Green Chemistry

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Unit-I-Introduction to Green Chemistry

OBJECTIVES :

- To define "green chemistry" and place its birth and expansion in an historical context.
- To introduce the principles of green chemistry, outline examples, and establish the arguments for our need to recognize green criteria in the practice of chemistry.

Prerequisite :

- Basic understandings of basic chemistry concepts

What is Green Chemistry?

We can say “Doing chemistry with personal safety and the Environment in mind” is green chemistry.

Definition:

❖ Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. ❖ Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal. Green chemistry is also known as sustainable chemistry

Importance of Green Chemistry:

Prevents pollution at the molecular level.

Is a philosophy that applies to all areas of chemistry, not a single discipline of chemistry.

Applies innovative scientific solutions to real-world environmental problems.

Results in source reduction because it prevents the generation of pollution.

Reduces the negative impacts of chemical products and processes on human health and the environment.

Lessens and sometimes eliminates hazard from existing products and processes.

Designs chemical products and processes to reduce their intrinsic hazards.

Chemistry & Society

Pharmaceutical:

Drugs (pain killers, antibiotics, heart and hypertensive drugs), disinfectants, vaccines, dental fillings, anesthetics, contraceptives.

Agriculture:

Fertilizers, pesticides.

Food:

Preservatives, packaging and food wraps, refrigerants. **Transportation:**

Petrol and diesel, catalytic converters to reduce exhaust emissions. **Clothing:**

Synthetic fibres, dyes, waterproofing materials.

Safety:

Polycarbonate materials for crash helmets.

Sports:

Composite materials for rackets, all weather surfaces Office inks, photocopying toners.

Homes:

Paints, vanishes and polish, detergents, pest killers.

CHEMICAL DISASTERS:

1956: Minamata disease was first discovered in Minamata city in Japan.It was caused by the release of methyl mercury in the industrial wastewater from a chemical factory.

1961: Itai-itai disease was caused by cadmium poisoning due to mining in Toyama Prefecture in Japan.

1976: The Seveso disaster was an industrial accident that occurred in a small chemical manufacturing plant near Milan in Italy. It resulted in the highest known exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxinin residential population.

1984: The Bhopal disaster was an industrial catastrophy that took place at a pesticide plant owned and operated by Union Carbide (UCIL) in Bhopal India resulting in the exposure of over 500,000 people. It was caused by methyl Iso cyanate (MIC) gas.

1986: The Chernobyl disaster was a nuclear accident at the Chernobyl nuclear plant in Ukraine. It resulted in a severe release of radioactive materials. Most fatalities from the accident were caused by radiation poisoning.

1989: Exxon Valdez, an oil tanker hit a reef and spilled an estimated minimum 10.8 million US gallons (40.9 million litres) of crude oil. This has been recorded as one of the largest spills in United States history and one of the largest ecological disasters.

HISTORY OF GREEN CHEMISTRY :

1. In 1990 the Pollution Prevention Act was passed in the United States. This act helped create a modus operandi for dealing with pollution in an original and innovative way. This paved the way to the green chemistry concept.
2. Paul Anastas and John Warner coined the two letter word "green chemistry" and developed the twelve principles of green chemistry.
3. In 2005 Ryoji Noyori identified three key developments in green chemistry: use of supercritical carbon dioxide as green solvent, aqueous hydrogen peroxide for clean oxidations and the use of hydrogen in asymmetric synthesis.

CONCEPTS OF GREEN CHEMISTRY:

- ❖ Green Chemistry, or sustainable/ environmentally benign.
- ❖ Chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.

- ❖ As a chemical philosophy, green chemistry applies to organic chemistry, inorganic chemistry, biochemistry, analytical chemistry and physical chemistry.

Green chemistry focuses on to

- **Minimize:**

  –waste

  –energy use

  –resource use (maximize efficiency)

- **Utilize renewable resources**

GLOBAL RECOGNITION OF GREEN CHEMISTRY:

Australia: The Royal Australian Chemical Institute (RACI) presents Australia's Green Chemistry Challenge Awards.

Canada: The Canadian Green Chemistry Medal is an annual award given to any individual or group for promotion and development of green chemistry

Italy: Green Chemistry activities in Italy centre on inter-university consortium known as INCA. In 1999, INCA has given three awards annually to industry for applications of green chemistry.

Japan: In Japan, The Green & Sustainable Chemistry Network (GSCN), formed in 1999, is an organization consisting of representatives from chemical manufacturers and researcher.

UK: In the United Kingdom, the Crystal Faraday Partnership, a non-profit group founded in 2001, awards businesses annually for incorporation of green chemistry.

USA: United States Environmental Protection Agency (EPA).

Nobel Prize in Green chemistry:

1. The Nobel Prize Committee recognized the importance of green chemistry in 2005 by awarding Yves Chauvin, Robert H. Grubbs, and Richard R. Schrock the Nobel Prize for Chemistry for "the development of the metathesis method in organic synthesis.
2. Frances Arnold won in 2018, it for the directed evolution of enzymes, a technique she has pioneered over the past 25 years and has used to pursue new avenues within green chemistry and to engineer reactions completely new to nature.

Green chemistry and Sustainable development:

❖ The UN defines sustainable development as ‘meeting the needs of present without compromising the ability of future generation.

❖ Green chemistry focuses on how to achieve sustainability through science and technology.

❖ To better understand and solve the issue of environmental pollution, many approaches and models have been developed for environmental impact assessments.

❖ Some of these approaches and models have been successful in predicting impacts for selected chemicals in selected environmental settings. ❖ These models have joined air and water quality aspects to point and nonpoint sources and have been very useful for the development of emission control and compliance strategies.

❖ However, some of the approaches and models were aimed primarily at evaluating the quantity of pollutants that could be discharged into the environment with acceptable impact, but failed to focus on pollution prevention.

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- ❖ The concept of end-of-pipe approaches to waste management decreased, and strategies such as environmentally conscious manufacturing, eco-efficient production, or pollution prevention gained recognition.

PRINCIPLES OF GREEN CHEMISTRY:

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1.Prevention

It is better to prevent waste than to treat or clean up waste after it is formed.

2. Atom economy

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Less hazardous chemical syntheses

Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing safer chemicals

Chemical products should be designed to preserve efficacy of function while reducing toxicity.

5.Safer Solvents and Auxiliaries

The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

6. Design for energy efficiency

The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary, wherever possible and innocuous when use.

7. Use of renewable feedstock

Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

8.Reduce derivatives

A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable.

9.Catalysis

Reduce derivatives - Unnecessary derivation (blocking group, protection/ deprotection, temporary modification) should be avoided whenever possible. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Design for degradation

Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products.

11. Real time analysis for pollution prevention

Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently safer chemistry for accident prevention

Substances and the form of a substance used in a chemical process should be chosen to minimize potential for chemical accidents, including releases, explosions, and fires.

Progress in Green Chemistry (Real World Cases):

Over the past decade, green chemistry has convincingly demonstrated how fundamental scientific methodologies can be devised and applied to protect human health and the environment in an economically beneficial manner.

Significant progress has been made in key research areas, such as *atom economy, alternative synthetic route for feedstock's and starting materials, biocatalysis, greensolvent, biosorption, designing safer chemicals, energy and waste management.*

ATOM ECONOMY (Synthesis of Ibuprofen):

Atom economy is one of the fundamental principles of green chemistry. Atom economy looks at the number of atoms in the reactants that end up in the final product and by- product or waste.

% Atom economy = **100** **x** **Relative molecular mass of product** **/** **Relative molecular mass of reactants**

Rearrangement Rxn: A mechanism step or **reaction** in which an atom or group migrates from one carbon atom to another. The **reaction** often includes the breaking and/or making of carbon-carbon sigma bonds.

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ESSENTIAL READING BOOKS :

1. Lancaster, M. Green Chemistry: An Introductory Text; The Royal Society of Chemistry:2002.
2. Manahan, S.E. Green Chemistry and the Ten Commandments of Sustainability; ChemChar Research Inc, 2005

RECOMMONDED READING BOOKS :

1.J. Clark, D. Macquarrie, "Handbook of Green chemistry and Technology", Blackwell Science, 2002.

WEB LINKS FOR REFERENCE

1. https://www.rsc.org/journals-books-databases/about-journals/green-chemistry/
2. https://www.acs.org/content/acs/en/greenchemistry/research-innovation.html

E-BOOKS (subject to copyrights laws)

1.https://bookboon.com/en/fundamentals-of-green-chemistry-ebook