CEMADSE04T: GREEN CHEMISTRY

(Credits: Theory-04, Practicals-02) Theory: 60 Lectures Marks: 50

Introduction to Green Chemistry: (04 Lectures) Marks: 06 What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry

Principles of Green Chemistry and Designing a Chemical synthesis: (30 Lectures) Marks: 22

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following:

 Designing a Green Synthesis using these principles; Prevention of Waste/ byproducts; maximum incorporation of the materials used in the process into the final products, Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions. Prevention/ minimization of hazardous/ toxic products reducing toxicity. risk = (function) hazard × exposure; waste or pollution prevention hierarchy.

• Green solvents- supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized

□ solvents and how to compare greenness of solvents.

- Energy requirements for reactions alternative sources of energy: use of microwaves and ultrasonic energy. □
- Selection of starting materials; avoidance of unnecessary derivatization careful □ use of blocking/protecting groups. □
- Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and

 \Box homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis. \Box

• 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,

 \Box simplification, substitution, moderation and limitation. \Box

■ Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes. □

Examples of Green Synthesis/ Reactions and some real world cases: (16 Lectures) Marks: 12

- 1. Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis)
- 2. Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave assisted reactions

in organic solvents Diels-Alder reaction and Decarboxylation reaction

3. Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction

(Ultrasonic alternative to Iodine)

- 4 Surfactants for carbon dioxide replacing smog producing and ozone depleting solvents with CO₂ for precision cleaning and dry cleaning of garments.
- 5 Designing of Environmentally safe marine antifoulant.
- 6 Rightfit pigment: synthetic azopigments to replace toxic organic and inorganic pigments.
- 7 An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.
- 8 Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of no Trans-Fats and Oils
- 9 Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting

Future Trends in Green Chemistry: (10 Lectures) Marks:10

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; co crystal controlled solid state synthesis (C^2S^3); Green chemistry in sustainable development.

Reference Books

- 1. Anastas, P.T. & Warner, J.K.: *Green Chemistry Theory and Practical*, Oxford University Press (1998).
- 2. Matlack, A.S. Introduction to Green Chemistry, Marcel Dekker (2001).
- 3. Cann, M.C. & Connely, M.E. *Real-World cases in Green Chemistry*, American Chemical Society, Washington (2000).
- 4. Ryan, M.A. & Tinnesand, M. Introduction to Green Chemistry, American Chemical Society, Washington (2002).
- 5. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.

CEMADSE04P: GREEN CHEMISTRY LAB (60 Lectures/Contact Hours) Marks: 25

1. Safer starting materials

• Preparation and characterization of nanoparticles of gold using tea leaves.

2. Using renewable resources

• Preparation of biodiesel from vegetable/ waste cooking oil.

3.Avoiding waste

Principle of atom economy

- Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.
- Preparation of propene by two methods can be studied

Triethylamine ion + $OH^- \rightarrow propene + trimethylpropene + water$

 $\begin{array}{c} H_2SO_4/\Delta\\ 1\text{-propanol} \longrightarrow & \text{propene} + \text{water} \end{array}$

• Other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy.

4.Use of enzymes as catalysts

•Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide.

5.Alternative Green solvents

•Extraction of D-limonene from orange peel using liquid CO2 prepared form dry ice.

Mechanochemical solvent free synthesis of azomethines

6. Alternative sources of energy

- Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).
- Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Reference Books

1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice*, Oxford University Press (1998).

2. Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate chemistryexperiment*. American Chemical Society, Washington DC (2002).

3. Ryan, M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).

4. Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. I.K. *Green Chemistry Experiment:A monograph International Publishing House Pvt Ltd. New Delhi*. Bangalore CISBN978-93-81141-55-7 (2013).

5. Cann, M.C. & Connelly, M. E. *Real world cases in Green Chemistry*, American Chemical Society (2008).

6. Cann, M. C. & Thomas, P. *Real world cases in Green Chemistry*, American Chemical Society (2008).

7. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2ndEdition, 2010.

8. Pavia, D.L., Lampman, G.M., Kriz, G.S. & Engel, R.G. Introduction to OrganicLaboratory Techniques: A Microscale and Macro Scale Approach, W.B.Saunders, 1995.