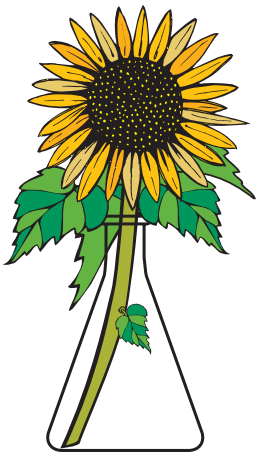
Greening the School Science Lab



For more than 35 years, Flinn Scientific has embraced a consistent philosophy regarding the use of chemicals in academic science labs: "Chemicals in any form can be safely stored, handled or used if the physical, chemical, and hazardous properties are fully understood and the necessary precautions, including the use of proper safeguards and personal protective equipment, are observed."

We still believe this philosophy is appropriate. Nevertheless, the list of banned or restricted lab chemicals continues to grow. A majority of states, for example, have banned mercury, even in thermometers. With so much negative attention on "problem" chemicals, the idea of "green chemistry" may seem like an oxymoron. Green chemistry, however, is real, and it carries a positive message about chemistry and science. The *Green Chemistry Program* was initiated by the U.S. Environmental Protection Agency in the 1990s with the goal of applying chemical principles to prevent pollution. The program calls for the design of chemical products and processes that will reduce the use and generation of hazardous substances. How can your institution benefit from the principles of green chemistry?

As your "Safer Source for Science," Flinn Scientific believes that knowledge is the most important tool we can provide to reduce waste and improve safety. We strive to provide the most reliable and helpful information possible concerning the safe purchase, storage, handling, use, and disposal of laboratory chemicals.

Basic Principles of Green Chemistry

Green chemistry presents a wonderful opportunity for science instructors to increase safety, improve science education, and impart the values and benefits of science to the next generation. The basic principles of green chemistry as they relate to academic science labs include:

- Design lab activities to avoid generating hazardous byproducts that require waste disposal.
- Substitute less hazardous and less toxic chemicals in chemical reactions or lab tests.
- Perform lab activities on a small-scale or microscale level to reduce the amounts of chemicals used.
- Use catalysts to avoid byproduct formation in chemical reactions.
- Use safer solvents.
- Avoid high temperature or high pressure conditions for chemical reactions.

> The goals of the Green Chemistry Program are embodied in the *Twelve Principles of Green Chemistry,* originally published by Paul Anastas and John Warner in 1998, which provide a roadmap for scientists to reduce and prevent pollution. The program supports fundamental research, sponsors educational and scientific outreach activities, and recognizes achievement through the *Presidential Green Chemistry Challenge Awards.* For more information about the principles of green chemistry, visit the EPA Web site at http://www.epa.gov/greenchemistry/pubs/principles.html.

Reviewing and Planning Lab Activities

To implement green chemistry, faculty and staff need to know what chemicals are being used in lab activities. This requires two things—an accurate inventory of chemicals, and a list of chemicals used in experiments and demonstrations for all lab courses. The second requirement may seem like tall order, but it is vital. After compiling this list of chemicals, most departments find that half of the chemicals in their inventory are never used! In reviewing current lab activities, carefully compare the hazards of chemicals versus the learning goals and objectives. A lab activity may use lead nitrate, for example, to precipitate lead iodide and demonstrate crystal formation. No doubt, it is a beautiful demonstration! Is the need for licensed hazardous waste disposal of the heavy metals used in this demonstration justified in terms of the learning goals? Would another demonstration accomplish the same objective? Mixing copper chloride and sodium phosphate solutions gives a turquoise solid. This reaction is "greener" and safer than lead iodide.

Set up regular department meetings to discuss some of the "not so green" lab activities in the curriculum and to share ideas for possible alternatives. Also, don't think that just because you don't have time to review every single chemical, you shouldn't do anything. Remember, a journey of a thousand miles begins with a single step. Take the first step!

Advantages of Microscale Labs

The advantages of microscale lab activities are well known—the labs are faster, so students can do more trials and gather more data, students and instructors are exposed to lower concentrations of possibly hazardous chemicals (especially for volatile substances), departments save money in the cost of chemicals, glassware, and equipment, faculty and staff spend less time setting up and cleaning up, and the amount of waste generated is greatly reduced. Many common lab activities can be reduced to the microscale level simply by combining drops of liquids in a well plate instead of mixing milliliters of liquid in a beaker.

Color the Curriculum Green!

Try the following suggestions to get started on the path to greener science labs in your school:

- Incorporate disposal treatment into the lab procedure—neutralize acid products with sodium carbonate, reduce halogen waste with sodium thiosulfate, precipitate silver ions with sodium chloride, etc.
- Purchase digital thermometers—they are safer and more precise than spirit-filled glass thermometers.
- Use lower concentrations or less hazardous forms of chemicals whenever possible.
  - –Always work with the lowest concentration possible of strong acids. If a procedure calls for 3 M hydrochloric acid, try 1 or 2 M HCl. Copper wire requires concentrated nitric acid to dissolve, but copper foil will dissolve in 6 M HNO_3.
  - –Substitute solutions for pure solids whenever possible. The LD_{50} of copper(II) chloride is 140 mg/kg—extremely toxic. Using 1 M $CuCl_2$ solution reduces the toxicity hazard almost tenfold! There is also a reduced risk of exposure to toxic fumes or dust when working with solutions.
  - –Avoid finely divided forms of metals. Granular zinc is safer than zinc dust; magnesium ribbon is safer than magnesium powder. Finally divided metals may be both a reactivity or flammability hazard (Zn, Mg) and an inhalation hazard (Pb, Cr, etc).

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– Sodium chlorate is more stable than potassium chlorate for small-scale oxygen generation.

– Ammonium chloride is less hazardous than ammonium nitrate for endothermic solution experiments.

– Prepare bromine solutions in water ("bromine water").

– Use methyl tert-butyl ether rather than diethyl ether for extraction procedures.

See the "Boyle's Law in a Bottle" Student Laboratory Kit (Catalog No. AP6855) on page 457 for a description of this environmentally friendly Boyle's law experiment.

- Perform a modern variation of the classic Boyle's law experiment using a syringe in a special pressurized soda bottle—get rid of the mercury-filled column.
- To determine molar volume, generate hydrogen gas (from magnesium and hydrochloric acid) instead of oxygen, which requires dangerous potassium chlorate.
- Use sodium hypochlorite rather than sodium dichromate as an oxidizing agent (the latter is a carcinogen).
- For the synthesis of a coordination compound, use an iron compound instead of nickel or cobalt.
- Incorporate applications-oriented lab activities into the curriculum wherever possible to make the experiments more interesting to students while at the same time reducing the use of hazardous chemicals. Examples include acid–base titrations of fruit juices, redox reactions using Vitamin C as a reducing agent, paper chromatography of food dyes, and the preparation of biodiesel.
- Teach fundamental principles in environmental chemistry and biology.

– Determine the alkalinity or buffer capacity of water by acid–base titration.

– Use the Winkler method to measure dissolved oxygen concentrations in water as a function of nutrient levels, such as nitrate and phosphate ions.

– Compare the ability of soil versus sand to bind nutrients and exchange ions using ionic indicator dyes.

– Simulate the production and the properties of acid rain.

– Investigate how the specific heat of geological materials such as sand, soil, and water influence climate.

- Look for lab activities to teach recent advances in science and technology. Interesting kits we have developed in recent years include building a solar cell, preparing and testing biodiesel fuel made from vegetable oil, and demonstrating the properties of "colloidal gold" nanoparticles. Please consult the index to find these kits and many more!

Notice that Green Chemistry does NOT mean doing fewer labs, "dumbing down" the curriculum, or teaching less science! In fact, the opposite is true. By practicing green chemistry across the curriculum, you will be able to teach the same concepts and accomplish the same learning goals. More importantly, you will feel better knowing that you're making a positive contribution to the environment and to science education by empowering and exciting the next generation of scientists.

Flinn ChemTopic™ Labs

Flinn Scientific has developed a series of 23 chemistry lab manuals to help you adopt a safer, "greener" attitude in chemistry labs. Created under the direction of an Advisory Board of award-winning teachers, each lab manual in the *Flinn ChemTopic™ Labs* series contains 4–6 experiments on essential concepts and applications in a single content area. Each lab manual also contains 4–6 demonstrations to capture your students' attention. All of the lab activities were optimized to match them to the knowledge and skill level of high school chemistry. The use of hazardous reagents was critically evaluated, the preparations were scaled down, and the procedures were reviewed and optimized to make them as safe as possible while still providing satisfying outcomes. There are microscale, technology-based, and guided inquiry labs for each topic. Best of all, all of the activities were tested and retested—you know they will work! For maximum safety in choosing lab activities, try *Flinn ChemTopic™ Labs*.

Enviromental Science Kits

Bioassay Experiment. FB1881
Copper Mining FB1913
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Specific Heat and Climate. . FB1883