Green Chemistry: A Greener Clean

Chicago ACS Chemistry Day

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

◆ Green chemistry can also be described as
  ■ Sustainable chemistry.
  ■ Chemistry that is benign by design.
  ■ Pollution prevention at the molecular level.
  ■ All of the above.
Twelve Principles of Green Chemistry

1. Prevention
2. Atom Economy
3. Less Hazardous Chemical Syntheses
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
Applications of Greener Cleaning Technologies

- Antibacterial Products
- Laundry
- Water Purification
- Industrial Cleaning
Antibacterial Products

- Environmentally benign antibacterial agents
  - Alternatives to traditional chlorine or tin containing antibacterial agents

- Applications
  - Bandages, sutures, hospital gowns, acne medication, toothpastes, air filters, antiviral agents

  USDA

  magnesium hydroperoxyacetate
  \[ \text{HO–O–Mg–OAc} \]

  magnesium dihydroperoxide
  \[ \text{HO–O–Mg–O–OH} \]
Cleaning Clothes

- TAML catalysts activate hydrogen peroxide
  - Inhibit dye transfer
  - Potential for washing machines that use less water

Collins, Carnegie Mellon University

Cat$^+$ = Li$^+$, [Me$_4$N]$^+$, [Et$_4$N]$^+$, [PPh$_4$]$^+$

$X = \text{Cl, H, OCH}_3$
Cleaning Clothes

◆ Total Impact Program (TIP®)
  ■ Chemistry + application knowledge + product stewardship
  ■ Laundry formulation incorporates neutral pH detergent, enzymes, surfactants, oxygen bleach, and biodegradable softeners

◆ Benefits
  ■ Avoids high pH detergents, chlorine bleach, acid neutralization, poorly degradable surfactants

Anderson Chemical Company
Dry cleaning with liquid carbon dioxide

- current process uses perc (perchloroethylene), a suspected carcinogen and groundwater contaminant
- new process uses liquid carbon dioxide, a nonflammable, nontoxic, and renewable substance
Cleaning Clothes

◆ Sodium iminodisuccinate
  ■ Biodegradable, environmentally friendly chelating agent
  ■ Synthesized in a waste-free process
  ■ Eliminates use of hydrogen cyanide

Bayer Corporation and Bayer AG
2001 Alternative Synthetic Pathways Award Winner
Cleaning Water

◆ Chlorine disinfection
  ■ Important for preventing disease
  ■ Toxic to aquatic life
  ■ Sulfur-based compounds used to neutralize chlorine

◆ Vitamin C (ascorbic acid)
  ■ Safer, effective neutralization alternative
  ■ Boosts immune system of aquatic life

Skagit County Public Utilities, Washington State
Cleaning Water

◆ Ultimer™ Polymer Technology

- manufacture of high molecular weight, water soluble polymers in aqueous salt solution
- eliminates use of oils and surfactants in manufacture and use
- uses ammonium sulfate, a waste by-product from the manufacture of caprolactam
- eliminates need for expensive mixing equipment required for water-in-oil emulsions

Nalco Chemical Company
Industrial Cleaning

◆ Crystal Simple Green®
  ■ Water based industrial cleaner
  ■ Non-toxic, biodegradable surfactants
  ■ Replaces traditional organic solvents
  ■ Eliminates hazardous waste sludge production and VOC pollution

Sunshine Makers, Inc.
Isomet

- Mixture of isoparaffinic hydrocarbon, propylene glycol monomethyl ether, and isopropyl alcohol
- Replaces Typewash (mixture of methylene chloride, toluene, and acetone)
- Excellent performance in postage stamp and overprinting presses
- Acceptable properties (cleaning ability, solvent evaporation rate, odor, environmental compliance, and cost)

U.S. Bureau of Engraving and Printing
Printed circuit boards assembled using Surface Mount Technology (SMT)
- Lead/tin solder paste stenciled onto substrate
- Stencils cleaned before reuse
  - CFC solvents
  - Aqueous solvents (high temperature, high pH)

440-R SMT Detergent
- Aqueous-based, contains no VOCs
- Ultrasonic technology

Smart Sonic Corporation
Industrial Cleaning
Green Chemistry

- Not a solution to all environmental problems.
- The most fundamental approach to preventing pollution.
- Recognizes the importance of incremental improvements.
Green chemistry is:
- A reaction that utilizes a green liquid.
- The design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.
- Anything, including treatment or recycling, that reduces pollution.
- Any reaction performed by Kermit the Frog or his relatives.

Question #1
Question #2

A renewable feedstock (starting material) that may be used as a source for organic chemicals is
- Petroleum.
- Biomass.
- Coal.
- Natural gas.
Question #3

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Question #4

A “green” solvent that may be used in some organic reactions is

- Benzene.
- Methylene chloride.
- Water.
- Ether.
1. The design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.
2. Biomass.
3. All of the above.