Chapter 9
Standard Operating Procedures
9. 1 Laboratory Equipment
9.1.1 Glassware
Students in science labs use several types of glassware. In a study of accidents in academic chemistry laboratories, 54% of the accidents examined involved glass beakers, glass tubing, rods or thermometers. 1 The most frequent injurious activity involved assembling equipment, especially inserting glass tubing into rubber stoppers. Cuts and burns from glass are the most common injury in school laboratories. In the 1986 study, 62% of the accidents reported were lacerations and 35% were burns.1 Glassware is used for:
1. measuring volume:
pipets
graduated cylinders
medicine droppers
volumetric flasks
burets
2. storing solids and liquids:
bottles and vials
3. containing reactive chemicals during experiments:
beakers
flasks
test tubes
watch glasses
test plates
stirring rods
4. transferring liquids and gases
glass tubing
funnels
5. measuring temperature
thermometers
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Rules for Using Glassware
Each type of glassware has its proper use and should be used only for its intended purpose. A summary of some rules for using glassware is listed below. More detailed explanations of each rule follow.
Summary of Rules for Using Glassware
1. Use glassware only for its intended use.
2. Use glassware that is without defect.
3. Use proper disposal procedures.
4. Use the correct kind of glass.
5. Use care when working with hot glass.
6. Use glass bottles for storing chemicals that are compatible with the glass.
7. Keep glassware clean.
8. Be careful with glassware that is “frozen.”

9. Use gloves or towels to protect hands when breaking glass tubing. Wear goggles to protect eyes.

Detailed Rules for Using Glassware

1. Use glassware only for its intended use.

For example:

- do not use burets and volumetric flasks to store solutions;
- do not use beakers to measure volume.

2. Use glassware that is without defect.

Glass breaks easily and broken glass has sharp edges. The most common injury involving glass is a cut. Cuts occur when a student is not careful with broken glass or glass breaks as a student is using it. Glassware should have:

- smooth edges. You can smooth edges of glass tubing by fire polishing.
- no cracks or chips. Be particularly watchful for star-cracks in beakers and flasks. These usually appear at the bottom of the flask. Dispose ofcracked glassware properly.

3. Use proper disposal procedures.

- dispose of properly: Do not put broken glass in the general trash barrel or waste basket. Use a thick-walled cardboard, plastic, or ceramic container lined with a very tough plastic bag so custodians can remove the liner without handling the broken glass. Clearly label the container "**BROKEN GLASS ONLY**".
- thick gloves: Wear cut-resistant gloves when handling broken glass or use a broom and dustpan. Do not pick up broken glass in your bare hands.

4. Use the correct kind of glass.

Usually, beakers and flasks are made of borosilicate glass (Pyrex® brand or Kimax® brand), a type of glass that is resistant to breaking when heated or cooled. This is not true for common glass. Common glass breaks easily with thermal shock.

Only use borosilicate glass when heating is required. If you use test tubes, beakers or flasks for heating liquids or solids, make sure the Pyrex® or Kimax® label is on the glassware. Note that test tubes are not always made of borosilicate glass. Do not use bottles, vials, or volumetric flasks for heating.

Remember, however, that borosilicate glass only resists thermal shock. Even a Pyrex® beaker will break if cold water is poured into a hot beaker.

5. Use care when working with hot glass.

Hot glass looks the same as room temperature glass. Therefore, do not leave hot glassware unattended, and allow ample time for the glass to cool before touching.

Check the temperature of the glassware by placing your hand near, but not touching, the potentially hot object. Have hot pads, thick gloves, or beaker tongs available for grasping hot glassware.

6. Use glass bottles for storing chemicals that are compatible with the glass. Most solutions containing water and almost all organic chemicals are compatible with glass. The most common materials used in science labs that are incompatible with glass are solutions of hydroxides and carbonates. These chemicals slowly etch glass. Glass can be used for short-term storage of such chemicals, but plastic containers should be used for longer storage. The tops for reagent bottles containing corrosive chemicals should be plastic.

7. Keep glassware clean.

- Clean immediately after use. The longer glassware sits, the harder it is to clean.
- Use detergent (such as dishwashing powder for dishwashers) to help in cleaning. Be sure to rinse the glassware well. It is good practice to rinse the glassware with distilled water and then let it drain to dry.
- Chromate solutions are dangerous to use and harmful to pour down the sink. Under no circumstances should chromate solutions be used in schools.
- If you use brushes for cleaning glassware, make sure the metal part of the brush does not scratch the glass.
- Ultrasonic cleaners can often help clean dirt out of small crevices.

8. Be careful with glassware that is "frozen".

Here are some common situations of "frozen" glassware:

- nested beakers that have jammed together
- stoppers that cannot be removed from bottles
- stopcocks that cannot be moved

Only teachers should try to release the frozen area. Teachers should use gloves and goggles while doing so. Heating the outside glass and letting paraffin run between the frozen parts will sometimes help free stoppers from bottles. Frozen nested beakers can be released by carefully squeezing the largest beaker on the side perpendicular to the lip of the inner beaker. If all else fails, discard it.

9. Use gloves or toweling to protect hands when breaking glass tubing. Wear goggles to protect eyes.

Learn the proper technique for breaking tubing. Always fire-polish the ends before using.

- Scratch the glass with a file or score.
- Wrap the glass in a towel.
- Place the thumbs together opposite the scratch.
- Pull and bend in one quick motion.
- Fire polish the broken ends.

9.1.2 Corks and Stoppers

Corks and rubber stoppers are commonly used to seal glassware. Use corks for sealing organic solvents and rubber stoppers for sealing aqueous solutions. Often thermometers and glass tubing are inserted through the cork or stopper. In schools, only teachers should do this and then with great caution. Dreadful accidents can occur when students either insert or remove tubing or thermometers from stoppers, and the tubing or thermometer breaks.

To insert glass tubing or a thermometer into a cork or stopper:

- protect your hands with leather gloves;
- check that the hole is the correct size;
- lubricate the hole before inserting thermometers or tubing. Use glycerin or soapy water;
- hold the glass close to the stopper and keep this distance short;
- use a rotary motion to guide the glass through the stopper;
- remove thermometers immediately after use. If they are difficult to remove, carefully cut away the cork or stopper.

9.1.3 Thermometers

Most students have experience with fever thermometers, not laboratory thermometers. As a result, someone will try to "shake it down" before using. Students must be told specifically not to do this. There are a variety of ways to measure temperature, including: thermometers, thermocouples, resistance thermometers. Consider using resistance thermometers (thermal probes) as an alternative to glass thermometers. Many of these can be interfaced easily to computers or pH meters. Alcohol thermometers are **strongly** recommended in place of mercury thermometers for many school experiments. If mercury thermometers are used for their greater accuracy, Teflon® coated thermometers are available. Consider purchasing antiroll thermometers.

Rules for Using Thermometers

- Do not use thermometers as a stirring device.
- Never swing or shake down a thermometer.
- Never use an open flame on a thermometer bulb.
- Use extreme care when inserting or removing a thermometer from a rubber stopper.
- Mercury thermometers should not be used in heated ovens where breakage might easily occur. If thermometers are broken, the mercury is difficult to clean from the ovens, and the elevated temperatures can produce significant mercury vapors. Metalstemmed thermometers should be substituted.

9.1.4 Mercury Handling

Mercury vaporizes rapidly, is readily absorbed, is very poisonous, and is difficult to clean up. **Minimize or even avoid the use of mercury in school laboratories**. Do not do the old Torricelli experiment of making your own barometer. Do not let students make silver coins by placing them in mercury. Do not do experiments with mercury salts. None of these are worth the risks. If you use mercury for any purpose, you should have a spill kit available. These can be purchased from lab safety suppliers. The common practice of using powdered sulfur to pick up mercury dropletts is not reliable. Powdered zinc can be used to dust surfaces, but the mercury sponge available in kits is best.

9.1.5 Pipetting

Pipets are convenient for measuring and dispensing volumes of liquids and come in a variety of types and sizes. These include:

Use volumetric and graduated pipets that are designed to deliver . They will be stamped with a TD label on the stem Since pipets look a lot like straws, student have a tendency to try to use them likestraws. Therefore strict rules are necessary:

- **volumetric pipets** (a) — pipets that dispense a fixed volume of liquid
- **graduated pipets** (b) — pipets with graduations along the side. These dispense a variable amount of liquid. Graduated pipets are available in glass or plastic.
- **Pasteur pipets** (c) — disposable glass or plastic pipets for measuring drops (an eye dropper is a variety of Pasteur pipet). The plastic sealed eye droppers are particularly nice to use in school settings partly for safety reasons and partly because they have interesting uses in microscale chemistry.

Using a Pipet

(a) (b)

- Never put a pipet in your mouth.

- Draw the liquid into the pipet using a rubber bulb. For volumetric or graduated pipets, use a rubber bulb that creates only temporary contact with the opening of the pipet to create a suction that draws the liquid into the pipet (a).
- Remove the bulb and place your index finger over the pipet opening to stop the flow of liquid (b).
- Carefully raise your finger slightly to allow the pipet to drain under your control.
- Never withdraw a liquid from a near-empty container. If you attempt to fill a pipet under conditions where air can enter the pipet, the liquid will shoot up into the rubber bulb uncontrollably.
- Never lay a pipet flat on a table or turn upside down with the rubber bulb attached. The liquid will flow into the rubber bulb, contaminating the bulb and the pipet.
- Dispose of broken glass pipets in an appropriate glass-disposal box

9.1.6 Heat Sources

The Bunsen burner is being replaced in many school labs. Hot plates are a much better substitute for providing heat. Alcohol burners are dangerous and should be used only if no other source is available.

Using an Electric Hot Plate

- Use a smooth surface hot plate
- Cover the surface with aluminum foil for easy cleaning
- Hot plates look the same hot as cool. Always assume they are hot.

9.1.7 Dispensing Chemicals

Material Safety Data Sheets (MSDSs) are the most complete sources of information about the physical and chemical properties, the health and fire hazards, spill procedures, handling procedures, and first aid for any substance (section 4.1.6). No chemical should be used or handled until the label and MSDS have been read and understood. **The teacher has the responsibility for instructing students about safe methods for working with chemicals**.

- Use the smallest amount of chemical possible in any experiment. Microscale is a method of reducing the amount of chemicals used in an experiment. It is safer, it is economical, it produces less waste and requires less storage space. Even if you do not use microscale, try to use smaller quantities (section 4.1.1)..

Using a Bunsen burner

- Make sure you know the location of the master gas shutoff valve.
- Match the type of burner to the type of gas available.
- Use lighters. They are safer than matches for lighting burners.
- Make sure all students know how to operate the burner safely.
- Make sure there are no leaks in rubber hoses connecting the source to the burner.
- Keep rubber hoses away from the flame.

- Consider having the instructor dispense the amount of chemical for an experiment into vials for each student. This will minimize waste and save time during the class period. The best practice for weighing samples is to weigh a vial containing the chemical, pour the sample from the vial into a reaction vessel, then reweigh the bottle. When students weigh chemicals directly on balances, it wastes time and causes cleanup problems.

- Use proper containers for dispensing solids and liquids. Solids should be contained in wide-mouth bottles and liquids in containers that have dripproof lips. The containers should be labeled properly. Student should be taught to remove glass stoppers with the backs of their hands, hold the bottle with the label in their palms, and clean up any spills.

- Do not return dispensed chemicals to stock bottles. This invites contamination despite your best precautions.

9.1.8 Vacuum

The dangers of systems under vacuum are similar to those under excessive pressure. (The destruction created by a tornado is really due to vacuum) Containers that have been evacuated will implode rather than explode. Since a vacuum is more commonly created in glass containers, the implosion hazard creates the possibility of flying glass. We create vacuum in the lab with pumps and aspirators. We can also create vacuums (either intentionally or accidentally) by condensing vapors in a closed system. The familiar demonstration of crushing a soda can by heating water in the can to change it to steam and then cooling the can after sealing the top is a dramatic example of the effects of a vacuum.

- Place guards around glass containers in which a vacuum might be created. Plastic electrical tape works well. Do not tape vacuum equipment so thoroughly that impairs visibility. If a container is repeatedly used to contain a vacuum (like a vacuum desiccator), you may purchase an appropriate shield.

- Always design a relief system into vacuum systems. This can often be a stopcock or an unused Bunsen burner, something that slowly bleeds air into a system under vacuum.

- Avoid reactions or experimental procedures in closed systems For example, make sure that distillation setups have some part that is open to the air or to a vacuum relief system.

- Properly handle and maintain vacuum pumps
  - Change the oil on a regular basis
  - Always have a trap attached
  - Have belt guards around belts and pulleys

9.1.9 Centrifuges

Centrifuges can be dangerous because the rotor develops considerable force.

- Make sure the centrifuge operates vibration-free up to the top speed.
- Position test tubes opposite each other with the same weight of material in each tube. Out of balance centrifuges can “walk” off the table.
- Never leave a centrifuge running unattended.
- Keep rotors and buckets clean.
- Do not try to stop the centrifuge by grabbing it. Make sure the centrifuge is completely stopped before removing tubes from it.

9.1.10 Cryogenics

Working with dry ice and liquid nitrogen can be educational, but both are dangerous and should be handled only by the teacher. Liquid nitrogen requires special flasks for storage. These will break easily if handled carelessly. Use goggles at a minimum (complete face shield is better), thick gloves, and long sleeves when working with either of these substances. It is very important that students observing demonstrations with cryogenics have eye protection and be seated at a safe distance from the demonstration.

9.1.11 Compressed Gases

Compressing a gas allows a lot of matter to exist in a small container. When compressed, a normally safe gas (like nitrogen or air) becomes a great safety risk. **A gas cylinder could behave like a bullet if improperly handled!**

- Have available proper carts for transporting cylinders. Do not roll large cylinders around.

- Use the proper tank and fittings designed for each gas. Your gas supplier will be able to help you with this.

- Always use compressed gases in a well-ventilated area. Asphyxiation is the most subtle danger of working with compressed gases. You should anticipate that leaks will occur and that the release of any gas in an enclosed space will lower the amount of available oxygen in the air. Special dangers are possible if flammable or toxic gases are used.

- Always make tanks secure. No compressed gas tank should be allowed to stand free. Strap or tightly chain full or empty tanks to rigid support to prevent accidental toppling of the tank.

- Keep electrical lines free from compressed gas tanks.

- Keep gas tanks away from heat sources.

9.1.12 Batteries and Electrical Equipment

Use low current, low voltage sources whenever possible. Alkaline or dry cell batteries are safest for use in the classroom.

- Avoid lead storage batteries since they contain concentrated sulfuric acid and can emit explosive hydrogen gas when recharged.
- Dispose of all spent and leaking batteries properly.
- Do not try to recharge batteries unless they are specifically designed for recharge.
- Do not try to heat a battery.
- Store batteries in a refrigerator.
- Avoid using apparatus (such as a conductivity tester) that connect directly into the 110v line.
- Ground all electrical outlets. Consider having a qualified electrician check the circuits. Any outlet within 6 feet of a water source should be equipped with a ground fault interrupter.
- Provide every science classroom with a master shut-off switch for electricity
- Label all live switches and circuits clearly.

• Make sure students' hands and work areas are dry before letting them use electrical devices.
• Check all circuits before the power is turned on.
• Connect the live portion last and disconnect it first when assembling circuits.
• ground all electrical equipment.
• Avoid using extension cords.
• Tape cords to table legs if possible. This will help absorb the force of a pull in case a person trips over the cord.
• Inspect equipment regularly for wear and damage.
• Stop using any electrical equipment that is working erratically.

9.1.13 Lasers

Many types of lasers are available including ones that are sold as pointers. The high intensity beam of a laser is especially harmful to eyes. When using a laser:

- make sure you read the safety rules and operating instructions for the laser you are using;
- use laser goggles;
- make sure that the laser beam is never pointed at anyone;
- check your experimental setup by marking the paths of intense laser light;
- anticipate and examine projected light paths before adding or removing optical components;
- remove all reflective jewelry before working with lasers;
- never view either the direct or reflected beams;
- keep the laser beam at or below chest height;
- never leave the laser unattended;
- block off the beam past the target.

9.2 Safety Committees and Inspections

A safety committee should be instituted for each school and should include faculty, school nurse, administrators, and students. Custodians and faculty from fine arts and industrial arts programs should be included.The committee would be responsible for formulating and assessing compliance with safety regulations. The responsibilities of the safety committee are to:

- encourage safe practice throughout the school;
- know proper emergency responses;
- collect and maintain material safety data sheets and a safety library;
- conduct safety audits and regular inspections of laboratories to make sure safety equipment is present and is maintained, including flushing eye wash stations and checking fire extinguishers;
- verify whether or not rules and procedures are being followed;
- act as a clearing center for reporting dangerous activities or situations;
- enforce proper storage and handling of hazardous materials.

9.3 References

1. Hellmann, M. A., Savage, E. P., Keefe, T. J. 1986. Epidemiology of Accidents in Academic Chemistry Laboratories. *J. Chem. Educ.* 63:A267-70; A290-293