EWCE-105

Environmental Chemistry

(Lecture-2)

Various divisions of Environmental Chemistry

- AQUATIC CHEMISTRY
- ATMOSPHERIC CHEMISTRY
- GEOCHEMISTRY
- SOIL ENVIRONMENTAL CHEMISTRY
- TOXICOLOGICAL CHEMISTRY
- GREEN CHEMISTRY

Aquatic Chemistry

It helps to understand water pollution and gives an idea of chemical phenomena that occur in water. Aquatic environmental chemistry involves-

- Acid-Base reactions,
- Solubility,
- Oxidation-reduction, and
- Complex reactions.

It plays an important role in the health, abundance and diversity of the **aquatic life** that can live in a stream. Excessive amounts of some constituents (nutrients), or the lack of others (dissolved oxygen), can result in degraded conditions and harm aquatic life.

Atmospheric Chemistry

Atmospheric chemistry plays an **important** role in controlling climate change, interactions between the atmosphere and living organisms.

Examples of problems which have been addressed by atmospheric chemistry include acid rain, ozone depletion, photochemical smog, greenhouse gases and global warming.

Atmospheric environmental chemical phenomena involve:

- Gaseous Oxides in the Atmosphere (NOx, SOx)
- Hydrocarbons (CH4) and Photochemical Smog, and
- Particulate Matter.

Geochemistry

Geochemistry deals with chemical species, reactions, and processes in the lithosphere and their interactions with the atmosphere and hydrosphere.

The study of the chemical composition of the earth and its rocks and minerals. This is important to know because the geosphere provides us with food, minerals and fuels.

Environmental Geochemistry is concerned with the sources, distributions and the interactions of chemical elements in the system rock- soil – water – air – life.

Toxicological Chemistry

Ultimately, most pollutants and hazardous substances are of concern because of their toxic effects. It is the study of adverse effects that occur in living organisms due to chemicals.

The general aspects of these effects are addressed in toxicological chemistry. Toxicological chemistry involves:

- Poison, or toxicant (Toxicology is the science of poisons)
- Whether a substance is poisonous depends upon:
  - Type of organism exposed,
  - The amount of the substance (dosage),
  - Duration of exposure, and
  - The route of exposure.

Green Chemistry

Sustainable, safe, and nonpolluting practice of chemical science and **manufacturing** in a manner that consumes **minimum amounts of materials and energy** while producing **little or no waste disposal**.

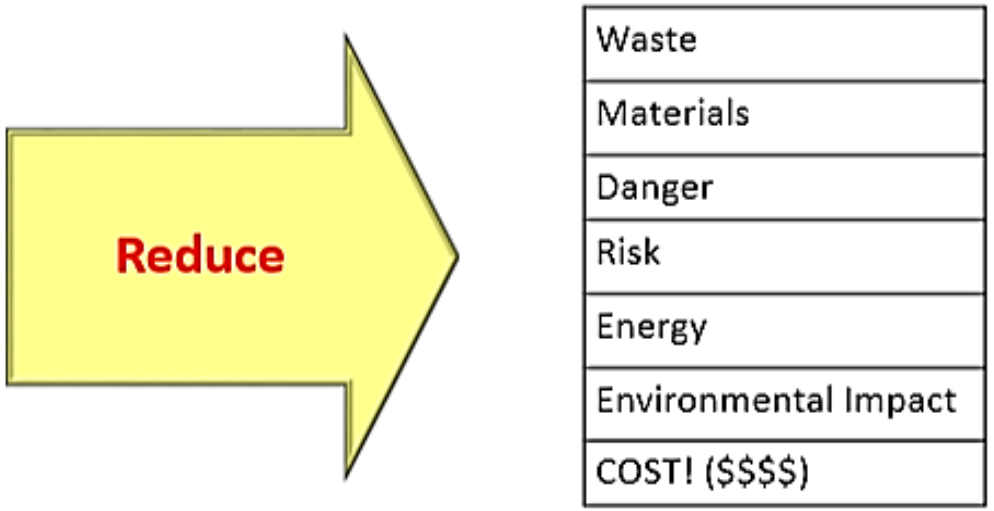


In other words, Green chemistry, is called also gentle chemistry or clean chemistry for **sustainability**.

Green Chemistry

It is the design of **chemical** products and processes that reduce or eliminate the use or generation of hazardous substances.

Green chemistry is looking to:



Green Chemistry vs Environmental Chemistry



Twelve Principles of Green Chemistry



1. **Pollution Prevention**
2. **Atom Economy**
3. **Less Hazardous Chemical Synthesis**
4. **Designing Safer Chemicals**
5. **Safer Solvents and Auxiliaries**
6. **Design for Energy Efficiency**
7. **Use of Renewable Feedstocks**
8. **Reduce Derivatives**
9. **Catalysis**
10. **Design for Degradation**
11. **Real-Time Analysis for Pollution Prevention**
12. **Inherently Safer Chemistry for Accident Prevention**

Twelve Principles of Green Chemistry

1. Prevent Waste

- Design chemical synthesis to prevent waste, leaving no waste to treat or clean up.
- Easier to clean up, transport or store.
- Transforming chemical reactions that incorporate the largest amount of the starting materials = Less waste!

Twelve Principles of Green Chemistry

Possible sources of waste reduction:

- Inputs - “eco-friendly” solvents & solvent recycling.
- Production Optimization - reaction time, temperature & pressure.
- Discharges - reduce water usage, improve filtering procedures and reuse waste products.

Twelve Principles of Green Chemistry

2. Maximize atom economy: (Relates to Green Synthetic Chemistry)

- Final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.
- Relation between atoms in the products and atoms in the reagents

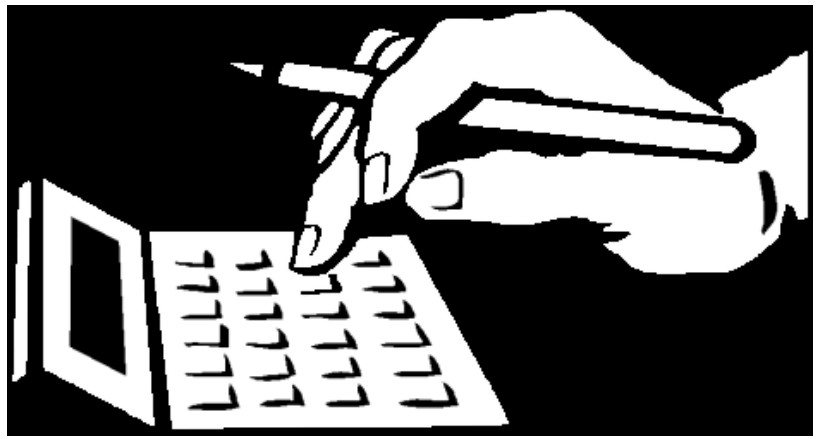
Addition –good atom efficiency

Elimination –not so good

Twelve Principles of Green Chemistry

Atom economy:

Evaluate the efficiency of the chemical transformation.



"Because an Atom is a Terrible thing to Waste"

How many of the atoms of the reactants are incorporated into the final product and how many are wasted?

Twelve Principles of Green Chemistry

How a reaction's efficiency is measured?

Reaction Yield

- % yield = $\frac{\text{(actual quantity of products achieved)}}{\text{(theoretical quantity of products achievable)}}$ x 100

Calculation of Atom Economy

$$\text{atom economy} = \frac{\text{mass of atoms in desired product}}{\text{mass of atoms in reactants}} \times 100\%$$

Twelve Principles of Green Chemistry

3. Design less hazardous chemical syntheses:

- Use and generate substances with little or no toxicity to humans and the environment.
- Avoid reactions that give dangerous by-products

Twelve Principles of Green Chemistry

4. Design safer chemicals and products:

- Design chemical products to be fully effective, yet have little or no toxicity.
- Chemicals that are less hazardous to human health and the environment are:
  - Less toxic to ecosystems
  - Not persistent or bio-degradable
  - Inherently safer to handle and use

Twelve Principles of Green Chemistry

5. Use safer solvents and reaction conditions

- Avoid: solvents, separation agents and auxiliary chemicals.
- USE: harmless chemicals

Twelve Principles of Green Chemistry

6. Use catalysts:

- They are selective,
- Catalysts are used in small amounts,
- Can carry out a single reaction many times,
- Improve production and energy consumption &
- They are preferable to stoichiometric reagents. which are used in excess and work only once.

Twelve Principles of Green Chemistry

7. Use renewable feedstock (raw materials/ fuels):

- Use raw materials and feedstocks that are renewable rather than depleting
- Agricultural products
- Wastes of other processes
- Reduce dependency from fossil fuels (petroleum, natural gas, or coal) or are mined.

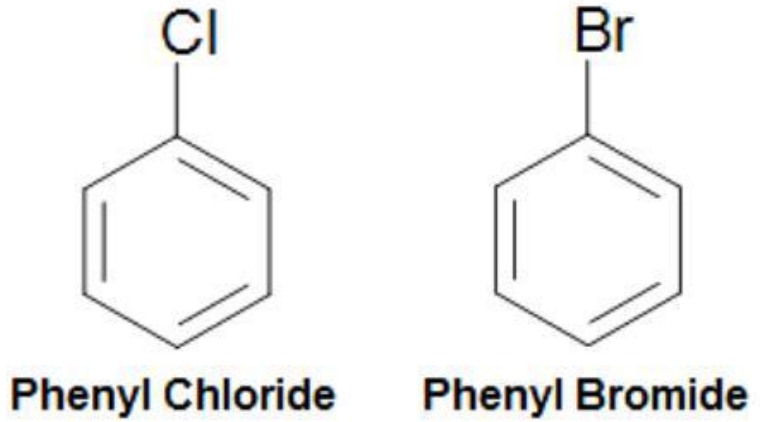
Twelve Principles of Green Chemistry

8. Avoid chemical derivatives:

A **derivative** is a compound that can be imagined to arise or actually be synthesized from a parent compound by replacement of one atom with another atom or group of atoms.

Benzene and its Derivatives

- **Phenyl Group**



Twelve Principles of Green Chemistry

9. Increase energy efficiency:

• Run chemical reactions at ambient temperature and pressure whenever possible.

10. Design chemicals and products to degrade after use:

• Design chemical products to break down to harmless substances after use so that they do not accumulate in the environment.

11. Analyze in real time to prevent pollution:

• Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.

Twelve Principles of Green Chemistry

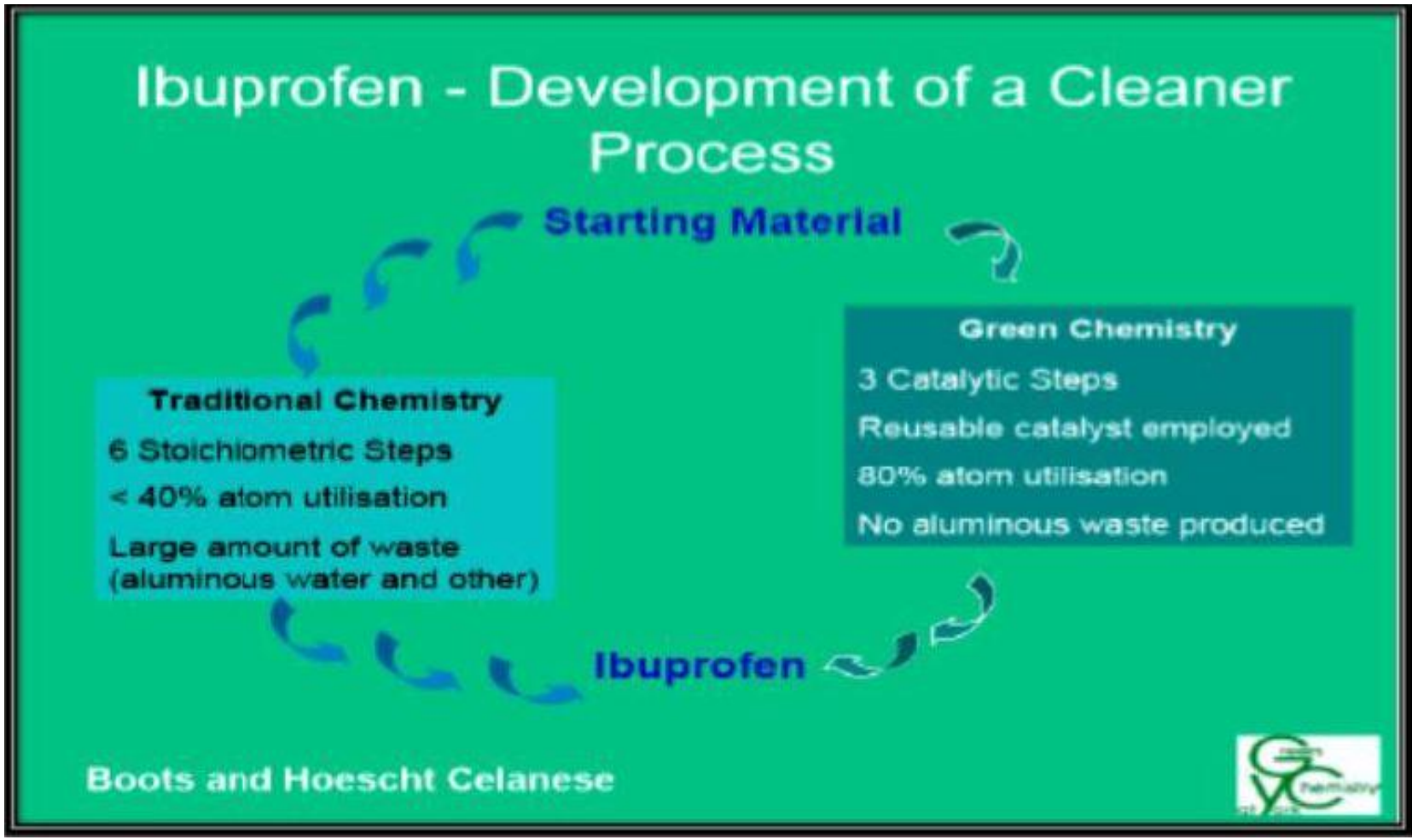
12. Minimize the potential for accidents:

- Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents:
  - explosions,
  - fires, and
  - releases to the environment.

Example of Green Chemistry Synthesis - Ibuprofen

- Ibuprofen is a non-steroidal anti-inflammatory drug (NSAID).
- It works by reducing hormones that cause inflammation and pain in the body.

Example of Green Chemistry Synthesis - Ibuprofen



Specific Aspects of Green Chemistry

- Chemical transformation under mild condition
- Green catalysts
- Solvent less processes
- Less dangerous and polluting solvents
- Process Intensification
- Renewable Feedstock
- Design for degradability

Three undesirable characteristics of chemicals

- Persistent
- Strong tendency to undergo bioaccumulation
- Toxic

Some examples of green chemistry

- Reducing Lead Pollution
- Putting out fires the green way
- Safer dry cleaning

Lead Pollution

LEAD POLLUTION HAS BEEN DECREASED BY…

- Replacing lead in paint with safe alternatives, and
- Replacing tetraethyl lead with less toxic additives (e.g., “lead-free” gasoline).

Paint manufacturers have **replaced** white **lead** with a less toxic substitute, Titanium white (based on the pigment titanium dioxide), which was first used in **paints** in the 19th century.

Chemical foams to fight fire

- Millions of tons of chemical fire-fighting foams used worldwide have discharged toxic substances into the environment, contaminating water supplies and depleting the ozone layer.
- A new foam called Pyrocool FEF has now been invented to put out fires effectively without producing the toxic substances found in other fire-fighting materials.



Dry cleaning

Chemicals for dry cleaning:

- Perchloroethylene("perc") is the solvent most widely used in dry cleaning clothing.
- Perc is suspected of causing cancer and its disposal can contaminate ground water.

A safer method of dry cleaning:

- Liquid CO_2 can be used as a safer solvent if a wetting agent is used with it to dissolve grease.
- This method is now being used commercially by some dry cleaners.

Lecture Summary

- Various Divisions of Environmental Chemistry
- Green Chemistry
- Example of Green Chemistry