

GENERIC ELECTIVES -21 : GREEN CHEMISTRY

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/Practice		
Green Chemistry (GE-20)	4	2	0	2	Class XII Pass	----

Learning Objectives

Huge rise in environmental pollution, depleting resources, climate change, ozone depletion, heaps and heaps of landfills piling up has forced the society to become more and more environmentally conscious. Future chemists and innovators are compelled to work towards sustainable practices. Green chemistry has arisen from these concerns. It is not a new branch of chemistry but helps to improve the creative and innovative thinking in undergraduate students. Green chemistry is a way to boost profits, increase productivity and ensure sustainability with absolute zero waste. Innovations and applications of green chemistry in education have helped companies to gain environmental benefits as well as to achieve economic and societal goals also. Undergraduate students are the ultimate scientific community of tomorrow. Training them to practice chemistry in the safest way possible is key towards safe working conditions in the laboratories as well as the chemical industry and extends to society in a sustainable future for the planet.

Learning Outcomes:

By the end of this course, students will be able to:

- Understand the twelve principles of green chemistry and also build the basic understanding of toxicity, hazard and risk related to chemical substances.
- Calculate atom economy, E-factor and relate them in all organic synthesis
- Appreciate the use of catalyst over stoichiometric reagents
- Learn to use green solvents, renewable feedstock and renewable energy sources for carrying out safer chemistry
- Appreciate the use of green chemistry in problem solving skills and critical thinking to innovate and find solutions to environmental problems.
- Learn to design safer processes, chemicals and products through understanding of inherently safer design (ISD)
- Appreciate the success stories and real-world cases as motivation for them to practice green chemistry

Syllabus :

Unit 1: Introduction	08 Hours
Definition of green chemistry and how it is different from conventional chemistry and environmental chemistry.	
<ul style="list-style-type: none">• Need of green chemistry• Importance of green chemistry in- daily life, Industries and solving human health problems (four examples each).• A brief study of Green Chemistry Challenge Awards (Introduction, award categories and study about five last recent awards).	
Unit 2: Twelve Principles of Green Chemistry	12 Hours
The twelve principles of the Green Chemistry with their explanation, Special emphasis on the following:	
<ul style="list-style-type: none">• Prevention of waste / byproducts, pollution prevention hierarchy.• Green metrics to assess greenness of a reaction: environmental impact factor, atom economy and calculation of atom economy.• Green solvents-supercritical fluids, water as a solvent for organic reactions, ionic liquids, solvent less reactions, solvents obtained from renewable sources.• Catalysis and green chemistry- comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis.• Green energy and sustainability.• Real-time analysis for pollution prevention.• Prevention of chemical accidents, designing greener processes, inherent safer design, principle of ISD “What you don’t have cannot harm you”, greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation	
Unit 3:	10 Hours
The following Real-world Cases in green chemistry should be discussed: Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO ₂ for precision cleaning and dry cleaning of garments. Designing of environmentally safe marine antifoulant. Rightfit pigment: Synthetic azo pigments to replace toxic organic and inorganic pigments. An efficient, green synthesis of a compostable and widely applicable plastic (polylactic acid) made from corn.	
Practical:	(60 Hours)
Characterization by melting point, UV-Visible spectroscopy, IR spectroscopy and any other specific method should be done (wherever applicable).	
<ol style="list-style-type: none">1. Preparation and characterization of nanoparticles of gold using tea leaves/silver nanoparticles using plant extracts.	

2. Preparation of biodiesel from waste cooking oil and characterization (TLC, pH, solubility, combustion test, density, viscosity, gel formation at low temperature and IR can be provided).
3. Benzoin condensation using thiamine hydrochloride as a catalyst instead of cyanide.
4. Extraction of D-limonene from orange peel using liquid CO₂ prepared from dry ice.
5. Mechanochemical solvent free, solid-solid synthesis of azomethine using *p*-toluidine and *o*-vanillin/*p*-vanillin.
6. Microwave-assisted Knoevenagel reaction using anisaldehyde, ethylcyanoacetate and ammonium formate.
7. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.
8. Photochemical conversion of dimethyl maleate to dimethyl fumarate (*cis-trans* isomerisation)
9. Benzil- Benzilic acid rearrangement: Preparation of benzilic acid in solid state under solvent-free condition.

References:

Theory:

1. Anastas, P.T., Warner, J.C. (2014), **Green Chemistry, Theory and Practice**, Oxford University Press.
2. Lancaster, M. (2016), **Green Chemistry: An Introductory Text**, 3rd Edition, RSC Publishing.
3. Cann, M. C., Connely, M.E. (2000), **Real-World cases in Green Chemistry**, American Chemical Society, Washington.
4. Matlack, A.S. (2010), **Introduction to Green Chemistry**, 2nd Edition, Boca Raton: CRC Press/Taylor & Francis Group publisher.
5. Alhuwalia, V.K., Kidwai, M.R. (2005), **New Trends in Green chemistry**, Anamalaya Publishers.
6. Sidhwani, I.T, Sharma, R.K. (2020), **An Introductory Text on Green Chemistry**, Wiley India Pvt Ltd.

Practical:

1. Kirchoff, M.; Ryan, M.A. (2002), **Greener approaches to undergraduate chemistry experiment**, American Chemical Society, Washington DC.
2. Sharma, R.K.; Sidhwani, I.T.; Chaudhari, M.K. (2013), **Green Chemistry Experiments: A monograph**, I.K. International Publishing House Pvt Ltd. New Delhi.
3. Pavia, D.L.; Lamponom, G.H.; Kriz, G.S.W. B. (2012), **Introduction to organic Laboratory Technique- A Microscale approach**, 4th Edition, Brooks-Cole Laboratory Series for Organic chemistry.
4. Sidhwani I.T. (2015), Wealth from Waste: A green method to produce biodiesel from waste cooking oil and generation of useful products from waste further generated. **DU Journal of Undergraduate Research and Innovation**, 1(1),131-151. ISSN: 2395-2334.
5. Sidhwani, I.T; Sharma, R.K. (2020), **An Introductory Text on Green Chemistry**, Wiley India Pvt Ltd.

6. **Monograph on Green Chemistry Laboratory Experiments**, Green Chemistry Task Force Committee, Department of Science and Technology, Government of India.

Keywords: Green chemistry, Twelve principles of green chemistry, Atom economy, Waste minimization, green metric, green solvents, Solvent free, Catalyst, Bio-catalyst, Renewable energy sources, Hazardous, Renewable feedstock, Ionic liquids, Supercritical fluids, Inherent safer design, green synthesis, combinatorial, Sustainable development, Presidential green chemistry awards.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.