Introduction to Green Chemistry
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Overview

- The Benefits of Organic Chemistry
- Costs of a Chemical Society
- What is Green Chemistry?
- Why is Green Chemistry important?
- 12 Principles of Green Chemistry
- The Future of Green Chemistry
Benefits of An Organic World

- Organic chemistry and organic molecules play profound roles in our lives.
As individuals and as a society, we depend on these products
Benefits at What Cost?

- Global chemical sales totaled 1.5 trillion dollars in 1998.
  - This corresponds to the annual production of millions of tons of chemicals
- The production of chemicals leads to chemical emissions
  - In the United States in 1994, there were 2.26 billion pounds of 300 hazardous substances released into the environment
Early Chemical Industry

Waste Disposal – land, air, water
Chemical Hazards – unknown, unconcerned
Safety – minimize personal exposure
Hazard Avoidance – Minimize Exposure

Canadian Explosives Research Laboratory (Ottawa)

Washington University (St. Louis) $55M Lab Science Building
Accidents Can Happen
Accidents Can Happen

Bhopal, India (1984)

Cyanide spill
‘Dilution is the Solution to Pollution’

- Chemical emissions were essentially unregulated from the start of the Industrial Revolution through the mid 1950s
- Chemical release into the air, water, and land did not seem to matter
- Ignorance of:
  - Chronic toxicity
  - Bioaccumulation
  - Carcinogenicity
Early Waste Disposal

Valley of the Drums
Bullitt County, Kentucky
http://www.epa.gov/superfund/20years/ch3pg1.htm

Bucktail Creek
(Cobalt, Idaho)
http://www.darrp.noaa.gov/northwest/black/
A Legacy of Pollution

Love Canal (New York)
A Legacy of Pollution

Cuyahoga River, near Cleveland
1969

Cuyahoga River, 1952
Mixed Perceptions of Chemistry

“Merchants of Death” (1930’s)

Better Things for Better Living … Through Chemistry (1935)

Better Things for Better Living (1980’s)

(1999)
Better Living Through Chemistry
Claude Moller
Mixed Media
69" x 51"
1994
What Can We Do?
We Can’t Just Ignore the Problem
UNLESS someone like you cares a whole awful lot, nothing is going to get better. It's not.
Role of Chemistry

- Chemistry is the scientific discipline which addresses the structure, composition, reactivity, and energetics of substances from bulk properties to the level of atoms and molecules.

- As chemists, we are uniquely situated to address the global need to discover, develop, and utilize sustainable practices.
What is Sustainability?

- Sustainability can be defined as the ability of society to utilize natural resources without impairing the ability of future generations to do the same.
In 2006 the NSF recognized four major areas of importance within sustainability:

- Environment
- Energy
- Green Chemistry
- Education
Green Chemistry: An Essential Component of Sustainability
What is Green Chemistry?

- Green chemistry can be thought of as an overarching philosophy of chemistry
- Chemical choices - minimizing the hazards and maximizing efficiency
- Green chemistry is fundamentally about waste prevention at the level of atoms and molecules
- Chemistry with respect, not disregard, for health and the environment
It is distinct from environmental chemistry which focuses on the chemical phenomena in the environment.
Risk is a function of hazard and exposure

Risk = f[hazard, exposure]

By reducing intrinsic hazard, risk can be minimized even in the event of accidental exposure.
Is Green Chemistry Expensive?

Waste = Lost Profit
The Rise of Regulation

- The last 40 years has seen:
  - Public recognition of pollution
  - The creation of the EPA
  - Proliferation of environmental regulation
  - Recognition of the need for environmental stewardship
- Much has been done – even more to do
Public Relations
“Environmental” Control is Expensive

There are an estimated 85,000 fume hoods in California, and more than 500,000 in the United States.

A single fume hood running 24 hours a day uses as much energy as an entire house.

Berkeley Lab researchers estimate that a new fume hood technology could save 360 gigawatt-hours of electricity in California, and 2,100 GWh in the United States. At $0.08 per kWh, the annual electricity savings per hood is about $1,000 (close to 8,500 kWh saved per hood).

http://www.lbl.gov/Science-Articles/Archive/fume-hood-elec-movie.html
12 Principles of Green Chemistry

John Warner and Paul Anastas

1. Prevention
2. Atom Economy
3. Less Hazardous Chemical Synthesis
4. Design Safer Chemicals
5. Safer Solvents and Auxiliaries
6. Design of Energy Efficiency
12 Principles of Green Chemistry

7. Use Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Accident Prevention

Braungart and McDonough Cradle-to-Cradle: Remaking the Way We Make Things (2002)
Trash or Feedstock?
Use of Conceptual Metrics to Reduce a Product’s Environmental Footprint
If we employ the principles of green chemistry coupled with new metrics for performance, we have the opportunity to make significant new discoveries.
When economic, social and environmental benefits are integrated and balanced, sustainability can be maintained.
Green Products?

- Greenwashing is a term that describes misleading claims about the environmental safety and effects of a product or service.
- The use of appropriate metrics will stem the greenwashing of products.

Note - the Clorox product line depicted may or may not be green – need metrics!
Does Green chemistry have a Direct Impact on Your Life?
Direct Impact on Your Life

Green Chemistry can make your community a cleaner, safer place

- Reducing local pollution
- Reducing transportation of hazardous materials
- More affordable products
Where does the Future lay?
Future Educational Challenges

1. Cultivate an understanding of basic principles of chemistry, environmental sciences, toxicology and sustainability
Future Educational Challenges

2. Foster interest in careers in science, chemistry, engineering and other related disciplines
3. Build a workforce equipped with the scope and breadth of knowledge and skills to advance green chemistry and an intellectual environment that catalyzes the development of new ideas and technological innovations.
Future Educational Challenges

4. Develop a well-informed citizenry capable of actively engaging in demanding and supporting green products and processes and avoiding unsafe chemical use and disposal practices
Questions?