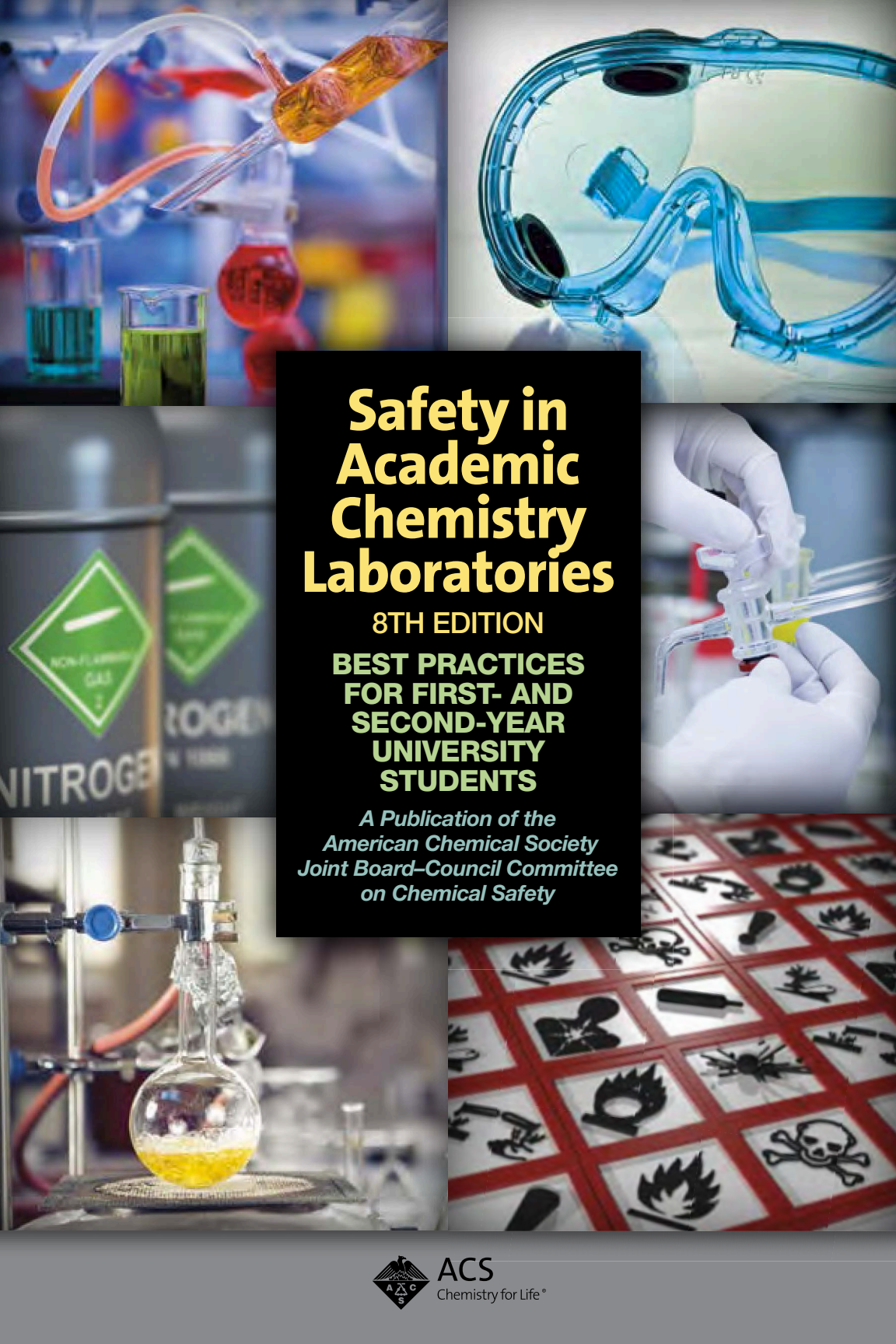


Safety in Academic Chemistry Laboratories

8TH EDITION

BEST PRACTICES FOR FIRST- AND SECOND-YEAR UNIVERSITY STUDENTS

A Publication of the American Chemical Society Joint Board–Council Committee on Chemical Safety

ACS Chemistry for Life®

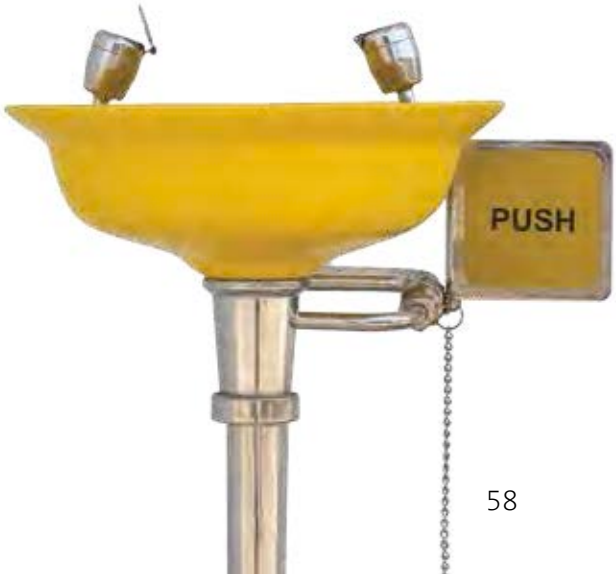
CHAPTER 5

Safety Equipment and Emergency Response

Introduction

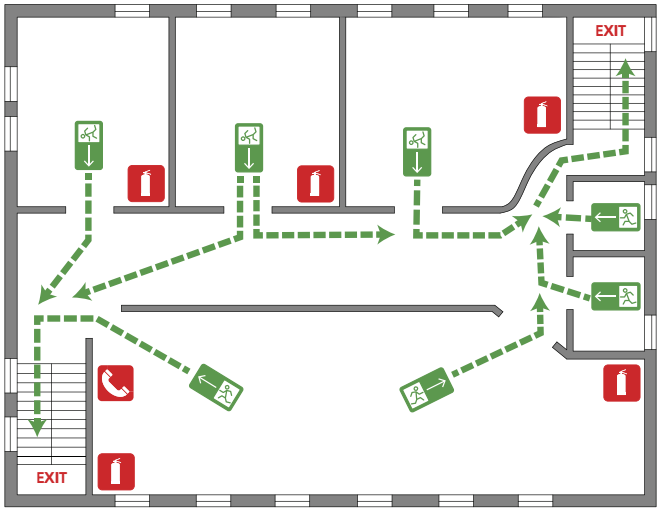
Although the laboratory is designed to be a place for learning and skill development, it is important to prepare to respond appropriately to unexpected events. Even when recognized hazards are appropriately managed, incidents may occur. In an academic setting, the instructor's responsibility to respond to an incident is certainly greater than the student's, but the intent of this chapter is to help you prepare for the unexpected as a student and later as a scientist. With this in mind, always follow the directions of your instructor and the policies of your institution.

In previous chapters, you have learned about the first three principles of RAMP: Recognize the hazards, Assess the risks of hazards, and Minimize the risks of hazards. The first three principles of RAMP will reduce incidents and help to avoid emergencies but may not prevent them entirely. The fourth part of RAMP is Prepare for emergencies.



This chapter covers how to ***prevent incidents from occurring and prepare to respond*** to unexpected emergencies. You are more likely to remain calm and respond appropriately to an emergency if you have put some effort into thinking about potential incidents and your response. In introductory laboratories, the most common emergencies that you may need to respond to involve spills, fires, cuts, and/or burns.

Evacuation Route Example



As you begin to think about how you might respond to an emergency, take a moment to look around the laboratory when you first enter to identify safety equipment, signs, fire alarms, and exits. Some of the items you can locate include a fire extinguisher, safety shower, eyewash station, evacuation signage, emergency gas shutoff (if accessible), first aid kit, and fire blanket. If your laboratory is equipped with more than one of each of these items, note the location of those closest to you. Some of this safety equipment, such as fire extinguishers and eyewash stations, is tested periodically and will have a tag including the date that testing is due. Although it is not your responsibility to inspect this safety equipment, notify your instructor if you notice that any of the equipment is overdue for inspection or if access is blocked.

It is likely that your instructor will be the first to respond to a laboratory incident. However, your instructor may be momentarily away, working with another student, or farther away from the incident, and you will need to respond quickly. While preparing to respond to an emergency, remember that the primary goal is to protect human life and minimize injury. Never put yourself in danger. The second goal is to minimize damage to structures or equipment. You should follow the emergency procedures established by your institution under the direction of your instructor.

In certain situations, you may be the only person who can respond. Before you attempt to help another person, assess the current situation and evaluate the potential risks to yourself. You cannot help another person if you are injured in the process. In general, the emergency

Combustible or Flammable?

These terms are often used interchangeably in everyday conversations. Many dictionaries use these terms to define each other. The following is typical (and not very useful): "Combustible: flammable; capable of combustion."

When these terms are used to describe the fire risk associated with organic solvents, the National Fire Protection Association (NFPA) and the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) use two criteria that affect the fire risk present when using a solvent: the flash point and the boiling point. The flash point of a volatile solvent is the minimum temperature at which sufficient vapor is given off from the liquid surface to form an ignitable mixture with air.

Unfortunately, the NFPA and the GHS define slightly different criteria for "flammable" and "combustible", but the general difference is that flammable liquids ignite and burn at normal temperatures and combustible liquids burn at higher temperatures. Flammable liquids generally present a greater hazard in the laboratory. Combustible liquids may or may not continue to burn when the ignition source is removed.

In both the NFPA system and the GHS, there are additional criteria defining these terms for gases and solids. In all cases, combustible and flammable materials will add fuel to a fire, and appropriate precautions must be taken in the laboratory.

procedure that you may need to follow will depend on the type of immediate danger and injuries sustained, but may include elements of the following steps.

- Determine whether you and others need to leave the area immediately or whether there is something you can safely do to minimize injury and damage (see later sections).
- Report the nature and location of the emergency to your instructor or, if necessary, call 911 (or your institution's emergency number) to contact the appropriate fire or medical assistance. Be prepared to answer questions from the dispatcher, such as your name, the location, and the nature of the incident. It may be necessary to send someone to meet the ambulance or fire crew at the building entrance, because these crews may not be familiar with your building.
- Notify others in the area about the nature of the emergency, and call the security office on your campus.
- Do not move injured individuals unless they are in immediate danger from chemical exposure or fire. Keep them warm. Unnecessary movement can severely complicate neck injuries and fractures.

Fires

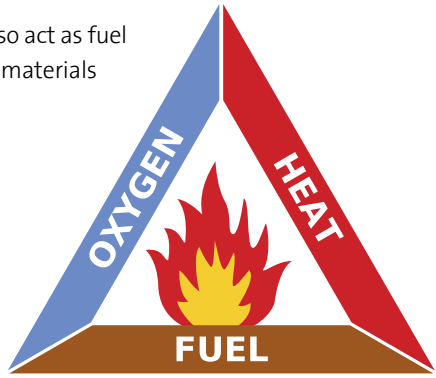
Fire Prevention

The best way to fight a fire is to prevent it. Think about fire prevention using the principles of RAMP.

- Are you working with any source of heat, flame, or spark?
- Are you working with flammable liquids or vapors?
- Are there any damaged wires on the electrical equipment?
- Are bottles or glassware (containing flammable solvents) too close to the edge of the laboratory bench?
- Is the workspace cluttered?

When you are using a flammable liquid, minimize the quantity in your workspace by dispensing only the quantity required by the experimental procedure and returning the reagent bottle to its proper storage location immediately after dispensing the material. Excess flammable material in the immediate work area will act as an additional fuel source in a fire. You should also keep combustible materials, such as paper, away from areas where experiments are being performed with flammable chemicals.

In the event of a fire, combustible materials will also act as fuel to keep the fire burning. NEVER store combustible materials on top of a flammable cabinet.



When heating flammable solvents, it is important to avoid the presence of ignition sources. An open flame should never be used for heating a flammable solvent. Electrical hot plates are safer, but electrical equipment can often generate a small spark when it cycles on and off. This spark can start a fire if sufficient vapor from a solvent is present. Some electrical equipment is designed to be "intrinsically safe", which means that it is designed to prevent such sparks, but this is not the common situation in most laboratories. Thus, it is important to avoid the possibility of flammable vapors when heating solvents, which generally requires that this process be done in a hood. If any electrical equipment is sparking or has frayed wires, turn it off immediately and inform your instructor.

Good housekeeping habits will go a long way to preventing incidents and minimizing the effects if an incident occurs. Although it is primarily the instructor's role to regularly inspect electrical cords on equipment and to make sure that aisles and exits are clear, learning to survey the "scene" or area is a good habit for you to develop. Even when risk is managed well, an emergency situation may still arise in an academic laboratory with many students present. It may be that you find yourself responding to a situation that you did not cause.

Prepare to Respond to a Fire

Consider the three components of the fire triangle: heat, fuel (flammable or combustible material), and oxygen (or other oxidizer). All three components must be present for a fire to begin and continue. Removing one of these components will prevent the fire or extinguish one that has started.

If a fire unexpectedly occurs, it could be that a quick response on your part will prevent a small incident from becoming a large incident. You will need to decide whether you should fight the fire or flee to safety, but always follow the directions of your instructor. If you decide to try to put out the fire, you will want to be confident that your actions will not spread the fire or put yourself or others in more danger. It is best practice for your institution to conduct its own fire training as part of the safety training associated with the laboratory. If so, you and your fellow students should know what is expected in a fire emergency and follow these guidelines.

You should never pick up a vessel or piece of equipment that is on fire. The physical act of throwing water on some types of fires may spread the fire. The best method of extinguishing a small laboratory fire is to smother it. Consider taking the following steps only if you are confident that you can do so safely as you prepare to respond to a fire emergency.

Classes of Fires

The National Fire Protection Association (NFPA) identifies four main types of fires:

Class A: *fires involving ordinary combustibles, such as paper, wood, and furniture;*

Class B: *fires involving flammable organic liquids and gases;*

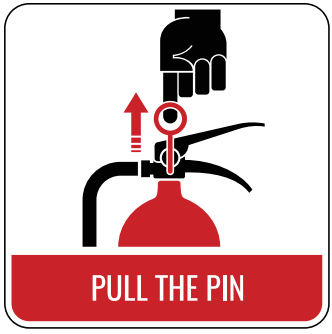
Class C: *fires involving live electricity; and*

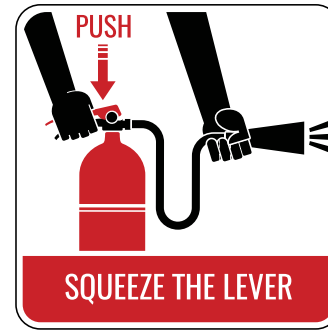
Class D: *fires involving active metals (which usually react with water).*

Most fires are Class A fires. In some chemistry laboratories where organic solvents are used, Class B fires are possible, and common. Some Class A fires are also Class C fires, such as a burning computer. The class of a fire helps to determine what kind of extinguisher to use; in fact, fire extinguishers are commonly labeled as "A", "BC", or "ABC". The fire code requires that portable extinguishers that are made available in hallways (or in laboratories) are the proper type for the most likely kind of fire. Most laboratories have "ABC" extinguishers.

Class D fires are uncommon in most offices and buildings, but they are a possibility in laboratories where active metals are used. Therefore, a Class D extinguisher should be available in laboratories where Class D fires are possible.

- Remove the heat source by turning off the gas supply to a Bunsen burner or unplugging an electric heater.
- A fire contained in a small vessel often can be suffocated by limiting the air/oxygen. For example, a fire in a small beaker or Erlenmeyer flask can be smothered using a noncombustible item, such as a watch glass held in tongs or the flat bottom of a larger beaker.
- NEVER use dry towels or cloths to cover the fire, because these will burn to add fuel. You can use a wetted material if available. To avoid spreading the fire, remove nearby combustible or flammable materials, but only if it is safe to do so.
- If the steps listed above are not practical or do not extinguish the fire, a fire extinguisher may possibly be used to extinguish the fire. If you have been trained in the use of a fire extinguisher or otherwise feel confident using one, position yourself between the fire and an escape route (e.g., a door), and fight the fire from this position to be sure that you can escape. Small fires often can be extinguished, but not always. It is easy to underestimate a fire. If not extinguished, a fire can quickly threaten your life.
- If the fire is burning over an area too large for the fire to be extinguished quickly and simply, everyone should evacuate the area. Pull the fire alarm, and follow the evacuation procedures established by your institution. Once you are safe, make sure that you or someone else calls 911 (or your institution's emergency number) to notify the proper emergency assistance. Although it is difficult to know who is inside a university building when a fire breaks out, it is important to locate other students and faculty outside of the building to let them know that you are safe. Offer assistance to others who may be mobility-impaired, if you are able.





When You Are On Fire

Prepare to Respond to Personal Injuries Involving Fires

If someone's clothing catches on fire, this will be a frightening situation, and the person involved may instinctively run. Running will make the situation worse by fanning the flames, and the heat and gaseous product of combustion are likely to be inhaled for someone who is standing, walking, or running. Firmly tell the person to ***stop, drop, and roll***. This may smother the flames. You can try to extinguish any small, still-burning flames by patting them out with a towel or jacket. After getting the person to lie down, start at the head and the shoulders, and then work downward toward the feet. These recommendations follow the procedures outlined by the National Fire Protection Association (NFPA), which assume that someone is in an ordinary, non-laboratory environment. Another option in the laboratory is to douse the person under a safety shower or with water from a drench hose at a laboratory sink, if these are convenient options. You will have to make a judgment call about the best way that you can help.

Never wrap a standing person in a fire blanket, because this may direct flames and toxic gases to the face area in what is known as the chimney effect. Fire blankets can be used as a modesty curtain while an individual is in the shower, to keep an injured person warm, as a pad to keep the person off the floor, as a wrap if no emergency clothing is available, and as a stretcher. If your institution has fire blankets, you should follow local instructions about how to use them. Get medical attention promptly by calling 911 (or your institution's emergency number). Covering the victim with a blanket or jacket may help to avoid shock and exposure.

Chemical Contamination on Skin, Clothing, and Eyes

Preventing Chemical Contact

Exposure to chemicals can arise from incidental contact with the skin, splashes, and contact with spills. Spills, and how to prevent and respond to them, are discussed below. Chapter 2 covers practical rules for the laboratory to help you to avoid chemical contact, including various forms of personal protective equipment (PPE). You may want to review those practical rules, which can prevent incidents.

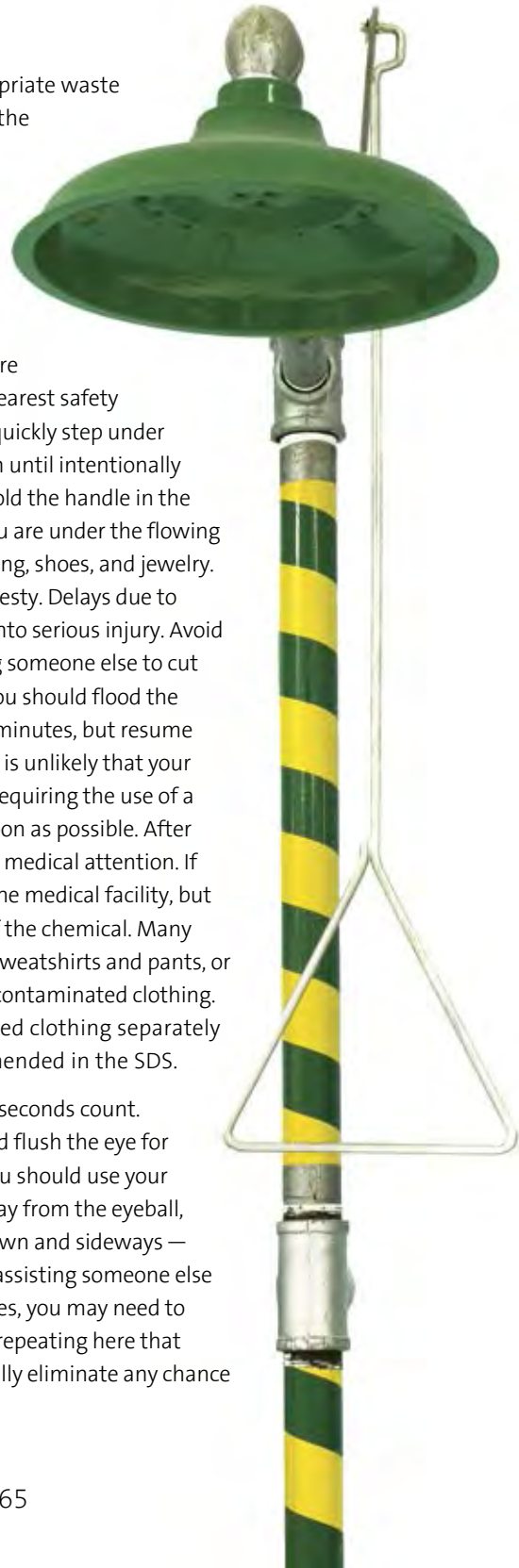
Prepare to Respond to Chemical Contact

Once again, your instructor will likely be present to assist you or another student in the event of an incident. The advice given here is general and will help you to know how to respond to an incident.

For a small liquid spill or splash that affects only a small area of skin, you should immediately flush the skin with flowing water for at least 15 minutes (30 minutes for bases). You should remove any jewelry, to facilitate removal of possible residual liquid between your skin and the jewelry. This is one reason why you are advised not to wear jewelry in the laboratory at all. After the initial rinse with water, wash the entire area of the affected skin with warm water and soap. You or a fellow student should notify your instructor as soon as possible. After rinsing your skin, check the Safety Data Sheet (SDS) to see whether any delayed effects should be expected. It is advisable to seek medical attention for even minor chemical burns. Many institutions will require you to fill out a short initial notification of injury form. This is for your protection should complications develop from an exposure in the laboratory.

If you spill solid chemicals on your skin, it is advisable to brush the solid off before applying water. (A credit card is useful for this procedure.) Brushing off a corrosive solid can usually be done with no adverse consequences, and may actually lessen the exposure by avoiding increased temperature due to an exothermic heat of solution, which is common when water is added. After the material is brushed away from your skin, wash your skin with soap and water and notify your instructor of the incident. The brushed-off

solid should, of course, be put into the appropriate waste container, rather than down the sink or into the regular trash. In the event of contact with an acid, do not put a neutralizing chemical (such as sodium bicarbonate) on your skin. The heat of neutralization can increase an injury.



If your skin or clothing is contaminated with larger spills of a liquid, you may have more serious consequences. You should go to the nearest safety shower immediately, turn on the water, and quickly step under the water spray. Some showers will remain on until intentionally turned off, but others may require that you hold the handle in the "on" position to keep water flowing. While you are under the flowing water, remove all of your contaminated clothing, shoes, and jewelry. Seconds count, so don't waste time with modesty. Delays due to modesty have resulted in exposures turning into serious injury. Avoid contaminating your eyes and face by allowing someone else to cut off a pullover shirt or sweater with scissors. You should flood the affected body area with water for at least 15 minutes, but resume flushing the area with water if pain returns. It is unlikely that your instructor would not be aware of a situation requiring the use of a safety shower, but notify your instructor as soon as possible. After thoroughly flushing the area with water, seek medical attention. If possible, your instructor will take the SDS to the medical facility, but you may be helpful in identifying the name of the chemical. Many institutions will have extra clothing (such as sweatshirts and pants, or hospital scrubs) to immediately replace your contaminated clothing. As indicated in Chapter 2, wash contaminated clothing separately from other clothing or discard it, as recommended in the SDS.

If you are splashed in the eye with chemicals, seconds count. Quickly go to the nearest eyewash station, and flush the eye for at least 15 minutes (30 minutes for bases). You should use your thumb and forefinger to hold your eyelids away from the eyeball, and move your eye continuously — up and down and sideways — to flush the area behind the eyelid. If you are assisting someone else who has had chemicals splashed into their eyes, you may need to lead them to the eyewash station. It is worth repeating here that wearing chemical splash goggles will essentially eliminate any chance of this kind of incident occurring.

If an eyewash fountain is not available, you should use the nearest source of running water and make the water as close to room temperature as you can. Alternatively, you could help an injured person onto their back and pour water gently into the corners of the affected eye for at least 15 minutes. If possible, remove contact lenses. Your instructor should be notified as soon as possible. After flushing the affected eye, seek medical attention. If possible, identify the chemical contaminant, so that your instructor can take a copy of the SDS to the medical facility.

NOTE: Although current best practices call for tepid water to be dispensed from eyewash fountains and safety showers, this is likely not the case everywhere. Should the exposed person start shivering or complain about being too cold, use your best judgment about the rinsing time. You do not want to induce hypothermia in a person with a chemical exposure.

■ IN YOUR FUTURE: Treatment of HF Exposure

As mentioned in Chapter 3, the hazards of hydrofluoric acid (HF) make its use very high-risk. HF exposures are extremely hazardous and require special treatment; a calcium gluconate gel or cream should always be available when using HF. If skin is contaminated with HF, you should apply this gel and immediately seek emergency medical treatment. You should not work with HF without special training and supervision.

Other Personal Injury

Preventing Other Personal Injuries

Other types of personal injuries include slips, trips, falls, electrical shock, chemical ingestion, inhalation, and cuts. You should review the general rules in Chapter 2 and the use of chemical hoods and electrical equipment in Chapter 4 to avoid these incidents.

Prepare to Respond to Other Personal Injury Incidents

Although fires and spills are the most common types of laboratory incidents, you should think about how you would respond to some other possibilities, including chemical inhalation, chemical ingestion, electrical shock, and cuts.

If you or someone else in the laboratory is overcome with smoke, vapors, or fumes, move yourself and others away from the area to fresh air. You should warn other people in the area of the potential for harm, and seek medical assistance immediately. If you suspect that someone has ingested hazardous chemicals, call 911 (or your institution's emergency number) and follow the first aid treatment shown on the label or in the SDS. You may be asked to assist your instructor with first aid treatment. You should never give anything by mouth to an unconscious person. Your instructor will ensure that the medical facility is provided with a copy of the SDS, but you may be needed to identify which chemical is involved.

You should not touch someone who is in contact with a live electrical circuit. The circuit must be disconnected by unplugging the device or turning off the circuit breaker, or you will be shocked too.

If the injured person is not breathing and has no pulse, you should provide cardiopulmonary resuscitation (CPR) if you are trained to do so, or use an automated external defibrillator (AED) if one is available. You should call 911 (or your institution's emergency number) immediately, or tell someone else to do so while you are tending to the victim. Because it is likely in academic laboratories that several people will be present, it is best to have one person call 911 and another person locate a laboratory instructor or other person in authority, call campus security, and assist with CPR.

If you or someone else is bleeding severely, try to control the bleeding by placing a cloth on the wound and applying firm pressure. If possible, elevate the injury above the level of the heart. ***You should take reasonable precautions to avoid contact with someone else's blood.*** There are gloves available in most chemistry laboratories. Except in the case of a trivial wound, wrap the injured person in a blanket or coat to avoid shock and get them immediate medical attention. ***Do not clean up a biological spill that may contain blood-borne pathogens unless you are trained to do so.***

Chemical Spills

Preventing Chemical Spills

Chemical spills are probably the most common laboratory incidents. Good housekeeping habits will help you to avoid spilling chemicals. Keep laboratory items well away from the edge of your laboratory bench or other workspace. You should measure quantities of chemicals according to the laboratory procedure and avoid taking excess chemicals. Return reagent bottles to their proper location once you have procured the minimum amount needed for your experiment. Notify your instructor if you observe obstructions in the aisles or walkways of the laboratory space. Walk slowly and carefully in the laboratory. Rushing may cause you to bump into other students or into cabinets and laboratory furnishings.

If you must transport samples or solutions from one part of the laboratory to another, support the beaker or flask with one hand under the container. Alert others to your presence if needed. The transport of chemicals out of the laboratory to an instrument or storage area requires secondary containment with a rubber carry bucket or plastic tote.

Prepare to Respond to a Chemical Spill

If you or someone near your workspace has a chemical spill, you and other students in the area should move away from the spill. If a flammable liquid is spilled, warn other students in the area to extinguish all flames and turn off electrical equipment, if you can do so without putting yourself in harm's way. If the spill occurs in a chemical hood, close the hood sash to allow the vapors to be removed more effectively. You should report the spill to your instructor immediately. Your instructor should know how to handle the spill. If a significant amount of flammable, toxic, or volatile material is spilled, it may be necessary to vacate the entire laboratory or building.

If a small spill of a solid material occurs, your instructor may direct you or others to use a dustpan and brush, typically stored in the laboratory, to clean up the material. If a small spill of a liquid material occurs, your instructor

may direct you or others to use paper towels or another absorbent to soak up the liquid. To pick up broken glass, use tongs or wear leather or cut-resistant gloves. Broken glass can also be swept up using a small brush and dustpan. Most likely, an instructor will clean up broken glass, or you may be asked to do this under close supervision. Dispose of the material, including paper towels, as directed by the instructor.

If a large spill of a material occurs, or if the material is toxic or flammable, your institution will have a formal procedure for handling the spill. Follow the directions given by your instructor. These spills are not handled by students in introductory laboratories.

Your instructor or other trained personnel may contain larger liquid spills on the floor by surrounding the involved area with an absorbent retaining material. The absorbent material used may be one that neutralizes the spilled material (limestone or sodium carbonate for acids, sodium thiosulfate solution for bromine, etc.). There are commercial absorbent kits (e.g., Oil-Dri and Zorb-All), but other readily available absorbents, such as vermiculite or small particles (about 30 mesh) of *clay-based* kitty litter, can also be used effectively. When you are directed to return to the area, make sure that the floor does not feel slippery to you. Let the instructor know if the area seems unsafe for any reason.

Chemical Spills — Minor or Major?

Determining whether you are qualified to clean up a spill requires understanding the variables. Consider the following.

Minor or simple spill:

- *A spill that can be managed by one person*
- *A spill that does not spread rapidly other than by direct contact*
- *A spill that does not pose immediate danger to the environment*
- *The hazards (physical, health, and environmental) are understood by workers (toxicity, flammability, corrosivity, and reactivity)*
- *Personal protective equipment (PPE) and a spill kit are available.*

Major or complex spill:

- *A spill that also involves injury*
- *A spill of a highly toxic or flammable material requiring immediate evacuation of the area*
- *A spill in a stairwell or other high-traffic area*
- *A spill that has serious potential for impact on the environment.*

SUMMARY

The most likely emergency situations that might arise in an introductory or organic chemistry laboratory are ignition of a flammable solvent, chemical exposure on skin or in eyes, cuts from broken glassware, and chemical spills. You are more likely to respond appropriately, thus minimizing injury and damage, if you have considered your response in advance.

Learning to work safely in a laboratory is an important component of undergraduate chemical education. Recognizing hazards and assessing and minimizing risks are habits that should continue to be developed throughout your education and your career. This chapter has presented information on how to ***prevent an incident or spill***. Prevention education is important, but ***preparing to respond*** in an emergency is just as important and should also be part of your education.