Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-623 **Title of the course:** Concepts in Green Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied M.Sc. Part-I Chemistry/Biochemistry.	
Course Objective:	1. To understand various concepts involved in Green synthesis 2. To understand green technologies used in chemistry 3. To learn application of green chemistry approaches to chemical industry	
Content	**1. Principles and Concepts of Green Chemistry** a. Introduction, twelve green principles, sustainable development and green chemistry. b. Atom Economy: atom economic reactions- rearrangement and addition reactions. c. Atom un-economic reactions- substitution, elimination and Wittig reactions. Reducing toxicity.	No of hours 6
	2. Waste: Production, Problems and Prevention a. Introduction, Some problems caused by waste, sources of waste from the chemical industry and the cost of waste. b. Waste minimization techniques: the team approach and process design for waste minimization, minimizing waste from existing processes. c. On-site waste treatment: Physical, chemical and biotreatment. d. Design for degradation: degradation and surfactants, DDT, polymers and some rules for degradation. e. Polymer recycling: separation and sorting, incineration, mechanical recycling and chemical recycling to monomers.	6
	3. Measuring and Controlling Environmental Performance a. The importance of measurement: Lactic acid production, safer gasoline. b. Introduction to life cycle assessment and green process metrics. c. Environmental management systems: ISO and European Eco-Management and Audit Scheme, eco-labels, green chemical supply, Strategies, Legislation and integrated pollution prevention and control.	6
	4. Catalytic processes and Green Chemistry a. Introduction to catalysis and comparison of catalyst types. b. Heterogeneous catalysts: Basics of heterogeneous catalysis, Zeolites and the bulk chemical industry, heterogeneous	10

	catalysis in the fine chemical and pharmaceutical industries. Catalytic converters. c. Homogeneous catalysis: Transition metal catalysts with phosphine ligands, greener Lewis acids and asymmetric catalysis. d. Phase transfer catalysis: Hazard reduction, C – C bond formation and oxidation using hydrogen peroxide. e. Biocatalysis and photocatalysis.	
	5. Organic Solvents: Environmentally Benign Solutions a. Organic solvents and volatile organic components, solvent free systems. b. Supercritical fluids: supercritical carbon dioxide and supercritical water. c. Water as a reaction solvent and water-based coatings. d. Ionic liquids as catalysts and solvents. e. Fluorous biphase solvents. f. Deep eutectic solvents	10
	6. Renewable Resources a. Biomass as a renewable resource. Energy: Fossil fuels, biomass, solar power, fuel cells and other forms of renewable energy. b. Chemicals and polymers from renewable feedstock. c. Alternative economies: the syngas economy and the biorefinery.	6
	7. Greener Technologies and Alternative Energy Sources a. Design for energy efficiency b. Photochemical reactions: advantages of and challenges faced by photochemical processes, examples of photochemical reactions. c. Chemistry using Microwaves: microwave heating and microwave-assisted reactions. d. Sonochemistry and green chemistry examples. e. Electrochemical synthesis and examples. f. Flow chemistry	10
	8. Industrial case studies a. A brighter shade of green: synthesis of stilbene intermediates for optical brightners. b. Greening of acetic acid manufacture, EPDM rubbers and Vitamin C. c. Leather manufacture: tanning and fatliquoring. d. Dyeing to be green: some manufacturing and products improvement and dye application.	6

	e. Polyethene: Radical process, Ziegler – Natta and metallocene catalysis. f. Eco-friendly pesticides.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. M. Lancaster, Green Chemistry, The Royal Society of Chemistry, Cambridge, UK, 2002. 2. V. K. Ahluwalia, Green Chemistry: Environmentally Benign Reactions, Ane Books India, New Delhi, 2006. 3. A. S. Matlack, Introduction to Green Chemistry, Marcel Dekker, Inc., New York, 2001. 4. P. T. Anastas and T. C. Williamson, Green Chemistry: Frontiers in benign chemical synthesis and processes, Oxford University Press, Oxford, Ed. 1998. 5. R. Sanghi and M. M. Srivastava, Green Chemistry: Environment Friendly Alternatives, Narosa Publishing House, Ed. New Delhi, 2007. 6. Samuel Delvin, Green Chemistry, IVY Publishing House, Delhi, 2006. 7. V. K. Ahluwalia and M. Kidwai, New Trends in Green Chemistry, Anamaya Publishers, New Delhi, 2004. 8. P. G. Jessop and W. Leitner, Chemical Synthesis using Supercritical fluids, Wiley – VCH, Verlag, Ed., Weinheim, 1999. 9. K. Tanaka, Solvent Free Organic Synthesis, Wiley – VCH GmbH and Co. KgaA, Weinheim, 2003. 10. P. T. Anastas and J. C. Warner, Green Chemistry, Theory and Practice, Oxford University Press, N. York, 1998. 11. C - Jun Li and T – Hang Chan, Organic Reactions in Aqueous Media, John Wiley and Sons INC., N. York, 2001. 12. F. Z. Dorwald, Organic Synthesis on Solid Phase, Wiley – VCH Verlag, Weinheim, 2002. 13. P. Wasserscheid and T. Welton, Ionic Liquids in Synthesis, Wiley – VCH Verlag, Ed., Weinheim, 2003. 14. A. Loupy, Microwaves in Organic Synthesis, Wiley – VCH Verlag, Weinheim, (Ed.), 2002. 15. R. V. Eldik and F. G. Klarner, High Pressure Chemistry, Wiley – VCH Verlag, (Eds.), Weinheim, 2002. 16. F. Darvas, G. Dorman, V. Hessel, Flow Chemistry - Fundamentals: Vol.1, De Gruyter, 1st Ed. 2014.	
Course Outcome:	1. Students will be in a position to understand how chemistry can be done using greener alternatives 2. Students will be in a position to apply green technologies as a sustainable solution for making molecules	