

ST. JOSEPH'S COLLEGE (AUTONOMOUS)

BENGALURU - 27

DEPARTMENT OF CHEMISTRY

**SYLLABUS FOR POSTGRADUATE COURSE
M.Sc. ANALYTICAL / ORGANIC CHEMISTRY
FOURTH SEMESTER - DEPARTMENT ELECTIVE**

2021-2024



Re-accredited with 'A++' GRADE and 3.79/4 CGPA by NAAC
Recognised as "College of Excellence" by UGC

FROM 2021-2022 ONWARDS

Semester	IV
Paper Code	CHDE 0321
Paper title	Dept. elective: GREEN CHEMISTRY AND DIVERSITY OF ITS APPLICATIONS
Number of teaching hours per week	4
Total number of teaching hours per semester	60
Number of credits	4

1. PRINCIPLES OF GREEN CHEMISTRY

3 h

Twelve Principles of green chemistry: prevention of waste, less hazardous chemical synthesis, safer solvents and auxiliaries, use of renewable feed stock, catalysis, real time analysis for pollution prevention, atom efficiency, designing safer chemicals, design for energy efficiency, reduced derivatives, design for degradation, inherently safer chemistry for accident prevention.

2. USE OF ULTRASOUND AND MICROWAVE IN ORGANIC SYNTHESIS (4 + 1)

h

Use of ultrasound: instrumentation and the phenomenon of cavitation. Sonochemical esterification, oxidation and reduction. Use of microwave: introduction, reaction vessel and medium, specific effects, atom efficiency, advantages and limitations, N-alkylation and alkylation of active methylene compounds with aldehydes and amines.

Diels-Alder reaction and oxidation of alcohols.

3. MECHANOCHEMISTRY

5 h

Definition of mechanochemistry. Mortar and pestle for organic synthesis. Ball milling as reactors for organic synthesis; effect of operating frequency, milling time and reaction temperature. Energy efficiency; comparison of KMnO_4 mediated oxidation of p-toluidine to other methods (classic heating, microwave and ultrasound).

4. POLYMER SUPPORTED REAGENTS IN ORGANIC SYNTHESIS

(5 + 1)

h

Introduction- structure of polymer supports, properties of polymer support, advantages of polymer supported reagents and choice of polymers.

Applications: substrate covalently bound to the support- synthesis of oligosaccharides, Dieckmann cyclisation. Use of Merrifield resin in peptide synthesis.

Linkers and advantages, reagent linked to a polymeric material - synthesis of polymer bound per acid and its applications.

Polymer supported catalytic reactions: preparation of polymer supported $AlCl_3$, and application in acetal formation reaction.

5. PHASE TRANSFER CATALYSIS (PTC) AND CROWN ETHERS (6 + 1) h

Definition, mechanism of PTC, types of PTC reactions and advantages. Preparation of catalysts and their application in alkylation, oxidation, and reduction reactions.

Crown ethers: general structure, nomenclature, features, and nature of donor site. General synthesis of crown ethers. Synthetic applications: aromatic substitutions.

Generation of carbenes and alkylation.

6. MULTICOMPONENT ONE-POT REACTIONS (4 + 1) h

Meaning of one pot synthesis (mention of synonyms domino/cascade/ tandem reactions).

Effective reactions for one-pot synthesis; reaction in which the intermediate compound is unstable, reaction in which the intermediate compound is hazardous, reactions in which there is equilibrium between intermediate compounds, reaction in which the starting compound is in equilibrium with the intermediate, reaction in which same reagents are employed in subsequent reactions; an example each. Restriction for one-pot reactions; reaction, solvent, amount of reagent. Ex: Passerini, Ugi, Biginelli and Mannich reactions.

7. ORGANOCATALYSIS (12 + 1) h

Introduction- types of organocatalysts, advantages, reusability.

Enamine catalysis: Aldol and Mannich type reactions, α -heteroatom functionalization, direct conjugate additions via enamine activation.

Iminium catalysis: cycloaddition reactions, 1,4-addition reactions, transfer hydrogen reactions, cascade reactions- total synthesis of natural products- tetrahydroquinoline alkaloids.

N-Heterocyclic Carbenes (NHC): Conjugate umpolung of α,β -unsaturated aldehydes for the synthesis of gamma-butyrolactone.

Hydrogen bonding networks - epoxidation of olefins and Baeyer–Villiger oxidation of ketones.
Supported organocatalyst and Ionic liquid organocatalyst.

Precursors and generation of NHC.

8. GREEN CHEMISTRY PRACTICES IN PHARMACEUTICAL INDUSTRY (10+1) h

Solvent categories in pharmaceutical process development and greenness factor.

Supercritical fluids and applications.

Water as solvent: under pressure enabling reactions at high temperature, in ring closure reactions under PTC conditions, dehydrohalogenation under PTC conditions.

Solvent free reactions: ex; Biginelli reaction.

Case studies: (i) Convergent synthesis of Sildenafil citrate (ii) Comparison of old and new commercial synthesis of sertraline HCl (use of green solvent) (iii) Use of biocatalyst to replace Cr based catalyst in the synthesis of LY 300164 (iv) Improved ecological footprint in the synthesis of Celecoxib (v) Quinaprin synthesis avoiding the use of potentially explosive hydroxybenzotriazole

Green technologies in generic pharmaceutical industry: Current vs greener method, ex; bromination (Reddy's lab).

9. FLOW CHEMISTRY (3 + 2) h

Introduction: Batch vs flow operations, flow reactor, types of reactors. Meaning of residence time and molar flow rate.

Mass transfer: mixing rate vs reaction rate, Damkohler number, manipulation of Damkohler number: e.g. synthesis of Verubecestat.

Advantages of flow chemistry: Outpacing intramolecular reactions, e.g. Fries rearrangement.

Practical applications: Fischer esterification using in-line GC analysis.

Swern-Moffatt oxidation.

Handling hazardous reagents, ex; diazomethane, phosgene.

Limitations of flow chemistry

References:

1. Green Chemistry Twelve Principles, K R Desai, Bhuvanaben D Mistry, Tarulata N Chhowala. Himalaya publishing House, 2018
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4. Green Chemistry in Pharmaceutical Industry, Peter J. Dunn, Andrew S. Wells and Michael T. Williams. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2010.
5. Supercritical Carbon Dioxide in Polymer Reaction Engineering, Kemmere, M. F., Meyer, T. (eds.) 2005, ISBN: 978-3-527-31092-0
6. Green synthesis interventions of pharmaceutical industries for sustainable development, Mohit Mishra, Mansi Sharma, Ragini Dubey, Pooja Kumari, Vikas Ranjan, Jaya Pandey. Current Research in sustainable Chemistry. 4 (2021) 100174.
7. Green process chemistry in the pharmaceutical industry, Berkeley W. Cue , pp 193-211, Green Chemistry Letters and Reviews Vol. 2, No. 4, December 2009, Published online: 10 Nov 2009. <https://doi.org/10.1080/17518250903258150>.
8. Organocatalysis, M T Reetz, B List, S Jaroch, H Weinmann (Ed), Springer Publications, 2008.
9. Flow Chemistry applications. Ed: Ferenc Darvas, Gyorgy Dorman, Volker Hessel and Steven V. Ley. 2014, 2nd edn. Walter de Gruyter GmbH and Co KG.
10. Christoph Grondal, Matthieu Jeanty and Dieter Enders. Organocatalytic cascade reactions as a new tool in total synthesis. Nature Chemistry, 2010, 2, 167-179.
11. Burstein C, Glorius F. Organocatalyzed conjugate umpolung of α , β -unsaturated aldehydes for the synthesis of γ -butyrolactones. Angew Chem Int Ed 2004, 43, 6205–6208.
12. Berkessel A, Andreae MRM. Efficient catalytic methods for the Baeyer-Villiger oxidation and epoxidation with hydrogen peroxide. Tetrahedron Lett, 2001, 42:2293–2295.
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14. Some Modern Methods of Organic Synthesis, W. Carruthers, 2nd edn. Cambridge Uni. Press London.
15. Organic chemistry, J. Clayden, N. Greeves, S. Warren, 2nd edn, Oxford Uni. Press, 2001.

16. Advanced Organic Chemistry, Part-A, F. A. Carey, R. J. Sundberg, 5th edn, Springer International edition, 3rd Indian reprint, 2015.
17. Advanced Organic Chemistry, Part-B, F. A. Carey and R. J. Sundberg, 4th edn, Springer international edn, 2001. 7. Green chemistry: Environmentally friendly alternatives, R. Sanghi and M. M. Srivastava, Norosa, New Delhi, 2003. 8. Green Chemistry-an introduction text, The Royal Society of Chemistry.

Blue print

Code number and Title of the paper: CHDE 0321:

Green Chemistry and diversity of its applications

Chapter Number	Title	Number of teaching hours (As mentioned in the syllabus)	Maximum marks for which questions are to be framed from this chapter (including bonus questions)
1.	Principles of green chemistry	3	5
2.	Use of ultrasound and microwaves in organic synthesis	5	9
3.	Mechanochemistry	5	9
4.	Polymer supported reagents in organic synthesis	6	10
5.	Phase transfer catalysis (ptc) and crown ethers	7	12
6.	Multicomponent one-pot reactions	5	8
7.	Organocatalysis	13	22
8.	Green chemistry practices in pharmaceutical industry	11	19
9.	Flow chemistry	5	9
<i>Total marks excluding bonus questions</i>			70
<i>Total marks including bonus questions</i>			103