Youngstown
STATE UNIVERSITY

One University Plaza, Youngstown, Ohio 44555
Office of Environmental and Occupational Health and Safety

YSU Lab Safety Plan

Contents

Preface and Acknowledgments

This manual contains a number of guidelines that can help all of us perform our research and teaching tasks more safely and maintain better order and safety in our laboratories. Each student and employee working in the lab is expected to read this manual thoroughly and act in accord with the guidelines. This manual should also be kept available for future reference.

One of the most fundamental aspects of safety in research is good laboratory housekeeping. This includes the proper storage and handling of chemicals, gas cylinders, electrical equipment, and so on. The appearance and organization of our facilities directly affects their safety and productivity as well as our university's reputation. There are two golden rules in developing a safe and productive environment:

1) Whenever you use a lab, it is your responsibility to see that unsafe conditions are corrected immediately; and
2) Always leave a laboratory in better condition than you found it.

If we all take this level of personal responsibility, our facilities can only improve.

The text of this safety manual borrows extensively and often verbatim from ones issued by the University of Akron, Northwestern University[1] and UCLA[2]. It also uses portions from Virginia Tech[3] and The Ohio State University[4]. Much of the material is in turn sourced directly from "Prudent Practices in the Laboratory", issued by the National Research Council[5].

Introduction Laboratory safety is an integral part of laboratory research and learning environment at the Youngstown State University. The university's goal is to prevent workplace injuries and illnesses, environmental incidents and property losses or damage. Safety is also essential in complying with all applicable health, safety and environmental protection laws, regulations and requirements.

The risks associated with laboratory research are greatly reduced or eliminated when proper precautions and practices are observed in the laboratory. This Laboratory Safety Manual should be used to better manage and mitigate these risks. Each laboratory using hazardous materials is required to have a copy of this manual readily available to all laboratory personnel. Each laboratory worker must be familiar with the contents of the manual and the procedures for obtaining additional safety information needed to perform their duties safely.

This manual includes information on safe laboratory practices, the use of personal protective equipment, emergency procedures, use and storage of chemicals, and the proper methods of waste disposal. It also covers hazard communication and incident response. This information is intended to be a resource and to help laboratory personnel minimize hazards.

In view of the wide variety of chemical products handled in laboratories, it should not be assumed that the precautions and requirements stated in this manual are all-inclusive. Faculty, researchers and students are expected to learn about the hazards of chemical products before handling them. Principal Investigators (PIs) and Laboratory Supervisors should include supplemental information pertinent to their specific areas in this manual.

Laboratory operations that utilize radioactive materials or radiation producing machines, biological hazards, laser operations, or shop activities must to follow additional guidelines outlined in hazard-specific (e.g., Biosafety Guidelines, Radiation Safety Manual, etc.) manuals.

The Laboratory Safety Manual is comprised of the following sections:

1. General Laboratory Safety Information and Emergency Response.

General laboratory safety information sets forth basic laboratory rules, including PPE and facility expectations. It also covers information pertinent to the appropriate responses to general emergency situations on campus.

2. Chemical Hygiene Plan.

The Chemical Hygiene Plan (CHP) establishes a formal written program for protecting laboratory personnel against adverse health and safety hazards associated with exposure to potentially hazardous chemicals and must be made available to all employees working with hazardous chemicals. The CHP describes the proper use, handling practices and procedures to be followed by faculty, staff, students, visiting scholars, and all other personnel working with potentially hazardous chemicals in laboratory settings.

3. Laboratory Specific Standard Operating Procedures.

Standard Operating Procedures (SOPs) are written instructions that detail the steps that will be performed during a given experimental procedure and include information about potential hazards and how these hazards will be mitigated. Laboratory personnel who are most knowledgeable and involved with the experimental process should write SOPs. The development and implementation of SOPs is a core component of promoting a strong safety culture in the laboratory and helps ensure a safe work environment. PIs/Laboratory Supervisors are required to develop and implement laboratory-specific SOPs for certain hazardous chemicals and “particularly hazardous substances” (PHS) that are used in their laboratories. For certain hazardous chemicals, PHS, or specialized practices, consideration must be given to whether additional consultation with safety professionals is warranted or required. Circumstances requiring prior approval from the PI/Laboratory Supervisor must also be addressed in laboratory-specific SOPs. The Chemical Hygiene Plan provides more detailed information on SOPs. SOPs should be kept within the laboratory, and copies of the SOPs retained with the Laboratory Safety Manual for that lab. See Appendix D.

4. Safety Training Records.

Effective training is a critical component to facilitating a safe environment and for the prevention of laboratory accidents. All employees must be trained in general safe work practices and be given specific instructions on hazards unique to their job assignment. Meeting safety training requirements is a cooperative effort between departments, Principal Investigators and Laboratory Supervisors, laboratory staff, and EOHS. Training at YSU is available in person and online using www.industrysafe.com.

An effective health and safety training program must include appropriate oversight, proper recordkeeping, instruction on the proper use of PPE (e.g., eye protection, gloves, laboratory coats,

respirators, etc.), and extensive outreach. Accurate recordkeeping of training activities demonstrates a commitment to the safety and health of the campus community, integrity of research, and protection of the environment. EOHS is responsible for maintaining records of training conducted by EOHS staff members.
Departments or laboratories are required to document and maintain record of all health and safety training, including safety meetings, one-on-one training, and classroom and online training. Safety training records should be kept with the PI / Laboratory Supervisor.

5. Laboratory Inspection Records.

EOHS has instituted a laboratory inspection program for all laboratories in the science, engineering and technology areas. Laboratories are currently inspected on an annual basis by EOHS to ensure compliance with federal, state and university requirements. EOHS conduct inspections, issue reports, conduct re-inspections when deficiencies are noted, and provide training and coaching on safety and compliance in laboratories. Strong compliance is a critical part of an effective safety program. The PI / Laboratory Supervisor should keep laboratory inspection reports.

Once a semester, the faculty member will accompany EOHS during an inspection.

Copies of the inspection reports will be sent to the Dean and Department Chair.

Inspection follow-up: EOHS will send out inspection reports to the PI, Department Chair and Dean of the College. The researchers in the lab should correct most issues. All serious and repeat violations will require a written plan of action from the PI.

6. Building Emergency Action Guidelines.

Each building on campus has an Emergency Action Guidelines document with basic reference instructions on how to deal with emergencies, including where to report to and who to contact. This document should be kept with the laboratory safety manual binder. Here is the link for the emergency actions plans.

Laboratory Personnel

Review your department’s Injury and Illness Prevention Plan.

Familiarize yourself with your department contacts, how to report a hazard in your laboratory and how to report injuries.

- Review the Chemical Hygiene Plan:
    - Know your responsibilities.
    - Know how to identify hazardous chemicals.
    - Understand how to reduce your potential for exposure to hazardous chemicals (engineering controls, administrative controls and personal protective equipment).
- Review your building’s Emergency Action Guidelines document and ensure you know what to do to prepare for and respond to an emergency.
- Review PPE requirements with your PI and ensure you know how to acquire additional or replacement PPE.

- Review the laboratory-specific SOPs with your PI and document your training. All training, whether formal or on-the-job, should be documented and placed behind the appropriate tab.
- Ask for clarification if there are any questions related to your laboratory work before you begin a new task.

Questions? For further information on this Laboratory Safety Manual or on any health and safety related topics, please contact the EOHS at 330-941-3700.

1. GENERAL LABORATORY SAFETY AND EMERGENCY REPSONSE

Working safely in a laboratory requires having the proper containment equipment and engineering controls, wearing appropriate personal protective equipment, using proper work practices, knowing safety information for the materials and equipment used, and following safety instructions and laboratory protocols.

The general safety information in this section is provided to assist investigators and supervisors in planning work and guiding those actually carrying out procedures.

Some laboratories contain more than one type of hazardous material. For example, biochemistry laboratories may work with chemicals, biological agents, and radioactive materials. In such cases, the protective equipment and work practices to be used are those that provide protection against the most hazardous agent or meet the most stringent legal requirement.

1.1 In an Emergency

1.2 In University buildings

Always call 911 if there is an explosion, fire, injury, or spill related evacuation. Do not attempt to resolve the situation without notifying trained responders first. Call for assistance when needed.
If there is a chemical, radioactive or biological material spill beyond the laboratory worker's ability to safely contain or clean up, call University Police at 911 at any time, and that office will contact Environmental and Occupational Health and Safety (EOHS) personnel to assist.

1.3 Building Emergency and Evacuation Plans

Follow the emergency procedures for each building per the emergency plan.

1.31 Incident (Accident) Response and Reporting

Laboratory incidents shall be investigated. The faculty member shall provide a written Incident Report Form to EOHS in case of injury, minor spills, fires, or hazardous material release.

EOHS may ask for assistance to investigate and prepare an investigation report. Investigations are made and reports written not only to satisfy certain laws but also to learn the cause of the problem and what changes in procedures, equipment, or training should be made to avoid other accidents.

EOHS Assistance

EOHS will respond to chemical, radioactive and biological materials spills. However, if the spilled material is not volatile and there is no immediate fire or toxic hazard, cleanup may be done by laboratory employees (under direction of the PI or EOHS). In situations involving a fire or research chemicals or toxic hazards, EOHS will advise on evacuation or other precautions to protect persons or property in the immediate area.

1.3.2 Burn from Fire

- If your clothing catches fire, immediately get under a safety shower or other water source.
- If a safety shower is not immediately available, stop, drop, and roll to extinguish the fire, holding your hands over your face to shield your face and eyes.
- Assess the condition of the skin's burn area. If skin is not broken, run water over the burn area to remove heat. Do not put ice on the burn. If skin is broken, apply a dry, sterile dressing over the wound.

Seek medical attention as soon as possible.

1.3.3 Inhalation

A person exposed to smoke or fumes shall be removed to uncontaminated air. Any victim overcome by smoke or fumes shall be treated for shock. Call 911. Give cardiopulmonary resuscitation (CPR) if necessary and if trained personnel are available. If a person needs to be rescued from a contaminated area, evaluate the possibility of harm to the rescuer before anyone enters or remains in the contaminated area without proper protective equipment. If a printed SDS is available for the material inhaled, it should accompany the victim to the medical treatment facility.

1.3.4 Shock

Shock is likely to develop in any serious illness or injury. Shock is a condition in which the circulatory system fails to deliver blood to all parts of the body. When the body’s organs do not receive adequate blood supply, they fail to function properly.

The following signals are indicators that the victim is suffering from shock:

- restlessness or irritability (often the first sign that the body is experiencing a significant problem)
- altered consciousness
- pale, cool, moist skin
- rapid breathing
- rapid pulse

In caring for shock, have the victim lie down. Help the victim rest as comfortably as possible to minimize pain and thereby slow the progression of shock. Control any external bleeding. Help the victim maintain a normal body temperature and avoid chilling. Elevate the victim’s legs about 12 inches unless you suspect broken bones or possible head, neck, or back injuries. If in doubt, leave the patient lying flat.

Do NOT give the victim anything to eat or drink although (s)he may complain of thirst. Obtain medical assistance promptly since shock cannot be managed by first aid alone.

1.3.5 Ingestion

If a person ingests a toxic chemical, determine, if possible, what was ingested and notify the emergency medical personnel. Contact the Poison Control Hotline at (800) 222-1222 for emergency response information for the specific compound.

Inform the hotline personnel of the first aid treatment shown on the container label or the SDS. The printed SDS should accompany the victim to the medical treatment facility.

1.3.6 Puncture or Cut

When treating a victim with a puncture wound or cut, wear personal protective equipment (e.g., gloves) to minimize exposure to human blood, body fluids, or other chemical or biological contamination. Apply a pressure pad or clean cloth firmly to the wound. Raise the wounded area above the level of the heart to slow the bleeding. For severe bleeding or spurting, very firmly press the pressure pad directly on the wound and apply pressure at the applicable body pressure point above the wound to stop the flow of blood. In a severe injury, keep the victim warm, calm, and oriented to prevent shock.

1.3.7 Needlestick

Needlesticks or other accidents involving skin punctures by a chemical or biological agent shall be reported to the supervisor immediately. Appropriate medical testing, treatment, and follow up may be indicated and shall be provided as appropriate. When a needlestick occurs, do not wait to report the incident and obtain medical attention. See the Bloodborne Pathogens Standard for more information on needlestick exposures to human blood and other potentially infectious human materials.

1.3.8 Dermal Contact

If a chemical spills on a person, the first goal is to remove the chemical from the person's skin as soon as possible, without spreading it onto yourself. For chemicals that can cause burns, the stronger the chemical and the longer the contact, the worse the burn. The chemical continues to burn as long as it remains on the skin. For all chemicals except hydrofluoric (HF) acid, flush the skin under a safety shower for at least 15 minutes. For limited skin exposure on a small area, a drench hose may be adequate for flushing.

Remove contaminated clothing while the person is under the shower stream, taking care not to spread contamination from the clothing onto more of the person's skin. If the clothing must be pulled over the head or down along the legs to be removed, cut it away with first aid kit scissors instead. Many safety showers are equipped with curtains to give privacy to the victim. Do not let modesty keep you from removing contaminated clothing that remains against skin.

Do not treat the burn. Do not puncture any blisters that may develop. Allow trained medical personnel to administer treatment after flushing is complete. Your first aid kit will probably contain antibiotic ointment and sterile gauze for burns. These are intended only for minor burns such as those you might encounter in your household, e.g., small burns from cooking at a stove and sunburns.

It is advisable for pregnant women to avoid touching anything in a laboratory barehanded. Disposable gloves provide a barrier from low-level contamination of common surfaces.

1.3.9 Cryogenic Liquid Contact

Contact with cryogenic liquids may cause crystals to form in tissues under the spill area, either superficially or more deeply in the fluids and underlying soft tissues. The first aid procedure for contact with cryogenic liquids is identical to that for frostbite. Re-warm the affected area as quickly as possible by immersing it in warm, but not hot, water (between 102° and 105° F). Do not rub the affected tissues. Do not apply heat lamps or hot water and do not break blisters. Cover the affected area with a sterile covering and seek assistance as you would for burns.

1.3.10 Eye Contact

Should a chemical enter a person's eye(s), wash the eye(s) with water for at least 15 minutes, while waiting for medical help to arrive. Keep the affected eye (if only one has been contaminated) lower than the unaffected eye to prevent the spread of contamination.

Be aware that particulates and liquids can become trapped in the conjunctiva where they may continue to cause damage. The entire interior of the eye socket must be flushed as well as the exposed cornea.

A "buddy" in the lab is vital to the injured person to help find the eyewash, call for help, keep the eyes open under the water stream, and prevent the person from rubbing the eye(s) and aggravating the damage.

1.4 Facility Considerations and Events

1.4.1 General Housekeeping

Keeping things clean and organized helps provide a safer laboratory. Laboratory surface cleanliness is especially important for laboratory workers of reproductive age and pregnant women. Keep drawers and cabinet doors closed and electrical cords off the floor to avoid tripping hazards. Keep aisles clear of obstacles such as boxes, chemical containers, and other storage items that might be put there even temporarily. Avoid slipping hazards by cleaning up spilled liquids promptly and keeping the floor free of stirring rods, glass beads, stoppers, and other such items. Never block or even partially block the path to an exit or to safety equipment, such as a fire extinguisher or safety shower.

Make sure that supplies and equipment on shelves provide sufficient clearance so that fire sprinkler heads operate correctly. There shall not be any storage within 18 inches of a sprinkler head.

Put ordinary wastepaper in a wastepaper basket separate from chemical wastes. Broken glass and other sharp items shall be disposed of in rigid, puncture-resistant containers to protect persons collecting the waste materials. Needles and syringes must be disposed of in a rigid, puncture-resistant sharps container. When discarding empty boxes or other containers bearing hazardous materials labels, the labels shall be defaced or removed before disposal. Contaminated boxes or containers shall not be disposed of in the regular trash.

Chemical wastes and unwanted chemicals shall be disposed of promptly and not left to clutter a laboratory. Follow all procedures for Hazardous Waste Disposal.

1.4.2 Food and Drink

The storage, handling, and consumption of food and drink is prohibited in laboratories.

1.4.3 Transporting Chemicals In-House

The precautions that should be followed to protect colleagues, non-laboratory personnel, and facilities when you transport chemicals in University buildings are listed below.

- Use secondary containers. The container-within-a-container concept will protect the primary containers from shock during any sudden change of movement. Secondary containment is especially important when chemicals are moved in public areas, such as hallways or elevators, where the effects of a spill would be more severe. Transport large containers of corrosives in a chemically resistant bucket or other container designed for this purpose.
- Always use a sturdy cart, and make sure the cart has a low center of gravity. Carts with large wheels are best for negotiating irregularities in floors and at elevator doors.
- Use the Chemical Management Elevator for moving chemicals and biological materials. Passenger elevators shall not be used for this purpose. If using a public elevator, hazardous waste or cryogenic liquids shall only be accompanied by the person transporting the materials – no public.
- Do not transport incompatible chemicals in container sizes >2kg or 2 liters together on the same cart.
- Only transport gas cylinders with the valve-protection cap on. Only transport toxic gases with the valve-protection cap and the valve outlet cap on.
- All chemical containers being transported shall have labels identifying the contents.

1.4.4 Working Alone (Buddy System)

Work with chemical or physical hazards (e.g. high voltage, mechanical hazards not known to be intrinsically safe) or any other work that might prove immediately dangerous to life and health (IDLH) shall not be conducted alone in any laboratory. It is recommended that all laboratory work be conducted with a partner or co-worker, or in proximity to others, in case of emergency.

1.4.5 Unattended/Overnight Operations

If experiments run while a researcher is not present, an Unattended Experiment Notice, found on the Chemical Management Website, containing information about the experiment and the name of a contact person for emergencies shall be posted on the laboratory door. Forms are also available from the EOHS office.

The "Emergency Information for Laboratories" posting on the outside of the laboratory shall have current emergency contact information.

Reactions that are left unattended for long periods of time or overnight are prime sources of fires, floods, and explosions. When equipment such as power stirrers, hot plates, heating mantles, and water condensers are run unattended or overnight only fail-safe designs must be used. Hotplates and ovens must be equipped with safe temperature limits set within 25C of the maximum experiment temperature. Other examples are flow monitors that will shut down equipment in case of water supply failure or fail-safe hose connectors.

At night, emergency personnel are entirely dependent on accurate instructions and information available at the laboratory. Unplug heating mantles, hotplates and other heating devices that are not in use to avoid accidental heating of combustibles and flammables.

1.4.6 Visitors to Laboratories

Do not allow visitors, including children and pets, in laboratories where hazardous substances are stored or are in use or hazardous activities are in progress. Students from primary and secondary schools occasionally may enter laboratories as part of educational programs under carefully controlled and supervised conditions. Colleagues, prospective students, and others may be invited into laboratories for legitimate academic and research purposes. Each individual working in a laboratory should prudently evaluate the risks to visitors, especially to persons of increased risk such as children and immune-suppressed individuals. Contact EOHS with any questions.

1.4.7 Relocating or Closing a Laboratory

Disposition of all unwanted chemicals is the responsibility of the PI. All chemicals that will not be relocated shall be listed on a Hazardous Waste Pickup Request. The request shall be completed and submitted before the PI relinquishes possession of the vacated laboratory. The department of record is responsible for the safe and lawful cleanup and disposition of all chemical, biological, and radioactive materials that are abandoned.

The PI or faculty in charge ensures that surfaces and equipment potentially contaminated with hazardous chemicals, radioactive materials, or biological agents are decontaminated before the laboratory is vacated. Accessible surfaces (chemical fume hoods, sinks, benchtops) should be cleaned, when practical, by the PI and staff. If this is not possible, an outside contractor specializing in the testing and cleaning of contaminated laboratory equipment should be contacted. The PI shall provide the contractor with thorough and accurate information pertaining to the past uses of the equipment.

To confirm that a vacated lab is properly emptied of hazardous materials, decontaminated, and ready for new occupants, the PI or laboratory supervisor shall work with EOHS. Should the PI fail to complete the items required on the form, the department becomes financially and administratively responsible for the safe disposition of the hazardous materials and the decontamination of work surfaces.

1.4.8 Loss of Power

Most laboratory buildings experience occasional brief periods of power loss. Such instances may be minor disturbances or could damage equipment or ruin experimentation. Longer-term power outages may cause significant disruption and loss. It is prudent to consider the effects of long term and short-term power loss and implement plans to minimize negative outcomes.

When developing a plan for handling a short-term power loss, consideration should be given as to what state a piece of equipment goes to during a loss of power or a resumption of power. Equipment should enter a fail-safe state and it should be tested for this state by purposely shutting off power to it and then reenergizing the circuit. Any interlocks (e.g., against high temperatures on heating mantles) should be rechecked after a loss of power. Some equipment must be restarted manually after a shutdown, resulting in longer-term power loss even when power is restored. Uninterruptable power supplies and automatic generators should be considered for freezers and refrigerators that are used to store unstable compounds.

Laboratory Procedures

If laboratory personnel are present when power is lost, and power is not restored immediately, consider the following actions:

- Turn off equipment, particularly if leaving before power is restored. Some equipment can be damaged if turned on abruptly once power comes back online. If no one is in the laboratory when the power is restored, equipment that does turn on will be running unattended.
- Discontinue operations requiring local ventilation, such as laboratory chemical hoods. The building ventilation system may not be on emergency power.
- Close laboratory chemical hood sashes.
- Experiments that rely on power may need to be discontinued and disassembled. Leaving the materials in place may not be prudent. Assign responsibility to identify problems and ensure that materials are safely stored.

Environmental and Storage Conditions

The most common problem during a power outage is storage of materials that require specialized environmental conditions, such as refrigeration and humidity controls. For example, sub-80 C freezers may hold their temperature for a few hours after a power loss but will eventually warm. This warming may lead to loss of samples. Materials that become unstable when warmed may become hazardous conditions, including fire, over pressurization, or release.

Generator Power and Uninterruptible Power Supplies (UPS)

YSU only has backup generators for emergency lightning. Plans should be put in place if power is to be off for a long period of time.

When generator power is not available or if equipment is sensitive to the slight power delay, UPS systems may be the right choice for continued power. UPS systems are composed of large rechargeable batteries that immediately provide emergency power when the main supply is interrupted.

UPS systems come in a variety of types and sizes. The three basic types are offline, line interactive, and online. The differences among the three are related to the level and type of surge protection, with the offline providing the least amount of surge protection and the online providing the most sophisticated protection. Size varies based on power needs. When purchasing an UPS for equipment other than a computer, consult with the equipment manufacturer to help choose the right solution. All UPS systems require some degree of maintenance. The battery needs to be replaced at an interval specified by the manufacturer. Battery cost should be figured into the system cost.

1.4.9 Flood

Floods could be due to rain, water pipe breaks, or accidental or deliberate acts. Some areas are more prone to floods than others are. Laboratories on the basement or ground level are more likely to be flooded in a storm than those on higher floors. Safety showers and eyewash stations that are not properly plumbed or do not have floor drains nearby may also be a source of flooding. Consider the likelihood of flooding and its impact. Also, consider whether the laboratory contains equipment that is very sensitive to water damage. If flooding occurs, could it affect the space below the flood? If so, is the floor sealed appropriately? Are there overhead pipes?

To avoid flooding, do not block the sink drains. Place rubber matting in the bottom of the sinks to prevent breakage of glassware and to avoid injuries. While the use of water as a coolant in laboratory condensers and other equipment remains common practice, there are alternative means (for example a condenser that cools by air). Most flooding occurs when the tubing supplying the water to the condenser disconnects. Hoses can pop off when building water pressure fluctuates, causing irregular flows, or can break when the hose material has deteriorated from long-term or improper use. Floods also result when exit hoses jump out of the sink from a strong flow pulse or sink drains are blocked by an accumulation of extraneous material. Proper use of hose clamps and maintenance of the entire cooling system or alternative use of a portable cooling bath with suction feed can resolve such problems.

1.5 General Laboratory Apparatus and Procedures

1.5.1 Centrifuges

If a tabletop centrifuge is used, make certain that it is securely anchored in a location where its vibration will not cause bottles or equipment to fall. Ensure that the disconnect switch is working properly and shuts off the equipment when the top is opened. Centrifuge rotors shall be balanced each time they are used. Securely anchor and shield each unit against flying rotors. Regularly clean rotors and buckets with non-corrosive cleaning solutions.

Always close the centrifuge lid during operation, and do not leave the centrifuge until full operating speed is attained and the machine appears to be running safely without vibration. Stop the centrifuge immediately and check the load balances if vibration occurs. Check swingout buckets for clearance and support.

1.5.2 Vacuum Work and Apparatus

Vacuum work can result in an implosion and the possible hazards of flying glass, spattering chemicals, and fire. Set up and operate all vacuum operations with careful consideration of the potential risks. Although a vacuum distillation apparatus may appear to provide some of its own protection in the form of heating mantles and column insulation, this is not sufficient because an implosion could scatter hot flammable liquid. Use an explosion shield and a full-face shield to protect laboratory personnel, and carry the procedure out in a laboratory chemical hood. Glassware under vacuum should be kept behind a shield or hood sash, taped, or resin (plastic) coated.

Equipment at reduced pressure is especially prone to rapid pressure changes, which can create large pressure differences within the apparatus. Such conditions can push liquids into unwanted locations, sometimes with undesirable consequences.

Do not allow water, solvents, and corrosive gases to be drawn into a building vacuum system. When the potential for such a problem exists, use a cold trap. Water aspirators are not recommended.

Precautions to be taken when working with vacuum lines and other glassware used at sub-ambient pressure are mainly concerned with the substantial danger of injury in the event of glass breakage. The degree of hazard does not depend significantly on the magnitude of the vacuum because the external pressure leading to implosion is always atmosphere. Thus, evacuated systems using aspirators merit as much respect as high-vacuum systems. Injury due to flying glass is not the only hazard in vacuum work. Additional dangers can result from the possible toxicity of the chemicals contained in the vacuum system, as well as from fire following breakage of a flask (e.g., of a solvent stored over sodium or potassium).

Because vacuum lines typically require cold traps (generally liquid nitrogen) between the pumps and the vacuum line, precautions regarding the use of cryogens should be observed also. Liquid nitrogen–cooled traps open to the atmosphere condense liquid air rapidly. When the coolant is removed, an explosive pressure buildup occurs, usually with enough force to shatter glass equipment if the system has been closed. Hence, only sealed or evacuated equipment should be so cooled. Vacuum traps must not be left under static vacuum; liquid nitrogen in Dewar flasks must be removed from these traps when the vacuum pumps are turned off.

Residues from vacuum distillations have been known to explode when the still was vented suddenly to the air before the residue was cool. To avoid such explosions, vent the still pot with nitrogen, cool it before venting, or restore pressure slowly. Sudden venting may produce a shock wave that explodes sensitive materials.

1.5.2.1 Vacuum Pumps

Distillation or similar operations requiring a vacuum must use a trapping device to protect the vacuum source, personnel, and the environment. This requirement also applies to oil-free Teflon-lined diaphragm pumps. Normally the vacuum source is a cold trap cooled with dry ice or liquid nitrogen. Even with the use of a trap, the oil in a mechanical vacuum trap can become contaminated and the waste oil must be treated as a hazardous waste.

Vent the output of each pump to a proper air exhaust system. This procedure is essential when the pump is being used to evacuate a system containing a volatile toxic or corrosive substance. Failure to observe this precaution results in pumping volatile substances into the laboratory atmosphere.

Scrubbing or absorbing the gases exiting the pump is also recommended. Even with these precautions, volatile toxic or corrosive substances may accumulate in the pump oil and thus be discharged into the laboratory atmosphere during future pump use. Avoid this hazard by draining and replacing the pump oil when it becomes contaminated. Vacuum pumps should carry tags indicating the date of the most recent oil change. Oil should be changed once a month or sooner if it is known that the oil has been unintentionally exposed to reactive gases. It may be desirable to maintain a log of pump usage as a guide to length of use and potential contaminants in the pump oil.

All pumps should be either vented into a hood or trapped. Vent lines may be Tygon, rubber, or copper. If Tygon or rubber lines are used, they should be supported so that they do not sag and cause a trap for condensed liquids.

Belt-driven mechanical pumps must have protective guards. Such guards are particularly important for pumps installed on portable carts or tops of benches where laboratory personnel might accidentally entangle clothing, hair, or fingers in the moving belt or wheels.

1.5.2.2 Glass Vessels

Although glass vessels are frequently used in low-vacuum operations, evacuated glass vessels may collapse violently, either spontaneously from strain or from an accidental blow. Therefore, conduct pressure and vacuum operations in glass vessels behind adequate shielding. Check for flaws such as star cracks, scratches, and etching marks each time a vacuum apparatus is used. These flaws can often be noticed if the vessel is help up to a light. Use only round-bottom or thick-walled (e.g., Pyrex) evacuated reaction vessels specifically designed for operations at reduced pressure. Do not use glass vessels with angled or squared edges in vacuum applications unless specifically designed for the purpose (e.g., extra thick glass). Repaired glassware must be properly annealed and inspected with a cross-polarizer before vacuum or thermal stress is applied. Never evacuate thin-walled, Erlenmeyer, or round-bottom flasks larger than 1 L.

1.5.2.3 Dewar Flasks

Glass Dewar flasks are under high vacuum and can collapse as a result of thermal shock or a very slight mechanical shock. Shield them, either by a layer of fiber-reinforced friction tape or by enclosure in a wooden or metal container, to reduce the risk of flying glass in case of collapse. Use metal Dewar flasks whenever there is a possibility of breakage.

Styrofoam buckets with lids can be a safer form of short-term storage and conveyance of cryogenic liquids than glass vacuum Dewar flasks. Although they do not insulate as well as Dewar flasks, they eliminate the danger of implosion.

1.5.2.4 Assembly of Vacuum Apparatus

Assemble vacuum apparatus to avoid strain. Joints must allow various sections of the apparatus to be moved if necessary without transmitting strain to the necks of the flasks. Support heavy apparatus from below as well as by the neck. Protect vacuum and Schlenk lines from over pressurization with a bubbler. Gas regulators and metal pressure-relief devices must not be relied on to protect vacuum and Schlenk lines from over pressurization. If a slight positive pressure of gas on these lines is desired, the recommended pressure range is not in excess of 1 to 2 psi. This pressure range is easily obtained by proper bubbler design (depth of the exit tubing in the bubbler liquid).

Place vacuum apparatus well back onto the bench or into the laboratory chemical hood where it will not be inadvertently hit. If the back of the vacuum setup faces the open laboratory, protect it with panels of suitably heavy transparent plastic to prevent injury to nearby personnel from flying glass in case of implosion.

1.5.3 Syringes and Scalpel Blades

Syringes used with hazardous agents shall have needle-locking or equivalent tips to assure that the needles cannot separate during use. Do not recap disposable needles after use. Recapping of needles potentially contaminated with human blood, blood products, or other potentially infectious materials is prohibited.

Syringes, needles, or scalpels shall be disposed of immediately after use in sealable, puncture resistant, disposable containers that are leak-proof on the sides and bottom. The containers shall be appropriately labeled as to the chemical or biological hazard. Sharps containers shall be easily accessible to personnel in the immediate area of use.

1.5.4 Glassware and Plastic Labware

Borosilicate glassware, such as Pyrex 7740, is the type preferred for laboratory experimentation, except in special experiments involving ultraviolet or other light sources or hydrofluoric acid, for which polypropylene containers are most appropriate. Measuring glassware, stirring rods, tubing, and reagent bottles may be ordinary soft glass. Vacuum or suction flasks shall be designed with heavy walls. Dewar flasks and large vacuum vessels shall be taped or otherwise screened or contained in metal to prevent glass from flying if they should implode. An ordinary thin-walled thermos bottle is not an acceptable replacement for a Dewar flask.

Because it can be damaged in shipping, handling, or storage, inspect glassware carefully before using it to be sure it does not have hairline cracks or chips. Even the smallest flaw renders glassware unacceptable and possibly dangerous. Flawed glassware shall be discarded in a rigid, puncture- resistant broken-glass bin. Where the integrity of glassware is especially important, it can be examined in polarized light for strains. Do not store strong oxidizing agents in plastic labware except that made of Teflon. Prolonged exposure causes embrittlement and failure.

1.5.4.1 Cleaning Glassware

When cleaning laboratory glassware, wear appropriate gloves that have been checked for tears or holes. Avoid accumulating too many articles in the cleanup area around the sink; space is usually limited, and piling up glassware leads to breakage. Do not clean food containers in a sink that is used for cleaning contaminated glassware.

Many fingers have been badly cut by broken glass from glassware that was intact when put into the sink water. Handle glassware carefully and watch out for broken glass at the bottom of the sink. A rubber or plastic mat in the sink will help minimize breakage.

Avoid using strong cleaning agents such as nitric acid, chromic acid, sulfuric acid, strong oxidizers, or any chemical with "per" in its name (perchloric acid, ammonium persulfate, etc.) unless no alternatives are available.

If you must use these substances for cleaning, you should be thoroughly familiar with their hazardous characteristics and use appropriate protective equipment. Flammable solvents such as acetone should be used in minimum quantities for cleaning and with appropriate precautions taken during their use. Acids and solvents shall not be rinsed down the drain during cleaning but shall be collected for proper treatment and disposal.

1.5.5 Assembling Apparatus

Apparatus should be set up well back from the edge of the work area, be it a bench or a hood. When assembled in a hood, apparatus should not obstruct the area. To avoid overflow, choose apparatus with at least 20 percent more capacity than would normally accommodate the volume of chemical planned for the operation. All parts of the apparatus shall be firmly balanced and supported. Tubing shall be fastened with wire or appropriate clamps.

Stirrer motors and vessels shall be positioned and secured to ensure proper alignment. Magnetic stirring is preferable, and non-sparking motors or air motors shall be used in any laboratory that might contain flammable vapors.

Funnels and other apparatus with stopcocks shall be firmly supported and oriented so that gravity will not loosen the stopcock plug. Use a retainer on the stopcock plug and lubricate glass stopcocks. Do not lubricate Teflon stopcocks.

Include a vent in apparatus for chemicals that are to be heated and place boiling stones in unstirred vessels. A pan under a reaction vessel or container will confine spilled liquids in the event of glass breakage.

1.5.5.1 Extractions

Extractions can present a hazard because of the potential buildup of pressure from a volatile solvent and an immiscible aqueous phase. Glass separator funnels used in laboratory operations are particularly susceptible to problems because their stoppers or stopcocks can be forced out, resulting in a spill of the contained liquid. It is even possible for pressure to burst the vessel.

To use a separator funnel correctly, do not attempt to extract a solution until it is cooler than the boiling point of the extractant. When a volatile solvent is used, the unstoppered separator funnel should first be swirled to allow some solvent to vaporize and expel some air. Close the funnel, invert it with the stopper held in place, and immediately open the stopcock to release more air plus vapor. Do this with the hand extended around the barrel to keep the stopcock plug securely seated.

Point the barrel of the separator funnel away from yourself and others and vent it to the hood. Do not vent the funnel near a flame or other ignition source. Close the stopcock, shake with a swirl, and immediately open the stopcock with the funnel in the inverted position to vent the vapors again. If it is necessary to use a separator funnel larger than one liter for an extraction with a volatile solvent, the force on the stopper may be too great, causing the stopper to be expelled. Consider performing the extraction in several smaller batches.

1.5.5.2 Distillations[5]

Distillation of flammable and combustible solvents is dangerous due to the presence of heat and flammable vapors. Distillations should be maintained under inert atmosphere. At the completion of vacuum distillations, backfill the apparatus with inert gas. Perform such distillations in a chemical hood. Stills in use should be attended at all times and should have an automatic high-temperature shutoff. Distillation can sometimes be avoided by purchasing smaller quantities and high-purity solvents.

Certain common laboratory chemicals form peroxides on exposure to oxygen in air. Over time, some chemicals continue to build peroxides to potentially dangerous levels, whereas others accumulate a relatively low equilibrium concentration of peroxide, which becomes dangerous only after being concentrated by evaporation or distillation. Because distillation of a stabilized liquid removes the stabilizer, the distillate must be stored with care and monitored for peroxide formation.

The chemicals below are a peroxide hazard on concentration (distillation/evaporation). A test for peroxide should be performed if concentration is intended or suspected.

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

1.5.5.3 Solvent Stills

Solvent stills are used to produce dry, oxygen-free, high-purity solvents. Most high-purity solvents are commercially available in specialized kegs or may be obtained from column purification systems; thus, thermal distillation processes should be a last resort. There have been numerous fires attributed to solvent stills, some resulting in serious injuries and extensive damage to the labs. [See, e.g., Yarnell (2002).]

The process involves reflux and distillation of organic solvents (many of which are flammable liquids) over drying materials, under nitrogen or argon gas. The most commonly used drying agents involve potentially pyrophoric metals: sodium metal/benzophenone and magnesium metal/iodine. The stills must be periodically quenched to prepare the still bottoms for disposal.

This usually involves adding solvent to consume the scavenging agents. The process itself poses a risk of reactive metal adhering to the bottom of the flask, with the potential for exposure to air causing a spontaneous fire. Most thermal stills rely on electric heating mantles to heat the flammable solvents upward of 82 °C (180 °F), presenting a fire risk and potential ignition source.

Always set up stills in a chemical hood. Although many procedures suggest allowing the process to run overnight, it is prudent to ensure that it is not left completely unattended. Start the process at the beginning of the day and let it run as long as laboratory workers are present. Place Plexiglas shields around the still to protect workers in the event of a serious accident. Deactivate the stills under argon or nitrogen, never air. Do not add fresh solvent, drying agent, or indicator while the still is hot. Ensure that water-cooling lines are in good condition. Do not allow material to accumulate at the bottom of the still; quench the still at the end of every procedure and clean thoroughly. Use caution when collecting the reactive materials as waste.

1.5.5.4 Column Purification Systems or "Push Stills"

Column purification systems offer a safer, more environmentally friendly process for providing dry, oxygen-free, high-purity solvents as compared with thermal distillation. The level of impurity (water, oxygen, peroxides) is comparable to thermal distillation. The system is usually composed of refillable stainless steel "kegs" that hold high-purity solvent and act as a solvent reservoir. Inert gas (nitrogen, argon) is used to maintain an inert atmosphere as well as to force solvent through the packed columns that contain activated alumina (for water scavenging) and copper catalyst (for oxygen scavenging). For those solvents that are incompatible with copper (e.g., tetrahydrofuran, methylene chloride, acetonitrile), a second column of alumna is used along with a dry nitrogen or argon purge to facilitate oxygen removal. The solvent product is dispensed from the columns into a variety of specialized containers for use in the laboratory (glass, stainless steel, etc.).

Column purification systems present much less of a fire risk compared with thermal distillation, because they do not employ heating devices or reactive metals. Because glass containers are not needed, the potential for injury or spill related to breakage is also eliminated.

There is no need for heating mantles when solvent is present, and the intrinsically safe properties of the system allow it to be set up virtually anywhere in the laboratory, thus eliminating the need to place the apparatus in a chemical hood. As a result, there is a significant savings in electricity usage, although heating jackets may be required for installations where the water and oxygen scavengers are activated or regenerated. When using a column purification system, it is important not to draw down the column completely empty. Bubbling or splattering as the product is drawn from the column is an indication of breakthrough of argon. For the column to be functional again, a lengthy priming operation may be needed.

1.5.6 Temperature Control

Since the rates of most reactions accelerate as the temperature increases, highly exothermic reactions can become violent without adequate cooling. Viscous liquids transfer heat poorly and require special precautions. Apparatus shall be assembled so that either heating or cooling can be applied or withdrawn readily.

Whenever an electrical heating device is used, either a temperature controller or a temperature-sensing device must be used that will turn off the electric power if the temperature of the heating device exceeds some preset limit. Similar control devices are available that will turn off the electric power if the flow of cooling water through a condenser is stopped owing to the loss of water pressure or loosening of the water supply hose to a condenser. Independent temperature sensors must be used for the temperature controller and shutoff devices. Fail-safe devices, which can be either purchased or fabricated, can prevent the more serious problems of fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent, or loss of cooling. Use fail-safe devices for stills purifying reaction solvents, because such stills are often left unattended for significant periods of time. Temperature-sensing devices absolutely must be securely clamped or firmly fixed in place, maintaining contact with the object or medium being heated at all times. If the temperature sensor for the controller is not properly located or has fallen out of place, the controller will continue to supply power until the sensor reaches the temperature setting, creating an extremely hazardous situation.[5]

Insert a thermometer in heated liquids if dangerous exothermic decomposition is possible. This will provide a warning and may allow time to remove the heat and apply external cooling.

A more thorough hazard review should be done when reaction temperatures (> 150 °C; < -30 °C), the pressure within a reaction vessel can be expected to exceed 10 bar, or reagents are fed at >2 bar of pressure.[6]

1.5.6 Temperature Control

Since the rates of most reactions accelerate as the temperature increases, highly exothermic reactions can become violent without adequate cooling. Viscous liquids transfer heat poorly and require special precautions. Apparatus shall be assembled so that either heating or cooling can be applied or withdrawn readily.

Whenever an electrical heating device is used, either a temperature controller or a temperature-sensing device must be used that will turn off the electric power if the temperature of the heating device exceeds some preset limit. Similar control devices are available that will turn off the electric power if the flow of cooling water through a condenser is stopped owing to the loss of water pressure or loosening of the water supply hose to a condenser. Independent temperature sensors must be used for
the temperature controller and shutoff devices. Fail-safe devices, which can be either purchased or fabricated, can prevent the more serious problems of fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent, or loss of cooling. Use fail-safe devices for stills purifying reaction solvents, because such stills are often left unattended for significant periods of time. Temperature-sensing devices absolutely must be securely clamped or firmly fixed in place, maintaining contact with the object or medium being heated at all times. If the temperature sensor for the controller is not properly located or has fallen out of place, the controller will continue to supply power until the sensor reaches the temperature setting, creating an extremely hazardous situation.[5]

Insert a thermometer in heated liquids if dangerous exothermic decomposition is possible. This will provide a warning and may allow time to remove the heat and apply external cooling.

A more thorough hazard review should be done when reaction temperatures (> 150 °C; < -30 °C), the pressure within a reaction vessel can be expected to exceed 10 bar, or reagents are fed at >2 bar of pressure.[6]

1.5.6.1 Drying Ovens and Furnaces

Volatile organics shall not be dried in ovens that vent to the room air. Glassware rinsed with organics should not be oven dried unless it is first re-rinsed with water. Bimetallic strip thermometers rather than mercury thermometers are recommended for measuring oven temperatures. If a mercury thermometer breaks in an oven, the oven shall be turned off and cooled before cleanup is attempted. Wear heat-resistant gloves and appropriate eye protection when working at ovens or furnaces. ANSI- approved eyewear (i.e., heat-absorbing, reflective goggles) offers protection against projectiles and infrared radiation.

1.5.6.2 Heat Blocks, Oil and Sand Baths[5]

Heat blocks, specifically sized for round bottom flasks, can be placed directly on a stirring hotplate. Heat blocks are a good replacement for oil baths or heating mantles.

Improper use of a hot oil or sand bath may create serious hazards such as an overturned bath, spatter from water falling into the bath, smoke caused by decomposition of the oil or organic materials in the oil, and fire from overheating the oil. Baths shall not be left unattended without a high-temperature shutoff. The oil shall be properly labeled, including information on its safe working temperature.

Fresh silicone oils have higher auto ignition temperatures and are recommended over the use of paraffin oil. Contact with oxygen and long exposure to temperature at the upper end of their application range accelerates the degradation of silicone oils and will lower the auto ignition temperature. Replace the silicone oil in openly heated oil baths at least annually.

Contain heated oil in either a metal pan or a heavy-walled porcelain dish; a Pyrex dish or beaker can break and spill hot oil if struck accidentally with a hard object. Mount the oil bath carefully on a stable horizontal support such as a laboratory jack that can be raised or lowered easily without danger of the bath tipping over. Always clamp equipment high enough above a hot plate or oil bath so if the reaction begins to overheat, the heater can be lowered immediately and replaced with a cooling bath without having to readjust the clamps holding the equipment setup. Never support a bath on an iron ring because of the greater likelihood of accidentally tipping the bath over. Provide secondary containment in the event of a spill of hot oil. Wear proper protective gloves when handling a hot bath. If stirring combustible or flammable liquids, use a stirrer instead of a stirring hotplate to avoid accidental overheating.

1.5.6.3 Cooling Baths[5]

The preferred liquids for dry-ice cooling baths are isopropyl alcohol or glycols; add dry ice slowly to the liquid portion of the cooling bath to avoid foaming. Avoid the common practice of using acetone–dry ice as a coolant; the alternatives are less flammable, less prone to foaming and splattering with dry ice, and less likely to damage some trap components (O-rings, plastic). Dry ice and liquefied gases used in refrigerant baths should always be open to the atmosphere. Never use them in closed systems, where they may develop uncontrolled and dangerously high pressures.

Exercise extreme caution in using liquid nitrogen as a coolant for a cold trap.
If such a system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere. The oxygen could then combine with any organic material in the trap to create a highly explosive mixture. Therefore, do not open a system that is connected to a liquid nitrogen trap to the atmosphere until the liquid nitrogen Dewar flask or container has been removed. A liquid nitrogen–cooled trap must never be left under static vacuum. In addition, if the system is closed after even a brief exposure to the atmosphere, some oxygen may have already condensed. Then, when the liquid nitrogen bath is removed or when it evaporates, the condensed gases will vaporize, producing a pressure buildup and the potential for explosion. The same explosion hazard can be created if liquid nitrogen is used to cool a flammable mixture that is exposed to air. Caution must be applied when using argon, for instance as an inert gas for Schlenk or vacuum lines, because it condenses as a colorless solid at liquid nitrogen temperature. A trap containing frozen argon is indistinguishable from one containing condensed solvent or other volatiles and presents an explosion hazard if allowed to warm without venting.

1.5.7 Laboratory Reactor Pressure Vessels

Laboratory reactor pressure vessels may also be referred to as sample preparation bombs, acid digestion bombs, hydrothermal reactors or chemical digestion autoclaves[7].

Heating chemicals inside a closed vessel can result in some of the highest gas or super critical fluid pressures encountered in a laboratory.

Novice users must be directly supervised in experimental design, vessel assembly and heating mode selection until they exhibit full understanding and proficiency.

As part of a laboratory reactor pressure vessel safety program, write detailed standard operating procedures, including intended operating pressures and temperatures, and upload to NSIS. Contact EOHS for experiments that are intended to build up pressure above 500psia (34 bar)[8].

If you use laboratory reactor pressure vessels in your experiments, it is important to understand what conditions increase the hazards associated with use so you can prevent dangerous ruptures or explosions from occurring. All laboratory reactor pressure vessels shall be equipped with a form of overpressure relief to protect the vessel from the hazards of unexpected or dangerously high internal pressures. Appropriate over pressure relief through a safety rupture disk or safety relief valve must be part of the laboratory reactor pressure vessel design.

- DO NOT use a laboratory reactor pressure vessel without overpressure relief.
- DO NOT use laboratory reactor pressure vessels without manufacturer's documentation of maximum pressure and temperature.
- DO NOT assemble or maintain pressure vessels without manufacturer's literature.
- DO NOT exceed temperature limits for reactions or pressure vessels specifications.
- DO NOT exceed vessel-loading limits.
- DO NOT form explosive materials inside a pressure vessel. Some chemicals and mixtures are prohibited in laboratory reactor pressure vessels.
- DO NOT treat fats, fatty acids, glycerin and similar materials with nitric acid in pressure vessels.
- DO NOT treat cellulosic materials with mixed nitric and sulfuric acids.
- DO NOT use perchloric acid, picric acid or concentrated hydrazine in these vessels.

- AVOID reactions which are highly exothermic or which may be expected to release large volumes of gas.

Overloading of a pressure vessel is a significant hazard. Where available, identify the charging limits for each chemical and vessel size in the manufacturer's literature.

Always evaluate the stoichiometry and chemistry that you are trying to achieve with special considerations for catalysts and gaseous by-products that may affect pressure build up inside the vessel. Assess any intermediates, side-products and products that may form and their behavior within the vessel, including their corrosive nature and their tendency to violently decompose at elevated temperature and pressure. Determine maximum temperature and pressure limits expected, taking into account the energetics of the reaction being conducted and any pathways that might cause the reaction to run out of control. A formal written risk assessment is strongly encouraged.

Defective temperature controls or operator inattention can be the cause of dangerous overheating. In order to prevent dangerous overheating, the best practice is to:

- Use ovens or heating devices with high temperature limit controllers.
- Heat general-purpose metal body laboratory reactor pressure vessels only in an oven.
- Heat polymer body laboratory reactor pressure vessels only in a microwave oven.
- Heat other laboratory reactor pressure apparatus behind a blast shield or suitable barrier.
- Post caution signs or an Unattended Experiment Notice when heating pressure vessels unattended

Some pressure vessels are equipped with a polytetrafluoroethylene (PTFE) cup and lid liner. Due to PTFE flow, once a PTFE cup and lid is pressurized it becomes a uniquely matching pair. Using unmatched pairs of cups and lids will cause leaks. Store all the parts of a pressure vessel together to avoid mismatches. Periodically conduct a leak check in accordance with the manufacturer's literature.

Not all pressure vessels use a PTFE insert. Internal wetted parts of a pressure vessel have to be constructed resistant to corrosive materials at the expected operating pressure. Each alloy has its own physical strength and temperature characteristics as well as its own unique resistance to certain corrosive materials. All of these factors must be considered when making a selection. Dedicate pressure vessels for either acid or base service. Do not interchange the use of acids and bases in the same pressure vessel.

1.5.8 Reduced Pressure Operations

Protect vacuum desiccators by covering them with cloth-backed friction or duct tape or shielding them for protection in case of implosion. Vacuum lines shall be trapped and shielding used whenever apparatus is under reduced pressure. Only chemicals being dehydrated should be stored in a desiccator. Before opening a desiccator that is under reduced pressure, make sure that atmospheric pressure has been restored.

Water aspirators for reduced pressure are used mainly for filtration purposes, and only equipment that is approved for this purpose should be used. Never apply reduced pressure to a flat-bottomed flask unless it is a heavy-walled filter flask designed for that purpose. Place a trap and a check valve between the aspirator and the apparatus so that water cannot be sucked back into the system if the water pressure falls unexpectedly during filtering. This also applies to rotary evaporation equipment that use water aspirators for reduced pressure.

If vacuum pumps are used, place a cold trap between the apparatus and the vacuum pump so that volatiles from a reaction or distillation do not get into the pump oil or out into the atmosphere.

Exhausts from pumps shall be vented to a hood or ventilation system. Pumps with belt drives must be equipped with belt guards to prevent hands, hair, or loose clothing from being caught in the belt pulley.

1.5.8.1 Desiccators[5]

If a glass vacuum desiccator is used, it should be made of Pyrex or similar glass, completely enclosed in a shield or wrapped with friction tape in a grid pattern that leaves the contents visible and at the same time guards against flying glass if the vessel implodes. Plastic (e.g., polycarbonate) desiccators reduce the risk of implosion and may be preferable but should also be shielded while evacuated. Solid desiccants are preferred. Never carry or move an evacuated desiccator. Take care opening the valve to avoid spraying the desiccator contents from the sudden in rush of gas.

1.5.8.2 Rotary Evaporators[5]

Glass components of the rotary evaporator should be made of Pyrex or similar glass. Completely enclose in a shield to guard against flying glass should the components implode. Gradually increase rotation speed and application of vacuum to the flask whose solvent is to be evaporated.

1.5.9 Cold Traps

Cryogenic liquids are materials with boiling points of less than −73 °C (−100 °F). Liquid nitrogen, helium, argon, and slush mixtures of dry ice with isopropyl alcohol are the materials most commonly used in cold traps to condense volatile vapors from a gas or vapor stream. Cold traps used in reduced- pressure systems should be placed in vermiculite-filled metal cans. If this option is not possible, the cold traps should be coated with plastic resin or wrapped with cloth-backed friction or duct tape. In the event of an implosion, the coating will reduce the amount of flying glass.[5]

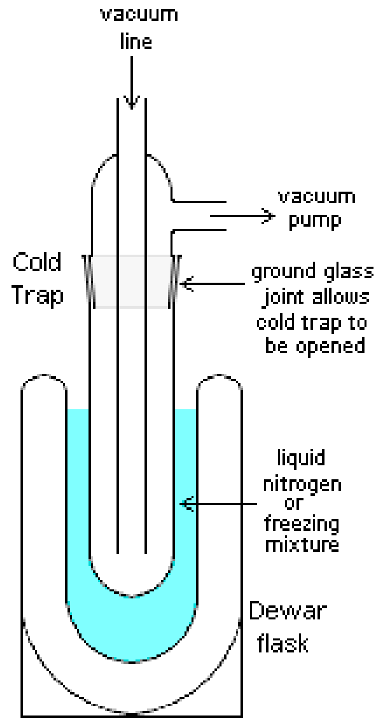

Figure 1: Cold Trap

Users of cold traps should be aware of the boiling points of the components and the possible materials that can condense in the reduced-pressure system. After completion of an operation in which a cold trap has been used, isolate the trap from the source, remove from the coolant, and vent to atmospheric pressure in a safe and environmentally acceptable way. Otherwise, pressure could build up, creating a possible explosion or sucking pump oil into a vacuum system. Dry ice and liquefied gases used in refrigerant baths should always be open to the atmosphere. Never use them in closed systems, where they may develop uncontrolled and dangerously high pressures. [5]

Exercise extreme caution in using liquid nitrogen as a coolant for a cold trap. If such a system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere. Caution must be applied when using argon as an inert gas for Schlenk or vacuum lines, because it condenses as a colorless solid at liquid nitrogen temperature. A trap containing frozen argon is indistinguishable from one containing condensed solvent or other volatiles and presents an explosion hazard if allowed to warm without venting. [5]

1.5.10 Regulators

Regulators are gas-specific which limits interchange and adds safety. Special installation processes, not mentioned here, are used for toxic or high purity gases. Always make sure that the regulator and valve fittings are compatible.

To select the appropriate regulator:

- Determine the gas pressure needed.
- Determine the maximum pressure the system might require.
- Select a delivery pressure range so the required pressures are in the 25%-90% range of the regulator delivery pressure.
- Check with the gas supplier about compatible connections and regulators.

Check cylinder outlet and regulator inlet connections for debris or contamination before connecting. Some gases, such as carbon dioxide, require a gasket. Ensure that a required gasket is in place before assembling the regulator onto the cylinder.

Tighten connecting nut with a smooth jaw wrench. Back out the adjusting knob or key on the regulator. Open the cylinder valve just enough to indicate pressure on the regulator gauge (no more than one full turn). Check connections with a soap solution for leaks. Never use oil or grease on the regulator of a cylinder valve.

All compressed gas regulators should, at a minimum, be checked for external leakage and internal leakage (creep or crawl) regularly. Regulators should be removed from service at least every five years (more frequent in some cases) and returned to the manufacturer, or a competent agent to be inspected and/or refurbished as necessary. Regulators should also be tagged or labeled to identify the last date of inspection. Users should consult the manufacturer for specific procedures on how to check for external and internal leakage as well as the recommended frequency of the tests. Regulators are continuously exposed to high stresses due to cylinder pressures. In addition, the materials of construction are attacked internally by both mildly and severely corrosive gases. External corrosive environments can cause gauges and springs to corrode. Argon, helium and nitrogen regulators (CGA 580) will, under a given set of conditions, have a longer service life than regulators used for hydrogen chloride and hydrogen sulfide (CGA 330) simply because the gas service is more severe (corrosive).

The most common type of regulator failure is the internal leak, sometimes called creep or crawl. This can occur when the seat becomes damaged or displaced due to a foreign particle such as a metal chip or other material. When the seat cannot close completely, delivery pressure will not be maintained and regulator pressure cannot reach a state of equilibrium. Downstream or delivery pressure will continue to climb until the safety relief mechanism on the regulator is activated (usually a relief valve or a diaphragm burst hole). Checking for this type of failure is relatively easy if the device has a gauge that reads regulated pressure. The gauge pressure will start to rise above the set point and continue upward. This creates a potentially hazardous condition where any downstream equipment would be subjected to pressures beyond the rated limit. Regulators should be visually checked for this type of failure. Excessive flexing of metal regulator diaphragms can cause a radial crack, which allows gas to escape to the atmosphere through the vent hole in the bonnet.

1.6 Energy sources

1.6.1 Electricity and Electrical Equipment

Electrical currents of very low amperage and voltage may result in fatal shock under certain circumstances. Voltages as low as 24 volts AC can be dangerous and present a lethal threat. Low-voltage DC circuits do not normally present a hazard to human life, although severe burns are possible. The duration of contact with a live circuit affects the degree of damage, especially with regard to burns.

All electrical switches shall be labeled, including circuit breakers in the service panels, and all laboratory personnel shall know where these controls are and how to shut off circuits or equipment in case of fire or other accident. Any electrical equipment that is not operating properly or seems to be overheating shall be turned off immediately and inspected by a qualified technician.

Electrical equipment should be inspected periodically to confirm that the cords and plugs are in safe condition. Circuit diagrams, operating instructions, descriptions of hazards, and safety devices are usually provided by the manufacturer and should be kept on file for reference.

Only three-wire grounded, double-insulated or isolated wiring and equipment shall be used in 110V-115V AC applications. All wiring and equipment shall comply with the National Electrical Code. In specifically designated laboratories, cold rooms, or storage rooms or other locations where concentrations of flammable vapor-air mixtures are likely to occur, certified explosion-proof wiring and equipment, including light fixtures, switches, refrigerators, and telephones, shall be used.

Series-wound motors with carbon brushes, typically found in household appliances such as blenders and mixers, are not spark-free and shall not be used in laboratories where flammable vapors accumulate. Equipment manufactured for use in laboratories generally contains induction motors.

Electrical extension cords should be avoided, where practical, by installing additional electrical outlets. Only electricians from Facilities Management are permitted to make electrical modifications in University properties. When extension cords are used, the current carrying capacity shall be larger than the current requirement of the equipment connected to it. Electrical cords on equipment shall be discarded or repaired if frayed or damaged. Cords should be kept as short as practical to avoid tripping hazards and tangles. In wet locations, ground fault circuit interrupters (GFCI) should be used.

Place electrical equipment to minimize the possibility that water or chemicals could spill on it or that water could condense and enter the motor or controls. In particular, place such equipment away from safety showers. In cold rooms, condensation can be minimized by mounting electrical equipment on walls or vertical panels.

Only qualified individuals are permitted to make electrical repairs to any kind of electrical equipment. All electrical equipment shall be de-energized and tagged or locked out according to OSHA requirements before repairs are made. If adjustments or other contacts are to be made with energized electrical equipment, a second person shall be present. Be sure you are not on a damp surface or touching a potential grounding surface. Use insulated tools, keep your hands dry, and wear safety glasses to prevent injury from sparks.

If a worker receives an electrical shock and is in contact with the energized device, use nonconductive gloves or a non-conducting device to pull or push the victim free from the electrical source. Help victims only if you are certain that you will not endanger your own safety. Turn off or disconnect the power source if possible. Call Campus Police at 911. If a trained person is available, start CPR if necessary. Get medical assistance at once.

1.6.2 Ultraviolet, Visible, and Near-Infrared Radiation

Ultraviolet, visible, and infrared radiation from lamps and lasers in the laboratory can produce a number of hazards. Medium-pressure Hanovia 450 Hg lamps are commonly used for ultraviolet irradiation in photochemical experiments. Ultraviolet lights used in biosafety cabinets, as decontamination devices, or in light boxes to visualize DNA can cause serious skin and corneal burns. Powerful arc lamps can cause eye damage and blindness within seconds. Some compounds (e.g., chlorine dioxide) are explosively photosensitive.

When incorrectly used, the light from lasers poses a hazard to the eyes of the operators and other people present in the room and is a potential fire hazard. See the Laser Safety Handbook for further details about laser registration and hazard control. Glassblowing and the use of laser or ultraviolet light sources require special eye protective glasses or goggles.

1.6.3 Electromagnetic Radiation and Magnetic Fields[5]

Increasingly, instruments that generate large static magnetic fields (e.g., NMR spectrometers, MRI) are present in research laboratories. Such magnets typically have fields of 14,000 to 235,000 G (1.4 to 23.5 T), far above that of Earth’s magnetic field, which is approximately 0.5 G. The magnitude of these large static magnetic fields falls off rapidly with distance. Many instruments now have internal shielding, which reduces the strength of the magnetic field outside of the instrument. Strong attraction occurs when the magnetic field is greater than 50 to 100 G and increases by the seventh power as the separation is reduced. However, this highly nonlinear falloff of magnetic field with distance results in an insidious hazard. Objects made of ferromagnetic materials such as ordinary steel may be scarcely affected beyond a certain distance, but at a slightly shorter distance may experience a significant attraction to the field. If the object is able to move closer, the attraction force increases rapidly, and the object can become a projectile aimed at the magnet. Objects ranging from scissors, knives, wrenches, and other tools, keys, steel gas cylinders, buffing machines, and wheelchairs have been pulled from a considerable distance to the magnet itself.

Superconducting magnets use liquid nitrogen and liquid helium coolants. Thus, the hazards associated with cryogenic liquids are of concern, as well.

The health effects of exposure to static magnetic fields are an area of active research. Currently, there is no clear evidence of a negative health impact from exposure to static magnetic fields, although biological effects have been observed (Schenck, 2000), and recently, guidelines on limits of exposure to static magnetic fields have been issued by the International Commission on Non-ionizing Radiation (ICNIRP, 2009), which is a collaborating organization with the World Health Organization’s International Electromagnetic Field Project.

1.6.3.1 Magnetic Field Effects and Hazard Warning

An object that moves into the attractive field of a strong magnet system, such as a nuclear magnetic resonance (NMR) system or any other instrument system requiring a superconducting magnet, can become a projectile that is pulled rapidly toward the magnet. For example, the large attractive force of an NMR requires that objects ranging from keys, scissors, knives, wrenches, other tools, oxygen cylinders, buffing machines, wheelchairs, and other ferromagnetic objects are excluded from the immediate vicinity of the magnet to protect safety and data quality.

Magnetic fields of ~10 G can adversely affect credit cards, watches, and other magnetic objects. Computer and television screens in neighboring areas may be affected by shifts in small, peripheral magnetic fields as magnets are brought up to field or decommissioned. Prudent practices require posting warnings, cordoning off the area at the 5-G line, and limiting access to areas with more than 10 to 20 G to knowledgeable staff. Keep people wearing heart pacemakers and other electronic or electromagnetic prosthetic devices or other potentially magnetic surgical implants, such as aneurysm clips, away from strong magnetic sources. Repairs done near a strong magnet should be performed with non-ferromagnetic tools.

Magnetic fields operate in three dimensions, and when considering the impact of an instrument, field strength should be checked on the floors above and below the floor where a superconducting magnet is installed. The 5-G line should be identified in all affected rooms, and appropriate warnings should be posted.

Because superconducting magnets use liquid nitrogen and liquid helium coolants, the precautions associated with the use of cryogenic liquids must be observed as well. If the superconducting magnet loses superconductivity because of damage, physical shock, or for any other reason, the coil will heat the cryogenic liquid that surrounds it, the magnet will quench (lose field), and the helium will boil off rapidly into the surrounding space. Low-oxygen alarms are recommended in rooms where instruments with superconducting magnets are located. In the event of a quench, all personnel should leave the area and not return until oxygen levels return to normal. If emergency personnel must enter the area before the oxygen levels have been verified, they should wear a self-contained breathing apparatus (SCBA).

Rooms containing superconducting magnets should provide enough clearance for coolant fills to be performed safely.

If an object becomes stuck to a superconducting magnet, do not attempt to remove it, but call the vendor of the magnet for guidance. Attempting to remove the object could result in injury to personnel and damage to the magnet. It may also cause the magnet to quench, releasing dangerous quantities of gaseous helium into the area.

Effects	*Field Strength at Which Effects Occur (G)*
Effects on sensitive equipment such as electron microscopes, image intensifiers, and nuclear cameras	*1*
Disturbance of cathode ray tubes; possible detrimental effects on medical equipment, such as pacemakers, implants, surgical clips, or neurostimulators	*5*
Erasure of credit card and bank cards; disruption of small mechanical devices, such as analog watches and clocks; and disturbance of X-ray tubes	*10*
Destruction or corruption of magnetic storage material	*20*
Saturation of transformers and amplifiers	*50*

Table 1: Summary of magnetic field effects

1.6.4 Frequency and Microwave Radiation[5]

1.6.4.1 Radio Frequency and Microwave

Hazards Radio frequency (rf) and microwaves occur within the range 10 kHz to 300,000 MHz and are used in rf ovens and furnaces, induction heaters, and microwave ovens. Extreme overexposure to microwaves can result in the development of cataracts, sterility or both. Microwave ovens are increasingly being used in laboratories for organic synthesis and digestion of analytical samples. Only microwave ovens designed for laboratory or industrial use should be used in a laboratory. Use of metal in microwave ovens can result in arcing and, if a flammable solvent is present, in fire or explosion. Superheating of liquids can occur. Capping of vials and other containers used in the oven can result in explosion from pressure buildup within the vial. Inappropriately selected plastic containers may melt.

1.6.4.2 Microwave Ovens

Use microwave ovens specifically designed for laboratory use. Domestic microwave ovens are not appropriate.

Microwave heating presents several potential hazards not commonly encountered with other heating methods: extremely rapid temperature and pressure rise, liquid superheating, arcing, and microwave leakage. Microwave ovens designed for the laboratory have built-in safety features and operation procedures to mitigate or eliminate these hazards. Users of such equipment must be thoroughly knowledgeable of operation procedures and safety devices and protocols before beginning experiments, especially when there is a possibility of fire (flammable solvents), over-pressurization, or arcing (Foster and Cournoyer, 2005).

To avoid exposure to microwaves, never operate ovens with the doors open. Do not place wires and other objects between the sealing surface and the door on the oven's front face. Keep the sealing surfaces clean. To avoid electrical hazards, the oven must be grounded. If use of an extension cord is necessary, use only a three-wire cord with a rating equal to or greater than that for the oven. To reduce the risk of fire in the oven, do not overheat samples. The oven must be closely watched when combustible materials are in it. Do not use metal containers or metal- containing objects (e.g., stir bars) in the microwave, because they can cause arcing.

In general, do not use heat-sealed containers in a microwave oven because of the danger of explosion. If sealed containers must be used, select their materials carefully and ensure the containers are properly designed. Commercially available microwave acid digestion bombs, for example, incorporate a Teflon sample cup, a self-sealing Teflon O-ring and a compressible pressure-relief valve. Do not exceed the manufacturer's loading limits. For such applications, properly vent the microwave oven using an exhaust system. Placing a large item, such as a laboratory microwave or an oven, inside a chemical fume hood is not recommended.

Heating a container with a loosened cap or lid poses a significant risk. Microwave ovens can heat material (e.g., solidified agar) so quickly that, even though the container lid is loosened to accommodate expansion, the lid can seat upward against the threads and the container can explode. Screw caps must be removed from containers being microwaved. If the sterility of the contents must be preserved, screw caps may be replaced with cotton or foam plugs.

Although industrial ovens may reduce the risk of such hazards, significant caution is required in their use. In general, the use of closed vessels should be avoided. Any reactions conducted in a microwave oven should be regarded with the same caution as those conducted with highly reactive and explosive chemicals. Reactions should use the smallest scale possible to determine the potential for explosions and fires. Precautions must be taken for proper ventilation and potential explosion.

1.6.5 Ionizing Radiation

Ionizing radiation is a classification for high-energy radiation capable of breaking chemical bonds. This class of radiation encompasses both photonic (high ultraviolet radiation, x-rays, and gamma rays) and particulate (alpha particles, beta particles, positrons, and neutrons) forms of emissions. Before dealing with these sources, training must be completed under the Radiation Safety Officer. Contact EOHS at ext. 3703. For more specific information on ionizing radiation hazards, please consult the Radiation Safety Manual and the Radiation-Generating Equipment Quality Assurance Program document.

1.7 Laboratory Infrastructure

1.7.1 Laboratory Ventilation

Laboratories shall be provided with general ventilation adequate for employee comfort and sufficient to supply air for chemical fume hoods and other local ventilation devices. Because the general air supply is not adequate for manipulating hazardous materials on an open lab bench, volatile or toxic chemicals shall be handled in a chemical fume hood or other appropriate containment device.

Laboratory ventilation should change the air at least six times per hour. Higher air exchange rates may be required depending on the nature of the laboratory work. Except in special circumstances approved by EOHS, air in laboratories shall be at a negative pressure with respect to the rest of the building. Air diffusers or grilles shall be so designed and located as to direct the air over the laboratory personnel and sweep the contaminated air away from their breathing zone. To promote uniform distribution and mixing of air in large laboratories, the supply registers shall deliver the air in all directions, at a typical velocity of 20 linear feet per minute.

Problems with general ventilation shall be reported promptly to Facilities Management. Adjustments or alterations to the general ventilation equipment of a laboratory shall be performed only under the supervision of Facilities Management.

On occasion, Facilities Management will issue notices of intent to perform maintenance work on the ventilation system. These notices shall be heeded and chemical fume hoods shall not be used when Facilities Management is involved in repairing or adjusting the ventilation system. The supervisor of the laboratory is responsible for ensuring that the Facilities Management crew is informed of the hazards in the area. The chemical fume hood shall be cleared of toxic materials and properly decontaminated before such work begins. Facilities Management may request EOHS to inspect the chemical fume hood prior to maintenance or repair work. Be prepared to supply a detailed history of chemical and biological agent use in the chemical fume hood for safety evaluation purposes.

1.7.2 Chemical Fume Hoods

A chemical fume hood is an important engineering control for preventing exposure to hazardous materials. In conjunction with sound laboratory techniques, a chemical fume hood serves as an effective means for capturing toxic, carcinogenic, offensive, flammable vapors or other airborne contaminants. A chemical fume hood is an important engineering control for preventing exposure to hazardous materials. In conjunction with sound laboratory techniques, a chemical fume hood serves as an effective means for capturing toxic, carcinogenic, offensive, flammable vapors or other airborne contaminants that would otherwise enter the general laboratory atmosphere. With the sash lowered, the chemical fume hood also forms a physical barrier to protect workers from hazards such as chemical splashes or sprays, fires and minor explosions. Chemical fume hoods may also provide effective containment for accidental spills of chemicals although this is not their primary purpose. The deliberate release and venting of chemicals (i.e., evaporation) in chemical fume hoods shall never be used as a means of disposal.

Turbulence is the greatest enemy to proper chemical fume hood operation. It can lead to back spill of contaminants out of the chemical fume hood. The operator has significant control over the factors that cause turbulence and consequently, the chemical fume hood’s capture efficiency.

For example, chemical fume hoods with active experiments are not meant for storage of chemicals at the same time. Storing chemical containers and equipment in a chemical fume hood impairs its performance. The containers and equipment create turbulence as airflow is diverted around them.

Volatile and odorous chemicals and highly toxic gases shall be stored in ventilated cabinets.

If chemical containers or bulky devices must be maintained in the chemical fume hood during an experiment, they should be elevated 2 to 3 inches above the interior work surface using jacks, apparatus scaffolding, support stands, ring stands, metal bars or stilts, etc. Materials remaining directly on the work surface block the incoming air and propel it back toward the chemical fume hood face.

The elevation of materials in the chemical fume hood allows air to pass unimpeded to the bottom exhaust opening at the chemical fume hood's back wall.

Turbulence is also created at the face of the chemical fume hood when obstacles to airflow such as containers and equipment are too close to the sash. Containers and equipment should always be moved 6 inches back from the inner edge of the air sill. This practice can reduce vapor concentrations at the chemical fume hood face by about 90 percent.

Even the movement of one's hands can interrupt airflow patterns and disturb proper circulation of exhaust air. When reaching into the chemical fume hood, take care to move your hands slowly with smooth gestures. If working at a chemical fume hood with a horizontal sash, use one of the panes as a barrier to splashes. Position the pane directly in front of you and move your hands on opposite sides of the pane.

Chemical fume hood performance is also dependent on the room's airflow pattern, including airflow generated by drafts and persons walking by. Minimize traffic, opening and closing of doors near the chemical fume hood. When the chemical fume hood is in use, the sashes should be pulled down as far as workable for minimal external airflow interference and maximum barrier protection.

Chemical fume hoods used for hazardous chemicals shall have an average face velocity of 80 to 100 feet per minute at a minimum sash height of 12 inches. Face velocity shall not exceed 120 fpm at the working sash height.

Compounds such as perchloric acid or aqua regia are likely to cause chemical fume hood corrosion. Perchloric acid use requires a special fume. Only one such hood is in room 6003 in Ward Beecher Hall.

Chemical fume hoods shall be evaluated for performance upon installation and following any alterations. EOHS monitors chemical fume hoods annually. The fans and duct systems are maintained and inspected by Facilities Management. Any problems with hood ventilation or airflow should be reported to EOHS or Facilities Management for inspection and evaluation.

1.7.3 Safety Showers

Safety showers shall be installed in all areas where employees may be exposed to splashes or spills of materials that may be injurious to the eyes and body. As a rule, new shower installations shall adhere to the recommendations for shower location and minimum performance requirements established in American National Standard Z-358.1 (2009). Showers shall be placed as close to the hazard as possible, but in no case more than 10 seconds' travel time from the hazard. Department heads shall ensure that safety showers are installed in the department where needed. Drench hoses substitute for showers in some locations on campus.

Every laboratory employee shall be instructed in the location(s) and use of a safety shower. Ideally, a person should be able to find the shower with his or her eyes closed. Safety showers shall provide a minimum of 20 gallons of water per minute and deliver the volume at low velocity; a high-velocity shower could further damage injured tissue.

Ideally, the water temperature of the shower should be tepid to prevent pain or shock to a person standing under it for 15 minutes. Safety showers shall have quick-opening valves requiring manual closing so that a person does not have to hold the valve open while trying to undress or wash off. The pull handle shall be a delta bar or large ring within easy reach but not so low as to be in the way.

Flammable-liquid cabinets or other hazardous equipment or material shall not be placed near a safety shower, and access to the shower or the activating handle shall not be impeded. The floor shall be clear in a 34-inch-diameter area under the shower.

Safety showers shall be tested and inspected at least annually. Inspection includes a visual check of visible plumbing and verification of proper operation. EOHS conducts the annual tests and maintains related records.

1.7.4 Eyewash Fountain

An eyewash providing a continuous, low-pressure stream of aerated water shall be provided in each laboratory in which chemical or biological agents are used or stored. The designated eyewash(es) shall be easily accessible from any part of the laboratory and labeled. If possible, the eyewash should be located near the safety shower so that, if necessary, the eyes can be washed while the body is showered.

New eyewash installations shall adhere to the recommendations for minimum performance requirements established in American National Standard Z-358.1 (2009). Eyewash fountains shall supply 0.4 gallons of water per minute for 15 minutes. The three basic kinds of eyewash fountains are the fixed-base shower, much like a drinking fountain, with arm or foot-pedal operation, faucet- mounted units, and the handheld-hose type, with aerating nozzle(s) and lever-operated valve. Some labs have Fend All 1000 units. The main criteria are that, whichever eyewash chosen:

- it shall activate within one second,
- it shall provide hands-free continuous operation once activated, and
- the flushing streams shall rise to approximately equal heights and the flushing fluid will wash both eyes simultaneously.

Contact EOHS for information on the types of eyewashes available. Bottle-type portable eyewashes are not acceptable, as they do not have the capacity to deliver 0.4 gallons of water per minute.

Faculty and lab or studio managers are responsible for ensuring that the labeled eyewash fountains in their labs are flushed weekly. Operate the valve, visually observe availability of the aerated water stream, and flush the pipes or hose of sediment that may have collected. Issue a work order to Facilities Management if an eyewash station does not provide a clean water stream of sufficient pressure and attach an Out-of-order sign as documentation for your maintenance action. Fend All units should be checked monthly.

1.7.5 Laboratory Sinks and Drain Traps

Every laboratory using chemical, radioactive or biological agents shall have at least one sink, preferably located near the room exit, available for handwashing. The sink shall be cleaned regularly to eliminate contamination, and soap shall be supplied for handwashing. Antimicrobial soaps are not necessary. They tend to dry the user's skin by stripping natural oils.

Drain traps in sinks, floors and other places will dry out if they are not used regularly allowing odors and contamination to back up into the room. Drain traps shall be kept filled with water to prevent backup. Also, fill cup sinks on benches and in chemical fume hoods.

1.7.6 Fire Extinguisher Policy

Fire extinguishers are provided by the University in corridors, public areas, laboratories, and other locations where required by building and life safety code. EOHS provides fire extinguishers in new and renovated laboratories during the construction phase. All existing labs are equipped with extinguishers. Missing extinguishers should be reported to EOHS. Extinguishers in individual labs are ordered through EOHS at no cost to the PI. EOHS will inspect and maintain all fire extinguishers, both inside and outside laboratories.

1.7.7 Laboratory Doors

Fire and life safety codes may require that corridor doors be fire rated and equipped with door closers. Doors with door closers are generally kept closed at all times, unless the door release is tied into the building's fire alarm system. Keeping laboratory doors to corridors closed helps ensure that ventilation systems work properly and maintain contaminant-containing pressure differentials between labs and corridors. Doors in internal laboratory suites may have less stringent door closing requirements.

2 CHEMICAL HYGIENE PLAN

2.1 Introduction

2.1.1 Purpose

Youngstown State University is committed to providing a healthy and safe working environment for the campus community, free from recognized hazards. The Chemical Hygiene Plan (CHP) establishes a formal written program for protecting laboratory personnel against adverse health and safety hazards associated with exposure to potentially hazardous chemicals and must be made available to all employees working with hazardous chemicals The CHP describes the proper use and handling practices and procedures to be followed by faculty, staff, students, visiting scholars, volunteers and all other personnel working with potentially hazardous chemicals in laboratory settings. This plan is based on best practices identified in, among others sources, "Prudent Practices for Handling Hazardous Chemicals in Laboratories"[5] published by the National Research Council, and the American Chemical Society's "Safety in Academic Chemistry Laboratories.[9]

2.1.2 Scope

The CHP applies to all laboratories that use, store or handle potentially hazardous chemicals and all personnel who work in these facilities. It does not apply to research involving exclusively radiological or biological materials, as these safety procedures and regulatory requirements are outlined in the

Radiation Safety Manual and Biosafety Guidelines respectively. Research involving more than one type of hazard must comply with all applicable regulatory requirements and follow guidance outlined in the relevant safety manuals. The information presented in the CHP represents best practices and provides a broad overview of the information necessary for the safe operation of laboratories that utilize potentially hazardous chemicals. It is not intended to be all-inclusive. Departments, divisions or other work units engaged in work with potentially hazardous chemicals that have unusual characteristics, or are otherwise not sufficiently covered in the written CHP, must customize the document by adding additional sections addressing the hazards and how to mitigate their risks, as appropriate. Such customizations must receive prior approval from the PI/Laboratory Supervisor and/or EOHS. For information on specific chemical safety topics not covered in the CHP, please contact EOHS at 330-941-3703.

2.1.3 Regulatory Requirements

Implementation of the necessary work practices, procedures, and policies outlined in this CHP is required by the following:

- Title 29 CFR 1910.1450 "Occupational Exposure to Hazardous Chemicals in Laboratories" https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10106&p_table=STANDARDS
- Ohio Public Employment Risk Reduction Program (PERRP) https://www.bwc.ohio.gov/employer/programs/safety/sandhperrp.asp

These regulations require that the CHP be readily available wherever potentially hazardous chemicals are used, handled, or stored. EOHS will review and evaluate the effectiveness of this Plan at least annually and update it as necessary.

2.1.4 Rights and Responsibilities

Employees and other personnel who work in laboratories have the right to be informed about the potential hazards of the chemicals in their work areas and to be properly trained to work safely with these substances. This includes custodial staff and other personnel who work to clean and maintain laboratories. Employees have the right to file a complaint with PERRP if they feel they are being exposed to unsafe or unhealthy work conditions and cannot be discharged, suspended, or otherwise disciplined by their employer for filing a complaint or exercising these rights. All personnel working with potentially hazardous chemicals are encouraged to report (anonymously, if preferred) any concerns about unsafe work conditions to the EOHS at 330-941-3700.

Responsibility for the health and safety of the campus community extends to the highest administrative levels of Youngstown State University. The day-to-day responsibility for the management of laboratory safety and adherence to safe laboratory practices rests with the PI/Laboratory Supervisor within individual laboratory units and associated departments. All personnel, including PIs/Laboratory Supervisors, employees, and students, have a duty to fulfill their obligations with respect to maintaining a safe work environment. All employees and other personnel working with potentially hazardous chemicals have the responsibility to conscientiously participate in training seminars on general laboratory safety and review and be familiar with the contents of the CHP. Those working with chemicals are responsible for staying informed about the chemicals in their work areas, safe work practices and proper personal protective equipment (PPE) required for the safe performance of their job. Failure to comply with these requirements will result in progressive disciplinary action up to suspension of all laboratory activities or dismissal from the University, in accordance with University policy.

2.1.4.1 Responsibilities of Principal Investigator (PI) / Laboratory Supervisor

The PI/Laboratory Supervisor has responsibility for the health and safety of all personnel working in his or her laboratory who handle hazardous chemicals. The PI/Laboratory Supervisor may delegate safety duties, but remains responsible for ensuring that delegated safety duties are adequately performed. The PI/Laboratory Supervisor is responsible for:

1. Knowing all applicable health and safety rules and regulations, training and reporting requirements and standard operating procedures associated with chemical safety for regulated substances;
2. Identifying hazardous conditions or operations in the laboratory or other facility containing hazardous chemicals and determining safe procedures and controls, and implementing and enforcing standard safety procedures;
3. Establishing standard safety operating procedures (general and protocol specific) and relaying recognized health and safety best practices for non-routine laboratory specific work to all supervised personnel;
4. Providing prior-approval for the use of hazardous chemicals in the PI/Laboratory Supervisor’s laboratory or other facility with hazardous chemicals;
5. Consulting with EOHS and/or Departmental Safety Committee on use of higher risk materials, such as use of particularly hazardous substances, or conducting higher risk experimental procedures so that special safety precautions may be taken;
6. Maintaining an updated chemical inventory for the laboratory or facility;
7. Ensuring laboratory or other personnel under his/her supervision have access to and are familiar with the appropriate Safety Manual(s);
8. Training all laboratory or other personnel he/she supervises to work safely with hazardous materials and maintain written records of laboratory-specific or other specialized training in the appropriate Safety Manual(s). Electronic records of training are encouraged. Training must include information of the location and availability of hazard information;
9. Promptly notifying EOHS (330-941-3700) and/or Facilities (330-941-3232) should he/she become aware that work place engineering controls (e.g., fume hoods) and safety equipment (e.g., emergency showers/eyewashes, fire extinguishers, etc.) become non-operational;
10. Ensuring the availability of all appropriate personal protective equipment (PPE) (e.g., laboratory coats, gloves, eye protection, etc.) and ensuring the PPE is maintained in working order;
11. Conducting periodic self-inspections of laboratory or facility and maintaining records of inspections, as required;
12. Promptly reporting of accidents and injuries to EOHS. Serious injuries MUST be reported to EOHS immediately to allow for compliance with the OSHA 8-hour reporting period. Any doubt as to whether an injury is serious should favor reporting; EOHS Staff may be reached 24/7 by contacting YSY PD;
13. Providing funding for medical surveillance and/or medical consultation and examination for laboratory and other personnel, as required by programs such as Hearing Conservation or Respiratory Protection Programs;

14. Informing facilities personnel, other non-laboratory personnel and any outside contractors of potential laboratory-related hazards when they are required to work in the laboratory environment; and
15. Identifying and minimizing potential hazards to provide a safe environment for repairs and renovations.

2.1.4.2 Responsibilities of All Personnel Who Handle Hazardous Chemicals

All personnel in research or teaching laboratories that use, handle or store potentially hazardous chemicals are responsible for:

1. Reviewing and following requirements of the CHP and all appropriate Safety Manuals and Policies;
2. Following all verbal and written laboratory safety rules, regulations, and standard operating procedures required for the tasks assigned;
3. Developing good personal chemical hygiene habits, including but not limited to, keeping the work areas safe and uncluttered;
4. Planning, reviewing and understanding the hazards of materials and processes in their laboratory research or other work procedures prior to conducting work;
5. Utilizing appropriate measures to control identified hazards, including consistent and proper use of engineering controls, personal protective equipment, and administrative controls;
6. Understanding the capabilities and limitations of PPE issued to them;
7. Gaining prior approval from the PI/Laboratory Supervisor for the use of restricted chemicals and other materials;
8. Consulting with PI/Laboratory Supervisor before using particularly hazardous substances (PHS), explosives and other highly hazardous materials or conducting certain higher risk experimental procedures;
9. Immediately reporting all accidents and unsafe conditions to the PI/Laboratory Supervisor;
10. Completing all required health, safety and environmental training and providing written documentation to their supervisor;
11. Participating in the medical surveillance program, when required by programs such as Hearing Conservation or Respiratory Protection Programs ;
12. Informing the PI/Laboratory Supervisor of any work modifications ordered by a physician as a result of medical surveillance, occupational injury or exposure; and
13. When working autonomously or performing independent research or work:
    a. Reviewing the plan or scope of work for their proposed research with the PI/Laboratory Supervisor
    b. Notifying in writing and consulting with the PI/Laboratory Supervisor, in advance, if they intend to significantly deviate from previously reviewed procedures (Note: Significant change may include, but is not limited to, change in the objectives, change in PI, change in the duration, quantity, frequency, temperature or location, increase or change in PPE, and reduction or elimination of engineering controls.)
    c. Preparing SOPs and performing literature searches relevant to safety and health that are appropriate for their work; and
    d. Providing appropriate oversight, training and safety information to laboratory or other personnel they supervise or direct.

2.1.4.3 Responsibilities of EOHS and Chemical Hygiene Officer

EOHS is responsible for administering and overseeing institutional implementation of the Laboratory Safety Program.

The Chemical Hygiene Officer (CHO) has primary responsibility for ensuring the implementation of all components of the CHP. In case of life safety matters or imminent danger to life or health, the Director of EOHS or designee has the authority to order the cessation of the activity until the hazardous condition is abated. EOHS provides technical guidance to personnel at all levels of responsibility on matters pertaining to laboratory use of hazardous materials. The CHO is a member of EOHS and, with support from other EOHS personnel, is responsible for:

1. Informing PIs/Laboratory Supervisors of all health and safety requirements and assisting with the selection of appropriate safety controls, including laboratory and other workplace practices, personal protective equipment, engineering controls, training, etc.;
2. Conducting periodic inspections and immediately taking steps to abate hazards that may pose a risk to life or safety upon discovery of such hazards;
3. Performing hazard assessments, upon request;
4. Maintaining area and personal exposure monitoring records;
5. Helping to develop and implement appropriate chemical hygiene policies and practices;
6. Having working knowledge of current health and safety rules and regulations, training, reporting requirements and standard operating procedures associated with regulated substances. Such knowledge may be supplemented and developed through research and training materials;
7. Working with Departmental Safety Committee to review existing and developing new SOPs for handling hazardous chemicals;
8. Providing technical guidance and investigation, as appropriate, for laboratory and other types of accidents and injuries;
9. Helping to determine medical surveillance requirements for potentially exposed personnel;
10. Reviewing plans for installation of engineering controls and new facility construction/renovation, as requested;
11. Reviewing and evaluating the effectiveness of the CHP at least annually and updating it as appropriate; and
12. Providing management oversight and assistance with environmental compliance, transport and disposal of hazardous waste.

2.1.5 Additional Resources for Principal Investigators

EOHS has published numerous factsheets and other resources to assist PIs and lab personnel. See below for important links.

1. https://www.osha.gov/SLTC/laboratories/hazard_recognition.html
2. https://www.osha.gov/Publications/laboratory/OSHA3404laboratory-safety-guidance.pdf
3. http://www.cpsc.gov//PageFiles/122344/NIOSH2007107.pdf CDC/NIOSH Lab Safety Guidelines
4. http://www.nap.edu/openbook.php?record_id=12654&page=R1 Prudent Practices in the Laboratory
5. http://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/academicsafety-culture-report-final-v2.pdf

6. https://ysu.edu/eohs/safety-forms

2.2 Classes of Hazardous Chemicals

2.2.1 Identification and Classification of Hazardous Chemicals

Chemicals can be divided into several different hazard classes. The hazard class will determine how these materials should be stored and handled and what special equipment and procedures are needed to use them safely. Each chemical container, whether supplied by a vendor or produced in the laboratory, must include labels that clearly identify the hazards associated with that chemical. In addition to specific chemical labels, hazard information for specific chemicals can be found by referencing the Safety Data Sheet (SDS) for that chemical.

Rooms containing hazardous chemicals must be labeled properly with the appropriate globally harmonized system pictogram shown below.

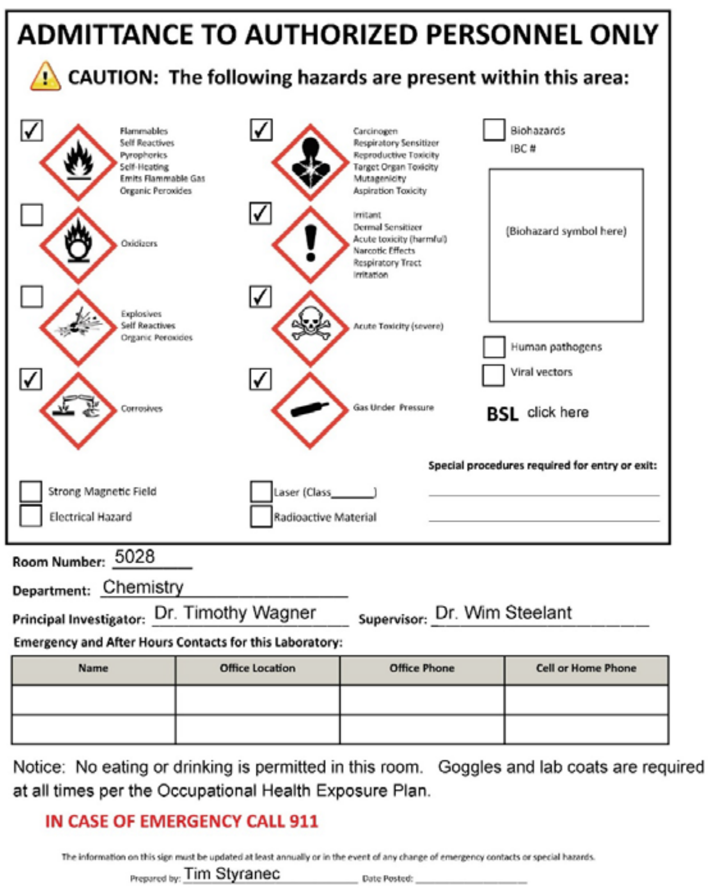

Figure 2: Door Label

It is essential that all laboratory workers understand the types of hazards, recognize the routes of exposure, and are familiar with the major hazard classes of chemicals. In many cases, the specific hazards associated with new compounds and mixtures will not be known, so it is recommended that new chemical compounds be treated as if they were potentially harmful and to use appropriate eye, inhalation and skin protection equipment.

2.2.2 Flammability Hazards

A number of highly flammable substances are in common use in campus laboratories.
Flammable liquids include those chemicals that have a flashpoint of less than 100 degrees Fahrenheit. These materials must be stored in flammable storage cabinets if aggregate quantities of 10 gallons/room or more are stored in the lab and if the container size is greater than 1 gallon (4L). Flame-resistant laboratory coats must be worn when working with flammable materials and/or with procedures where a significant fire risk is present (e.g., when working with open flame, etc.). These materials can constitute a significant immediate threat and should be treated with particular care, even though the use of these materials is fairly common in the laboratory setting.
Particular attention should be given to preventing static electricity and sparks when handling flammable liquids.

Figure 3: GHS Flammable

2.2.3 Reactivity Hazards

Reactive and explosive substances are materials that decompose under conditions of mechanical shock, elevated temperature, or chemical action, and release of large volumes of gases and heat. Some materials, such as peroxide formers, may not be explosive, but may form explosive substances over time. These substances pose an immediate potential hazard and procedures that use them must be carefully reviewed. These materials must also be stored in a separate flame-resistant storage cabinet or, in many cases, in a laboratory grade refrigerator or freezer that is designed for storing flammable and reactive chemicals. Pyrophoric chemicals are a special classification of reactive materials that spontaneously combust when in contact with air and require laboratory-specific training. Flame-resistant laboratory coats must always be worn when working with pyrophoric chemicals. Pyrophorics must also always be handled in laboratories equipped with emergency sprinkler systems.

2.2.4 Health Hazards

OSHA uses the following definition for health hazards:
The term 'health hazard' includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes.

The major classes of "hazardous" and "particularly hazardous substances" and their related health and safety risks are detailed below.

2.2.4.1 Corrosive Substances

As a health hazard, corrosive substances cause destruction of, or alterations in, living tissue by chemical action at the site of contact.
Major classes of corrosive substances include:

- Strong acids – e.g., sulfuric, nitric, hydrochloric and hydrofluoric acids
- Strong bases – e.g., sodium hydroxide, potassium hydroxide and ammonium hydroxide
- Dehydrating agents – e.g., sulfuric acid, sodium hydroxide, phosphorus pentoxide and calcium oxide
- Oxidizing agents – e.g., hydrogen peroxide, chlorine and bromine.

Symptoms of exposure for inhalation include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea, and vomiting. For eyes, symptoms include pain, blood shot eyes, tearing, and blurring of vision. For skin, symptoms may include reddening, pain, inflammation, bleeding, blistering and burns. As a physical hazard, corrosive substances may corrode materials they come in contact with and may be highly reactive with other substances. It is important to review information regarding the materials they may corrode, and their reactivity with other substances, as well as information on health effects. In most cases, these materials should be segregated from other chemicals and require secondary containment when in storage.

Figure 4: GHS Corrosive

2.2.4.2 Irritants

Irritants are defined as non-corrosive chemicals that cause reversible inflammatory effects on living tissue by chemical action at the site of contact. Wide varieties of organic and inorganic compounds, including many chemicals that are in a powder or crystalline form, are irritants. The most common example of an irritant may be ordinary smoke that can irritate the nasal passages and respiratory system. Consequently, eye and skin contact with all laboratory chemicals should always be avoided. Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.

2.2.4.3 Sensitizers

A sensitizer (allergen) is a substance that causes exposed people to develop an allergic reaction in normal tissue after repeated exposure to the substance. Examples of sensitizers include diazomethane, chromium, nickel, formaldehyde, isocyanates, arylhydrazines, benzylic and allylic halides, and many phenol derivatives. Sensitizer exposure can lead to all of the symptoms associated with allergic reactions, or can increase an individual's existing allergies.

2.2.4.4 Hazardous Substances with Toxic Effects on Specific Organs

Substances included in this category include:

- Hepatotoxins – i.e., substances that produce liver damage, such as nitrosamines and carbon tetrachloride.
- Nephrotoxins – i.e., agents causing damage to the kidneys, such as certain halogenated hydrocarbons
- Neurotoxins – i.e., substances that produce their primary toxic effects on the nervous system, such as mercury, acrylamide and carbon disulfide.
- Agents that act on the hematopoietic system – e.g., carbon monoxide and cyanides that decrease hemoglobin function and deprive the body tissues of oxygen.
- Agents that damage lung tissue – e.g., asbestos and silica. Symptoms of exposure to these materials vary. Staff working with these materials should review the SDS for the specific material being used and should take special note of the associated symptoms of exposure.

2.2.4.5 Particularly Hazardous Substances (PHSs)

Substances that pose such significant threats to human health are classified as "particularly hazardous substances" (PHSs). The OSHA Laboratory Standard and OSHA regulation require that special provisions be established to prevent the harmful exposure of researchers to PHSs, including the establishment of designated areas for their use.

Particularly hazardous substances are divided into three primary types: Acute Toxins, Reproductive Toxins, and Carcinogens.

Acute Toxins

Substances that have a high degree of acute toxicity are interpreted by OSHA as being substances that "may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration." These chemicals, associated chemical waste, and storage containers must be handled with care to prevent cross contamination of work areas and unexpected contact. These chemicals must be labeled as "Toxic." Empty containers of these substances must be packaged and disposed of as hazardous waste without rinsing trace amounts into the sanitary sewer system.

Reproductive Toxins

Reproductive toxins include any chemical that may affect the reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogenesis).
Reproductive toxins can affect the reproductive health of both men and women if proper procedures and controls are not used. For women, exposure to reproductive toxins during pregnancy can cause adverse effects on the fetus; these effects include embryolethality (death of the fertilized egg, embryo or fetus), malformations (teratogenic effects), and postnatal functional defects. For men, exposure can lead to sterility.

Examples of embryotoxins include thalidomide and certain antibiotics such as tetracycline. Women of childbearing potential should note that embryotoxins have the greatest impact during the first trimester of pregnancy. Because a woman often does not know that she is pregnant during this period of high susceptibility, special caution is advised when working with all chemicals, especially those rapidly absorbed through the skin (e.g., formamide). Pregnant women and women intending to become pregnant should consult with their laboratory supervisor and EOHS before working with substances that are suspected to be reproductive toxins.

Carcinogens

Carcinogens are chemical or physical agents that cause cancer. Generally, they are chronically toxic substances; that is, they cause damage after repeated or long-duration exposure, and their effects may only become evident after a long latency period. Chronic toxins are particularly insidious because they may have no immediately apparent harmful effects. These materials are separated into two classes:

1. Select Carcinogens;
2. Regulated Carcinogens.

Select Carcinogens are materials that have met certain criteria established by the National Toxicology Program or the International Agency for Research on Cancer regarding the risk of cancer via certain exposure routes. It is important to recognize that some substances involved in research laboratories are new compounds and have not been subjected to testing for carcinogenicity. The following references are used to determine which substances are select carcinogens:

- OSHA Carcinogen List https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10007&p_table=standards
- Annual Report on Carcinogens published by the National Toxicology Program (NTP), including all of the substances listed as "known to be carcinogens" and some substances

listed as "reasonably anticipated to be carcinogens" http://ntp.niehs.nih.gov/pubhealth/roc/roc13/index.html

- International Agency for Research on Cancer (IARC), including all of Group 1 "carcinogen to humans" by the International Agency for Research on Cancer Monographs (IARC) (Volumes 1-48 and Supplements 1-8); and some in Group 2A or 2B, "reasonably anticipated to be carcinogens" by the National Toxicology Program (NTP), and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:
- after inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m3;
    - (ii) after repeated skin application of less than 300 mg/kg of body weight per week; or
    - (iii) after oral dosages of less than 50 mg/kg of body weight per day http://monographs.iarc.fr/ENG/Monographs/PDFs/index.php

Regulated Carcinogens fall into a higher hazard class and have extensive additional requirements associated with them. The use of these agents may require personal exposure sampling based on usage. When working with Regulated Carcinogens, it is particularly important to review and effectively apply engineering and administrative safety controls as the regulatory requirements for laboratories that may exceed long-term (8 hour) or short-term (15 minutes) threshold values for these chemicals are very extensive.

2.2.5 Nanomaterials

The increasing use of nanomaterials in research labs warrants consideration of the hazards they may pose. As is the case with many new technologies, the health effects of nanomaterials have not been thoroughly investigated. Consequently, the uncertainty surrounding the toxicity of nanomaterials merits a cautious approach when working with them.

Nanomaterials include any materials or particles that have an external dimension in the nanoscale (~1 – 100 nm). Nanomaterials are both naturally occurring in the environment and intentionally produced. Intentionally produced nanomaterials are referred to as Engineered Nanomaterials (ENMs). Materials whose properties do not differ significantly between their nanoscale and larger forms are generally excluded from ENMs. The most common types of ENMs are carbon-based materials such as nanotubes, metals and metal oxides such as silver and zinc oxide, and quantum dots made of compounds such as zinc selenide (Figure 5).

Carbon Based	*Buckyballs or Fullerenes, Carbon Nanotubes*, Dendrimers Often includes functional groups like* PEG (polyethylene glycol), Pyrrolidine, N, N-dimethylethylenediamine, imidazole*
Metals and Metal Oxides	*Titanium Dioxide (Titania)**, Zinc Oxide, Cerium Oxide (Ceria), Aluminum oxide, Iron Oxide, Silver, Gold, and Zero Valent Iron (ZVI) nanoparticles*
Quantum Dots	*ZnSe, ZnS, ZnTe, CdS, CdTe, CdSe, GaAs, AlGaAs, PbSe, PbS, InP Includes crystalline nanoparticle that exhibits size-dependent properties due to quantum confinement effects on the electronic states (ISO/TS 27687:2008).*

Figure 5: Types of Nanomaterials

Nanomaterials can be categorized by the potential risk of exposure they pose to personnel based on the physical state of the materials and the conditions in which they are used . In general, the risk of exposure is lowest when nanomaterials are bound in a solid matrix with little potential to create airborne dust or when in a non-volatile liquid suspension. The risk of exposure increases when nanomaterials are used as fine powders or are suspended in volatile solvents or gases. The parent compound of the nanomaterial should also be taken into consideration when evaluating the potential hazards associated with exposure (e.g., a highly toxic compound such as cadmium should be anticipated to be at least as toxic and possibly more toxic when used as a nanomaterial).

For further information, see the National Institute of Occupational Safety & Health's (NIOSH) "Safe Practices for Working with Engineered Nanomaterials in Research Laboratories."

RISK LEVEL	*MATERIAL STATE OR TYPE OF USE*	*EXAMPLE*
Category 1 Lower Exposure Potential	*Material State No potential for airborne release (when handling) • Solid: Bound in a substrate or matrix • Liquid: Water-based liquid suspensions or gels • Gas: No potential for release into air*	*• Non- destructive handling of solid engineered nanoparticle composites or nanoparticles permanently bonded to a substrate*
Category 2 Moderate Exposure Potential	*Material State Moderate potential for airborne release (when handling) • Solid: Powders or Pellets • Liquid: Solvent-based liquid suspensions or gels • Air: Potential for release into air (when*	*• Pouring, heating ,or mixing liquid suspensions (e.g., stirring or pipetting), or operations with high degree of agitation involved (e.g., sonication) • Weighing or transferring*
Category 3 Higher Exposure Potential	*Material State High potential for airborne release (when handling) • Solid: Powders or Pellets with extreme potential for release into air • Gas: Suspended in gas*	*• Generating or manipulating nanomaterials in gas phase or in aerosol form • Furnace operations • Cleaning reactors • Changing filter elements*

Figure 6: Nanomaterial Risk Table

2.3 How to Reduce Exposure to Hazardous Chemicals

2.3.1 Introduction

Hazardous chemicals require a carefully considered, multi-tiered approach to ensure safety. There are four primary routes of exposure for chemicals that have associated health hazards (illustrated in Figure): 1. Inhalation; 2. Absorption (through the skin or eyes); 3. Ingestion; and 4. Injection (skin being punctured by a contaminated sharp object or uptake through an existing open wound).

Of these, the most likely route of exposure in the laboratory is by inhalation. Many hazardous chemicals may affect people through more than one of these exposure modes, so it is critical that protective measures are in place for each of these uptake mechanisms.

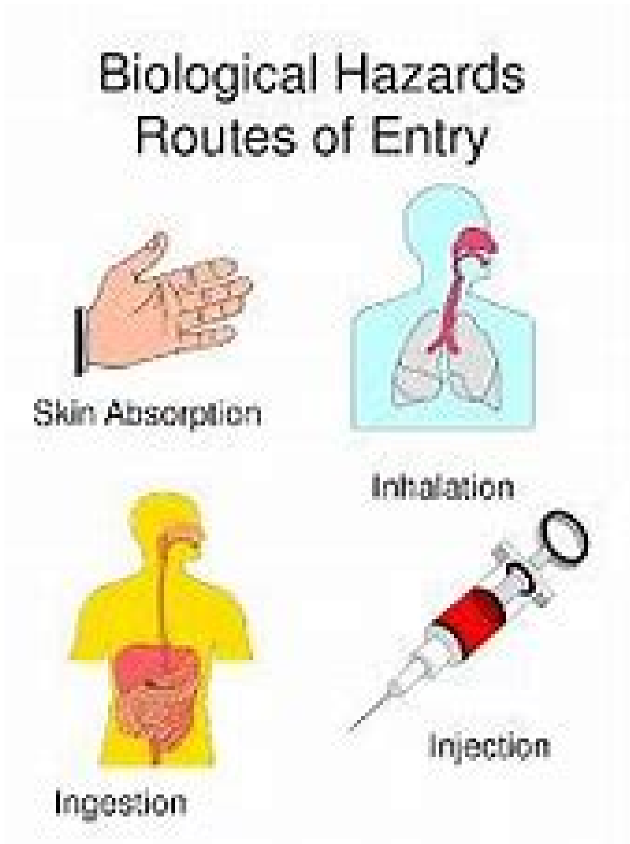

Figure 7: Routes of Exposure

2.3.2 Safety Controls

Safety controls are divided into two classifications:

1. Engineering Controls
2. Administrative Controls

Elements of each are used in a layered approach along with personal protective equipment (PPE) to create a safe working environment. The principles of each of these controls are detailed below.

2.3.2.1 Engineering Controls

Engineering controls include all “built in” safety systems. These controls offer the first line of protection and are highly effective in that they generally require minimal special procedures or actions on the part of the user except in emergencies. Additionally, engineering controls often involve the replacement or elimination of hazards for a work environment. A fundamental and very common example is the laboratory fume hood, which is very effective at containing chemical hazards and protecting users from inhalation hazards. Other examples of engineering controls include general room ventilation, flammable material storage units, and secondary containment.

General Laboratory Ventilation

All laboratory rooms in which hazardous materials are used must have fresh air ventilation with 100% of the exhaust venting to the outside; laboratory rooms should not be part of recycled air systems. In cases where this is not desirable, a formal hazard evaluation will be made by EOHS to determine what work can be done in the space and under what special conditions or limitations. Laboratory rooms should be kept at negative pressure compared to public areas to prevent the spread of hazardous vapors.

Fume Hoods

Fume hoods are the most commonly used local exhaust system on campus. Other methods include vented enclosures for large pieces of equipment or chemical storage, and portable exhaust systems for capturing contaminants near the point of release. Some systems are equipped with air cleaning devices (HEPA filters or carbon absorbers). Exhaust from fume hoods are designed to terminate at least ten feet above the roof deck or two feet above the top of any parapet wall, whichever is higher.
Figure 8 displays the key components of a fume hood.

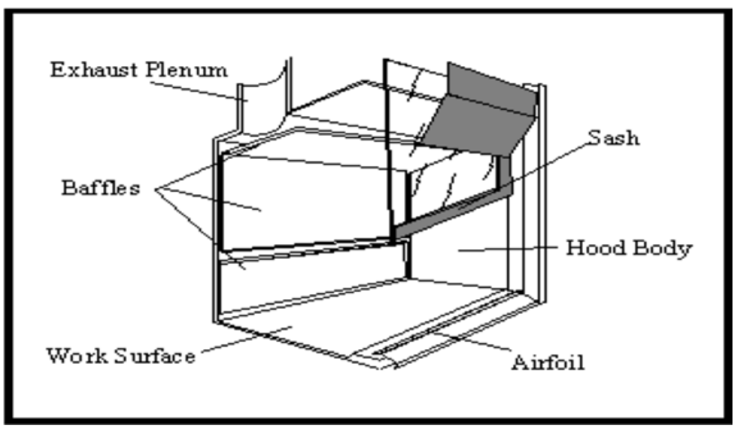

Figure 8: Fume Hood Parts

It is advisable to use a fume hood when working with all hazardous substances. In addition, a fume hood or other suitable containment device must be used for all work with "particularly hazardous substances." A properly operating and correctly used fume hood can reduce or eliminate gases from volatile liquids, dusts and mists. Fume hoods are evaluated for operation and certified by EOHS on an annual basis. These annual evaluations check the fume hood airflow velocity to ensure that the unit will contain hazardous vapors. Data on annual fume hood monitoring is maintained by EOHS.

Each fume hood should have a current calibration sticker and a marker indicating the highest sash height to be used when working with hazardous materials. Contact EOHS (330-941-3703) for a hood evaluation if these labels are missing. The average of face velocity readings must be at least 80 linear feet per minute (lfm). The average face velocity should not exceed 160 lfm.

Each fume hood may be equipped with at least one type of continuous quantitative monitoring device designed to provide the user with current information on the operational status of the fume hood. These sensors will reduce the fume hood's airflow as part of the campus' energy savings effort. When hazardous materials are in a fume hood, but it is not under active use (e.g., during an unattended reaction or experiment), the sash should be closed. Fume hoods are not designed for storage of hazardous materials.

Routine maintenance and repairs of fume hoods are conducted by Facilities. Fume hood users may route requests for hood repair directly to Facilities (facilites@ysu.edu). EOHS does not initiate maintenance but will coordinate with Facilities to ensure that it is completed. Upon reported completion by Facilities, EOHS will re-inspect the fume hood following maintenance or repairs.

General Rules for Fume Hood Use

The following general rules should be followed when using laboratory hoods

1. Fume hoods should not be used for work involving hazardous substances unless they have a certification label that confirms certification has occurred within the past year.
2. Always keep hazardous chemicals >6 inches behind the plane of the sash.
3. Never put your head inside an operating laboratory hood. The plane of the sash is the barrier between contaminated and uncontaminated air.
4. Work with the hood sash in the lowest practical position. The sash acts as a physical barrier in the event of an accident. Keep the sash closed when not conducting work in the hood.
5. Do not clutter your hood with unnecessary bottles or equipment. Keep it clean and clear. Only materials actively in use should be in the hood.
6. Do not make any modifications to hoods, ductwork, or the exhaust system without first contacting the EOHS.
7. Do not use large equipment in laboratory hoods unless the hood is dedicated for this purpose, as large obstructions can change the airflow patterns and render the hood unsafe or out of compliance.
8. Shut your sash! For energy efficiency, make sure to shut your sash when the hood is not in use.

Fume hoods are one of the most important pieces of equipment used to protect laboratory and other workers from exposure to hazardous chemicals. Chemical fume hoods should be inspected upon installation, renovation, when a deficiency is reported, or a change has been made to the operating characteristics of the hood. Contact EOHS if the intended use changes, particularly if carcinogenic materials will be used.

Glove Boxes and Ventilation Devices

In addition to fume hoods, some laboratories use contained glove box units for working with reactive chemicals under an inert environment, working with very toxic substances in a completely closed system, or for creating a stable, breeze free, system for weighing hazardous or reactive materials. These units can be very effective because they offer complete containment.

Other Engineering Controls

In addition to the elements listed above, consideration must be given to providing sufficient engineering controls for the storage and handling of hazardous materials. No more than 10 gallons of flammable chemicals may be stored outside of an approved flammable storage cabinet. For refrigerated or frozen storage, flammable and explosive materials must be kept in refrigeration units specifically designed for storing these materials. Generally, these units do not have internal lights or electronic systems that could spark and trigger an ignition; additionally, the cooling elements are external to the unit. These units should be labeled with a rating from Underwriters Laboratory or other certifying organization.

Secondary containment must be provided for highly corrosive liquids chemicals and is recommended for all other hazardous chemicals. Secondary containment should be made of chemically resistant materials and should be sufficient to hold the volume of at least the largest single bottle stored in the container.

Laboratories that use hazardous materials must contain a sink, kept clear for hand washing to remove any final residual contamination. Hand washing is recommended whenever a staff member who has been working with hazardous materials plans to exit the laboratory or work on a project that does not involve hazardous materials.

2.3.2.2 Administrative Controls

These controls consist of policies and procedures; they are not generally as reliable as engineering controls in that the user has to carefully follow the appropriate procedures and must be fully trained and aware in order to do so.

EOHS requires that each laboratory have safety procedures, which include safety practices, for any work that involves hazardous materials. These safety procedures should be laboratory specific, communicated via lab specific trainings, Standard Operating Procedures, or Job Safety Analyses, and properly documented.

Standard Operating Procedures

SOPs are written instructions that detail the steps that will be performed during a given experimental procedure and include information about potential hazards and how these hazards will be mitigated. While general guidance regarding laboratory work with chemicals is contained in this plan, PIs/Laboratory Supervisors are required to develop and implement laboratory-specific standard operating procedures (SOPs) for certain hazardous chemicals and "particularly hazardous substances" (PHS) that are used in their laboratories. SOPs are also required for laboratory equipment and instrumentation, as well as routine lab procedures. The development and implementation of SOPs is a core component of promoting a strong safety culture in the laboratory and helps ensure a safe work environment.

Laboratory personnel who are most knowledgeable and involved with the experimental process should write SOPs. The Principal Investigator and all personnel responsible for performing the procedures detailed in the SOP shall sign the SOP acknowledging the contents, requirements and responsibilities outlined in the SOP. Additional review and approval by the Principal Investigator is required when deviations in conditions, methodologies, equipment, or use of the chemical will occur. For certain hazardous chemicals, PHS, or specialized practices, consideration must be given to whether additional consultation with safety professionals is warranted or required.

When drafting an SOP involving a chemical, consider the type and quantity of the chemical being used, along with the frequency of use. The Safety Data Sheet (SDS) for each hazardous chemical or PHS that will be addressed in the SOP should be referenced during SOP development. The SDS lists important information that will need to be considered, such as exposure limits, type of toxicity, warning properties, and symptoms of exposure. If a new chemical will be produced during the experiment, an SDS will not necessarily be available. In these cases, the toxicity is unknown and it must be assumed that the substance is particularly hazardous, as a mixture of chemicals will generally be more toxic than its most toxic component.

2.3.3 Personal Protective Equipment (PPE)

Personal protective equipment serves as a researcher's last line of defense against chemical exposures and is required by everyone entering a laboratory containing hazardous chemicals. The PPE policy outlines the basic PPE requirements, which include but are not limited to:

- Full length pants and close-toed shoes, or equivalent
- Protective gloves, laboratory coats, & eye protection when working with, or adjacent to, hazardous chemicals
- Flame resistant laboratory coats for high hazard materials, pyrophorics, and flammables.

The primary goal of basic PPE is to mitigate, at a minimum, the hazard associated with exposure to hazardous substances. The SDS for a chemical or material should always be consulted to determine the appropriate required PPE. In some cases, additional, or more protective, equipment must be used. If a project involves a chemical splash hazard, chemical goggles are required; face shields may also be required when working with chemicals that may cause immediate skin damage.

2.3.3.1 Clothing

Cover unprotected skin whenever possible. Suitable clothing shall be worn in the laboratory; shorts are not appropriate. Clothing may absorb liquid spills that would otherwise be exposed to your skin. Long sleeves protect arms and shall fit snugly, especially when you are working around machinery. Nomex and wool affords more protection from flash burns or corrosive chemicals than cotton or synthetic fabrics. Some synthetic fabrics may increase the severity of injury in case of fire. Cotton is less prone to static electricity buildup than nylon or other synthetics.

Wear substantial closed-toed shoes in the laboratory to protect against chemical splashes or broken glass. Do not wear sandals, cloth sport shoes, perforated shoes, or open-toed shoes. If you clean up a spill from the floor, you may need the added protection of rubber boots or plastic shoe covers. Steel-toed shoes may be required for handling heavy items, such as gas cylinders or heavy equipment components.

Aprons, laboratory coats, gloves, and other protective clothing, preferably made of chemically inert material, shall be readily available and used. Laboratory coats are essential to protect street clothing from biological agent aerosols or chemical and radioactive material splashes and spills, vapors, or dusts. For work involving carcinogens, disposable coats may be preferred.

When the potential for fire exists, consider wearing a laboratory coat specifically designed to be flame retardant. Several types of flame-resistant clothes are available from safety suppliers. A low-cost option is a disposable cotton coat that has been treated with a flame-resistant material. The treatment slows combustion and provides an additional level of protection from fire and heat. However, repeated washing degrades the chemical treatment and compromises fire protection.

More durable flame-resistant cotton laboratory coats are also available. A fabric known as Nomex provides the best protection against flame hazards. This material has a structure that thickens and carbonizes when exposed to heat. This unique characteristic gives Nomex lab coats excellent thermal protection. Because the characteristics of the material are inherent to the fiber, repeated laundering does not change the thermal protection capabilities. Lab coats are available for the Chemistry Departments and Biological Sciences Departments at YSU.

2.3.3.2 Eye Protection

Eye protection is mandatory in laboratories because of the obvious hazards of flying objects, splashing chemicals, and corrosive vapors. Eyes are very vascular and can quickly absorb many chemicals.

Regulations require protective eye and face equipment where there is a reasonable probability that using them can prevent injury. Eye protection shall be required in all laboratories where chemicals are used or stored. Eye protection is not interchangeable among employees and shall be provided for each individual unless disinfected after use.

Safety glasses with clear side shields are adequate protection for general laboratory use. Goggles shall be worn when there is danger of splashing chemicals or flying particles, such as when chemicals are poured or glassware is used under elevated or reduced pressure. Safety goggles differ from safety glasses in that they form a seal with the face, which completely isolates the eyes from the hazard. A face shield with goggles offers maximum protection (for example, with vacuum systems that may implode).

Corrective lenses in spectacles do not in themselves provide sufficient protection. Regulations require that persons whose vision requires corrective lenses, and who are required to wear eye protection, shall wear goggles over their eyeglasses, prescription safety glasses, or goggles with prescription lenses. If contact lenses are worn, they should not be handled in the laboratory and shall be worn with regularly required eye protection, such as plastic goggles.

2.3.3.3 Gloves

Gloves are worn to prevent skin contact with toxic, radioactive or biological agents, burns from hot or extremely cold surfaces or corrosives, or cuts from sharp objects. Many gloves are made for specific uses. For adequate protection, select the correct glove for the hazard in question.

Leather and Kevlar gloves provide good protection for picking up broken glass, handling objects with sharp edges, and inserting glass tubing into stoppers. Cuts from forcing glass tubing into stoppers or plastic tubing are a common laboratory accident and are often serious. However, because they absorb liquid, these gloves do not provide protection from chemicals, nor are they adequate for handling extremely hot or cold surfaces. Gloves designed to insulate against hot surfaces and dry ice are not suitable for handling other chemicals.

Sometimes the ideal glove is actually two gloves worn together. Wearing one pair of gloves (such as reusable nitrile, neoprene, butyl, or Viton) over a flexible laminate combines the advantages of both.

When choosing an appropriate glove, consider the required thickness and length of the gloves as well as the material. Consult the glove manufacturer for chemical-specific glove recommendations and information about degradation and permeation times.

Disposable gloves are for single use; once removed they are to be disposed. Only gloves designed and stated as reusable are to be reused. Even reusable gloves degrade over time, so they should be replaced as recommended to ensure adequate protection.

- Butyl is a synthetic rubber with good resistance to weathering and a wide variety of chemicals.
- Natural rubber latex is a highly flexible and conforming material made from a liquid tapped from rubber plants. Use of latex is not recommended as it can cause allergic reactions.
- Neoprene is a synthetic rubber having chemical and wear-resistance properties superior to those of natural rubber.
- Nitrile is a copolymer available in a wide range of acrylonitrile content; chemical resistance and stiffness increase with higher acrylonitrile content.
- Polyethylene is a fairly chemical-resistant material used as a freestanding film or a fabric coating.
- Poly (vinyl alcohol) is a water-soluble polymer that exhibits exceptional resistance to many organic solvents that rapidly permeate most rubbers.
- Poly (vinyl chloride) is a stiff polymer that is made softer and more suitable for protective clothing applications by the addition of plasticizers.
- Polyurethane is an abrasion-resistant rubber that is either coated into fabrics or formed into gloves or boots.
- 4H® or Silvershield® is a registered trademark of North Hand Protection; it is highly chemical-resistant to many different classes of chemicals.
- Viton®, a registered trademark of DuPont, is a highly chemical-resistant but expensive synthetic elastomer.

Chemicals can eventually permeate all glove materials. Select glove materials resistant to the chemical being used, and change gloves periodically to minimize penetration. The chemical resistance of common glove materials varies according to the glove manufacturer, as manufacturers may vary the thicknesses and formulations of materials.

General guidelines to the selection and use of protective gloves:

- Do not use a glove beyond its expiration date. Gloves degrade over time, even in an unopened box.
- When not in use, store gloves in the laboratory but not close to volatile materials. To prevent chemical contamination of non-laboratory areas by people coming to retrieve them, gloves must not be stored in offices or in break rooms or lunchrooms.
- Inspect gloves for small holes, tears, and signs of degradation before use.
- Replace gloves periodically because they degrade with use, depending on the frequency of use and their permeation and degradation characteristics relative to the substances handled.
- Replace gloves immediately if they become contaminated or torn.
- Decontaminate or wash gloves appropriately before removing them. [Note: Some gloves, e.g., leather and poly (vinyl alcohol), are water permeable. Unless coated with a protective layer, poly (vinyl alcohol) gloves will degrade in the presence of water.]
- Do not wear gloves outside the laboratory, to avoid contamination of surfaces used by unprotected individuals.
- Gloves on a glovebox should be inspected with the same care as any other gloves used in the laboratory. Disposable gloves appropriate for the materials being handled within the glovebox should be used in addition to the gloves attached to the box. Protect glovebox gloves by removing all jewelry prior to use.

2.3.3.4 Respiratory Protection

Typically, respiratory protection is not needed in a laboratory. Under most circumstances, safe work practices, small-scale usage, and engineering controls (fume hoods, biosafety cabinets, and general ventilation) adequately protect laboratory workers from chemical and biological hazards.

Under certain circumstances, however, respiratory protection may be needed. These can include:

- An accidental spill such as a chemical spill outside the fume hood or a spill of biohazardous material outside a biosafety cabinet.
- Performance of an unusual operation that cannot be conducted under the fume hood or biosafety cabinet.
- When weighing powdered chemicals or microbiological media outside a glove box or other protective enclosure. Disposable filtering face-piece respirators are generally recommended for nuisance dusts. If the chemicals are toxic, contact EOHS for additional evaluation.
- When exposure monitoring indicates that exposures exist that cannot be controlled by engineering or administrative controls.
- As required by a specific laboratory protocol or as defined by applicable regulations. Because there are numerous types of respirators available, and each has specific limitations and applications, respirator selection and use requires pre-approval by EOHS. For either required or voluntary use of a respirator, the employee must fill out a Respirator Protection Request form; review it with his/her supervisor, and return the completed form to EOHS. EOHS will then contact the employee to evaluate the potential exposure. The review will include an evaluation of the work area and activities for the following:
    a. Provision of additional ventilation controls or enclosure of the airborne hazard.
    b. Substitution with a less hazardous substance.

c. Qualitative or quantitative exposure assessment.
d. Respirator usage.

Tasks with potential airborne hazards that cannot be eliminated by engineering or administrative controls will not be authorized by EOHS until affected employees can be incorporated into the Respirator Protection Program.

Because wearing respiratory equipment places a physical burden on the user, laboratory workers must be medically evaluated prior to wearing respiratory equipment. Certain individuals (e.g., persons with severe asthma, heart conditions, or claustrophobia) may not be medically qualified to wear a respirator. The employee will be required to fill out a medical questionnaire. A nurse practitioner before the employee proceeds with respirator training will evaluate the completed medical questionnaire. NOTE: This medical questionnaire is confidential. The employee will be provided additional information on how to contact the nurse practitioner for follow up questions. After successful completion of the medical evaluation, the employee will be training and fit testing will be arranged by EOHS.

Training topics include:

- Why the respirator is necessary and how improper fit, usage, or maintenance can compromise the protective effect of the respirator.
- What the limitations and capabilities of the respirator are.
- How to use the respirator effectively in emergencies, including situations in which the respirator malfunctions.
- How to inspect, put on and remove, use, and check the seals of the respirator.
- What the procedures are for maintenance and storage of the respirator.
- How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators.
- The general requirements of the respiratory program.

Finally, a qualitative or quantitative fit test is conducted by EOHS for each respirator user. The fit test ensures a proper face-to-face piece seal for each individual and his/her mask. Fit testing is done in accordance with OSHA's regulations. An annual refresher is required for the medical evaluation, respirator training, and fit testing. In addition to the annual training refresher, a more frequent re-training, fit testing or medical evaluation must be performed when any of the following occur:

- Changes in the workplace or the type of respirator render previous training obsolete.
- Inadequacies in the employee's knowledge or use of the respirator indicate that the employee has not retained the requisite understanding or skill.
- Any other situation arises in which reevaluation appears necessary to ensure safe respirator use.
- Facial scarring, dental changes, cosmetic surgery, or an obvious change in body weight.
- An employee reports medical signs or symptoms related to their ability to use a respirator.

2.3.3.5 How to Use and Maintain PPE

Personal protective equipment should be kept clean and stored in an area where it will not become contaminated. Personal protective equipment should be inspected prior to use to ensure it is in good condition. It should fit properly and be worn properly. If it becomes contaminated or damaged, it should be cleaned or repaired when possible, or discarded and replaced.

2.3.3.6 Contaminated Clothing/PPE

In cases where spills or splashes of hazardous chemicals on clothing or PPE occur, the clothing/PPE should immediately be removed and placed in a closed container that prevents release of the chemical. Heavily contaminated clothing/PPE resulting from an accidental spill should be disposed of as hazardous waste. Non-heavily contaminated laboratory coats should be cleaned and properly laundered, as appropriate. Laboratory personnel should never take contaminated items home for cleaning or laundering. Persons or companies hired to clean contaminated items must be informed of potentially harmful effects of exposure to hazardous chemicals and must be provided with information to protect themselves.

The Chemistry and Biology departments provide labs coats with a laundering service. No lab coat should be taken home for cleaning. These lab coats must be returned to the Chemical Management Center.

The Chemical Management Center also has a change of clothes as well as an area to decontaminate.

2.3.4 Laboratory Safety Equipment

New personnel must be instructed in the location of fire extinguishers, safety showers, and other safety equipment before they begin work in the laboratory. This training is considered part of the laboratory specific training that all staff members must attend.

2.3.4.1 Fire Extinguisher

All laboratories working with combustible or flammable chemicals must be outfitted with appropriate fire extinguishers. All extinguishers should be mounted on a wall in an area free of clutter or stored in a fire extinguisher cabinet. Research personnel should be familiar with the location, use and classification of the extinguishers in their laboratory.

Laboratory personnel are not required to extinguish fires that occur in their work areas and should not attempt to do so unless:

- The building's fire alarm system has been activated.
- The fire is small (i.e., small trash can sized fire).
- Appropriate training has been received.
- It is safe to do so.

Any time a fire extinguisher is used, no matter for how brief a period, the PI/Laboratory Supervisor, or most senior laboratory personnel present at the time of the incident, must immediately report the incident to EOHS.

The EOHS website contains instructions on how to use a fire extinguisher: https://ysu.edu/eohs
Training is provided each fall and spring semester on the basics of using a fire extinguisher.

2.3.4.2 Safety Showers and Eyewash Stations

All laboratories using hazardous chemicals must have immediate access to safety showers with eyewash stations. Access must be available in 10 seconds or less for a potentially injured individual and access routes must be kept clear. Safety showers or spray nozzles must have a minimum clearance of 16 inches from the centerline of the spray pattern in all directions at all times; this means that no objects should be stored or left within this distance of the safety shower.

In the event of an emergency, individuals using the safety shower should be assisted by an uninjured person to aid in decontamination and should be encouraged to stay in the safety shower for 15 minutes to remove all hazardous material.

Safety shower/eyewash stations are tested by EOHS on a regular basis. If an eyewash or safety shower needs repair, call EOHS at 330-941-3703.

Figure 9: Fend All 1000 Eyewash

2.3.4.3 Fire Doors

Many areas of buildings may contain critical fire doors as part of the building design. These doors are an important element of the fire containment system and should remain closed unless they are on a magnetic self-closing or other automated self-closing system.

2.3.5 Prudent Laboratory Practices

It is prudent to minimize all chemical exposures. Few laboratory chemicals are without hazards, and general precautions for handling all laboratory chemicals should be adopted, in addition to specific guidelines for particular chemicals. Exposure should be minimized even for substances of no known significant hazard, and special precautions should be taken for work with substances that present special hazards. One should assume that any mixture will be more toxic than its most toxic component and that all substances of unknown toxicity are toxic. Avoid inadvertent exposures to hazardous chemicals by developing and encouraging safe habits and thereby promoting a strong safety culture.

A safety program must include layers of policies and protective equipment to allow for a safe working environment, but to achieve effectiveness, a number of fundamental elements must become basic working habits for the research community. Some of these elements are detailed below:

2.3.5.1 Personal Protective Equipment:

- Do not enter the laboratory without wearing appropriate clothing, including closed-toe shoes and full-length pants, or equivalent. The area of skin between the shoe and ankle should not be exposed.
- Ensure that all persons, including visitors, where chemicals are stored or handled, wear appropriate PPE.
- Confine long hair and loose clothing.
- Utilize appropriate PPE while in the laboratory and while performing procedures that involve the use of hazardous chemicals or materials. These items may include laboratory coats, gloves, and safety glasses or goggles.
- Wear appropriate gloves when the potential for contact with toxic materials exists; inspect the gloves before each use, and replace them often.
- Remove laboratory coats or gloves immediately on significant contamination, as well as before leaving the laboratory.
- Do not wear laboratory coats or gloves outside of the laboratory area, unless in the process of transporting chemicals. Remove at least one glove for handling common surface (door handles, elevator buttons, railing, etc.).
- Use appropriate respiratory equipment when air contaminant concentrations are not sufficiently restricted by engineering controls, inspecting the respirator before use. Use of respirators requires successful review and approval by EOHS.
- Use any other protective and emergency apparel and equipment as appropriate. Be aware of the locations of first aid kits and emergency eyewash and shower stations.

2.3.5.2 Chemical Handling:

- Use only those chemicals for which the quality of the available ventilation system is appropriate.
- Vent apparatus that may discharge toxic chemicals (vacuum pumps, distillation columns, etc.) into local exhaust devices.
- Properly label and store all chemicals.
- Deposit chemical waste in appropriately labeled receptacles and follow all other waste disposal procedures of the Chemical Hygiene Plan.
- Do not allow release of toxic substances or fumes into cold or warm rooms, as these types of areas typically involve re-circulated atmospheres.
- Do not smell or taste chemicals.
- Never use mouth suction for pipetting or starting a siphon.
- Do not dispose of any hazardous chemicals through the sewer system. These substances might interfere with the biological activity of wastewater treatment plants, create fire or explosion hazards, cause structural damage or obstruct flow.

- Be prepared for an accident or spill and refer to the emergency response procedures for the specific material. Procedures should be readily available to all personnel. For general guidance, the following situations should be addressed:
  - Eye Contact: Promptly flush eyes with water for a prolonged period (15 minutes) and seek medical attention.
  - Skin Contact: Promptly flush the affected area with water and remove any contaminated clothing. Seek medical attention.

2.3.5.3 Equipment Storage and Handling:

- Use equipment only for its designed purpose.
- Store laboratory glassware with care to avoid damage. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them to contain chemicals and fragments should implosion occur.
- Use certified fume hoods, glove boxes, or other ventilation devices for operations that might result in release of toxic chemical vapors or dust. Preventing the escape of these types of materials into the working atmosphere is one of the best ways to prevent exposure.
- Keep hood closed when you are not working in the hood.
- Leave the fume hood "on" even when it is not in active use if toxic substances are in the fume hood or if it is uncertain whether adequate general laboratory ventilation will be maintained when it is "off."
- Do not use damaged glassware or other equipment.
- Do not use uncertified fume hoods for hazardous chemical handling.
- Avoid storing materials in fume hoods that would obstruct proper airflow.

2.3.5.4 Laboratory Operations:

- Keep the work area clean and uncluttered.
- Seek information and advice about hazards, plan appropriate protective procedures, and plan positioning of equipment before beginning any new operation.
- If unattended operations are unavoidable, and have been approved by the PI/Laboratory Supervisor, place an appropriate sign on the door, leave lights on, and provide for containment of toxic substances in the event of failure of a utility service (such as cooling water). Submit the Unattended Experiment Form.
- Be alert to unsafe conditions and ensure that they are corrected when detected.
- Receive both general and lab specific trainings.
- Research staff and students should never work alone on procedures involving hazardous chemicals, biological agents, or other physical hazards.
- If minors are in laboratories be sure to follow Youngstown Policy on Minors in Labs and Shops.
- Do not engage in distracting behavior such as practical jokes in the laboratory. This type of conduct may confuse, startle, or distract another worker.

2.3.5.5 Food/Drink:

- No food or drink may be present or consumed in a laboratory or any other space in which hazardous materials are stored or handled.
- Do not smoke, chew gum, or apply cosmetics in areas where laboratory chemicals are present; wash hands before conducting these activities.
- Do not dispose of food/drink waste in laboratory trash containers.
- Do not store, handle, or consume food or beverages in storage areas, refrigerators, glassware or utensils, which are also used for laboratory operations.
- Wash areas of exposed skin well before leaving the laboratory.

2.3.5.6 Eliminating Mercury Thermometers and Mercury Containing Devices

Metallic mercury is highly toxic by skin absorption, inhalation, and ingestion. Lab workers face limited potential exposure whenever they break mercury-filled thermometers. The mercury contamination may infiltrate cracks in benches and the floor or spread beneath equipment and instruments. The contamination is insidious and difficult to remove completely. The difficulty is magnified if the thermometer breaks in a water bath or sink.

One of the best methods for eliminating this hazard and metallic mercury in labs is to replace all mercury thermometers with non-mercury instruments. Alternatives to mercury thermometers are spirit-filled or digital units. EOHS strongly urges you to substitute non-mercury thermometers whenever possible.

Alkyl mercury compounds require prior approval from EOHS and the Chemical Management Center before purchase or use.

2.4 Chemical Exposure Assessment

2.4.1 Regulatory Overview

OSHA regulates Permissible Exposure Limits (PELs) for airborne contaminants to which “nearly all workers may be exposed daily during a 40-hour workweek for a working lifetime (of 40 years) without adverse effect”, and are based upon an 8-hour Time-Weighted Average (TWA) exposure. Thus, the PELs are the maximum permitted 8-hour TWA concentration of an airborne contaminant without the use of respiratory protection. OSHA has also defined Short Term Exposure Limits (STELs) as the maximum TWA exposure during any 15 minute period, provided the daily PEL is not exceeded and Ceiling (C) exposures that shall not be exceeded at any time.

OSHA has listed established PELs, STELs and Ceiling exposures for chemical contaminants. In the absence of a published Ceiling limit for a chemical, OSHA requires employee exposure to concentrations above the PEL be controlled to prevent harmful effects. Further, OSHA has promulgated specific standards covering several regulated carcinogens, which may include an Action Level (AL), triggering medical surveillance requirements or the imposition of a specific Excursion Limit (such as for asbestos) with a unique measurement of the duration of an exposure.

2.4.2 Exposure Assessment Overview

All University employees require protection from exposure to hazardous chemicals above PELs, STELs and Ceiling concentrations. OSHA requires the person supervising, directing, or evaluating the exposure assessment monitoring be competent in the practice of industrial hygiene. Thus, only representatives of EOHS and not the PI/Laboratory Supervisor should perform exposure assessment.

Minimizing an exposure may be accomplished using a combination of engineering controls, administrative controls and personal protective equipment, listed in order of priority. Assessing exposure to hazardous chemicals may be accomplished through a number of methods performed by EOHS, including employee interviews, visual observation of chemical use, evaluation of engineering controls, use of direct reading instrumentation, or the collection of analytical samples from the employee's breathing zone. Personal exposure assessment will be performed under any of the following situations:

- EOHS bases whether an exposure assessment is warranted by reviewing chemical inventories, reviewing Standard Operating Procedures (SOPs), types of engineering controls present, laboratory inspection results; or
- User of a hazardous chemical has concern or reason to believe exposure is not minimized or eliminated through use of engineering controls or administrative practices (such as transfer of a chemical through a double needle performed entirely in a fume hood) and the potential for exposure exists. The user should then inform his or her PI/Laboratory Supervisor, who will in turn contact EOHS. EOHS will then determine the best course of action in assessing employee exposure, including visual assessment, air monitoring, medical evaluation, examination, or medical surveillance.; or
- A regulatory requirement exists to perform an initial and if warranted periodic monitoring.

In event of any serious injury or exposure, including chemical splash involving dermal or eye contact, immediately call 911 from a campus phone or cell phone and obtain medical treatment immediately. Do not wait for an exposure assessment to be performed before seeking medical care.

2.4.3 Exposure Assessment Protocol

The EOHS Industrial Hygiene Program conducts exposure assessments for members of the campus community. Exposure assessments may be performed for hazardous chemicals, as well as for physical hazards including noise and heat stress to determine if exposures are within PELs or other appropriate exposure limits that are considered safe for routine occupational exposure. General protocol in conducting an exposure assessment may include any of the following:

- Employee interviews;
- Visual observation of chemical usage and/or laboratory operations;
- Evaluation of simultaneous exposure to multiple chemicals;
- Evaluation of potential for absorption through the skin, mucus membranes or eyes;
- Evaluating existing engineering controls (such as measuring face velocity of a fume hood);
- Use of direct reading instrumentation; and

- Collection of analytical samples of concentrations of hazardous chemicals taken from the employees breathing zone, or noise dosimetry collected from an employee's shirt collar or various forms of radiation dosimetry.

If exposure monitoring determines an employee exposure to be over the action level (or the PEL) for a hazard for which OSHA has developed a specific standard (e.g., lead), the medical surveillance provisions of that standard shall be followed. It is the responsibility of the PI/Laboratory Supervisor to ensure that any necessary medical surveillance requirements are met. When necessary, EOHS will make recommendations regarding adjustments to engineering controls or administrative procedures to maintain exposure below any applicable PEL. Where the use of respirators is necessary to maintain exposure below permissible exposure limits, the Principal Investigator will provide, at no cost to the employee, the proper respiratory equipment and training. Respirators will be selected and used in accordance with the University's Respirator Protection Program.

In assessing exposure to hazardous chemicals for which OSHA has not published a PEL, STEL or Ceiling exposure, EOHS defers to the Recommended Exposure Limits (RELs) established by the National Institute of Occupational Safety & Health (NIOSH). Please contact EOHS for more information regarding these chemicals.

2.4.3.1 Notification

The Industrial Hygiene Program will promptly notify the employee and his/her PI/Laboratory Supervisor of the results in writing (within 15 working days or less when required by regulation) after receipt of the monitoring results. The Industrial Hygiene Program will establish and maintain an accurate record of any measurements taken to monitor exposures for each employee.

2.4.3.2 Exposure Assessment Use to Determine and Implement Controls

EOHS will use any of the following criteria to determine required control measures to reduce employee's occupational exposure:

- Verbal information obtained from employees regarding chemical usage;
- Visual observations of chemical use or laboratory operations;
- Evaluation of existing engineering control measures or administrative practices;
- Recommendations expressed in Safety Data Sheets;
- Regulatory requirements of OSHA;
- Recommendations from professional industrial hygiene organizations;
- Direct reading instrumentation results;
- Employee exposure monitoring results; and/or
- Medical evaluation, examination and/or surveillance findings.

Particular attention shall be given to the selection of safety control measures for chemicals that are known to be extremely hazardous. The control of harmful exposures shall be prevented by implementation of control measures in the following order:

1. Engineering controls, whenever feasible;
2. Administrative controls whenever engineering controls are not feasible or do not achieve full compliance and administrative controls are practical; and

3. Personal protective equipment, including respiratory protection, during:
    a. the time necessary to install or implement feasible engineering controls.
    b. when engineering and administrative controls fail to achieve full compliance.
    c. emergencies.

2.5 Chemical Inventory and Chemical Hazard Communication

2.5.1 Regulatory Requirements

Youngstown State University has an established Hazard Communication Program that complies with the OSHA Hazard Communication Standard. The purpose of the Hazard Communication Program is to ensure that all employees and, upon request, their personal physicians, have the right to receive information regarding the hazardous substances to which they may have been exposed at work. The university is responsible for providing information about the hazardous substances in the workplace, the associated hazards, and the control of these hazards, through a comprehensive hazard communication program that is summarized briefly below.

The requirements of the Hazard Communication Program apply to laboratory environments due to the potential for large-scale experiments and for activities that may occur outside of areas where engineering controls are available. Proper hazard communication involves the active participation of the PI/Laboratory Supervisor, the EOHS Chemical Safety Officer, and the Laboratory/Facility Safety Coordinator, who are each responsible for providing consultation and safety information to employees working with hazardous chemicals.

2.5.2 Chemical Inventories

The chemical database is maintained by the Chemical Management Center at www.chemicalsafety.com. For login information, please contact Tim Styranec at tmstyranec@ysu.edu or 330-941-3703.
The chemical inventory list should be reviewed prior to ordering new chemicals and only the minimum quantities of chemicals necessary for the research and teaching labs should be purchased. As new chemicals are added to the inventory, each laboratory group must confirm that they have access to the Safety Data Sheets (SDS) for those chemicals. Where practical, each chemical should be dated so that expired chemicals can be easily identified for disposal. Inventory the materials in your laboratory frequently (at least annually) to avoid overcrowding with materials that are no longer useful and note the items that should be replaced, have deteriorated, or show container deterioration. Unneeded items should be returned to the storeroom/stockroom and compromised items should be discarded as chemical waste.

Indications for disposal include:

- Cloudiness in liquids.
- Color change.
- Evidence of liquids in solids, or solids in liquids.
- "Puddling" of material around outside of containers.
- Pressure build-up within containers.
- Obvious deterioration of containers.

Access to hazardous chemicals, including toxic and corrosive substances, should be restricted at all times. These materials must be stored in laboratories or storerooms that are kept locked when laboratory personnel are not present. Locked storage cabinets or other precautions are always recommended, and in some cases may be required in the case of unusually toxic or hazardous chemicals. Unusually toxic chemicals may include those that are associated with very low immediately dangerous to life or health (IDLH) conditions. For guidance on locked storage requirements, please contact EOHS. On termination or transfer of laboratory personnel, all related hazardous materials should be properly disposed of, or transferred to the laboratory supervisor or a designee.

2.5.3 Hazard Determination

PIs/Laboratory Supervisors are responsible for verifying if any items on their chemical inventory are subject to the requirements of the hazard communication regulation.

2.5.4 Safety Data Sheets (SDS)

An SDS must be available for each hazardous substance in a laboratory's chemical inventory. SDSs are available from the Chemical Management Center (https://ysu.edu/eohs/chemical-management-center).

The CMC also updated SDS's in the main file and respective labs as chemicals arrived on campus.

New chemical substances synthesized or produced in a laboratory, and used or shared outside of a laboratory suite require the preparation of an SDS for each synthesized substance.

New Global Harmonization System requires the standardization of SDSs.

The minimum information required for an SDS is:

1. Identification of the substance or mixture and of the supplier.
2. Hazards identification.
3. Composition/information on ingredients.
4. First aid measures.
5. Firefighting measures.
6. Accidental release measures.
7. Handling and storage.
8. Exposure controls/personal protection.
9. Physical and chemical properties.
10. Stability and reactivity.
11. Toxicological information.
12. Ecological information.
13. Disposal considerations.
14. Transport information.
15. Regulatory information.
16. Other information including information on preparation and revision of the SDS.

2.5.5 Labels and Other Forms of Warning

Labeling requirements for all hazardous substances are summarized as follows:

- All containers of hazardous materials must be labeled with the identity of the hazardous substance.
- The label must contain all applicable hazard warning statements.
- The name and address of the chemical manufacturer or other responsible party must be present.
- Manufacturer's product labels must remain on all containers, and must not be defaced in any way.
- Labels must be legible, in English, and prominently displayed.
- Symbols are required for non-English speaking employees.
- Secondary containers (such as spray bottles) must be labeled with the identity of the substance and appropriate hazard warnings.
- New synthesized compounds must be labeled with the appropriate hazard warnings based on the knowledge of the chemical and physical properties of that substance.

2.5.6 Chemical Labeling

Every chemical found in the laboratory must be properly labeled. Most chemicals come with a manufacturer's label that contains the necessary information, so care should be taken to not damage or remove these labels. Each chemical bottle, including diluted chemical solutions, must be labeled with its contents and the hazards associated with this chemical. It is recommended that each bottle also be dated when received and when opened to assist in determining which chemicals are expired and require disposal. When new chemicals and compounds are generated by laboratory operations, these new chemical bottles must be labeled with the name, date, and hazard information; the generator or other party responsible for this chemical should be named on the container so that they may be contacted if questions arise about the container's contents.

Peroxide forming chemicals (e.g., ethers) must be labeled with a date on receipt and on first opening the bottle. These chemicals are only allowed a one year shelf life and should be disposed of as waste in one year. These chemicals can degrade to form shock sensitive, highly reactive compounds and should be stored and labeled very carefully.

Particularly Hazardous Substances (PHS) require additional labeling. In addition, the storage area where they are kept must be labeled with the type of hazard. These chemicals should be segregated from less hazardous chemicals to help with proper access control and hazard identification.

2.5.7 Global Harmonization System (Hazard Communication Standard Pictograms)

The United States has adopted the United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS). The GHS is a comprehensive approach to defining a chemical's hazards and communicating those hazards and protective measures to workers. Pictograms identify health, physical, and environmental hazards associated with a chemical. Each hazard classification contains one or more hazard categories indicating the degree of the hazard, with Category 1 being the most hazardous. The pictograms are presented in Figure 10.

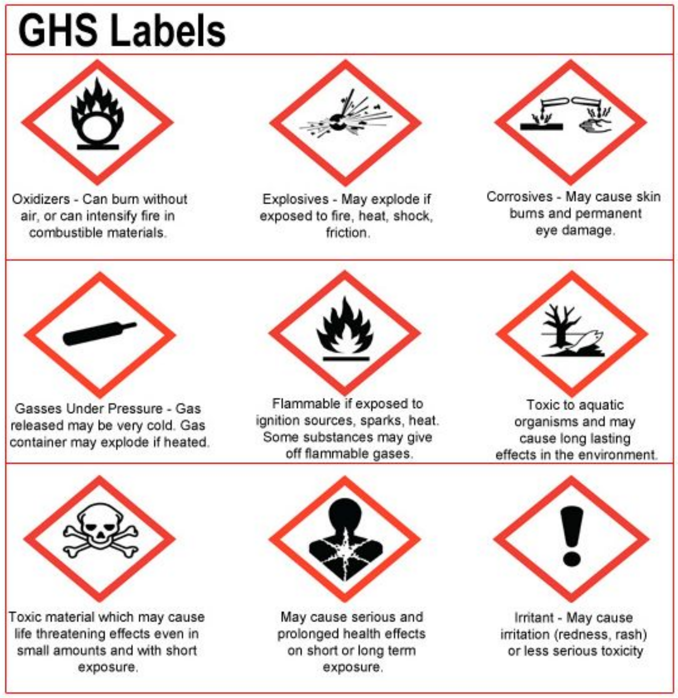

Figure 10: GHS Pictograms

2.5.8 Employee Information and Training

Employee training on specific workplace hazards must be provided at the time of initial assignment, whenever a new hazard is introduced into the workplace, and whenever employees may be exposed to hazards in other work areas.

General Hazard Communication Training is available by contacting EOHS. Additional employee training is required whenever a new hazard is introduced into the work environment, and must be provided within 30 days of receiving the SDS or other safety information. All training must be in the appropriate language, educational level, and vocabulary for laboratory personnel. Employees must be given the opportunity to ask questions.

Other Resources:

1. Standard Operating Procedures (SOPs) for handling toxic chemicals.
2. General information on the signs and symptoms associated with exposure to hazardous substances used in the laboratory or facility.
    a. Identity labels, showing contents of containers (including waste receptacles) and associated hazards.
    b. Warnings at areas or equipment where special or unusual hazards exist (e.g., particularly hazardous substances).
3. Procedures to follow in case of an emergency including:
    a. Emergency telephone numbers of emergency personnel/facilities, supervisors, laboratory workers and

b. Location signs for safety showers, eyewash stations, other safety and first aid equipment, exits and areas where food and beverage consumption and storage are permitted.

2.6 Storage, Security, and Transport

2.6.1 Chemical Storage & Segregation

Establish and follow safe chemical storage & segregation procedures for your laboratory. Storage guidelines are included for materials that are flammable, oxidizers, corrosive, water reactive, explosive, and highly toxic. The specific Safety Data Sheet (SDS) should always be consulted when doubts arise concerning chemical properties and associated hazards. All procedures employed must comply with OSHA, Fire Code, and building code regulations. Each laboratory is required to conduct lab specific training on the hazardous chemicals and to effectively communicate the hazards stored in a laboratory. Table 2.4 lists chemical safety storage priorities.

Keep in mind that most chemicals pose multiple hazards and a decision must be made as to which storage area would be most appropriate for each specific chemical.

Consider in order:

1. Flammability. When establishing a storage scheme, the number one consideration should be the flammability characteristics of the material. If the material is flammable, a flammable cabinet or a refrigerator rated for flammable storage is the best practice. The maximum amount of flammables allowed outside a flammable storage cabinet, safety can, or approved refrigerator/freezer is 10 gallons.

2. Isolate. If the material will contribute significantly to a fire (e.g., oxidizers), it should be isolated from the flammables. If there were a fire in the laboratory and response to the fire with water would exaggerate the situation, isolate the water reactive material from possible contact with water.

3. Corrosivity. Next look at the corrosivity of the material, and store accordingly.

There will always be some chemicals that will not fit neatly into one category, but with careful consideration of the hazards involved, most of these cases can be handled in a reasonable fashion. Please contact EOHS with any questions.

Figure 11: Chemical Storage Priorities

2.6.1.1 General Recommendations for Safe Storage of Chemicals

Each chemical in the laboratory must be stored in a specific location and returned there after each use. Acceptable chemical storage locations may include corrosive cabinets, flammable cabinets, laboratory shelves, or appropriate refrigerators or freezers. Fume hoods should not be used as general storage areas for chemicals, as this may seriously impair the ventilating capacity of the hood. Figure 12 depicts improper fume hood storage. Chemicals should not be routinely stored on bench tops or stored on the floor.

Laboratory shelves should have a raised lip along the outer edge to prevent containers from falling. Hazardous liquids or corrosive chemicals should not be stored on shelves above eye-level and chemicals that are highly toxic or corrosive should be in unbreakable secondary containers.

Chemicals must be stored at an appropriate temperature and humidity level and should never be stored in direct sunlight or near heat sources, such as laboratory ovens. Incompatible materials should be stored in separate cabinets, whenever possible. If these chemicals must be stored in one cabinet, due to space limitations, adequate segregation and secondary containment must be ensured to eliminate the possibility of mixing and of adverse reactions. All stored containers and research samples must be appropriately labeled and tightly capped to prevent vapor interactions and to alleviate nuisance odors. Storing chemicals in flasks with cork, rubber or glass stoppers should be avoided because of the potential for leakage.

Laboratory refrigerators and freezers must be labeled appropriately with "No Food/Drink" and must never be used for the storage of consumables. Freezers should be defrosted periodically so that chemicals do not become trapped in ice formations.

Figure 12: Improper Fume Hood Storage

2.6.1.2 Flammable and Combustible Liquids

Large quantities of flammable or combustible materials should not be stored in the laboratory. The maximum total quantity of flammable and combustible liquids must not exceed 60 gallons within a flammable storage cabinet. The maximum quantity allowed to be kept outside a flammable storage cabinet, safety can, or approved refrigerator/freezer is 10 gallons with no container being larger than 1 gallon. Only the amounts needed for the current procedure should be kept on bench tops and the remainder should be kept in flammable storage cabinets, refrigerators/freezers that are approved for the storage of flammable substances, or approved safety cans or drums that are grounded.

Always segregate flammable or combustible liquids from oxidizing acids and oxidizers. Flammable materials must never be stored in domestic-type refrigerators/freezers. Flammable or combustible liquids must not be stored on the floor or in any exit access. Handle flammable and combustible substances only in areas free of ignition sources and use the chemical in a fume hood whenever practical. Only the amount of material required for the experiment or procedure should be stored in the work area. Always transfer flammable and combustible chemicals from glass containers to glassware or from glass container/glassware to plastic. Transferring these types of chemicals between plastic containers may lead to a fire hazard due to static electricity.

2.6.1.3 Pyrophoric and Water Reactive Substances

Because pyrophoric substances can spontaneously ignite on contact with air and/or water, they must be handled under an inert atmosphere and in such a way that rigorously excludes air and moisture. Some pyrophoric materials are also toxic and many are dissolved or immersed in a flammable solvent. Other common hazards include corrosivity, teratogenicity, or peroxide formation. Only minimal amounts of reactive chemicals should be used in experiments or stored in the laboratory. These chemicals must be stored as recommended in the SDS. Reactive materials containers must be clearly labeled with the correct chemical name, in English, along with a hazard warning. Suitable storage locations may include inert gas-filled desiccators or glove boxes; however, some pyrophoric materials must be stored in a flammable substance approved freezer. If pyrophoric or water reactive reagents are received in a specially designed shipping, storage or dispensing container (such as the Aldrich Sure/Seal packaging system), ensure that the integrity of that container is maintained. Ensure that sufficient protective solvent, oil, kerosene, or inert gas remains in the container while pyrophoric materials are stored. Never store reactive chemicals with flammable materials or in a flammable liquids storage cabinet. Never return excess reactive chemical to the original container. Small amounts of impurities introduced into the container may cause a fire or explosion.

2.6.1.4 Oxidizers

Oxidizers (e.g., hydrogen peroxide, potassium dichromate, sodium nitrate) should be stored in a cool, dry place and kept away from flammable and combustible materials, such as wood, paper, Styrofoam, plastics, flammable organic chemicals, and away from reducing agents, such as zinc, alkaline metals, and formic acid.

2.6.1.5 Peroxide Forming Chemicals (PFCs)

Peroxide forming chemicals (e.g. diethyl ether, cyclohexene, tetrahydrofuran) should be stored in airtight containers in a dark, cool, and dry place and must be segregated from other classes of chemicals that could create a serious hazard to life or property should an accident occur (e.g., acids, bases, oxidizers). All containers with PFCs should be labeled with the date received and the date opened. This information, along with the chemical identity should face forward to minimize container handling during inspection. Minimize the quantity of peroxide forming chemicals stored in the laboratory and dispose of peroxide forming chemicals before peroxide formation. Contact EOHS with questions.

Carefully review all cautionary material supplied by the manufacturer prior to use. Avoid evaporation or distillation, as distillation defeats the stabilizer added to the solvents. Ensure that containers are tightly sealed to avoid evaporation and that they are free of exterior contamination or crystallization. Never return unused quantities back to the original container and clean all spills immediately. If old containers of peroxide forming chemicals are discovered in the laboratory, (the container is greater than two years past the expiration date, if the date of the container is unknown, or you are not comfortable handling the container), do not handle the container. If crystallization is present in or on the exterior of a container, do not handle the container. Secure it and contact EOHS for pick-up and disposal.

2.6.1.6 Corrosives

Store corrosive chemicals (i.e., acids, bases) below eye level and in secondary containers that are large enough to contain at least 10% of the total volume of liquid stored or the volume of the largest container, whichever is greater. Acids must always be segregated from bases and from active metals (e.g., sodium, potassium, magnesium) at all times and must also be segregated from chemicals which could generate toxic gases upon contact (e.g., sodium cyanide, iron sulfide).

Specific types of acids require additional segregation. Mineral acids must be kept away from organic acids and oxidizing acids must be segregated from flammable and combustible substances. Perchloric acid should be stored by itself, away from other chemicals. Picric Acid is reactive with metals or metal salts and explosive when dry and must contain at least 10% water to inhibit explosion. Nitric acid must be kept separate from other acids since it is an oxidizer.

2.6.1.7 Chemical Segregation

Figure 13 contains information regarding the general hazard class segregation that should be followed. These chemicals require separation by at least an appropriate secondary container and in some cases should be located in different cabinets or locations completely. Such circumstance includes flammable and oxidizing gases.

Hazard Class	***Keep out of contact with:***
Flammables	*Oxidizers*
Acids	*Bases*
Organic Acids	*Inorganic Acids*
Water Reactive Chemicals	*Water and Aqueous Solutions*

Figure 13: Hazard Class Segregation

Chemical hazardous waste containing these hazard classes should also be segregated.

Figure 14 contains a list of incompatible chemicals. The following chemicals, listed in the left column, should not be used with chemicals listed in the right column, except under specially controlled conditions. Chemicals in the left column should not be stored in the immediate area with chemicals in the right column. Incompatible chemicals should always be handled, stored or packed so that they cannot accidentally be exposed to one another. This list is representative of chemical incompatibilities and is not complete, nor are all incompatibilities shown. Please see manufacturer's SDS for additional information.

Chemical	*Keep out of contact with:*
Alkaline metals, such as powdered aluminum, magnesium, sodium, potassium, etc.	*Carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide and water*
Acetic Acid	*Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides and permanganates*
Acetylene	*Chlorine, bromine, copper, fluorine, silver and mercury*
Ammonia	*Mercury, chlorine, calcium hypochlorite, iodine, bromine and hydrofluoric acid*
Ammonium nitrate	*Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials*
Carbon, activated	*Calcium hypochlorite*
Copper	*Acetylene and hydrogen peroxide*
Chromic acid	*Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol and flammable liquids*
Chlorine	*Ammonia, acetylene, butadiene, butane, methane, propane, hydrogen, sodium carbide, turpentine, benzene and finely divided metals*
Cyanides	*Acids - organic or inorganic*
Hydrogen peroxide	*Copper, chromium, iron, most metals, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids and combustible materials*
Hydrogen sulfide	*Fuming nitric acid and oxidizing gases*
Hydrocarbons (butane, propane, benzene, gasoline, turpentine etc.)	*Fluorine, chlorine, bromine, chromic acid and sodium peroxide*
Iodine	*Acetylene, ammonia and hydrogen*
Nitric acid	*Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, brass and any heavy metals*
Perchloric acid	*Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, ether, oils and grease*
Phosphorous	*Oxidizing agents, oxygen, strong bases*
Potassium chlorate	*Sulfuric and other acids*
Potassium permanganate	*Glycerin, ethylene glycol, benzaldehyde and sulfuric acid*
Sodium	*Carbon tetrachloride, carbon dioxide and water*
Sodium nitrite	*Ammonium nitrate and other ammonium salts*
Sodium peroxide	*Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate and furfural*
Sulfides, inorganic	*Acids Sulfuric acid Potassium chlorate, potassium perchlorate and potassium permanganate*

Figure 14: Incompatible Chemicals

Special Segregation of Incompatible

Chemicals In addition to the segregation noted in Figure 14 dangerously incompatible substances, even in small quantities, should not be stored next to each other on shelves or in such a position that accidental rupture of containers may allow mixing. Table 2.7 contains examples of dangerously incompatible substances. Table 2.8 contains examples of incompatible oxidizing agents and reducing agents.

Chemical	***Keep out of contact with:***
Chlorine	*Acetylene*
Chromic acid	*Ethyl alcohol*
Oxygen(compressed, liquefied)	*Propane*
Sodium	*Chloroform and aqueous solutions*
Nitrocellulose (wet, dry)	*Phosphorous*
Potassium permanganate	*Sulfuric acid*
Perchloric acid	*Acetic acid*
Sodium chlorate	*Sulfur in bulk*

Figure 15: Dangerously Incompatible Substances

Oxidizing Agents	***Reducing Agents***
Chlorates	*Ammonia*
Chromates	*Carbon*
Dichromates	*Metals*
Chromium trioxide	*Metal hydrides*
Halogens	*Nitrates*
Halogenating agents	*Organic Compounds*
Hydrogen peroxide	*Phosphorus*
Nitric acid	*Silicon*
Nitrates	*Sulfur*
Perchlorates	
Peroxides	
Permanganates	
Persulfates	

Figure 16: Incompatible Oxidizing and Reducing Agents

2.6.2 Compressed and Liquefied Gases

2.6.2.1 General Precautions

- Never drop cylinders or permit them to strike each other violently.
- Do not expose cylinders to temperatures higher than 50° C. Some rupture devices on cylinders release at about 65° C.
- Never tamper with pressure relief devices in valves or cylinders.
- Before using cylinders, read all label information and Safety Data Sheet associated with the gas being used.

2.6.2.2 Types of Compressed Gas Cylinders

There are three major groups of compressed gases stored in cylinders.

- Liquefied gases are liquid at normal temperature and charge pressure. Examples: chlorine, propane, nitrous oxide.
- Non-liquefied gases are entirely gaseous at normal temperatures regardless of charge pressure. Examples: argon, oxygen, nitrogen. The standard 5-foot gas cylinders supplied by gas vendors at a pressure of 2,200 – 2,400psi contain an average of 250 cubic feet of gas at normal temperature.
- Dissolved gases are dissolved in a liquid phase solvent. Dissolved gas cylinders are packed with an inert, porous filter saturated with the solvent that stabilizes the volatile gas. Acetylene is the only common dissolved gas. Some gases, such as carbon dioxide, are commonly used in both a liquid and gas form. Cylinders designed for liquid phase dispensing have a siphon, or "dip", tube.

2.6.2.3 Securing Cylinders

Keep cylinders secured to the bench or wall and to keep the caps on when they are not in use. Chicago code requires that cylinders be chained to the wall. In Evanston, cylinders may be secured by bench straps, floor stands, or chains.

2.6.2.4 Lecture Bottles

In addition to standard precautions, the following special rules apply to work with lecture bottles in the laboratory:

- Lecture bottles do not have pressure-relief devices to prevent rupturing or a transport cap.
- Unlike larger cylinders, lecture bottles all have identical valve threads, irrespective of the gas contained within.
- If labels and valve tags do not agree or if there is any question as to the contents of a lecture bottle, return the unused bottle to the supplier or contact EOHS. Whenever possible, purchase lecture bottles from suppliers who will accept the return of empty or partially empty bottles.
- When transporting lecture bottles, use a cart and block the bottles to prevent rolling and falling.

2.6.2.5 Storage

Maximum allowable storage quantities vary depending on campus, building, floor, control area, fire rated design and type of gas. Only cylinders that are in use shall be kept in the laboratory. When the cylinder is not in use, close the main cylinder valve tightly and add the protective cap.

Promptly remove the regulator from an empty cylinder, replace the protective cap, and label the cylinder by using an "empty" tag or writing on the side of the cylinder with chalk. Never bleed cylinders completely empty; leave a slight pressure to keep contaminants out. Empty cylinders shall be promptly removed.

2.6.2.6 Return and Transport

When returning empty cylinders leave some positive pressure in the cylinder. Transport using a wheeled cylinder cart with the capped cylinder strapped to the cart.

2.6.2.7 Toxic Gases

Flow-restricting orifices are recommended on cylinders of toxic gases. All portable tanks and cylinders must be marked to indicate the orifice (inches) on the certification tags and the vessel themselves. Toxic-gas cylinders shall be stored in continuously mechanically ventilated enclosures with an extinguishing system (IFC 2012 – Section 6004.1.2). If the net toxic gas content exceeds one pound per cylinder no more than three cylinders of toxic gas are allowed per enclosure (gas cabinet). Any new laboratory construction shall require vented gas cabinets for storage of highly toxic gases. Gas cylinder cabinets for toxic gases must have a fire extinguishing system (IFC 2012 – 6004.1.2). Purchase of diluted toxic gas, if feasible below a concentration known to be dangerous, will serve to reduce exposure risk. Waste toxic gases shall be treated by absorption, wet or dry scrubbing, combustion, or condensation via refrigeration, before being vented to chemical fume hoods or other local exhaust arrangements. The safe venting of pressure-relief devices should be considered. (IFC 2012 – Section 6003.1.3 Treatment Systems) If the physiological warning properties for the toxic or highly toxic gas(es) are above the PEL an emergency alarm system is required (IFC 2012 – 6004.2.2.10); consult EOHS regarding this determination.

2.6.2.8 Flammable Gases

Purchase of diluted flammable gas, if feasible below the explosive range, will serve to reduce the explosion risk.

Flammable gas cylinders must be stored 20ft away from oxidizers and oxygen gas cylinders or separated by a fire rated wall.

Acetylene

The in house transfer, handling, storage, and utilization of acetylene in cylinders shall be in accordance with Compressed Gas Association Pamphlet G-1-2015. Acetylene cylinders have a porous filler material filled with acetone and dissolved acetylene. The cylinder must only be used in the upright position. If a cylinder has been handled in a non-upright position, do not use it until it has sat upright for at least 30 minutes. Some tubing materials, such as copper and lead solder, form explosive acetylides. Never exceed the delivery pressure limit of 15psig indicated by the warning red line of an acetylene pressure gauge. The use of an excess flow control valve is not recommended. Install a flash arrestor downstream from the regulator and check valves wherever backflow needs to be prevented.

Hydrogen

Individual hydrogen gas cylinders should contain less than 400scf. Larger hydrogen gas vessels may require a laboratory designed with explosion control and other safety measures. The installation of a flash arrestor is required and the installation of an excess flow control valve is recommended.

2.6.2.9 Cryogenic Liquids and Liquefied Gases

The hazards of cryogenic liquids include fire or explosion, pressure buildup, embrittlement of structural materials, asphyxiation, and destruction of living tissue on contact. Liquid helium, argon or nitrogen may displace air and create an atmosphere without sufficient oxygen. Portable cylinders of cryogens must only be stored in well-ventilated areas. Storage of cryogenic liquids (i.e. liquid nitrogen) or liquefied gases (i.e. carbon dioxide) in cold rooms or other rooms without external ventilation is prohibited. Fire or explosion may occur when the liquid form of flammable gases, such as hydrogen, is used without proper management of the gaseous phase. Liquid oxygen may produce an enriched oxygen atmosphere, which increases the flammability of ordinary combustible materials. Enriched oxygen levels may also cause some nonflammable materials, such as carbon steel, to burn readily.

2.6.2.9 Cryogenic Liquids and Liquefied Gases

The hazards of cryogenic liquids include fire or explosion, pressure buildup, embrittlement of structural materials, asphyxiation, and destruction of living tissue on contact.

Liquid helium, argon or nitrogen may displace air and create an atmosphere without sufficient oxygen. Portable cylinders of cryogens must only be stored in well-ventilated areas. Storage of cryogenic liquids (i.e. liquid nitrogen) or liquefied gases (i.e. carbon dioxide) in cold rooms or other rooms without external ventilation is prohibited. Fire or explosion may occur when the liquid form of flammable gases, such as hydrogen, is used without proper management of the gaseous phase. Liquid oxygen may produce an enriched oxygen atmosphere, which increases the flammability of ordinary combustible materials. Enriched oxygen levels may also cause some nonflammable materials, such as carbon steel, to burn readily.

Liquid Nitrogen

Because liquid nitrogen containers are at low pressure and have protective rings mounted around the regulator, they are not required to be affixed to a permanent fixture such as a wall. However, additional protection considerations should be addressed when storing liquid nitrogen in a laboratory. The primary risk to laboratory personnel from liquid nitrogen is skin or eye thermal damage caused by contact with the material. In addition, nitrogen expands 696:1 when changing from a cryogenic liquid to a room temperature gas. The gases usually are not toxic, but if too much oxygen is displaced, asphyxiation is a possibility. A physical hazard also exists for cyrovials stored in the liquid phase, which may explode when warmed. Always use appropriate thermally insulated gloves when handling liquid nitrogen. Face shields may be needed in cases where splashing can occur, or when cyrovials are being removed and warmed. Use a phase separator or special filling funnel to prevent splashing and spilling when transferring liquid nitrogen into or from a Dewar. The top of the funnel should be partly covered to reduce splashing. Use only small, easily handled Dewars for pouring liquid. For the larger, heavier containers, use a cryogenic liquid withdrawal device to transfer liquid from one container to another. Be sure to follow instructions supplied with the withdrawal device. The receiving vessel must be raised so the delivery tube is immediately above the mouth of the vessel (i.e., the cryogenic liquid should never be allowed to fall through air to reach the receiving vessel). When a warm tube is inserted into liquid nitrogen, liquid will spout from the bottom of the tube due to gasification and rapid expansion of liquid inside the tube. Wooden or solid metal dipsticks are recommended; avoid using plastics that may become very brittle at cryogenic temperatures.

2.6.2.10 Monitoring for Oxygen Deficiency

Indoor areas where bulk inert gas systems are newly installed shall be continuously monitored with an atmosphere monitoring system. The system shall provide an audible and visual alarm (red light) when the oxygen level drops to 19.5%. The audible and visual alarm shall be located inside the area and immediately outside of all entrances to the indoor area. A blue indicator light shall indicate a detection system malfunction.

2.6.2.11 Minimum Ventilation Rate

Natural or mechanical ventilation shall be provided when bulk inert gas systems are installed in buildings, rooms, or any indoor confined area. Ventilation shall be provided throughout the space at the rate of not less than 1.0 cubic foot per minute per square foot of floor area determined by the area enclosed. (Reference: IFC2012 – 5004.3.1)

2.6.3 Laboratory Security

It is critical that chemicals be secured to prevent theft from campus laboratories. Numerous federal agencies are involved in the maintenance of laboratory security, including the Drug Enforcement Agency (http://www.deadiversion.usdoj.gov/schedules), Federal Bureau of Investigations (http://www.fbi.gov/about-us/investigate/terrorism/wmd), and Department of Homeland Security (http://www.dhs.gov/xlibrary/assets/chemsec_appendixachemicalofinterestlist.pdf).

It is each laboratory's responsibility to prevent and report any theft of chemicals from their laboratory to the Chemical Management Center. Labs can increase their security by simply keeping lab doors closed and locked when unoccupied, maintaining a current and accurate chemical inventory, training personnel on security procedures, and controlling access to keys. Labs should report any suspicious activity to Campus Police.

2.6.4 On-Campus Distribution of Hazardous Chemicals

Precautions must be taken when transporting hazardous substances between laboratories. Chemicals must be transported between stockrooms and laboratories in break-resistant, secondary containers such as commercially available bottle carriers made of rubber, metal, or plastic, that include carrying handle(s) and which are large enough to hold the contents of the chemical container in the event of breakage.

2.6.5 Off-Campus Distribution of Hazardous Chemicals

The transportation of hazardous chemicals and compressed gases over public roads, or by air, is strictly governed by international, federal, and state regulatory agencies, including the U.S. Department of Transportation (DOT) and the International Air Transport Association (IATA). Any person who prepares and/or ships these types of materials must ensure compliance with pertinent regulations regarding training, quantity, packaging, and labeling. Without proper training, it is illegal to ship hazardous materials. Those who violate the hazardous materials shipment regulations are subject to criminal investigation and penalties. Individuals who wish to ship or transport hazardous chemicals or compressed gases off-campus, must contact the Chemical Management center. This is the only place allowed to package and ship hazardous materials on the campus of YSU.

2.7 Training

Effective training is critical to facilitate a safe and healthy work environment and prevent laboratory accidents. All Faculty/Laboratory Supervisors must participate in formal safety training and ensure that all their employees have appropriate safety training before working in a laboratory. Contact EOHS at extension 3703 or tmstyranec@ysu.edu to arrange training using www.industrysafe.com.

2.7.1 Types of Training

All laboratory personnel must complete general safety training before:

- Beginning work in the laboratory;
- Prior to new exposure situations; and
- As work conditions change.

Annual refresher training is also required for all laboratory personnel. EOHS offers general Class-room and online training, plus resource materials to assist laboratories in implementing laboratory-specific training.

2.7.1.1 General Laboratory Safety Training

Anyone working in a laboratory is required to complete General Laboratory Safety training, which includes:

- Review of laboratory rules and regulations, including the Chemical Hygiene Plan.
- Recognition of laboratory hazards.
- Use of engineering controls, administrative controls and personal protective equipment to mitigate hazards.
- Exposure limits for hazardous chemicals.
- Signs and symptoms associated with exposures to hazardous chemicals.
- Chemical exposure monitoring.

- Review of reference materials (e.g., SDS) on hazards, handling, storage and disposal of hazardous chemicals.
- Procedures for disposing of hazardous chemical waste.
- Fire safety and emergency procedures.

2.7.2 Documentation of Training

Accurate recordkeeping is a critical component of health and safety training. Per OSHA regulations, departments or laboratories are responsible for documenting health and safety training, including safety meetings, one-on-one training, in-class and online trainings. Electronic copies are encouraged, however if hard copies are maintained documentation should be located in the laboratory safety manual. For lab specific trainings please include a sign in sheet with sufficient details such as date, topics discussed, and who lead the training. Additional information on recordkeeping can be found in Chapter 8: Compliance and Enforcement. EOHS will keep track of all in person training as well as training using www.industrysafe.com.

2.8 Inspection and Compliance

2.8.1 Chemical Safety Inspections

EOHS has a comprehensive chemical safety compliance program to assist laboratories and other facilities that use, handle or store hazardous chemicals to maintain a safe work environment. This program helps to ensure compliance with regulations and to fulfill YSU's commitment to protecting the health and safety of the campus community. As part of this chemical safety program, EOHS conducts inspections of laboratories and other facilities with hazardous chemicals to ensure the laboratory is operating in a safe manner and to ensure compliance with all federal, state and university safety requirements. The primary goal of inspection is to identify both existing and potential accident-causing hazards, actions, faulty operations and procedures that can be corrected before an accident occurs. The chemical safety inspection is comprehensive in nature and looks into all key aspects of working with hazardous chemicals. While inspections are a snapshot in time and cannot identify every accident-causing mistake, they do provide important information on the overall operation of a particular laboratory. They can also help to identify weaknesses that may require more systematic action across a broader spectrum of laboratories, and strengths that should be fostered in other laboratories. Please see Appendix C: EOHS Laboratory Inspection Checklist. Specific inspection compliance categories include:

- Documentation and Training;
- Hazard Communication (including review of SOPs);
- Emergency and Safety Information;
- Fire Safety;
- General Safety;
- Use of personal protective equipment (PPE);
- Housekeeping;
- Chemical Storage;
- Fume Hoods;
- Chemical Waste Disposal and Transport;
- Seismic Safety; and
- Mechanical and Electrical Safety.

Once the inspection is completed, EOHS issues a Laboratory Inspection Report via email. The report identifies findings in the laboratory, both serious and non-serious. Serious findings are those that have the potential to lead to serious injuries or be of critical importance in the event of an emergency. These findings must be immediately corrected. Non-serious findings must be corrected within 30-days.

2.8.2 Notification and Accountability

The compliance program requires that PIs/Laboratory Supervisors and other responsible parties take appropriate and effective corrective action upon receipt of written notification of inspection findings. Serious findings are required to be corrected within 48-hours; non-serious findings must be corrected within 30 days. Failure to take corrective actions within the required timeframe will result in a repeat finding and an escalation of the notification to the Department Chair, Dean, and Provost. Depending on the severity of the finding, the EOHS Director, in consultation with the administration may suspend research activities until the finding is corrected. In some cases, the faculty may be required to provide a corrective action plan to EOHS prior to resumption of research activities.

2.8.2.1 Recordkeeping Requirements

Accurate recordkeeping demonstrates a commitment to the safety and health of the campus community, integrity of research, and protection of the environment. EOHS is responsible for maintaining records of inspections, accident investigations, equipment calibration, and training conducted by EOHS staff. Per OSHA regulations, departments or laboratories must document health and safety training, including safety meetings, one-on-one training, and classroom and online training. Additionally, the following records must be retained in accordance with the requirements of state and federal regulations:

- Accident records;
- Measurements taken to monitor employee exposures;
- Chemical Hygiene Plan records should document that the facilities and precautions were compatible with current knowledge and regulations;
- Inventory and usage records for high-risk substances should be kept;
- Medical records must be retained in accordance with the requirements of state and federal regulations.

2.9 Hazardous Chemical Waste Management

2.9.1 Regulation of Hazardous Waste

Federal EPA regulations govern hazardous waste management. These hazardous waste regulations are part of the Resource Conservation and Recovery Act, or RCRA.

2.9.2 Hazardous Waste Program

The EOHS Hazardous Materials Program manages the shipment and disposal of all hazardous waste generated on campus. Each laboratory employee must comply with the campus Hazardous Waste Management Program requirements and all applicable regulations. A regular pickup service is provided to most research buildings equipped with wet labs, and a pick-up is available upon request to other locations where hazardous waste is generated.

Laboratory personnel are responsible for identifying waste, labeling it, storing it properly in the laboratory and transporting waste to their designated pick-up location on time. Laboratory clean-outs and disposal of high hazard compounds (e.g. expired peroxide forming chemicals, dried picric acid, or abandoned unknown chemicals) must be scheduled in advance, and fees for these services are sometimes applied. The PI/Laboratory Supervisor is responsible for coordinating the disposal of all chemicals from his/her laboratories prior to closing down laboratory operations.

2.9.2.1 Definition of Hazardous Waste

EPA regulations define hazardous waste as substances having one of the following hazardous characteristics:

- Corrosive: pH < 2 or >12.5*.
- Ignitable: liquids with flash point below 60º C or 140º F [e.g. Methanol, Acetone].
- Reactive: unstable, explosive or reacts violently with air or water, or produces a toxic gas when combined with water [e.g., Sodium metal].
- Toxic: Determined by toxicity testing [e.g., Mercury].

The EPA definition of hazardous waste also extends to the following items:

- Abandoned chemicals.
- Unused or unwanted chemicals.
- Chemicals in deteriorating containers.
- Empty containers that have visible residues.
- Containers with conflicting labels.
- Unlabeled or unknown chemicals.

Chemicals not in frequent use must be carefully managed to prevent them from being considered a hazardous waste. This is especially true for certain compounds that degrade and destabilize over time and require careful management so that they do not become a safety hazard.

2.9.2.2 Extremely Hazardous Waste

Certain compounds meet an additional definition known as “extremely hazardous waste”. This list of compounds includes carcinogens, pesticides, and reactive compounds, among others (e.g., cyanides, sodium azide, and hydrofluoric acid). The Federal EPA refers to this waste as “acutely hazardous waste”. NOTE: While there is some overlap with the list of Particularly Hazardous Substances, such as the examples listed above, the extremely hazardous waste list is specific to the hazardous waste Management program.

2.9.3 Proper Hazardous Waste Management

2.9.3.1 Training

All personnel who are responsible for handling, managing or disposing of hazardous waste must attend training prior to working with these materials. The Hazardous Chemical Waste training covers the hazardous waste program requirements and includes training on the container-labeling program.

2.9.3.2 Waste Identification

All the chemical constituents in each hazardous waste stream must be accurately identified by knowledgeable laboratory personnel. This is a critical safety issue for both laboratory employees and the waste technicians that handle the waste once it is turned over to EOHS. Mixing of incompatible waste streams has the potential to create violent reactions and is a common cause of laboratory accidents. If there is uncertainty about the composition of a waste stream resulting from an experimental process, laboratory workers must consult the PI/Laboratory Supervisor, or the Chemical Hygiene Officer. In most cases, careful documentation and review of all chemical products used in the experimental protocol will result in accurate waste stream characterization. The manufacturer's SDS provides detailed information on each hazardous ingredient in laboratory reagents and other chemical products, and the chemical, physical, and toxicological properties of that ingredient.

2.9.3.3 Storage

The hazardous waste storage area is in the Chemical Management Center. Waste accumulation site in each lab are to be checked and removed weekly. According to EPA requirements, this area must remain under the control of the persons producing the waste. This means that it should be located in an area that is supervised and is not accessible to the public. Other requirements include:

- Hazardous waste containers must be labeled at all times.
- Waste must be collected and stored at or near the point of generation.
- The maximum amount of flammable solvents allowed to be stored in a laboratory outside a flammable storage cabinet is 10 gallons; this figure also includes waste solvents.
- All hazardous waste containers in the laboratory must be kept closed when not in use.
- Hazardous waste streams must have compatible constituents, and must be compatible with the containers that they are stored in.
- Hazardous liquid waste containers must be stored in secondary containment at all times.
- Containers must be in good condition with leak proof lids.
- Containers must be less than 90% full.
- Dry wastes must be double-bagged in clear, 3-mil plastic bags (these do not require secondary containment).

2.9.3.4 Segregation

All hazardous materials must be managed in a manner that prevents spills and uncontrolled reactions. Hazard class should segregate stored chemicals and waste. Examples of proper segregation are:

- Segregate acids from bases.
- Segregate oxidizers from organics.

- Segregate cyanides from acids.

Segregation of waste streams should be conducted in a similar manner to segregation of chemical products.

2.9.3.5 Incompatible Waste Streams

Mixing incompatible waste streams, or selecting a container that is not compatible with its contents, is a common cause of accidents in laboratories and waste storage facilities. Reactive mixtures can rupture containers and explode, resulting in serious injury and property damage. All chemical constituents and their waste byproducts must be compatible for each waste container generated. Waste tags must be updated immediately when a new constituent is added to a mixed waste container, so that others in the laboratory will be aware and manage it accordingly. Some common incompatible waste streams include:

- Oxidizers added to any fuel can create an exothermic reaction and explode. The most frequent is acids oxidizing flammable liquids. For this reason, all flammable liquids are pH tested before they are consolidated.
- Piranha etch solution is a specific waste stream that contains sulfuric acid and hydrogen peroxide, which form a reactive mixture that is often still fuming during disposal. For this waste stream, and other reactive mixtures like it, vented caps are mandatory.

2.9.3.6 Wastes that Require Special Handling

Unknowns

Unlabeled chemical containers and unknown/unlabeled wastes are considered unknowns, and additional fees must be paid to have these materials analyzed and identified. These containers must be labeled with the word “unknown”. Never mix unknowns for any reason.

Peroxide Forming Chemicals

Peroxide forming chemicals, or PFCs, include a number of substances that can react with air, moisture or product impurities, and undergo a change in their chemical composition during normal storage. The peroxides that form are highly reactive and can explode upon shock or spark. Peroxides are not particularly volatile and thus tend to precipitate out of liquid solutions. It is particularly dangerous to allow a container of these materials to evaporate to dryness, leaving the crystals of peroxide on the surfaces of the container. Each container of peroxide forming chemicals should be dated with the date received and the date first opened. There are four classes of peroxide forming chemicals, with each class having different management guidelines. Ensure containers of PFCs are kept tightly sealed to avoid unnecessary evaporation, as this inhibits the stabilizers that are sometimes added. Visually inspect containers periodically to ensure that they are free of exterior contamination or crystallization. PFC containers must be disposed of prior to expiration date. If old containers of peroxide forming chemicals are discovered in the laboratory, (greater than two years past the expiration date or if the date of the container is unknown), do not handle the container. If crystallization is present in or on the exterior of a container, do not handle the container. Secure it and contact EOHS at 330-941-3703.

Dry Picric Acid

Picric acid (also known as trinitrophenol) must be kept hydrated at all times, as it becomes increasingly unstable as it loses water content. When dehydrated, it is not only explosive but also sensitive to shock, heat and friction. Picric acid is highly reactive with a wide variety of compounds (including many metals) and is extremely susceptible to the formation of picrate salts. Be sure to label all containers that contain picric acid with the date received, and then monitor the water content every 6 months. Add distilled water as needed to maintain a consistent liquid volume.

If an old or previously unaccounted for bottle of picric acid is discovered, do not touch the container. Depending on how long the bottle has been abandoned and the state of the product inside, even a minor disturbance could be dangerous. Visually inspect the contents of the bottle without moving it to evaluate its water content and look for signs of crystallization inside the bottle and around the lid. If there is even the slightest indication of crystallization, signs of evaporation, or the formation of solids in the bottle, do not handle the container and contact EOHS at 330-941-3703 immediately. Secure the area and restrict access to the container until it can be evaluated by EOHS personnel.

Explosives and Compounds with Shipping Restrictions A variety of other compounds that are classified as explosives or are water or air reactive are used in research laboratories. These compounds often have shipping restrictions and special packaging requirements. When disposing of these compounds, employees must ensure that they are stored appropriately for transport. Flammable metals must be completely submerged in oil before they are brought to a waste pick-up. Many pyrophoric and reactive compounds can be stabilized using a quenching procedure prior to disposal.

Chemicals classified by the Department of Transportation (DOT) as explosives (e.g., many nitro and azo-compounds) will require special packaging and shipping, and may require stabilization prior to disposal. Consult with EOHS for disposal considerations.

2.9.3.7 Managing Empty Containers

Empty containers that held Extremely Hazardous waste must be managed as hazardous waste, and brought to the waste pick-up. Do not rinse or reuse these containers.

All other hazardous waste containers, if they are less than 5 gallons in size, should either be reused for hazardous waste collection, or should be returned to the Chemical Management Center. Proper cleaning involves triple rinsing the container, with the first rinse collected as hazardous waste. Then the labels should be completely defaced (remove it or mark it out completely). Dispose or recycle rinsed plastic or glass containers as regular trash or in a campus recycling bin.

2.9.3.8 Transportation

It is a violation of DOT regulations to transport hazardous waste in personal vehicles, or to carry hazardous waste across campus streets that are open to the public. As a result, EOHS provides pick-up services for all hazardous waste generators. These routine waste pick-ups are for routinely generated research wastes. Special pick-ups and laboratory clean-outs are available upon request for large volumes (more than 30 containers or 50 gallons). When transporting waste to the pick-up location, inspect all containers to make sure that they are safe to transport. Verify that each container has an accurate waste tag, and the containers are clean, free of residue, and do not show any signs of bulging, fuming, or bubbling. Use only a stable, heavy-duty cart for transporting waste. Containers should be segregated on carts, and carts should be equipped with secondary containment. Do not overload a cart or stack containers more than one level high. Never leave the waste unattended after departing the laboratory. Employees must wear long pants and closed toe shoes (and carry gloves with them) when transporting waste. An appropriate lab coat, gloves and eye protection must be carried as a spill response measure but should not be worn while transporting waste.

2.9.3.9 Disposal

Frequent disposal will ensure that waste accumulation areas in labs are managed properly, and that maximum storage volumes are not exceeded. Hazardous chemical waste can be stored in a laboratory for up to 90 days. Once a waste container is 90% full or it is near the 90-day time limit, call the Chemical Management Center for pickup. Once an experiment or process is completed, all partially filled containers should be scheduled for pickup.

2.9.4 Hazardous Waste Minimization

YSU is a small-quantity generator of hazardous waste. In order to meet our permit obligations and our sustainability mission, EOHS has developed a Hazardous Waste Minimization Program in an effort to minimize the costs, health hazards, and environmental impacts associated with the disposal of hazardous waste.

2.9.4.1 Administrative Controls

In order to reduce the amount of chemicals that become waste, administrative and operational waste minimization controls can be implemented. Usage of chemicals in the laboratory areas should be reviewed to identify practices that can be modified to reduce the amount of hazardous waste generated.

Purchasing Control: The Chemical Management Center helps with process. The CMS checks the inventory of new products are ordered. When entering a chemical order, use the account 701115. Ordering chemicals with a credit card is prohibited.

Inventory Control: The Chemical Management Center reviews and maintains the chemical inventory using www.chemicalsafety.com .

Operational Controls: Review your experimental protocol to ensure that chemical usage is minimized. Reduce total volumes used in experiments; employ small-scale procedures when possible. Instead of wet chemical techniques, use instrumental methods, as these generally require smaller quantities of chemicals. Evaluate the costs and benefits of off-site analytical services. Avoid mixing hazardous and non-hazardous waste streams. Use less hazardous or non-hazardous substitutes when feasible. Some examples include:

- Specialty detergents can be substituted for sulfuric acid/chromic acid cleaning solutions.
- Gel Green and Gel Red are recommended in place of ethidium bromide.

2.9.4.2 Drain Disposal

YSU does not permit drain disposal of chemical wastes, unless a specific dilution and/or neutralization method for a consistent waste stream has been reviewed and approved by EOHS. This applies to weak acid and base solutions. As indicated in previous sections, EPA hazardous waste definitions specify that materials with a pH between 2 and 12.5 are not hazardous wastes. However, drain disposal of these materials is still not permitted, because local industrial wastewater discharge requirements have more restrictive pH thresholds. In addition, acid and base neutralization is considered waste treatment, a process that is strictly regulated by the EPA (see “Bench Top Treatment” below). Contact EOHS for specific questions about drain disposal variances. Drain disposal of properly disinfected infectious or bio-hazardous liquids is acceptable, if disinfection is conducted as specified by the Biosafety plan at YSU, and the liquids disposed contain no other hazardous constituents.

2.10 Accidents and Spills

2.10.1 Overview

Laboratory emergencies may result from a variety of factors, including serious injuries, fires and explosions, spills and exposures, and natural disasters. All laboratory employees should be familiar with the Lab Safety Plan. Before beginning any laboratory task, know what to do in the event of an emergency. Identify the location of safety equipment, including first aid kits, eyewashes, safety showers, fire extinguishers, fire alarm pull stations, and spill kits. Plan and know the location of the closest fire alarms, exits, and telephones in your laboratory. For all incidents requiring emergency response, call campus police at 911 from a campus phone or cell phone.

2.10.2 Accidents PIs/Laboratory

Supervisors are responsible for ensuring that their employees receive appropriate medical attention in the event of an occupational injury or illness. All accidents and near misses must be reported to EOHS at 330-941-3703. EOHS will conduct an accident investigation and develop recommendations and corrective actions to prevent future accidents. At a minimum, each laboratory must have the following preparations in place:

- Posting of emergency telephone numbers.
- Training of adequate number of staff in basic CPR and first aid.
- Training of staff to accompany injured personnel to medical treatment site and to provide medical personnel with copies of Safety Data sheets (SDS) for the chemical(s) involved in the incident.

Accident Prevention Methods	
Do	***Don't***
• *Always wear appropriate eye protection* • *Always wear appropriate laboratory coat* • *Always wear appropriate gloves* • *Always wear closed-toe shoes and long pants* • *Always confine long hair and loose clothing* • *Always use the appropriate safety controls (e.g., certified fume hoods)* • *Always label and store chemicals properly* • *Always keep the work area clean and uncluttered*	• *Never enter the laboratory wearing inappropriate clothing (e.g., open-toe shoes and shorts)* • *Never work alone on procedures involving hazardous chemicals, biological agents, or other physical hazards* • *Never eat, drink, chew gum or tobacco, smoke, or apply cosmetics in the laboratory* • *Never use damaged glassware or other equipment*

If an employee has a severe or life threatening injury, call 330-941-3703 for emergency response. Serious occupational injuries, illnesses, and exposures to hazardous substances must be reported to campus police and EOHS at 330-941-3700 immediately. EOHS will investigate the accident, and complete exposure monitoring if necessary. Serious injuries include those that result in permanent impairment or disfigurement, or require hospitalization.

Examples include amputations, lacerations with severe bleeding, burns, concussions, fractures and crush injuries. As soon as PIs/Laboratory Supervisors are aware of a potentially serious incident, they must contact EOHS.

2.10.3 Fire-related Emergencies

If you encounter a fire, or a fire-related emergency (e.g., abnormal heating, smoke, burning odor), immediately follow these instructions:

1. Pull the fire alarm pull station and call 911 from a campus phone or cell phone.
2. Evacuate and isolate the area.
   a. Use portable fire extinguishers to facilitate evacuation and/or control a small fire (i.e., size of a small trashcan), if safe to do so.
   b. If possible, shut off equipment before leaving.
3. Close doors.
4. Evacuate the building when the alarm sounds. Remain safely outside the affected area to provide details to emergency responders. It is against state law to remain in the building when the alarm is sounding. If the alarm sounds due to a false alarm or drill, you will be allowed to re-enter the building as soon as the Fire Department determines that it is safe to do so. Do not go back in the building until the alarm stops and you are cleared to reenter.

If your clothing catches on fire, go to the nearest emergency shower immediately. If a shower is not immediately available, then stop, drop, and roll. A fire extinguisher may be used to extinguish a fire on someone's person. Report any burn injuries to the supervisor immediately and seek medical treatment. Call 911.

2.10.4 Chemical Spills

Chemical spills can result in chemical exposures and contaminations. Chemical spills become emergencies when:

- The spill results in a release to the environment (e.g., sink or floor drain)
- The material or its hazards are unknown
- Laboratory staff cannot safety manage the hazard because the material is too hazardous or the quantity is too large

Effective emergency response to these situations is imperative to mitigate or minimize adverse reactions when chemical incidents occur. In the event of a significant chemical exposure or contamination, immediately try to remove or isolate the chemical if safe to do so. When skin or eye exposures occur, remove contaminated clothing and flush the affected area using an eyewash or shower for at least 15 minutes. If a chemical is ingested, consult the SDS. Obtain medical assistance as indicated. Remember to wear appropriate PPE before helping others. PIs/ Laboratory Supervisors must review all exposure situations, make sure affected employees receive appropriate medical treatment and/or assessment, and arrange for containment and clean-up of the chemical as appropriate.

Laboratory personnel who have been trained in spill clean-up and with the appropriate materials can clean up small chemical spills. A small spill is generally defined as < 1 liter of chemical that is not highly toxic, does not present a significant fire or environmental hazard, and is not in a public area such as a common hallway. Broken Mercury Thermometers should not be cleaned by the laboratory. Please try to prevent the spread of the spilled mercury, and do not allow people to walk through the contaminated area. Call 330-941-3700 for assistance. Large chemical spills include spills of larger quantities, spills of any quantity of highly toxic chemicals, or chemicals in public areas or adjacent to drains. Large spills require emergency response. Call 911 from a campus phone or cell phone.

2.10.4.1 What to do with a Small Chemical Spill (<1 Liter)

Laboratory personnel can clean up small spills if trained and competent to do so. Small spills include chemical spills that are up to 1 liter in size and of limited toxicity, flammability, and volatility. If respiratory protection is needed for spill clean-up, the spill is too large to be handled by laboratory personnel – dial 911 from a campus phone or cell phone. Spill kits can be obtained from the Chemical Management Center at extension 3703.

Chemical Spill Kit:

- Sodium Bicarbonate or other acid cleanup powder
- Citric Acid of other base cleanup powder
- •Organic solvent cleanup powder
- Vermiculite or other diking material
- 1 pair neoprene or nitrile gloves
- 1 pair goggles
- 1 scoop
- Spill pillows, sorbent pads
- Disposable shoe covers (plastic bags may work)

Chemical Spill:

1. Evacuate all non-essential persons from the spill area.
2. If needed, call for medical assistance by dialing 911 from a campus phone or cell phone.
3. Help anyone who may have been contaminated. Use emergency eyewashes/showers by flushing the skin or eyes for at least 15 minutes.
4. Post someone just outside the spill area to keep people from entering. Avoid walking through contaminated areas.
5. You must have the proper protective equipment and clean-up materials to clean-up spills.
6. Check the chemical's SDS in your laboratory or online for spill clean-up procedures, or call EOHS for advice.
7. Turn off sources of flames, electrical heaters, and other electrical apparatus, and close valves on gas cylinders if the chemical is flammable.
8. Confine the spill to a small area. Do not let it spread.
9. Avoid breathing vapors from the spill. If the spill is in a non-ventilated area, do not attempt to clean it up. Call for emergency personnel to respond and clean up the spill.
10. Wear personal protective equipment, including safety goggles, gloves, and a laboratory coat or other protective garment to clean-up the spill.
11. Work with another person to clean-up the spill. Do not clean-up a spill alone.
12. DO NOT ADD WATER TO THE SPILL.
13. Use an appropriate kit to neutralize and absorb inorganic acids and bases. For other chemicals, use the appropriate kit or absorb the spill with sorbent pads, paper towels, vermiculite, dry sand, or diatomaceous earth. See below for additional information.
14. Collect the residue and place it in a clear plastic bag. Double bag the waste and label the bag with the contents.
15. Notify EOHS at extension 3703.

Weak Inorganic Acid or Base Spill Clean Up Procedure

1. Wear gloves, goggles, laboratory coat and shoe covers.
2. To clean-up a spill of weak inorganic acid or base, neutralize the spilled liquid to pH 5 to 8 using a neutralizing Agent such as:
   a. Sodium bicarbonate
   b. Soda ash
   c. Sodium bisulfate
   d. Citric acid
3. Absorb the neutralized liquid with an Absorbent such as:

   a. Sorbent pads
   b. Diatomaceous earth
   c. Dry sand

   d. Sponges
   e. Paper towels
   f. Vermiculite
4. Rinse the absorbent pads or sponges in a sink with water. Scoop or place the other absorbent materials into a clear plastic bag. Double bag and tag the bag with a chemical waste tag. Take it to your chemical waste pick-up.

Solvent Spill Clean Up Procedure

1. Absorb the spill with a non-reactive material such as:
   a. Vermiculite
   b. b. Dry sand
   c. c. Paper towels
   d. d. Sponges
2. Package as described above. Do not rinse or dispose of any chemicals down the sink or into any drain.

2.10.4.2 What to do with a Large Chemical Spill (>1 Liter)

Large chemical spills require emergency response. Call 911 from a campus phone or cell phone. If the spill presents a situation that is immediately dangerous to life or health (IDLH) or presents a significant fire risk, activate a fire alarm, evacuate the area and wait for emergency response to arrive.

- Remove the injured and/or contaminated person(s) and provide first aid.
- Call for emergency medical response.
- As you evacuate the laboratory, close the door behind you, and:
  - Post someone safely outside and away from the spill area to keep people from entering.
  - Confine the spill area if possible and safe to do so.
  - Leave on or establish exhaust ventilation.
  - If possible, turn off all sources of flames, electrical heaters, and other electrical equipment if the spilled material is flammable.
  - Avoid walking through contaminated areas or breathing vapors of the spilled material.
- Any employee with known contact with a particularly hazardous chemical must shower, including washing of the hair as soon as possible unless contraindicated by physical injuries.

APPENDIX A: References and Source Material

1.) Northwestern Laboratory Manual and Chemical Hygiene Plan
2.) UCLA Laboratory Manual and Chemical Hygiene Plan
3.) The Ohio State University Laboratory Manual
4.) Virginia Tech Laboratory Manual and Chemical Hygiene Plan
5.) Prudent Practices in the Laboratory. National Research Council. 2011
6.) Leggett, D. Chemical Reactivity Assessments in R&D. MRSC
7.) Parr No.230M Safety in the Operation of Laboratory Reactors and Pressure Vessels
8.) Pressure Classification of Reactions, NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals (2011 Edition) Annex C 45-39
9.) Safety in Academic Chemistry Laboratories. American Chemical Society (https://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/safety-in-academic-chemistry-laboratories-faculty.pdf)

APPENDIX B: Glossary

ACGIH - The American Conference of Governmental Industrial Hygienists is a voluntary membership organization of professional industrial hygiene personnel in governmental or educational institutions. The ACGIH develops and publishes recommended occupational exposure limits each year called Threshold Limit Values (TLVs) for hundreds of chemicals, physical agents, and biological exposure indices. AEROSOL - Liquid droplets or solid particles dispersed in air that are of fine enough size (less than 100 micrometers) to remain dispersed for a period of time.

ASPHYXIANT - A chemical (gas or vapor) that can cause death or unconsciousness by suffocation. Simple asphyxiants, such as nitrogen, either use up or displace oxygen in the air. They become especially dangerous in confined or enclosed spaces. Chemical asphyxiants, such as carbon monoxide and hydrogen sulfide, interfere with the body's ability to absorb or transport oxygen to the tissues.

"C" OR CEILING - A description usually seen in connection with a published exposure limit. It refers to the concentration that should not be exceeded, even for an instant. It may be written as TLV-C or Threshold Limit Value - Ceiling. (See also Threshold Limit Value).

CARCINOGEN - A cancer-producing substance or physical agent in animals or humans. A chemical is considered a carcinogen or potential carcinogen if it is so identified in any of the following:

- National Toxicology Program, "Annual Report of Carcinogens" (latest edition)
- International Agency for Research on Cancer, "Monographs"(latest edition)
- OSHA, 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances

CHEMICAL HYGIENE OFFICER - An employee who is designated by the employer and who is qualified by training or experience to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan.

CHEMICAL HYGIENE PLAN - A written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment, and work practices that are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and (2) meets the requirements of OSHA regulation 29 CFR 1910.1450.

COMBUSTIBLE LIQUID - Any liquid having a flashpoint at or above 100°F (37.8°C) but below 200°F (93.3°C) except any mixture having components with flashpoints of 200°F or higher, the total volume of which make up 99% or more of the total volume of the mixture.

COMPRESSED GAS - A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70°F (21.1°C), or; a gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C), or; a liquid having a vapor pressure exceeding 40psi at 100°F(37.8°C)as determined by ASTMD-323-72.

CORROSIVE - A substance that, according to the DOT, causes visible destruction or permanent changes in human skin tissue at the site of contact or is highly corrosive to steel.

DESIGNATED AREA - An area which has been established and posted with signage for work involving hazards (e.g., "select carcinogens," reproductive toxins, or substances which have a high degree of acute toxicity). A designated area may be the entire laboratory, an area of a laboratory, or a device such as a laboratory hood.

EMERGENCY - Any potential occurrence, such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment which could result in an uncontrolled release of a hazardous chemical into the workplace.

EXPLOSIVE - A chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to a sudden shock, pressure, or high temperature.

FLAMMABLE - A chemical that falls into one of the following categories:

1. Flammable aerosol - an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening;
2. Flammable gas - a gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13% by volume or less; or a gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12% by volume, regardless of the lower limit;
3. Flammable liquid - any liquid having a flashpoint below 100°F (37.8°C), except any mixture having components with flashpoints of 100°F (37.8°C) or higher, the total of which make up 99% or more of the total volume of the mixture; or
4. Flammable solid - a solid, other than a blasting agent or explosive as defined in1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and, when ignited, burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a greater than one-tenth of an inch per second along its major axis.
FLASHPOINT - The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite in the presence of an ignition source or when tested as follows:
1. Tagliabue Closed Tester (See American National Standard Method of Test for Flashpoint by Tag Closed Tested, Z11.24-1979 (ASTM D-56-79) for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100°F (37.8°C) or that contain suspended solids and do not have a tendency to form a surface film;
2. Pensky-Martens Closed Tester (See American National Standard Method of Test for Flashpoint by Pensky-Martens Closed Tester, Z11.7-1979 (ASTM D-73-79) for liquids with a viscosity equal to or greater than 45 SUS at 100°F (37.8°C), or that contain suspended solids, or that have a tendency to form a surface film under test; or,
3. Setaflash Closed Tester (See American National Standard Method of Test for Flashpoint of Set a flash Closed Tester (ASTM D-3278-78)). Organic peroxides, which undergo auto accelerating thermal decomposition, are excluded from any flashpoint determination methods specified above.
GENERAL VENTILATION - Also known as general exhaust ventilation, this is a system of ventilation consisting of either natural or mechanically induced fresh air movements to mix with and dilute contaminants in the workroom air. This is not the recommended type of ventilation to control contaminants that are highly toxic, when there may be corrosion problems from the contaminant, when the worker is close to where the contaminant is being generated, and where fire or explosion hazards are generated close to sources of ignition. (See Local Exhaust Ventilation)
GLOBALLY HARMONIZED SYSTEM (GHS) - The GHS is a system for standardizing and harmonizing the classification and labeling of chemicals. It is a logical and comprehensive approach to defining health, physical and environmental hazards of chemicals; creating classification processes that use available data on chemicals for comparison with the defined hazard criteria; and communicating hazard information, as well as protective measures, on labels and Safety Data Sheets (SDS).
HAZARD ASSESSMENT - A formal procedure undertaken by the supervisor in which occupational hazards for all employees are described per procedure or task, and by affected body part(s) or organ(s), and which is documented and posted in the workplace with all personal protective equipment requirements.
HAZARD WARNING - Any words, pictures, symbols or combination thereof appearing on a label or other appropriate form of warning that convey the hazards of the chemical(s) in the container(s).
HAZARDOUS MATERIAL - Any material that is a potential/actual physical or health hazard to humans.

HAZARDOUS MATERIAL (DOT) - A substance or material capable of posing an unreasonable risk to health, safety, and property when transported including, but not limited to, compressed gas, combustible liquid, corrosive material, cryogenic liquid, flammable solid, irritating material, material poisonous by inhalation, magnetic material, organic peroxide, oxidizer, poisonous material, pyrophoric liquid, radioactive material, spontaneously combustible material, and water reactive material.
HAZARDOUS CHEMICAL - A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents which damage the lungs, skin, eyes or mucous membranes. A chemical is also considered hazardous if it is listed in any of the following:

1. OSHA, 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances
2. “Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment,” ACGIH (latest edition)
3. “The Registry of Toxic Effects of Chemical Substances,” NIOSH (latest edition)

HIGHLY TOXIC - A substance falling within any of the following categories:

1. A substance that has a median lethal dose (LD50) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.
2. A substance that has a median lethal dose (LD50) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.
3. A substance that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

IGNITABLE - A solid, liquid or compressed gas waste that has a flashpoint of less than 140°F. Ignitable material may be regulated by the EPA as a hazardous waste as well.
INCOMPATIBLE - The term applies to two substances to indicate that one material cannot be mixed with the other without the possibility of a dangerous reaction.
IRRITANT - A substance which, by contact in sufficient concentration for a sufficient period of time, will cause an inflammatory response or reaction of the eye, skin, nose or respiratory system. The contact may be a single exposure or multiple exposures. Some primary irritants: chromic acid, nitric acid, sodium hydroxide, calcium chloride, amines, metallic salts, chlorinated hydrocarbons, ketones and alcohols.
LABEL - Any written, printed or graphic material displayed on or affixed to containers of chemicals, both hazardous and non-hazardous.
LABORATORY TYPE HOOD - A device located in a laboratory, enclosed on five sides with a movable sash or fixed partial enclosure on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.
LABORATORY USE OF HAZARDOUS CHEMICALS - Handling or use of such chemicals in which all of the following conditions are met:

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

LOCAL EXHAUST VENTILATION (Also known as exhaust ventilation) – A ventilation system that captures and removes the contaminants at the point they are being produced before they escape into the workroom air. The system consists of hoods, ductwork, a fan, and possibly an air-cleaning device. Advantages of local exhaust ventilation over general ventilation include: it removes the contaminant rather than dilutes it, requires less airflow and, thus, is more economical over the long term; and the system can be used to conserve or reclaim valuable materials; however, the system must be properly designed with the correctly shaped and placed hoods, and correctly sized fans and ductwork.

MEDICAL CONSULTATION -A consultation that takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.

MIXTURE - Any combination of two or more chemicals if the combination is not, in whole or in part, the result of a chemical reaction.

MUTAGEN - Anything that can cause a change (or mutation) in the genetic material of a living cell.

NFPA - The National Fire Protection Association; a voluntary membership organization whose aims are to promote and improve fire protection and prevention. NFPA has published 16 volumes of codes known as the National Fire Codes. Within these codes is Standard No. 705, "Identification of the Fire Hazards of Materials". This is a system that rates the hazard of a material during a fire. These hazards are divided into health, flammability, and reactivity hazards and appear in a well-known diamond system using from zero through four to indicate severity of the hazard. Zero indicates no special hazard and four indicates severe hazard.

NIOSH - The National Institute for Occupational Safety and Health; a federal agency that among its various responsibilities trains occupational health and safety professionals, conducts research on health and safety concerns, and tests and certifies respirators for workplace use.

ODOR THRESHOLD - The minimum concentration of a substance at which a majority of test subjects can detect and identify the substance's characteristic odor.

OXIDIZER - Is a substance that gives up oxygen easily to stimulate combustion of organic material.

PERMISSIBLE EXPOSURE LIMIT (PEL) - An exposure, inhalation or dermal permissible exposure limit specified in 8 CCR 5155. PELs may be either a time-weighted average (TWA) exposure limit (8-hour), a 15-minute short-term limit (STEL), or a ceiling (C).

PERSONAL PROTECTIVE EQUIPMENT -Any devices or clothing worn by the worker to protect against hazards in the environment. Examples are respirators, gloves, and chemical splash goggles.

PHYSICAL HAZARD - A chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive), or water-reactive.

PYROPHORIC - A chemical that will spontaneously ignite in the air at a temperature of 130°F (54.4o C) or below.

REACTIVITY - A substance's susceptibility to undergoing a chemical reaction or change that may result in dangerous side effects, such as explosion, burning, and corrosive or toxic emissions. Conditions that cause the reaction, (ex: heat, other chemicals, dropping), will usually be specified as "Conditions to Avoid" when a chemical's reactivity is discussed on an SDS.

REPRODUCTIVE TOXINS - Chemicals that affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis).

RESPIRATOR - A device that is designed to protect the wearer from inhaling harmful contaminants.

RESPIRATORY HAZARD - A particular concentration of an airborne contaminant that, when it enters the body by way of the respiratory system or by being breathed into the lungs, results in some body function impairment.

SAFETY DATA SHEET (SDS) - Written or printed material concerning a hazardous chemical which is prepared in accordance with paragraph (g) of 29 CFR 1910.1200 SELECT CARCINOGENS - Any substance which meets one of the following: 1. It is regulated by OSHA as a carcinogen; or 2. It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or 3. It is listed under Group 1 ("carcinogen to humans") by the International Agency for Research on Cancer Monographs (IARC) (latest editions); or 4. It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP.

SENSITIZER - A substance that may cause no reaction in a person during initial exposures, but afterwards, further exposures will cause an allergic response to the substance.

SHORT-TERM EXPOSURE LIMIT - Represented as STEL or TLV-STEL, this is the maximum concentration to which workers can be exposed for a short period of time (15 minutes) for only four times throughout the day with at least one hour between exposures. In addition, the daily TLV/TWA must not be exceeded.

SOLVENT - A substance, commonly water, but in industry often an organic compound, which dissolves another substance.

THRESHOLD LIMITVALUE (TLV) -Airborne concentration of substances devised by the ACGIH that represents conditions under which it is believed that nearly all workers may be exposed day after day with no adverse effect. TLVs are advisory exposure guidelines, not legal standards that are based on evidence from industrial experience, animal studies, or human studies when they exist. There are three different types of TLVs: Time-Weighted Average (TLV-TWA), Short-Term Exposure Limit (TLV-STEL), and Ceiling (TLV-C). (See also PEL).

TOXICITY - A relative property of a material to exert a poisonous effect on humans or animals and a description of the effect and the conditions or concentration under which the effect takes place.

VAPOR - The gaseous form of substances which are normally in the liquid or solid state (at normal room temperature and pressure). Vapors evaporate into the air from liquids such as solvents. Solvents with lower boiling points will evaporate faster.

Appendix C

Lab Inspection Form

Appendix D

Lab Signage

Appendix E

Standard Operating Procedure Template