Green Chemistry

Green Chemistry is the use of chemistry for source reduction, the highest tier of the Pollution Prevention Act Risk Management Hierarchy.

Green Chemistry

Green Chemistry is the *design of* chemical products and processes that reduce or eliminate the *use and/or generation* of hazardous substances

Focus on Design

The moment a chemist puts pencil to paper, he/she is making determinations about the human health and environmental impacts associated with the chemicals used in or generated from the manufacture, processing, use, and disposal of chemical products.

Focus on Use and Generation

Risk = Hazard x Exposure

Green chemistry focuses on reducing risk by reducing hazard.

Focus on Use and Generation

Risk = Hazard x Exposure

Green chemistry focuses on reducing risk by reducing both hazard and exposure.

Green Chemistry

Green chemistry involves a fundamental shift in the way that science views chemical design and synthesis.

Green Chemistry

Historical factors influencing chemical design and synthesis:

- number of synthetic steps
- cost and availability of starting materials
- product yield

Green Chemistry

Factors driving green chemical design and synthesis:

- number of synthetic steps
- cost and availability of starting materials
- product yield
- chemical handling costs
- waste treatment/control/disposal costs
- regulatory compliance costs

Green Chemistry

Green chemistry identifies synthetic chemists as the key practitioners in identifying, developing, and implementing pollution prevention technologies.

Green Chemistry

- not a solution to all environmental problems
- the most fundamental approach to preventing pollution
- recognizes the importance of incremental improvements

Green Chemistry

- "designing chemistry for the environment"
- "pollution prevention at the molecular level"
- "preventative medicine for the environment"

Green Chemistry

Green Chemistry encompasses all aspects and types of chemical processes - including synthesis, catalysis, analysis, monitoring, separations and reaction conditions - that reduce risk to human health and the environment relative to the current state of the art

Green Chemical Synthesis

- Alternative Synthetic Pathway Design
- Alternative Solvents/Reaction Conditions
- Designing Safer Chemicals
- Process Analytical Chemistry
- Inherently Safer Chemistry

Alternative Synthetic Pathway Design

the design of single chemical transformations or entire synthetic pathways that reduce or eliminate the use or generation of hazardous substances (feedstocks, catalysts, reagents, products, co-products, or by-products)

Alternative Solvents/Reaction Conditions

the development and utilization of more environmentally benign solvents and solventless systems that reduce or eliminate the use of toxic or environmentally hazardous solvents

Alternative Solvents/Reaction Conditions (cont.)

the development and optimization of reaction conditions to reduce to eliminate the use or generation of hazardous materials while maximizing product yield and minimizing energy usage

Designing Safer Chemicals

designing the molecular structure of a chemical product such that toxicity is reduced or eliminated while the efficacy of the chemical is maintained

Process Analytical Chemistry

- the development of real-time, in-process sensors to detect trace amounts of waste and adjust process controls to minimize this waste
- “you cannot control what you cannot measure”

Inherently Safer Chemistry

- ensures that pollution prevention enhances accident prevention through use of safer chemistry
- examples include use of solids rather than volatile liquids or gases, in-situ generation of hazardous reactants, and just-in-time supplies of hazardous substances to reduce on-site inventory

Principles of Green Chemistry

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

Principles of Green Chemistry

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

Principles of Green Chemistry

- Synthetic methodologies should be designed to maximize the incorporation of all materials used in the process into the final product. If by-product and co-products are necessarily formed, they should also posses little or no toxicity to human health and the environment.

Principles of Green Chemistry

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

Principles of Green Chemistry

- Catalytic reagents (as selective as possible) are superior to stoichiometric reagents (all other factors being equal).

Principles of Green Chemistry

- Unnecessary derivatization (e.g. blocking groups, protecting groups, temporary modification of physical/chemical properties, etc.) should be avoided where possible

Principles of Green Chemistry

- The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary wherever practicable, and in cases where they are necessary, should be innocuous

Principles of Green Chemistry

- Energy requirements should be recognized for their environmental and economic impacts and correspondingly minimized.

Principles of Green Chemistry

- Chemical products should be designed to achieve efficacy of function while reducing the toxicity

Principles of Green Chemistry

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

Principles of Green Chemistry

- Substances used in a chemical process, and the specific form of those substances, should be chosen so as to minimize the potential for chemical accidents resulting from, for example, releases, explosions, and fires

Principles of Green Chemistry

- Analytical methodologies should be developed and utilized to allow for real-time, in-process monitoring and control in order to reduce or eliminate the formation of hazardous or unwanted substances