

# Clemson University Laboratory Safety Manual



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# I. Introduction

## 1. Purpose

The purpose of this manual is to provide guidance on Clemson University's rules and regulations for those overseeing and working in laboratories that utilize hazardous chemicals as well as provide information on prudent practices for operating safely in these environments. This manual is not intended to be a comprehensive review of all safety practices, but rather an overview of prudent safety practices applicable to the majority of Clemson laboratories. For subjects not explicitly covered in this manual, researchers should contact [Occupational and Environmental Safety](#) (OES) for guidance. Other excellent resources for guidance on safe laboratory practices include [Prudent Practices in the Laboratory](#) and [CRC Handbook of Laboratory Safety](#). Other resources are listed in the Resources section of this manual.

## 2. Scope

This manual applies to all Clemson laboratories that use, store, or handle hazardous chemicals and meet the criteria under [OSHA 29 CFR 1910.1450](#) (*Occupational Exposure to Hazardous Chemicals in Laboratories*). These criteria are (all must be met):

- Chemical manipulations are carried out on a laboratory scale
- Multiple chemical procedures or chemicals are used
- The procedures involved are not part of a production process, nor in any way simulate a production process
- "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals

Laboratories or shops that do not meet these criteria are subject to [OSHA 29 CFR 1910.1200](#) (Hazard Communication Standard) and should ensure compliance with that standard. Contact OES for clarification on which standard is applicable to your lab. For specific guidance on biological and radiation safety, please refer to the [Biological Safety Manual](#) and [Radiation Safety Manual](#).

This manual is designed as a supplement to the Clemson University [Chemical Hygiene Plan](#) (CHP), which outlines specific rules, regulations, and policies applicable to chemical laboratories. The CHP outlines the roles and responsibilities of the numerous stakeholders from the university administration level to the individual researcher.

### 3. Occupational and Environmental Safety

The role of OES's lab safety program is to support the research and education mission of Clemson University by providing guidance on prudent lab practices, and to assist researchers in maintaining regulatory compliance. This guidance extends from college and department heads to undergraduate researchers working in labs. All members of the Clemson research and teaching community are responsible for the collective safety of our students, employees, and the public.

### 4. Regulatory Requirements

The guidance and practices provided in this manual are intended to assist researchers in complying with federal, state, and local regulations applicable to work in laboratories. Applicable regulations include, but are not limited to:

- [OSHA 29 CFR 1450.1950](#): *Occupational Exposure to Hazardous Chemicals in Laboratories (Lab Standard)*, implemented as OSHA approved state plan.
- [South Carolina Fire Code](#) -2021.
- [South Carolina Building Code](#) -2021.
- [NFPA 30](#): *Flammable and Combustible Liquids Code*, adopted by South Carolina.
- [NFPA 55](#): *Compressed Gases and Cryogenic Fluids Code*, adopted by South Carolina.
- [NFPA 70](#): *National Electric Code*, adopted by South Carolina.

In this manual, the word “shall” is used to denote requirements that are stipulated under these and other regulatory statutes or university policies.

### 5. How to use this manual

This manual serves as a supplement to the Clemson University Chemical Hygiene Plan and outlines pertinent policies, protocols, and practices as required under the OSHA Lab Standard. All new employees who will work in laboratories that fall under this statute should read and understand the material in this manual as well as the other resources and references provided.

This manual is divided into several chapters that provide guidance on many of the common hazards and safety concerns found in chemical laboratories. Hyperlinks are provided in the table of contents to allow quick access to specific sections of this manual (ctrl and click). Hyperlinks are also provided throughout this manual with links to useful resources and cited material. Particularly important points are called out in ***bold / italics / underlined*** throughout the manual.

For any concerns or questions not addressed in this manual, please contact OES. In-person classes are offered for numerous specific safety topics and are strongly encouraged. To arrange an in-person training session contact [OES](#) and indicate the type of training you need. In-person training sessions are custom designed to meet the specific needs of researchers in a variety of fields.

The appendices of this manual cover specific concerns that do not apply to every lab, but due to specific hazards, require guidance on prudent practices and university policies.

## **II. The Laboratory**

The purpose of this section is to provide guidance for maintaining a safe and secure laboratory environment. Engineering controls used in labs are introduced and guidance provided for their proper use and maintenance. As all research labs are unique in the work conducted as well as their physical layout, specific concerns or questions should be directed to OES for evaluation and advice.

### **Highlights:**

- The laboratory should be clean and well organized to enhance efficiency and minimize the potential for accidents.
- All aisleways should be free of trip hazards and other clutter.
- Benchtops should be free of excess clutter and chemicals. Chemicals not in current use should be stored in the proper location. Chemicals should not be stored on the floor.
- Access to safety showers / eyewashes, fire extinguishers, first aid kits, spill kits, electrical panels, and other safety equipment shall not be obstructed.
- Laboratory doors should remain closed at all times to maintain negative pressure within the lab space. Propping of lab doors is prohibited.
- Lab doors should remain locked when no lab members are present. All lab members should have key / card access to the lab.
- Lab doors should remain unlocked while work is being conducted.
- Lab door windows should remain unobstructed unless approved by OES.
- The integrity of lab ceilings and walls shall be maintained. No unauthorized modifications are permitted.
- Lab fume hoods should be inspected once a year by OES to ensure proper performance and operation. Hoods beyond the one-year inspection date should be reported to OES.
- Fume hoods that have failed annual or other inspection shall not be used for chemical manipulations.
- All lab personnel should be trained in the proper use of fume hoods, snorkels, and other exhaust devices.
- Fume hoods and other ventilation devices shall not be modified in any way by lab personnel. Request a consultation from OES for specific ventilation needs.
- Fume hood sashes should remain at or below 18 inches when in use and lowered when not in use.
- Annual lab inspections shall be performed by OES. Periodic “walk-through” inspections may also be conducted throughout the year to help identify compliance and safety issues.



## 1. The laboratory

The laboratory itself serves as a critical component of the risk minimization plan. The laboratory serves not simply as a work area, but also provides containment and appropriate ventilation to ensure concentrations of airborne hazardous chemicals (vapors, mists, particulates, etc.) are diluted and removed from the lab. To ensure overall safety in the lab, the integrity and operation of the lab space should be constantly maintained and upgraded as needed.

The laboratory space should remain clean and uncluttered at all times. Chemicals and apparatus not in use should remain in the appropriate storage locations until needed. Aisleways should remain clear of obstructions to prevent tripping as well as allow for rapid egress in the event of an emergency. Extension cords or tubing shall not be draped across aisleways where they can present a hazard. Cords that must be extended across an aisleway should be covered with a rigid cable cover secured to the floor. Do not run tubing or cords within drop ceilings or breach ceiling tiles. Contact OES for assistance in designing a lab layout plan to accommodate such circumstances.



Examples of clean and orderly labs. Efficient use of space allows for a safe and efficient work area despite limited available space.



Access to emergency equipment such as safety showers, eyewashes, spill kits, first aid kits, electrical panels, and fire extinguishers shall remain unobstructed at all times. Locations of these devices should be clearly indicated with appropriate signage and their location and proper usage known by all lab members.

Lab door windows shall remain unobstructed at all times (except when explicitly permitted following consultation with OES). Door windows can provide visibility into a lab in the event of an emergency. For example, if a lab member is seen on the ground through the door window, this may indicate a toxic or oxygen deficient atmosphere exists. In such cases, it would be prudent to call for emergency assistance rather than enter the space and potentially become harmed as well.

Laboratory air pressure is maintained negative relative to corridors. This is to ensure that airborne contaminants and odors cannot escape into common areas as well as ensure proper ventilation flow rates (i.e. fume hoods). To ensure proper pressure balance, **lab doors shall not be propped open** (aside from briefly for bringing large items in or out of the lab).

Access to laboratories shall be restricted to authorized personnel only. Lab doors should remain locked at all times when lab members are not present. This ensures security of laboratory chemicals, apparatus, and other dual-use materials as well as provides security for personal items stored within the lab (i.e. computers, notebooks, backpacks, etc.). Lab principal investigators (PIs) shall ensure that all lab members have keys or access cards to the laboratory. Loss or theft of these items by lab members shall be reported immediately to the PI, building manager, and department head.

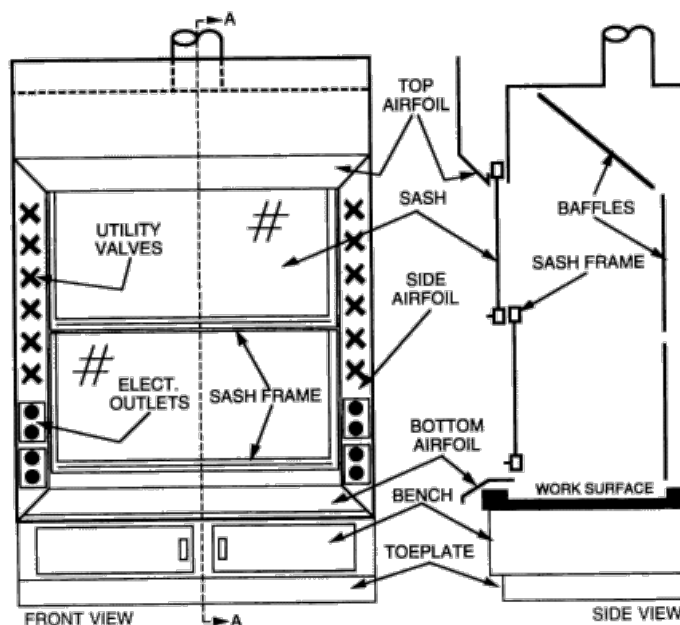
## **2. Laboratory ventilation**

Proper laboratory ventilation (to include local exhaust systems such as fume hoods, snorkels, glove boxes, etc.) is critical to maintaining a safe research environment. These systems work to contain and exhaust harmful contaminants while providing fresh air to lab spaces.

To ensure that possible airborne contaminants (to include vapor, mist, particulate, etc.) are removed from the lab it is important to ensure that all lab ventilation systems are functioning nominally and used properly. Proper exhaust function also helps ensure the lab space maintains a negative pressure relative to corridors.

## **Fume hoods**

Chemical fume hoods are available in numerous sizes and configurations. The majority of hoods at Clemson are 5 or 6-foot wide varieties with either vertical-opening sashes or horizontal sliding windows (or combination of both). These devices are designed to capture, contain, and exhaust hazardous contaminants and prevent exposure of lab personnel to hazardous chemicals. These devices also provide physical protection from projectiles and splashes via the hood sash. Fume hoods are also designed to contain small fires.

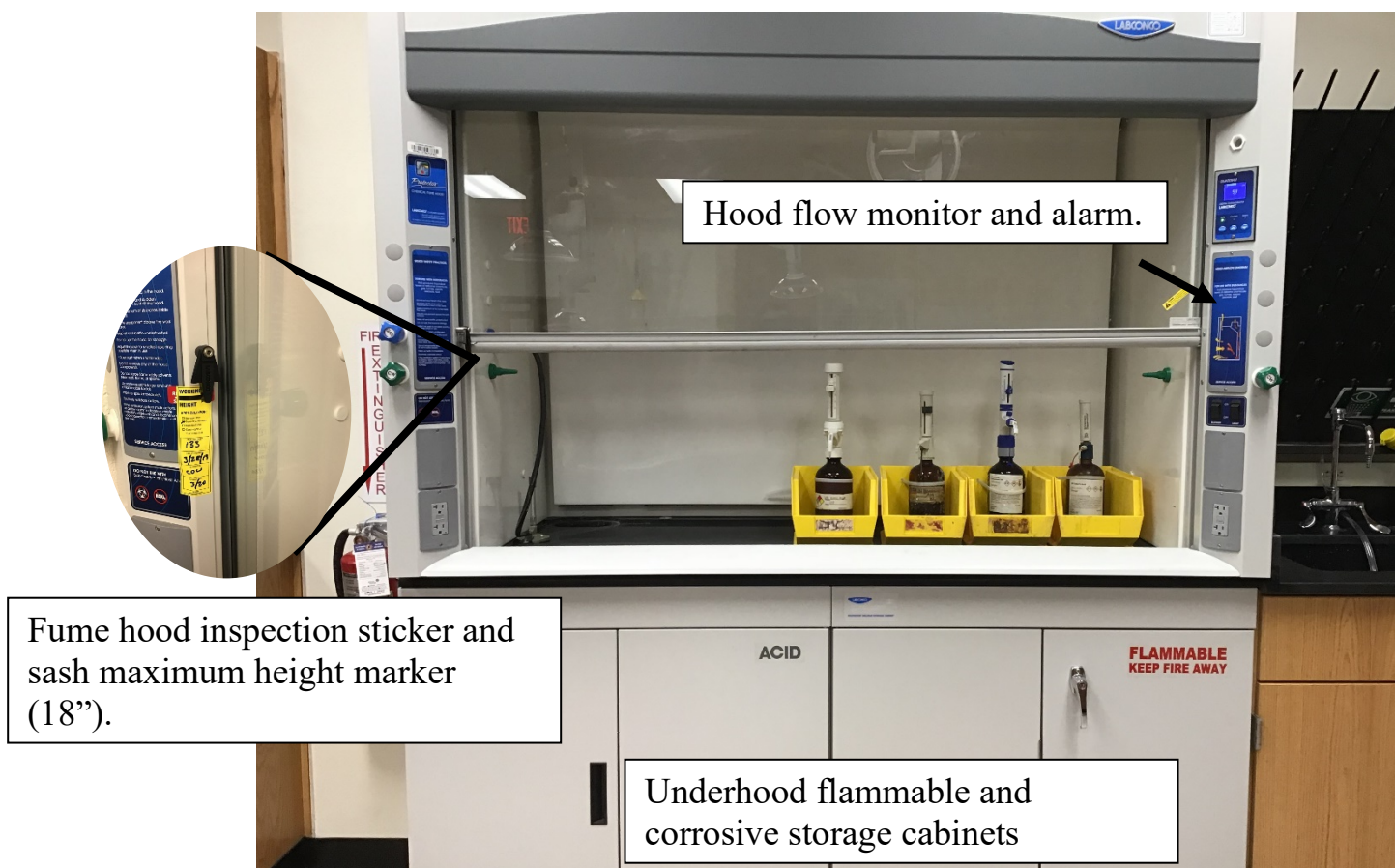


Schematic of common fume hood. Many configurations of hood are available and the specific operation and limitations of each should be understood by lab personnel.

Observe the following guidelines when operating any fume hood:

- Do not use any fume hood that has failed inspection, is showing a low flow condition (via the flow monitor), is clearly damaged (i.e. broken sash, removed side panels, etc.) or otherwise not in proper operating condition.
- Fume hood baffles shall remain unobstructed. Chemicals and apparatus should not be placed in such a position as to block or obstruct the hood baffles. Items should be placed several inches away from the baffles to allow adequate airflow. Large items (such as small furnaces, sonicators, etc.) can be elevated a few inches to allow flow under the item (large items can cause turbulent airflow).
- The fume hood sash shall remain at or below 18 inches (as denoted by marker on hood) when in use. When not in use, the sash should be lowered to the lowest position. The hood sash provides protection to the user's upper body from splashes and projectiles.

- Do not lean inside of the fume hood. Vapors generated inside the hood are not always immediately exhausted from the enclosure. Placing your head and upper body inside the hood exposes you to these vapors and other hazards.
- Chemicals and chemical manipulations shall be conducted at least 6-inches inside the front of the hood. Performing work at 6-inches or greater from the front of the hood helps ensure effective capture of contaminants and minimizes the potential for reverse air flow.
- The airfoil shall not be obstructed. The airfoil helps ensure proper airflow into the hood. Obstruction of the airfoil can lead to turbulent and / or reverse flow of contaminated air.
- No modification shall be made to any fume hood. If modifications of fume hoods are needed or repairs necessary, contact OES for an evaluation. Compromising the integrity of the hood by cutting holes in side panels or other alterations can result in poor containment and possible exposure to hazardous chemicals.
- Fume hoods should be kept clean and orderly. The hood should be well organized and clean. This increases work efficiency and minimizes the potential for spills and other accidents.
- Fume hoods shall not be used for chemical storage. Chemicals should be stored in the appropriate storage locations / cabinets when not in use.
- Report any fume hood or air flow monitor problems to OES immediately.
- Notify OES if a fume hood is beyond its annual inspection date.



Example of commonly used fume hood with indicators for inspection sticker, sash height marker, flow alarm, and underhood storage. Many hood configurations are found in labs so be familiar with the features of your hood.

### *Specialty hoods*

Some fume hoods are designed for or designated for a specific use such as perchloric acid, radioactive materials, hydrofluoric acid use, distillation hoods, etc. Specific protocols are required for these hoods and are outlined in sections where they apply.

**There are currently no approved perchloric acid hoods at Clemson University.** While some hoods may indicate they are perchloric acid hoods, they are not ducted for such an application (requires a washdown systems, vertical ducts, etc.). **No hot perchloric acid digestions are permitted.**

Requirements for hydrofluoric acid hoods and radioactive materials hoods are indicated in the HF guidelines section and radiation safety training respectively.

## **Snorkels**

Snorkels (also called elephant trunks) are local exhaust devices that extend from an exhaust duct to the point of use. They can be flexible or rigid and may be mounted on an articulated arm. It is important that the snorkel opening be positioned as close as possible to the source of contaminants as the ability to effectively capture contaminants falls away to near zero at a distance of about half of the opening diameter. The opening should be positioned opposite of the user to draw fumes away from the breathing zone. Snorkels are commonly used for:

- Soldering and joining work
- Capture of furnace exhaust fumes from exhaust port or tube
- Low hazard chemical manipulations (i.e. dispensing small volumes of acids or solvents)
- Small scale coating operations.

Snorkels should not be relied upon for highly hazardous chemical work or work that will generate large volumes of mist or vapor. Such work should be carried out in a fume hood. Contact OES for a consultation regarding proper use of snorkels in the laboratory.



Snorkels on articulated arms used in a general chemistry lab.

## **Biological safety cabinets**

Biological safety cabinets (biosafety cabinets or BSCs) are used to provide a work area free of contaminants, in particular, biological contaminants. To do this, BSCs pass air through HEPA filters and recirculate it into the room and cabinet itself. As these devices are designed specifically for biological and particulate capture, chemicals should not be used in BSCs. The use of chemicals can cause deterioration of the filter material resulting in ineffective decontamination. **BSCs should be inspected and certified once a year to ensure proper operation and filter integrity (if being used for infectious materials research).** Contact the [biosafety officer](#) for information on maintaining BSCs.



Example of a biological safety cabinet.

### **Other ventilated enclosures / systems**

Numerous laboratory operations require local exhaust to ensure worker safety. Such devices include ventilated enclosures, ventilated storage cabinets, canopy hoods, analytical instruments that require dedicated exhaust, etc. Prior to beginning any new project or ordering new instrumentation, it is imperative to determine if ventilation will be required. OES can assist in performing a hazard analysis to determine what type of ventilation (if any) is needed as well as work with Facilities Services to ensure proper placement and installation. **Do not modify any existing laboratory ventilation ducts or ventilated enclosures.** Contact OES with any questions regarding the need for ventilation.

## **3. Annual inspections and self-inspections**

Annual laboratory inspections are an important tool to assist in compliance with federal, state, and local regulations as well as ensuring the observance of prudent lab practices. OES conducts lab inspections on an annual basis. Labs may or may not be notified prior to the inspection date. It is not necessary to have a member of the lab present during the time of the inspection, but it is beneficial to help answer pertinent questions and receive feedback and corrective action from the inspector. Formal inspection reports are emailed to the lab PI with deficiencies noted. “Critical”<sup>1</sup> deficiencies must be corrected immediately (conditions found that are immediately hazardous to life and health may result in immediate closure of the lab). *All* noted deficiencies should be corrected by lab personnel in a timely manner. OES will assist in finding solutions to issues found during inspections.

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<sup>1</sup> Critical deficiencies are defined as those that pose a serious health and safety hazard or are in violation of federal, state, or local regulations.



If critical and other deficiencies are not corrected within the allotted timeframe, the department chair will be notified, and an escalation process initiated.

OES will conduct periodic “walk-through” inspections throughout the year. The intent of these inspections is to discuss with researchers the nature of the work being conducted and to help identify any potential needs with regard to safety or compliance. The goal of OES is to assist lab personnel in identifying potential hazards and correct them before an issue can arise.

Lab PIs and personnel are encouraged to perform self-inspections on a regular basis. These inspections (available via SciShield) utilize the same criteria as the annual inspection (or more stringent) and allow lab personnel to monitor their level of safety and compliance. OES can assist in developing a self-inspection template for the particular hazards found in the lab. Lab self-inspections can be used to formulate lab-specific standard operating procedures and serve as a basis for safety discussions at regular group meetings. Self-inspections allow for researcher ownership of lab safety and help increase overall safety, efficiency, and quality of research.



### **III. General Laboratory Safety Practices**

The purpose of this section is to provide general rules and guidance on laboratory safety. This guidance applies to all Clemson laboratories. Information and guidance on specific hazards will be addressed in later sections of this manual.

#### **Highlights:**

- All lab workers must have completed the relevant safety training modules prior to beginning work.
- Proper laboratory attire must be worn at all times in the lab.
- Proper personal protective equipment (PPE) must be worn when working in the lab.
- No food or drink is permitted in the lab.
- Do not apply cosmetics in the lab.
- No unauthorized persons or animals are permitted in the lab.
- Know the location of emergency exits and emergency equipment in the lab prior to commencing work.
- Perform experiments only in approved areas.
- Emergency contact information should be prominently displayed on the lab door and inside the lab.
- Laboratory door sign should be up to date with chemical and physical hazards listed.
- Only dispense odiferous and volatile chemicals in a fume hood.
- Minors are not permitted in labs without registration with the Clemson Pre-Collegiate Programs Office and OES.
- Chemicals not in use should be secured in the appropriate storage location.
- Wash hands prior to leaving the lab.
- Working alone and / or after normal working hours in the laboratory is not recommended. However, if necessary, lab specific protocols should be developed to ensure safety of personnel during these times.

## 1. Required training modules

Laboratory training requirements are identified and assigned by the SciShield software program based on the activities and hazards identified by the Principal Investigator. All persons working in laboratories are required to complete the [\*Laboratory Safety and Chemical Hygiene Training\*](#) module either online or via an in-person class provided by OES. This training is required prior to beginning any work in the lab. This requirement applies to principal investigators, faculty, staff, graduate students, undergraduate research students, and temporary workers. Questions regarding the need for this training should be directed to OES for clarification. Other training may be required based on the type of research being conducted. These includes [\*Hazardous Waste Training, Biological Safety Training, Radiation Safety Training, Hazard Communication Training, etc.\*](#) All applicable training must be completed prior to beginning work in the lab. Other special training requirements may apply based on specific work hazards such as working with hydrofluoric acid or blood borne pathogens.

## 2. Proper laboratory attire

Appropriate lab attire must be worn at all times when working in the laboratory. Proper attire provides a temporary barrier to chemical exposure or physical injuries (i.e. from flying debris, etc.). This attire should also allow for free, unencumbered movement and minimize the chances to entanglement. Basic proper attire includes:

- Closed toe shoes (no flip-flops, sandals, etc.).
- Long pants or dresses which completely cover exposed skin (no miniskirts, shorts, etc.).
- No sleeveless shirts or tank-tops. Long sleeve shirts recommended.
- Long hair should be tied back or in a bun to avoid entanglement, fire, or exposure.
- Contact lenses may be worn in the lab, but proper PPE is still required (see below).

For work where there is the potential for exposure to fire (i.e. open flame, pyrophoric chemicals, flammable materials, etc.), care should be taken to avoid synthetic fabrics. These materials ignite very rapidly and can adhere to the body leading to serious burns. Cotton or cotton blends (cotton in high percentage) fabrics are recommended for such work environments. In all cases, appropriate PPE must be worn based on the hazards.

### 3. Personal Protective Equipment (PPE)

PPE is the last line of defense against chemical exposure, fire, heat, cold, projectiles, and other hazards present in the lab. Proper PPE selection and use is an essential part of the overall laboratory risk minimization plan. It is important that all researchers be aware of the proper selection and use of PPE as well as its limitations. PPE is not intended to substitute for proper [hazard assessments and risk minimization](#) (i.e. elimination, substitution, engineering and administrative controls).

The chemical and physical hazards associated with your research must be fully evaluated and understood before selecting the appropriate PPE. Requirements for PPE include:

- Proper PPE must be provided for all researchers in the lab by the PI based on the hazards present in the lab. Extra PPE should be maintained for use by visitors as well as replacement for damaged or obsolete PPE.
- Proper eye protection (approved safety glasses with side shields or chemical splash goggles) should be worn at **ALL TIMES** in any lab where chemicals are used, stored, or handled, or where a risk of flying particles is present. Prescription glasses are not a substitute for approved safety glasses.
- Lab coats should be worn by **ALL** researchers in a lab when **ANYONE** is using hazardous chemicals. Lab coat selection is based on the nature of the hazards present. Lab coats should not be worn outside the lab or laundered at home. Check with your department safety coordinator or OES about laundering lab coats.
- Gloves should be worn when there is the potential for skin contact with hazardous chemicals or when physical hazards present a risk of injury. The selection and use of gloves is based on the nature of the hazard. Gloves should not be worn outside of the lab and should be removed when not needed.
- A face shield should be used when there is a significant splash or projectile risk. Face shields are not a substitute for proper eye protection.
- Hearing protection should be worn when exposure to loud machinery, instruments, or reactions occur or is likely. OES can provide consultations to determine if hearing protection is necessary and what type is appropriate.
- Respirators are generally not worn or needed for laboratory research. Respirators should only be worn after consulting OES and completing respiratory protection training and fitting.

**Eye protection:** Safety glasses should be worn at all times when in the lab. This will provide the minimum protection to chemical splashes and projectiles. Safety glasses must have side shields to minimize exposure from the sides. Chemical splash goggles provide superior protection to chemical splashes and should be worn when such a risk is present.



## Chemical splash goggles and standard safety glasses

Regular prescription eyeglasses are not a substitute for approved safety glasses. Over-the-glasses eye protection is available through several vendors and prescription eye protection is available. If you have difficulty finding eye protection to accommodate prescription eyeglasses, contact OES for assistance. For those who wear contact lenses, chemical splash goggles are recommended.

All laboratory eye protection must meet requirements set by the ANSI Z87.1 standard. This certification is stamped on the lens or the frame of safety glasses and goggles.



ANSI Z87.1 certification stamp on safety glasses frame and lens.

**Lab coats:** Lab coats should be worn whenever *anyone* in the lab is using hazardous chemicals. It is important to remember that others working with chemicals may pose a risk to your safety in the event of a spill or other accident. The type of lab coat will vary based on the type of work being conducted. For general chemical work, a cotton lab coat is recommended. This material has a greater resistance to fire than synthetics and synthetic blends. If working with pyrophoric materials or experiments which present a fire hazard, a fire-resistant lab coat is recommended. Several suppliers offer lab coats which are both chemical and fire resistant. While these may be a bit more expensive upfront, their durability and protection may be worth the investment.



Standard cotton lab coat (left) and fire and chemical resistant Workrite™ lab coat (right).

**Gloves:** Gloves should be worn when there is the potential for chemical exposure to the skin. Gloves are not intended to serve as a long-term barrier to chemicals, but rather to minimize the risk associated with incidental contact with chemicals. **The necessity for and choice of gloves will depend on the hazards of the chemicals being utilized.** For example, when pouring buffer from a stock bottle to a beaker, gloves may not be necessary. However, when handling toxic or highly toxic chemicals, gloves are mandatory due to the elevated risk. The choice of gloves also depends on the chemicals being used. Manufacturer's glove charts will provide information on the permeation rate and breakthrough time for many chemicals. This information can be used to determine the appropriate glove choice. Glove chemical resistance charts are readily available from the manufacturer's websites. It is also important to balance dexterity with chemical resistance and glove thickness. While thicker gloves will provide greater protection, they also inhibit dexterity which may lead to spills, etc. In such situations, double gloving with a thinner glove may be appropriate. Be aware that some people have an allergy or sensitivity to latex when selecting gloves.



Common purple nitrile gloves (left) and thicker butyl rubber gloves used for handling corrosives (right).

Other lab operations may necessitate the use of gloves such as handling cryogenic liquids, hot or cold surfaces, sharps, etc. It is important to select the appropriate glove for the task. In all cases, gloves should be inspected for tears or holes prior to use and after. If a glove becomes contaminated or damaged, remove the glove carefully and dispose of properly. **Gloves should not be worn outside the lab.** It is recommended that gloves be removed when not needed for handling chemicals to minimize the potential for contamination of lab surfaces.



Proper lab attire and PPE.

**Face shields:** Face shields offer increased protection to the full face and neck. Shields should be worn in situations where an increased risk of splashes or projectiles is present. Face shields are not a substitute for safety glasses / goggles and should be worn in addition to these.

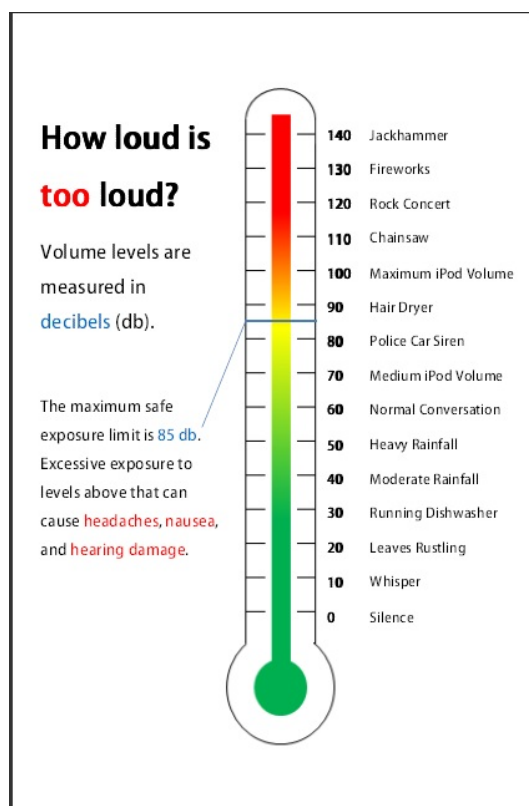




**Respiratory protection:** Respiratory protection is generally not needed or appropriate for laboratory research. If you believe you may need a respirator to perform your research, contact OES for a consultation and evaluation.

In some situations, it may be desired to wear a nuisance dust mask (also known as an N95 respirator) to minimize exposure to particulates. Consultation with OES is still required; however, if OES determines the task does not require use of a respirator, you may still use an N95 respirator if a “Voluntary Dust Mask Use Form” is completed and submitted (available on the OES website).

**Hearing protection:** Exposure to excessive noise can cause permanent hearing damage based on the noise level, sound frequency, frequency of exposure, and duration. Sources of noise in the lab can be machinery, instruments, reactions, animals, ultrasonicators, etc. OES can provide an assessment and consultation to determine if hearing protection is recommended. The type of protection can vary from disposable ear plugs to full ear muffs or both, depending on the noise level and duration of exposure.



Examples of hazardous sound levels (measured in decibels).



**Disposal of PPE:** Damaged or contaminated PPE should be disposed of immediately. Old PPE which is no longer useful can be disposed of in the normal trash. For chemically contaminated PPE, dispose of as follows:

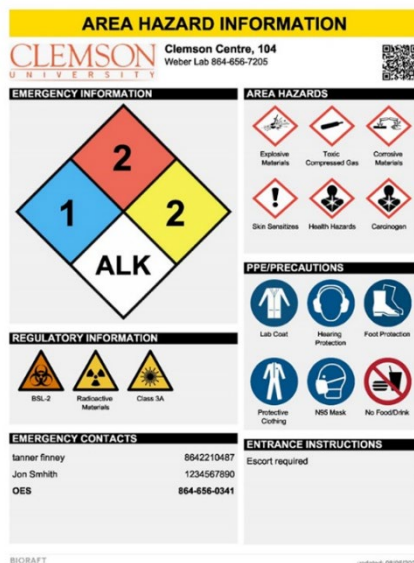
- For incidental contact with chemicals which are not acutely toxic (i.e. small amount of dry or wet chemical in contact with glove), carefully remove glove and dispose of in normal trash.
- For glove contact involving acutely / highly toxic chemicals or P-list chemicals, carefully remove glove, avoiding contact with skin and dispose of as hazardous waste. Wash hands with soap and water prior to putting on new gloves.
- For contact with highly odiferous chemicals, allow gloves to remain in a fume hood until odor is no longer detected or place in a zip-lock bag and declare as hazardous waste.
- Old or worn-out lab coats contaminated with acutely / highly toxic or P-list chemicals, should be declared as hazardous waste.
- If uncertain of proper disposal method, contact the OES [Hazardous Materials Manager](#).

#### **4. Laboratory Door Sign and Contact Information**

The laboratory door sign provides vital hazard information to first responders and other university staff. It is critical that hazard information and contact information on door signs be kept up to date. OES provides a door sign template for creating lab door signs. The up to date door signs should be clearly posted on the outside of all lab doors in a plastic holder (available from RS). Elements of the current door sign template are shown below.

- Identity of chemical hazards in the lab.
- Compressed gases (identity).
- Specific hazards in the lab (i.e. highly toxic chemicals, electrical hazards, explosion hazards, etc.).
- Location of SDS information (online is acceptable).
- Contact information for RS personnel and lab contact personnel. Lab contact information should include business and after hours contact numbers for the lab PI, lab safety contact, lab manager (if applicable), building manager, and department safety coordinator. Other contacts may be listed, such as a backup contact.
- Symbols for biohazards, radiation, and laser hazards if present.
- Color code for custodian access (red: no entry; yellow: escorted entry only; green: access allowed).

Labs are encouraged to post contact information for all lab members inside of the lab in the event of emergency.



Click image to proceed to door sign template.

## 5. Minors in Laboratories

This guidance applies to those ages 14-17 that will be working in Clemson University research labs in any capacity. It does not apply to enrolled students. For programs involving participants that are 13 or younger, please contact OES for guidance.

All minors working in programs and activities occupying labs must be registered with the Pre-Collegiate Programs Office (PcPO) as outlined by the **Protection of Minors in Youth Programs and Activities Policy** and youth programs operating standards (<https://www.clemson.edu/administration/pre-collegiate/documents/CUOSfYP.pdf>). Minors not registered with PcPO are **not permitted in Clemson laboratories**.

**Guidelines for Principal Investigator (PI) or laboratory supervisor:** PIs are expected to uphold the same training and safety standards with minors as with any undergraduate or graduate level research student. This includes:

- Ensure the laboratory is compliant with regulations and safety standards set forth by the ORS and Clemson University.

- Provide appropriate safety training based on all hazards present in the laboratory as well as specific safety training based on the hazards of the work to be conducted. Such training can be conducted by the PI in consultation with ORS or ORS can provide in-person and online training tailored to the needs of the PI / research hazards.
- Research groups operating under IBC or IACUC protocols must update their protocols to include minor(s) and ensure appropriate safety training is completed as determined by these protocols. However, registration for medical surveillance is optional:

<https://www.clemson.edu/cbshs/centers-institutes/sullivan/services/medical-surveillance.html>

- PIs must provide all personal protective equipment necessary for the minor to safely conduct their research and ensure proper lab attire is worn at all times.
- Minors may never work in the lab alone and the **Protection of Minors in Youth Programs and Activities Policy** states that two adults are required to be present with a minor at all times.

**Prohibitions:** Minors are prohibited from working with the following:

- Explosives
- Acutely toxic chemicals (i.e. sodium azide, hydrogen cyanide, phosgene)
- Pyrophoric chemicals
- Biological agents characterized above Biological Safety Level 2
- DEA controlled substances

Specialized hazard training and enhanced oversight must be provided for minors working with:

- Carcinogens
- Reproductive toxins
- Radiation and X-ray equipment
- Lasers
- Hazardous mechanical equipment (i.e. drill press, lathes, etc.)
- Biosafety Level 1 and 2 materials

In the event an accident occurs, the following action should be taken:

- If it is an emergency, call 911 and await emergency responders.
- If necessary, the minor should be taken to Redfern medical clinic (or other medical provider covered by the minor's medical insurance) and accompanied by the PI or representative and provide relevant information (SDS for chemicals, nature of work, accident details, etc.).

- Fill out the following incident report form via SciShield

## **6. Working alone and / or after working hours in the lab**

Working alone is defined as working in the laboratory when no other individuals are within voice contact range. Working after hours is defined as working after standard working hours (~8 am – 6 pm) or weekends.

Working alone at any time is strongly discouraged. It is important to have others in the vicinity in the event of an emergency. For this reason, it is recommended that research be conducted during standard working hours on weekdays. However, it is understood that, given the dynamic nature of laboratory research, it is often necessary to conduct laboratory work after standard hours or on the weekends. If this is necessary, prudent steps should be taken to ensure the safety of laboratory personnel. Examples include:

- All after hours work shall have the approval of the lab PI.
- Only conduct procedures that have minimal hazards. Highly hazardous procedures (i.e. use of hydrofluoric acid, use of acutely toxic chemicals, large scale syntheses, etc.) should never be conducted while alone.
- Notify another lab member that you will be in the lab after hours and notify them when you have completed work and left.
- Coordinate with other lab members who need to conduct after hours work so multiple people will be in the lab.
- Ensure access to communication is available in the event help is needed (i.e. good cell phone coverage, landline, etc.).
- Plan for potential emergencies. Most buildings automatically lock after hours and on weekends. Take into account that, in event of an emergency, first responders will not be able to easily access the building.

Each lab should have lab-specific policies in place regarding after hours or working alone. It is the responsibility of the lab PI to ensure that these policies are understood and followed. Department level policies regarding working alone and / or after hours must also be observed.

## IV. Chemical Safety

The purpose of this section is to provide information on general chemical safety in the laboratory. The number of chemicals and possible scenarios is too vast to cover in this section, so a broad guidance is provided that is applicable to a majority of labs. For specific hazards or concerns, please consult OES or additional resources. In all cases it is the responsibility of the lab PI to ensure that all lab members are informed and knowledgeable in the hazards, proper storage and use, and risks associated with hazardous chemicals and processes in the laboratory.

### Highlights:

- Lab personnel shall be made aware of the hazards (health and physical) of the chemical stored and used in the laboratory.
- Access to chemical Safety Data Sheets shall be ensured at all times (electronic access is acceptable).
- Appropriate PPE shall be provided based on a hazard assessment of the chemicals stored and used in the lab.
- A hazard assessment should be conducted prior to conducting chemical manipulations in the laboratory.
- All chemicals shall be segregated according to compatibility and hazard class.
- Flammable chemicals shall be stored in approved flammable storage cabinets. No more than 10 gallons of flammable liquids may be stored outside of a flammable storage cabinet at one time.
- Transfers of flammable solvents should be conducted in such a manner as to prevent exposure to an ignition source including static discharge.
- Highly toxic or acutely toxic chemicals should be segregated from other chemicals due to their high degree of toxicity.
- Chemicals received from suppliers must retain the original GHS label at all times.
- An up to date chemical inventory should be maintained (via ChemTracker on the SciShield platform)
- Chemicals transferred from original containers or generated in the lab shall be labeled with the name and hazard of the chemical (storage containers) at a minimum. Small sample vials must contain a label with a unique identifier that will allow identification of the contents.
- Chemical containers should be kept clean and free of chemical residue or contamination.
- All chemical containers shall be closed with a screw top lid when not in immediate use.

- Chemicals that are known to form peroxides over time shall be tested regularly for peroxide accumulation following opening. Storage life recommendations for peroxide former classes shall be observed. If peroxides are detected, the chemical should be declared as hazardous waste.
- Standard operating procedures for Particularly Hazardous Substances (PHS) shall be established, understood, and followed by all lab personnel.
- Chemical manipulations should be conducted within a certified chemical fume hood.
- Special precautions should be made for unattended chemical reactions or processes.

## 1. Chemical hazard identification (Safety Data Sheets)

It is important that all lab personnel are familiar with the health and physical hazards of the chemicals contained in the lab (including those not directly used). Multiple resources are available for determining these hazards. A primary resource is chemical Safety Data Sheets (SDS). These data sheets utilize the [Globally Harmonized System \(GHS\) for Classification and Labeling of Chemicals](#) that provides consistency in hazard identification and labeling standards among chemical suppliers and across international lines.

SDS contains 16 sections<sup>2</sup>:

1. Identification includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.
2. Hazard(s) identification includes all hazards regarding the chemical; required label elements.
3. Composition/information on ingredients includes information on chemical ingredients; trade secret claims.
4. First-aid measures includes important symptoms/effects, acute, delayed; required treatment.
5. Fire-fighting measures lists suitable extinguishing techniques, equipment; chemical hazards from fire.
6. Accidental release measures lists emergency procedures; protective equipment; proper methods of containment and cleanup.
7. Handling and storage lists precautions for safe handling and storage, including incompatibilities.
8. Exposure controls/personal protection lists OSHA's Permissible Exposure Limits (PELs); ACGIH Threshold Limit Values (TLVs); and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the SDS where available as well as appropriate engineering controls; personal protective equipment (PPE).
9. Physical and chemical properties lists the chemical's characteristics.
10. Stability and reactivity lists chemical stability and possibility of hazardous reactions.
11. Toxicological information includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.
12. Ecological information
13. Disposal considerations
14. Transport information
15. Regulatory information

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<sup>2</sup> OSHA Quickcard, *Hazard Communication Safety Data Sheets*,  
[https://www.osha.gov/Publications/HazComm\\_QuickCard\\_SafetyData.html](https://www.osha.gov/Publications/HazComm_QuickCard_SafetyData.html).



16. Other information, includes the date of preparation or last revision.

All lab personnel shall have access to SDS (SciShield home page) and understand how to interpret the information. Electronic access via the internet or electronic database is acceptable. SDS are required to be provided by chemical manufacturers, distributors, and importers for all chemicals.

***It is the responsibility of the lab PI to ensure that all lab personnel are aware of the hazards associated with chemicals stored and used in the lab and any processes utilizing these chemicals. The PI must also ensure lab personnel know how to access safety data sheets.***

### **Physical and health hazards**

Physical and health hazards associated with chemicals are broken into 28 hazard classes (16 physical hazards, 10 health hazards, and 2 environmental hazards). These hazard classes are:

#### *Physical hazards*

- Explosives
- Flammable Gases
- Aerosols
- Oxidizing Gases
- Gases Under Pressure
- Flammable Liquids
- Flammable Solids
- Self-Reactive Substances
- Pyrophoric Liquids
- Pyrophoric Solids
- Self-Heating Substances
- Substances which, in contact with water emit flammable gases
- Oxidizing Liquids
- Oxidizing Solids
- Organic Peroxides
- Corrosive to Metals

#### *Health hazards*

- Acute Toxicity (Oral/Dermal/Inhalation)
- Skin Corrosion/Irritation
- Serious Eye Damage/Eye Irritation
- Respiratory or Skin Sensitization










- Germ Cell Mutagenicity
- Carcinogenicity
- Reproductive Toxicology
- Target Organ Systemic Toxicity - Single Exposure
- Target Organ Systemic Toxicity - Repeated Exposure
- Aspiration Toxicity

### *Environmental hazards*

- Hazardous to Aquatic Environment (Acute/Chronic)
- Hazardous to the Ozone Layer

To provide rapid hazard identification, pictograms are used and correspond to hazard classes. The chart below shows the 9 pictograms and their meanings. Note that some pictograms correspond to several hazards.

### HCS Pictograms and Hazards

<b>Health Hazard</b>  <ul style="list-style-type: none"> <li>• Carcinogen</li> <li>• Mutagenicity</li> <li>• Reproductive Toxicity</li> <li>• Respiratory Sensitizer</li> <li>• Target Organ Toxicity</li> <li>• Aspiration Toxicity</li> </ul>	<b>Flame</b>  <ul style="list-style-type: none"> <li>• Flammables</li> <li>• Pyrophorics</li> <li>• Self-Heating</li> <li>• Emits Flammable Gas</li> <li>• Self-Reactives</li> <li>• Organic Peroxides</li> </ul>	<b>Exclamation Mark</b>  <ul style="list-style-type: none"> <li>• Irritant (skin and eye)</li> <li>• Skin Sensitizer</li> <li>• Acute Toxicity (harmful)</li> <li>• Narcotic Effects</li> <li>• Respiratory Tract Irritant</li> <li>• Hazardous to Ozone Layer (Non-Mandatory)</li> </ul>
<b>Gas Cylinder</b>  <ul style="list-style-type: none"> <li>• Gases Under Pressure</li> </ul>	<b>Corrosion</b>  <ul style="list-style-type: none"> <li>• Skin Corrosion/ Burns</li> <li>• Eye Damage</li> <li>• Corrosive to Metals</li> </ul>	<b>Exploding Bomb</b>  <ul style="list-style-type: none"> <li>• Explosives</li> <li>• Self-Reactives</li> <li>• Organic Peroxides</li> </ul>
<b>Flame Over Circle</b>  <ul style="list-style-type: none"> <li>• Oxidizers</li> </ul>	<b>Environment (Non-Mandatory)</b>  <ul style="list-style-type: none"> <li>• Aquatic Toxicity</li> </ul>	<b>Skull and Crossbones</b>  <ul style="list-style-type: none"> <li>• Acute Toxicity (fatal or toxic)</li> </ul>

SDS hazard classes are further subdivided in hazard categories. **The severity of the hazard increases with decreasing numerical value.** Thus, a flammability hazard category of 1 is more flammable than a category 4 flammable chemical. It should be noted that this is the reverse of the commonly used [NFPA 704](#) system that uses increasing numerical value for increased severity. The specific criteria that determine the hazard class and category are described in detail in [OSHA 29 CFR 1910.1200](#) (Hazard Communication). This information should be reviewed by all lab personnel.

In the event of chemical exposure or spill, SDS should be provided to medical personnel or first responders. The content of the SDS should also be verbally relayed to aid first responders in understanding the hazards of the chemical in question.

The determination of the type of PPE required can be determined (in part) from SDS information. It is important to ensure that the type of PPE used will provide the necessary protection against a particular chemical. For example, glove manufacturer resistance charts should be consulted in determining the proper choice of gloves. **Careful analysis of the hazards associated with the chemicals and the process should be conducted to determine the appropriate PPE needed.**

### **Permissible Exposure Limit (PEL), Threshold Limit Value (TLV), Recommended Exposure Limit (REL)**

Exposure limits for a large number of chemicals have been determined and are provided in the SDS information.

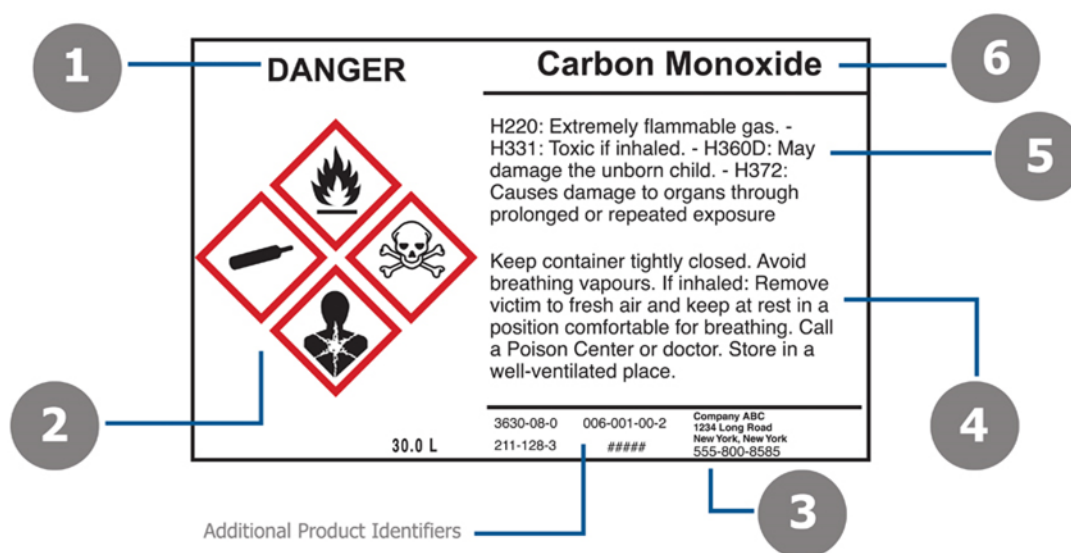
- PEL: Limits set by OSHA and is a legal limit on the exposure of individuals in the lab to hazardous chemicals or other agent (such as noise). The PEL is given as a time-weighted average (TWA) over an 8-hour period or as a short-term exposure limit (STEL). The STEL is the average permissible exposure limit over a 15-minute period. A ceiling concentration (denoted by a “C”) is an exposure limit that may not be exceeded at any time.
- TLV: These exposure limits are distributed by the American Conference of Governmental Industrial Hygienists (ACGIH). These values are also provided as 8-hour TWA, STEL, and ceiling limits and are generally more conservative than the OSHA PEL values. These values are generally considered as providing greater worker protection based on current research data. These values are not necessarily legally binding as the OSHA PEL values are.
- REL: These exposure limits are distributed by the National Institute for Occupational Safety and Health (NIOSH).

Similar to ACGIH TLV values, REL values are not legally binding but are considered as providing greater worker protection based on current research data.

For detailed information on OSHA PEL definitions, requirements, and lists of values, consult OSHA [29 CFR 1910.1000](#). The [ACGIH](#) and [NIOSH](#) also provide information and list through their respective websites.

### **Chemical labeling (GHS)**

Chemical manufacturers are required to label all chemicals according to GHS standards. All chemicals received from manufacturers must contain this label. **This original label shall be maintained at all times** and replaced if damaged. The required elements of the GHS label are shown below.



1. Signal word: Indicates the relative level of severity of the hazard. “Warning” is used for less severe hazards, “Danger” is used for more severe hazards.
2. Pictogram: Symbols used to communicate specific information about the hazards of a chemical.
3. Name, address, and phone number: Name, address, and phone number of the chemical manufacturer.
4. Precautionary statement: Recommended measures to minimize or prevent adverse effects from exposure to chemical.
5. Hazard statement: Describes the nature and severity of the hazard.
6. Product identifier: How the chemical is identified, most often the chemical name.

### **Other chemical hazard resources**

SDS are a valuable (and required) source of chemical hazard information, however, they may fail to capture the context of the particular application or reaction in which the chemical is being used. For example, the kinetics of a particular incompatible reaction would not be readily conveyed. Such a reaction may proceed slowly or extremely rapidly based on reaction conditions and other factors.

It is important to review other sources of chemical information (along with a fundamental knowledge of chemistry) prior to using chemicals for the first time (and reviewing them thereafter) to gain a more complete understanding of the hazards and potential incompatibilities or adverse reactions. Other resources include:

- Bretherick's Handbook of Reactive Chemical Hazards
- CRC Handbook of Chemistry and Physics
- The Merck Index
- CRC Handbook of Laboratory Safety
- Lange's Handbook of Chemistry
- Internet resources (TOXNET, PUBCHEM, NIOSH Pocket Guide to Chemical Hazards, etc.)

## **2. Chemical segregation and storage**

Many accidents involving chemicals in the laboratory result from chemical incompatibilities. Prudent segregation and storage of chemicals in the lab can help prevent many common accidents as well as aid in the organization and efficiency of the lab. Chemical segregation can be difficult given that many chemicals have multiple hazards and laboratory space can be extremely limited; however, steps should be taken to minimize the risk of incompatible reactions during storage based on an evaluation of the chemical properties. OES can assist in developing a chemical segregation scheme based on the lab space available and the chemicals in use / storage. The following section provides some basic guidance on chemical segregation and storage that is applicable to the majority of labs.

### **Chemical storage (general guidelines)**

All chemicals should be stored according to the manufacturer's guidelines (room temperature, reduced temperature, under inert atmosphere, etc.). Labs should ensure that chemicals are kept under these conditions. Special care should be taken for air-sensitive chemicals, acute / highly toxic chemicals, peroxide forming chemicals, and other chemicals that possess unique hazards (i.e. temperature sensitive, shock sensitive, etc.). An up to date inventory of all chemicals stored in the lab should be maintained.

### *Shelf storage of chemicals*

Most laboratories have shelves or cabinets for storing chemicals. These shelves should be in good condition and securely affixed to the wall or other permanent lab fixture. It is advisable to have a rail or lip (~1-2 inches high) on the exposed edges of the shelf to prevent items from sliding off if inadvertently jostled. Chemicals should not be stored above head height, particularly liquids. Heavy chemical containers should be stored on lower shelves.

Higher shelves can be reserved for lightweight, low hazard chemicals or lightweight lab items such as gloves, kimwipes, etc. A stepstool should be available to lab personnel for accessing these items. Chemicals, other than cleaning supplies, should not be stored under sinks.

It is advisable to store all chemicals in secondary containment trays if practical. These plastic trays are inexpensive and provide containment in the event of a container rupture (containers do sometimes break while sitting alone on a shelf). Secondary containment trays also aid in chemical segregation when lab space is limited (see below).



A chemical container (hygroscopic chemical) that burst, without interaction, resulting from moisture accumulation and swelling over time.

**All chemical containers should be free of chemical contamination on the outside surface and have a screw top lid.** Stopper-top storage bottles should not be used unless for short-term or immediate use. If chemical containers become heavily contaminated over time, they should be carefully decontaminated or declared as hazardous waste and a pickup requested.

### **General chemical segregation**

Chemicals in the lab present numerous health and physical hazards. To minimize the potential for reaction from chemical incompatibility as well as providing rapid hazard identification, chemical segregation based on hazards and compatibility is required. This can be difficult given chemicals often have multiple hazards and lab space is limited. The chart below provides some basic guidance on chemical segregation. This guide takes into account the limited storage space in laboratories.



Stanford University Compatible Storage Group Classification System  
Should be used in conjunction with specific storage conditions taken from the manufacturer's label and MSDS.

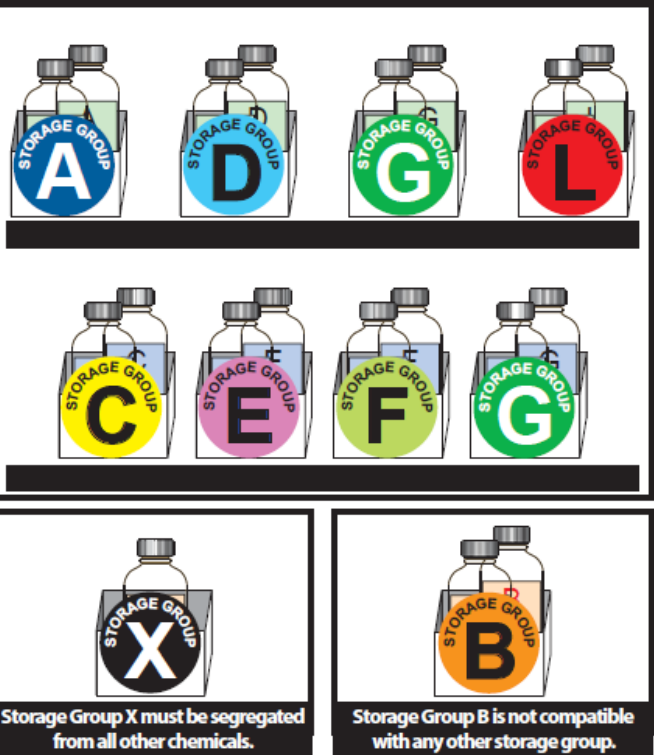
## STORAGE GROUPS

Store chemicals in separate secondary containment and cabinets

<b>A</b>	Compatible Organic Bases
<b>B</b>	Compatible Pyrophoric & Water Reactive Materials
<b>C</b>	Compatible Inorganic Bases
<b>D</b>	Compatible Organic Acids
<b>E</b>	Compatible Oxidizers including Peroxides
<b>F</b>	Compatible Inorganic Acids not including Oxidizers or Combustible
<b>G</b>	Not Intrinsically Reactive or Flammable or Combustible
<b>J*</b>	Poison Compressed Gases
<b>K*</b>	Compatible Explosive or other highly Unstable Material
<b>L</b>	Non-Reactive Flammable and Combustible, including solvents
<b>X*</b>	Incompatible with ALL other storage groups

**\*Storage Groups J, K and X: Consult EHS Department For specific storage - consult manufacturer's MSDS**

If space does not allow Storage Groups to be kept in separate cabinets the following scheme can be used with extra care taken to provide stable, uncrowded, and carefully monitored conditions.



Storage Group X must be segregated from all other chemicals.

Storage Group B is not compatible with any other storage group.

Last updated 04/17/09

General chemical segregation scheme for use in labs when space is limited (*Prudent Practices in the Laboratory*, 2011).

When space is not sufficient to separate chemical storage groups via distance (i.e. different cabinets, shelving units, etc.), secondary containment can be used to provide segregation between certain groups. Note that some groups should be segregated from all other chemicals due to the hazards associated with them. This will be discussed more below. A non-comprehensive list of chemicals that fall into the different storage groups is provided as a supplement to this manual.

Chemical segregation rules apply to all storage conditions (i.e. inside a refrigerator or freezer) as well as when chemicals are transported.

The use of chemical storage groups also allows for rapid identification of chemical hazards and may help efficiency in the lab. No one chemical segregation plan will work in all labs. For assistance in designing and implementing a chemical segregation scheme for your lab, contact OES.



### **Flammable materials storage**

Flammable materials shall be stored in an approved flammable materials storage cabinet. **No more than 10 gallons of flammable liquids may be stored outside of a flammable storage cabinet at one time. Flammable materials that require refrigerated storage must be stored in an approved flammable materials storage refrigerator or freezer.** Oxidizers and other incompatible chemicals shall not be stored with flammable chemicals in the storage cabinet. If a surplus flammable materials cabinet is to be used as a conventional chemical storage cabinet, signage should be placed on it indicating that it is not being used for flammable materials storage. Flammable materials storage cabinets must comply with the requirements specified in NFPA 30 (Flammable and Combustible Liquids Code).



Flammable materials storage cabinet. A variety of sizes are available from multiple manufacturers. Ensure that any cabinet meets NFPA and OSHA standards for flammable materials storage. Small under-hood cabinets are also available.

**Flammable materials storage cabinets should NOT be vented unless there is a specific need due to the storage of highly toxic chemicals.** OES should be contacted to conduct an evaluation to determine if ventilation is required. The cabinet bung caps should be in place at all times and cabinet doors shut when not actively adding or removing containers from the cabinet. Old or damaged cabinets should be evaluated by OES.

### **Corrosives storage (acids / bases)**

Corrosive acids and bases should be properly segregated and stored in corrosive cabinets (if available). If such cabinets are not available, these chemicals should be segregated and stored in secondary containment in available compatible cabinetry or storage areas. Care should be taken to ensure all containers are sealed to prevent vapor escape and corrosion of storage area.

### *Segregation*

Acids and bases should be segregated according to the following general guidelines:

- Acids should be segregated from bases by storing them in separate cabinets.
- Organic acids (i.e. acetic acid, formic acid, etc.) should be segregated from inorganic acids (i.e. sulfuric acid, hydrochloric acid, phosphoric acid, etc.) by storing them in separate cabinets.
- Oxidizing inorganic acids (i.e. nitric acid) should be segregated from all organic acids and organic chemicals by distance, as well as separated from other non-oxidizing inorganic acids by distance or secondary containment. For example, if space is limited, nitric acid can be stored near other inorganic acids if it is placed in a separate secondary container.
- Perchloric acid shall be stored in a compatible secondary container (ceramic, glass, PTFE, etc.). Perchloric acid must not be allowed to come into contact with organic materials (including wood). No organic chemicals shall be stored with perchloric acid. OES should be notified if perchloric acid will be used in the lab. **Hot perchloric acid digestions are not permitted.**
- Hydrofluoric acid shall be stored according to the guidelines provided for [HF storage and use](#).



Corrosive materials storage cabinet for storage or acids. Small under-hood cabinets are also available. These cabinets are constructed from plastic or are coated in a resistant coating to prevent corrosion over time.

## **Oxidizers**

Oxidizing chemicals (i.e. perchlorates, permanganates, nitrates, nitrites, etc.) should be segregated from incompatible chemicals (organic chemicals, fuel sources, flammable solvents, etc.) by distance or secondary containment. It should be noted that even in the solids state, oxidizers can slowly react with organics over time generating heat that further drives the reaction. Some oxidizers can react with organics resulting in combustion without the need for an ignition source. An example of this is the reaction between potassium permanganate and ethylene glycol, both common laboratory chemicals.

## **Highly / acutely toxic chemicals**

Highly toxic and acutely toxic chemicals (i.e. sodium azide, methyl mercury, cyanide salts, etc.) should be segregated from other chemicals based on their high degree of toxicity (not necessarily due to incompatibility). These chemicals should be stored in a secondary container with clear labeling that indicates the high degree of toxicity. This segregation is to help ensure that lab personnel are aware of the hazard of these particular chemicals.



Example label for storage of highly toxic chemicals

## **Air-sensitive chemicals: water reactive and pyrophoric chemicals**

Air-sensitive chemicals such as water reactive chemicals (metal hydrides, alkali metals, phosphorus pentoxide, etc.) and pyrophoric chemicals (butyllithiums, trimethylaluminum, diethylzinc, etc.) should be segregated from other chemicals and stored according to the manufacturer's instructions. If required to be stored at reduced temperatures, a flammable materials storage refrigerator must be used. These chemicals should be properly sealed under inert atmosphere (nitrogen or argon). If possible, these chemicals should be stored in a glovebox or desiccator to minimize the potential for contact with moist atmosphere. Air-sensitive chemicals should only be used by those who have been trained in the proper usage and transfer techniques. Proper PPE (i.e. flame resistance lab coat when using pyrophoric chemicals) shall be worn at all times when handling these chemicals and appropriate engineering controls should be in place.



Air-sensitive chemicals: t-butyllithium is pyrophoric (left) and sodium metal is air and water reactive (right).

### 3. Chemical labeling

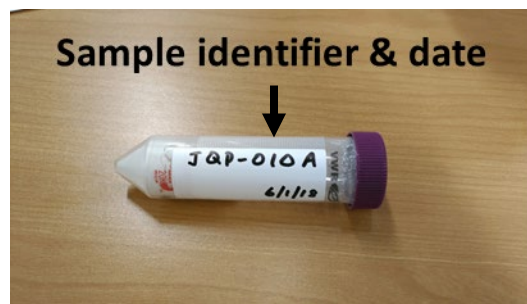
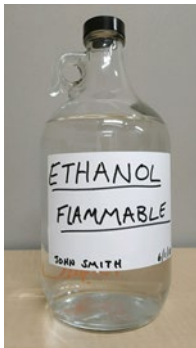
**All chemical containers in the lab shall be labeled (exceptions: beakers, flasks, and other lab glassware in immediate use under the control of a researcher).** The labeling requirements for chemical containers are broken down by container class:

- Original (i.e. manufacturer's / distributor's) container: These containers are required to have the original GHS label affixed at all times. Chemicals should not be accepted if they do not have this label. If, during storage or use, the label becomes defaced or illegible, an equivalent label should be obtained and attached to the container. These can be readily obtained from online databases or the manufacturer's website and printed.
- Storage container: A storage container is a container used to store chemicals taken from the original manufacturer's container. An example of this would be a 1-liter bottle used to store ethanol taken from a 20-liter drum. At a minimum, these containers must be labeled with the full name of the chemical and known (or suspected) hazards (i.e. ETHANOL: FLAMMABLE). Other information should also be listed if space allows such as date of preparation, name of preparer, other pertinent chemical information, etc. The label should be prepared to resist chemical degradation such as a resistant label (available from OES) or a paper label covered with transparent tape.

Long term storage of chemicals prepared or purified in the lab (i.e. purified and dried salts, distilled solvents, synthesized precursor chemicals, etc.) should also follow this labeling standard.

- Small sample containers: Small samples generated in the lab are often stored in small containers that make it difficult to apply full, detailed labels that indicate the contents and hazards. For such containers, at a minimum, a unique identifier should be placed on the container. Often this is in the form of the preparer's initials and notebook page number.

This identifying method should be understood by all lab personnel so that identification of the contents can be readily determined. If possible, other information should be added (chemical formulas or understood abbreviations can be used when space is limited)



Examples of acceptable chemical container labeling for an original container (left), a storage container (center), and a small sample container (right). When space is adequate, as much relevant information should be provided on container labels.

*Special labeling requirements (for storage or sample containers)*

Certain chemicals should possess extra labeling beyond that listed above. These include:

- Air-sensitive chemicals (water / air reactive, pyrophoric, etc.): Any container (regardless of size) of air-sensitive chemical shall contain a label that clearly states that the chemical is air-sensitive (and any special precautions).
- Highly or acutely toxic chemicals: Any container (regardless of size) of acutely or highly toxic chemical shall be clearly labeled indicating that the contents are highly toxic. The use of GHS symbol is recommended.
- Unstable chemicals (i.e. organic peroxides, shock sensitive materials, temperature sensitive chemicals, etc.). Any container (regardless of size) of unstable chemicals shall be clearly labeled to indicate the hazard (i.e. shock sensitive, temperature sensitive, etc.). Specifics as to proper storage shall also be listed on the label such as storage temperature. These chemicals shall be stored according to the required storage conditions.
- Compressed gases: Compressed gas cylinders shall be labeled according to DOT, NFPA, and fire code standards that include full chemical name and hazards (see relevant standards for specific requirements). Highly toxic gases shall be stored in approved gas cabinets or ventilated enclosure (i.e. fume hood for lecture bottles).

**In all circumstances, it is the responsibility of the lab PI to ensure that labeling standards are understood by all lab personnel and followed.**

Lab labeling standards (i.e. for small sample containers) should be reviewed regularly so contents are able to be quickly identified in the event of spill or chemical exposure.

#### **4. Peroxide forming chemicals**

Several common chemicals stored and used in the laboratory have the ability to form shock and light sensitive peroxides over time. These explosive peroxides have been the cause of many lab accidents and injuries (and deaths). Chemicals that have the potential to form explosive peroxides over time should be identified prior to purchase and proper procedures in place to ensure safe use and storage. The following chart lists many common peroxide forming chemicals (not comprehensive).

##### **Classes of Chemicals That Can Form Peroxides**

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###### **Class A: Chemicals that form explosive levels of peroxides without concentration**

Isopropyl ether	Sodium Amide
Butadiene	Tetrafluoroethylene
Chlorobutadiene	Divinyl acetylene
Potassium amide	Vinylidene chloride
Potassium metal	

###### **Class B: These chemicals are a peroxide hazard on concentration (distillation/evaporation). A test for peroxide should be performed if concentration is intended or suspected.**

Acetal	Dioxane (p-dioxane)
Cumene	Ethylene glycol dimethyl ether (glyme)
Cyclohexene	Furan
Cyclooctene	Methyl acetylene
Diacetylene	Methyl cyclopentane
Dicyclopentadiene	Methyl-isobutyl ketone
Diethylene glycol dimethyl ether (diglyme)	Tetrahydrofuran
Diethyl ether	Tetrahydronaphthalene
Vinyl ethers	



**Class C: Unsaturated monomers that may autopolymerize as a result of peroxide accumulation if inhibitors have been removed or depleted.**

Acrylic acid	Styrene
Butadiene	Vinyl acetate
Chlorotrifluoroethylene	Vinyl chloride
Ethyl acrylate	Vinyl pyridine
Methyl methacrylate	

Non comprehensive list of common peroxide forming chemicals by class (*Prudent Practices in the Laboratory*, National Academies Press, 2011).

Peroxide formers are separated by class (A-C).

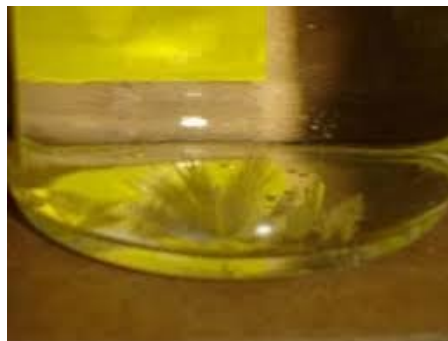
- Class A peroxide formers: Can form explosive levels of peroxides without concentration of the parent chemical. These chemicals should be ordered only when immediately needed. These chemicals should be disposed of after ~3 months of receipt if not used.
- Class B peroxide formers: These chemicals can form explosive levels of peroxides when concentrated (i.e. via evaporation or distillation). These chemicals should be used on a first-in, first-out basis and storage kept to a minimum. These chemicals should be tested for peroxides within ~6 months of opening and on a regular basis after. Peroxide levels of 10ppm or more should be declared as hazardous waste.
- Class C peroxide formers: These chemicals can accumulate peroxide that result in exothermic polymerization reactions.

*Storage*

Peroxide forming chemicals should be stored according to the manufacturer's directions and according to hazard class (i.e. flammable, etc.). Efforts should be made to store peroxide forming chemicals in the dark or in amber bottles. **All peroxide forming chemicals shall have the date received and the date opened clearly marked on the bottle. Dates of peroxide tests and results shall also be maintained.**

**If crystals, stratification, or discoloration is observed in / on peroxide forming solvents, do not open or move the container (MANY PEROXIDES ARE SHOCK AND LIGHT SENSITIVE EXPLOSIVES).** Isolate the area and call OES for an evaluation. It may be necessary to have the container removed and destroyed by specialty contractors if a large accumulation of explosive peroxides is present.





Peroxide crystals formed on the interior surfaces of peroxide forming solvent bottles. Never touch a peroxide forming chemical bottle that contains crystals on the interior, around cap, or under cap.

Some peroxide formers are solids such as sodium amide and potassium metal. Potassium metal is not inert when stored under mineral oil in air. Over time, oxygen reacts with the metal to form potassium superoxide and eventually peroxide. The superoxide forms a yellow film on the surface of the metal. **Potassium containing superoxide should not be cut as contact between the superoxide and metal can result in a highly energetic reaction.**

### Testing

Peroxide test strips are available from several vendors and should be maintained in labs that store peroxide forming chemicals. Testing should be performed on class B and C peroxide formers ~6 months after opening and on a regular basis after that (~every month). Peroxide forming chemicals should be tested prior to using them in a distillation or any process that involves concentration of the solution (i.e. rotovap, etc.). **If peroxides are detected, do not use for any process that involves concentration of the solution.** Chemicals that contain peroxides should be declared as hazardous waste.



Peroxide test strip that indicates a level of 30ppm peroxide from a THF sample.

## 5. Particularly Hazardous Substances (PHS)

The OSHA Lab Standard identifies PHS as:

*“select carcinogens,” reproductive toxins, and substances which have a high degree of acute toxicity.”*

The Standard requires that consideration be given to the following provisions (with regard to use of these chemicals):

- Establishment of a designated area (for use and storage)
- Use of containment devices such as fume hoods or glove boxes
- Procedures for safe removal of contaminated waste
- Decontamination procedures

As with all chemicals, it is the responsibility of the PI to ensure that all lab personnel are familiar with the health and physical hazards of chemicals stored and used in the laboratory.

The number of chemicals that fall into this category are too expansive to list here, however, determination if a particular chemical falls into these categories can be determined from the SDS information.

Other chemicals that fall under the umbrella of PHS are those which pose hazards such as being pyrophoric, water reactive, self-reactive, explosive, etc. **Labs utilizing these chemicals should have established standard operating procedures (SOPs) for the storage, use, and disposal of such chemicals.** Lab personnel shall not utilize such chemicals unless they have been properly trained in how to do so. Contact [OES](#) for assistance if training is needed.

**It is the responsibility of the lab PI to ensure that personnel using PHS are adequately trained in the hazards and SOPs associated with these chemicals. This lab-specific training shall be documented.**

Contact OES for assistance in determining which chemicals are considered PHS as well as assistance in developing training, SOPs, and emergency procedures.

## 6. Unattended operations

In many circumstances it may be necessary to allow a chemical reaction or other laboratory process to run unattended or overnight (or for days on end). While it is certainly advisable to remain present during chemical processes in event of emergency, this is not always practical.

In circumstances where reactions or processes must continue unattended, the following guidelines should be followed:

- All unattended operations should be conducted in a fume hood or other appropriate enclosure. Sash should be lowered when unattended.
- Reaction apparatus should be thoroughly checked for any potential problems such as cracked glassware, faulty joints, improper connections, etc.
- Pressure relief mechanisms should be present for any operation conducted at low or elevated pressure or where pressure changes are anticipated.
- For any heated process, temperature controllers should be checked for proper operation and set with appropriate overhead protection and failsafe points.
- Any cooling requiring water flow should be conducted using a recirculating chiller (closed loop).
- All lab personnel should be made aware of the unattended procedure and hazards involved.
- Appropriate monitors should be employed where / when necessary, such as gas monitors, pressure sensors, etc.
- Electronic test equipment should be checked for proper function and appropriate compliance and failsafe settings employed.
- Notification should be left on the hood sash and on lab exterior door indicating that an unattended operation is being performed. Basic information on the nature of the procedure, chemicals used, hazards, etc. should be listed. Hazard and emergency information on the procedure should be written such that a non-specialist can understand.

Contact information should be provided in the event of an accident or concern. A basic “Unattended Procedure” notification sheet is available from the OES website.

## **V. Emergency Equipment and Procedures**

The purpose of this section is to provide guidance on laboratory emergency equipment and procedures. This section is intended as a general guide as the myriad and variable contingencies possible in the laboratory require lab-specific planning and procedures. For assistance in identifying potential emergencies or formulating emergency procedures, contact OES.

### **Highlights:**

- Laboratories shall be equipped with a safety shower and / or facewash or eyewash based on a hazard assessment conducted by OES. Showers and facewash / eyewash units shall be tested (function test) once a month and results recorded. Any deficiencies shall be immediately reported to OES. Facilities Life Safety shall conduct annual certifications on all units.
- Emergency procedures for chemical exposure and the use of safety showers / eyewashes should be understood by all lab personnel.
- Laboratories shall be equipped with an emergency chemical spill kit to handle small chemical spills or incidental contamination.
- Lab personnel should be trained in proper use of spill kit materials as well as emergency procedures for chemical spills.
- All laboratories shall contain fire extinguishers of a type and quantity determined by a hazard assessment conducted by OES and in accordance with local fire code. A shelf check of extinguisher pressure should be conducted by each lab on a monthly basis and any deficiencies reported to OES.
- Lab personnel should be trained in the use of fire extinguishers.
- Emergency procedures for fire should be understood by all lab personnel.
- Laboratories should maintain a fully stocked first aid kit.
- First aid / CPR training is recommended for laboratory personnel.
- Laboratories should maintain procedures for loss of power and / or ventilation.
- Emergency contact information shall be maintained on the laboratory door sign with primary, secondary, and tertiary contact names and numbers.
- Written lab-specific emergency procedures shall be maintained and understood by all lab members.

## 1. Chemical exposure emergency equipment

All labs shall have procedures in place for handling chemical exposures as well as the appropriate safety equipment such as safety showers, eyewash / facewash, drench hoses, etc. The following section describes the use and maintenance of such equipment. The particular emergency equipment required in each lab will depend on the health and physical hazards of chemicals used / stored as well as the type of research being conducted. A hazard assessment by OES will determine the specific needs of the lab.

### **Safety shower**

A safety shower (deluge shower) shall be present and functional in any lab where it is deemed necessary by a hazard assessment. The safety shower placement and performance shall conform with the criteria stipulated in [ANSI Z385.1](#). Safety shower units may be stand alone or combination units which include an eyewash or facewash.



Combination eyewash / safety shower (left) and stand-alone safety shower (right) examples.

A function test shall be performed on safety showers by lab personnel (or designated individual) once a month. Using a test apparatus to contain water (contact department DSC or building manager), the shower should be briefly activated to ensure proper flow and water quality. Immediately report any water discoloration or flow problems (i.e. low flow, obstructed flow, etc.) to OES. The results of the monthly check shall be recorded and made available upon request.

### **Eyewash and facewash**

An eyewash is designed to provide emergency flushing fluid to the eyes in the event of chemical exposure. A facewash is designed to provide flushing fluid to the entire face in the event of chemical exposure.

Both style of units must satisfy the criteria of the ANSI Z385.1 standard and have a function test performed once a month. Due to the ease of performing a function test on eyewash and facewash units, a weekly test is recommended. Best practice is to check the eyewash for flow and operation each day prior to lab activities.

Eyewash and facewash units may be stand alone, combination units with a shower, or sink mounted. **Portable eyewash bottles do not meet the requirement for emergency eye flushing equipment** but may supplement a fixed unit. Some sink mounted eyewash units are attached to an extendible hose and can serve as an emergency drench hose.



Stand-alone eyewash, sink mounted eyewash / drench hose, and facewash (left to right).

### **Drench hose**

A drench hose is a supplemental flushing device used for emergency flushing of chemical exposures. This type of device does not satisfy the requirement for a dedicated eyewash or safety shower. This unit should have a function test performed on the same schedule as eyewashes.



Drench hose for supplementary flushing.

## 2. Emergency procedures for chemical exposures

Any chemical exposure of personnel must be handled rapidly and correctly to minimize the potential for long-term injury. The following section outlines the basic response to chemical exposures; however, it is important to fully understand the nature of the chemicals you are working with and any specific protocols associated with chemical exposure.

All members of the lab should be familiar with what to do in the event of a chemical exposure and discuss these regularly within the group.

The response to any chemical exposure or spill should follow the following basic response structure:

1. NOTIFY those around you that you have had a chemical exposure, so they can assist you if necessary.
2. ISOLATE the area so others do not become contaminated or spread contamination.
3. TREAT the exposure based on the properties of the chemical, scale of exposure, exposure route, exposure duration, etc.

If the situation warrants it, 911 should be called for emergency assistance. **If the exposure is to an acutely or highly toxic chemical, 911 should be called regardless of the scale of the exposure.**

### **Chemical exposures of the skin (small area)**

Chemical exposures of the skin affecting only a small surface area of the body should be handled using the following guidelines:

1. Proceed (with assistance if necessary) to a sink and wash the affected area for 15 minutes under running tepid water (use soap if suggested by SDS).
2. Remove any contaminated clothing (i.e. lab coat, shirt, etc.) or jewelry.
3. If necessary, call 911 or proceed to Redfern Medical Clinic. A second person should stay with the affected individual until help arrives or arriving at the clinic. The chemical SDS (safety data sheet) should be provided to medical personnel as well as the time of exposure, exposure route, exposure duration, actions taken, etc.
4. If medical attention is not needed, continue to monitor the affected area for signs of any delayed effects. If pain or delayed effects are observed, immediately seek medical attention.
5. All chemical exposures should be reported to the lab PI and the Office of Risk Management and OES (online incident report forms).



Some chemical exposures can occur on parts of the body which are not readily accessible, such as the back of the neck. In such cases, assistance from others may be needed to effectively wash the affected area. If assisting others with a chemical exposure be sure to wear appropriate PPE to prevent contaminating yourself. Have a plan for handling such exposures.

If the chemical exposure requires a specific response or first aid treatment such as using soap or calcium gluconate gel (as determined from the SDS first aid information), follow those instructions.

### **Chemical exposures of the skin (large area)**

Chemical exposures of the skin covering a large percentage of body surface area (i.e. arm, face, torso, etc.) can be extremely serious and rapid response is necessary. **In all cases of large-scale chemical exposure, 911 shall be called.** The nature of the accident, chemical information, time of incident, exposure route, body area affected, etc. should be relayed to the dispatcher.

Individuals who have had a large area chemical exposure should:

1. Immediately proceed to the safety shower (with assistance if necessary) and activate the flow of water by pulling the handle.
2. Remove all contaminated clothing and PPE. Others can provide privacy using a blanket or lab coats as a modesty screen.
3. Remain in the flow of water for at least 15 minutes or until medical personnel instruct you to stop.
4. All large-scale exposures should be evaluated by medical personnel
5. All chemical exposures should be reported to the lab PI and the Office of Risk Management and OES (online incident report forms).



### **Chemical exposure of the eyes**

The following steps should be taken in event of chemical exposure of the eyes:

1. Proceed (with assistance if necessary) to the nearest eye wash station.
2. Flush eyes, while holding eyelids open and away from eyeball, for 15 minutes.
3. If necessary, call 911 or proceed to Redfern Medical Clinic. A second person should stay with the affected individual until help arrives or arriving at the clinic. The chemical SDS (safety data sheet) should be provided to medical personnel as well as the time of exposure, exposure route, exposure duration, actions taken, etc.
4. If medical attention is not needed, continue to monitor the affected area for signs of any delayed effects. If pain or delayed effects are observed, immediately seek medical attention.
5. All chemical exposures should be reported to the lab PI and the Office of Risk Management and OES (online incident report forms).



### **Inhalation exposure to chemicals**

Inhalation exposure to hazardous chemicals can be difficult to diagnose due to the range of symptoms possible, which may be delayed. The signs and symptoms of exposure will depend on the particular chemical as well as dose and duration of exposure. Signs of inhalation exposure to chemicals include:

- Difficulty breathing
- Pain / irritation of airways
- Wheezing, coughing
- Dizziness
- Headache
- Blurred vision
- Loss of consciousness
- Nausea

If inhalation of chemicals is suspected or known, immediately:

1. Move the victim to fresh air.
2. Evacuate the area if source of chemical is unknown.
3. Call 911 for emergency assistance. If breathing stops, provide artificial respiration (if you are able / willing).
4. Provide dispatcher and emergency personnel with SDS information (if known), symptoms, duration of exposure and symptoms, actions taken, etc.
5. Remain with victim until help arrives.

### 3. Chemical spills

Chemical spills in the laboratory are unfortunately a common occurrence. All efforts should be made to observe prudent lab practices to prevent spills, but when they occur, personnel must be prepared to handle them. The following section provides basic guidance for handling chemical spills in the laboratory. It must be stressed that the response to any chemical spill will depend on many factors, starting with the health and physical hazards of the chemical being used. SDS and other chemical information sources should be reviewed prior to beginning work with a new chemical. Always have an answer for the question, “what do I do if this spills?”

**Lab personnel are not required to clean chemical spills themselves. The CUFD HAZMAT team is the primary agency responsible for cleaning spills of hazardous chemicals. However, if lab members are properly equipped, trained, and it is safe to do so, small incidental chemical spills may be handled by laboratory personnel.**

#### **Chemical spill kit**

Each lab should be equipped with a chemical spill kit and all members should be aware of its location and proper use. Spill kit contents will vary based on the chemicals stored and used in the lab, but basic spill kits will contain items such as:

- Absorbent spill pads and socks



- Thick plastic bags for hazardous waste (with hazardous waste labels)
- Absorbent material (i.e. vermiculite, diatomaceous earth, etc.)
- Nitrile gloves (or other material based on chemical resistance)
- Safety glasses
- Neutralizing agent (baking soda, calcium carbonate, or other based on chemical)
- Non-metallic dustpan and brush

Commercially available spill kits can be purchased from numerous vendors and will often contain many of the above items. These kits can be augmented to meet the needs of the lab.

OES can assist in selecting items for a chemical spill kit. Some chemicals (i.e. hydrofluoric and perchloric acid) have specific spill response protocols and require a specific spill kit and response. Contact OES for a consultation.

### **Small (incidental) chemical spills**

Small spills are characterized as small volumes of chemical (~2 liters or less) that are not highly or acutely toxic or possess other properties that would require immediate evacuation (i.e. explosive, fuming, etc.). As with chemical exposures, follow the NOTIFY and ISOLATE sequence, however, in the case of spills, you must decide whether to TREAT / CLEAN the spill or EVACUATE the area. **Small spills should only be cleaned if you are aware of the chemical and physical properties, and associated hazards, of the chemical and are trained to clean the spill.** If the decision is made to clean the spill the following basic steps should be followed:

#### *Liquid chemical spill*

1. Ensure you are wearing appropriate PPE (glasses, gloves, lab coat).
2. If the chemical is flammable, remove/isolate/disable any source of ignition (i.e. open flames, hotplates, heating mantles, etc. Remember static is a potential ignition source).
3. Contain the spill around the periphery using spill socks or pads.
4. Use tongs or forceps to pick up any broken glass.
5. If the chemical requires neutralization, use the appropriate neutralizing agent.
6. Working from the outside in, use absorbent pads to absorb the liquid and place the pads into the hazardous waste bag.
7. Wipe or mop the area with soap and water after all chemical is collected.



### *Solid chemical spill*

1. Contain the spill around the periphery
2. Use dustpan and brush to carefully collect the solid and place it in a hazardous waste bag.
3. Wipe or mop the area with soap and water after all chemical is collected.

The collected hazardous waste should be declared as such and a waste pickup scheduled.

If you do not feel comfortable handling a small spill, or do not feel it is safe to do so, call OES or, if an emergency, 911 for CUFD HAZMAT. Continue to isolate the area until assistance arrives.

### **Large chemical spills**

Large volume chemical spills (~ 2 liters or greater) should not be handled by lab personnel.

**Spills of this volume should be referred to CUFD HAZMAT for evaluation and remediation.**

In such cases, NOTIFY other lab members that a spill has occurred and what the nature is. EVACUATE the immediate area and ISOLATE the area and prevent access. If the spill is of a highly toxic or odiferous chemical and effects are observable outside the immediate area (i.e. outside the lab in hallways, common areas, etc.) it may be necessary to evacuate the floor or building.

If you feel, based on the chemical and the scale of the spill, that building evacuation is needed:

1. Proceed to pull the nearest fire alarm pull-station
2. Once in a safe location call 911 and notify the dispatcher that CUFD HAZMAT is needed for a chemical spill (or local HAZMAT if off main campus). Provide the dispatcher with the chemical name and properties, scale of the spill, time of spill, actions taken, any injuries or exposures, etc.
3. Provide information to first responders when they arrive.
4. Do not reenter the building or lab until it is deemed safe by CUFD.



## 4. Fire

Fire is a serious hazard in the laboratory and can have catastrophic consequences. Lab personnel are responsible for performing a hazard assessment when working with flammable materials and preparing for potential emergencies. Information on hazard assessment and lab fire-safety is provided in the appendix of this manual. The location of the nearest fire alarm pull stations should be known by all members of the lab. Fire department contact information should be posted on lab door signs. In event of emergency, always call 911 and provide the location and details of the incident to the dispatcher. The following section provides information on emergency equipment and procedures for handling fires in the laboratory.

If the building fire alarm is activated, all laboratory personnel should cease work, secure any open chemicals, turn off any heat sources, and evacuate the building. Lab personnel should assemble at a predesignated location and not reenter the building until directed to do so by emergency personnel.

**It is important to remember that you are not expected to put yourself in danger if you decide to attempt to extinguish a fire. In any case where you do not feel comfortable or are uncertain, immediately evacuate the area and pull the fire alarm to notify CUFD.** Only attempt to extinguish a fire if:











- Fire has not spread beyond point of origin
- Fire is not too large
- Air in area is safe to breath
- Evacuation rout is known and not obstructed

This list is not comprehensive, and individuals should err on the side of protecting life (including their own) when deciding to attempt to extinguish a fire. In the event of a fire:

1. NOTIFY those around you that a fire has occurred.
2. ISOLATE the area and prevent access
3. EVACUATE and pull the fire alarm or EXTINGUISH the fire only if it is safe to do so and you have been trained.

### **Fire extinguishers**

All labs shall be equipped with the appropriate fire extinguisher(s) based on a hazard assessment. The number of extinguishers required is based on the South Carolina Fire Code (2018) and OSHA regulations. All lab members should be aware of the location of each extinguisher as well as trained in proper usage. The following chart shows the types of fire extinguishers and their use.

Class of Fire	Type of Fire	Type of Extinguisher	Extinguisher Identification	Symbol
<b>A</b>	Ordinary combustibles: wood, paper, rubber, fabrics, and many plastics	Water, Dry Powder, Halon		
<b>B</b>	Flammable Liquids and Gases: gasoline, oils, paint, lacquer, and tar	Carbon Dioxide, Dry Powder, Halon		
<b>C</b>	Fires involving Live Electrical Equipment	Carbon Dioxide, Dry Powder, Halon		
<b>D</b>	Combustible Metals or Combustible Metal Alloys	Special Agents		No Picture Symbol 
<b>K</b>	Fires in Cooking Appliances that involve Combustible Cooking Media: Vegetable or Animal Oils and Fats			

The majority of labs are equipped with ABC extinguishers that utilize monoammonium phosphate as an extinguishing agent. These extinguishers are used on fires that fall under categories A, B, and C. For labs that utilize reactive metals (sodium, potassium, finely divided metals such as titanium, etc.), a class D fire extinguisher may be needed. Contact OES for an evaluation.

Fire extinguishers should be mounted on the wall and unobstructed. Lab members should perform a monthly self-check of the extinguisher and ensure that the pressure is in the green. If under or overpressure is observed, notify OES. If a fire extinguisher is discharged, always notify OES so a replacement can be provided.

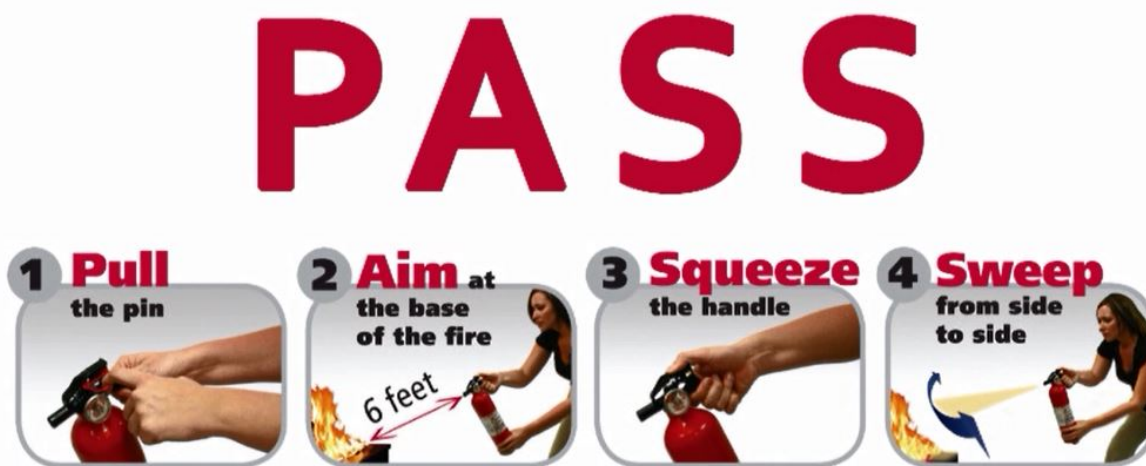


Ensure needle on extinguisher pressure gauge is located in the green region. Notify OES if any other condition is observed.



### **Fire extinguisher use**

If it is determined that a fire extinguisher must be used (and it is safe to do so), use the PASS method to attempt to extinguish the fire.



If this action fails to completely extinguish the fire, immediately evacuate the area and pull the nearest fire alarm. **In all cases of fire in the laboratory (whether extinguished or not), the Clemson Fire Department shall be notified to handle the situation or perform a follow up inspection and evaluation.** In all events of fire, incident report forms shall be completed with the Office of Risk Management and OES.

### **Other items for extinguishing fires**

Other items are available in most laboratories for handling small fires. Lab groups should have regular discussions on how to handle potential fire emergencies of any scale. Some of these items include:

*Fire blankets:* Fire blankets can be used to smother a small fire on a benchtop, floor, etc. or be used as a tool to assist an individual whose clothes have caught fire. If the lab is equipped with a fire blanket, it must be inspected on a regular basis (for damage and wear) and replaced if necessary.



*Sand:* Sand can be used to smother small fires. Care must be taken when using sand on flammable solvents as the resulting mixture will still contain flammable solvent and potentially reignite.

*Watch glasses, beakers, etc.:* A common situation is the ignition of flammable liquid in a beaker or reaction vessel. A watch glass or another beaker, etc. can be used to deprive the fire of oxygen by placing it over the container that is on fire. Care must be taken not to knock over the vessel and spreading the fire.

*Water / safety shower:* Depending on the nature of the fire, water can be used as an extinguishing agent. In emergency situations, an individual whose clothes are on fire can be doused in the safety shower (if in immediate proximity). The safety shower can also be used as first aid treatment for soothing burns in such a scenario.

### **Personnel on fire**

In the unlikely event your clothing catches fire, immediately

**STOP**

**DROP**

**ROLL**

and **SMOTHER** to extinguish the flames. If you witness another lab member who is on fire, you can assist (if it is safe to do so) by attempting to smother the fire with a fire blanket or lab coat. As mentioned above, the safety shower can be a tool in such a scenario. **In all cases involving an individual on fire, 911 should be called and medical treatment sought.**

First aid can be administered to the individual if you are trained and equipped to do so. Rapid medical attention is required as burns can represent a life-threatening situation.

## **5. Medical emergencies**

Injuries may occur in the lab and they may be minor (cut finger, small burn, etc.) or major (deep laceration, severe burns, major trauma, etc.). All labs should regularly discuss procedures for dealing with common medical emergencies. A fully stocked first aid kit should be maintained in the lab at all times. It is recommended that lab members receive training in basic first aid and CPR. While not required, these skills are useful in and out of the laboratory.

**In all cases of major injuries, or circumstances where the severity of the injury is not known, 911 should be called immediately.** Relay pertinent information to the dispatcher including location, time of incident, incident details, treatments performed, etc. Someone should remain with the injured person until help arrives. If chemicals are involved, provide the SDS information and nature of the exposure to medical personnel.

## 6. Power and / or ventilation failure

Unexpected electrical power outages can present a risk to personal safety as well as the potential for damage to sensitive laboratory equipment. Each lab should maintain detailed procedures and protocols in their lab standard operating procedures (SOP) to ensure the safety and security of the lab in the event of power loss. When the loss of electrical power is expected or likely, the following minimum steps should be taken.

- No laboratory work should be conducted during power / ventilation outage.
- Ensure all chemical reactions / experiments are ceased, all chemicals and biological samples are capped and properly stored, and gas cylinders closed at the valve.
- Lower fume hood and biological safety cabinet sashes to their lowest position.
- If you have chemicals which require low temperature storage, prepare for their storage in event of long-term outage such as using dry ice.
- Any chemicals which may decompose violently at elevated temperatures should be transferred to a unit with backup power.
- Ensure electrical equipment and chords are raised off the floor in the event of flooding (especially around freezers and refrigerators where melted ice might leak).
- Power down and unplug non-essential, sensitive electronic equipment to protect them from power surges upon restoration of power.
- Ensure electronic equipment which cannot be powered down is surge protected.
- Turn off vacuum pumps and vent lines to prevent backflow.
- Monitor reports of power outages in the area and designate personnel to check the lab (if conditions are safe to do so) when normal power is restored.
- Emergency generators can fail, be prepared for such situations and take preventative actions.
- Ensure laboratory security. Electronic card readers and locks may not work during an outage.
- Maintain photographs of laboratory equipment in the event of damage.

When Normal power is restored:

- Do not enter facilities until it has been deemed safe to do.
- Carefully inspect all equipment for signs of damage prior to restarting.
- Ensure all fume hoods and biological safety cabinets are functioning properly before using.

## **7. Emergency contact information**

Up to date emergency contact information should be maintained and posted on the lab door. Primary, secondary, and tertiary contacts should be provided (at a minimum). In event of an issue occurring overnight (i.e. smells, smoke from lab, etc.) these individuals may be contacted to provide first responders with information regarding ongoing procedures or chemicals stored in the lab. Lab staff are an important resource during a response.

## **8. Lab specific emergency plans**

Each lab should create and maintain lab-specific emergency plans for procedures or equipment specific to their line of research. Examples include:

- Electrical test equipment
- Solvent stills
- Pyrophoric chemicals
- Air-free techniques and transfers
- Compressed gas systems
- Mechanical processes
- Glove boxes
- High pressure systems
- Etc.

These procedures should be reviewed and discussed regularly so that all lab members are familiar with them. The procedures should be written and updated as necessary. For assistance in creating emergency procedures for hazardous lab processes or chemicals, contact OES.

## **7. Incident reporting**

All incidents that occur in lab (i.e. chemical spills, exposures, fire, etc.) as well as near-misses shall be reported to OES. An incident report form is available on your SciShield page with instructions. Near-miss incidents are valuable learning tools and can also be reported using SciShield. If an injury or exposure has occurred involving a university employee, an incident report must also be filed with the [Office of Risk Services](#).

## **VI. Compressed Gas Cylinders**

The purpose of this section is to provide basic guidance on the storage, transportation, and use of compressed gas cylinders. Due to the myriad cylinder types, contents, and applications, OES should be consulted to provide guidance on specific circumstances that are outside the scope of this basic information.

### **Requirements:**

- Lab personnel should be familiar with the hazards of compressed gas cylinders and systems as well as the hazards of the chemicals they contain. Contact OES to schedule a training session.
- All compressed gas cylinders shall be properly secured to an appropriate bracket while in storage or in use. Mounts shall be affixed to immovable objects such as a wall or a fixed laboratory bench.
- Cylinders shall be secured to brackets using a strap or chain rated for the weight of the cylinder. The strap or chain should be snug to the cylinder and positioned between the midpoint and the cylinder shoulder.
- Gas cylinders must be stored upright, exceptions being cylinders that are specifically designed for horizontal use.
- Gas cylinders shall be segregated according to compatibility as with other chemicals. Oxygen must be separated from fuel gas (i.e. hydrogen, methane, etc.) by 20ft or by a noncombustible barrier 5ft high with a fire resistance rating of one-half hour.
- Highly toxic gas cylinders must be stored in an approved ventilated gas cabinet. Consult OES prior to purchasing compressed gas cylinders of highly toxic chemicals.
- Compressed gas cylinders shall not be stored in quantities in excess of that permitted by South Carolina Fire Code (2015). Consult OES for determination of allowable quantities.
- Cylinders shall be moved using a cylinder dolly and not rolled on the cylinder edge.
- Cylinders should not be accompanied in elevators.
- Damaged or unlabeled cylinders shall not be accepted from vendors.
- Cylinders not in use shall have the cylinder cap in place. Cylinders in use shall have the appropriate regulator in place. Regulators shall not be modified.
- Gas delivery systems should be evaluated by OES (during design stage if possible) to identify the need of any infrastructure alterations or improvements.
- Labs should have written emergency plans for handling cylinder leaks, ruptures, or other potential accidents.

## 1. Compressed gas safety

Compressed gases present unique hazards and risks that must be planned for in the laboratory. Three primary hazards associated with compressed gas cylinders are:

- The tank itself. Common type-K compressed gas cylinders can weigh ~140 lbs and presents a physical hazard when moving and securing these cylinders. The most common injuries associated with gas cylinders are physical injuries resulting from moving or falling cylinders. The tank itself is also under high pressure (typically 2000-3000 psig) and this can result in an extremely hazardous condition in the event of a rupture. Severing of the cylinder valve stem can result in the cylinder becoming a deadly projectile.
- The tank contents. The cylinder contents present hazards and risks associated with the chemical and physical properties of the chemical. SDS and other information should be consulted to determine these hazards and steps taken to minimize risk. Inert gases present an asphyxiation risk in the event of cylinder venting or rupture. All hazards of cylinder contents should be understood by all lab members.
- Gas delivery system / method. The method of delivering the gas from the cylinder to the point of use also presents hazards that must be evaluated. The proper type of regulator (based on the gas) must be used. Improperly connected, damaged, or modified regulators can lead to gas leakage. Appropriate tubing or piping compatible with the gas must be employed and leak checked regularly. Pressure relief devices should be used in-line to prevent overpressure of the delivery system or test apparatus. Flashback arrestors and check valves should be used with when necessary.

In-person training can be scheduled with OES to familiarize labs with basic compressed gas safety and operation. More in-depth information on compressed gas safety and regulations can be found in the following references.

- Handbook of Compressed Gases, 4<sup>th</sup> Ed., Compressed Gas Association, Inc., 1999.
- [NFPA 55](#), Compressed Gases and Cryogenic Fluids Code, 2020.
- [South Carolina Fire Code, 2021](#).



## 2. Compressed gas cylinder and cryogen storage

Compressed gas cylinders should be stored in a cool, dry location out of direct sunlight. Care should be taken to position cylinders in a location where they will not be exposed to excessive heat, cold, moisture, corrosive vapors, etc. Cylinders must not be situated where they can become part of an electric circuit.

Compressed gas cylinders and cryogens (i.e. liquid nitrogen storage dewars) shall be stored in well ventilated areas to minimize the potential for oxygen deficient conditions due to venting or catastrophic release of gas (as well as fire for flammable gases). Storage rooms must have adequate ventilation and / or oxygen monitoring. OES will perform a hazard assessment to ensure storage spaces meet these criteria. **No one should ever enter a space with a suspected oxygen deficient atmosphere.** Cryogen safety is discussed further in Appendix 2.

Compressed gas cylinders shall be secured to a cylinder mount or bracket using a strap or chain to prevent tipping or falling. These should be capable of supporting the full weight of the cylinder. The cylinder shall be stored / used in the upright position unless the tank is specifically designed to be used in the horizontal position. The cylinder bracket shall be secured to a rigid, immovable object such as a wall or fixed lab bench. Cylinder stands can be used for temporary storage or during cylinder use but should not be used as a long-term storage method.



Compressed gas cylinders secured to a lab bench bracket (left) and wall mounted bracket (right).



Multiple cylinders can be grouped together and secured via a chain. The number of cylinders should be kept to a minimum ( $\leq 4$ ) and proper segregation should be observed. Contact OES for assistance in determining proper storage for larger groups of cylinders in the lab.

Cylinders not in use shall have the cylinder cap fully screwed onto the cylinder. Cylinders in use shall have the appropriate regulator properly attached to the valve stem outlet.

Gas cylinders shall be segregated based on chemical compatibility as with other laboratory chemicals. Empty gas cylinders shall be segregated in the same manner and labeled as “empty.”

Oxygen cylinders shall be separated from fuel gas cylinders (i.e. flammable gases) by 20ft or a 5ft tall noncombustible barrier that has a fire resistance rating of one-half hour. This barrier must block the line-of-sight between the two cylinders. Cylinders containing flammable gases should be stored as to avoid possible ignition sources, excessive heat, open flame, etc.

The use of check valves or flashback arresters are recommended when using some flammable gases (i.e. acetylene). Contact OES for guidance on storage and use of oxygen and fuel gas cylinders.



Oxygen (and other oxidizing gases) should not be stored with fuel gases (i.e. hydrogen).

Lecture bottles shall be stored according to chemical compatibility. These smaller compressed gas bottles should be stored in the vertical position. They should be stored in such a manner as to prevent rolling or damage to the valve stem or cylinder body.

The number of cylinders stored in the lab should be kept to a minimum and only what is necessary for the current research / experiments. The Maximum Allowable Quantity (MAQ) of specific types of compressed gases are regulated under the South Carolina Fire Code (2015) and NFPA 55 (Compressed Gases and Cryogenic Fluids Code, 2020 Ed.). For determination of the MAQ for gases contact OES or the Clemson Code Compliance Officer.

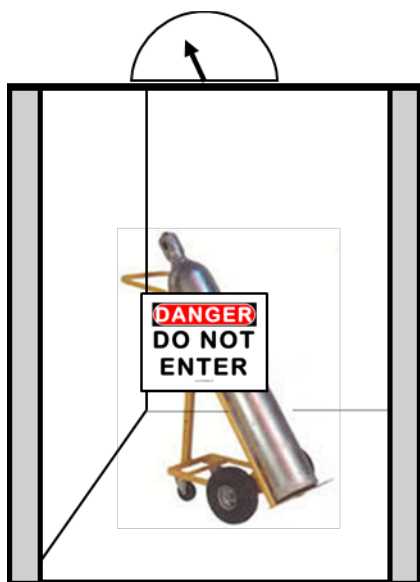
### **3. Transporting compressed gas cylinders**

Compressed gas cylinders shall not be dragged or rolled from the storage location to the point of use. A specifically designed cylinder dolly (available in most departments) shall be used. The cylinder should be secured during transport using the chain or strap on the dolly. Once at the point of use, the cylinder can be carefully rolled on its bottom the last short distance. Do not modify standard dollies or other equipment for this use. Contact OES or your building manager for assistance in locating an appropriate cylinder dolly. No attempt should be made to lift or hoist cylinders without explicit approval and appropriate equipment.



Compressed gas cylinder on cylinder dolly and secured with a chain.

Compressed gas cylinders should not be accompanied in elevators (or other confined spaces). In the unlikely event of gas venting or leak, an oxygen deficient atmosphere may rapidly result. Such accidents have occurred with fatal results. The dolly with the cylinder should be placed in the unoccupied elevator with a sign stating, “do not enter.” The elevator should be sent to the desired floor where a second person is waiting to receive it.



#### 4. Highly toxic, toxic, and corrosive gas storage and use

Highly toxic gas is defined as:

*A chemical that has a median lethal concentration ( $LC_{50}$ ) in air of 200 ppm by volume or less of gas or vapor, or 2 mg/L or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 0.44 lb and 0.66 lb (200 g and 300 g) each. (NFPA 55)*

Toxic gas is defined as:

*A chemical that has a median lethal concentration ( $LC_{50}$ ) in air of more than 200 ppm but not more than 2000 ppm by volume of gas or vapor, or more than 2 mg/L but not more than 20 mg/L of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 0.44 lb and 0.66 lb (200 g and 300 g) each. (NFPA 55)*

Corrosive gas is defined as:

*A gas that causes visible destruction of or irreversible alterations in living tissue by chemical action at the site of contact. (NFPA 55)*

OES should be notified if highly toxic, toxic, or corrosive gases are to be used in the laboratory in volumes greater than lecture bottle size. Details on the [Dangerous Gas program](#) can be found on the OES website.

If required in volumes greater than lecture bottle size, highly toxic gases ***shall*** be stored in approved, ventilated gas cabinets or exhausted enclosures. OES will conduct a hazard assessment and assist the lab in developing a plan for using such gases as well as recommendations for associated infrastructure.

The MAQs of highly toxic gases shall not be exceeded under any circumstances. If necessary (as determined by hazard and code assessment), additional safety and contingency training may be required. Other infrastructure requirements such as gas monitoring, washdown systems, emergency ventilation, etc. may be required when using these gases in volumes exceeding lecture bottle size.

If required in volumes greater than lecture bottle size, toxic and corrosive gases may be required to be stored in approved, ventilated gas cabinets or exhausted enclosures. This requirement, as well as other potential infrastructure and training requirements, will be based on a hazard assessment conducted by OES.

A hazard assessment should be conducted by researchers whenever using gases in these categories. A written SOP should be created outlining usage conditions, procedures, engineering controls, PPE, etc. Contingency plans should be formulated to handle potential leaks or ruptures.

**Lecture bottles (highly toxic, toxic, corrosive, highly reactive gases)**

It is recommended that when highly toxic, toxic, corrosive, or other highly reactive gases are required for research, that lecture bottles be used. These are smaller compressed gas cylinders that contain smaller volumes of gas.



Lecture bottles of compressed gases.

These cylinders require specific regulators for use. Do not modify standard regulators for use on lecture bottles. Lecture bottles containing highly toxic gases shall be stored and used in a chemical fume hood (or stored in an approved ventilated gas cabinet). Dispensing of toxic and corrosive gases shall be conducted in a chemical fume hood and stored appropriately according to chemical compatibility.

When in use, lecture bottles should be secured via clamp or specifically designed dispensing stations or mounts (available from several vendors) and prudent laboratory practices followed (i.e. controls, proper PPE, etc.). Empty or unwanted lecture bottles of highly toxic, toxic, or corrosive gas should be promptly declared as hazardous waste and a pickup request submitted.

## 5. Regulators

Compressed gas cylinders shall be fitted with the appropriate, functional, non-damaged regulator for dispensing gas. Homemade and modified regulators, or direct delivery from the valve stem outlet is not permitted. Ensure that the [appropriate regulator](#) for the type of gas is used (check manufacturer's instructions). **Do not use Teflon tape, sealing agent, or lubricant on the valve stem outlet when attaching regulators.**

## 6. Gas delivery systems

Laboratories that use large scale gas delivery systems should consult OES for a hazard assessment to determine the need for infrastructure modifications such as increased ventilation, gas monitors, fire suppression systems, etc. Such delivery systems consist of compressed gas cylinders attached to fixed piping to deliver the gas to a test apparatus. Such systems are designed to deliver larger quantities or long-term continuous flow. An example of such a system is a system for long-term testing of hydrogen fuel cells. These systems must also comply with the South Carolina Fire Code (2015) and NFPA 55 (2020) and other applicable local, state, and federal codes depending on the scale of the apparatus.

## 7. Lab specific emergency plans and standard operating procedures

Laboratories should create written standard operating procedures (SOPs) and emergency procedures based on the compressed gases stored and used in the lab. These plans should include usage and storage procedures, and planning for contingencies such as tank leaks, rupture, fire, etc. OES can assist in formulating these plans. These plans and procedures should be discussed within the group regularly and updated as necessary. General emergency procedures for handling leaking compressed gas cylinders are outlined below.

Lab and building-specific emergency plans should be developed and practiced based on the quantity and identity of the compressed gas cylinders stored and used.

### **Leaking compressed gas cylinder (minor size leak)**

A minor size leak is such that the volume of gas leaking is low as determined by lab personnel. An example would be a slow bubbling detected when using a leak check agent such as Snoop™ around the valve stem / cylinder connection. **If uncertain as to whether a leak is a minor leak or a major hazard, err on the side of caution and treat it as a major leak and follow the prescribed procedures.** In all cases of leaking gas cylinders, it is important to know and understand the health and physical hazards of the gas. The chemical health hazards will be determined by the type of gas. A primary physical hazard will be the pressure associated with the leaking gas. This pressure can be enough to pierce skin and cause significant injury. **In all cases of leaking gas cylinders, notify OES immediately. If the situation warrants, call 911 for emergency personnel.**

#### *Inert gas (i.e. nitrogen, argon, etc.)*

If a minor leak is found on an inert gas cylinder, attempt to close the outlet valve handwheel. If this does not terminate the leak, and it is safe to do so, move the cylinder to a well-ventilated location (i.e. floor mounted fume hood, outside loading dock, etc.) using a cylinder dolly. Isolate the area and allow the gas to escape until empty. Post signage to avoid the area and any hazards associated with the gas. Monitor the situation so others do not approach the cylinder. Call the cylinder supplier to report the leak.

#### *Flammable gas (i.e. hydrogen, methane, etc.)*

Care must be taken with leaking flammable gases as any ignition source (including static) can lead to a fire and more serious situation. Do not use tools on a leaking tank that may cause a spark. If a minor leak is detected, and it is safe to do so, move the cylinder to a well-ventilated location (i.e. floor mounted fume hood, parking lot, etc.) using a cylinder dolly. Ensure no oxidizers or ignition sources are in the vicinity. Isolate the area and allow the gas to escape until empty. Post signage to avoid the area and any hazards associated with the gas. Monitor the situation so others do not approach the cylinder.

In cases of leaking flammable gas, it may be prudent to notify the fire department for an evaluation. The cylinder supplier should be notified of the situation and they may send a team to help mitigate the leak.

Remember, hydrogen burns with a clear flame and it is difficult to visually determine if a leaking cylinder is ignited. **Never attempt to extinguish a leaking flammable gas cylinder fire if the gas source is not terminated. Evacuate the area and call 911.**



### *Oxidizing gases (i.e. oxygen)*

If a minor leak is found on an oxygen gas cylinder, attempt to close the outlet valve handwheel. If this does not terminate the leak, and it is safe to do so, move the cylinder to a well-ventilated location (i.e. floor mounted fume hood, outside loading dock, etc.) using a cylinder dolly.

Isolate the area and allow the gas to escape until empty. Ensure no flammable or combustible materials are in the area. Post signage to avoid the area and any hazards associated with the gas. Monitor the situation so others do not approach the cylinder. Call the cylinder supplier to report the leak. **Many oxidizers are also corrosive or toxic. If this is the case, follow the guidelines for those gases.**

*Corrosive, toxic, and highly toxic gases (Hydrogen chloride, ammonia, hydrogen fluoride, etc.)*  
Minor leaks of corrosive, toxic, and highly toxic gases shall be treated as major leaks (see below).

### **Leaking compressed gas cylinder (major size leak)**

In cases of major gas leaks (or minor leaks of corrosive, toxic, and highly toxic gases), immediately:

- Notify others of the leak and evacuate the area (use fire alarm pull station if necessary).
- Activate lab emergency ventilation purge (if lab is equipped).
- Isolate the area (from a safe distance) and ensure no one enters the area.
- Call CUFD (911) and notify them of the situation. Relay the location, nature of the leak, cylinder contents, etc.
- Notify OES of the situation.
- Notify cylinder supplier of the situation.
- Do not reenter the building / lab until it has been determined to be safe to do so by emergency personnel and OES.

As noted above, these are general guidelines for handling leaking compressed gas cylinders. The specific actions taken will be determined by the types and quantities of gases stored in the lab. Ensure that emergency procedures are developed and practiced for dealing with these and other contingencies.

## VII. Resources

Numerous resources are available that provide authoritative information and guidance on laboratory and chemical safety as well as information regarding hazard and risk assessment methods. Combined, this knowledge will allow researchers to effectively evaluate the hazards associated with their research as well as provide for effective risk minimization strategies. Links are provided where possible.

- [Prudent Practices in the Laboratory](#)
- [CRC Handbook of Laboratory Safety](#)
- [Bretherick's Handbook of Reactive Chemical Hazards](#)
- [Handbook of Compressed Gases](#)
- [NFPA standards and technical bulletins](#)
- [Identifying and Evaluating Hazards in Research Laboratories](#)
- CRC Handbook of Chemistry and Physics
- [Sigma Aldrich Technical Bulletins](#)
- [NIOSH Pocket Guide to Chemical Hazards](#)
- [ACGIH TLV Chemical Substances Introduction](#)
- The Manipulation of Air Sensitive Compounds
- [American Chemical Society safety resources](#)
- [OSHA regulations](#)
- [Clemson Occupational and Environmental Safety \(Chemical and Lab Safety\)](#)

## **Appendices**

## Appendix 1. Hydrofluoric acid guidelines

Extreme caution must be used when using, storing, and transporting HF due to its corrosive acidic properties as well as the high toxicity (acute and chronic) of the fluoride ion. Depending on acid concentration, onset of pain and other effects may be delayed up to 24 hours after exposure. HF can be anhydrous (hydrogen fluoride) or colorless aqueous solutions (hydrofluoric acid) of various concentrations and compositions.

**Requirements:** All laboratories which use or store hydrofluoric acid (HF) must receive training on the proper use, storage, and emergency procedures associated with this chemical. OES can provide in-person training to satisfy this requirement. Requirements for lab use and storage of HF include:

- OES shall be made aware of HF use and storage in laboratories.
- HF must be segregated from all incompatible chemicals and stored in compatible secondary containment.
- Signage shall be placed at the location of storage and use indicating the presence of HF as well as emergency procedures for spill and exposure.
- All lab members shall be trained in the hazards associated with HF and emergency procedures regardless of whether they are directly working with HF.
- Calcium gluconate gel (check expiration date) and other appropriate first aid materials shall be maintained at the location of HF storage and use.
- An HF spill kit shall be maintained at the location of HF storage and use.
- Proper PPE must be worn at all times when using HF.
- No one shall use HF while alone. The 2-person rule applies.
- Secondary containment shall be used in a designated work area within a fume hood for HF manipulations
- A lab specific standard operating procedure (SOP) shall be formulated and maintained outlining the hazards and use of HF.

### Hazards:

- HF is similar to other acids in that the initial extent of a burn depends on the concentration, the temperature, the duration of contact with the acid, and the exposure area. HF differs, however, from other acids because the fluoride ion readily penetrates the skin, causing destruction of deep tissue layers.
- Exposure to HF (vapor or liquid) can cause severe burns, metabolic imbalances, pulmonary edema, cardiac arrhythmias, and **DEATH** if left untreated.

- HF is highly corrosive to skin and mucous membranes. High concentration solutions cause painful burns on contact; however, dilute solutions may have delayed effects (up to 24 hours).
- The fluoride ion binds with calcium and magnesium ions in the blood leading to hypocalcemia and hypomagnesemia, as well as bone decalcification. Rapid treatment of exposures is critical.
- HF toxicity can be acute or chronic. Systemic toxicity is possible.

## First aid:

### Skin contact

- Immediately flush the affected area with copious amounts of tepid running water (if a large area exposure use safety shower). Notify others in the area that an HF exposure has occurred and to stay clear of the area.
- Carefully remove any contaminated clothing. Take care not to contaminate other areas of the body. If assisting another person wear proper PPE to prevent contamination.
- **Dial 911 for emergency assistance in any case of HF exposure.** Report all information to the dispatcher including exposure time, quantity (area of exposure), concentration of HF, time of calcium gluconate application, etc.
- After 5 minutes of water flushing, begin to apply calcium gluconate to the affected area by massaging the gel on the skin. Continue applying gel until medical help arrives.
- Do not apply burn cream or pain-relieving ointments to the affected area. Do not take pain medication. Pain relief is used to monitor the effectiveness of calcium gluconate treatment.
- A second person shall remain with the exposed individual until medical help arrives.



### Eye contact

- Immediately flush the eyes for 15 minutes (minimum) using the emergency eyewash station. Notify others in the area that an HF exposure has occurred and to stay clear of the area.
- Carefully remove any contaminated clothing. Take care not to contaminate other areas of the body. If assisting another person wear proper PPE to prevent contamination.
- Dial 911 for emergency assistance.
- A second person shall remain with the exposed individual until medical help arrives.

### Inhalation

- Immediately move the victim to fresh air.
- Call 911 for emergency assistance.
- A second person shall remain with the exposed individual until medical help arrives.

### Ingestion

- Do not induce vomiting.
- Large volumes of water or milk should be ingested.
- Call 911 for emergency assistance. **Ingestion of HF is a life-threatening emergency.**
- A second person shall remain with the exposed individual until medical help arrives.

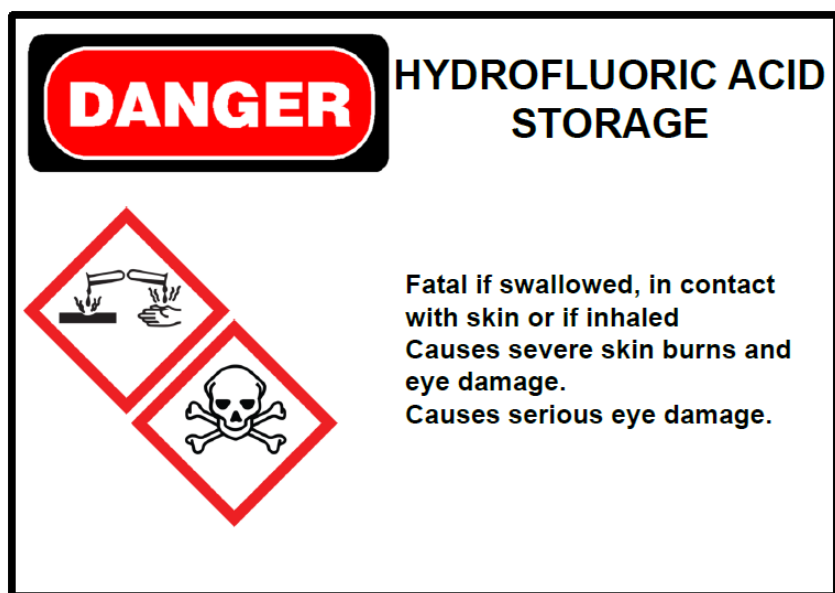
**Incompatibles:** HF is incompatible with several chemicals and materials and should be stored and used in such a manner to prevent contact with incompatible materials. Some incompatibles include:

- Glass/ceramics: Glass and ceramics are etched by HF. Only compatible plastic (polyethylene, PTFE) containers and utensils shall be used with HF.
- Sodium metal: Reaction with sodium metal is violent and potentially explosive.
- Potassium permanganate: Addition of potassium permanganate to concentrated HF is violently exothermic.
- Sulfuric acid: Dehydration of HF solutions by sulfuric acid is violently exothermic and explosive.
- Numerous other potential incompatibilities exist. Be sure to check for specific incompatibilities based on the chemical storage in your lab space.



## Storage:

- HF shall be stored segregated from all incompatible chemicals.
- HF shall be stored in compatible plastic containers.
- All HF containers shall have the original manufacturers label or full GHS label affixed. Labels should indicate acid concentration if diluted from a primary bottle.
- HF containers shall be sealed with a screw top to prevent spillage.
- HF should be stored in compatible secondary containment capable of containing the full volume of HF.
- The presence of HF shall be denoted by signage indicating the hazards and emergency procedures for spills and exposure. An example of an HF storage sign is below. OES can provide HF storage signs.
- All lab personnel shall be made aware of the location of HF as well as trained in emergency procedures.



## Laboratory usage of HF:

- HF shall only be manipulated in a designated fume hood. Ideally, no other work will be conducted in such a hood aside from HF, however, if this is not possible, a specific work area within the hood should be designated. No other work shall be conducted in such an arrangement when HF is being manipulated.
- Secondary containment using a compatible material (large, shallow polyethylene tray) should be used to contain any spills. This should be capable of containing the full volume of HF being used.

- HF shall never be used alone in the laboratory. The 2-person rule shall be observed where a second lab member is present in the vicinity and aware that HF is in use. This person should be prepared to assist in an emergency.
- HF waste should be collected in plastic waste containers and labeled with the appropriate “Hazardous Waste” label and the words “Hydrofluoric Acid, Corrosive/Toxic”.
- Personal protective equipment shall be worn at all time when using HF.

**Personal protective equipment (PPE):** *All lab personnel directly working with or observing the use of HF (2-person rule), must wear proper PPE at all times.* The proper PPE for HF use includes:

- Proper laboratory attire (long pants, closed toed shoes, etc.)
- Chemical splash goggles (not safety glasses)
- Lab coat
- Proper resistance gloves. Neoprene or butyl gloves are recommended (check glove manufacturers chemical resistance chart) when using HF. It is recommended that nitrile gloves be worn underneath these gloves. Always check gloves for pinholes or tears prior to each use. Immediately remove gloves upon HF contamination and dispose of properly.
- For high concentration HF, an acid resistant apron or butyl rubber jacket is recommended (consult manufacturers specifications for selection).
- For large volumes of acid, a face shield is also recommended.
- If acid drops are observed on gloves or other PPE, carefully remove the item and dispose as hazardous waste.

## Spills:

*Small spills (less than ~100 mL) inside fume hood*

- Notify others in the lab that an HF spill has occurred and to stay clear of the area.
- Wear proper PPE when conducting spill cleanup.
- If spill occurred in secondary containment dilute using water. Cover spill with calcium carbonate or sodium bicarbonate and allow to absorb and neutralize. Collect solid and residual liquid using an appropriate spill mat and place material in waste bag with appropriate label.
- Do not use vermiculite or silica-based absorbents for HF. HF can react with silica to generate toxic  $\text{SiF}_4$  gas.

Large spills or spills outside of fume hood

- Notify others in the lab that an HF spill has occurred and to stay clear of the area.
- Evacuate the lab and notify others in the vicinity to stay clear of the area.
- Call 911 for emergency HAZMAT assistance.
- Notify OES.
- Complete Incident Report Form (OES website) and submit.

**Resources:** HF information resources

[HF neutralization \(Honeywell\)](#)

[Recommended medical treatment for HF acid exposure \(Honeywell\)](#)

Bretherick's Handbook of Reactive Chemical Hazards (Academic Press)

Hazardous Laboratory Chemicals Disposal Guide (CRC Press)

## Appendix 2. Cryogen safety

Cryogens are often defined as those liquids possessing a boiling point of  $-150^{\circ}\text{C}$  or less (numerous definitions exist). The most often used cryogens in Clemson laboratories are liquid nitrogen and dry ice (technically not a cryogen, sublimates at  $-78^{\circ}\text{C}$ ) slush baths. These materials present numerous health and physical hazards that must be understood when storing, transporting, using, or disposing of these materials. This section outlines the basic hazards and prudent practices associated with cryogenic materials in laboratories.

### Highlights:

- All laboratory personnel using cryogenic materials must be trained in the physical and health hazards, emergency procedures, and standard operating procedures associated with these materials.
- Cryogens shall be stored in well ventilated areas. Storage areas / rooms should be assessed by OES for suitability.
- Liquid nitrogen should be stored in dewars designed for such use with appropriate pressure relief devices in place.
- Proper PPE shall be used when working with cryogens.
- Proper pressure relief systems shall be in place on storage dewars, delivery systems, and apparatuses utilizing cryogens.
- Measures to prevent oxygen condensation (i.e. when using liquid nitrogen) should be in place when appropriate.
- Liquid cryogen storage dewars shall be transported using an appropriate dolly and not accompanied into enclosed spaces such as elevators.
- Materials for delivery of cryogens should be selected based on compatibility.
- Emergency procedures for exposure and other contingencies should be understood by all lab members where cryogens are used and stored.

### Hazards:

- Exposure to cryogenic materials can cause serious damage to living tissue. Contact for more than a second or two with exposed skin can result in burns similar to frostbite and longer exposure can lead to necrosis and potentially blood clots. Contact with eyes can result in serious injury. Contact with internal organs via inhalation or ingestion can be a life-threatening situation.
- Discharge of cryogenic fluid (liquid or vapor) at velocity presents an immediate risk of serious skin damage upon contact.
- Contact of exposed skin with metals or other materials at cryogenic temperatures can result in immediate freezing of skin to the material and associated thermal injury.

- Release of cryogens, such as liquid nitrogen (vapor or liquid) or sublimation of large quantities of dry ice, can rapidly lead to an oxygen deficient atmosphere posing an asphyxiation hazard.
- Pressure buildup from evaporation (or sublimation) of cryogenic materials presents an explosion hazard when in a closed system.
- Condensation of oxygen (when using liquid nitrogen, helium, or hydrogen) can result in an explosion hazard from pressure buildup or chemical reaction.
- Slush baths present a fire hazard as they often use dry ice in combination with a flammable solvent such as isopropanol or acetone.

### **Personal Protective Equipment (PPE):**

Proper PPE shall be used whenever manipulating cryogenic materials.

#### Lab coat / proper lab attire

Exposed skin should be covered to minimize the potential for contact with cryogenic materials or cold surfaces. Feet are often a vulnerable area as droplets of liquid nitrogen may roll from benchtops and get inside the shoe if it is made from porous material (i.e. sneakers).

#### Safety glasses / goggles

Safety glasses or goggles should be worn whenever handling or working near cryogenics. Contact with the eye is an extremely serious situation. It is important to remember that vapor from pressure relief devices (i.e. on a large storage dewar) can also cause significant injury to the eyes.

#### Gloves

Insulated, loose fitting gloves should be worn when transferring liquid nitrogen via pouring or dispensing from a pressurized dewar (the dispensing tube will also be at cryogenic temperature). Glove length should be based on the situation. If glove length is too short, it is possible for liquid to get inside the glove. Loose fitting gloves allow for quick removal in this situation. Insulated gloves should be worn when handling dry ice. In both cases, gloves are not intended for long term contact with cryogenic materials.



Insulated gloves for handling cryogenics

### Face shields

A face shield may be necessary based on the procedure being performed. If large quantities are being used or the situation presents a significant splash hazard (such as filling portable dewars from a pressurized source), a face shield will provide face and neck protection. Face shields are to be used in conjunction with proper eye protection (i.e. safety glasses / goggles).

### **Storage and transport:**

Liquid nitrogen should be stored only in dewars designed for such use. Small dewars used in labs have loose fitting caps to prevent pressure buildup. Lab personnel should periodically inspect dewars for damage and wear. These vessels contain a vacuum jacket that presents a significant implosion hazard if compromised.



4-liter liquid nitrogen dewar commonly used in laboratories.



Liquid nitrogen may also be stored in larger, pressurized cylinders in the lab or in centralized dispensing location. These cylinders are often supplied by the cryogen supplier. Do not accept delivery of any cylinder that is damaged or does not have proper pressure relief. Report any issues with the cylinder to the provider, such as pressure relief stuck open, etc.



Larger pressurized cryogen storage cylinder used for bulk storage. Each should have a pressure relief device.

Rooms used for storage of large cryogen cylinder should be evaluated by OES to ensure that adequate ventilation is available. Depending on the condition and ventilation of the room, oxygen monitoring may be required. **NEVER enter a space if a low oxygen condition is suspected.** Storage areas (inside or outside) should have appropriate signage indicating the presence of cryogenic material and the associated hazards. Contact information of the responsible party should also be provided.

Dry ice should be stored in an insulated container with a loose-fitting lid or other approved container with pressure relief. **Do not store dry ice in any confined space as this may result in an oxygen deficient atmosphere.**

Large liquid nitrogen cylinders shall only be transported using the appropriate transport dolly. Do not modify other transport equipment for this purpose. Do not accompany large pressurized cylinders in an elevator. Venting of nitrogen in confined spaces such as elevators can lead to an oxygen deficient atmosphere. Observe the same rules for elevator transport as for compressed gas cylinders.

## **Pressure relief:**

All closed systems utilizing cryogenics should have pressure relief mechanism in event of over-pressurization. The volume of liquid nitrogen increases by a factor of  $\sim 700$  when converted from the liquid to gas phase. This pressure increase can cause rupturing of storage containers, transfer tubing, etc.

Accidents resulting from overpressurization have resulted in numerous serious injuries and deaths. In some situations, redundant pressure relief and monitoring may be required. Any experiments or procedure that may result in an over pressurization should have appropriate shielding and engineering controls in place. When working with cryogenics, a detailed hazard analysis and risk assessment should be conducted. Contact OES for assistance with this.

## **Condensation of oxygen:**

Due to the fact that oxygen has a higher boiling point ( $-183^{\circ}\text{C}$ ) than nitrogen ( $-196^{\circ}\text{C}$ ), liquid oxygen can condense from the air in the presence of liquid nitrogen. In the case of a vessel placed in a liquid nitrogen bath, such as the case of a cold trap, liquid oxygen can condense from air and concentrate. Liquid oxygen is a light blue colored liquid and is a very strong oxidizer. Liquid oxygen presents a significant hazard due to its incompatibility with numerous chemicals, organic chemicals in particular. Contact between liquid oxygen and organic solvents can result in highly exothermic reactions that may be explosive in nature.



Liquid oxygen condensed in a beaker.

Extreme care should be taken to ensure that liquid oxygen cannot condense in closed systems. Similar to liquid nitrogen, liquid oxygen expands ~850 times its liquid volume when converted from liquid to gas. If liquid oxygen has condensed within a closed system (i.e. a Schlenk line cold trap) and not noticed, the rapid warming and expansion upon removal of the cryogen source can lead to explosion of the glass manifold and trap, potentially leading to serious injuries.

Labs using liquid nitrogen cold traps, or other situations where oxygen can condense, should have emergency plans in place to handle such situations.

### **Emergency procedures:**

Laboratories storing and utilizing cryogens should have emergency procedures in place and they should be discussed regularly. Any procedure that uses cryogens should be reviewed and contingency plans in place for over pressurization, liquid oxygen condensation, etc. Basic emergency procedures are discussed below.

#### *Large nitrogen leak or spill (i.e. potential oxygen deficient atmosphere)*

If a large-scale release of a cryogen is observed or suspected (i.e. liquid nitrogen, dry ice, etc.) immediately

- Evacuate the immediate area and alert others in the vicinity.
- Isolate the area of the spill / release and prevent others from entering.
- If necessary, evacuate the larger area (i.e. floor or building). The fire alarm may be activated for this provided this would not result in personnel having to enter the affected area.
- Call 911 and report the incident.
- Notify OES and file an incident report.

NEVER enter an oxygen deficient atmosphere even if you observe a person in need of help (such as an unconscious individual). Your attempt to help may result in you becoming incapacitated as well. Wait for emergency responders to arrive and alert them of the individual in need of help.

#### *Skin / eye contact first aid*

Most cases of incidental skin contact (i.e. a drop or two contacting the skin) do not necessitate any treatment. This results from the rapid boiling of the droplet preventing direct contact with the skin (Liedenfrost effect).

However, contact for more than ~2 seconds may result in contact burns, which can be serious if contact is prolonged. Liquid nitrogen released at velocity can also cause immediate tissue damage. In the event of skin contact:

- Run lukewarm water over the affected area (do not use hot water). Water should be run at a slow rate to avoid further damaging tissue. Do not apply direct heat via the use of heaters, heat packs, etc.
- Avoid rubbing the area to warm it as this may cause tissue damage. If blistering is observed, do not attempt to rupture them as this may lead to infection.
- If necessary, wrap the affected area loosely with sterile gauze and proceed to a medical provider or emergency room.
- Do not apply burn creams or ointments unless directed by a physician.
- If an emergency (i.e. large-scale exposure, numerous injuries, etc.) call 911 immediately.
- Contact your medical provider if any prolonged or delayed symptoms are observed.

For contact with the eyes, flush the eyes with water using the emergency eyewash. As eye exposure to cryogenics can result in serious injury, it is recommended that medical evaluation be sought for any exposure to the eyes.

### Liquid oxygen condensation

As laboratory apparatuses vary considerably, the particular emergency procedures in the event of oxygen condensation must be evaluated by lab personnel. However, several general steps should be observed to minimize the potential for overpressurization and injury in such an event.

- If liquid oxygen is observed in a vessel at atmospheric pressure (i.e. a reaction vessel in a liquid nitrogen dewar left open to air), remove the source of liquid nitrogen by carefully raising the vessel from the dewar. Place the vessel containing the oxygen in a fume hood away from any incompatibles. Lower the hood sash and allow the oxygen to slowly evaporate.
- If liquid oxygen is observed upon removing the cryogen dewar (i.e. liquid nitrogen) from a closed system (such as a Schlenk line trap):
  - Immediately return the nitrogen dewar to its position to keep the liquid oxygen from rapidly evaporating.
  - Notify others in the lab of the situation.
  - Isolate the system from the vacuum source.
  - Open all the manifold lines so they can vent the trap. If the manifold has end caps, remove those as well.

- Lower the nitrogen dewar so that the trap is above the liquid nitrogen level.
- Close the hood sash and allow the liquid oxygen to slowly evaporate from the trap and vent from the manifold. It is important to provide adequate vent routes (i.e. open all lines and end caps). Failure to do so may result in overpressurization and rupture.

Similar emergency procedures can be developed based on the particular procedure and apparatus being used. These procedures should be reviewed by the group on a regular basis and practiced. Revisions should be made as needed.

**Resources:**

*Cryogenic Safety*, Peterson and Weisend, Springer, 2019

*Safety in the Handling of Cryogenic Fluids*, Edeskuty and Stewart, Plenum Press, 1996.