

Lesson 1—Green Chemistry

One of the most important new aspects of chemistry is the development of **Green Chemistry**. Supported by the American Chemical Society, the USEPA and other Federal agencies, **Green Chemistry** has emerged as an important aspect of all chemistry

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

Green Chemistry is based on Twelve Principles.

12 Principles of Green Chemistry

(Anastas, P. T.; Warner, J. C. *Green Chemistry: Theory and Practice*, Oxford University Press: New York, 1998, p.30. By permission of Oxford University Press)

1.

Prevention

It is better to prevent waste than to treat or clean up waste after it has been created.

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 methods 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 effect their desired function while minimizing their 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

Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

7.

Use of Renewable Feedstocks

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

8.

Reduce Derivatives

Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

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 break down into innocuous degradation products and do not persist in the

environment.

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 the potential for chemical accidents, including releases, explosions, and fires.

An important source of information on **Green Chemistry** is the American Chemical society website

<http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=education%5Cgreenchem%5Cindex.html>

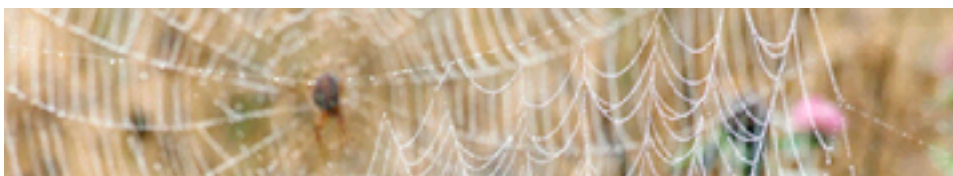
At this site you can gain access to the official ACS textbook on Green Chemistry, an annotated bibliography on Green Chemistry, Green Chemistry lab experiments, etc.

The following presentation on Green Chemistry is from the ACS website

GREEN CHEMISTRY

PREVENTING POLLUTION

SUSTAINING THE EARTH



**“ Chemistry has an important role to
play in achieving a sustainable
civilization on earth.”**

**— Dr. Terry Collins, Professor of Chemistry
Carnegie Mellon University**

WHAT IS A SUSTAINABLE CIVILIZATION?

**WE SHOULD CONSIDER
THIS QUESTION FROM
SEVERAL VIEWPOINTS:**

- **The environment and human health.**
- **A stable economy that uses energy and resources efficiently.**
- **Social and political systems that lead to a just society.**



**TO UNDERSTAND THE ROLE
OF CHEMISTRY IN
SUSTAINABILITY,
WE WILL LOOK AT THE
FIRST TWO POINTS...**

- **The environment and human health.**
- **A stable economy that uses energy and resources efficiently.**



**IN A SUSTAINABLE
CIVILIZATION...**

- **Technologies used for production of needed goods are not harmful to the environment or to human health.**
- **Renewable resources (such as plant-based substances or solar energy) are used rather than those, like fossil fuels, that will eventually run out.**



IN A SUSTAINABLE CIVILIZATION...

- **At the end of their use, materials are recycled if they are not biodegradable (easily broken down into harmless substances in the environment).**



IN A SUSTAINABLE CIVILIZATION...

- **Manufacturing processes are either designed so as not to produce waste products,**
- OR –**
- **Waste products are recycled or biodegradable.**



**WHILE WE HAVE MADE SOME
PROGRESS IN ACHIEVING
THESE GOALS, WE STILL
HAVE A LONG WAY TO GO ...**

- **Mountains of solid waste are piling up—particularly in industrialized nations.**
- **Air and water pollution continue to be problems in many places.**



**BUT HOW CAN
CHEMISTRY HELP US
TO ACHIEVE
A SUSTAINABLE
CIVILIZATION?**

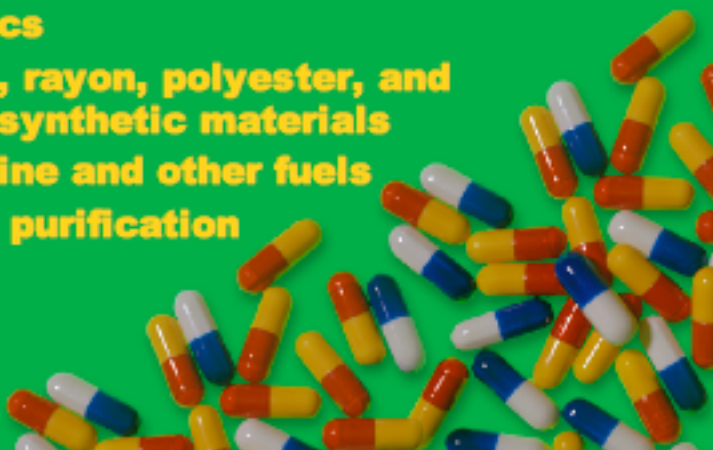


First, let's consider chemistry's benefits...

The chemical industry produces many products that improve our lives and upon which we depend.

BENEFITS OF CHEMICAL INDUSTRY:

- **Antibiotics and other medicines**
- **Fertilizers, pesticides**
- **Plastics**
- **Nylon, rayon, polyester, and other synthetic materials**
- **Gasoline and other fuels**
- **Water purification**





“Most of the environmental problems of past centuries and decades, such as the biological contamination of drinking water, were solved only when the methods of science in general—and chemistry in particular—were applied to them. The phenomenal rise in human life expectancy and in the material quality of life that has come about in recent decades is due in no small measure to chemicals and chemistry.”

— Colin Baird, *Environmental Chemistry*.



Although the positive contributions of chemistry and the chemical industry are many, some pollution problems have also resulted.

Many of these problems can now be solved.

SOME WELL-PUBLICIZED INCIDENTS FROM THE PAST FEW DECADES...

- **The Cuyahoga River in Ohio became so polluted with chemicals it caught fire.**
- **A plant accident in Bhopal, India, released methyl isocyanate. Nearly 4000 people died.**



SOME WELL-PUBLICIZED INCIDENTS FROM THE PAST FEW DECADES...

- **An accidental release of chemicals, including dioxin, in Seveso, Italy, in 1976 resulted in death of farm animals and long-term health problems for many local residents.**



**MANY COUNTRIES HAVE
ALREADY ENACTED LAWS AND
SIGNED **INTERNATIONAL**
TREATIES TO REDUCE POLLUTION
LEVELS, INCLUDING:**

- 
- **Montreal Protocol to Protect the Ozone Layer**
 - **Global Treaty on Persistent Organic Pollutants**
 - **Rio Declaration on Environment and Development**



**Despite these efforts,
large quantities of harmful
substances are still being
released into the environment.**

THE POLLUTION PREVENTION ACT OF 1990

- **This was the U.S. environmental law stating that the first choice for preventing pollution is to design industrial processes that do not lead to waste production.**
- **This is the approach of green chemistry.**

GREEN CHEMISTRY WORKS TOWARD SUSTAINABILITY BY:

- **Making chemical products that do not harm either our health or the environment,**
- **Using industrial processes that reduce or eliminate hazardous chemicals, and**



GREEN CHEMISTRY WORKS TOWARD SUSTAINABILITY BY:

- **Designing more efficient processes that minimize the production of waste materials.**



GREEN CHEMISTRY MEANS...

- **Preventing pollution before it happens rather than cleaning up the mess later.**





GREEN CHEMISTRY MEANS...

- **Saving companies money by using less energy and fewer/safer chemicals, thus reducing the costs of pollution control and waste disposal.**

EXAMPLES OF GREEN CHEMISTRY

- **Reducing lead pollution**
- **Putting out fires the green way**
- **Safer dry cleaning**



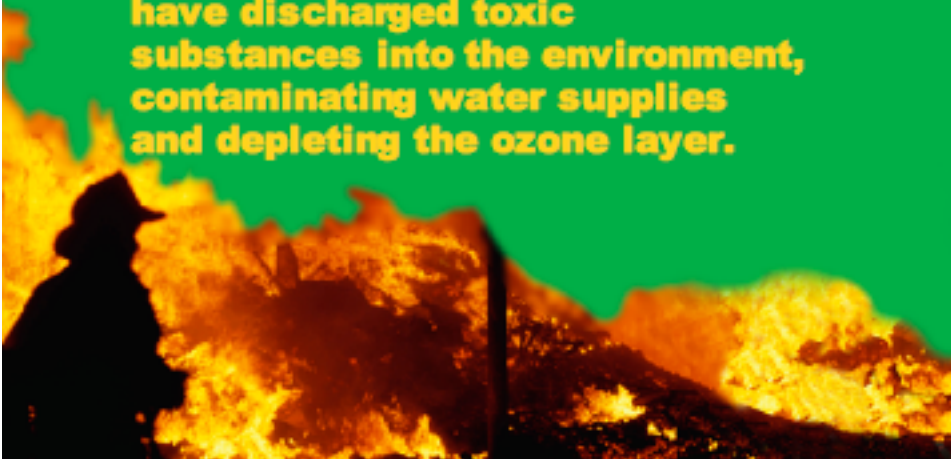
LEAD POLLUTION HAS BEEN DECREASED BY...

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



CHEMICAL FOAMS TO FIGHT FIRES

- **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.**



PUTTING OUT FIRES THE GREEN WAY

- **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.**



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 CO₂ 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.**



IN SUMMARY, GREEN CHEMISTRY IS...

- **Scientifically sound,**
- **Cost effective, and**
- **Leads toward a sustainable civilization.**



One Green Chemistry concept that is explored in the Baird and Cann textbook is that of **atom economy**. This concept, developed by Trost, focuses attention on how many of the atoms of the reactants are incorporated into the final desired product and how many are

wasted. Examples are given for the syntheses of 1-bromobutane and ibuprofen. You should study these examples and understand them.