evidence	06
2	**A) Carbanions in organic Chemistry** Ionization of carbon hydrogen bond and prototopy, Base and acid catalyzed halogenation of ketones, keto-enol equilibria, structure and	16

	rate in enolisation, concerted and carbanion mechanism for tautomerism, carbanion character in phenoxide and pyrrolyl anions, hydrolysis of haloforms, Aldol, Mannich, Cannizzaro, Darzens, Dieckmann, Claisen Baylis-Hillman reactions, Knoevenagel, benzoin condensation, alkylation of enolates and stereochemistry thereof, Conjugate additions **B) Enamines and Imines in Organic Synthesis**	
3	**Hammett equation** Hammet plots, Hammet equation, substituent constants, reaction constants, use of Hammet plots, +ve, -ve rho values, reaction with small -ve rho values, interpretation of mechanism using rho values, calculation of k and K, Deviations from straight line plots, Taft equation, solvent effects.	**08**
Section-II: Stereochemistry		
1	**Stereochemistry of six membered rings** Shape of cyclohexane ring, monosubstituted, disubstituted and polysubstituted cyclohexane, physical properties, conformation and chemical reactivity in cyclohexanes. Conformational effects in six membered rings containing unsaturation and six membered heterocyclic ring.	**08**
2	**Stereochemistry of rings other than six membered** Three, four, five membered, rings and larger than 6-membered medium rings, conformational effects in medium rings, trans annular effects, concept of I strain.	**06**
3	**Stereochemistry of fused and bridged rings** Nomenclature, synthesis, stereochemical aspects of perhydrophenanthrene, perhydroanthracene, hydrindane, steroids, bridged system (bi, tri and polycyclic system) including heteroatoms, Bredt's rule.	**08**
4	**Resolution of racemic modification** Resolution by mechanical separation of crystals, resolution by	**04**

	formation of diastereomers, second order asymmetric transformation, resolution by equilibrium asymmetric transformation, biochemical asymmetric transformation, criteria of optical purity.	
5	**Determination of stereochemistry organic compounds using NMR**	**04**

References:

1. Mechanism and structure in Organic Chemistry – E. S. Gould (Holt, Rinehart and Winston)
2. Advanced Organic Chemistry by J. March, 8th Ed.
3. Advanced organic chemistry. F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007)
4. Organic Synthesis-by Michael B. Smith Third Edition
5. A guidebook to mechanism in organic chemistry – Peter Sykes 6th Ed. Orient Longman
6. Organic Chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers. Oxford University Press
7. The Hammett Equation by C. D. Johnson, Cambridge University Press
8. Stereochemistry of carbon compounds - E. L. Eliel
9. Stereochemistry of carbon compounds - E. L. Eliel and S. H. Wilen
10. Organic Chemistry- J. Clayden, N. Greeves, S. Warren and P. Wothers 1st. Ed.
11. Stereochemistry of organic compounds – Nasipuri
12. Stereochemistry of organic compounds - Kalsi
13. Organic stereochemistry - Jagdamba Singh

CHO-602 MJ: Advanced Spectroscopic Methods in Structure Determination

Course type: Major Core (Theory) **No. of Credits: 4**

Course Outcomes

After completion of this course, the student will student will be able to

CO1: Learn the fundamental knowledge of ^{1}H NMR, ^{13}C NMR, ^{19}F NMR and Mass Spectral techniques.

CO2: Acquire advanced knowledge of ^{1}H NMR, ^{13}C NMR, ^{19}F NMR and Mass Spectral techniques.

CO3: Apply the knowledge of ^{1}H NMR, ^{13}C NMR, ^{19}F NMR and Mass Spectral techniques for structure determination.

CO4: Discuss probable spectral signals.

CO:5: Interpret different types of spectra.

CO6: Deduce the structure of the unknown compound using ^{1}H NMR, ^{13}C NMR and Mass Spectra.

Course Content

Chapter No.	Title with Contents	No. of hours
Section I		
1	**^{1}H NMR Spectroscopy:** Recapitulation of basic principle, Fourier Transform technique, Pulse sequence, relaxation processes. different types of spin coupling, first order analysis of spectra, different spin systems (AB, AM, AX, ABX/AMX spin systems with examples), factors affecting coupling constants, non-equivalence due to restricted rotations, rate processes. Simplification of complex spectra (High field NMR, Spin Decoupling, Shift reagents, NOE, Chiral Solvents, D_2O exchange, etc.), ^{31}P, ^{19}F NMR (Problems based	**16**

	on number of signals and splitting pattern)	
2	**^{13}C NMR Spectroscopy:** Principle, Types of ^{13}C NMR Spectra: un-decoupled, Proton decoupled, off resonance, APT, INEPT, DEPT, chemical shift, factors affecting chemical shifts, Homo nuclear (13C-13C) and Hetero nuclear (13C-1H) coupling constants.	**06**
3	**2D NMR Spectroscopy in structure elucidation:** (a) Homonuclear: COSY, TOCSY, 2DINADEQUATE, 2D-ADEQUATE, NOESY, ROESY (b) Heteronuclear: HETCOR, HSQC, HMQC, HMBC	**08**
Section II		
1	**Mass Spectrometry:** Principle, ionization methods like EI, CI, ESI, 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.	**12**
2	**^{19}F NMR spectroscopy:** Fundamentals and applications in structure elucidation of organic compounds and biomolecules. ^{19}F-^{13}C and ^{19}F-^{13}C Hetero nuclear coupling constants.	**04**
3	**Problems solving:** Structure elucidation using UV, IR, 1D (^{1}H and^{13}C) NMR and 2D NMR (^{1}H-^{1}H, COSY / ^{13}C- ^{1}H HETCOR only), APT, DEPT and MS data as well as spectra.	**14**
4	Use of NMR fid processing software's for Visualization, processing, analyzing and making reports of ^{1}H-NMR, ^{13}C-NMR and 2D NMR.	**Self-learning and for internal assessment only**

Study Tour: Students should visit at least one national level Institute/ University / Industry (Any one University, IIT's, IISER's, CSIR-NCL or industry etc.) and submit a report on their instrumentation facility.

References:

1. Spectrometric Identification of Organic Compounds by R. M. Silverstein, F. X.Webster, D. Kiemle, 6th Ed. John Wiley and Sons..
2. One and Two dimensional NMR Spectroscopy by Atta-Ur-Rehman, Elsevier (1989).
3. Structure determination of Organic compounds by E. Pretsch, P. Buhlman, and C. Affolter, Springer (2005).
4. Spectroscopy of organic molecule-PS Kalsi,Wiley, Esterna, New Delhi.
5. Introduction to Spectroscopy – D. L. Pavia, G.M. Lampman, G. S. Kriz, 5thEd. (Harcourt college publishers).
6. Organic Structures from Spectra by Field L.D. Kalman J.R. and Sternhell S. 4th Ed. John Wiley and Sons Ltd.
7. Organic Structural Spectroscopy by Joseph B. Lambert, Shurvell, Lightner, Cooks, Prentice-Hall (1998).
8. Organic Structure Analysis-Phillip Crews, Rodriguez, Jaspars by Oxford University Press (1998).
9. Mass Spectrometry Basics by Christopher G. Herbert Robert A.W. Johnstone
10. Mass Spectrometry Principles and Applications by Edmond de Hoffmann and Vincent Stroobant.
11. High-Resolution NMR Techniques in Organic Synthesis by Claridge, 3rd Ed., Wiley, 2016

CHO- 603 MJ: Heterocyclic Chemistry

Course type: Major Core (Theory) **No. of Credits: 2**

Course Outcomes

After completion of the course, students should-

CO1: learn the structures, nomenclature rules, and classifications of heterocyclic compounds.

CO2: understand advanced synthetic methodologies to design and execute the synthesis of various heterocyclic compounds.

CO3: Predict the molecular properties, electronic structures, and the reactivity of heterocyclic systems.

CO4: Distinguish the reactivity of heterocycles, elucidating reaction mechanisms and their pathways.

CO5: Evaluate the heterocyclic compounds with other organic compounds.

CO6: Summarize the significance and applications of heterocyclic chemistry.

Course Content

Chapter No.	Title with Contents	No. of hours
1	**Nomenclature and structure of Heterocyclic Compounds:** Systematic nomenclature (Hantzsch-Widman System) for monocyclic, fused and bridged heterocycles.	02
2	**Five membered Heterocyclic Compounds**: Pyrrole, Thiophene and Furan. Knorr synthesis, Paal Knorr synthesis, Hantzsch synthesis, Tromifov synthesis from oximes & alkynes, Fiest Benary synthesis, Hinsberg thiophene synthesis, use of acetylene dicarboxylate esters in synthesis **Reactions:** Electrophillic substitution 2) Nucleophillic and radical substitution 3) Ring Cleavage	08
3	**Condensed five memebered Heterocycles-**Indole, Benzofuran, Benzothiophene **Synthetic approaches:** i) Fischer Indole synthesis ii) Madelung’s synthesis iii) Reissert’s Indole synthesis iv) Nenitzescu synthesis	06

	v) Bischler Indole synthesis vi) Synthesis of Benozofuran from Coumarin vii) Claisen Reaarangement viii) Synthesis of Benzothiophenes & Benzofuran – i) Ring synthesis from 2-Arylthio or aryloxy-aldehydes or ketones or Acids from 2-(ortho-hydroxy or mercapto aryl) Acetaldehydes-ketones or acids.	
4	**Azoles 1,2 Azoles and 1,3 Azoles:** Synthesis of 1,2 azoles From 1,3 dicarbonyl compounds or precursors, 1.3 dipoloar cycloaddition of nitrile oxides & nitrile imines. Synthesis of 1,3 azoles From α halocarbonyl compound or an equivalent, dehydration of α acylamino carbonyl compounds, using isocynates. **Reactions:** Electrophilic substitution, Nucleophilic and radical substitution, quaternary azolium salts reactions.	05
5	**Quinoline & Isoquinoline**: Synthetic Approaches: Skraup , Friedlander & Pfitzingr, Bischler-Napieralski, Pictet-spengler, Pomerantz-Fritsch synthesis. Reactions: Electrophilic substitution, Nucleophilic and radical substitution, side chain reactivity.	05
6	**Pyridine group**: Synthesis: Hantzsch and Guareschi synthesis. Reactions: Electrophilic substitution, Nucleophilic substitution reaction of Pyridine N oxide.	04

References:

1. Heterocyclic Chemistry, J.A. Joule, K. Mills, Wiley, 2010.
2. The Essence of heterocyclic Chemistry, A. R. Parikh, H. Parikh, R. Khunt, New Age Int. Publication
3. Principles of Modern Heterocyclic Chemistry, L. A. Paquette, W. A. Benjamin, New York, 1968.
4. Heterocyclic Chemistry, J.A. Joule and G. F. Smith, van Nostrand, London, 1978.
5. Comprehensive Heterocyclic Chemistry. The structure, reactions, synthesis and use of Heterocyclic compounds, (Ed. A.R. Katritzky and C. W. Rees). Vol 1-8, Pergamon Press, 1984.
6. Handbook of Heterocyclic Chemistry, A. R. Katritzky, Pergamon Press, 1985.
7. Van der plas, H. C. Ring transformations of Heterocycles, Vols 1 and 2, Academic Press, 1974

Additional study material:

1. https://nptel.ac.in/content/syllabus_pdf/104105034.pdf
2. https://nptel.ac.in/courses/104/105/104105034/

CHO-604 MJP: Organic Synthesis Experiments

Course type: Major Core (Practical) **No. of Credits: 2**

Course Outcomes

After completion of this course, student will be able to-

CO1: Recall the sequential steps involved in the preparation of target compounds from given starting materials in single-stage, and double-stage preparations.

CO2: Recognize the mechanisms of organic preparations and their relevance to product formation.

CO3: Apply knowledge of functional group transformations to troubleshoot and optimize reaction conditions.

CO4: Assess the synthetic pathways for the efficient production of target compounds.

CO-5: Examine the structure and reactivity of starting materials to propose viable synthetic routes for heterocyclic compound synthesis.

CO6: Design multistep synthetic strategies for the construction of complex heterocyclic scaffolds from simple starting materials in heterocyclic compound synthesis.

Course Content

A. Double stage preparation (Any four)

1. Hydroquinone → Hydroquinone diacetate → 2,5-Dihydroxy acetophenone (Ref. 1)
2. Cyclohexanone →Enamine →2-Acetyl Cyclohexanone (Ref.2)
3. α-Pinene → Disiamylborane→ Pinanol (Ref 2)
4. p-Cresol → p-Cresyl benzoate → 2-Hydroxy-5-methyl Benzophenone (Ref. 1
5. Hippuric acid → Azalactone → 4-Benzylidene 2-phenyl oxazol-5-one (Ref.2)
6. Benzophenone→ Benzophenone oxime → Benzanilide (Ref 3)

B. Single stage Preparation (Any six)

1. Preparation of 2-hydroxy naphthaldehyde (Reimer-Tiemann reaction) (Ref.2)
2. Preparation of p-chlorotoluene from Toludine. (Ref 4)
3. Preparation of p-amino azobenzene from aniline (Ref. 2)
4. Preparation of tribromo benzene from aniline (Ref. 3)
5. Preparation of m-nitro phenol from m-nitro aniline (Ref.2)
6. Preparation of 4-nitrobenzoic acid from 4-nitrotoluene (Ref.2)

7. Preparation of 2-chlorobenzoic acid from anthranilic acid (Ref.1)
8. Preparation of acridone from 2-chlorobenzoic acid. (Ref 3)
9. Preparation of benzidine from nitrobenzene (Ref.2)
10. Preparation of congo red from benzidine. (Ref.2)
11. Preparation of benzylamine from phthalimide (Ref.2)

C. Synthesis of following heterocyclic compounds (Any two)

1. Synthesis of 2,5 dimethyl pyrrole from Acetonylacetone (Ref .1,6,7)
2. Synthesis of 1,2,3,4 tetrahydrocarbazole from cyclohexanone (Ref .1,6,7)
3. Synthesis of 2,5 dimethyl thiophene from Acetonylacetone (Ref .1,6,7)
4. Synthesis of Isatin from aniline (Ref .1,6,7)
5. Synthesis of 2-phenyl indole from acetophenone (Ref .1,6,7)
6. Synthesis of 2- benzoylbenzofuran from salicylaldehyde ((Ref .1,6,7)

References

1. Ahluwalia, V. K. and Aggarwal, R. (2000). Comprehensive practical organic chemistry: Preparation and Quantitative Analysis, Universities Press
2. Vogel's Textbook of Practical Organic Chemistry" by A.I. Vogel
3. Practical organic Chemistry: Mann and Saunders 4th edition.
4. "Experimental Organic Chemistry: A Miniscale & Microscale Approach" by John C. Gilbert and Stephen F. Martin
5. Advanced Practical Organic Chemistry - N. K. Vishnoi - Vikas 2nd Ed., (1996)
6. Katritzky, Alan R., et al. Handbook of heterocyclic chemistry. Elsevier, 2010.
7. Practical heterocyclic chemistry Fitton, Alan Ogden, and Robert Kenneth Smalley. Elsevier, 2013.

CHO-605 MJP: Ternary Mixture Separation

Course type: Major Core (Practical) **No. of Credits: 2**

Course Outcomes

After the completion of this course, students will be able to-
CO1: understand the concept of type determination and apply separation techniques.
CO2: comprehend different purification techniques.
CO3: accurately record and report physical constants.
CO4: analyze microscale chemical elemental analysis.
CO5: evaluate and execute qualitative estimation of functional groups.
CO6: create a report on ternary mixture separation.

Course Content

The students should perform Separation of minimum **eight (08)** mixtures containing three components. The mixtures should also involve separation of nitrophenols, amino acids, low boiling and melting compounds and water soluble and insoluble compounds, solids and liquids with multifunctional groups. The mixture separation should be carried out on micro-scale using ether.

References

1. Practical Organic Chemistry by F. G. Mann and B. C. Saunders, 4th Edn., Pearson, 2009.
2. Practical Heterocylic Chemistry, A. D. Fitton and R. K. Smalley, Academic Press, 2013.
3. Vogel's Text book of Practical Organic Chemistry, B. S. Furniss, A. J. Hannaford, P. W. G. Smith and A. R. Tatchell, 5th Edn., Pearson, 2003.
4. Organic Synthesis Collective, Volume I to XII, edited by J. B. Freeman, W. E. Noland, A. H. Blatt, N. Rabjohn, H. E. Baumgarten and C. K. Zercher, Wiley, 2015.
5. Macroscale and Microscale organic experiments by K. L. Williamson and K. M. Masters, 5th Edn., Books/Cole, 2016.
6. The Systematic Identification of Organic Compounds by Ralph L. Shriner, Christine K. F. Hermann, Terence C. Morrill and David Y. Curtin, 8th Edn., Wiley, 2004.
7. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis by V. K. Ahluwalia and Renu Aggarwal, Sangam Books Ltd., 2001.

CHO-610 (A) MJ: Synthetic Methods in Organic Chemistry

Course type: Major Elective (Theory) **No. of Credits: 2**

Course Outcomes

At the end of the course, students will be able to -

CO1: Know the concepts of ring formation mechanism and will apply in organic synthesis.

CO2: learn the synthetic applications of Organo-Boron, Organo-Tin and Organo Silicon

CO3: Predict the reaction conditions of organic reactions.

CO4: Analyze the products obtained from the synthetic methods.

CO5: Relate the reaction mechanism and its products.

CO5: Create a summary of synthetic methods in organic chemistry.

Course Content

Chapter No.	Title with Contents	No. of hours
1	Baldwin's Rule, Macrocyclic Ring Closures and synthetic approaches to Macrocyclic Lactones. (Ref-1: 517-531) **Ring formation reactions**: Pausan-Khand, Bergman and Nazarov cyclization.	**08**
2	**Synthetic applications of Organo-Boron and Organo-Tin and Organo-Silicon compounds:** Organo-Boranes: [Dialkylborane, diisoamylborane (disiamylborane or Sia_2BH), thexyl borane ($ThexBH_2$), diisopinocampheylborane (Ipc_2BH), 9-borabicyclo-[3,3,1]-nonane (9-BBN), allyl borane], Preparation and their reactivity, Applications in synthesis of alcohol, amine, halogenation, protonolysis and C-C bond formation. Reactions with alkyne, synthesis of E and Z alkene, Z,Z diene, E,E diene, **Organo-Tin** and **Organo-Silicon** reagents in organic synthesis. (Ref-1: Chapter 5 relevant pages, Ref. 3)	**10**

3	**Organic Reactions:** Wittig, Horner-Wordworth-Emmons, Julia-Lythgoe, McMurray, Peterson and Barton-Kellog olefination, Boord olefination, Corey winter olefination, Tebbe olefination, Baylis-Hilman, Ugi, Passerini, Biginelli and Mannich reaction.	**08**
4	**Umpolung of reactivity** (Ref-1: 633-642).	**04**

References

1. Organic synthesis – Michael B. Smith
2. Some modern methods of organic synthesis – W. Carruthers (Cambridge)
3. Organic Synthesis, The role of boran and silicon – Susan E Thomas
4. Advanced organic chemistry, Part B – F. A Carey and R. J.Sundberg, 5th edition (2007).
5. Strategic Applications of named reactions in organic synthesis - Laszlo Kurti and Barbara Czako
6. Name Reactions Jie Jack Li (Fourth Expanded Edition), PageNo: 1-582.
7. Organic chemistry – J. Clayden, N. Greeves, S. Warren and P.Wothers (Oxford Press),

CHO-610 (B) MJ: Carbohydrates and Chiron Approach

Course type: Major Elective (Theory) **No. of Credits: 2**

Course Outcomes

At the end of the course, students will be able to -

CO-1: Recall monosaccharide structures and D/L forms in Fisher projections.

CO-2: Understand cyclic hemiacetal forms and anomeric configurations.

CO-3: Applying Chiron approaches, they'll design syntheses of complex chiral molecules.

CO-4: Analyze protective group strategies between temporary and permanent groups.

CO-5: Evaluate glycosylation methods, stereoselectivity, and coupling efficiency.

CO-6: Summarize the planning of synthesis, pathways for chiral compound synthesis.

Course Content

Chapter No.	Title with Contents	No. of hours
1	**Basics of Carbohydrates:** Introduction of sugars, structures of monosaccharides, Nomenclature of monosaccharide , triose, tetrose, pentose, hexose, D/L forms of aldoses and ketoses in Fisher projections, cyclic hemiacetal forms of monosaccharides, representation of monosaccharide structure (Sickle, Fisher, Zig-zag, Mills, Haworth, Chair), The structure of Glucose, the anomeric configuration, Cyclic forms of the α and β-D-aldoses and their stability, mutarotation (D-Glucose), Conformations of monosaccharides, Conformations of the five membered rings, conformations of the six memberd rings , the anomeric effect. Modified monosaccharides, Reactions of open chain form of the sugars and reactions of the cyclic form of the sugar (Ref 1,2,6,7,8)	06
2	**Protective group strategies in carbohydrates:** Introduction, Protecting group, Hydroxyl protecting group (Temporary and	04

	permanent) , Anomeric / hemiacetal protecting group, Selective protection and deprotection methodology for hydroxyl group (Ref 1,2,3,4)	
3	**Synthesis of Glycosides:** Glycosyl donor and acceptor concept, general methods for glycosyl bond formation: Glycosyl halides, Trichloroacetimides, Glycals and Glycal derivatives, Thioglycosides, Phosphites, n-Pentyl glycosides, Sulfoxides, Diazarines Mannosides, Synthesis of 2-Deoxy Sugars, Orthogonal strategy in Oligosaccharide synthesis, Effect of protecting groups on glycosylation stereoselectivity and coupling efficiency, Intramolecular glycosylation (Ref 8, 9, 10, 11,12)	**10**
4	**Chiron approach:** Different strategies for asymmetric synthesis, Introduction of chiron approach, the concept of chiral templates, utilization of the basic concepts in synthesis of (S) Propanediol, (R) and (S) – Epichlorohydrin, L (+)-Alanine, (-) Multistratin, (-) Pentenomycin , prostaglandin , (-) Shikimic acid (Ref 5)	**10**

References:

1. Greene's protective groups in organic synthesis – Peter G. M. Wuts and Theodor R. A. Green 4th Edn. Wiley-India

2. Organic Chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press)

3. Modern organic synthesis-An introduction- George S. Zweifel, Michael H. Nantz.

4. Advanced Organic chemistry, Part B – F. A Carey and R. J. Sundberg, 5th edition (2007)

5. Chiron Approach in organic synthesis – S. Hanessian

6. Organic Chemistry – R. P. Morrison and R. N. Boyd

7. Organic Chemistry – I. L. Finar, volume II.

8. Essentials of Carbohydrate Chemistry and Biology: Thisbe K. Lindhorst, WILEY-VCH, 2000, Chapter 3.

9. Monosaccharide's: Their Chemistry and their Roles in Natural Products: Peter M. Collins, Robert J. Ferrier: John Wiley & Sons, 1995.

10. Carbohydrate in Chemistry and Biology: Part 1 Chemistry of Saccharides Vol.1. WILEY-VCH, 2000.

11. The Organic Chemistry of Sugars; By: Daniel E. Levy Peter Fugedi Publication: Taylor & Francis, Published on 2006

12. Handbook of Chemical Glycosylation by Alexei V. Demchenko, Wiley VCH, 2008

CHO: 610 (C) MJ: Medicinal Chemistry

Course type: Major Elective (Theory) **No. of Credits: 2**

Course Outcomes

At the end of the course, students will be able to -

CO1: Identify drug and learn different stages of drug design and development.

CO2: Know the application of computers in drug design.

CO3: Categorize various stages of Drug action and analyze various factors affecting drug action.

CO4: distinguish between infectious and non-infectious diseases

CO5: Relate the infectious diseases and causative agents.

CO6: Summarize the overall significance, development and applications of various drugs.

Course Content

Chapter No.	Title with Contents	No. of hours
1	**Introduction to drug design and development:** Definition: drug, need of drug, drug discovery: historical prospective, sources of drugs, including natural products as examples , general stages of drug discovery and design (from target identification to postmarket surveillance), structure and ligand based drug discovery, drug targets an overview, target identification and validation, screening of drugs, introduction to generic drugs, generics vs novel drugs, Computer assisted drug design (CADD): Introduction to CADD,applications of CADD in drug design, molecular docking and its subtypes, advantages and its limitations, overview of docking tools	08
2	**Introduction to drug action:** Pharmacokinetics (ADME) and pharmacodynamics, drug structure and solubility, effect of pH on drug solubility, partition coefficient, structure activity relationship (SAR), changing size, shape and substituents of existing lead. quantitative structure activity relationship (QSAR): regression study,	08

	lipophilic, electronic and steric parameters, approaches to lead optimization bioisosteric replacement, conformation restriction, molecular dissection, metabolic stabilization Case study: The design of Oxamniquine.	
3	**Chapter 3: Infectious diseases:** History of infectious diseases, classification, causative agents, source of the pathogen, modes of transmission, portals of entry, infectious dose, Germ theory of disease–Koch's postulates, vaccines, passive and active immunization, principles and effects of vaccination, history of antibacterial agents, antimicrobial chemotherapy, principles of antimicrobial therapy. Introduction, SAR, developments, mechanism of action, limitations of Case study: sulphonamides, beta lactam antibiotics, macrolides, tetracycline, artemisinin as antimalarial drug. Noninfectious diseases: Introduction, causes,treatment of ulcer, diabetics, cancer, and inflammation. Mechanism of action, SAR, developments and limitations of- Case study: anti-ulcer agents: cimetadine, anti-cancer drugs: intercalating agents, steroidal anti-inflammatory agents.	14

References:

1. An Introduction to Medicinal Chemistry, Fourth Edition Graham L. Patrick Oxford Press

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

6. Organic Chemistry of Drug Design and Drug Action, by R.B. Silverman

6 Practical Applications of computer aided drug design, by P.S. Charifson

7 Molecular modeling in Drug Design, by C. Cohen

8. Chemical Applications of Molecular modeling, by J. Goodman

CHO-631 RP: Research Project

Course type: Research Project **No. of Credits: 4**

Course Outcomes

At the end of the course, students will be able to -

CO-1: understand key concepts and principles relevant to the research topic.

CO-2: learn diverse research methodologies proficiently.

CO-3: write and communicate research findings persuasively through various mediums in the form of project report

CO-4: analyze and synthesize scholarly literature effectively.

CO-5: evaluate research findings and methodologies critically.

CO-6: design and execute original research projects independently.

Following guidelines should be followed for the conduction and evaluation of research project.

- Each student will perform project separately.
- Project working hours should be 30 hours for each credit.
- Choose a topic that aligns with your interests and career goals, but also consider its feasibility within the available resources and time frame.
- Consult with faculty members, advisors, or mentors to identify a research area that has potential for contribution to the field of chemistry.
- Adhere to ethical principles and standards in all aspects of your research.
- Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project followed by introduction, literature survey (recently published research papers must be included), experimental techniques, results and discussion, conclusions, Appendix consisting of i) references, ii) standard spectra / data if any and iii) safety precautions.
- 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

and 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.

- Students are encouraged to participate in national and international conferences and other project competitions.
- For conducting research study in M.Sc. Chemistry, it is highly recommended to follow the journals given below or any other journal from reputed publication.

1. **Journal of the American Chemical Society (JACS)**
   Publisher: American Chemical Society (ACS)
   Focus: Comprehensive coverage of all fields of chemistry, known for high-impact research.
2. **Angewandte Chemie International Edition**
   Publisher: Wiley-VCH on behalf of the German Chemical Society (GDCh)
   Focus: Broad coverage of all chemistry fields, emphasizing novel and significant research.
3. **Chemical Science**
   Publisher: Royal Society of Chemistry (RSC)
   Focus: Cutting-edge research across chemical sciences, open access.
4. **Nature Chemistry**
   Publisher: Nature Publishing Group
   Focus: Multidisciplinary and high-impact research across all areas of chemistry.
5. **Journal of Organic Chemistry (JOC)**
   Publisher: American Chemical Society (ACS)
   Focus: Specialized in organic chemistry, including synthesis and mechanisms.
6. **Inorganic Chemistry**
   Publisher: American Chemical Society (ACS)
   Focus: Research on inorganic and organometallic compounds.
7. **Analytical Chemistry**
   Publisher: American Chemical Society (ACS)
   Focus: Developments and applications in analytical techniques and methodologies.
8. **Physical Chemistry Chemical Physics (PCCP)**
   Publisher: Royal Society of Chemistry (RSC)
   Focus: Physical chemistry, chemical physics, and biophysical chemistry.
9. **Chemical Communications (ChemComm)**
   Publisher: Royal Society of Chemistry (RSC)

Focus: Rapid publication of high-quality communications across all chemical sciences.

10. **Accounts of Chemical Research**

    Publisher: American Chemical Society (ACS)

    Focus: Comprehensive reviews and accounts of current research topics in chemistry.

11. **Chemical Society Reviews**

    Publisher: Royal Society of Chemistry (RSC)

    Focus: The journal publishes high-quality, authoritative, and state-of-the-art reviews across all areas of chemical science. It covers comprehensive and critical reviews on a broad range of topics in chemistry, including emerging and interdisciplinary fields.

Semester-IV

CHO-651 MJ: Chemistry of Natural Products

Course type: Major Core (Theory) **No. of Credits: 4**

Course Outcomes

After the completion of this course, students will be able to-

CO1: Learn the fundamental aspects and knowledge of natural products.

CO2: Know the different pathways and biogenesis of natural products

CO3: Apply the gained knowledge in the synthesis of natural products.

CO4: Categorize the organic functional group transformations in their synthesis.

CO5: Interpret the logical retrosynthetic analysis.

CO6: Design the mechanism and stereochemistry of Natural products.

Course Content

Chapter No.	Title with Contents	No. of hours
Section I: Total Synthesis of some natural products		
1	**Synthesis, Stereochemistry and Structural Elucidation of Menthol**	**04**
2	**Longifolene: A case study- Synthesis by:** *a)* E. J. Corey and Co-Workers *b)* J. E. McMurry and S. J. Isser *c)* W. S. Johnson and Co-Workers *d)* B. Lei and A. G. Fallis	**08**
3	**Total Synthesis of:** a) Hirsutellone B	**18**

	b) Oseltamivir c) Atorvastatin d) Estrone and Mifepristone *e)* Prostaglandin F2α	
	Self-learning: Importance of total synthesis of natural products; Challenges in multistep synthesis; Merits and demerits of convergent and divergent synthesis; Need and criteria of protection and deprotection; importance of chemo, regio and stereo-selectivity in synthesis	

References:

1. Chemistry of Plant Natural Products: Stereochemistry, Conformation, Synthesis, Biology, and Medicine by Sunil Kumar Talapatra, Bani Talapatra, Spinger publications, page no. 388-396.
2. Advanced Organic Chemistry; Part B: Reactions and Synthesis by F. A. Carey and R. J. Sundberg, Fifth Edition
3. a) *Angew. Chem. Int. Ed.* 2009, 48, 6870 –6874. https://doi.org/10.1002/anie.200903382

   b) Chimia 2004, 58, 621-629. http://doi.org/10.2533/000942904777677605

   c) Medicinal Chemistry Letters, 2019, 10, 389-392. https://doi.org/10.1021/acsmedchemlett.8b00579

   d) Classics in total synthesis by K. C. Nicolaou and E. J. Sorensen
4. a) Virtual textbook of organic chemistry; William Revsch, Prof. Emeritus, Michiganstate university;

   b) Organic Chemistry; Clayden, Greeves, Warren and Wothers

Section II: Biogenesis – The building blocks and construction mechanism

1	**Terpenoids:** Melvalonate Pathway, Hemiterpenes, Monoterpenes, Irregular monoterpenes, Iridoids, Sesquiterpenes, Diterpenes, Sesterterpenes,	**12**

	Triterpenes and Steriods (Cholesterol	
2	**The Shikimate pathway:** Aromatic amino acids and simple benzoic acids, Phenylpropanoids: Cinnamic acids and esters,Lignans and lignin, Phenylpropenes, Benzoic acids from C6C3 compounds, Coumarins. Aromatic polyketides: Styrylpyrones, Flavonoids and stilbenes, Isoflavonoids, Terpenoid quinones	**09**
3	**Alkaloids:** Alkaloids derived from ornithine: Polyamines, Pyrrolidine and tropane alkaloids, Pyrrolizidine alkaloids, Alkaloids derived from lysine: Piperidine alkaloids, Quinolizidine alkaloids, Indolizidine alkaloids Alkaloids derived from nicotinic acid: Pyridine alkaloids, Alkaloids derived from tyrosine: Phenylethylamines, simple and modified tetrahydroisoquinoline alkaloids, Amaryllidaceae alkaloids , Alkaloids derived from tryptophan: Simple indole alkaloids, Simple β-carboline alkaloids, Terpenoids indole alkaloids	**09**

References:

1. Medicinal Natural Products - A Biosynthetic approach by Paul M. Dewick 3rd Ed. (Wiley)
2. Secondary metabolism - J. Mann, 2nd edition.
3. Chemical aspects of Biosynthesis – J. Mann (1994).

CHO-652 MJ: Advanced Synthetic Organic Chemistry

Course type: Major Core (Theory) **No. of Credits: 4**

Course Outcomes

After the completion of this course, students will be able to-

CO1: Learn the fundamental concepts of organometallic reactions and their bonding, reactivity, and mechanism.

CO2: Understand the significance of advanced organometallic reagents in organic chemistry.

CO3: Employ synthetic methodologies for cross-coupling reactions, enabling the formation of C-C, C-N, and other bonds.

CO4: Analyze the products of synthetic organic reactions.

CO5: Relate the products of the retrosynthetic transformations with the Target Molecules.

CO6: Design the summary of advanced synthetic reagents, their reactions and the products.

Course Content

Chapter No.	Title with Contents	No. of hours
	Section I	
1	**A. Synthetic applications of Transition metal complexes in organic synthesis:** Pd, Ni, Co, Ru, Fe, and Cu (only C-C, C-N, C-O bond formation reactions with catalytic cycle, terminology in Catalysis, Turnover number (TON), Turnover Frequency (TOF)oxidation states of transition metals, 16-18 rule, dissociation, association, insertion, oxidative addition, reductive elimination of transition metal ligand, and % mole concepts) **(06 Hrs)** **B. Synthetic applications of-** **Organo-Palladium reagents**: Heck arylation, allylic activation, carbonylation, Wacker oxidation, Stille, Sonogashira, Fukuyama, Kumada,	**30**

	Hiyama, Negeshi, Tsuji-Trost, Buchwald-Hartwig and Suzuki coupling reactions. **(12 Hrs)** **Organo-Nickel reagents**: Carbonylation, Oligomerisation and Reppe reaction. **(3 Hrs)** **Organo-Iron reagents**: Noyori reaction, Collmann's reagent, and Eletrophilic reactions**. (3 Hrs)** **Organo-Cobalt reagents**: Oxo Process, Nicholas reaction, Pausand Khand reaction, Volhardt's cotrimerisation reaction. **(3Hrs)** **Organo-Ruthenium and Organo-Rhodium reagents**: Reduction reactions using Wilkinson's Catalyst, Noyori reduction, Knowles asymmetric hydrogenation. **(3Hrs)**	
	Section II	
1	**Metathesis Reactions**: Olefin 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, and application in the synthesis of homo and heterocyclic compounds. Enyne methathesis, Alkyne meththesis.	**08**
2	**Click chemistry:** Criterion for click reaction, Sharpless azides cycloadditions. Regioselectivity in click reactions, Click reactions in synthesis of bioconjugates (sugars and proteins)	**04**
3	**Retrosynthetic Analysis:** Retrosynthetic analysis, disconnection approach, Synthons, multiple step synthesis, functional group interconversion, Illogical two group interconversion, C-C disconnection, Donor and acceptor Synthons, two group disconnection, 1,5 related functional group disconnection, Umpolung, convergent synthesis, special methods for small rings, Heteroatom and Heterocyclic compounds, problems,	**18**

	Self-learning: Application of Retrosynthetic Approach: Retrosynthetic analysis and synthesis of following Molecules: (+)-Asteriscanolide, (+)-Himbacine, Hirsutine, (+)-Paniculatin, Sildenafil] Ref. 21	

References:

1. Organic synthesis – Michael B. Smith
2. Transition Metal Reagents and Catalysis Innovations in Organic Synthesis – Jiro Tsuji, JOHN WILEY & SONS, LTD
3. Some modern methods of organic synthesis – W. Carruthers(Cambridge)
4. Advanced organic chemistry, Part B – F. A Carey and R. J.Sundberg, 5th edition (2007).
5. Strategic Applications of named reactions in organicsynthesis-Laszlo Kurti and Barbara Czako
6. Modern Organic Synthesis: An Introduction George S Zweifel and Michael H Nantz
7. Name Reactions Jie Jack Li (Fourth Expanded Edition), PageNo: 1-582.
8. Organic Synthesis Using Transition Metals, by RoderickBates, Second Edition, A John Wiley & Sons, Ltd., Publication.
9. Organic chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press),
10. Transition Metals for Organic Synthesis Volume 1 *Edited by M. Beller and C. Bolm* WILEY-VCH Verlag GmbH & Co. KGaAISBN: 3-527-30613-7
11. Multicomponent Reactions Edited by Jieping Zhu, HuguesBienayme WILEY-VCH Verlag GmbH & Co. KGaA
12. C–N bond forming cross-coupling reactions: an overview: by Jitender Bariwalab and Erik Van der Eycken *Chem. Soc. Rev.*, 2013, 42, 9283
13. Iron Catalysis in Organic Synthesis Chem. Rev. 2015, 115, 3170– 3387.
14. Recent advances in homogeneous nickel catalysis Nature 2014,Vol 509, Page 299-309.
15. Ruthenium-Catalyzed Reactions for Organic Synthesis *Chem. Rev.* 1998, *98,* 2599-2660.
16. Organic Synthesis Involving Iridium-Catalyzed Oxidation Chem. Rev. 2011, 111,

1825–1845.

17. Aerobic Copper-Catalyzed Organic Reactions Chem. Rev. 2013,113, 6234−6458.
18. Designing Organic Syntheses by Stuart Warren
19. Organic Chemistry from Retrosynthesis to Asymmetric Synthesis, by Vitomir Sunjic, Springer; 1st ed. 2016 edition
20. Classics in Total Synthesis by K.C. Nicolaou and E.J.Sorensen
21. Organic Synthesis Workbook II C. Bittner, A. S. Busemann, U. Griesbach, F. Haunert, W.-R.Krahnert, A. Modi, J.Olschimke, P.L. Stech

CHO-653 MJP: Convergent and Divergent Organic Synthesis

Course type: Major Core (Practical) **No. of Credits: 2**

Course Outcomes

After the completion of this course, students will be able to-

CO-1: Learn new synthetic methodologies for the selective modification of starting materials.

CO-2: Recognize the reactivity of starting materials towards different reagents and reaction conditions.

CO-3: Apply multi-step synthesis strategies to construct complex molecules from simple starting materials.

CO-4: Analyze reaction mechanisms and intermediates to understand the synthesis pathways.

CO-5 Evaluate the efficiency and practicality of different synthetic routes based on yield and selectivity.

CO-6: Create novel synthesis routes based on the principles of organic chemistry and reactivity patterns.

Course Content

Note: Any **2 sets** should be conducted from the following convergent and divergent synthesis sets.
Students should acquire **pre-experiment** (Reading MSDS, purification of reactants and reagents, mechanism, stoichiometry etc) and **post-experiment skills** (work-up, isolation and purification of products, physical constants characterization using any spectroscopic methods etc.)

SET-I

A) Convergent Synthesis 1 (Three Stage Synthesis)

1. Stage I: Anisole to 4-nitro anisole to 4-amino anisole (2 steps)
2. Stage II: Toluene to 4-nitro toluene to 3-acyl nitro toluene (2 steps)
3. Stage III: Synthesis of N-(1-(2-methyl-5-nitrophenyl) ethyl) aniline from 4-amino

anisole, 3-acyl nitro toluene and SBH (One pot synthesis: MCR)

B) Divergent Synthesis 1 (5 Single Stage Synthesis 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

SET-II

A) Convergent Synthesis 2 (Three Stage Synthesis)

1. Stage I: 4-Nitro toluene to 4-amino toluene (Reduction by using Sn/HCl)
2. Stage II: Phenol into 2-hydroxy benzaldehyde (Reimer-Tiemann reaction)
3. Stage III: Synthesis of amidoalkyl-2-naphthols from β-Naphthol,4-amino toluene and of 2-hydroxy benzaldehyde (One pot synthesis: MCR)

B) Divergent Synthesis (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-III

A) Convergent Synthesis-3 (Three Stage Synthesis)

1. Stage I: Salicylic acid to 5-Chloro-2-hydroxybenzoic acid
2. Stage II: o- Anisidine to 2-methoxy-4-nitroaniline
3. Stage III: Synthesis of 5-chloro-2-hydroxy-N-(2-methoxy-4-nitrophenyl) benzamide from 5-Chloro-2-hydroxybenzoic acid, -methoxy-4-nitroaniline (One pot synthesis: MCR)

B) Divergent Synthesis-3 (5 Single Stage Synthesis from Salysaldehyde)

1. Salicylaldehyde to Salicylaldehyde phenylhydrazone
2. Salicylaldehyde with melanonitrile to 2-iminochromene by intramolecular cyclization.

3. Salicylaldehyde to 2-hydroxy-3,5-dinitrobenzaldehyde
4. Salicylaldehyde to o-Formylphenoxy acetic acid
5. Salicylaldehyde to catechol

SET-IV

A) Convergent Synthesis- 4 (Three Stage Synthesis)

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

B) Divergent Synthesis-4 (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

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. Hermann, Terence C. Morrill and David Y. Curtin

CHO-654 MJP: Green Chemistry Experiments

Course type: Major Core (Practical) **No. of Credits: 2**

Course Outcomes

CO-1: Know the principles of green chemistry and the importance of sustainability in chemical processes.

CO-2: Identify solvent-free reactions using appropriate techniques and equipment.

CO-3: Optimize green chemistry reactions in the laboratory.

CO-4: Analyze the advantages and disadvantages of solvent-free reactions, green catalysts, and green solvents in comparison to traditional chemical methodologies.

CO-5: Assess the role of green catalysts in promoting the desired reactions while minimizing waste and environmental impact.

CO-6: Communicate experimental procedures, results, and conclusions effectively through written reports and oral presentations.

Course Content

Perform any 12 experiments from the given list. Provide description on green chemistry principles involved in the reaction.

1. Diazepinone synthesis (Ref no. 1, Page 228)
2. Alumina-supported permanganate oxidation (Ref no. 1, Page 15)
3. Rearrangement of diazoaminobenzene to p-aminoazobenzene (Ref no. 2, Page 36)
4. Knoevenagel condensation (Ref no. 1, Page 51)
5. Synthesis of dihydropyrimidinone (Ref.No.2, Page no.40)
6. Beckmann rearrangement (Ref no. 1, Page 346)
7. 1,3-dithiolane Synthesis (Ref no. 1, Page 299)
8. Clay catalysed solid state synthesis of 7-hydroxy-4-methylcoumarin (Ref.No.2, Page no.24)
9. Preparation of 1, 1-bis-2-naphthol from 2-naphthol. (Ref.No.2 Page no.36)
10. Pinacol coupling reaction by using Zn-$ZnCl_2$ (Ref.No.2 Page no.35)
11. Reformatsky reaction/Luche reaction (Ref.No.1 Page no.36)

12. Preparation of benzopinacolone from Benzopinacol using iodine (Ref.No.2 Page no.32)
13. Preparation of 2- phenyl benzothiazoles catalyzed by ionic liquid (Ref.No.2, Page no.53)
14. Diels-Alder reaction between furan and maleic acid (Ref.No.2, Page no.18)
15. Microwave-Assisted Organic Synthesis: Synthesis of aspirin using microwave irradiation. (Ref.No.6).
16. Solvent-Free Aldol Condensation: Reaction of indan-1-one and 3,4-dimethoxy benzaldehyde (Ref. no. 1 and 7).
17. Aqueous Phase Suzuki Coupling: Conducting Suzuki coupling reactions in water (Ref no. 8 and 9).
18. Ionic Liquids as Green Solvents: Performing Diels-Alder reactions using ionic liquids as solvents. (Ref no. 10 and 11).
19. Atom-Economical Synthesis: Synthesis of 12-crown-4 ether with high atom economy. (12 and 13).
20. Click Chemistry: Performing a copper-catalyzed azide-alkyne cycloaddition (CuAAC) in water. (Ref no. 14)
21. Green Reductions: Reducing ketones to alcohols using sodium borohydride in aqueous ethanol (Ref no. 11).
22. Friedel-Crafts Alkylation Reaction – Graphite catalyzed alkylation of p-xylene by 2-bromobutane. (Ref. no. 15 and 16)
23. Synthesis of tetrabutylammonium tribromide and its application in bromination of chalcone (Ref. no. 2)
24. Preparation of ionic liquid and its application in Preparation of 2- phenylbenzothiazoles (Ref. no. 2)

References:

1. Solvent-free Organic Synthesis by Koichi Tanaka (Copyright © 2009 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, ISBN: 978-3-527-32264-)
2. Monograph on Green Chemistry Laboratory Experiments by Green Chemistry Task Force Committee, DST

3. Chanda, A., & Fokin, V. V. (2009). Organic synthesis “on water”. Chemical reviews, 109(2), 725-748).
4. Comprehensive Practical Organic Chemistry by V.K. Ahluwalia and Renu Aggarwal
5. A. I. Vogel, *Textbook of Practical Organic Chemistry,* Fifth Edition, 1989
6. Microwave-Assisted Organic Synthesis: One Hundred Reaction Procedures by C. Oliver Kappe, Alexander Stadler
7. Green Techniques for Organic Synthesis and Medicinal Chemistry by Wei Zhang, Berkeley W. Cue Jr.
8. Suzuki-Miyaura Cross-Coupling Reactions in Water: From Metal-Catalyzed Reactions to Applications in Organic Synthesis by Ferenc Tóth, Attila Bényei
9. Organic Reactions in Aqueous Media by Chao-Jun Li, Tak-Hang Chan
10. Ionic Liquids in Synthesis by Peter Wasserscheid, Thomas Welton
11. Handbook of Green Chemistry and Technology by James H. Clark, Duncan J. Macquarrie.
12. Green Synthetic Approaches for Biologically Relevant Heterocycles by Wei Zhang, Berkeley W. Cue Jr.
13. Atom Economy: A Challenge for Organic Synthesis by Piet W. N. M. van Leeuwen, Karel W. Törnroos
14. Copper-Catalyzed Click Chemistry by Nuno Maulide, Chao-Jun Li
15. A Greener Alternative to Aluminum Chloride Alkylation of Xylene, Sereda, G.A. And Rajpara, V.B., J. Chem. Ed., 2007, 84(4), 692.
16. A Guide to Green Chemistry Experiments for Undergraduate Organic Chemistry Labs.

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

CHO-660 (A) MJ: Asymmetric Synthesis

Course type: Major Elective (Theory) **No. of Credits: 2**

Course Outcomes

After the completion of this course, students will be able to-

CO-1: Learn the principles of asymmetric synthesis to achieve stereoselectivity, enantio-selectivity, and diastereo-selectivity in cyclic compounds.

CO-2: Understand resolution techniques, including Dynamic Kinetic Resolution (DKR), for racemic mixtures of cyclohexane and decalin-based molecules, quantifying enantiomeric excess (EE) values.

CO-3: Interpret enantiomeric and diastereomeric excess in reactions,

CO-4: Distinguishing between R and S configurations in compounds.

CO-5: Evaluate total synthesis examples, integrate multiple asymmetric synthesis strategies to design efficient synthetic routes, and assess the applicability and limitations of different methods in complex synthesis challenges.

CO-6: summarize the concepts such as diastereoselectivity, enantiomeric and diastereomeric excess chiral pool, chiral auxiliaries, and chiral reagents and catalysts in asymmetric synthesis

Course Content

Chapter No.	Title with Contents	No. of hours
1	**Principles and applications of asymmetric synthesis:** Stereoselectivity in cyclic compounds, enantio-selectivity, diastereo-selectivity, enatiomeric and diastereomeric excess, stereoselective aldol reactions. Cram's rule, Felkin Anh rule, Cram's chelate model. Resolution of racemic mixture, Dynamic kinetic resolution (DKR), cyclohexane and decalin based molecules, enantiomeric excess: R and S 2-butanol, resolution of racemic acid using chiral amines.	15

2	**Asymmetric synthesis**: use of chiral pool, chiral auxiliaries, chiral reagents and catalysts, asymmetric Diles-Alder reactions, asymmetric hydrogenation, Sharpless asymmetric hydroxylation and epoxidation, Jacobsen and Shi epoxidations. Organocatalysis, Enzyme catalysis-reduction of ketones. Total synthesis examples	15

References:

1. Organic Chemistry – J. Clayden, N. Greeves and S. Warren 3rd Edition.
2. Catalytic Asymmetric Synthesis, 3rd ed,Ed: I. Ojima, John Wiley & Sons, New Jersey, 2010
3. Catalysis in Asymmetric Synthesis by Vittorio Caprio and Jonathan M. J. Williams
4. Angew. Chem. Int. Edn. 2008, 47, 4638–4660.
5. Principles and Applications of Asymmetric Synthesis by Guo-Qiang Lin, Yue-Ming Li, Albert S. C. Chan, A John Wiley & Sons, Inc., Publication
6. Additional Study Material : Catalytic Asymmetric Synthesis
   https://nptel.ac.in/content/syllabus_pdf/104103067.pdf
   https://nptel.ac.in/courses/104/103/104103067/

CHO-660 (B) MJ: Applied Organic Chemistry

Course type: Major Elective (Theory) **No. of Credits: 2**

Course Outcomes

After the completion of this course, students will be able to

CO1: Gain a comprehensive understanding of impurities in organic drugs, functional dyes, polymers, and metal-organic frameworks.

CO2: Demonstrate comprehension of the principles, structures, and mechanisms underlying each concept.

CO3: Identify functional dyes, polymers, metal-organic frameworks and impurities present in organic drugs.

CO4: Classify functional dyes, polymers, and metal-organic frameworks and impurities found in drugs according to relevant criteria.

CO5: Compare functional dyes, polymers, metal-organic frameworks, and the impurities in drugs.

CO6: Develop a strategic plan or workflow for the removal of impurities in organic drugs, identification of functional dyes and their properties, polymers properties and their synthesis, and metal-organic framework synthesis.

Course Content

Chapter No.	Title with Contents	No. of hours
1	**Impurity profiling in drug APIs:** Introduction of Active pharmaceutical ingredients (API), various aspects of the estimation of impurities in drugs, Impurities in API and Classification of impurities in drugs, nature, and origin of the impurities in drug substance, role and aims of impurity profiling in drug research, development and production; methods for impurity profiling [**ref. 1-4**]. Impurity profiling of some groups of drugs: Case study of selected examples (1) impurity profiling	08

	in steroid drugs synthesis [**ref.1, page: 712-730**] (2) Identification of novel rapamycin derivatives as low-level impurities in active pharmaceutical ingredients. [**Ref. 5**], (3) Identification and characterization of four process-related impurities in retigabine. [**Ref.6**].	
2	**Functional Dyes:** Introduction, Interactions of Functional Dyes, Functional Dyes by Application, Imaging, Laser Printing and Photocopying, Thermal Printing, Dyes for Ink-Jet Printing, Other Imaging Technologies, Invisible Imaging, Optical Data Storage, Other Technologies, Displays, Cathode Ray Tube, Liquid Crystal Displays, Organic Light-Emitting Devices, Electrochromic Displays, Electronic Materials, Organic Semiconductors, Solar Cells, Nonlinear Optical Dyes, Laser Dyes, Biomedical Applications, Fluorescent Sensors and Probes, Photodynamic Therapy **Ref.7**	08
3	**Applied polymer chemistry:** Polymers Synthesis and Characterization: Repeating units, degree of polymerization, linear, branched, and network polymers. Classification of polymers. Addition, radical, ionic, coordination and condensation polymerization; their mechanism and examples. Polymerization conditions and, polymer reactions. Polymerization in homogeneous and heterogeneous systems. Phenol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, epoxy resins and curing agents, Polyamides: nylon-6, nylon-66, processing of thermoplastics and thermosetting resins for films, fibers, foams, sheets, and tubing. **Ref: 8 to 10**	06
4	**A Metal-Organic Frameworks:** Metal-organic frameworks and Porous Organic Materials Coordination polymers, porous and cavity-containing structures, metallic clusters of MOFs, Design and synthesis of MOFs, Factors affecting synthesis of MOFs; solvents, effect of temperature and pH, Factors affecting the stability of MOFs, Major applications: Catalysis, Hydrogen storage, Stimuli-	08

	Responsive MOFs for drug delivery, sensors. Design principle of porous organic polymers, Types of porous polymers; micro-, meso- and macro-, Microporous polymers; synthetic methodologies; Hyper-crosslinked porous polymers, Conjugated microporous polymers, and Covalent organic frameworks, Applications of porous polymers (gas storage and adsorption, and catalytic applications). **Ref : 11 to 18**	

References:

1. Identification and determination of impurities in drugs by Görög, Sándor, 1st ed. Elsevier Science, 2000.
2. Analysis of Drug Impurities by Richard J. Smith, and Michael L. WebbBlackwell Publishing, 2007.
3. Determination of impurities in pharmaceuticals: why and how? by Liu KT, Chen CH. In Quality management and quality control-new trends and developments (chapter 7, pp. 1-17). London, UK: IntechOpen. 2019
4. Alsante, Karen M., Peter Boutros, Michel A. Couturier, Robert C. Friedmann, Jeffrey W. Harwood, George J. Horan, Andrew J. Jensen et al. "Pharmaceutical impurity identification: a case study using a multidisciplinary approach. " Journal of Pharmaceutical Sciences 93, no. 9 (2004): 2296-2309. https://doi.org/10.1002/jps.20120
5. Zech, S. G., Carr, M., Mohemmad, Q. K., Narasimhan, N. I., Murray, C., Rozamus, L. W., & Dalgarno, D. C. (2011). Identification of novel rapamycin derivatives as low-level impurities in active pharmaceutical ingredients. The Journal of Antibiotics, 64(9), 649-654. https://doi.org/10.1038/ja.2011.61
6. Wang, X., Zhou, H., Zheng, J., Huang, C., Liu, W., Yu, L., & Zeng, S. (2012). Identification and characterization of four process-related impurities in retigabine. Journal of pharmaceutical and biomedical analysis, 71, 148-151. https://doi.org/10.1016/j.jpba.2012.07.035
7. Industrial Dyes: Chemistry, Properties, Applications, Editor(s):Dr. Klaus Hunger, First published:9 December 2002, https://doi.org/10.1002/3527602011.ch6
8. Billmeyer, Jr., F.W. (2007). Textbook of Polymer Science. Wiley.

9. Gowariker, V. R., Viswanathan, N. V., and Sreedhar, J. (1986). Polymer Science. New Age International.
10. Takemoto, K. Inaki Y. and Ottanbrite R.M. (1997). Functional Monomers and Polymers, CRC Press.
11. Alcock H.R., Lambe, F.W., and Mark, J. E., (2003). Contemporary Polymer Chemistry, Prentice Hall.
12. Odian, G. (2004). Principles of Polymerization. John Wiley and Sons.
13. Peacock, A., and Calhoun, A. (2012). Polymer Chemistry-Properties and Applications. Hanser Publishers, Munich.
14. The Chemistry of Metal-Organic Frameworks - Synthesis, Characterization, and Applications by Stefan Kaskel; Wiley-VCH 2016
15. Metal-Organic Frameworks by Hermenegildo García, Sergio Navalón; Wiley-VCH 2018
16. Maria S. Lohse and Thomas Bein Adv. Funct. Mater. 2018, 28(33), 1705553.) DOI: 10.1002/adfm.201705553
17. Functional Supramolecular Materials from Surfaces to MOFs by Rahul Banerjee; The Royal Society of Chemistry 2017
18. Metal-Organic Frameworks: Applications from catalysis to gas storage" by David Farruseng, Wiley-VCH, 2011

CHO-660 (C) MJ: Industrial Organic Chemistry

Course type: Major Elective (Theory) **No. of Credits: 2**

Course Outcomes

After the completion of this course, students will be able to

CO-1: list the key industrial processes used in the synthesis of major organic chemicals.

CO-1: explain the basic principles and mechanisms underlying the production of organic chemicals.

CO-1: apply knowledge of organic reaction mechanisms to optimize conditions in industrial chemical processes.

CO-1: differentiate between various catalytic methods used in industrial organic synthesis and assess their efficiencies and environmental impacts.

CO-1: evaluate the economic and environmental considerations in the industrial production of organic compounds, making recommendations for improvements.

CO-1: design a conceptual plan for a new industrial process or product, incorporating principles of green chemistry and sustainability.

Course Content

Chapter No.	Title with Contents	No. of hours
1	**Industrial Organic Chemicals:** **Industrial Organic Chemicals.** Primary raw materials from petroleum and natural gas; petroleum refining reactions; cracking and reforming processes– reaction mechanisms. **Chemicals from Ethylene**. Polymerization via free radical and acid catalysts; Ziegler process in the formation of polyethylene; addition reactions and review of mechanisms. Vinyl chloride, vinyl acetate, polystyrene etc.	10

	Chemicals from Propylene. Polymerization to polypropylene; addition reactions; conversion to acrolein and acrylonitrile; cumene hydroperoxide; phenol and acetone. **Chemicals from the C_4 Stream**. Butadiene; polymerization; Diels-Alder reaction; 1,4-additions; adiponitrile and hexamethylenediamine for nylon production. **Chemicals from Benzene, Toluene and Xylene (BTX Process)**. Review of electrophilic substitution reactions; phenol-formaldehyde resins; reduction of benzene to cyclohexane; oxidation to adipic acid (nylon 6,6 and nylon 6), caprolactam from cyclohexanone oxime; Beckmann rearrangement; reactions of toluene, benzyl chloride, benzoic acid, benzaldehyde; xylene to phthalic anhydride (plasticizers). **Chemicals from Acetylene**. Addition reactions; Reppe chemistry; trichloromethylene (degreasing), perchloroethylene (drycleaning).	
2	**Sources of Chemicals Other than Petroleum and Natural Gas**: Coal, coal-tar chemicals, Fischer-Tropsch reaction, fats and oils, fatty acids and alcohols, carbohydrates, starch and cellulose, natural gums.	**03**
3	**Catalysts**: Discussion of the role of catalysts in industrial chemical processes; zeolites in petroleum refining; Ziegler-Natta catalysts in polymerization.	**02**
4	**Fermentation technology:** General discussion on the use of microorganisms (yeasts, bacteria and fungi) in production of commercial products. Specific examples chosen from the pharmaceutical industry (steroids, antibiotics etc). Use of plant cell cultures for production of plant-derived medicinal drugs. Isolation of enzymes and use of enzymes as "reagents" in organic synthesis.	**05**
5	**Pharmaceuticals**: Discussion on various aspects of the pharmaceutical industry–its difference from that of the petroleum and heavy chemicals industry, properties of a	**10**

	drug, cardiovascular drugs, drugs affecting the nervous system (barbiturates, psychotropic drugs, stimulants), antibacterial agents (sulfonamides, penicillins, cephalosporins, tetracyclines, macrolides), steroid drugs (oral contraceptives, sex hormones, adrenocortical hormones, anabolic agents, anti-inflammatory agents), analgesics (aspirin, acetaminophen), anti-histamines.	

References

1. Survey of Industrial Chemistry by Chenier, Philip W.
2. Riegel’s Handbook of Industrial Chemistry by Riegel, Emil Raymond.
3. Industrial Organic Chemicals in Perspectives by Wittcoff, Harold.
4. Organic Building Blocks of the Chemical Industry by Szmant, H.H.
5. Industrial Organic Chemistry by Hans-Jürgen Arpe, Stephen Hawkins.
6. Principles of Fermentation Technology by Peter F. Stanbury, Allan Whitaker and Stephen J. Hall.
7. Principles of Medicinal Chemistry" by David A. Williams and Thomas L. Lemke
8. Pharmacological Basis of Therapeutics" by Laurence Brunton, Randa Hilal-Dandan, and Bjorn Knollmann.

CHO-681 RP: Research Project

Course type: Research Project **No. of Credits: 6**

Course Outcomes

At the end of the course, students will be able to -

1. understand key concepts and principles relevant to the research topic.
2. learn diverse research methodologies proficiently.
3. write and communicate research findings persuasively through various mediums in the form of project report
4. analyze and synthesize scholarly literature effectively.
5. evaluate research findings and methodologies critically.
6. design and execute original research projects independently.

Following guidelines should be followed for the conduction and evaluation of research project.

- Each student will perform project separately.
- Project working hours should be 30 hours for each credit.
- Choose a topic that aligns with your interests and career goals, but also consider its feasibility within the available resources and time frame.
- Consult with faculty members, advisors, or mentors to identify a research area that has potential for contribution to the field of chemistry.
- Adhere to ethical principles and standards in all aspects of your research.
- Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project followed by introduction, literature survey (recently published research papers must be included), experimental techniques, results and discussion, conclusions, Appendix consisting of i) references, ii) standard spectra / data if any and iii) safety precautions.
- 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 and 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.
- Students are encouraged to participate in national and international conferences and other project competitions.
- For conducting research study in M.Sc. Chemistry, it is highly recommended to follow the journals given below or any other journal from reputed publication.

1. **Journal of the American Chemical Society (JACS)**
   Publisher: American Chemical Society (ACS)
   Focus: Comprehensive coverage of all fields of chemistry, known for high-impact research.

12. **Angewandte Chemie International Edition**
    Publisher: Wiley-VCH on behalf of the German Chemical Society (GDCh)
    Focus: Broad coverage of all chemistry fields, emphasizing novel and significant research.
13. **Chemical Science**
    Publisher: Royal Society of Chemistry (RSC)
    Focus: Cutting-edge research across chemical sciences, open access.
14. **Nature Chemistry**
    Publisher: Nature Publishing Group
    Focus: Multidisciplinary and high-impact research across all areas of chemistry.
15. **Journal of Organic Chemistry (JOC)**
    Publisher: American Chemical Society (ACS)
    Focus: Specialized in organic chemistry, including synthesis and mechanisms.
16. **Inorganic Chemistry**
    Publisher: American Chemical Society (ACS)
    Focus: Research on inorganic and organometallic compounds.
17. **Analytical Chemistry**

Publisher: American Chemical Society (ACS)

Focus: Developments and applications in analytical techniques and methodologies.

18. **Physical Chemistry Chemical Physics (PCCP)**

    Publisher: Royal Society of Chemistry (RSC)

    Focus: Physical chemistry, chemical physics, and biophysical chemistry.

19. **Chemical Communications (ChemComm)**

    Publisher: Royal Society of Chemistry (RSC)

    Focus: Rapid publication of high-quality communications across all chemical sciences.

20. **Accounts of Chemical Research**

    Publisher: American Chemical Society (ACS)

    Focus: Comprehensive reviews and accounts of current research topics in chemistry.

21. **Chemical Society Reviews**

    Publisher: Royal Society of Chemistry (RSC)

    Focus: The journal publishes high-quality, authoritative, and state-of-the-art reviews across all areas of chemical science. It covers comprehensive and critical reviews on a broad range of topics in chemistry, including emerging and interdisciplinary fields.