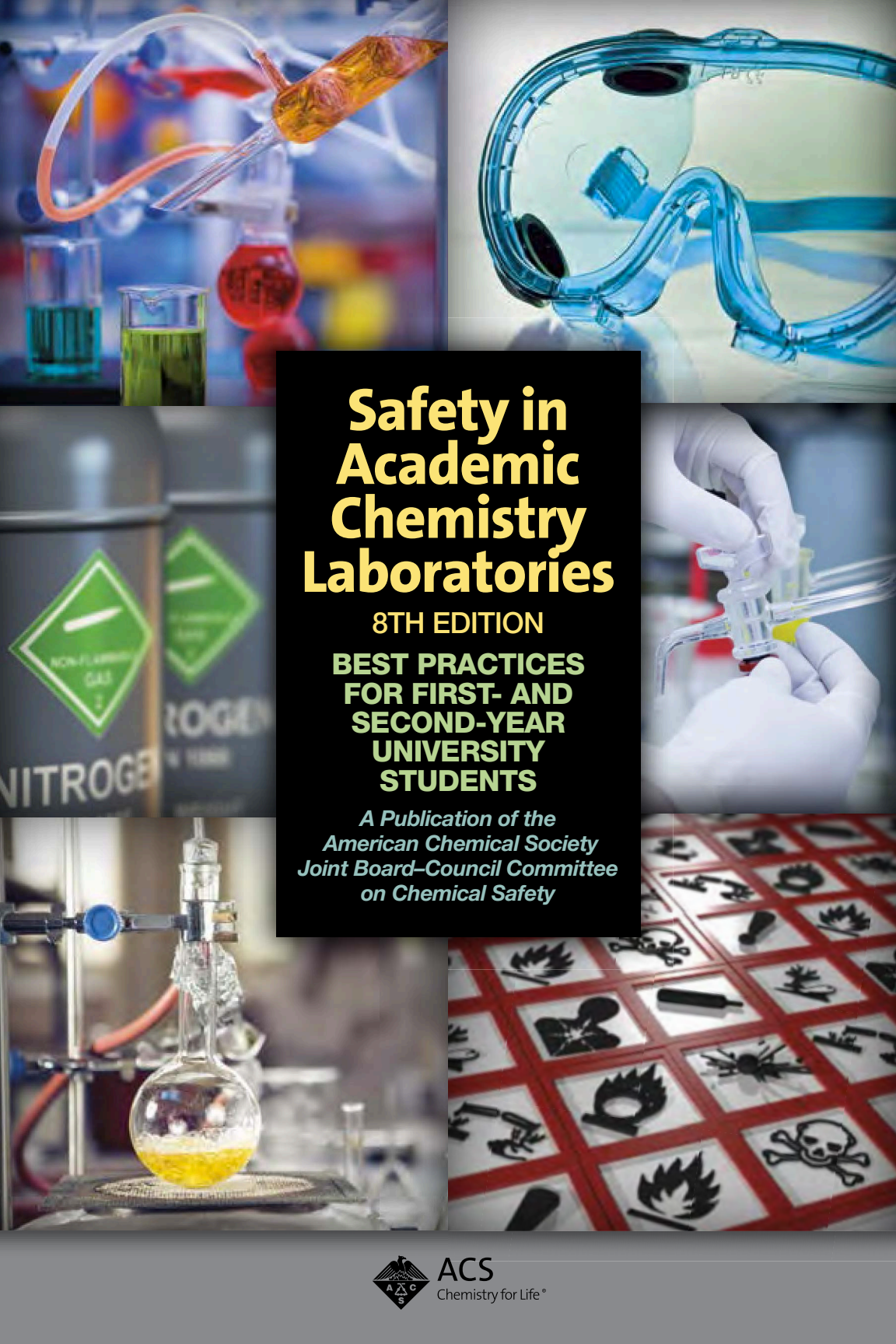

Safety in Academic Chemistry Laboratories

8TH EDITION

BEST PRACTICES FOR FIRST- AND SECOND-YEAR UNIVERSITY STUDENTS

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ACS Chemistry for Life®

CHAPTER 2

Your Responsibility for Safety in Laboratories

Introduction

Incident prevention is a collective responsibility, which requires the full cooperation of everyone in the laboratory. The responsibility for safety in the laboratory resides with you, your peers, the instructor, and the institution. Although everyone is responsible for safety in the laboratory, you, the experimenter, can most directly prevent incidents.

Incidents often result from:

- an indifferent attitude toward safety;
- failure to recognize hazards or hazardous situations;
- failure to assess the risks involved in the work being done;
- failure to be alert to your surroundings;
- failure to follow instructions or measures to minimize risks; and
- failure to recognize the limitations of your knowledge and experience.

You can be a victim of a mistake made by you or by someone else. If you are performing a laboratory procedure incorrectly and a classmate points this out to you, be grateful — it could be that he or she has just saved your life. If you observe a classmate making a mistake, let him or her know. In addition, unsafe acts should be reported to your instructor, so that mistakes will not be repeated.

Events, Incidents, and Accidents

Unexpected and unwanted events sometimes occur in laboratories. In this booklet, we use the term "incident" instead of "accident" so as not to imply that these events occur randomly or inevitably. Virtually all incidents are preventable if the guidelines and safety principles presented in this booklet are followed.

The guidelines in this chapter are provided to help you to develop an awareness of your role in maintaining a safe laboratory environment. Most of these guidelines and rules will be applicable to the introductory laboratory courses you take as an undergraduate student. In some cases, more information is provided to guide you as you advance to more laboratory experiences. At the end of the chapter, you will

find a summary list of guidelines or safety rules. These guidelines are the result of the application of years of lessons learned and are part of the M of RAMP: Minimize the risks of hazards. As you learn more about chemistry, you will learn to recognize hazards (Chapter 3). But before you enter a laboratory, you need to learn some basics about safety measures and safety equipment. Review the safety measures frequently, as a reminder.

IN YOUR FUTURE: Minimizing Risks of Hazards

In introductory and organic chemistry laboratory courses, it is unlikely that you will work with substances at pressures other than ambient, or with high-energy materials with the potential for vigorous reactions, such as foaming, overheating, boiling over, or even — if under pressure — small explosions (these are extremely rare occurrences). These types of laboratory experiments require the use of appropriate laboratory hoods, bench shields, chemical splash and impact goggles to protect your eyes, and face shields wide enough and long enough to protect your neck and ears.

Personal Protective Equipment (PPE)

Personal protective equipment (commonly known as PPE) is one of the principal ways of protecting you from harm when you work in the laboratory. It is important that you understand why your instructor will require you to use PPE.

PPE is used to eliminate or minimize exposure to some hazards encountered when working in the chemistry laboratory. PPE includes items designed to protect specific areas of your body, such as your eyes and hands. It commonly includes gloves, eye protection, laboratory coats, and aprons. Don't depend solely on PPE to protect you, because it is often the final barrier between you and exposure.

Hair and Apparel (Dressing for the Laboratory)

Clothing worn in the laboratory should offer your skin basic protection from splashes and spills. Shorts, short skirts, and shirts that expose your midriff will unnecessarily expose your skin to potential spills. It is always prudent to minimize the amount of skin exposed to the laboratory environment. Bulky and loose-fitting clothing is not appropriate in the laboratory. Loose sleeves may knock laboratory items over, be dragged through chemical spills, or present a fire hazard with open flames. Clothing should be made of natural fibers, such as cotton. Your instructor or institution may require you to wear laboratory coats or aprons. Nonflammable, nonporous aprons offer the most satisfactory and the least expensive protection. If you wear a laboratory jacket or coat instead of an apron, it should have snap fasteners rather than buttons, so that it can be readily removed in case of contamination.

In the laboratory, wear shoes with uppers made of leather or polymeric leather substitute that completely cover your feet and toes (closed-toe shoes). This will offer your feet the best protection from spills and dropped items. As you choose your laboratory footwear, keep in mind that the shoes you wear in the laboratory s*hould not expose the tops of your feet and should offer stability for standing and walking*.

Constrain long hair and loose clothing. Long hair can easily become entangled in equipment, can be exposed to chemicals, or can catch on fire by direct exposure to lit Bunsen burners. The wearing of jewelry, such as rings, bracelets, necklaces, and wristwatches, in the laboratory should be avoided. Jewelry can be damaged by chemical gases and vapors, and from spills. Chemical seepage between the jewelry and the skin can put corrosives in intimate contact with your skin and trap the chemicals there. Jewelry also can catch on equipment, causing injuries.

Eye Protection

Everyone in the laboratory, including visitors, must wear eye protection at all times, even when not performing a chemical operation. Some experiments present splash hazards, which necessitate wearing indirectly vented goggles; for other experiments, safety glasses can suffice. Because it is likely that you will not wish to purchase two forms of eye protection, it is prudent to use the more protective eyewear for variable environments. Thus, goggles rated for chemical splash protection are the preferred eye protection. The chemistry faculty at your institution will assess the risks of the hazards in your laboratory and determine the appropriate type of eye protection for the experiments being performed in their academic laboratories. Normal prescription eyeglasses do not provide appropriate laboratory eye protection against shrapnel from an explosion or splashes of hazardous chemicals. Serious injuries have resulted from the wearing of normal prescription eyewear without chemical splash goggles or safety glasses.

Gloves

Gloves are an important part of personal protection. Your instructor will assess the risks of hazards and will require the use of gloves when appropriate and provide the proper type of gloves. Glove material must be selected based on the chemicals being used. Always check your gloves before each use to ensure the absence of cracks and small holes. To avoid unintentionally

Does the Right Glove Material Matter? Lessons Learned

In August 1996, Dr. Karen Wetterhahn, a very accomplished researcher, was working in her laboratory on her current project, which required creating a standard by binding a mercury compound to a protein to be studied by nuclear magnetic resonance (NMR) spectroscopy. The recommended binding compound was dimethylmercury, which was known to be a very toxic compound. Recognizing the hazard, Dr. Wetterhahn made several attempts to prepare the standard using less toxic mercury chloride salts. When those products gave disappointing results, she decided to proceed with using dimethylmercury to prepare the standard.

Dr. Wetterhahn was working in a laboratory hood, wearing latex (natural rubber) gloves, and using accepted prudent laboratory practice. During the course of a transfer, two tiny drops of dimethylmercury dripped onto her latex glove. Not realizing the gravity of this, she finished her work for the day, cleaned up, and did not report the incident.

Within a year, she developed severe signs and symptoms of acute mercury poisoning and eventually slipped into a coma and passed away.

Her colleagues later tested the breakthrough time for the action of dimethylmercury on latex and found it to be 15 seconds or less. One lesson that can be learned from this tragic event is to make sure the glove you choose has been tested by the manufacturer for the chemical being used and that the manufacturer's recommendations are followed — especially for chemicals where one mistake could be catastrophic.

To read the full story, see "A Tribute to Karen Wetterhahn".[1]

spreading chemicals, remove your gloves before leaving the work area and before handling such things as cell phones, calculators, laptops, doorknobs, writing instruments, laboratory notebooks, and textbooks. You should wash your hands when leaving the laboratory, even if you have worn gloves.

A variety of gloves and materials are available: neoprene, butyl rubber, and many other materials. Different types of gloves have different gauntlet lengths; some cover the entire arm, some cover only the forearm, and some are only wrist-length. Individuals who are latex-sensitive should not wear gloves made of latex. Although cloth or leather gloves may protect against hot or cold objects, do not rely on them for protection against hazardous chemicals. The instructor and the institution are responsible for assessing the risks of hazards and for selecting the proper glove for the particular application.

Disposable gloves and gloves that have been permeated by a chemical should not be reused. The gloves cannot be reused safely because the chemical cannot be totally removed. Contaminated gloves may be considered to be a hazardous waste material, but this is not always the case. In all instances, dispose of your used gloves in the designated hazardous waste container or as directed by your instructor.

■ IN YOUR FUTURE: Selecting Gloves

Be aware that no glove material can provide permanent protection. Eventually, liquids will permeate all glove materials. Glove materials are rated by the manufacturer using the breakthrough time (the time it takes a particular chemical in contact with a glove to pass through the glove). For many organic solvents, the breakthrough time can be only a few minutes. Because the permeability of gloves made of the same material or a similar material can vary by manufacturer, refer to the information provided by the manufacturer of the gloves for specific guidance. If a chemical diffuses through a glove, it is then held against your skin; you could receive more exposure than if you hadn't worn a glove at all. Additional information can be obtained from the manufacturer of the gloves. An online search for "chemical glove selection" will yield several websites with useful information.

Laboratory Protocols

Laboratory Environment

The chemistry laboratory can provide a wealth of opportunity for learning, but while working in the laboratory, you should remain alert to your actions and the actions of those around you. Variations in procedure, including changes in the chemicals to be used or in the amounts that will be used, may be dangerous. Alterations should be made only with the knowledge and approval of your instructor.

Before working in the laboratory, take note of your surroundings. Locate the exits, fire alarm pull stations, eyewash fountains, safety showers, fire blankets, first aid kits, and fire extinguishers; practice walking to them. This is part of the P of RAMP: Prepare for emergencies.

Never eat or drink in the laboratory, to ensure that there is no chance that any contamination can lead to ingestion of a laboratory chemical. No food or drink should be carried into or stored in the laboratory.

Visitors in the Laboratory

All laboratory visitors, no matter how brief their visit, should wear eye protection. Visitors, such as friends and relatives, may not be aware of the hazards and may inadvertently commit unsafe acts. Obtain your laboratory instructor's approval before bringing visitors into the laboratory.

Housekeeping

In the laboratory and elsewhere, keeping things clean and neat generally leads to a safer environment. Keep aisles and access to safety equipment free of obstructions such as chairs, boxes, open drawers, backpacks, and waste receptacles. Avoid slipping hazards by keeping the floor clear of spilled liquids, ice, stoppers,

glass beads or rods, and other such small items. Keep workspaces and storage areas clear of broken glassware, leftover chemicals, and dirty glassware. Broken glassware should always be disposed of in a broken glass disposal container and NEVER in an ordinary trash can. Inform your instructor immediately if glass is broken or chemicals are spilled. Follow your laboratory's required procedure for the disposal of chemical wastes and unused chemicals. Wipe your bench area before leaving the laboratory, so that others will not inadvertently touch chemical residue. Never leave chemicals on balances, because this may unnecessarily expose the next user to the chemical; in addition, electronic balances are expensive and can easily be damaged by corrosive chemicals.

IN YOUR FUTURE: Special Cleaning Agents

Numerous incidents have been reported involving strong oxidizing cleaning solutions, such as nitric acid or chromic–sulfuric acid mixtures. Do not use flammable solvents as cleaning agents unless your instructor specifically requires their use. Do not use strong cleaning agents such as nitric acid, chromic acid, sulfuric acid, or other strong oxidizers unless specifically instructed to use them, and then only with specific training and proper protective equipment.

Labeling Chemicals

Improper or insufficient labeling of chemical containers has resulted in numerous adverse incidents. Labels are typically referred to as "manufacturer" and "secondary". It is important that a manufacturer label is never altered, covered, or otherwise changed until the container is verified as being empty. Often, empty containers will be reused, for example for solutions prepared by students. Before a container is reused for another solution, the obsolete label should be removed completely and the container should be thoroughly washed and allowed to air dry. It is unacceptable to use a marker to write over an existing manufacturer label. In no instance should a container ever have two labels, one on each side of the bottle.

Although it is unlikely that you will be involved in the management of manufacturer containers, you may prepare solutions and store them in your drawer in your introductory and organic chemistry laboratories. At a minimum, a secondary label for temporary use (during a laboratory period or until a future laboratory period) should have the name of the chemical, the name of the person who filled the container, the date it was filled, and the hazards. Containers prepared for longer storage should have a label that meets the standards of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (see Chapter 3).

Cleaning Glassware

Clean your dirty glassware at the laboratory sink using hot water, environmentally acceptable cleaning agents, and brushes of suitable stiffness and size. Do not force a brush into glassware. Always wear chemical splash goggles while washing dishes, and wear gloves

if instructed to do so. Many laboratory faucets have serrated nozzles that can produce high-velocity streams of water. When using these types of faucets, always adjust the stream slowly without holding glassware underneath. Water can come out forcefully and splash back into your face or knock the glassware out of your hands. Avoid accumulating too many items in the cleanup area.

Workspace around a sink is usually limited, and piling up dirty or cleaned glassware can lead to breakage. Remember that the turbid water in a sink may hide the sharp, jagged edge of a piece of broken glassware that was intact when it was put into the water. If glassware in the sink is broken, drain out the standing water. Use a pair of cut-resistant gloves, tweezers, or tongs to remove the pieces of broken glass. Be particularly careful when cleaning the drain area, because glass pieces can get caught in the holes and be nearly impossible to spot. To minimize breakage of glassware, sink bottoms may have rubber or plastic mats that do not block the drains.

Inhaling Harmful Chemicals

If you are instructed to smell something in the laboratory, use your hand to waft vapors toward your face and sniff gently. You should never sniff a chemical by placing your nose directly over a chemical container. The presence of an odor is not a reliable indication of potential harm, and the absence of an odor is not a reliable indication of the absence of harm.

Some people think that if they can smell a chemical, it is causing them harm. This is not necessarily correct. It is certainly correct that if you smell a chemical, you are inhaling it. Some harmful chemicals have no odor, and others can paralyze the sense

of smell. Some chemicals cannot be detected by the human nose at concentrations that are harmful, and some, even though they might have a decidedly noxious odor, are not harmful if inhaled.

Many substances that may or may not have an odor are harmful if their vapors, dusts, or mists are inhaled. The label on the container and the Safety Data Sheet (SDS) for the chemical (see Chapter 3) may carry a warning about inhalation hazards. Your instructor will direct you to dispense and handle these substances in a laboratory hood.

Disposal of Chemicals

Proper handling of reaction by-products, surplus, waste chemicals, and contaminated materials is a major element of incident prevention, and there are very strict rules for disposing of chemicals. Improper disposal can result in serious damage to the environment and can also result in legal issues for your institution. Every student is responsible for ensuring that these wastes are handled in a manner that minimizes personal hazard and recognizes the potential for environmental contamination.

Typically, your reaction by-products and surplus chemicals will be poured into appropriately labeled waste or hazardous waste containers for proper disposal. Your instructor will direct you to use designated, labeled waste containers. Most likely, different containers will be used for different classes of chemicals. Handle your waste materials in the specific ways designated by your instructor. ***Pouring waste into the wrong container could result in unexpected, adverse reactions, leading to fires or explosions*** *(see "Contains Nitric Acid— DO NOT ADD ORGANIC SOLVENTS" in Chapter 3)*. Remember to pay attention and follow instructions.

Sometimes your reaction by-products can be neutralized or deactivated as part of your procedure, and this can help to reduce waste handling, which lowers the cost of disposal. Once

your by-products are moved away from the experiment, they are subject to hazardous waste regulations established by your state government and the federal Environmental Protection Agency (EPA).

Some general disposal guidelines are as follows:

- When disposing of chemicals, put each class of waste chemical into its specifically labeled disposal container. Carefully read the contents label, and replace the cap after use.
- Never put chemicals into a sink or down the drain unless your instructor has told you that local regulations allow these substances to be put into the sanitary sewer system. For example, water and dilute aqueous solutions of sodium chloride, sugar, and soap from a chemistry laboratory may be disposed of in the sink.
- Put ordinary wastepaper into a wastepaper basket separate from chemical wastes. Materials that are contaminated with chemicals, such as paper towels used to clean up a spill, may need to be placed into a special container marked for this use. Your instructor will tell you whether cleanup materials need to be collected for hazardous waste or placed into the landfill containers.
- Broken glass belongs in its own marked waste container. If the broken glass is contaminated with chemicals, ask your instructor where to dispose of the glass. Thermometers that contain mercury may still be in use at your institution, but most of these have been replaced with thermometers that contain alcohol-based liquids. If you happen to be using a mercury thermometer and it breaks, immediately notify your laboratory instructor. Spilled mercury requires special cleanup procedures, and it should not be ignored, because mercury is toxic. Broken thermometers may contain mercury in the fragments; broken glass contaminated with mercury belongs in its own labeled container.

Photo courtesy of CP Lab Safety.

SUMMARY

Most of what we know about science was learned in laboratories somewhere. Laboratories can be interesting places to learn, but they can also be places with hazardous chemicals and equipment. In order to protect yourself and your peers, it is important to be conscious of these hazards and risks and to avoid actions that may lead to incidents that cause injury to you and your classmates or damage to the laboratory. Your duty as a student includes the duty to prevent incidents whenever you are in the chemistry laboratory. The following list summarizes the basic guidelines (to minimize the risks of hazards) intended to help you fulfill this important responsibility. Whenever you are in the laboratory:

PROPER CONDUCT/BEHAVIOR

- Do not work alone.
- Never perform unauthorized experiments or change procedures without approval.
- Maintain an awareness of your surroundings, and move purposefully around others.
- Never remove chemicals from the laboratory without proper authorization, and report to your instructor any observed unauthorized removal of chemicals by others.
- Never play tricks or engage in horseplay in a chemistry laboratory.
- Notify your instructor if you observe violations of your laboratory's safety rules; you could save someone's life.

PROPER LABORATORY ATTIRE

- Prevent skin exposure by covering your skin.
- Feet must be completely covered, and no skin should be showing between the top of the shoe and the bottom of the skirt or pants.
- Confine long hair, avoid wearing loose clothing, and remove scarves and jewelry.

SAFE HANDLING OF CHEMICALS

- Read the procedure ahead of time, listen carefully to your instructor's directions, and note any safety requirements for the experiment in your prelab notes.
- Never directly sniff a chemical. When instructed to smell something, use your hand to waft vapors toward your face and sniff gently.
- Never return reagents to the original container once they have been removed.

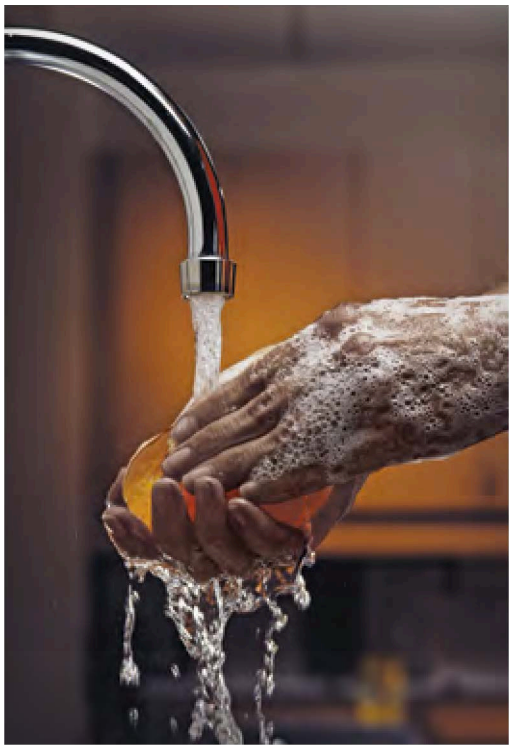
SAFE HANDLING OF EQUIPMENT

- Never pipet by mouth. Always use a pipet aid or suction bulb.
- Do not use hot plates with exposed or worn wiring.
- Check Bunsen burner hoses for holes.
- Always ensure balanced loading of test tubes in centrifuges.

ENGINEERING CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT

- Always wear the correct type of eye protection when working in the laboratory. Your instructor will tell you the level of eye protection required.

- Wear chemically resistant laboratory coats or aprons, if instructed to do so.
- Work in laboratory hoods as instructed.



PROPER HOUSEKEEPING

- Minimize tripping hazards by keeping aisles free of book bags and other tripping hazards.
- Prevent spills by keeping chemicals and apparatus well away from the edges of your laboratory bench or other workspace.
- Dispose of chemical hazardous waste as instructed, and always ask for guidance if you are unsure.
- Always wash laboratory coats or other clothing on which chemicals have been spilled separately from personal laundry.
- Wipe down your work area for the next user.
- Clean spills on the balances as instructed.

PROPER HYGIENE

- Do not prepare or store (even temporarily) food or beverages in a chemistry laboratory.
- Never consume any food or beverages when you are in a chemistry laboratory.
- Never wear or take laboratory aprons or laboratory coats into areas where food is consumed.
- Do not chew gum, smoke, or apply cosmetics or lip balm in the laboratory. Be aware that cosmetics, food, and tobacco products in opened packages can absorb chemical vapors.
- Never take your hands or pen to your face or mouth while working in the laboratory.
- Do not handle contact lenses in the laboratory, except to remove them when an emergency requires the use of the eyewash fountain or safety shower.
- Always wash your hands and arms with soap and water before leaving the laboratory, even if you wore gloves.

EMERGENCY PREPAREDNESS

- Become thoroughly acquainted with the location and use of safety equipment and facilities such as exits, evacuation routes, safety showers, eyewash fountains, fire extinguishers, and spill kits.

REFERENCES

[1] Dartmouth Toxic Metals Superfund Research Program. A Tribute to Karen Wetterhahn. www.dartmouth.edu/~toxmetal/about/tribute-to-karen-wetterhahn.html (accessed March 6, 2017).