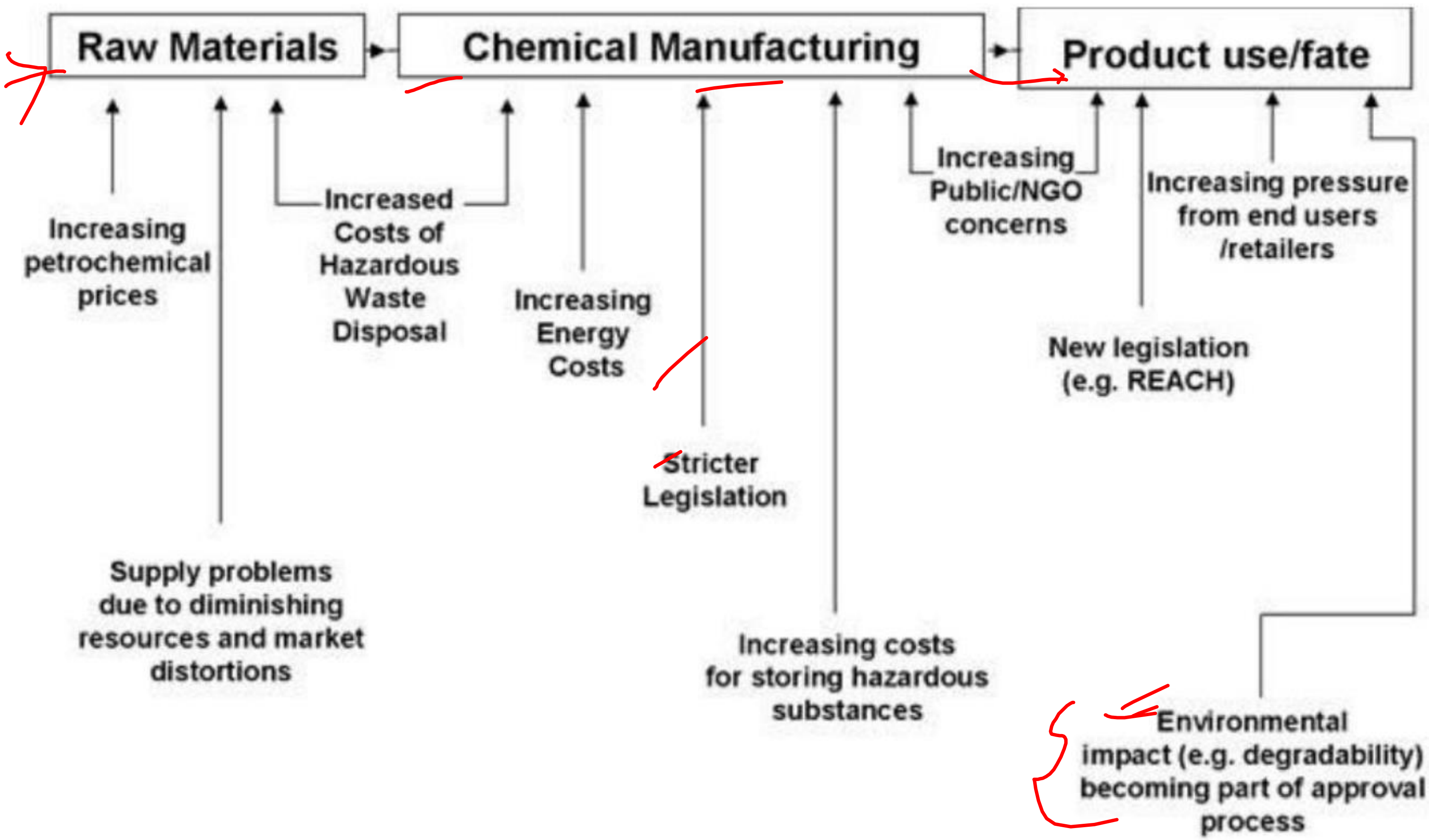
# Benefits of the Chemical Industry

# CHEMISTRY & SOCIETY

- **Pharmaceutical** –manufacture of drugs (pain killers, antibiotics, heart and hypertensive drugs).
- **Agriculture** –production of fertilizers, pesticides.
- **Food** –manufacture of preservatives, packaging and food wraps, refrigerants.
- **Medical** –disinfectants, vaccines, dental fillings, anesthetics, medicine.
- **Transportation** –production of petrol and diesel, catalytic converters to reduce exhaust emissions.
- **Clothing** –synthetic fibers, 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.

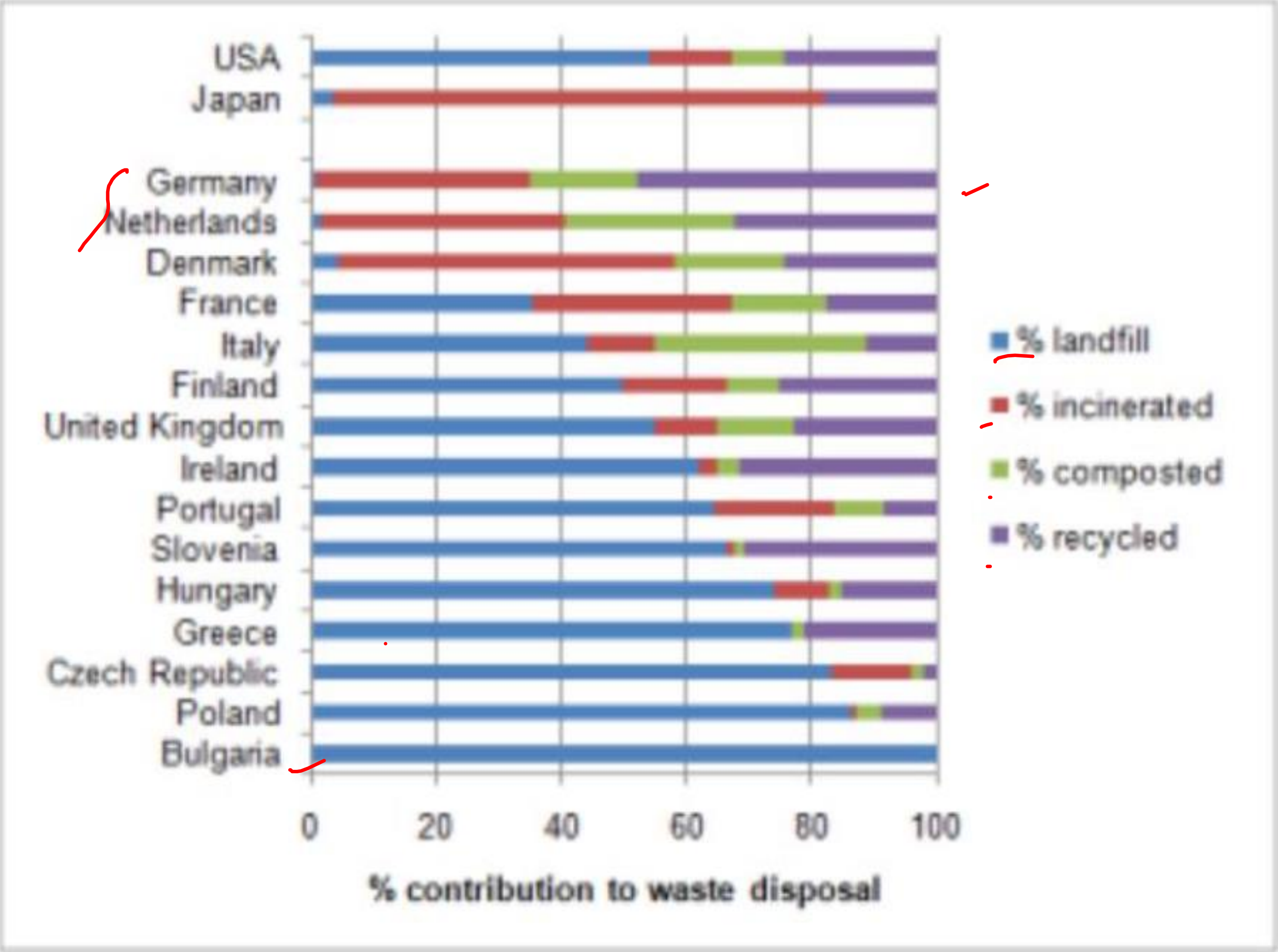
# Yet everybody hates chemicals!

## Pressures on the Chemical Industry Across the Lifecycle



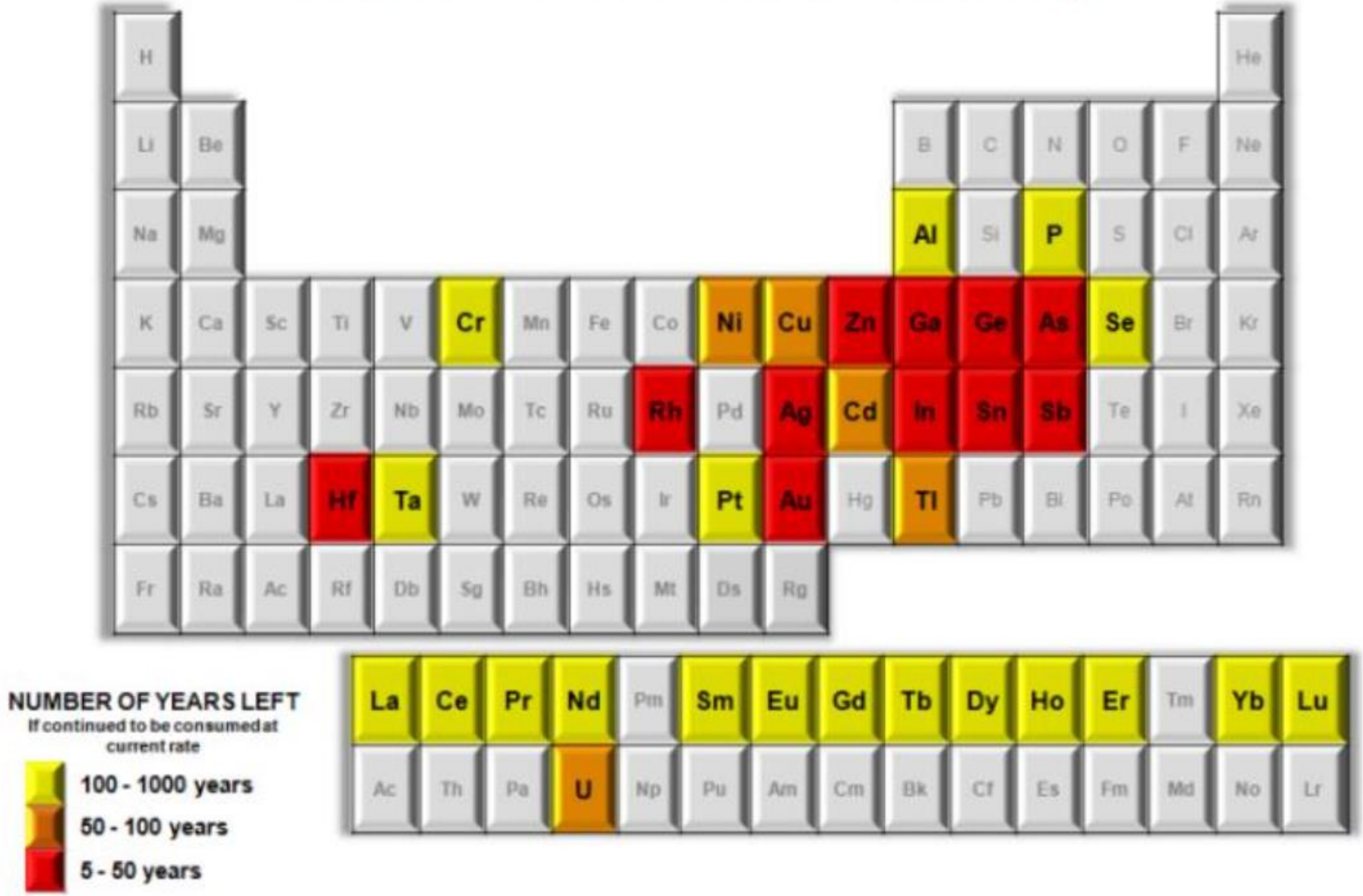
So much ends up in waste

# What do we do with our waste?



# We are running out of key elements

## Elemental unsustainability



# CHEMICAL DISASTERS

- **1956**: Minamata disease was first discovered in Minamata city in Japan. It was caused by the release of methylmercury 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.

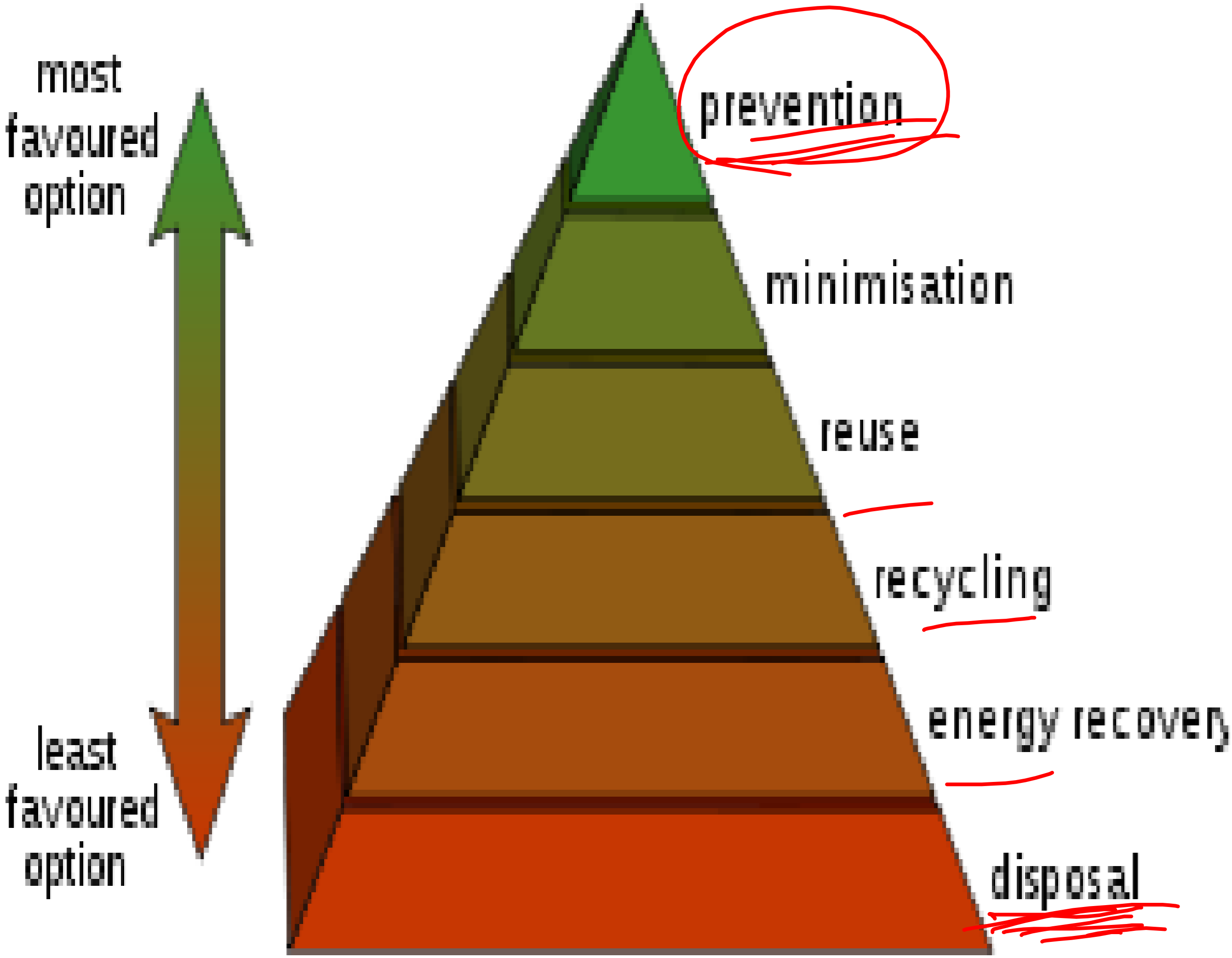
- **1976**: The Seveso disaster was an industrial accident that occurred in a small chemical manufacturing plant near Milan in Italy. It resulted in the highest known exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin in residential population.

- **1984**: The Bhopal disaster was an industrial catastrophe 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 isocyanate (MIC) gas.

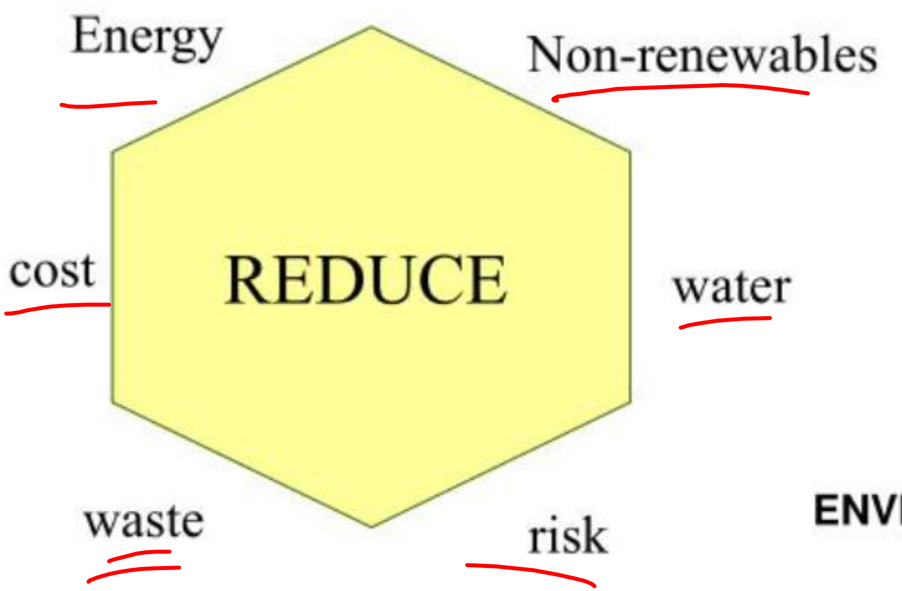
- **1986**: The Chernobyl disaster was a nuclear accident at the Chernobyl nuclear plant in Ukraine. It resulted in a severe release of radioactive materials. Most fatalities from the accident were caused by radiation poisoning.

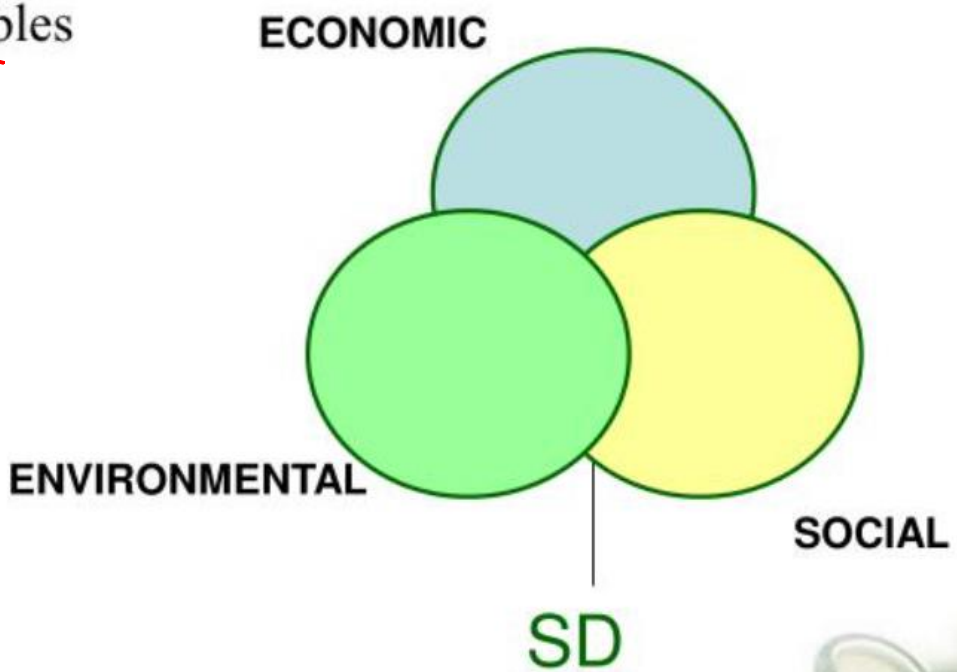
- **1989**: Exxon Valdez , an oil tanker hit a reef and spilled an estimated minimum 10.8 million US gallons (40.9 million liters) of crude oil. This has been recorded as one of the largest spills in United States history and one of the largest ecological disasters.

# WASTE MANAGEMENT



# What is Green Chemistry?
## Sustainable Development and Business



# HISTORY OF GREEN CHEMISTRY

- The idea of green chemistry was initially developed as a response to the Pollution Prevention Act of 1990, which declared that U.S. national policy should eliminate pollution by improved design (including cost-effective changes in products, processes, use of raw materials, and recycling) instead of treatment and disposal.

- Paul Anastas and John Warner coined the two letter word "green chemistry" and developed the twelve principles of green chemistry.

- In the last 10 years, national networks have proliferated, special issues devoted to green chemistry have appeared in major journals, and green chemistry concepts have continued to gain traction. A clear sign of this was provided by the citation for the 2005 Nobel Prize for Chemistry awarded to Chauvin, Grubbs, and Schrock, which commended their work as "a great step forward for green chemistry

# 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.

- **Minimize**:
  - waste
  - energy use
  - resource use (maximize efficiency).

- **utilize renewable resources**

# 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
- 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

# THE TWELVE PRINCIPLES OF GREEN CHEMISTRY

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.

$A + B \xrightarrow{R.T} C$

6. **Design for energy efficiency:** 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.

$A + B \xrightarrow{100^{\circ}C} C$

# THE TWELVE PRINCIPLES OF GREEN CHEMISTRY

7. **Use of renewable feedstock**: A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable.

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

9. **Catalysis:** 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.

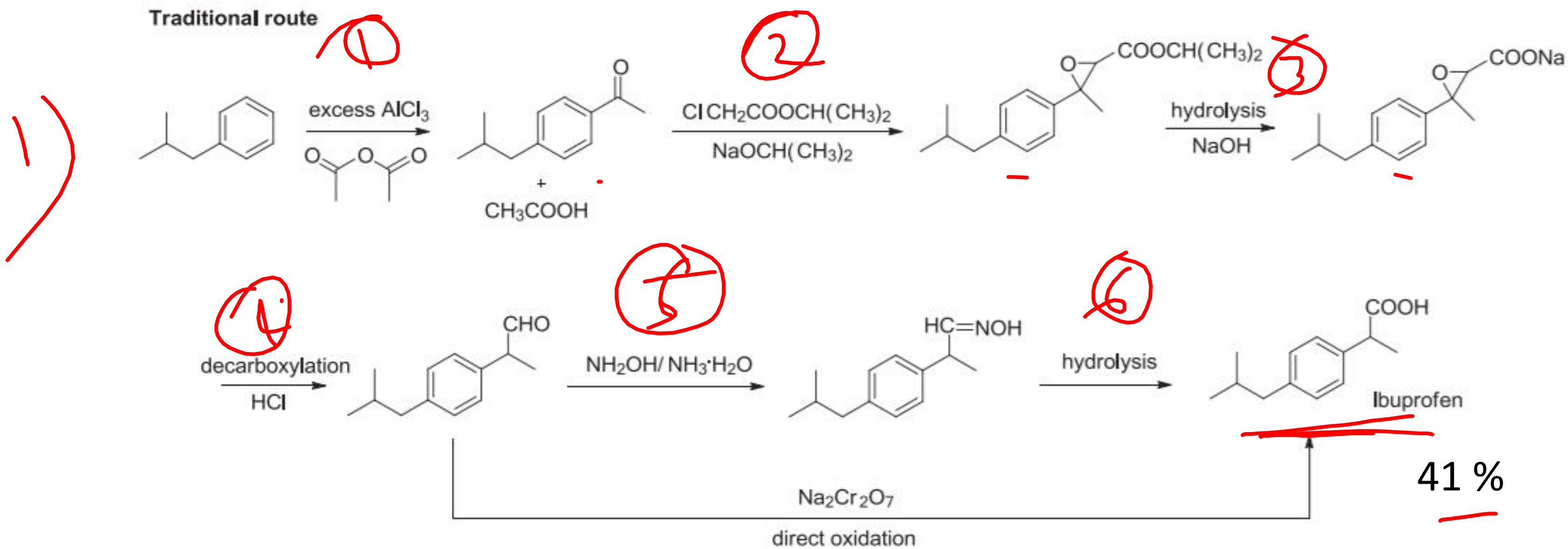
11. **Real time analysis for pollution prevention:** Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances and

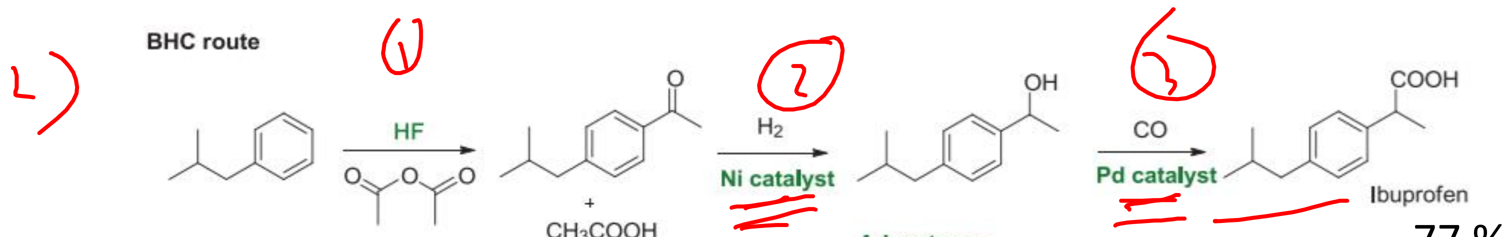
12. **Inherently safer chemistry for accident prevention:** Substances and the form of a substance used in a chemical process should be chosen to minimize potential for chemical accidents, including releases, explosions, and fires

# 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 feedstocks and starting materials, biocatalysis, green solvent, biosorption, designing safer chemicals, energy and waste management.

# PROGRESS IN GREEN CHEMISTRY (REAL WORLD CASES)




**Advantages:**

Greater atom economy

Catalytic versus stoichiometric reagents

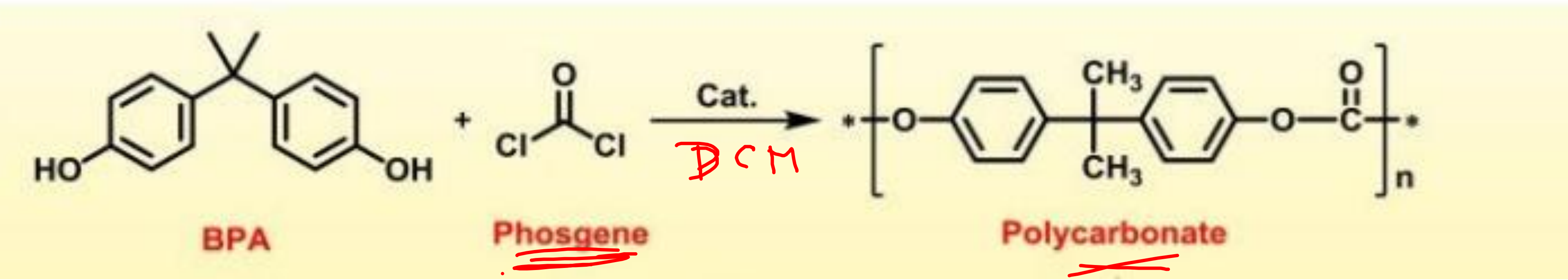
Recycling, reuse, recovery of byproducts and reagents

Shorter step and quantitative yield

Fewer auxiliary substances

# Principle 3: Non – toxic substances

## Polycarbonate synthesis : Phosgene process

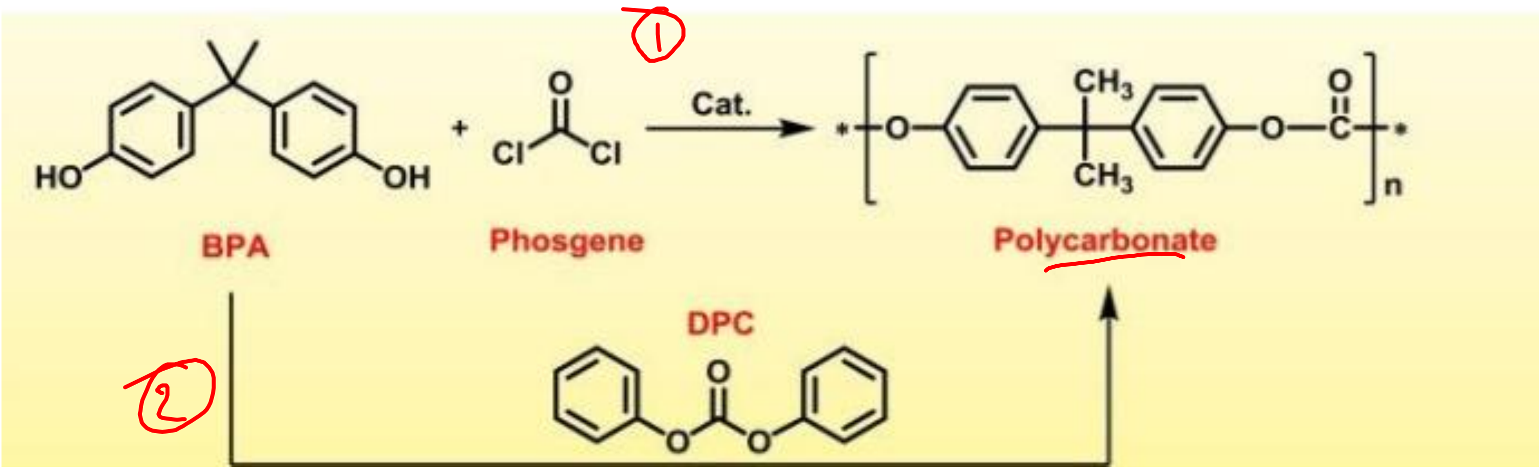



❖ **Disadvantages** :

- ✓ phosgene is toxic, corrosive.
- ✓ Requires large amount of dichloromethane solvent
- ✓ Polycarbonate contaminated with Cl impurities.

# Principle 3: Non – toxic substances

## Polycarbonate synthesis : solid state process




❖ Advantages :

✓ No need of toxic phosgene .
✓ Eliminates use of dichloromethane solvent
✓ High quality polycarbonates.

# GREEN SOLVENT

One of the green solvents is supercritical carbon dioxide ($scCO_2$). Supercritical carbon dioxide refers to carbon dioxide that is in a fluid state while also being at or above both its critical temperature and pressure ($T_c$ = 31.3 °C, $P_c$ = 1071 psi (72.9 atm) yielding rather uncommon properties. Supercritical carbon dioxide has been used as a processing solvent in polymer applications such as polymer modification, formation of polymer composites, polymer blending, microcellular foaming, particle production, and polymerization.

**Reaction of amines with $CO_2$**

$RNH_2 + CO_2 \longrightarrow RNHCOOH \longrightarrow RNH_3^+ \ RNHCOO^-$

$RNH_2 + 2H_2C(O)CH_2 \longrightarrow RN(CH_2CH_2OH)_2$

$H_2C\text{-}O\text{-}CH_2 + CO_2 \longrightarrow \text{-[COO-CR-C-O-]}$

(polycarbonates)

# BIOSORPTION

Biosorption is one such important phenomenon, which is based on one of the twelve principles of Green Chemistry, i.e., “Use of renewable resources.” It has gathered a great deal of attention in recent years due to a rise in environmental awareness and the consequent severity of legislation regarding the removal of toxic metal ions from wastewaters.

In recent years, a number of agricultural materials such as the following have been used to remove toxic metals from wastewater:

- palm kernel husk,
- modified cellulosic material,
- corn cobs,
- residual lignin,
- wool,
- apple residues,
- olive mill products,
- polymerized orange skin,
- banana husk,
- pine back,
- sawdust,
- coals,
- **MAIZE TASSEL**

# ENERGY

**FOSSIL FUEL**

- This is dogged with many environmental pollution problems. There is, therefore, a growing need for alternative energy sources to replace fossil fuels. Renewable energy resources that are currently receiving attention include, solar energy, wind energy, hydro energy, fuel cells to mention but four.

**SAFER PETROL**

- Removal of Pb from petrol;
- addition of ethanol produced from biomaterials to the petrol pool;
- addition of methyl *t*-butyl ether (MTBE) to the petrol pool. MTBE has high octane and
- use of electric vehicles powered by fuel cells.

# Atom economy

$A + B \rightarrow \boxed{C} + D$

imp

$AE = \frac{M_C}{(M_A + M_B)} \times 100\%$

$CH_4(g) + 2O_2(g) \Rightarrow 2H_2O(g) + CO_2(g)$

| $CH_4(g)$ | $2O_2(g)$ | $2H_2O(g)$ |
|---|---|---|
| 16.0 | 2 X 32.0 = 64.0 | 2 X 18.0 = 36.0 |

Total mass of reactant atoms
= 16.0 + 64.0
= 80.0

Total mass of desired product atoms
= 36.0

$$\text{Atom economy} = \frac{36.0}{80.0} \times 100$$

$$= 45.0\%$$