Greener is cleaner, and safer

One easy way to reduce the number of accidents in your lab is to go "green." Green chemistry, or sustainable chemistry, emerged about a decade ago, but the concept has been practiced for centuries by indigenous people of many continents. The basic principles of green chemistry are that you should use only what you need and recycle what you can.

Paul T. Anastas, an organic chemist working in the Office of Pollution Prevention and Toxins at EPA, coined the term *green chemistry* in 1991. It was defined as "the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products." Since that time, the definition has been expanded to include the production or use of improved chemicals with less waste, less energy, and reduced environmental impacts. Green chemistry also seeks to foster safer reactions by substituting nonhazardous chemicals for those that pose high risks, thereby reducing the quantities of hazardous chemical waste.

Green labs are safer

Microchemistry—using small amounts of chemicals instead of the large amounts called for in traditional labs—is an important part of green chemistry. However, green chemistry also requires that you

- create less-hazardous waste chemicals,
- store fewer hazardous waste chemicals,
- expose humans and the environment to little or no toxic chemicals,
- avoid unsafe solvents,
- stop creating chemical products that, when disposed of, will remain in the environment for long periods of time, and
- desist from using chemicals that have the potential for laboratory accidents, such as fires and explosions.

These goals reflect the *Twelve Principles of Green Chemistry*, the bedrock upon which the green chemistry movement is grounded (see sidebar).

Greening a lab

There are a number of strategies that can be used to begin converting the conventional science laboratory to a "green" laboratory. For existing science laboratories, the following strategies can be implemented:

- Plan hands-on science labs and activities that use environmentally friendly chemicals in lieu of environmentally unfriendly chemicals. In other words, use chemicals that can easily be recycled and have little or no impact on the environment. For example, using commercial vinegar in place of hydrochloric or sulfuric acids is a start. Greener chemicals also tend to be less expensive.
- Order only those chemicals that you will need for one year instead of larger amounts that may never be used. This requires less space and a lower level of maintenance. Keeping your chemical inventory up-to-date can help you achieve this goal.
- Use only small amounts of chemicals based on microscale methods and apparatus. In other words, instead of using grams of chemicals, use centigrams.
- Alternative computer simulations of laboratories that require no chemicals can be infused into certain sections of the science course.
- Make use of laboratory hoods when possible to reduce the volume use of general ventilation in the laboratory. This can save on heating or cooling energy if the laboratory has variable damper controls.
- Stress the connection between green chemistry and the environment by modeling green activities in the laboratory. Sustainable development is key to the future!

When renovating or building new laboratories, the following strategies can be implemented:

- Design laboratory ventilation in ways that are within the fire code but also green-friendly. For example, hoods can be used for certain experiments if necessary in lieu of increasing the ventilation in the whole laboratory.
- Select time-tested, milled-wood laboratory furniture that will stand up to use and abuse over time.
- Design laboratories to make use of active and/or passive solar energy, photovoltaic technology, heat pumps, and the myriad of other alternative energy sources available. This also includes proper insulation, window fixings, and so on.
- Use natural lighting whenever possible.
- Design laboratory utilities that reduce volume use. For example, have water restriction valves on lab benches to save water.

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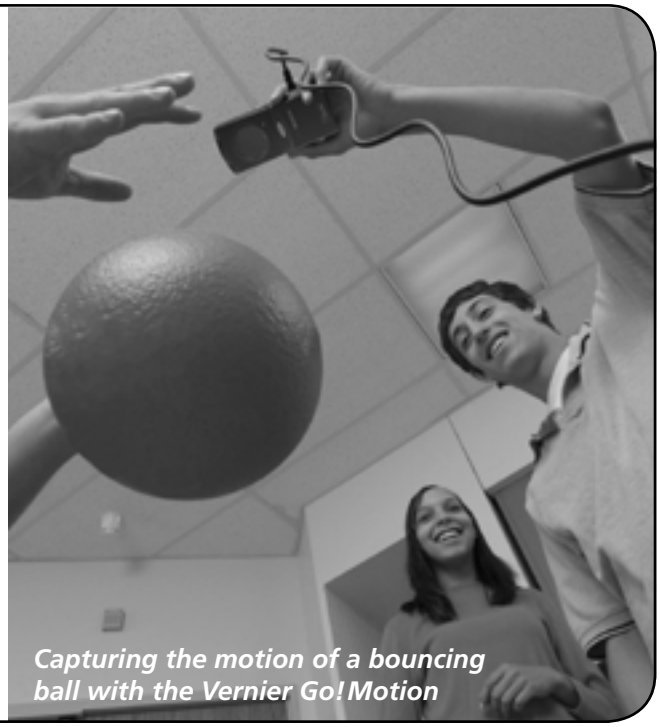

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Twelve principles of green chemistry

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 practical, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Design 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—solvents, separation agents, and others—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 renewable feedstocks—A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. Reduce derivatives—Unnecessary derivatives, such as the use of blocking groups, protection/deprotection, and temporary modification of physical/chemical processes, should be minimized or avoided 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.

FIGURE 4.1 (P. 30): "TWELVE PRINCIPLES OF GREEN CHEMISTRY" FROM "GREEN CHEMISTRY: THEORY AND PRACTICE." EDITED BY ANASTAS, P. T. AND J. C. WARNER (1998)

- Use recyclable labware whenever possible.
- Design laboratory waste retrieval or neutralizing technology, such as an acid trap, to render select chemicals going down the drain harmless to the environment.

Reference

Anastas, P. T., and J. C. Warner, eds. 1998. *Green chemistry: Theory and practice*. New York: Oxford University Press.

Resources

ACS Green Chemistry website—*www.chemistry.org/education/greenchem*
EPA's Green Chemistry Program—*www.epa.gov/greenchemistry*
EPA Green Chemistry Institute listserv—*gcilist@acs.org*
Green Chemistry Institute—*www.ian1.gov/greenchemistry*
Greening Schools—*www.greeningschools.org*
National Clearinghouse for Educational Facilities— *www.edfacilities.org/rl/science.cfm*
Royal Society of Chemistry's Green Chemistry Network—*www.chemsoc.org/networkds/gen/index.htm*

Question of the month

Why don't all material safety data sheets (MSDS) look the same?

Answer

The Occupational Safety and Health Administration prescribed the minimum type of information that is required on MSDS, but not the order or format in which the information is presented. On the MSDS, manufacturers and/or suppliers of hazardous chemicals are required to provide the user with the following information: The name of the chemical; physical/chemical characteristics; physical hazards; health hazards; exposure levels; known or suspected carcinogenic properties; control measures; first-aid procedures; date of MSDS preparation; name, address, and phone number of party responsible for preparing or revising the MSDS; and emergency phone numbers in case of an accident.

Do you have a question?

Submit questions relative to safety in the middle school science laboratory to Ken Roy at *royk@glastonburyus.org*.