Safety in the Chemistry Laboratory

Introduction

Chemistry is an experimental science. You cannot learn chemistry without getting your hands dirty. Any beginning chemistry student faces the prospect of laboratory work with some apprehension. It would be untruthful to say that there is no element of risk in a chemistry lab. *Chemicals can be dangerous.* The more you study chemistry, the larger the risk will become. However, if you approach your laboratory work calmly and studiously, you will minimize the risks.

During the first laboratory meeting, you should ask your instructor for a brief tour of the laboratory room. Ask him or her to point out for you the locations of the various pieces of emergency apparatus provided by your college or university. At your bench, construct a map of the laboratory, noting the location of the exits from the laboratory and the location of all safety equipment. Close your eyes, and test whether you can locate the exits and safety equipment from memory. A brief discussion of the major safety apparatus and safety procedures follows. A Safety Quiz is provided at the end of this section to test your comprehension and appreciation of this material. For additional information on safety in your particular laboratory, consult with your laboratory instructor or course professor.

Protection for the Eyes

Government regulations, as well as common sense, demand the wearing of protective eyeware while you are in the laboratory. Such eyeware must be worn even if you personally are not working on an experiment. Figure 1 shows one common form of plastic **safety goggle.**

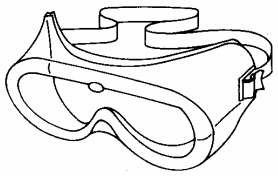

Figure 1. A typical plastic student safety goggle.

Although you may not use the particular type of goggle shown in the figure, your eyeware must include shatterproof lenses and side shields that will protect you from splashes. *Safety glasses must be worn at all times while you are in the laboratory.* Failure to wear safety glasses may result in your being failed or withdrawn from your chemistry course, or in some other disciplinary action being taken.

In addition to protective goggles, an **eyewash fountain** provides eye protection in the laboratory. Should a chemical splash near your eyes, you should use the eyewash fountain before the material has a chance to run in behind your safety glasses. A typical eyewash fountain is indicated in Figure 2:

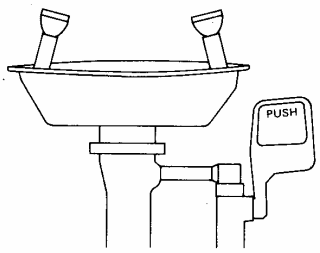

Figure 2. Laboratory emergency eyewash fountain.

The eyewash has a panic bar that enables the eyewash to be activated easily in an emergency. If you need the eyewash, don't be modest—*use it immediately.* It is critical that you protect your eyes properly.

Protection from Fire

The danger of uncontrolled fire in the chemistry laboratory is very real, since the lab typically has a fairly large number of flammable liquids in it, and open-flame gas burners are generally used for heating (see page xxiv for proper use of the gas burner). With careful attention, however, the danger of fire can be reduced considerably.

Always check around the lab before lighting a gas burner to ensure that no one is pouring or using any flammable liquids. Be especially aware that the vapors of most flammable liquids are heavier than air and tend to concentrate in sinks (where they may have been poured) and at floor level. Since your laboratory may be used by other classes, always check with your instructor before beginning to use gas burners.

The method used to fight fires that occur in spite of precautions being taken depends on the size of the fire and on the substance that is burning. If only a few drops of flammable liquid have been accidentally ignited, and no other reservoir of flammable liquid is nearby, the fire can usually be put out by covering it with a beaker. This deprives the fire of oxygen and will usually extinguish the fire in a few minutes. Leave the beaker in place for several minutes to ensure that the flammable material has cooled and will not flare up again.

In the unlikely event that a larger chemical fire occurs, carbon dioxide **fire extinguishers** are available in the lab (usually mounted near one of the exits from the room). An example of a typical carbon dioxide fire extinguisher is shown in Figure 3. Before activating the extinguisher, pull the metal safety ring from the handle. Direct the output from the extinguisher at the base of the flames. The carbon dioxide not only smothers the flames, it also cools the flammable material quickly. If it becomes necessary to use the fire extinguisher, be sure afterward to turn the extinguisher in at the stockroom so

that it can be refilled immediately. If the carbon dioxide extinguisher does not immediately put down the fire, evacuate the laboratory and call the fire department. Carbon dioxide fire extinguishers must *not* be used on fires involving magnesium or certain other reactive metals, since carbon dioxide may react vigorously with the burning metal and make the fire worse.

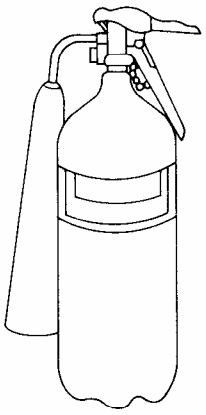

Figure 3. A typical carbon dioxide fire extinguisher. Pull the metal ring to activate the extinguisher.

One of the most frightening and potentially tragic accidents is the igniting of a person's clothing. For this reason, certain types of clothing are *not appropriate* for the laboratory and must not be worn. Since sleeves are most likely to come in closest proximity to flames, any garment that has bulky or loose sleeves should not be worn in the laboratory. Certain fabrics should also be avoided; such substances as silk and certain synthetic materials may be highly flammable. Ideally, students should wear laboratory coats with tightly fitting sleeves made specifically for the chemistry laboratory. This clothing may be required by your particular college or university. Long hair also presents a clear danger, if it is allowed to hang loosely in the vicinity of the flame. Long hair must be pinned back or held with a rubber band.

In the unlikely event a student's clothing or hair is ignited, his or her neighbors must take prompt action to prevent severe burns. Most laboratories have two options for extinguishing such fires: the **water shower** and the **fire blanket**. Figure 4 shows a typical laboratory emergency water shower.

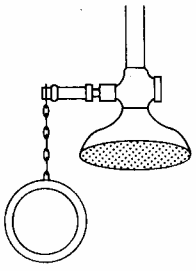

Figure 4. Laboratory emergency shower. Use the shower to extinguish clothing fires and in the event of a large-scale chemical spill.

Showers such as this generally are mounted near the exits from the laboratory. In the event someone's clothing or hair is on fire, *immediately* push or drag the person to

the shower and pull the metal ring of the shower. Safety showers generally dump 40–50 gallons of water, which should extinguish the flames. Be aware that the showers cannot be shut off once the metal ring has been pulled. For this reason, the shower cannot be demonstrated. (But note that the showers are checked for correct operation on a regular basis.) Figure 5 shows the other possible apparatus for extinguishing clothing fires, the fire blanket.

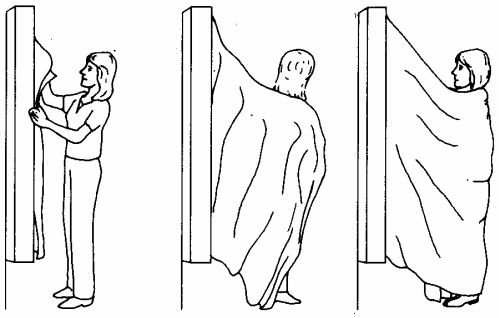

Figure 5. Fire blanket. The blanket is wrapped around the body to smother flames.

The fire blanket is intended to smother flames. Since it must be operated by the person suffering the clothing fire (he or she pulls the handle of the fire blanket and wraps it around himself or herself), it is therefore not the preferred method of dealing with such an event.

Protection from Chemical Burns

Most acids, alkali, oxidizing, and reducing agents must be assumed to be corrosive to skin. It is impossible to avoid these substances completely, since many of them form the backbone of the study of chemistry. Usually, a material's corrosiveness is proportional to its concentration. Most of the experiments in this manual have been set up to use as dilute a mixture of reagents as possible, but this does not entirely remove the problem. Make it a personal rule to *wash your hands regularly* after using any chemical substance and to wash immediately, with plenty of water, if any chemical substance is spilled on the skin.

After working with a substance known to be particularly corrosive, you should wash your hands immediately even if you did not spill the substance. Someone else using the bottle of reagent may have spilled the substance on the side of the bottle. It is also good practice to hold a bottle of corrosive substance with a paper towel, or to wear plastic gloves, during pouring. Do not make the mistake of thinking that because an experiment calls for dilute acid, this acid cannot burn your skin. Some of the acids used in the laboratory are not volatile, and as water evaporates from a spill, the acid becomes concentrated enough to damage skin. Whenever a corrosive substance is spilled on the skin, you should inform the instructor immediately. If there is any sign whatsoever of

damage to the skin, you will be sent to your college's health services for evaluation by a physician.

In the event of a major chemical spill, in which substantial portions of the body or clothing are affected, you must use the emergency water shower. Forget about modesty, and get under the shower immediately.

Protection from Toxic Fumes

Many volatile substances have toxic vapors. A rule of thumb for the chemistry lab is "If you can smell it, it can probably hurt you." Some toxic fumes (such as those of ammonia) can overpower you immediately, whereas other toxic fumes are more insidious. The substance may not have that bad an odor, but its fumes can do severe damage to the respiratory system. There is absolutely no need to expose yourself to toxic fumes. All chemistry laboratories are equipped with **fume exhaust hoods**. A typical hood is indicated in Figure 6.

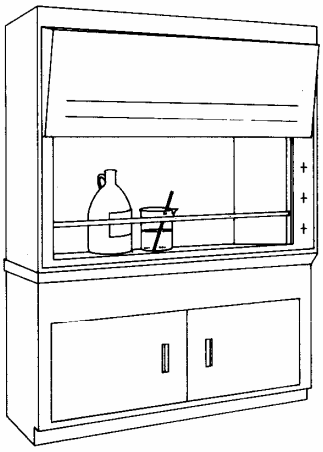

Figure 6. A common type of laboratory fume exhaust hood. Use the hood whenever a reaction involves toxic fumes. Keep the glass door of the hood partially closed to provide for rapid flow of air.

The exhaust hood has fans that draw vapors out of the hood and away from the user. The hood is also used when flammable solvents are required for a given procedure, since the hood will remove the vapors of such solvents from the laboratory and reduce the hazard of fire. The hood is equipped with a safety-glass window that can be used as a shield from reactions that could become too vigorous. Naturally, the number of exhaust hoods available in a particular laboratory is limited, but *never neglect to use the hood if it is called for*, merely to save a few minutes of waiting time. Finally, reagents are sometimes stored in a hood, especially if the reagents evolve toxic fumes. Be sure to return such reagents to the designated hood after use.

Protection from Cuts and Simple Burns

Perhaps the most common injuries to students in the beginning chemistry laboratory are simple cuts and burns. Glass tubing and glass thermometers are used in nearly every experiment and are often not prepared or used properly. The first experiment in this manual describes the correct manner for handling glass tubing; the experiment demonstrates how to cut and polish any sharp ends of glass. Most glass cuts occur when the glass (or thermometer) is being inserted through rubber stoppers in the construction of an apparatus. Use glycerine as a lubricant when inserting glass through rubber (several bottles of glycerine will be provided in your lab). Glycerine is a natural product of human and animal metabolism; it may be applied liberally to any piece of glass. Glycerine is water soluble, and though it is somewhat messy, it washes off easily. You should always remove glycerine before using an apparatus since the glycerine may react with the reagents to be used.

Most simple burns in the laboratory occur when a student forgets that an apparatus may be hot and touches it. Never touch an apparatus that has been heated until it has cooled for at least five minutes, or unless specific tongs for the apparatus are available.

Report any cuts or burns, no matter how apparently minor, to the instructor immediately. If there is any visible damage to the skin, you will be sent to your college's health services for immediate evaluation by a physician. What may seem like a scratch may be adversely affected by chemical reagents or may become infected; therefore, it must be attended to by trained personnel.

Proper Use of the Laboratory Burner

The laboratory burner is the most commonly used apparatus in the general chemistry laboratory, and may pose a major hazard if not used correctly and efficiently.

The typical laboratory burner is correctly called a **Tirrel burner** (though the term Bunsen burner is often used in a generic sense). A representation of a Tirrel burner is indicated in Figure 7. Compare the burner you will be using with the burner shown in the figure, and consult with your instructor if there seems to be any difference in construction. Burners from different manufacturers may differ slightly in appearance and operation from the one shown in the illustration.

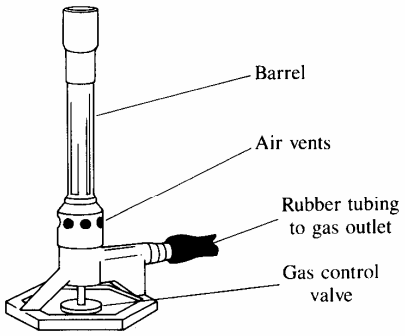

Figure 7. A Tirrel burner of the sort most commonly found in student laboratories. Compare this burner with the one you will use for any differences in construction or operation.

Most laboratories are supplied with natural gas, which consists primarily of the hydrocarbon methane (CH_4). If your college or university is some distance from natural

gas lines, your laboratory may be equipped with bottled gas, which consists mostly of the hydrocarbon propane (C_3H_8). In this case, your burner may have modifications to allow the efficient burning of propane.

A length of thin-walled rubber tubing should attach your burner to the gas main jet. If your burner has a screw-valve on the bottom for controlling the flow of gas, the valve should be closed (by turning in a right-hand direction) before you light the burner. The barrel of the burner should be rotated to close the air vents (or slide the air vent cover over the vent holes if your burner has this construction).

To light the burner, turn the gas main jet to the open position. If your burner has a screw-valve on the bottom, open this valve until you hear the hiss of gas. Without delay, use your striker or a match to light the burner. If the burner does not light on the first attempt, shut off the gas main jet, and make sure that all rubber tubing connections are tight. Then reattempt to light the burner. You may have to increase the flow of gas, using the screw-valve on the bottom of the burner.

After lighting the burner, the flame is likely to be yellow and very unstable (easily blown about by any drafts in the lab). The flame at this point is relatively cool (the gas is barely burning) and would be very inefficient in heating. To make the flame hotter and more stable, open the air vents on the barrel of the burner slowly to allow oxygen to mix with the gas before combustion. This should cause the flame's size to decrease and its color to change. A proper mixture of air and gas gives a pale blue flame, with a bright blue cone-shaped region in the center. The hottest part of the flame is directly above the tip of the bright blue cone. Whenever an item is to be heated strongly, it should be positioned directly above this bright blue cone. You should practice adjusting the flame to get the ideal pale blue flame with its blue inner cone, using the control valve on the bottom of the burner or the gas main jet.

Protection from Apparatus Accidents

An improperly constructed apparatus can create a major hazard in the laboratory, not only to the person using the apparatus, but to his or her neighbors as well. Any apparatus you set up should be constructed exactly as indicated in this manual. If you have any question as to whether you have set up the apparatus correctly, ask your instructor to check the apparatus before you begin the experiment.

Perhaps the most common apparatus accident in the lab is the tipping over of a flask or beaker while it is being heated or otherwise manipulated. All flasks should be *clamped securely* with an adjustable clamp to a ring support. This is indicated in Figure 8. Be aware that a vacuum flask is almost guaranteed to tip over during suction filtration if it is not clamped. This will result in loss of the crystals being filtered and will require that you begin the experiment again.

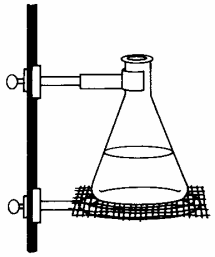

Figure 8. One method of supporting a flask. Be sure to clamp all glassware securely to a ring stand before using.

An all-too-common lab accident occurs when a liquid must be heated to boiling in a test tube. Test tubes hold only a few milliliters of liquid and require only a few seconds of heating to reach the boiling point. A test tube cannot be heated strongly in the direct full heat of the burner flame. The contents of the test tube will super-heat and blow out of the test tube like a bullet from a gun. Ideally, when a test tube requires heating, a **boiling water bath** in a beaker should be used. If this is not possible, then hold the test tube at a 45° angle a few inches above the flame and heat only *briefly*, keeping the test tube moving constantly (from top to bottom, and from side to side) through the flame during the heating. *Aim the mouth of the test tube away from yourself and your neighbors.* See Figure 9.

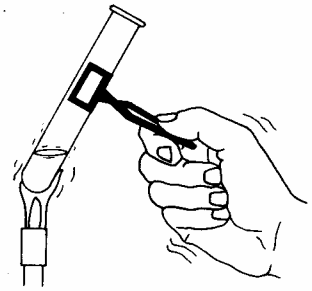

Figure 9. Method for heating a test tube containing a small quantity of liquid. Heat only for a few seconds, and aim the mouth of the test tube away from you and your neighbors.

Safety Regulations

- Wear safety glasses at all times while in the laboratory.
- Do not wear short skirts, shorts, and bare-midriff shirts in the laboratory.
- Do not wear scarves and neckties in the lab, as they may be ignited accidentally in the burner flame.
- Men who have long beards must secure them away from the burner flame.
- Open-toed shoes and sandals, as well as thin canvas sneakers, are not permitted in the laboratory.
- Never leave Bunsen burners unattended when lighted.
- Never heat solutions to dryness unless this is done in an evaporating dish on a hotplate or over a boiling water bath.
- Never heat a "closed system" such as a stoppered flask.
- Never smoke, chew gum, eat or drink in the laboratory, since you may inadvertently ingest some chemical substance.
- Always use the smallest amount of substance required for an experiment; more is never better in chemistry. Never return unused portions of a reagent to their original bottle.
- Never store chemicals in your laboratory locker unless you are specifically directed to do so by the instructor.
- Never remove any chemical substance from the laboratory. In many colleges, removal of chemicals from the laboratory is grounds for expulsion or other severe disciplinary action.
- Keep your work area clean, and help keep the common areas of the laboratory clean. If you spill something in a common area, remember that this substance may injure someone else.
- Never fully inhale the vapors of any substance. Waft a tiny amount of vapor toward your nose.
- To heat liquids, always add 2–3 boiling stones to make the boiling action smoother.
- Never add water to a concentrated reagent when diluting the reagent. Always add the reagent to the water. If water is added to a concentrated reagent, local heating and density effects may cause the water to be splashed back.
- Never work in the laboratory unless the instructor is present. If no instructor is present during your assigned work time, report this to the senior faculty member in charge of your course.
- Never perform any experiment that is not specifically authorized by your instructor. Do not play games with chemicals!
- Dispose of all reaction products as directed by the instructor. In particular, observe the special disposal techniques necessary for flammable or toxic substances.
- Dispose of all glass products in the special container provided.

Many of the pre-laboratory assignments in this manual require that you use several chemical handbooks available in any scientific library to look up various data for the substances you will be working with. You should also use such handbooks as a source of information about the hazards associated with the substances and procedures you will be using. A particularly useful general reference is the booklet *Safety in Academic Laboratories*, published by the American Chemical Society (your course professor or laboratory instructor may have copies).

Each of the experiments in this manual includes a section titled *Safety Precautions,* which gives important information about expected hazards. This manual also lists some of the hazards associated with common chemical substances in Appendix J. Such problems as flammability and toxicity are described in terms of a low/medium/high rating scale. If you have any questions about this material, consult with your instructor before the laboratory period.

You may now be even more hesitant about facing your chemistry laboratory experience, now that you have read all these warnings. Be cautious . . . be careful . . . be thoughtful . . . but do *not* be afraid. Every precaution will be taken by your instructor and your college or university for your protection. Realize, however, that *you* bear ultimate responsibility for safety in the laboratory.