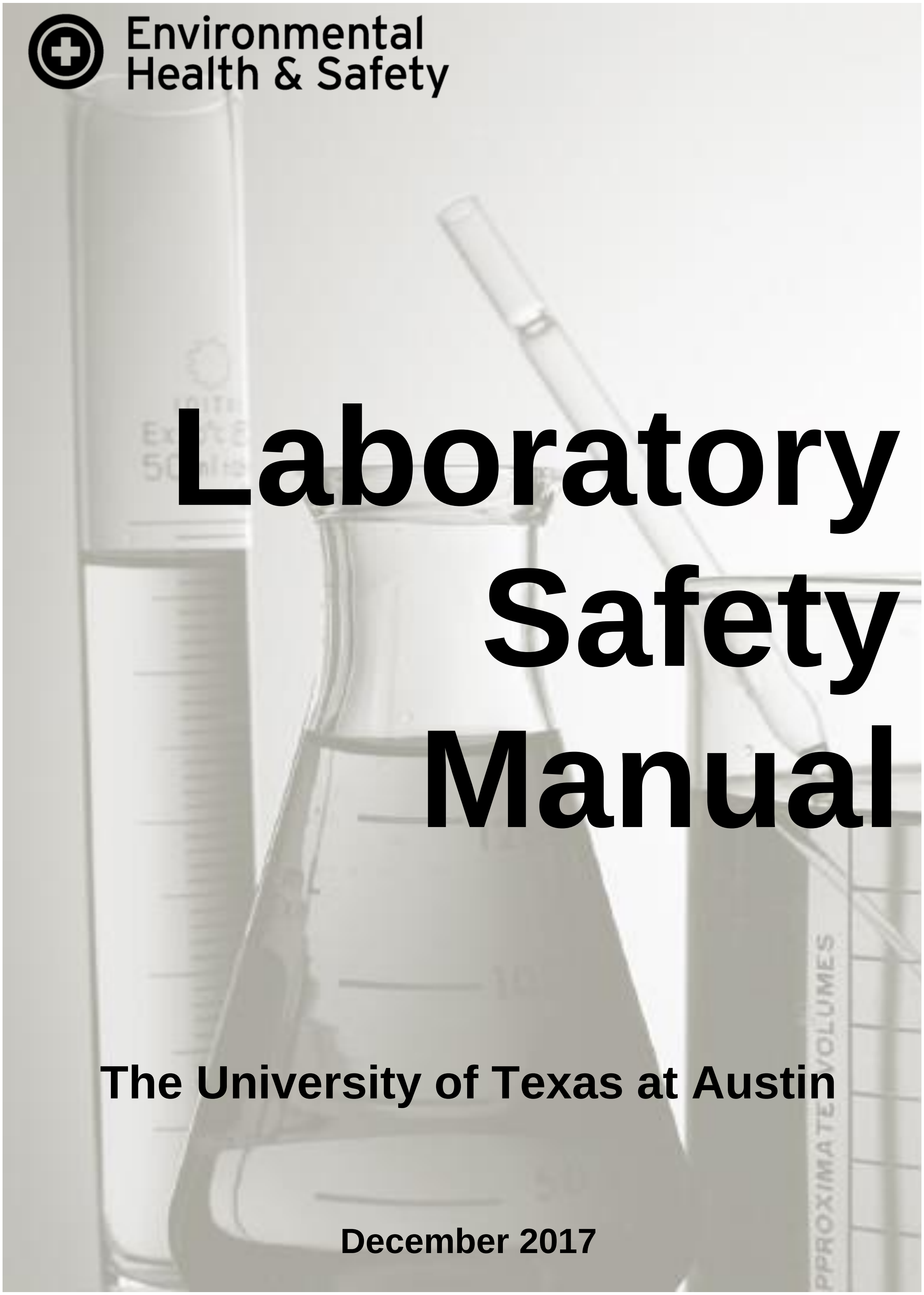

Environmental
Health & Safety

Laboratory Safety Manual

The University of Texas at Austin

December 2017

Laboratory Safety Manual

THE UNIVERSITY OF TEXAS AT AUSTIN
ENVIRONMENTAL HEALTH AND SAFETY

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Laboratory Safety Manual

Introduction

The University of Texas at Austin (UT Austin) is committed to maintaining the safest possible laboratories. We encourage faculty and researchers to take all reasonable precautions to protect the health and safety of everyone - staff, students, visitors and the general public. In other words, we want to keep you and those around you safe.

Laboratory operations can be dangerous whether you are working with hazardous materials or equipment or just performing common laboratory procedures. Every day there are incidents in teaching and research laboratories on university campuses across the U.S. Although many accidents are minor, there are also serious cases, including fatalities. Every year, UT Austin has multiple incidents in our laboratories. Our goal is to reduce that number and reduce accidental injuries.

This Laboratory Safety Manual has been prepared specifically for UT Austin by Environmental Health and Safety in collaboration with the faculty Research Safety Advisory Committee. The manual promotes safe and practical laboratory procedures. We have included information on the use of personal protective equipment (PPE), the use and storage of chemicals, hazard communication and the proper methods of waste disposal. This manual also covers emergency procedures and incident response should something go wrong.

It is important to recognize that this manual does not cover all the risks and hazards in every laboratory. There are a wide variety of hazardous materials handled in laboratories at UT Austin. Faculty and researchers know the most about the unique hazards in their laboratory. It is expected that the Principal Investigator will append any supplementary safety information to this manual pertinent to their specific laboratory.

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I. Responsibilities

Lab workers conducting chemical reactions, using chemicals, or performing laboratory procedures are required to have proper training in the safe handling and disposal of all materials they use. Each individual is responsible for conducting activities in a safe manner that complies with the applicable requirements of state and federal law as well as with university policies and procedures described in this manual. Oversight responsibility for ensuring that laboratory activities conform to prescribed standards is assigned as follows:

UNIVERSITY-WIDE LABORATORY SAFETY RESPOSIBILITIES

The President of the University

The President has ultimate responsibility for laboratory safety within the institution.

Environmental Health and Safety

- Provides training to laboratory personnel
- Conducts periodic and unannounced laboratory inspections
- Provides hazardous waste disposal services
- Provides hazardous material spill response services
- Reviews laboratory construction and renovation plans for safety design
- Conducts fume hood survey and testing
- Performs exposure monitoring upon request
- Provides guidance for maintaining compliance with federal, state, and local regulations, as well as the procedures stated in this manual
- Provides recommendations and assistance in obtaining personal protective equipment
- Investigates laboratory incidents and conducts follow-up activities to prevent future incidents
- Undertakes enforcement actions to ensure full compliance with all institutional safety policies, up to and including authority to shut down laboratories for violations of these policies

Personnel of the University

Personnel are responsible for following the procedures and faithfully executing the policies and responsibilities prescribed by this manual. Failure to do so is a serious breach of university policy and subject to disciplinary action that may include termination of employment at the university. If a lab is not in compliance with the safe operating procedures as outlined in this manual, EHS has the authority to close the lab until violations are corrected. Approval of the Dean is not required.

Facility Services

Facility Services maintains facilities and facility-related safety systems to assure continuous operation of laboratories.

Research Safety Advisory Committee (RSAC)

The RSAC is charged to act in an advisory and consultative capacity regarding the administration, implementation and coordination of policies and procedures for safety and environmental health in university research activities. The functions of this committee complement but do not overlap the responsibilities of the Institutional Biosafety Committee and the Radiation Safety Committee. Areas of consideration include regulatory compliance, training, inspections, hazardous materials management, waste minimization, emergency response, signage, and chemical/biological safety.

COLLEGE LABORATORY SAFETY RESPONSIBILITIES

Dean

- Responsible for ensuring the safe operation of all laboratories where hazardous materials are used or laboratory procedures are conducted
- Ensures compliance with all university's policies and procedures pertaining to laboratory safety
- Has independent enforcement authority to close a laboratory for safety violations
- Will appoint at least one Lab Safety Coordinator (LSC) for each College. Can appoint additional Lab Safety Coordinators for individual Departments. Will provide EHS with a list of LSCs.

Department Chairs and Directors

- Oversees laboratory safety within departmental laboratories
- Ensures laboratories complete and update annual inventories of hazardous chemicals as required by the university's Hazard Communication Program
- If authorized by the Dean, may appoint a Laboratory Safety Coordinator. Will serve as the LSC in the absence of the coordinator.

Laboratory Safety Coordinators

- Ensures laboratories develop and implement written site-specific safety policies
- Monitors procurement, safe practices and disposal of hazardous materials with EHS
- Ensures laboratories complete self evaluation forms
- Acts as a liaison with EHS to ensure inspection issues are corrected
- Notifies EHS if specialized training is needed
- Provides researchers technical guidance regarding lab safety issues
- Advises college administration on laboratory safety issues. Notifies EHS if issues require immediate action.
- Provides technical and administrative support for local safety committees
- Notifies EHS of incidents and near misses

Principal Investigators and Laboratory Supervisors

- Designs and conducts laboratory processes and operations to assure that personnel exposure to risk is minimized according to university policy
- Monitors the procurement, safe use, and proper disposal of hazardous materials

- Writes Standard Operating Procedures (SOPs) relevant to lab processes in their specific areas
- Instructs personnel on the contents of this manual and the location of the manual within the workplace
- Takes all reasonable precautions to protect the health and safety of laboratory workers and the environment
- Schedules hazardous waste disposal and oversees the handling of hazardous waste pending proper disposal
- Conducts laboratory safety self evaluations every semester (fall and spring)
- Completes and updates annual laboratory chemical inventories in accord with the instructions and schedule provided by EHS
- Inform personnel of the permissible exposure limits for the hazardous chemicals listed on inventories and the signs and symptoms associated with exposures to these chemicals
- Provides site specific training on laboratory hazards as described in the university's Hazard Communication Program
- Provides training and documentation for special procedures, activities or operations
- Provide appropriate personal protective equipment
- Ensures that all required safety equipment (fire extinguishers, fume hoods, flammable liquid storage cabinets, eye washes, safety showers, and spill cleanup kits) is available, in working order and that appropriate training for all safety equipment has been provided
- Maintains access to a current copy of a Material Safety Data Sheet (MSDS) for all hazardous chemicals in the laboratory
- Makes emergency telephone numbers available
- Reports to EHS if there is reason to believe that exposure levels for a hazardous chemical exceed the action level or the permissible exposure limits and document the incident
- Forwards documentation on laboratory accidents and exposures to EHS
- Provides for the safety of visitors

Personnel

- Maintains a thorough understanding of and follows the laboratory policies and procedures
- Uses and maintains required personal protective equipment (i.e. lab coats, safety glasses, goggles, face shields, respiratory protection, and gloves)
- Uses flammable liquid storage cabinets, acid storage cabinets, fume hoods, and other laboratory safety equipment provided
- Informs supervisor immediately of any laboratory safety equipment that is needed but not available or that is not in good working order
- Informs supervisor immediately of any exposure symptoms, accidents, or releases and documents incident
- Attends all applicable EHS laboratory safety training sessions
- Participates in the Occupational Health Program (OHP-Labs) if required as a condition of employment or as required by specific protocol

II. Emergency Procedures

All accidents, hazardous materials spills or other dangerous incidents must be reported to EHS. A list of telephone numbers must be posted on lab signs near laboratory entrances.

Telephone numbers should include:

- The Principal Investigator (or Laboratory Supervisor)
- UT Police Department (UTPD)/Austin Fire Department/Emergency Medical Services: 911
- Environmental Health and Safety (EHS): (512) 471-3511
- Occupational Health Services – Health Point (OHP): (512) 471-4647
- Building Manager
- Poison Control: 1-800-222-1222

Primary Emergency Procedures for Fires, Spills and Accidents

- In the event of a fire, pull the nearest fire alarm. If you are unable to control or extinguish a fire, follow the building evacuation procedures.
- Attend to any person(s) who may have been exposed and/or injured if it is safe to reach them. Use safety showers and eyewashes as appropriate. In the case of eye contact, promptly flush eyes with water for a minimum of 15 minutes and seek medical attention immediately.
- In cases of ingestion, contact the Poison Control Center
- In cases of skin contact, promptly flush the affected area with water and remove any contaminated clothing or jewelry. If symptoms persist after washing, seek medical attention.

Fire alarm pull station

- Notify persons in the immediate area about the spill, evacuating all personnel from the spill area and adjoining areas that may be impacted by vapors or a potential fire.
- If the spilled material is flammable, turn off all potential ignition sources. Avoid breathing vapors of the spilled materials. Be aware that some materials either have no odors or induce olfactory fatigue (i.e. the odor is detectable only briefly).
- Leave on or establish exhaust ventilation if it is safe to do so. Close doors to slow down the spread of odors.
- Notify EHS. Essential personnel familiar with the incident need to stay in communication with EHS.

If there is an immediate threat to life or health:

- Call UTPD for assistance.
- Give the nature and the extent of the emergency; be as specific and detailed as possible.

If the spill is minor:

Minor spill

- If you have been trained to respond, use a spill control kit to control material spilled. If you have not been trained, notify your supervisor.
- Determine the cleaning method by referring to the MSDS.
- If the spill is minor and of known limited danger, clean up immediately.
- Wear personal protective equipment during cleanup. The protective equipment required will depend upon the material spilled, the amount, and the airborne concentration. At a minimum a lab coat, chemical resistant gloves and goggles should be worn.
- Cover liquid spills with compatible absorbent material such as spill pillows.
- Powdered materials should be covered with wet paper towels (if compatible) to avoid dispersal. Corrosives should be neutralized prior to absorption. Clean spills from the outer areas first, cleaning towards the center.
- Place the spilled material into a waste container, seal it, attach waste tag and contact EHS for disposal.
- If appropriate, wash the affected surface with soap and water. Mop up the residues and place in container for disposal.
- Call EHS if you have questions or concerns with the clean up procedures, (512) 471-3511.

Special Procedures for Radioactive Hazards

(*In addition to these guidelines, refer to the University's Radiation Safety Manual*.)

- Do not take any action unless you have been trained to respond, except to summon assistance.
- If it is safe to do so, attend to anyone who may have been contaminated and/or injured. Use safety showers and eyewashes as appropriate. Notify EHS Radiation Safety Section (512) 471-3511 and obtain appropriate radiation meters and assistance.
- Notify the UT Police Department (911 on campus).
- Shut off ventilation, close windows and doors, and turn off hoods if possible. Do not do this if radioactive gas is involved, as release to the environment is preferable in that case.
- Remove all personnel from the immediate spill area to a safe meeting location in or near the lab.
- With the assistance of EHS Radiation Safety Section, check all personnel for skin and clothing contamination.
- Under the guidance of EHS Radiation Safety Section, decontaminate personnel and re-survey until radiation levels are at background.

Building Evacuation Procedures

Fire rescue team

- Building evacuation may be necessary if there is a chemical release, fire, explosion, natural disaster, or medical emergency.
- Be aware of the marked exits from your area and building.
- The evacuation alarm may have flashing lights and a loud continuous siren, horn or voice.
- To activate the building alarm system, pull the handle on one of the red boxes located in the hallway. If there is a fire, call UTPD at 911, give your name, and the building name, room number and size of the fire.
- Whenever the building evacuation alarm is sounded or when you are ordered to leave by the UTPD, EHS, or emergency response personnel, walk quickly to the nearest marked exit and ask others to do the same.
- Outside, proceed to a clear reassembly area that is at least 150 feet from the affected building. Keep walkways clear for emergency vehicles.
- To the best of your ability and without reentering the building, be available to assist UTPD and EHS in their attempts to determine that everyone has been evacuated safely.
- An Emergency Command Post will be set up near the emergency site by the emergency responders. Keep clear of the post unless you have important information to report.
- DO NOT re-enter the building until you are told to do so by the UTPD, EHS, or City of Austin responders.

III. Fundamentals of Laboratory Safety

1. Risk Assessment

A risk assessment should be done during the planning stage of any new or modified project. The risk assessment reviews the hazards associated with the project. This assessment should review the chemical properties, reactions/byproducts, procedural hazards, equipment used, potential routes of exposure as well as control measures to mitigate the hazards such as substitution using less hazardous chemicals or micro-scaling projects. It is recommended that risk assessment process be documented.

Resources for developing a risk assessment include reviewing Material Safety Data Sheets (MSDS), consulting published resources and contacting Environmental Health and Safety (EHS).

Risk assessment guidance can be found at Appendix E.

2. Standard Operating Procedures (SOPs)

Once a risk assessment is completed for a project, Standard Operating Procedures (SOPs) can be developed. SOPs should include:

- Personal protective equipment to be used
- Engineering controls such as fume hoods or other safety equipment
- Work practice controls such as designated areas or work restrictions
- Monitoring (if needed)
- Occupational Health requirements (if needed)
- Training requirements
- Storage, cleanup and waste disposal
- Emergency procedures

An example SOP can be found at Appendix E.

3. Training

The university requires that all individuals that work in a laboratory are adequately informed about the physical and health hazards present in the laboratory, the known risks, and what to do if an accident occurs.

a. Site Specific Training (OH 102)

Every laboratory worker must be trained to know the location and proper use of available personal protective clothing and equipment. The laboratory supervisor is responsible for providing information to their personnel about any hazards present in the lab. Document the training on the OH102 form and submit to EHS. This information must be provided at the time of a lab person's initial assignment and prior to any assignments involving new potential chemical exposure situations. The following lists the information that should be provided by the PI/Lab Supervisor:

1) Lab-specific standard operating procedures (SOPs) for the safe handling and use of hazardous materials (chemical, biological, radioactive).
2) Physical and health hazards (acute and chronic) associated with the materials.
3) Signs and symptoms associated with exposures to hazardous materials in the lab.
4) Methods and observation techniques to determine the presence or release of hazardous materials.
5) Procedures for using safety equipment including fume hood, biosafety cabinets, special ventilation or other equipment.
6) Location of signage including safety signs, emergency numbers and the Texas Hazard-Communication Employee notification poster.
7) The lab's housekeeping procedures.
8) Procedures for transporting hazardous materials safely across campus.
9) Inform personnel how to register for EHS safety training classes.
10) Storage location of chemicals and their segregation by compatibility.
11) Requirements for chemical labeling on primary and secondary containers.
12) Use, storage, and handling of gas cylinders and cryogenics.
13) Use of hazardous chemicals that warrant exposure monitoring.
14) Inform personnel how to request monitoring by EHS.
15) Location of machine guards and their use.
16) PPE requirements for personnel including; selection, maintenance and use.
17) How personnel can obtain PPE and how to dispose of PPE after use.
18) How to respond to an emergency including; exposures, first aid and evacuation route.
19) Location of emergency equipment including; spill kits, fire-fighting equipment, alarms, emergency shut-offs, eyewashes and safety showers.
20) Emergency procedures including how to clean up spills.
21) How to contact EHS in the event of an accident/injury.
22) Procedures for proper waste disposal including waste location and process for requesting waste disposal.
23) Procedure for accessing and using Material Safety Data Sheets and institutional Laboratory Safety Manuals (General, Radiation, Biosafety).
24) Occupational Health requirements such as medical evaluation, respirator fit-testing, or vaccinations.

Personnel must be re-trained when new chemical hazards are introduced into their workplace, or when new hazards are updated on applicable Material Safety Data Sheets (MSDS), as well as upon assignment to different workplaces that involve new chemical hazards or protective measures. Site-specific training must be conducted by the PI or lab supervisor.

In addition to the site specific training that is the responsibility of each Lab Supervisor, the following hazardous materials training is offered by EHS and is required for all lab personnel (graduate students, staff, faculty and visitors) that engage in laboratory activities:

b. Hazard Communication Training (OH 101) *Online*

Hazard Communication training is required for all personnel of UT Austin, including faculty, staff, students and visitors who have the potential for exposure to hazardous materials. Any work in a laboratory using hazardous materials meets the definition of the requirement. EHS offers this training on a regular schedule and it is available online. Training is required before the personnel can be assigned work in or around hazardous materials.

OH 101 training takes approximately 1.5 hours and includes:

- Central requirements of the act, including training, chemical labels, and Material Safety Data Sheets (MSDS)
- Spill clean-up and chemical disposal procedures
- Chemical storage guidelines
- Hazards specific to different chemical groups

c. Laboratory Safety Training (OH 201) *Online*

Laboratory safety training is required for all personnel of UT Austin, including faculty, staff, and students who may work in a laboratory using hazardous chemicals or biological materials. This training must be received prior to or within 30 days after the beginning of a laboratory assignment. EHS offers this training on a regular schedule and it is available online.

OH 201 training takes approximately two hours and includes:

- Safety equipment and practices
- Emergency procedures
- Emergency equipment
- Waste disposal

d. Fire Extinguisher Training (FF 205)

Provided by Fire Prevention Services, fire extinguisher training, with live fire suppression, is required for all laboratory workers.

FF 205 training covers:

- What to do in the event of a fire
- The behavior of fire and how it spreads
- The classes of fires
- The proper selection and use of a fire extinguisher

This training program will familiarize laboratory workers with the general principles of fire extinguisher use; give them confidence in their ability to operate extinguishers; and remove fears associated with putting out a fire by showing them successful fire extinguishers use.

e. Hazardous Waste Management Training (OH 202) *Online*

Hazardous waste management training is required for all laboratory personnel, including faculty, staff, and graduate students where hazardous chemicals or biological materials are in use. Every teaching lab must have one or more individuals that have received this training and are responsible for following the procedures included in the training. EHS only offers this training online.

The training takes approximately 1 hour and includes:

- Hazardous waste definitions and regulatory environment
- Spill clean-up and chemical waste disposal procedures
- Chemical waste storage and segregation guidelines
- Waste minimization
- Drain disposal

f. Bloodborne Pathogens and Biosafety Training (OH 218, OH 207) *Online*

Bloodborne pathogens and biosafety training is required for personnel of UT Austin, including faculty, staff, and graduate students who work in laboratories where infectious agents or human or non-human primate body fluids are in use. EHS offers this training on a regular schedule and can arrange special sessions with advance notice. This training is also available online.

OH 218 and 207 training takes less than two hours and may include, as appropriate to the attendees:

- Definition of a bloodborne pathogen
- Universal precautions
- Spill clean-up
- Practices and equipment required for work at different biosafety levels

g. Other Lab Safety Training Classes

Other laboratory safety classes include:

- Compressed Gases and Cryogens (OH 204)
- Laser Safety (OH 304)
- Radiation Safety (OH 301)
- X-Ray Safety (OH 306)

h. Checking Your Training History Online

You can check your training history online at: https://utdirect.utexas.edu/txclass/index.WBX

4. Personal Protective Equipment Policy

It is the Principal Investigator and/or Lab Supervisor's responsibility to provide all necessary personal protective clothing for laboratory workers. The university is responsible for providing basic safety equipment such as fire extinguishers, eyewashes and safety showers.

Refer to the *Basic Rules and Procedures for Working with Chemicals* section of this manual for further information on personal protection requirements.

Personal Clothing and Shoes in Labs

Personal clothing provides an additional layer of protection between PPE and the skin.

There have been a number of laboratory injuries where adequate personal clothing would have reduced the extent of an exposure.
EHS recommends that at a minimum, laboratory personnel who work with hazardous materials or are in the presence of hazardous materials that are in use wear a combination of proper personal clothing and PPE such as lab coats so essentially the skin is covered from the shoulders to the hands and feet.

Proper PPE

Improper PPE

EHS requires that closed-toed shoes be worn at all times in the laboratory. All shoes worn in the laboratory must have slip-resistant, non-absorbent soles. Sandals and perforated shoes are not allowed in the laboratory. Proper shoes reduce the potential for exposure to chemicals and injuries from broken glass and dropped items.

Personnel who want to wear shorts/sandals to campus should bring an additional change of clothing to work in the lab.

5. Chemical Procurement, Transport, and Storage

a. Procurement

Before a chemical is received, information on proper handling, storage, and disposal should be reviewed. Refer to the appropriate MSDS for further information. No container may be accepted into a laboratory without an appropriate identifying label. This label cannot be removed, defaced or damaged in any way.

b. Stockrooms/Storerooms

Toxic chemicals must be segregated in a well-identified area with local exhaust ventilation. Chemicals which are highly toxic or chemicals whose containers have been opened must be in unbreakable secondary containers. For example, place containers of concentrated acids or bases into acid cabinets or plastic tubs to help contain any leakage.

Properly labeled secondary storage container

Improperly labeled secondary storage container

Stored chemicals should be examined periodically (at least annually) for expiration dates, replacement, deterioration and container integrity. The labels must be checked to ensure they are still readable. If labels begin to fall off the container, attach new labels. If a label is becoming unreadable, affix a new label to the container with the identity of the contents, product date, health hazards (including target organs and manufacturer).

EHS can also make labels for chemical containers on request.

c. Transporting/Shipping

When chemicals are hand carried, place the container in an outside (secondary) container or bucket. Container carriers for breakable containers such as glass can be purchased through a variety of vendors. These secondary containers provide protection to the bottle. They also help to minimize spillage if the bottle breaks.

Use a cart if transporting more than 4 liters or two bottles of a chemical. When transporting chemicals on a cart, use a box or other secondary container to prevent containers from breaking or falling off the cart.

Freight-only elevators (when available) should be used when transporting chemicals. Avoid using stairs.

Chemicals that are shipped off-campus may need special packaging and may need to be shipped by trained certified personnel. Contact EHS for assistance with shipping chemicals.

d. Laboratory Chemical Storage (See Chemical Segregation Chart Appendix B)

Read the label carefully before storing a chemical. All chemicals must be stored according to their hazard class. Note that this is a simplified scheme and that in some instances chemicals of the same category may be incompatible.

Store all chemicals by their hazard class, and NOT IN ALPHABETICAL ORDER. Storing chemicals by alphabetical order will often result in the placement of incompatible chemicals being next to one another. Only within the segregation groups can chemicals be stored in alphabetical order. If a chemical exhibits more than one hazard, segregate by using the characteristic that exhibits the primary hazard.

Do not store chemicals or combustible materials near heat sources such as ovens, Bunsen burners, hot plates or steam pipes. Also, do not store chemicals in direct sunlight.

Date chemicals when received and first opened. If a particular chemical can become unsafe while in storage, (e.g., diethyl ether) then an expiration date should also be included. Keep in mind that expiration dates set by the manufacturer do not necessarily imply that the chemical is safe to use up to that date.

- Do not use work surfaces as permanent storage for chemicals. In these locations, the chemicals could easily be knocked over, incompatible chemicals may be alongside one another, and the chemicals will be unprotected in the event of a fire.
- Each chemical must have a proper designated storage location and be returned to their proper place after use.
- Make sure chemical lids are tightly closed to prevent chemicals from being released into the lab.
- Inspect your chemicals routinely for any signs of deterioration and for the integrity of the label. State law requires that **all** chemicals must be clearly labeled. Another benefit of labeling is to prevent chemicals from becoming "unknowns." (See Section III.7, Signs and Labels, for more information.)
- Avoid storing any chemicals in glass containers on the floor, unless positioned in such a way that they cannot be broken, (i.e. pushed under a table).
- Inspect shelving periodically to ensure that the shelving can support the chemicals.

Rusted shelf supports

Proper shelving

Bowed shelving

- Do not use fume hoods as a permanent storage location for chemicals, with the exception of highly odorous chemicals that require ventilation. Some chemical fume hoods have ventilated storage cabinets underneath for storage of frequently used chemicals that require ventilation. Also, avoid placing chemical containers on the edge of the fume hood, as these can easily fall and break.

Proper use of a fume hood

Improper storage in a fume hood

- Promptly contact EHS for the disposal of any old, expired, or unused chemicals. http://www.utexas.edu/safety/ehs/forms/chemrfd2.pdf
- Chemicals that require refrigeration must be sealed with tight-fitting caps and securely placed within the refrigerator. Lab-safe refrigerators/freezers must be used for cold storage of flammables. Refrigerators not specified as lab-safe can be a potential ignition source.
- Do not store hazardous chemicals above eye level. If the container breaks, the contents can spill onto your face and upper body.

Proper storage of chemicals below eye level

Improper storage of chemicals above eye level

- Do not store excessive amounts of chemicals in the lab. Buying chemicals in large quantities creates a serious fire hazard and limits work space.

Proper storage of flammable chemicals

Improper storage of flammable chemicals

- Chemical containers should not extend over the edge of shelves or be packed in too tightly.

6. Storage Cabinets

Specialized types of storage cabinets must be used in laboratories in order to separate incompatible chemicals from one another and to safely store all chemicals. All chemicals must be stored in a secure container, preferably within enclosed cabinets. Periodically check shelves and supports for corrosion.

a. Flammable Storage Cabinets

Flammables not in active use must be stored inside fire resistant storage cabinets. Flammable storage cabinets should be used for all labs that use flammable chemicals.

The cabinet design must meet National Fire Protection Association (NFPA) 30 & Occupational Safety and Health Administration (OSHA) 1910.106 standards.

Flammable storage cabinets are designed to protect the contents from the heat and flames of external fire rather than to confine burning liquids within. They can perform their protective function only if used and maintained properly.

Cabinets are typically designed with double-walled construction and doors which are two inches above the base (the cabinet is liquid-proof up to that point). Cabinet doors should be self-closing. Keep the doors closed.

Examples of flammable storage cabinets

b. Acid Storage Cabinets

Acids should be kept in acid storage cabinets specially designed to hold them. Such cabinets are made of plastic or metal coated with epoxy enamel to protect against corrosion. If not provided as part of the cabinet, use polyethylene trays to contain small spills.

Plastic tubs in a wooden cabinet are considered an acceptable substitute when acid cabinets are not available.

Proper and improper acid storage methods

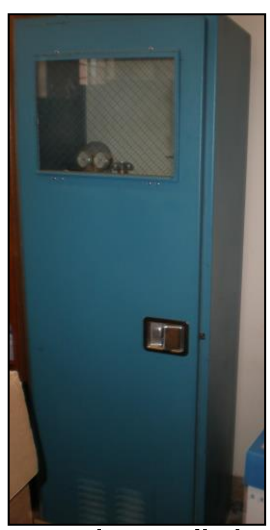
Proper acid storage

Nitric acid should always be stored in its own acid tray or in a separate acid cabinet compartment.

Improper storage of nitric acid

c. Compressed Gas Cylinder Cabinets

Cylinders containing the compressed gases listed in this section must be kept in a continuously, mechanically ventilated enclosure.



Compressed gas cylinder cabinet

All compressed gas cylinders having a NFPA Health Hazard Rating of 3 or 4 (e.g. ammonia, chlorine, phosgene) and those with a Health Hazard Rating of 2 but no physiological warning properties (e.g. carbon monoxide) must be kept in a gas cylinder cabinet. EHS can help you determine the Health Hazard Rating of compressed gases.

Full size cylinders must be stored in a gas cylinder cabinet while smaller cylinders, e.g., lecture bottles, can be stored in a chemical fume hood, a storage cabinet under the fume hood (if ventilated), or some other ventilated enclosure. No more than two small cylinders should be stored in single cabinet. When stored in a cabinet or hood, small cylinders must be positioned and secured so that they will not fall out and be fixed to a stationary object.

Compressed gas cylinder cabinets must meet NFPA 55 and the following requirements: negative pressure in relation to the surrounding area with the exhaust from the cabinet going to the outside of the building, self-closing doors, and internally sprinklered or installed in a sprinklered area.

Cylinders stored in gas cylinder cabinets or other ventilated enclosures must be secured at all times. Cylinders should be firmly secured at their center of gravity, not near the top or bottom.

Acceptable method of securing a gas cylinder

Unacceptable method of securing a gas cylinder

Hazardous gases include:

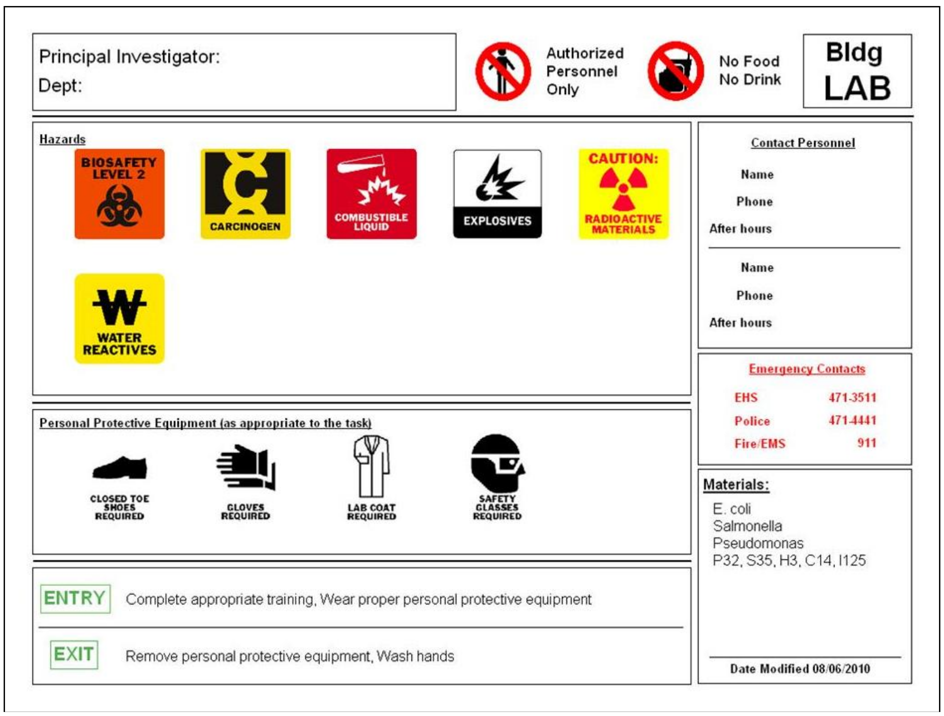
Acetylene	Fluorine
Ammonia	Formaldehyde
Arsenic Pentafluoride	Germane
Arsine	Hydrogen Chloride, anhydrous
Boron Trifluoride	Hydrogen Cyanide
1,3 - Butadiene	Hydrogen Fluoride
Carbon Monoxide	Hydrogen Selenide
Carbon Oxysulfide	Hydrogen Sulfide
Chlorine	Methylamine
Chlorine Monoxide	Methyl Bromide
Chlorine Trifluoride	Methyl Chloride
Chloroethane	Methyl Mercaptan

Cyanogen
Diborane
Dichloroborane
Dichlorosilane
Dimethylamine
Ethane
Ethylamine
Ethylene Oxide
Nitrogen Oxides
Phosgene
Phosphine
Silane
Silicon Tetrafluoride
Stibine
Trimethylamine
Vinyl Chloride

7. Signs and Labels

Prominent signs and labels of the following types should be used:

- Laboratory signs, including emergency contacts and chemical inventory, must be posted outside each work area
  - ➢ Emergency Instruction signs must be prominently posted on the wall outside the lab.



Example of a laboratory sign

- Chemical containers must be labeled, showing container contents and its associated hazards.
- Labels on all chemical containers should not be removed or defaced (unless the container is empty and ready for disposal).
- Secondary Containers
  - ➢ When a chemical is transferred from the original container into another container, e.g. a solvent wash bottle, for other than immediate use, it is called a secondary container.
  - ➢ Secondary containers must be labeled with the name of the chemical (common name or abbreviation or chemical structure). This does not apply to reaction vessels

or to bench top research apparatus in active use.

- The PI or Lab Supervisor is responsible for compliance with labeling chemical containers.
- EHS Waste Disposal Tags must be filled out and affixed to waste containers to identify the container as "Waste”.
- Notification Posters
  - Personnel notification posters describing rights under the Texas Hazard Communication Act must be posted in common building areas.
  - Posters should be a current version.
- Location signs for safety equipment, first aid equipment, and exits are recommended.
- Warning signs are posted at areas or equipment where special or unusual hazards exist.

8. Records

a. Hazardous Chemical Inventory

Maintaining current records of hazardous chemicals assists in implementing proper storage and safety procedures and is necessary for emergency response pre-planning, both by EHS and the City of Austin Emergency Services. It is the Lab Supervisor’s responsibility to keep an updated hazardous chemical inventory on file with EHS. This inventory should be updated periodically.

Lab personnel should also keep usage records of high-risk substances.

b. Laboratory Incidents

Lab supervisors should document and report any lab incidents to EHS as soon as possible. Personnel who are exposed/injured in a laboratory should contact Occupational Health and complete a First Report of Injury or Illness form. This form is available from Human Resources.

Any medical records associated with a person's exposure to hazardous materials will be maintained by The university in accordance with state and federal regulations. Occupational Health will maintain medical records related to laboratory safety.

c. Monitoring

EHS maintains records whenever monitoring of hazardous materials is performed.

d. Material Safety Data Sheets (MSDS)

Material Safety Data Sheets (MSDS) provide information on hazardous chemicals and must be readily available for all hazardous chemicals in the lab. MSDS are available online and from EHS. If paper copies are maintained, they should be quickly available.

Information on the university’s Hazard Communication plan can be found at: http://www.utexas.edu/safety/ehs/train/hazcom97/hazcom2000.PDF

9. Occupational Health Program

a. Procedures for Authorizing Medical Treatment

It is the responsibility of every Lab Supervisor to promptly contact EHS when a suspected exposure to hazardous materials has occurred. The Lab Supervisor will provide details of the exposure, including the identity of the material, a description of the conditions under which the exposure occurred, a description of the signs and symptoms of the exposure, and the MSDS.

In the event of serious adverse symptoms or injury, medical attention should be sought prior to notification of EHS. When the need is not immediate, EHS will advise exposed personnel to contact Occupational Health. This notification will request that employees contact the HealthPoint Occupational Health Program (OHP) for consultation at (512) 471-4OHP (4647) and that students in a non-employment status consult with a qualified medical provider for consultation.

A medical examination or consultation for lab personnel will be made available by UT Austin under the following circumstances:

- Whenever a lab employee develops signs or symptoms associated with a hazardous chemical to which that person may have been exposed in the laboratory
- Where exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the Permissible Exposure Level PEL) for an OSHA regulated substance, for which there are exposure monitoring and medical surveillance requirements; medical surveillance will be established for the affected personnel as prescribed by the particular standard
- Whenever an event takes place in the work area such as a spill, leak, explosion, or other occurrence resulting in the likelihood of a hazardous exposure, the affected personnel will be provided an opportunity for a medical consultation. The consultation will determine if there is a need for additional medical services.

All medical exams and consultations described under this Medical Program section will be performed by or under the delegation of a licensed physician and will be provided at UT Austin’s expense, without loss of pay and at a reasonable time and place. The arrangements for a medical consultation or exam for employees will be made with the assistance of the HealthPoint OHP, unless it is an emergency.

If known, EHS will provide details of the exposure (identity of the hazardous material, a description of the conditions under which the exposure occurred, a description of signs and symptoms of exposure, and the applicable MSDS, and any other relevant information) to the health care provider.

For medical emergencies, call 911 and for transport to the nearest hospital. If the injury involves an animal, chemical or biological exposure on main campus, request transport to St. David's Hospital.
For minor work related injuries, employees may seek treatment from the HealthPoint OHP clinic located in the Student Services Building (SSB), room 3.202. Call first for an appointment at (512) 471-4OHP(4647) or email HealthPoint.OHP@austin.utexas.edu

For non-emergency injuries that require treatment during periods of OHP closure, you may contact any health care provider including your own physician so long as they accept workers' compensation. Note: University Health Services (UHS) does not accept workers’ compensation or work related injuries. Students in a non-employment status may seek urgent care from UHS (see sub-section 9c below).

Urgent care clinics that accept workers' compensation include but are not limited to:

- Concentra Medical Centers
- ProMed Medical Clinics
- St. David's Occupational Health Services. **Call 544-8195** to schedule an appointment.
- Texas MedClinic

b. Physician's Written Opinion

If a medical consultation or exam is performed, HealthPoint OHP will obtain a written opinion from the examining physician which includes the following information:

- Any recommendation for further medical follow-up
- The results of the medical examination and any associated tests
- Any medical condition which may be revealed in the course of the examination which may place the lab person at increased risk as a result of exposure to a hazardous chemical found in the lab
- A statement that the lab person has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment

The written opinion cannot reveal findings of diagnoses unrelated to occupational exposure. HealthPoint OHP may release the physician's written opinion to EHS or others involved in the accident investigation to further the purpose of providing a safe working environment for employees and/or to meet regulatory reporting requirements.

c. University Health Services

During normal university hours, UHS on main campus is available for routine care of students who are injured or ill in their student capacity. UHS does not treat work injuries. UHS maintains an Urgent Care Clinic open for limited hours in the evenings and on weekends. During these times, a small after-hours fee is charged.

Hours and advice can be obtained by calling the UHS 24-hour Nurse Advice Line at (512) 475-NURS (512-475-6877). If care is needed that UHS cannot provide or when UHS is closed, students may seek care from local emergency rooms that are in close proximity to the university, e.g., St. David's, Seton, Brackenridge, etc.

10. Chemical Waste Disposal Program

Chemical wastes are regulated by the Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act (RCRA). Laboratory Supervisors are responsible for advising laboratory workers on how to handle *all* wastes generated in laboratory operations.

Information on the disposal of hazardous waste can be found at: http://www.utexas.edu/safety/ehs/disposal/procedures/

a. Chemical Waste Containers

Containers used for hazardous waste must be in good condition, free of leaks, and compatible with the waste being stored in them. A waste container should be opened only when it is necessary to add waste, and should otherwise be closed. Hazardous waste must not be placed in unwashed containers that previously held an incompatible material (see chart in Appendix B for examples of incompatible chemicals).

If a container holding hazardous waste is not in good condition or if it begins to leak, transfer the waste from this container into a container that is in good condition, pack the container in a larger and non-leaking container, or provide other secondary containment so the waste prevents the potential for a release or contamination. Contact EHS at (512) 471-3511 if assistance is required.

A storage container holding a hazardous waste that is incompatible with any waste or other materials stored nearby in other containers must be separated from the other materials or protected from them by means of a partition, wall, or other secondary containment device.

All waste containers:

- Must be marked with the word “waste” or “spent” and their contents listed on the waste tag.
- List specific chemicals. It is not sufficient to list waste as “halogenated” or “non-halogenated”.
- Containers should have EHS waste disposal tag attached.

Waste container with EHS waste disposal tag attached

Waste container without proper identification

- **No** container should be marked with the words “hazardous” or “non-hazardous.”
- Remove or deface old labels.
- Must be kept at or near (immediate vicinity) the site of generation and under control of the generator.
- Must be compatible with contents (i.e. acid should not be stored in metal cans).
- Must be closed at all times except when actively receiving waste.

Properly closed waste container

Open waste container

- Waste tags should be complete before pickup is requested.
- Must be safe for transport with non-leaking screw-on caps.
- Must be filled to a safe level (not beyond the bottom of the neck of the container or a 2-inch head space for 30 gallon drums).

Note:

- ➢ Do not use biological waste containers or sharps containers for hazardous chemical waste collection.
- ➢ Do not put broken glassware that is contaminated with chemicals in glass disposal boxes.
- ➢ Contact EHS for assistance with contaminated sharps or glassware.

b. Accumulation of Chemical Waste

A generator of potentially hazardous waste may not accumulate more than 55 gallons of waste, or one quart of acutely hazardous waste (see Hazardous Waste Manual for list of acutely hazardous waste) at or near the point of generation.

If a process will generate more than this volume at one time, EHS must be contacted in advance to arrange a special waste pick up. Hazardous waste in excess of 55 gallons cannot be stored at your site for more than three days; therefore EHS requires advance notice of generation in order to determine if the waste meets the definition of hazardous and to arrange for prompt removal.

It is essential that the generator keep incompatible hazardous wastes separated. Mixing wastes can make it more difficult and expensive to dispose. In all cases, do not mix incompatible wastes or other materials in the same container or place wastes in an unwashed container that previously held an incompatible waste or material.

Labeling Containers for Pick-Up by EHS

- Before chemical waste can be picked up by EHS, a waste tag is required
- It should be filled out by the waste generator and attached to each container at all times. The information on the tag is used to categorize and treat the waste.
- Fill out tag legibly, accurately, and completely.

c. Submitting Requests for Disposal of Chemical Waste to EHS

When a chemical waste container is ready for disposal and is properly tagged, the laboratory supervisor should contact Environmental Health and Safety through submittal of a request form.

11. Laboratory Evaluations

EHS inspects all labs at the Main Campus, Dell Pediatric Institute, Pickle Research Campus, the Marine Science Institute, and other outlying locations on an annual basis. Information on the lab inspection program can be found at:
http://www.utexas.edu/safety/ehs/lab/labinspection.html

a. Self Evaluations

Labs are also expected to perform laboratory safety self evaluations within the first sixty days of each semester. A copy of the self evaluation must be sent to EHS upon completion.

12. Minors (Children) in Laboratories

This section of the manual provides guidance to principal investigators and research personnel regarding minors in laboratories or other potentially hazardous facilities. The presence of minors in hazardous areas raises concerns for their safety as well as the safety or workers in the hazardous areas whose attention might be diverted by the presence of minors.

Scope

This section applies to all university laboratories and animal facilities. It covers all minors whether students, employees, or volunteers. Minors under the age of 15 are NOT PERMITTED inside research/animal laboratories at the university that contain hazardous materials or devices.

It is intended for all university faculty, staff, students, visiting minors, and their sponsors and includes all persons under age 18, whether students, employees, or volunteers.

Policy

- No person under the age of 15 is allowed in a university laboratory that contains hazardous materials. This age limit applies unless the laboratory activity is specifically designed for children below the age limit or the children are research study participants. In addition, a signed parental/guardian consent may be required for the minor to participate in either activity.

- Laboratories include facilities where there are hazardous chemicals, biological or radiological agents/devices used or stored, where laboratory animals are present or Class 3B and 4 lasers.

- Minors who are on a tour of a laboratory must be escorted at all times. All hazardous materials and equipment must be secured and made safe.

Exceptions

- No person under the age of 18 may access a university laboratory with the exception of:
  - Minors enrolled in an academic degree program at the university who are participating or observing in laboratories as a part of their course work.
  - Minors who are employed at the university and whose employment responsibilities are in the laboratory.
  - Minors who are subjects in approved studies.*
  - Minors who are volunteers or interns in the laboratory in a formal internship training program approved in writing by the appropriate Department Chair or unit head. *
  - Minors who are participating in a formal mentoring program with an individual faculty member approved in writing by the appropriate Department Chair or unit head.*
  - Minors who are participating in a university-sponsored program.*
  - Minors whose presence in the laboratory is for a specific educational purpose (i.e., tours)
  - Minors who are accompanied by and under direct, continuous and active supervision of a parent or legal guardian.
  - Other exceptions will be reviewed on a case-by-case basis with written approval by the Director of Environmental Health and Safety

*A signed parental/guardian consent is required.

Requirements

- Minors of any age who qualify under one or more of the exceptions listed prior may be in a university laboratory or other potentially hazardous area only if:
  - The minor has been authorized by the Department to be in that specific laboratory or facility.
  - A designated faculty member or administrator is assigned primary responsibility for ensuring that the minor is supervised, trained and provided Personal Protective Equipment
  - The minor has reviewed and signed the Guidelines for Non-student, Non-employee Visitors in Researcher Laboratories and the required releases.* http://www.utexas.edu/provost/policies/lab/
  - Appropriate hazard-specific safety training is completed and has been documented by the Principal Investigator/Sponsor.*
  - The minor is informed of the proper emergency/evacuation policies and procedures specific to the laboratory, department and the University.*
  - Personal protective equipment specific to the hazard, is provided to the minor with instructions for use and disposal.*
  - The minor is continuously and actively supervised by a knowledgeable and experienced adult University employee (i.e. the faculty member, principal investigator, adult researcher, or designated supervisor) at all times.
  - The laboratory/facility is in full compliance with all applicable university safety programs and regulations.
  - The faculty member, principal investigator, laboratory manager, or designated supervisor may place additional restrictions on the presence of minors in their specific activity areas.

*The minor must also demonstrate an effective understanding of the topic.

High Hazard Areas

- All minors (including the exceptions listed above) are not allowed in any of the following "high hazard areas":
    - Any laboratory designated as Biosafety Level 3 or follows BSL-3 practices.
    - Any laboratory where explosives, acute/reproductive toxins or carcinogens are used or stored.
    - Any animal housing or procedure area considered high risk (contact the ARC Director for a case-by-case determination)
    - Other high hazards areas (radiation, lasers, etc…) as determined by Environmental Health and Safety

Children of University Personnel

Children are allowed to be in areas adjacent to the laboratory (i.e., an office or break room within the laboratory) if they are supervised.

Compliance

The faculty member, principal investigator, or laboratory supervisor/manager is directly responsible for compliance with this policy and for the safety of all minors who are approved to be in their areas under this policy. Non-compliance must be reported to a supervisor, and failure to comply with the conditions of the policy may result in disciplinary action .

IV. Basic Guidelines for Working with Hazardous Materials

1. General Rules

a. Laboratory Protocol

Everyone in the lab is responsible for their own safety and the safety of others.

Before starting any work in the lab, personnel should be familiar with the procedures and equipment being used. Lab personnel should be aware of the chemical hazards before working with them. Personnel who are unfamiliar with the hazardous material or a new procedure should consult their supervisor.

MSDS information available here: http://www.utexas.edu/safety/ehs/msds/

The following guidelines are recommendations for working safely in a lab:

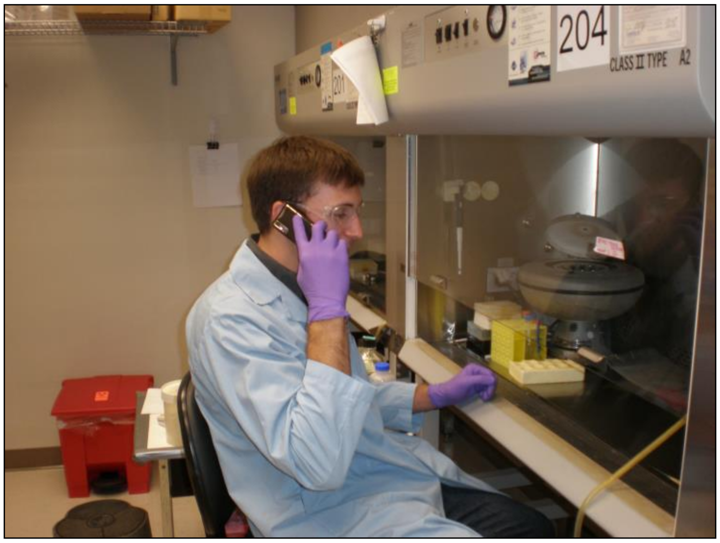
Personal Safety Practices

- Lab coats, gloves and safety glasses should be worn as appropriate in all laboratories.
- Do not wear shorts, sandals, or open-toed shoes in lab.
- Minors or personal pets are not permitted in laboratories.
- Do not mouth pipette.
- Secure any dangling jewelry, restrain loose clothing, and tie back long hair that might get caught in equipment before starting work.
- Food and drink should not be consumed in the lab.
- Do not store food and drinks in laboratory refrigerators.

Refrigerator sign

- Avoid working alone in the lab. If you must work alone, make someone (such as a supervisor) aware of your location.
- Wash your hands frequently throughout the day and before leaving the lab.
- Do not wear lab coats, gloves, or other personal protective clothing outside of lab areas. This clothing may have become contaminated and you could spread the contamination.

- Cell phones and use of music headphones should be avoided while working in the lab. They can be distracting and thereby increase the potential for an accident to occur. They can also become contaminated if handled while working with hazardous materials.



Cell phones should not be used while working in the lab

Housekeeping and Decontamination

- Work areas must be kept clean and free of unnecessary chemicals. Clean the work area throughout the day and before leaving the lab for the day.
- If necessary, clean equipment after use to avoid the possibility of exposing the next person who uses it.
- Keep all aisles and walkways in the lab clear to provide a safe walking surface and an unobstructed exit. Do not block doors.
- Do not block access to emergency equipment (i.e. fire extinguishers, eyewashes, etc.), emergency shut-offs, and utility controls (i.e. electrical panels).

Cluttered workspace. Emergency eyewash obstructed.

Blocked fire extinguisher

b. Accidents and Spills

See the Emergency Procedures section for detailed procedures. Do not clean up spills unless trained to do so.

Supplies for cleaning up minor spills should be readily available. In case of release, promptly clean up spills using appropriate personal protective equipment (PPE).

Spill Response Equipment
Supplies for a chemical spill should include:

- An inert absorbent such as kitty litter or vermiculite or a 50/50 mixture of the two or a commercial absorbent
- A plastic (non-sparking) scoop, plastic bags for the spilled material
- Chemical resistant gloves
- Goggles
- Sodium bicarbonate to neutralize acids.

Items that should be included in a spill kit

Note: All spent spill clean-up materials should be disposed of in the same manner as the spilled chemical or biological material. Spill clean-up supplies should be checked and re-stocked as necessary. Dispose of clean-up material through the EHS waste disposal program.

c. Steps to Prevent Routine Exposure

- Develop and encourage safe habits
- Avoid unnecessary exposure to chemicals by any route
- Do not smell or taste chemicals
- Vent any apparatus which may discharge toxic chemicals (e.g., vacuum pumps, distillation columns) into local exhaust devices such as fume hoods

- Inspect gloves and test glove boxes before use
- Do not allow release of toxic substances in cold rooms or warm rooms, since these have contained, re-circulated air

d. Equipment and Glassware

EHS recommends the following guidelines for the use and care of glassware and other laboratory equipment:

Glassware and Glass Bottles

- Inspect all glassware before use. Discard any broken, cracked, or chipped glassware.
- Tape or shield glass vacuum vessels to prevent flying glass in the case of an implosion. Also, tape or shield glass vacuum desiccators.
- Transport all glass chemical containers in rubber or polyethylene bottle carriers when leaving one lab area to enter another. Use a cart if transporting more than two bottles.

Bottle carrier

- Fire-polish all cut glass tubing and rods before use.
- Practice the following when inserting glass tubes or rods into stoppers:
  - ➢ Be certain that the diameter of the tube is compatible with the diameter of the stopper.
  - ➢ Fire-polish the end of the glass tube.
  - ➢ Lubricate the glass with water or glycerol.
  - ➢ Wear heavy gloves and hold the glass not more than two inches from the end to be inserted.
  - ➢ Insert the glass carefully with a twisting motion.
  - ➢ Remove stuck tubes by slitting the stopper with a sharp knife.

Assembly of Laboratory Apparatus

- Firmly clamp apparatus and set up away from the edge of the lab bench.
- Only use equipment that is free from cracks, chips, or other defects.
- If possible, place a pan under a reaction vessel or other container to contain liquid if the glassware breaks.

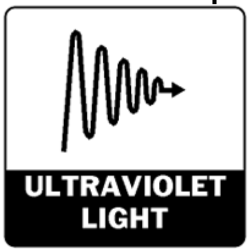
- Do not allow burners or any other ignition sources nearby when working with flammable liquids.
- Lubricate glass stopcocks.
- Properly support and secure condensers and water hoses with clamps and wires. Be sure to direct the water hoses so that any drips that come off the hoses do not splash down onto any electrical wires.
- Position apparatus that is attached to a ring stand with the center of gravity over the base and not to one side.
- Assemble the apparatus so that burners or baths can be removed quickly.
- Use an appropriate vapor trap and confine the setup to a fume hood if there is a possibility of hazardous vapors.
- Put the setup in a fume hood whenever conducting a reaction that could result in an implosion or explosion. Keep the sash pulled down. If it is not possible to use a fume hood, use a standing shield that is stabilized and secured.

Centrifuges

- Securely anchor tabletop centrifuges and place in a location where the vibration will not cause lab equipment to fall off the bench top.
- Keep the centrifuge lid closed while operating and do not leave the centrifuge until you are certain it is running safely without vibration.
- If the centrifuge starts vibrating, stop and check the load balances.
- Regularly clean rotors and buckets with a non-corrosive cleaning solution.
- Use sealed safety cups while centrifuging hazardous materials.

Sealed safety cups being used in a centrifuge

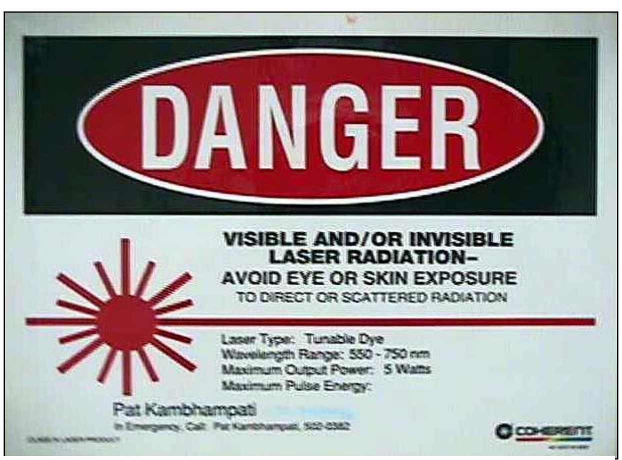
Ultraviolet Lamps



- Wear ultraviolet absorbing protective safety glasses while working with ultraviolet light.
- Protect your skin from potential burns due to ultraviolet light.
- Shield any project in which ultraviolet light is used to prevent escape of the direct beam or scattered radiation.

Lasers

- Always wear goggles that protect against the specific wavelength of the laser.
- Never look directly at the beam.
- Do not allow any reflective materials in or along the path of the beam.
- Post warning signs in all laser areas. If required, use a flashing light at the lab entrance to indicate when a laser is in use.



Laser warning sign

Laser warning light

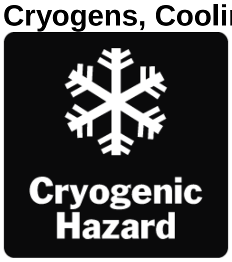
- Consult the EHS Laser Safety Manual for more information or contact the Laser

Safety Officer at EHS.

Separatory Funnels

- Use extreme caution if the temperature of the materials is elevated.
- When a volatile solvent is used, swirl the unstoppered separatory funnel first to allow some solvent to vaporize and to release pressure.
- Close the funnel and invert it with the stopper held in place, then immediately open the stopcock to release pressure.
- Do not vent the separatory funnel near a flame or any other ignition source.
- Do not point the funnel at a co-worker. Be aware of nearby co-workers.
- Vent the separatory funnel into a fume hood.
- Close the stopcock, swirl the funnel, then immediately open the stopcock with the funnel in an inverted position to vent the vapors again.

Cryogens, Cooling Baths and Cold Traps



- Always use caution when working with cryogenic coolants.
- Use temperature resistant gloves and a face shield while slowly immersing an object to be cooled.
- Do not pour cold liquid onto the edge of a glass Dewar flask when filling because the flask may break and implode.
- Never lower your head into a dry ice chest; no oxygen is present.
- Wear temperature resistant gloves while handling dry ice. If no protection is used, severe burns can result.

Vacuum Pumps

Vacuum pump

Mechanical vacuum pumps used in laboratories pose many hazards. There are mechanical hazards associated with the moving parts. There are chemical hazards of contaminating the pump oil with volatile substances and subsequently releasing them into the lab. There are also fire hazards when pumps malfunction or overheat and ignite nearby flammable or combustible materials.

Follow these guidelines for safe pump operation:

Physical (injuries/fires)

- Ensure that pumps have belt guards in place during operation to prevent hands or loose clothing from getting caught in the belt pulley.
- Ensure that electrical cords and switches are free from defects.
- Do not place pumps in an enclosed, unventilated cabinet allowing heat and exhaust to build up.
- Do not operate pumps near containers of flammable chemicals, flammable chemical wastes, or combustible materials such as paper or cardboard.
- Use correct vacuum tubing (thick walls) not thin Tygon-type hoses.
- Replace old tubing; crumbly tubing can degrade performance.
- Use the shortest length of tubing that reaches where needed.

Chemical

- Do not use solvents which might damage the pump.
- Always close the valve between the vacuum vessel and the pump before shutting off the pump to avoid sucking vacuum oil into the system.
- Place a pan under pumps to catch oil drips.
- Check oil levels and change oil when necessary. Replace and properly dispose of vacuum pump oil that is contaminated with condensate. Used pump oil must be disposed as hazardous waste.
- With oil rotary pumps many vapors condense in the pump oil. Solvents in the oil degrade its performance (and eventually ruin the pump), create a chemical hazard when the oil is changed, and are emitted in an oil mist vented from the system. Other vapors pass directly into the exhaust stream. To avoid these problems:
  - Trap evaporated materials with a cold trap before they reach the pump. Depending on the material that is to be trapped, this can be a filtration flask either at room temperature or placed in an ice bath. For more volatile solvents more sophisticated options exist (e.g. dry ice trap).
  - Vent the pump exhaust properly.

Personnel

- Conduct all vacuum operations behind a table shield or in a fume hood and always wear safety glasses, lab coat, and gloves.
- Keep a record for each pump to record oil change dates and to keep track of the maintenance schedule.

Electrical

- Examine all electrical cords periodically for signs of wear and damage. If damaged electrical cords are discovered, unplug the equipment and have it repaired.

- Properly ground all electrical equipment.
- If sparks are noticed while plugging or unplugging equipment or if the cord feels hot, do not use the equipment until it can be serviced by an electrician.
- Do not run electrical cords along the floor where they will be a tripping hazard and be subject to wear. If a cord must be run along the floor, protect it with a cord cover.
- Do not run electrical cords above the ceiling. The cord must be visible at all times to ensure it is in good condition.
- Do not plug too many items into a single outlet. Cords that enable you to plug more than one item in at a time should not be used.
- Multi-plug strips can be used if they are protected with a circuit breaker. Do not overuse or daisy-chain in a series.

Overused multi-plug strip

Electrical cords daisy-chained

- Do not use extension cords for permanent wiring. If you must use extension cords throughout the lab, then it is time to have additional outlets installed.

e. Personal Protective Equipment (PPE)

The most important thing to remember about protective clothing is that it only protects you if you wear it. The lab supervisor must ensure that appropriate personal protective equipment is worn by all persons, including visitors, in areas where chemicals are stored or handled.

Material Safety Data Sheets or other references should be consulted for information on the type of protective clothing required for the particular work you are performing.

In general, when working in an area with hazardous materials, your skin should be covered from shoulders to toes.

Protective Eyewear

- Goggles provide the best protection against chemical splashes, vapors, dusts, and mists.
- Goggles that have indirect vents or are non-vented provide the most protection, and an anti-fog agent can be applied.
- Standard safety glasses provide protection against impact.
- Remember, prescription glasses do not provide adequate protection in a laboratory setting. Prescription safety glasses can be purchased from most opticians.
- Alternatively, safety glasses and goggles designed to fit over prescription glasses are available through commercial vendors.

Face shields

- Face shields can protect against impact, dust, particulates, and splashes to the face, eyes, and throat. However, always wear protective eyewear such as goggles underneath a face shield. Chemical vapors and splashes can still travel under and around a face shield.
- If scratches or cracks are noticed in the face shield, replace the window.

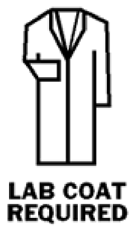
Protective Gloves

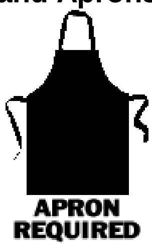
- Any glove can be permeated by chemicals. The rate at which this occurs depends on the composition of the glove, the chemicals present and their concentration, and the exposure time to the glove. If you are not certain which type of glove provides you with the protection you need, contact the manufacturer and ask for specifics on that glove.
- Chemical Compatibility Guides
- If direct chemical contact occurs, replace gloves regularly throughout the day. Wash hands regularly and remove gloves before answering the telephone or opening doors to prevent the spread of contamination.
- Check gloves for tears, holes and cracks.
- Butyl, neoprene, and nitrile gloves are resistant to most chemicals, e.g., alcohols, aldehydes, ketones, most inorganic acids, and most caustics.
- Disposable latex and vinyl gloves protect against some chemicals, most aqueous solutions, and microorganisms and reduce risk of product contamination.

- Leather and some knit gloves will protect against cuts, abrasions, and scratches, but not against chemicals.
- Temperature-resistant gloves protect against cryogenic liquids, flames, and high temperatures such as autoclaves.

Note: Latex gloves should not be worn if a person has or suspects a latex allergy.

Lab Coats and Aprons





- The primary purpose of a lab coat is to protect against splashes and spills. A lab coat should be nonflammable, where necessary, and should be easily removed. Other types of lab coats such as flame resistant coats are available.
- Lab coats should be buttoned when in use.
- Rubber coated aprons can be worn to protect against chemical splashes and may be worn over a lab coat for additional protection.

Shoes

- Shoes that fully cover the feet should always be worn in a lab. If work is going to be performed that includes moving large and heavy objects, steel-toed shoes should be worn.

Respirators

Contact EHS if you are conducting research that necessitates the need for a respirator. EHS will evaluate whether there is a need for a respirator and what type of respirator is needed. Occupational Health will conduct fit-testing and a medical respiratory protection evaluation.

f. Unattended Operations

Leave lights on, place an *appropriate* sign on the door, and provide for containment of toxic substances in the event of failure of a utility service (such as cooling water) to an unattended operation.

g. Use of Fume Hoods

Use a fume hood for all procedures that might result in the release of hazardous chemical vapors or dust.

- Confirm that the hood is working before use by holding a Kimwipe®, or other lightweight paper, up to the opening of the hood.
- The paper should be pulled inward.
- Leave the hood "on" when it is not in active use if toxic substances are stored inside or if it is uncertain whether adequate general laboratory ventilation will be maintained when it is "off."

Proper Use of Fume Hoods

- Equipment and other materials should be placed at least six inches behind the sash, preferably in the middle of the hood. This will reduce the exposure of personnel to chemical vapors that may escape into the lab due to air turbulence.
- When the hood is not in use, pull the sash all the way down. While personnel are working at the hood, pull down the sash as far as is practical. The sash is constructed of safety glass to protect users against fire, splashes, and explosions.

Work with the fume hood sash down as far as practical

Improper use of the fume hood

- Fume hood sash should be at or below 18 inches.
- Do not keep loose papers, paper towels, or tissues (e.g., Kimwipes®) in the hood. These materials can be drawn into the blower and adversely affect the performance of the hood.
- Do not use a fume hood as a storage cabinet for chemicals.

Do not store chemicals or other items in the fume hood

- Excessive storage of chemicals and other items will disrupt the designed airflow in the hood. In particular, do not store chemicals against the baffle at the back of the hood, because this will interfere with the laminar airflow across the hood.
- If large equipment must be kept in a fume hood, raise it 1.5 inches off the work surface to allow air to flow underneath. This dramatically reduces the turbulence within the hood and increases its efficiency.
- Do not place objects directly in front of a fume hood (such as refrigerators or lab coats hanging on the manual controls) as this can disrupt the airflow and draw contaminants out of the hood.
- Keep in mind that modifications made to a fume hood system, e.g., adding a snorkel, can render the entire system ineffective. Modifications should not be done without proper authorization.
- Minimize the amount of foot traffic immediately in front of a hood. Walking past hoods causes turbulence that can draw contaminants out of the hood and into the room.

h. Storage of Chemicals in the Lab

Refer to the section on laboratory chemical storage in Chapter C.1.

2. Working with Allergens

A wide variety of substances can illicit skin and lung hypersensitivity. Examples include common substances such as; diazomethane, chromium, nickel, bichromates, formaldehyde, isocyanates, and certain phenols. Because of this variety and the varying response of individuals, suitable gloves should be used whenever there is potential for contact with chemicals that may cause skin irritation.

3. Working with Embryotoxins

Embryotoxins are substances that cause adverse effects on the developing fetus in pregnant women. These effects may include embryolethality (death of the fertilized egg, the embryo, or the fetus), malformations (teratogenic effects), retarded growth, and postnatal function deficits.

A few substances have been demonstrated to be embryotoxic in humans.

These include:

Benzene	Azo dyes	Nitrous oxide
Heavy Metals	Propylene glycol	Toluene
Carbon Tetrachloride	Xylene	
Chloroform	Formaldehyde	

Many substances, some as common as sodium chloride, have been shown to be embryotoxic to animals at some exposure level, but usually this is at a considerably higher level than is encountered in the course of normal laboratory work. However, some substances do require special controls due to embryotoxic properties. One common example is formamide: women of childbearing potential should handle this substance only in a hood and should take precautions to avoid skin contact with the liquid because of the ease with which it passes through the skin.

Because the period of greatest susceptibility to embryotoxins is the first 8-12 weeks of pregnancy, which includes a period when a woman may not know that she is pregnant; women of childbearing potential should take care to avoid skin contact with all chemicals. The following procedures are recommended to be followed routinely by women of childbearing potential in working with chemicals requiring special control because of embryotoxic properties:

- Each procedure involving embryotoxins should be reviewed for particular hazards by the Principal Investigator or Lab Supervisor, who will decide whether special procedures are warranted or whether warning signs should be posted. Consultation with appropriate safety personnel (EHS, Occupational Health) is recommended. In cases of continued use of a known embryotoxin, the operation should be reviewed annually and/or whenever a change in procedures is made.
- Embryotoxins requiring special control should be stored in an adequately ventilated area. The container should be labeled in a clear manner such as the following: **EMBRYOTOXIN: READ SPECIFIC PROCEDURES FOR USE.** If the storage container is breakable, it should be kept in an impermeable, unbreakable secondary container.
- Women of childbearing potential should take adequate precautions to guard against spills and splashes. Operations should be carried out using impermeable containers and in adequately ventilated areas. Appropriate safety apparel, especially gloves, should be worn. All fume hoods, glove boxes, or other essential engineering controls should be working properly before work is started.
- Supervisors must be notified regarding all incidents of exposure or spills of embryotoxins requiring special control. Occupational Health should be consulted about any exposures of women of childbearing potential above the acceptable level (i.e. any skin contact or inhalation exposures).

4. Working with Chemicals of Moderate Chronic or High Acute Toxicity

Before beginning a laboratory operation, each worker is strongly advised to learn about the substances to be used. The precautions and procedures described in this section should be followed if any of the substances used in significant quantities are known to be moderately or highly toxic (if any of the substances used are known to be highly toxic, it is recommended that two people be present in the area at all times).

These procedures should also be followed if the toxicological properties of any of the substances used or prepared are unknown. If any of the substances to be used or prepared are known to have high, chronic toxicity (e.g., compounds of heavy metals and other potent carcinogens), then the directions and procedures described below should be supplemented with additional precautions to aid in containing and ultimately destroying the substances having high chronic toxicity. Some examples of potent carcinogens (substances known to have high chronic toxicity), along with their corresponding chemical class, are:

Alkylating Agents:

α -Halo Ethers
- Bis(Chloromethyl) Ether
- Methyl Chloromethyl Ether

Aziridines
- Ethylene Imine
- 2-Methylaziridine

Diazo, Azo, and Azoxy Compounds
- 4-Dimethylaminoazobenzene

Electrophilic Alkenes and Alkynes
- Acrylonitrile
- Acrolein
- Ethyl Acrylate

Epoxides
- Ethylene Oxide
- Diepoxybutane
- Epichlorohydrin
- Propylene Oxide
- Styrene Oxide

Sulfonates
- Diethyl Sulfate

Acylating Agents:
- β –Butyrolactone
- β -Propiolactone
- Dimethylcarbamoyl Chloride

Aromatic Amines:
- 4-Aminobiphenyl
- Aniline
- o-Anisidine
- Benzidine
- o-Toluidine

Organohalogen Compounds:
- 1,2-Dibromo-3-Chloropropane
- Bis(2-Chloroethyl) Sulfide
- Vinyl Chloride
- Chloroform
- Methyl Iodide
- 2,4,6-Trichlorophenol
- Carbon Tetrachloride
- Hexachlorobenzene
- 1,4-Dichlorobenzene

Natural Products:
- Adriamycin
- Aflatoxins

Dimethyl Sulfate
Ethyl Methanesulfonate
Methyl Methanesulfonate
Methyl Trifluoromethanesulfonate
1,3-Propanesultone
1,4-Butanedioldimethanesulfonate

Bleomycin
Progesterone
Reserpine
Safrole

Inorganic Compounds:

Cisplatin

The overall objective of the procedures outlined in this section is to minimize exposure of the laboratory worker to toxic substances by taking all reasonable precautions. Thus, the general precautions outlined in Section D.1 should normally be followed whenever a toxic substance is being transferred from one container to another or is being subjected to some chemical or physical manipulation. The following precautions should always be followed:

1) Protect the hands and forearms by wearing either gloves and a laboratory coat or suitable long gloves to avoid contact of the toxic material with the skin.
2) Procedures involving volatile toxic substances and those involving solid or liquid toxic substances that may result in the generation of aerosols should be conducted in a fume hood or other suitable containment device.
3) After working with toxic materials, wash the hands and arms immediately. Never eat, drink, chew gum or tobacco, apply cosmetics or contact lenses, take medicine, or store foods in areas where toxic substances are being used.

These standard precautions will provide laboratory workers with good protection from most toxic substances. In addition, records that include amounts of material used and names of workers involved should be kept as part of the laboratory notebook record of the project. To minimize hazards from accidental breakage of apparatus or spills of toxic substances in the fume hood, containers of such substances should be stored in pans or trays made of polyethylene or other chemically resistant material and apparatus should be mounted above trays of the same type of material.

Alternatively, the working surface of the hood can be fitted with a removable liner of adsorbent plastic-backed paper. These materials will contain spilled toxic substances in a pan, tray, or absorbent liner and greatly simplifies subsequent cleanup and disposal. Any material that comes in contact with toxic substances should be disposed of as a toxic substance. Vapors that are discharged from the apparatus should be trapped or condensed to avoid adding substantial amounts of toxic vapor to the hood exhaust air. Areas where toxic substances are being used and stored must have restricted access, and warning signs must be posted if a special toxicity hazard exists.

The general waste disposal procedures described in the EHS Waste Disposal manual must be followed for these types of chemicals. In general, the waste materials and solvents containing toxic substances must be stored in closed, impervious containers so that personnel handling the containers will not be exposed to their contents.

The laboratory worker must be prepared for potential accidents or spills involving toxic substances. Lab workers must be trained in handling toxic materials and spill clean-up before beginning work with toxic substances.

If a toxic substance contacts the skin, the area should be washed with water. If there is a major spill outside of the hood, the room or appropriate area should be evacuated and necessary measures should be taken to prevent exposure of other workers. Spills must be cleaned by personnel wearing suitable personal protective apparel. If a spill of a toxic material occurs outside the hood, an air-supplied full-face respirator may be needed. Immediately contact EHS for assistance.

In addition to the precautions described in this section, researchers should develop written standard operating procedures intended to establish a concise, step-by-step method for carrying out routine laboratory operations with the substance in question and train lab personnel on these procedures.

5. Working with Substances of High Chronic Toxicity

All of the procedures and precautions described in the previous section should be followed when working with substances known to have high chronic toxicity. In addition, when such substances are used in quantities exceeding a few milligrams to a few grams, depending on the hazards posed by the particular substance, the additional precautions described in this section should be followed. Each laboratory worker's plan for project work and for disposing of waste materials must be approved by the laboratory supervisor.

Consultation with the departmental Lab Safety Coordinator or EHS is recommended to ensure that the toxic material is effectively contained during the project and that waste materials are disposed of in a safe manner. Substances in this high chronic toxicity category include certain heavy metal compounds (e.g., dimethylmercury and nickel carbonyl) and compounds normally classified as select carcinogens. Examples of compounds normally classified as select carcinogens include the following:

- 2-acetylaminofluorene
- aflatoxin B_1
- benzo[a]pyrene
- bis(chloromethyl) ether
- 7,12-dimethylbenz[a]anthracene
- dimethylcarbamoyl chloride
- hexamethylphosphoramide
- 3-methylcholanthrene
- 2-nitronaphthalene
- propane sultone
- various N-nitrosamides
- various N-nitrosamines

Record of the amounts of substances of high chronic toxicity being stored and the amounts used, dates of use, and names of users. It is appropriate to keep such records as part of the record of project work in the laboratory workers' research notebook, but it must be understood that the research supervisor is responsible for ensuring that accurate records are maintained.

Any volatile substances having high chronic toxicity must be stored in a ventilated storage area in a secondary tray or container having sufficient capacity to contain the material should the primary storage container fail. All containers of substances in this category should have labels that identify the contents and include a warning such as: **WARNING!**

HIGHLY TOXIC OR SUSPECTED CARCINOGEN. Storage areas for substances in this category must have limited access, and special signs should be posted if a special toxicity hazard exists. Any area used for storage of substances of high chronic toxicity must be maintained under negative pressure with respect to the surroundings. Contact EHS if there is a problem with airflow in the storage areas.

All projects with and transfers of such substances or mixtures containing such substances must be done in a controlled area (i.e., a laboratory, or a portion of a laboratory, or a facility such as an exhaust hood or a glove box that is designated for the use of highly toxic substances. Its use need not be restricted to the handling of highly toxic substances if all personnel who have access to the controlled area are aware of the nature of the substances being used and the precautions that are necessary). When a glove box is used, the ventilation rate in the box should be at least two volume changes per hour, the pressure should be at least 0.5 inches of water lower than that of the surrounding environment, and the exhaust should be passed through a trap, charcoal or High Efficiency Particulate Air (HEPA) filter as appropriate.

Positive pressure glove boxes are normally used to provide an inert anhydrous atmosphere. If these glove boxes are used with highly toxic compounds, then the box should be thoroughly checked for leaks before use and the exit gases should be passed through a suitable trap or filter. Laboratory vacuum pumps used with substances having high chronic toxicity should be protected by high-efficiency scrubbers or HEPA filters and vented into an exhaust hood. Motor-driven vacuum pumps are recommended because they are easy to decontaminate.

Proper gloves must be worn when transferring or otherwise handling substances or solutions of substances having high chronic toxicity. In some cases, the laboratory worker or the research supervisor may deem it necessary to use other protective apparel, such as an apron of reduced permeability covered by a disposable coat. Additional precautions such as these might be taken, for example, when handling large amounts of certain heavy metals and their derivatives or known potent carcinogens.

Surfaces on which high chronic toxicity substances are handled must be protected from contamination by chemically resistant trays or pans that can be decontaminated after the project or by using dry, absorbent plastic-backed paper.

On leaving a controlled area, laboratory workers must remove any used PPE and thoroughly wash hands, forearms, face, and neck. If disposable apparel or absorbent paper liners have been used, these items must be placed in a closed and impervious container that should then be labeled in some manner such as: **CAUTION: CONTENTS CONTAMINATED WITH SUBSTANCES OF HIGH CHRONIC TOXICITY** (for waste disposal purposes, chemical names are required). Non-disposable protective apparel should be thoroughly washed, and containers of non reusable apparel and protective liners must be disposed of through EHS.

Wastes and residues must be placed in an impervious container and disposed of through EHS. In general, liquid wastes containing such compounds must be placed in a glass or polyethylene bottle half filled with vermiculite.

Normal laboratory work must not be resumed in a space that has been used as a controlled area until it has been adequately decontaminated. Work surfaces must be thoroughly washed and rinsed. If projects have involved the use of finely divided solid materials, dry sweeping should not be done. In such cases, surfaces must be cleaned by wet mopping or by use of a vacuum cleaner equipped with a HEPA filter. All equipment (e.g., glassware, vacuum pumps, and containers) that is known or suspected to have been in contact with substances of high chronic toxicity should be washed and rinsed before removing from the controlled area.

In the event of continued exposure to a substance of high chronic toxicity (i.e., if a worker regularly uses significant quantities of such a substance at least three times a week), Occupational Health should be consulted to determine whether it is advisable to establish a regular schedule of medical surveillance or biological monitoring.

In addition to the precautions described in this section, lab supervisors must develop written standard operating procedures intended to establish a concise, step-by-step method for carrying out routine laboratory operations with the substance in question. These procedures should be reviewed by a department laboratory safety coordinator or EHS.

V. Procedures for Specific Classes of Hazardous Chemicals

This section offers specific guidelines for working with common hazardous materials that, for varying reasons, may pose a significant risk to human life and health if used improperly. Six fundamental classes of laboratory chemicals will be discussed; flammables, corrosives, oxidizers, reactives, compressed gases, and nanomaterials. These classes of chemicals may include chemicals that are also covered in the previous section regarding their property of toxicity.

Note that the hazard characteristics of the classes of hazardous chemicals are generalized. Check the MSDS to determine the specific hazard characteristics for the chemical before using it.

1. Flammable Liquids

a. Terms and Definitions

Flammable liquids are among the most common chemicals found in a laboratory. The primary hazard associated with flammable liquids is their ability to readily ignite and burn. The vapor of a flammable liquid, not the liquid itself, can ignite and start a fire.

- ***Vapor pressure*** - The rate at which a liquid vaporizes. In general, liquids with high vapor pressure evaporate at a higher rate compared to liquids of lower vapor pressure. The vapor pressure increases rapidly as the temperature is raised. A low-pressure environment also accelerates the rate of evaporation.
- ***Flash point*** - The lowest temperature at which a liquid gives off vapor to form an air-vapor mixture that will ignite, but will not sustain ignition. Many commonly used flammable liquids have flashpoints significantly lower than room temperature:

Compound	Flash Point (° C)
diethyl ether	-45.0
acetone	-17.8
isopropyl alcohol	11.7

- ***Limits of Flammability*** or ***Explosivity*** - The range of fuel:air mixtures that will sustain combustion. The lower limit of this range is called the *Lower Explosive Limit* (*LEL)*, and the higher limit of this range is called the *Upper Explosive Limit* (*UEL)*. Materials with very broad flammability ranges (e.g., acetylene, LEL = 3%, UEL = 65%) are particularly dangerous due to the fact that virtually any fuel:air combination may form an explosive atmosphere.
- ***Vapor Density*** of a flammable liquid - The density (mass to volume ratio) of the corresponding vapor relative to air under specific temperature and pressure conditions. Flammable vapors with densities greater than 1.0 (and thus "heavier"

than air) are hazardous because they can accumulate at floor level and spread. These mobile vapors may eventually reach an ignition source, such as an electrical outlet or a Bunsen burner.

- **Autoignition temperature -** The minimum temperature at which a substance can ignite without a spark or flame. Some examples: acetone 538°C (1000°F), ethyl ether 180°C (356°F), phenol 715°C 91319°F).

b. Use and Storage of Flammables

- Flammable liquids that are not in active use should be stored inside fire resistant flammable storage cabinets.
- Minimize the amount of flammable liquids stored in the lab. Do not store more than 10 gal outside of flammable storage cabinets.
- Keep flammables away from vacuum pumps and other ignition sources.
- The transfer of material to/from a metal container can result in an accumulation of static charge on the container. When transferring flammable liquids, this static charge could generate a spark, thereby igniting the liquid. To make these transfers safer, flammable liquid dispensing and receiving containers should be bonded together before pouring.
- Large containers such as drums must also be grounded when used as dispensing or receiving vessels. All grounding and bonding connections must be metal to metal.
- Do not heat flammables with an open flame. Instead, use steam baths, water baths, oil baths, hot air baths, sand baths or heating mantles.
- Do not store flammable chemicals in a standard household refrigerator. There are several ignition sources located inside a standard refrigerator that can cause a fire or explosion. Flammables that need to refrigeration should be stored cold in a lab-safe explosion-proof refrigerator.

Refrigerator warning label

c. Health Hazards Associated with Flammables

The vapors of many flammables are irritating to mucous membranes of the respiratory system and eyes. Routes of entry with corresponding symptoms are listed below.

Acute Health Effects

- *Inhalation* - headache, fatigue, dizziness, drowsiness, narcosis (stupor and unresponsiveness)
- *Ingestion* - slight gastrointestinal irritation, dizziness, fatigue

- *Skin Contact* - dry, cracked, and chapped skin
- *Eye Contact* - stinging, watering eyes, and inflammation of the eyelids

Chronic Health Effects

The chronic health effects will vary depending on the specific chemical, the duration of the exposure and the extent of the exposure. However, damage to the lungs, liver, kidneys, heart and/or central nervous system may occur. Cancer and reproductive effects are also possible.

Flammable Groups Exhibiting Similar Health Effects

- *Hydrocarbons* - aliphatic hydrocarbons are narcotic, but their systemic toxicity is relatively low. Aromatic hydrocarbons are potent narcotic agents, and overexposure to the vapors can lead to loss of muscular coordination, collapse and unconsciousness. Benzene is toxic to bone marrow and can cause leukemia.
- *Alcohols* – vapors can be moderately narcotic.
- *Ethers* - exhibit strong narcotic properties and can be moderately toxic.
- *Esters* - vapors may result in irritation to the eyes, nose and upper respiratory tract.
- *Ketones* - systemic toxicity is generally low.

d. First Aid Procedures for Exposures to Flammable Materials

- *Inhalation Exposures* – remove the person from the contaminated area. Get medical attention.
- *Ingestion Exposures* - Get medical attention.
- *Dermal Exposures* – remove the person from the source of contamination. Remove clothing and jewelry from the affected areas. Rinse in a safety shower for at least 15 minutes and obtain medical attention.
- *Eye Contact* – remove the person from the source of contamination. Flush with an eyewash for at least 15 minutes and obtain medical attention.

e. Personal Protective Equipment (PPE)

Fume hoods should be used when working with flammable liquids. Nitrile and neoprene gloves provide protection against most flammables. Wear a fire-resistant lab coat to provide a barrier to your skin. Safety goggles/glasses should be worn if there is a splash risk.

Proper PPE

2. Oxidizers

a. General Characteristics

- Oxidizers present fire and explosion hazards on contact with flammable and combustible materials. Depending on the class, an oxidizing material may increase the burning rate of combustibles which it contacts; cause the spontaneous ignition of combustibles which it contacts, or produce an explosive reaction when exposed to heat, shock or friction.
- Oxidizers are generally corrosive.

b. Examples of Common Oxidizers

Peroxides	Chlorates
Nitrates	Chlorites
Nitrites	Hypochlorites
Perchlorates	Dichromates

c. Use and Storage of Oxidizers

- Store oxidizers away from flammables, organic compounds and combustible materials.
- Strong oxidizing agents like chromic acid should be stored in glass or some other inert container. Corks and rubber stoppers should not be used.
- Reaction vessels containing oxidizing material should be heated in a mantle or sand bath. Oil baths should not be used.

d. Use and Storage of Perchloric Acid

- Perchloric acid is an oxidizing agent of particular concern. The oxidizing power of perchloric acid increases as the concentration and temperature increase. Cold, 70% perchloric acid is a strong, non-oxidizing corrosive. A 72% perchloric acid solution at elevated temperatures is a strong oxidizing agent. An 85% perchloric acid solution is a strong oxidizer at room temperature.
- Do not attempt to heat perchloric acid if you do not have access to a properly

functioning perchloric acid fume hood. Perchloric acid can only be heated in a hood specially equipped with a washdown system to remove any perchloric acid residue. The hood should be washed down after each use, and it is preferred that the hood be restricted to perchloric acid use only.

- Whenever possible, substitute a less hazardous chemical for perchloric acid or use a dilute solution.
- Perchloric acid can be stored in a perchloric acid fume hood. Keep only the minimum amount necessary for your work. Another acceptable storage site for perchloric acid is in an acid cabinet that has secondary containment.
- Do not allow perchloric acid to come in contact with any strong dehydrating agents such as sulfuric acid. The dehydration of perchloric acid is a severe fire and explosion hazard.
- Do not order or use anhydrous perchloric acid. It is unstable at room temperature and can decompose spontaneously with a severe explosion. Anhydrous perchloric acid will explode upon contact with wood.
- Consult with EHS before working with perchloric acid.

e. Health Hazards Associated with Oxidizers

Acute Health Effects:

Some oxidizers such as nitric and sulfuric acid vapors, chlorine, and hydrogen peroxide act as irritant gases. All irritant gases can cause inflammation in the surface layer of tissues when in direct contact. They can also cause irritation of the upper airways, conjunctiva, and throat.

- Fluorine, can cause severe burns of the skin and mucus membranes.
- Chlorine trifluoride is extremely toxic and can cause severe burns to tissue.
- Nitrogen trioxide is very damaging to tissue, especially the respiratory tract. The symptoms from an exposure to nitrogen trioxide may be delayed for hours, but fatal pulmonary edema may result.
- Osmium tetroxide also dangerous due to its high degree of acute toxicity. It is a severe irritant of the eyes and respiratory tract. Inhalation can cause headache, coughing, dizziness, lung damage, difficulty breathing and death. Osmium tetroxide is regarded by many in the field as having "poor warning properties." This is due to the fact that it is difficult to detect in the atmosphere (by smell or other means). The OSHA Permissible Exposure Limit (PEL) for osmium tetroxide is 0.002 ppm, while its odor threshold is 2 ppm -this means that one could conceivably be exposed to osmium tetroxide at concentrations 1,000 times the PEL without knowing it. It is recommended that laboratories using osmium tetroxide have necessary safeguards in place before the container is even opened.

Chronic Health Effects:

Nitrobenzene and chromium compounds can cause hematological and neurological changes. Compounds of chromium and manganese can cause liver and kidney disease. Chromium (VI) compounds have been associated with lung cancer.

f. First Aid

If a person has inhaled, ingested or come into direct contact with these materials, the person should be removed from the immediate area as quickly as possible. Seek medical attention immediately. Rinse with a safety shower for at least 15 minutes if there is direct skin exposure. Flush with an eyewash for at least 15 minutes if there is direct eye exposure.

g. Personal Protective Equipment (PPE)

Neoprene, polyvinyl chloride (PVC), or nitrile gloves are acceptable. Consult a glove compatibility chart to ensure the glove material is appropriate for the particular chemical you are using.

Safety glasses must be worn if the potential for splashing or exposure to vapor/gas exists.

Oxidizers should be used in a chemical fume hood due to the inhalation hazard risk.

3. Corrosives (Acids and Bases)

a. General Characteristics

- Corrosives are most commonly acids and bases, but many other materials can be severely damaging to living tissue.
- Corrosives can damage tissue. Inhalation of the vapor or mist can cause severe bronchial irritation. Corrosives are particularly damaging to the skin and eyes.
- Certain substances considered non-corrosive in their natural dry state are corrosive when they come in contact with moist skin or mucus membranes. Examples include lithium chloride, halogen fluorides, and allyl iodide.
- Sulfuric acid is a very strong dehydrating agent while nitric acid is a strong oxidizing agent. Dehydrating agents can cause severe burns to the eyes due to their affinity for water.

b. Examples of Corrosives

Sulfuric Acid	Chromic Acid	Bromine
Ammonium Hydroxide		

c. Use and Storage of Corrosives

- Always store acids and bases separately. Store acids in acid storage cabinets or plastic secondary containment away from flammables as many acids are also strong oxidizers.

Acids stored in acid storage cabinet

- Do not work with corrosives unless an emergency shower and eyewash are available within 10 sec travel time.   Contact EHS if one is not available.
- Add acid to water, but never add water to acid.
- Do not store liquid acids above eye level. Store on a low shelf or inside a cabinet.
- Store acids in a plastic tray, tub or rubber bucket to contain any leakage.

Acids stored in a plastic tray

- Purchase corrosives in containers that are plastic coated, this will reduce the danger to personnel if the container is dropped.
- Store acids in an acid cabinet or one that has a corrosion-resistant lining. Acids stored in an ordinary metal cabinet will quickly corrode the interior. If an acid cabinet is not available, store the corrosive in a plastic tub inside a wooden cabinet.
- Nitric acid should always be stored away from other acids and organic materials in a separate cabinet or compartment due to its high reactivity.

d. Use and Storage of Hydrofluoric Acid

- Hydrofluoric acid can cause severe burns. Inhalation of anhydrous hydrogen fluoride can be fatal. Initial skin contact with hydrofluoric acid may not produce any symptoms. However, hydrofluoric acid can scavenge calcium for the skin and bones, causing severe injuries.
- Always use hydrofluoric acid in a properly functioning fume hood. Wear personal protective clothing.
- If you suspect that you have come in direct contact with hydrofluoric acid; wash the area with water for at least 5 minutes, then apply cream. Remove contaminated clothing and seek medical attention. If hydrogen fluoride vapors are inhaled, move the person immediately to an uncontaminated atmosphere (if safe to do so) and seek prompt medical attention.
- Never store hydrofluoric acid in a glass container as it is incompatible with glass. Hydrofluoric acid usually comes in a plastic bottle.
- Store hydrofluoric acid separately in an acid storage cabinet and keep only the amount necessary in the lab.
- Creams such as calcium gluconate for treatment of hydrofluoric acid exposure are commercially available and should be stored in the lab. Calcium gluconate reacts with hydrofluoric acid reducing attack of calcium in the body.

Health Hazards Associated with Corrosives

All corrosives possess the property of being severely damaging to living tissues. Acids also react with other materials such as metals.

Skin contact with alkali metal hydroxides (e.g., sodium hydroxide and potassium hydroxide) is more dangerous than with strong acids. Contact with base metal hydroxides normally causes deeper tissue damage because there is less pain than with an acid exposure. The exposed person may not wash it off thoroughly enough or seek prompt medical attention.

All hydrogen halides are acids that are serious respiratory irritants and also cause severe burns.

Acute Health Effects

- *Inhalation* - irritation of mucus membranes, difficulty in breathing, fits of coughing, pulmonary edema Ingestion - irritation and burning sensation of lips, mouth, and throat; pain in swallowing; swelling of the throat; painful abdominal cramps; vomiting; shock; risk of perforation of the stomach
- *Skin Contact* - burning, redness and swelling, painful blisters, profound damage to tissues, and with alkalis; a slippery, soapy feeling
- *Eye Contact* - stinging, watering of eyes, swelling of eyelids, intense pain, ulceration of eyes, loss of eyes or eyesight

Chronic Health Effects

Symptoms associated with a chronic exposure vary greatly depending on the chemical. For example, the chronic effect of hydrochloric acid is damage to the teeth; the chronic effects of hydrofluoric acid are decreased bone density, fluorosis, and anemia

e. First Aid

- *Inhalation* - remove person from source of contamination if safe to do so. Seek medical attention.
- *Ingestion* - remove person from source of contamination. Seek medical attention and inform emergency responders of the name of the chemical swallowed.
- *Skin Contact* - remove person from source of contamination and take immediately to an emergency shower or source of water. Remove clothing, shoes, socks, and jewelry from affected areas as quickly as possible, cutting them off if necessary. Be careful not to get any chemical on your skin or to inhale the vapors. Flush the affected area with water for a minimum of 15 minutes. Get medical attention.
- *Eye Contact* - remove person from source of contamination and take immediately to an eyewash or source of water. Rinse the eyes for a minimum of 15 minutes. Have the person look up and down and from side to side. Get medical attention. Do not let the person rub their eyes or keep them tightly shut.

f. Personal Protective Equipment (PPE)

Always wear the proper gloves when working with corrosives. Neoprene and nitrile gloves are effective against most acids and bases. Polyvinyl chloride (PVC) is also effective for most acids. A rubber coated apron and goggles should also be worn. If splashing is likely to occur, wear a face shield over the goggles. Always use corrosives in a chemical fume hood.

4. Reactives

a. General Characteristics

Polymerization Reactions

Polymerization is a chemical reaction in which two or more molecules of a substance combine to form repeating structural units of the original molecule. This can result in an extremely high or uncontrolled release of heat. An example of a chemical which can undergo a polymerization reaction is styrene.

Water Reactive Materials

- When water reactive materials come in contact with water, one or more of the following can occur: liberation of heat which may cause ignition of the chemical itself if it is flammable, or ignition of flammables that are stored nearby; release of a flammable, toxic, or strong oxidizing gas; release of metal oxide fumes; and formation of corrosive acids.
- Water reactive chemicals can be particularly hazardous to firefighting personnel responding to a fire in a lab, because water is the most commonly used fire extinguishing medium.
- Examples of water reactive materials:

Alkali Metals:	Silanes
-Lithium, Sodium, Potassium	Alkylaluminums
Magnesium	Zinc
Aluminum	

Pyrophorics

- Pyrophoric materials can ignite spontaneously in the presence of air.
- Examples of pyrophoric materials:

  Tert-butyllithium
  Diethylzinc
  Triethylaluminum
  Several organometallic compounds

Peroxide-Forming Materials

- Peroxides are very unstable and some chemicals that can form them are commonly used in laboratories. This makes peroxide-forming materials some of the most hazardous substances found in a lab. Peroxide-forming materials are chemicals that react with air, moisture, or impurities to form peroxides. The tendency to form peroxides by most of these materials is greatly increased by evaporation or distillation.
- Organic peroxides are extremely sensitive to shock, sparks, heat, friction, impact, and light. Many peroxides formed from materials used in laboratories are more shock sensitive than TNT. Just the friction from unscrewing the cap of a container of ether that has peroxides in it can provide enough energy to cause a severe explosion.

- Examples of peroxide-forming materials (the italicized group is the more hazardous):

Diisopropyl Ether	Divinylacetylene
Sodium Amide	Potassium Amide
Dioxane	Diethyl Ether
Tetrahydrofuran	Vinyl Ethers
Butadiene	Vinylpyridine
Acrylonitrile	Styrene

Peroxide Testing

For certain classes of compounds (e.g., ethers as peroxide formers), the date the container was opened should be written on the label. Peroxide formers should have the test history and date of discard written on the label as well.

The following tests can detect most (but not all) peroxy compounds, including all hydroperoxides:

-Add 1 to 3 milliliters (mL) of the liquid to be tested to an equal volume of acetic acid, add a few drops of 5% aqueous potassium iodide solution, and shake. The appearance of a yellow to brown color indicates the presence of peroxides. Alternatively, addition of 1 mL of a freshly prepared 10% solution of potassium iodide to 10 mL of an organic liquid in a 25-mL glass cylinder should produce a yellow color if peroxides are present.

-Add 0.5 mL of the liquid to be tested to a mixture of 1 mL of 10% aqueous potassium iodide solution and 0.5 mL of dilute hydrochloric acid to which has been added a few drops of starch solution just prior to the test. The appearance of a blue or blue-black color within a minute indicates the presence of peroxides.

-Peroxide test strips, which turn to an indicative color in the presence of peroxides, are available commercially. Note that these strips must be air dried until the solvent evaporates and then exposed to moisture for proper operation.

None of these tests should be applied to materials (such as metallic potassium) that may be contaminated with inorganic peroxides.

Note: Peroxide test strips are available through the chemical storeroom in Welch.

Other Shock-Sensitive Materials

- These materials are explosive and sensitive to heat and shock.
- Examples of shock-sensitive materials:

  Chemicals containing nitro-functional groups
  Fulminates
  Hydrogen Peroxide (30% +)
  Ammonium Perchlorate
  Benzoyl Peroxide (when dry)
  Compounds containing the functional groups: acetylide, azide, diazo, halamine, nitroso, and ozonide.

b. Use and Storage of Reactives

- A good way to reduce the potential risks is to minimize the amount of material used in the project. Use only the amount of material necessary to achieve the desired results.
- Always substitute a less hazardous chemical for a highly reactive chemical whenever possible. If it is necessary to use a highly reactive chemical, order only the amount that is necessary for the work.

Water Reactive Materials

Store water-reactive chemicals in an isolated part of the lab. A cabinet removed from water sources, such as sinks, emergency showers, and chillers, is an appropriate location. Clearly label the cabinet "Water-Reactive Chemicals – No Water".

Pyrophorics

Store pyrophorics in an isolated part of the lab and in a clearly marked cabinet. Be sure to routinely check the integrity of the container and have the material disposed of through EHS if the container is corroded or otherwise damaged.

Additional safety guidance on pyrophorics can be found at:
http://www.utexas.edu/safety/ehs/lab/pyrophorics.html

Peroxide-Forming Materials

- Do not open the chemical container if peroxide formation is suspected. The act of opening the container could be sufficient to cause a severe explosion. Visually inspect liquid peroxide-forming materials for crystals or unusual viscosity before opening. Pay special attention to the area around the cap. Peroxides usually form upon evaporation, so they will most likely be formed on the threads under the cap.
- Date all peroxide forming materials with the date received. Chemicals such as diisopropyl ether, divinyl acetylene, sodium amide, and vinylidene chloride should be discarded after three months. Chemicals such as dioxane, diethyl ether, and tetrahydrofuran should be submitted to EHS for disposal after one year if opened or expired.
- Store all peroxide-forming materials away from heat, light, and sources of ignition. Light accelerates the formation of peroxides.
- Secure the lids and caps on these containers to discourage the evaporation and concentration of these chemicals.
- Never store peroxide-forming materials in glass containers with screw cap lids or glass stoppers. Friction and grinding must be avoided.
- **From Prudent Practices in the Laboratory – Handling and Disposing of Chemicals – 1995 – Page 100 – Section 5.G.3.1 Peroxide Detection Tests**
  The following tests can detect most (but not all) peroxy compounds, including all hydroperoxides:
  Add 1 to 3 milliliters (mL) of the liquid to be tested to an equal volume of acetic acid, add a few drops of 5% aqueous potassium iodide solution, and shake. The appearance of a yellow to brown color indicates the presence of peroxides. Alternatively, addition of 1 mL of a freshly prepared 10% solution of potassium iodide to 10 mL of an organic liquid in a 25-mL glass cylinder should produce a yellow color if peroxides are present.

  Add 0.5 mL of the liquid to be tested to a mixture of 1 mL of 10% aqueous potassium iodide solution and 0.5 mL of dilute hydrochloric acid to which has been added a few drops of starch solution just prior to the test. The appearance of a blue or blue-black color within a minute indicates the presence of peroxides.

  Peroxide test strips, which turn to an indicative color in the presence of peroxides, are available commercially. Note that these strips must be air dried until the solvent evaporates and then exposed to moisture for proper operation.

  None of these tests should be applied to materials (such as metallic potassium) that may be contaminated with inorganic peroxides.
- If you suspect that peroxides may be present contact EHS. If you notice crystal formation in the container or around the cap, do not attempt to open or move the container. Call EHS for proper disposal.
- Never distill ether unless it is known to be free of peroxides.

Chemical containers in poor condition from corrosion and crystal formation.

Other Shock Sensitive Materials
Store these materials separately from other chemicals and in a clearly labeled cabinet.

Never allow picric acid (Bouin's solution) to dry out, as it is extremely explosive. Always store picric acid in a moist environment.

c. Health Hazards Associated with Reactives
Reactive chemicals are grouped as a category primarily because of the safety hazards associated with their use and storage and not because of similar acute or chronic health effects. For health hazard information on specific reactive materials consult the MSDS, the manufacturer, or EHS. However, there are some hazards common to the use of reactive materials. Injuries can occur due to: heat or flames, inhalation of fumes, vapors, reaction products, and flying debris.

First Aid
If someone is seriously injured, the most important step to take is to contact emergency responders as quickly as possible. Explain the situation and describe the location clearly and accurately.

If someone is severely bleeding, put on protective gloves and apply a sterile dressing, clean cloth, or handkerchief to the wound. Then place the palm of your hand directly over the wound and apply pressure and keep the person calm. Continue to apply pressure until help arrives.

If a person's clothes are on fire, he or she should drop immediately to the floor and roll. If a fire blanket is available, put it over the individual. An emergency shower, if one is immediately available, can also be used to douse flames.

If a person goes into shock, have the individual lie down on their back (if safe to do so) and raise the feet about one foot above the floor.

Personal Protective Equipment (PPE)
Wear appropriate personal protective clothing while working with highly reactive materials. This might include: impact resistant safety glasses or goggles, a face shield, gloves, a flame-resistant lab coat (to minimize injuries from flying glass or an explosive flash), and a blast shield. Conduct work within a chemical fume hood as much as possible and pull down the sash as far as is practical. While the project does not require you to reach into the fume hood, keep the sash closed.
Barriers can offer protection of personnel against explosions and should be used. Many safety catalogs offer commercial shields which are commonly polycarbonate and are weighted at the bottom for stability. It may be necessary to secure the shields firmly to the work surface.

5. Compressed Gas Cylinders

a. General Characteristics

- Cylinders of compressed gases can pose a chemical as well as a physical hazard.
- If the valve were to break off a cylinder, the amount of force present could propel the cylinder through a brick wall. For example, a cylinder of compressed breathing air used by SCUBA divers has the explosive force of 1 1/2 pounds of TNT.

b. Purchase Policy

Purchase of gases in non-returnable cylinders is restricted by policy at UT Austin. The UT Austin Gas Cylinder policy, which went into effect in May 1993, requires that all gas cylinders purchased for use on campus must be returnable to the vendor. The only exception to this policy is for a compelling research reason. The original policy indicated such exceptions would require prior approval and that a $1,000 deposit would be required to cover potential disposal costs. The specific procedures to be followed to request permission to purchase a research gas in a non-returnable gas cylinder are outlined below.

The Principal Investigator (PI) should prepare a request for an exception and include the reason why a non-returnable gas cylinder purchase is essential. This request must contain a Letter of Credit commitment that specifically states the requesting PI will be responsible for the proper disposal of the non-returnable cylinder and agrees to pay a $1,000 disposal fee if UT Austin is required to dispose of the cylinder. This request should be submitted to the department chair and the dean for review and approval. The request should then be forwarded to the Provost for final action. Please note: identification of a specific account or funding source by the PI for the possible $1,000 disposal expenditure is not required but approval by the department and the college constitutes a commitment by them that department or college funds are available to cover disposal costs if the PI is unable to cover these costs.

A copy of the approval request will be returned to the PI and a copy will be forwarded to EHS. The PI should attach a copy of the approved request to the purchase order used to obtain the desired gas.

Final disposal of the non-returnable gas cylinder should be completed no later than three years after purchase unless written approval for an extension is obtained from the Provost upon recommendation of the chair and dean. Evidence of the proper disposal of the cylinder must be provided to EHS. If the cylinder is disposed of through normal channels (e.g. the EHS Hazardous Waste Program) at no extra cost to UT Austin, the $1,000 Letter of Credit commitment will be canceled. The cylinder will be acceptable for normal waste disposal if the valve has been removed from the cylinder and the cylinder has been cleaned. Similarly, if the cylinder has been returned to the manufacturer or distributor, and this is verified in the form of a receipt or a bill of lading, the Letter of Credit commitment will be canceled. If however, the university must dispose of the cylinder outside of normal procedures because of the cylinder's condition (e.g. damaged or corroded valve) the disposal fee of $1,000 will be assessed to the PI. It is the responsibility of the PI to provide an appropriate account for this charge at that time.

c. Use and Storage

- Whenever possible, use flammable and reactive gases in a fume hood or other ventilated enclosure. As noted previously, concerning storage cabinets, certain categories of toxic gases must always be stored and used in ventilated enclosures. Note specific gases that require ventilated storage.
- Always use the appropriate regulator on a cylinder. If a regulator will not fit a cylinder's valve, replace the cylinder, not the regulator. Do not attempt to adapt or modify a regulator to fit a cylinder it was not designed for. Regulators are designed to fit only specific cylinder valves to avoid improper use.

Properly attached regulator and safety cap

- Inspect regulators, pressure relief devices, valves, cylinder connections, and hose lines frequently for damage.
- Do not use a cylinder that cannot be positively identified. Color coding is not a reliable way of identifying a cylinder because the colors can vary from supplier to supplier.
- Do not use oil or grease on any cylinder component because a fire or explosion can result.
- Do not transfer gases from one cylinder to another. The gas may be incompatible with the residual gas remaining in the cylinder or may be incompatible with the cylinder material.
- Never completely empty cylinders during lab operations
    - Leave approximately 25 PSI of pressure. This will prevent any residual gas in the cylinder from becoming contaminated. However, if the cylinder is non-

returnable, call EHS for instructions. If inert, vent the remainder of the gas. If not inert, react the remainder of gas off. In either case, EHS will be able to discard the cylinder after valve removal. If venting or reacting is unsafe, EHS can still dispose of most cylinders.

- Orient cylinders so that the main valve is always accessible and the name of the gas is visible.
- Close the main cylinder valve whenever the cylinder is not in use.
- Remove regulators from unused cylinders and always put the safety cap in place to protect the valve.
- Always secure cylinders, whether empty or full, to prevent them from falling over and damaging the valve (or falling on your foot). Secure cylinders by firmly chaining or strapping them to a wall, lab bench, or other fixed support.

Compressed gas cylinders **(Picture courtesy of Airgas, Inc.)**

- Oxygen should be stored in an area that is at least 20 feet away from any flammable or combustible materials (including gasses) or separated from combustibles by a non-combustible barrier at least 5 feet high and having a fire-resistance rating of at least 1/2 hour.
- To transport a cylinder, put on the safety cap and strap the cylinder to a hand truck in an upright position. Never roll a cylinder.

Proper transport of a gas cylinder
(Picture courtesy of Airgas, Inc.)

- Always clearly mark empty cylinders and store them separately.
- Be careful while handling compressed gas cylinders and never drop or strike a cylinder against anything.
- Use only wrenches or other tools supplied by the cylinder supplier to open a valve.
- Open cylinder valves slowly.
- Only compatible gases should be stored together in a gas cylinder cabinet.
- Do not store compressed gas cylinders in areas where the temperature can exceed 125F.

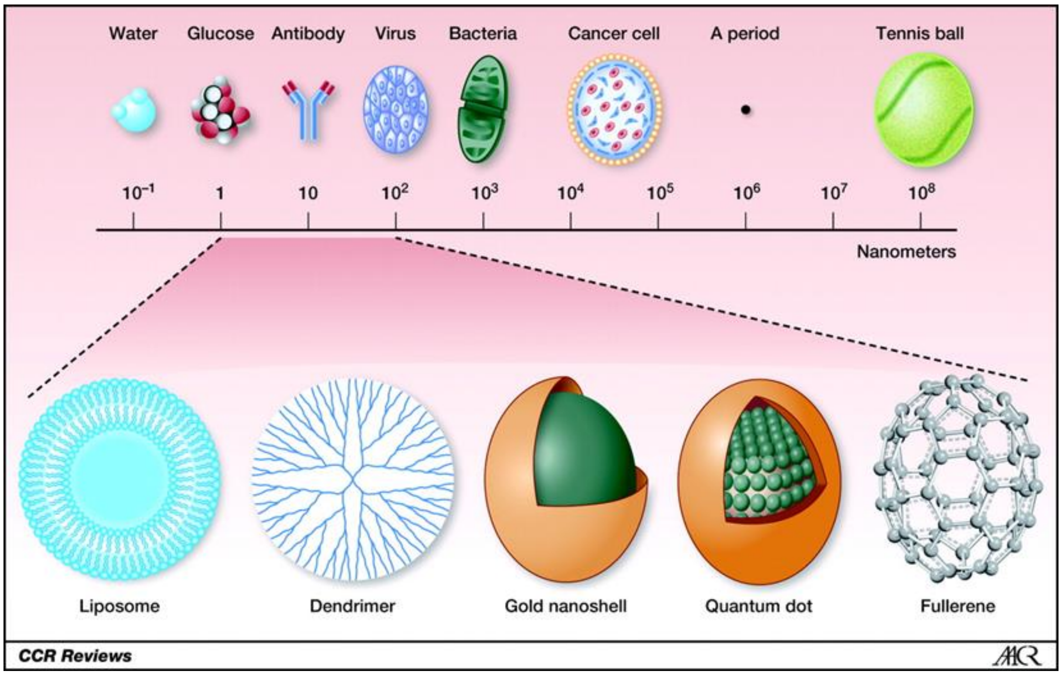
6. Nanomaterials

a. Overview

Nanotechnology involves the manipulation of matter at nanometer scales to produce new materials, structures, and devices. Engineered nanomaterials (NM) are becoming more prevalent in research. One of the concerns of using nanoparticles/nanomaterials is that in some cases, very little is known about the physical toxicity of the nanoparticle/nanomaterial. Variances in size, shape, and surface area can affect toxicity at different levels. Materials that are normally considered non-toxic may be toxic at the nanosize regime. NM can enter the bloodstream via the skin or lungs and be retained in different organs. While there is still great uncertainty about toxicity profiles of engineered nanomaterials, there is enough circumstantial evidence to indicate that precautions should be taken.

For this reason, the safe science of NM use will be regularly monitored by Environmental Health and Safety (EHS). This document will be updated periodically to remain current on NM handling best practices.

Based on current knowledge and practices, NM should be treated as potentially hazardous unless it has been documented that exposure to the specific NM is not hazardous.



b. Regulations

At this time, there are no federal regulations that specifically address the health and safety implications of nanotechnology. There are also no national or international consensus standards on measurement techniques for nanomaterials in the workplace. However, as with conventional chemicals, research with nanomaterials must be conducted in a manner that is safe and responsible. All chemicals, including nanomaterials, must be transported, stored, used, and disposed in accordance with all federal, state, and local requirements.

The Occupational Safety and Health Administration (OSHA) require employers to maintain a safe and healthful workplace, "free from recognized hazards likely to cause death or serious physical harm" (29 USC 654). According to OSHA, laboratory personnel must be informed of the risks associated with workplace hazards. This is generally accomplished through training programs, material safety data sheets, labeling and signage.

The Resource Conservation and Recovery Act of 1976 (RCRA) regulates the transportation, treatment, disposal, and cleanup of hazardous waste. Nanomaterials that meet the definition of a "hazardous waste" in RCRA are subject to this rule.

Nanomaterials that are defined as “chemical substances” under the Toxic Substances Control Act (TSCA) and which are not on the TSCA Inventory must be reported to U.S. Environmental Protection Agency (EPA). A Pre-manufacture Notice must be submitted to the EPA by anyone intending to manufacture or import a chemical substance that is not on the TSCA Inventory of Chemical Substances.

It should also be noted that the U.S. Food and Drug Administration currently regulates a wide range of products including those that utilize nanotechnology or that contain nanomaterials (e.g., a drug delivery device).

c. Risk Analysis/Assessment

Research with nanomaterials has shown that the physico-chemical characteristics of nanoparticles can influence their effects in biological as well as non- biological systems. Some of these characteristics associated with nanomaterials include:

- Charge;
- Chemical reactivity;
- Degree of agglomeration;
- Shape;
- Size;
- Solubility;
- Surface area; and
- Surface composition.

There are many unknowns as to whether the unique properties of engineered nanomaterials pose health concerns. The potential health risk following exposure to a substance is generally associated with the following (CDC/NIOSH, 2009):

- Magnitude and duration of the exposure;
- Persistence of the material in the body;
- Inherent toxicity of the material; and
- Susceptibility or health status of the person.

Unfortunately, there is limited data regarding the health risks related to nanomaterials. As such, this document is to provide EHS-accepted recommendations for practicing prudent health and safety measures when working with nanomaterials.

If Material Safety Data Sheet (SDS) information is available for nanomaterials it should be consulted to determine the material’s potential hazardous properties, Personal Protective Equipment (PPE), as well as its containment, handling and disposal. When a SDS is not available, the researcher should conduct a literature review to perform a risk analysis. If no information is available, the researcher should, at a minimum, use standard precautions described below for handling the material as if it were potentially hazardous. Part of the risk analysis/assessment should include:

- Assessment of the potential implications of human exposure to the NM being used recognizing that the characteristics of the NM are different from those of larger particles with the same chemical composition.
- Assessment of any potentially hazardous manipulations that increase the risk of human exposure such as cytotoxicity, aerosolization, injection, excretion, etc.

“The physicochemical characterizations of NM are important steps in toxicological and ecotoxicological studies in order to correctly evaluate and assess their potential exposure routes, toxicity, and related risk.” (Nanotoxicity, Monteiro-Riviere and Tran, 2007, p.19) Records of research use will ideally include the size, shape, surface area, chemical composition, lattice structure, surface charge, and aggregation state, as well as the makeup of any associated liquid media if supplied as suspension.

Mass, surface-area and number concentration remain important exposure metrics. Inter-disciplinary collaboration is essential to understanding and managing potential risk.

Researchers should develop their own standard operating procedures (SOP) based on their risk assessment and in consultation with this document and EHS. This standard operating procedure, when used in conjunction with completion of hazard communication training, should provide employees and students with an adequate “hazard communication” basis for use of engineered nanomaterials at UT Austin. In addition, the SOP should provide a detailed description of the procedures being conducted including the specific requirements for engineering controls, PPE, dosing, handling, bedding/cage changes, disposal, emergency response and occupational health.

d. Exposure Routes

The deposition of discrete nanomaterials in the respiratory tract is determined by the particle’s aerodynamic or thermodynamic diameter. Particles that are capable of being deposited in the gas exchange region of the lungs are considered respirable particles. Discrete nanomaterials are deposited in the lungs to a greater extent than larger respirable particles. Deposition increases with exertion (due to an increase in breathing rate and change from nasal to mouth breathing). It also increases among persons with existing lung diseases or conditions. Based on animal studies (Oberdorster), discrete nanomaterials may enter the bloodstream from the lungs and translocate to other organs. Because of their ultra-small size, nanoparticles can penetrate cell membranes and integrate themselves into larger molecules. They can resist cellular defense systems but are large enough to interfere with cell processes.

Ingestion is another route whereby nanomaterials may enter the body. Ingestion can occur from unintentional hand-to-mouth transfer of materials. This can occur with traditional materials and it is scientifically reasonable to assume that it could happen during handling of nanomaterials. This is specifically true while handling very high surface area (>20 m^2/g), porous dry nanomaterials which includes metals, nonmetal oxides, or their mixed forms, and microporous or mesoporous metal organic framework. Some of the examples of commonly used materials of this category are CeO_2, TiO_2, SiO_2, Co_3O_4, Mn_3O_4, Ru_3O_4, ZnO OS_3O_4, V_2O_3, graphene, carbon nanotube and MgO. Ingestion may also accompany inhalation exposure because particles that are cleared from the respiratory tract via the mucociliary escalator may be swallowed.

A few studies (Murray, 2009, Wang et.al, 2011) suggest that nanomaterials may enter the body through the skin during exposure. At this time, little is known if skin penetration of nanomaterials would result in adverse health effects. There is also little information about the health effects of injecting nanomaterials into living organisms.

Potential Sources of Occupational Exposure to Nanomaterials for Various Synthesis Methods			
Process Synthesis	*Particle Formation*	*Exposure Source or Worker Activity*	*Primary Exposure Route***
Gas Phase	In Air	Direct leakage from reactor, especially if the reactor is operated at positive pressure	Inhalation
		Product recovery from bag filters in reactors.	Inhalation/Dermal
		Processing and packaging of dry powder.	Inhalation/Dermal
		Equipment cleaning/maintenance (including reactor evacuation and spent filters).	Dermal (and inhalation during reactor evacuation)

Vapor Deposition	On Substrate	Product recovery from reactor/dry contamination of workplace.	Inhalation
		Processing and packaging of dry powder.	Inhalation/Dermal
		Equipment cleaning/maintenance (including reactor evacuation).	Dermal (and inhalation during reactor evacuation)
Colloidal	Liquid Suspension	If liquid suspension is processed into a powder, potential exposure during spray drying to create a powder, and the processing and packaging of the dry powder.	Inhalation/Dermal
		Equipment cleaning/maintenance.	Dermal
Attrition	Liquid Suspension	If liquid suspension is processed into a powder, potential exposure during spray drying to create a powder, and the processing and packaging of the dry powder.	Dermal
		Equipment cleaning/maintenance.	Dermal
** Note: Ingestion would be a secondary route of exposure from all sources/activities from deposition of nanomaterials on food or subsequently swallowed (primary exposure route inhalation) and from hand-to-mouth contact (primary exposure route dermal).			

Table 1 – Sources of Exposure to Nanomaterials through Occupational Activities (Aiken et al. 2004)

e. Factors Affecting Exposure

Every attempt should be made to prevent or minimize exposure to nanomaterials. Factors affecting exposure to nanomaterials include the amount of material being used and whether it can be easily dispersed or form airborne sprays or droplets. The degree of containment and duration of use will also influence exposure. In the case of airborne material, particle or droplet size will determine whether the material can enter the respiratory tract and where it is most likely to deposit. Inhaled particles smaller than 10 micrometers in diameter have some probability of penetrating and being deposited in the gas-exchange (i.e., alveolar) region of the lungs, but there is at least a 50% probability that particles smaller than 4 micrometers in diameter will reach the gas-exchange region.

At present there is insufficient information to predict all of the situations and workplace scenarios that are likely to lead to exposure to nanomaterials. However, there are some workplace factors that will increase the potential for exposure, including (CDC/NIOSH, 2009):

- Working with nanomaterials in liquid media without adequate protection (e.g. gloves) will increase the risk of skin exposure.

- Working with nanomaterials in liquid media during pouring or mixing operations, or where a high degree of agitation is involved, will lead to an increased likelihood of inhalable and respirable droplets being formed.
- Generating nanomaterials in the gas phase in non-enclosed systems will increase the chances of aerosol release to the workplace.
- Handling nanopowders will lead to the possibility of aerosolization.
- Maintenance on equipment and processes used to produce or fabricate nanomaterials will pose a potential exposure risk to workers performing these tasks.
- Cleaning of dust collection systems used to capture nanomaterials will pose a potential for both skin and inhalation exposure.

f. Containment

The primary routes of exposure to NM are through the inhalation of airborne NM and dermal exposure; ingestion is a secondary route of exposure. The containment guidelines below are designed to help minimize a potential exposure through these routes.

The preferred method to minimize personnel exposure to liquid or matrix-bound NM is through engineering controls. Physical containment such as a fume hood, glove box, biological safety cabinet or downdraft table may be necessary to dose/handle animals and for changing bedding/cages. At a minimum, engineering controls should include local exhaust ventilation and localized filtration. Respiratory protection may be required when working with nanomaterials when local exhaust ventilation and filtration is not available.

The following engineering controls are recommended for the safe handling of nanomaterials (CDC/NIOSH, 2009; VCU, 2007):

- Use of containment is recommended for all tasks with potential of aerosolizing nanomaterials in either liquid or powder form.
- A well-designed local exhaust ventilation system with a local high-efficiency particulate air (HEPA) filter should be used to effectively remove nanomaterials.
- If heavy usage of aerosolized nanoparticles is in use, a proper decontamination, or buffer area should be utilized to ensure the nanomaterials are not transported outside of the working area.
- Laboratories and other spaces where nanomaterials are used or stored must be equipped with an eyewash station that meets American National Standards Institute (ANSI) and Occupational Safety and Health Administration (OSHA) requirements.

The second level of containment is through administrative controls. Employees are encouraged to use hand-washing facilities after removing PPE and before leaving the laboratory. Inadvertent contamination caused by the transfer of NM on clothing and skin can be reduced by training personnel to leave lab coats in the work area and provide laundry services for lab coats or implement disposable lab coats. In addition, it is important to incorporate the following administrative controls into all laboratory operations:

- The laboratory's safety plan should be modified to include health and safety considerations of nanomaterials used in the laboratory.
- Principal investigators should develop and implement standard operating procedures (SOPs) in the preparation and administration of nanomaterials (with minimal exposure).
- Protocols involving the *in vivo* use of nanomaterials must be reviewed and approved by the Institutional Animal Care and Use Committee (IACUC).
- Laboratory personnel must receive the appropriate training, including specific nanomaterial-related health and safety risks, standard operating procedures, and steps to be taken in event of an exposure or unintended release incident, prior to working with nanomaterials.
- Laboratory personnel must be instructed to use extreme caution when performing injections involving nanomaterials since accidental needle stick presents an exposure threat.
- Exposures involving nanomaterials or any other acutely hazardous material must be reported to the Environmental Health and Safety Department as soon as possible.
- Animals should be appropriately restrained and/or sedated prior to administering injections and other dosing methods.
- Frequent hand washing, especially before eating, smoking, applying cosmetics, or leaving the work area should be employed.

If engineering or administrative controls do not eliminate the exposure potential, use of personal protective equipment is indicated. The minimum PPE for working with potentially hazardous NM are gloves, a lab coat, and eye protection. Open–toed shoes, shorts, skirts, and cuffed pants are prohibited. Glove selection is best determined by a risk assessment and the chemicals used for the procedure. Nitrile or rubber gloves, which cover hands and wrists completely through overlapping sleeve of lab coat when working with nanomaterials, may provide adequate protection. Wearing of two sets of gloves "double gloving" is advised whenever performing tasks involving nanomaterials and other hazardous substances. Laboratory personnel should thoroughly wash hands with soap and water immediately upon removal of gloves.

Additional PPE may be necessary as determined by the risk assessment. Safety glasses or goggles are considered to be the appropriate level of eye protection for working with nanomaterials. EHS recommends wearing a full-face shield when conducting tasks posing potential for any generation of aerosol and/or droplets. A respirator may be needed if working with high surface area mesoporous/ microporous powders or aerosols outside of a glove box or fume hood. When working with nanomaterials, one of the following types of NIOSH-approved respirators may be needed:

- Filtering face piece (N-95 or greater)
- Elastomeric half- or full-face piece with N-100, R-100, or P-100 filters; or
- Powered air-purifying respirator with N-100, R-100, or P-100 filters.

If a respirator is advised based on the researcher's risk assessment and/or an EHS risk assessment, contact the Occupational Health Program to schedule annually required respiratory medical clearance and fit testing. If a respirator is advised then dust or surgical masks should not be used in place of NIOSH-approved respirators for protection against NM.

g. Using Nanomaterials with Animals

1) Dosing animals with nanoparticles related processes/procedures

- Dosage preparation should not be done in animal rooms or in multi-user rooms in the ARC. Dosage preparation should be done in the PI's lab. Unused materials should be returned to the PI's lab.
- Only essential personnel should be in the room during dosing. The room should be secured.
- Animals should be chemically or physically restrained during dosing.
- Work areas should be cleaned up and decontaminated after animal dosing is completed.
- Animals should be dosed in containment and absorbent paper used to contain small spills, syringe leakage, etc. Absorbent paper should be changed after each experiment and disposed as nanoparticles waste.
- Luer-lock syringes should be used to prevent needle "blow-off".
- If preparation is being administered via a syringe or other feeding device, a fume hood or BSC must be used. If administration is by food, use of a micro-isolator cage is recommended.

2) Handling Animals

If NM is expected to be shed by the animals, PPE should be worn when handling the animals. If the potential exists for the excreted NM to be aerosolized during handling, then the animals should be manipulated in ventilated containment (fume hood/BSC).

3) Bedding/Cage Changes

- Use of disposable cages after inoculating mice with NM is recommended. Cage cards should indicate animals have been inoculated in addition to the estimated washout period. Animals should be kept on a dedicated rack.
- If metabolic cages are used, use ventilated containment (BSC or fume hood) for handling waste containers and cleaning of cage components.
- Personnel should wear proper PPE (gloves, lab coats, respirator, and eyewear) during cage changes to reduce exposure.
- Once inoculated, NM may be excreted into the bedding. Waste/bedding/disposable cages should be disposed in appropriate containers by trained staff.
- Cage changes should not be performed for the first 72 hours.
- Animals can typically be transferred to standard micro-isolator cages after 72 hours.
- Cage changes/dumping may need to be conducted in containment (BSC) based on the risk assessment.

4) **Transportation**
Caution should be taken when transporting animals dosed with NM. To reduce the potential for exposure to the transporter/driver, dosed animals should typically not be transported until they have been transferred to a clean cage (for at least 72 hours after dosing). Consideration should be given to first transporting the animals to the new location before dosing them.

h. Waste Disposal

Dispose of both the engineered nanomaterial and any materials used for wipe up of work surfaces or wipe down of generation equipment with name of the material preceded by words “nanosize” such as “nanosize cadmium selenide contaminated waste unless “nano is contained in the name, such as “cadmium selenide nanodots”. Concentrated nanomaterials should be disposed as hazardous waste and a clearly written tag of nanowaste with their approximate composition in percent should be presented. Simply writing a bulk name or formula does not properly indicate the nano- waste.
Labs should submit a waste request for disposal form and arrange pick up with EHS. Contact EHS for assistance.

For questions concerning chemical waste and/or biological waste (including the need for waste containers for nanomaterials) disposal contact the Hazardous Materials Program in EHS 512-471-3511.

i. Training and Documentation

Personnel should be trained on the potential hazards of working with NM as part of their site-specific hazard communication training. An SOP should be developed and submitted to EHS for review. Review of SOPs should be documented for all personnel who handle NM.

Researchers submitting protocols to the IACUC should note the NM they are planning to use in the toxic/hazardous substance section of the protocol application.

j. Emergency Response

Report any spills to the PI and EHS.

1) Spills

- If a spill is minor and known limited danger, clean up immediately wearing PPE.
- Standard approaches for cleaning powder spills include using HEPA-filtered vacuum cleaners, or wiping up the powder using damp cloths or wetting the powder prior to dry wiping. Damp cleaning methods are preferred. Liquid spills may be cleaned by applying absorbent materials. At a minimum, the following procedures must be followed when managing an accidental spill of nanomaterials (CDC/NIOSH, 2009):

  -Small spills (typically involving less than 5 mg of material) of nanomaterials containing powder should be wet-wiped with cloth/gauze that is dampened with soapy water. Affected surfaces should be thoroughly wet-wiped three times over with appropriate cleaning agent and with a clean, damp cloth used for each wipe down. Following completion, all cloth and other spill clean-up materials with a potential for nanomaterial contamination must be disposed of as hazardous waste.

-Small spills (typically involving less 5 ml of material) of nanomaterial-containing solutions should be covered and absorbed with absorbent material. Areas affected by liquid spills should be triple cleaned with soap and water following removal of absorbent paper.

- Use of commercially available microfiber cleaning cloths may also be effective in removing NM from surfaces with minimal dispersion into the air. Cleaning cloths should be properly disposed.
- If a spill is major or potentially dangerous, evacuate the area and call EHS 512-471-3511.

2) Exposures
   - For dermal exposures to dry material, brush the material off the skin first with a gloved hand and paper towel or other assistive device, then wash the affected area for a minimum of 15 minutes with soap and water.
   - For dermal exposures to liquid material, immediately rinse the affected area for a minimum of 15 minutes with soap and water.
   - Remove any contaminated clothing and seal in a bag.
   - In the event of inhalation exposure, immediately seek fresh air.
   - In the event of eye contact, immediately flush eyes with water for at least 15 minutes.
   - In the event of a needlestick, remove needle and wash affected area with soap and water.
   - Contact Occupational Health at 512-471-4OHP(4647) for all exposure incidents. If an appointment with Occupational Health is required, bring the MSDS (if available) or risk assessment information for the NM being used.

k. Occupational Health

Occupational Health should be consulted whenever a suspected or actual exposure to NM takes place. Personnel who work with NM in animals should notify Occupational Health that they are working with NM on their initial Occupational Health Risk Assessment form and update their NM information on subsequent health monitoring update forms. Personnel who indicate on their Occupational Health Risk Assessment form that they wear respiratory protection (N95 or higher) will be scheduled for annual respiratory medical clearance.

l. Glossary

Nanotechnology Definitions

To assist with consistent terminology involving nanotechnology, UT has adopted the definitions for nanomaterials from the International Organization for Standardization Technical Committee 229 (Nanotechnologies).

According to ISO/TS 27687:2008, a *nano-object* is defined as material with one, two, or three external dimensions in the size range from approximately 1–100 nm. Sub-categories of nano-objects are:

(1) *nanoplate*, a nano-object with one external dimension at the nanoscale;
(2) *nanofiber*, a nano-object with two external dimensions at the nanoscale with a nanotube defined as a hollow nanofiber and a nanorod as a solid nanofiber; and
(3) *nanoparticle*, a nano-object with all three external dimensions at the nanoscale.

Nano-objects are commonly incorporated in a larger matrix or substrate referred to as a *nanomaterial*. Nano-objects may be suspended in a gas (as a nanoaerosol), suspended in a liquid (as a colloid or nanohydrosol), or embedded in a matrix (as a nanocomposite).

Additional definitions

Agglomerate – A group of particles held together by relatively weak forces, including van der Waals forces, electrostatic forces and surface tension.
Aggregate – A heterogeneous particle in which the various components are held together by relatively strong forces, and thus not easily broken apart.
Buckyballs - Spherical fullerenes composed entirely of carbon (C60).
Fullerenes - Molecules composed entirely of carbon, usually in the form of a hollow sphere, ellipsoid, or tube.
Graphene - A one-atom thick sheet monolayer of graphite.
Nanoscience – The study of phenomena and manipulation of materials at atomic, molecular and micromolecular scales, where properties differ significantly from those at a bulk scale.
Nanoaerosol – A collection of nanomaterials suspended in a gas.
Nanocolloid – A nanomaterial suspended in a gel or other semi-solid substance.
Nanocomposite – A solid material composed of two or more nanomaterials phase having different physical characteristics.
Nanoparticle – A substance with dimensions less than 100 nanometers in size.
Nanohydrosol – A nanomaterial suspended in a solution.
Nanotechnology – The understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications.
Nanotubes - A sheet of graphene rolled up into a seamless cylinder with diameter on the order of a nanometer.
Nanowires - A wire of dimensions on the order of a nanometer.
Nucleation - The first step in the process by which gases are converted to small liquid droplets.
Physicochemical – The underlying molecular organization of life that is manifested as chemical and energy transformations.
Pyrolysis - Chemical change brought about by the action of heat.
Quantum Dots – A nanomaterial that confines the motion of conduction band electrons, valence band holes, or excitons (pairs of conduction band electrons and valence band holes) in all three spatial directions.
Single-Walled Carbon Nanotube – A single sheet graphene wrapped into a tube approximately 1.5 nanometers in diameter.
Thermites – A mixture of aluminum powder and a metal oxide (as iron oxide) that when ignited evolves a great deal of heat and is used in welding and in incendiary bombs.
Translocation – The act, process, or an instance of changing location or position.
Transmission Electron Microscopy (TEM) – A microscopy technique whereby a beam of electrons is transmitted through an ultra thin specimen, interacting with the specimen

as it passes through, and produces an image formed from the interaction of the electrons transmitted through the specimen which is then magnified and focused onto an imaging device.
Ultra-Fine Particles - Airborne particles with an aerodynamic diameter of 0.1 m (100 nm) or less.

m. References

NIOSH Publication No. 2009-125: Approaches to Safe Nanotechnology Managing the Health and Safety Concerns Associated with Engineered Nanomaterials

NIOSH Publication No. 2009-116: Current Intelligence Bulletin 60: Interim Guidance for Medical Screening and Hazard Surveillance for Workers Potentially Exposed to Engineered Nanoparticles

NIOSH Publication No. 2008-112: Safe Nanotechnology in the Workplace

Interim Best Practices for Working with Nanoparticles Center for High-Rate Nanomanufacturing. M. Ellenbecker Revision 0 – November 2007

Aitken, R.J., Creely, K.S., Tran, C.L. *Nanoparticles: An Occupational Hygiene Review*. Research Report 274. Prepared by the Institute of Occupational Medicine for the Health and Safety Executive, North Riccarton, Edinburgh, England. 2004.

Nanotechnology and Nanoparticles – Safe Working Practices Information. Virginia Commonwealth University. Office of Environmental Health and Safety. 2007

Occupational Safety and Health Act of 1970 (29 U.S.C. 654). Section 5(a) (1).

Nanoparticles Safety Guide, The University of Texas Health Science Center at Houston, Safety, Health, Environment, and Risk Management

ISO/TS 27687:2008, Nanotechnologies -- Terminology and definitions for nano-objects -- Nanoparticle, nanofibre and nanoplate

Nanotechnology Health and Safety Resources:

- National Institute for Occupational Safety and Health
- NCI Nanotechnology Characterization Laboratory
- The Nano Risk Framework
- Good Nano Guide

VI. Physical Hazards

a. Fire Safety

In addition to other requirements, most laboratories on campus are subject to the National Fire Protection Association (NFPA), particularly NFPA 45 which is the Standard on Fire Protection for Labs using Chemicals. See below for useful information on how to keep your lab safe from a fire safety perspective:

- Tips to get your lab fire code compliant
- Guide for Lab Compliance with NFPA 45

b. Hearing

The university is committed to protecting the health and safety of lab workers. Review the information below to learn more about hearing protection. Contact EHS if you have questions or concerns about noise levels in your work environment.
Hearing Protection Informational Handout (PDF)

c. Shop Safety Rules

EHS wants to ensure that all employees and students who work in machine shops have the basic training to keep themselves and their colleagues safe. Please keep these rules in mind and take our OH 500 Shop Safety online training if you work in a machine shop. Review the general shops rules below:

- Never work alone. Follow your shop's after-hours policy.
- Never use machinery without the approval of the supervisor and completion of training.
- Never use damaged or malfunctioning equipment.
- Never talk to or touch the machine operator.
- Never allow student use of power machinery without the shop supervisor or a monitor present. Undergraduates must check in with monitor upon arrival.
- Never wear loose clothing in the shop—including ties, scarves, jewelry, and loose sleeves. No open-toed shoes or short pants allowed in the shop.
- Never use a cell phone or personal music player. Store them at the entrance to the shop prior to working. Loud music is prohibited.
- Never work if you are tired. Take frequent breaks to stay alert.
- Never use compressed air greater than 30 psi pressure for cleaning equipment. Never use compressed air to clean skin or clothing.
- Always complete general and shop-specific training before using facility.
- Always understand your operation before you begin or ask the shop supervisor for help.
- Always wear personal protective equipment (PPE), including glasses or face protection.

- Always remove jewelry before working—including rings, necklaces, bracelets, and watches.
- Always secure long hair including beards.
- Always use all guards and shields. They must be secured prior to operating equipment.
- Always check wood for screws or other embedded metal objects.
- Always clear dust and debris before and after machine use.
- Always keep aisles, exits, and access to emergency equipment clear.
- Always immediately report all problems or concerns to the shop supervisor or monitor.

Follow these guidelines if you work with hand tools such as drills, pliers, and hammers.

Hand Tool Safety (PDF)

d. Ergonomics

EHS can perform ergonomic assessments for employees on a referral basis from HealthPoint 512-471-4OHP(4647) or HealthPoint.OHP@austin.utexas.edu. If you are experiencing discomfort at your workstation please contact HealthPoint first. Ergonomic consultations and evaluations are provided at no cost to the department. However, any suggested items for purchase are at the department and/or employee’s own expense.

References:

CRC Handbook of Laboratory Safety, Fifth Ed. A. K. Furr, Ed. CRC Press. 2000.

First Aid Manual for Chemical Accidents. M. Lefevre. 1989.

Hazards in the Chemical Laboratory. L. Bretherick, Ed. 1986.

Matheson Gas Data Book. C. Yaws. 2001.

Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, Updated Version. National Academy Press. 1995.

Safety in Academic Chemistry Laboratories. American Chemical Society. 2003.

Sigma-Aldrich Library of Chemical Safety Data, Second Ed. R. E. Lenga, Ed. 2 volumes, 1988.

Texas Hazard Communication Act. Texas Department of Health.

APPENDIX A: LABORATORY SAFETY COORDINATOR

THE UNIVERSITY OF TEXAS AT AUSTIN
Laboratory Safety Coordinator

College/Department Name:____
_

Laboratory Safety Coordinator (LSC) Name:____
_

EID:____________________

LSC Address: Building: __________ Room: __________

Phone Number: __________ Campus Mail

Code:__________

Each college, department, organized research unit that has laboratories using hazardous materials should designate a Laboratory Safety Coordinator to carry out the duties and responsibilities of the LSC described in the Laboratory Safety Manual.

The individual identified above has been appointed LSC and has accepted the responsibilities and duties associated with this appointment.

Appointing official: Laboratory Safety Coordinator:

______________________________ ______________________________
Dean, Department Chair, or ORU Director Signature

____________________ ____________________
Date Date

A copy of this form shall be:
placed in the appropriate LABORATORY SAFETY MANUALS,
retained in the Dean's Office and by the Department Chair or ORU Director, and submitted to Environmental Health and Safety.

APPENDIX B – CHEMICAL STORAGE SEGREGATION SCHEME

Developing safe storage practices for laboratory chemicals is not always easy and often requires a considerable amount of thought and planning. Your ability to develop a safe storage system will depend on your knowledge of chemicals or your ability to find information on the hazards associated with materials you have.
The goal of your storage system should be to separate materials according to chemical compatibility and hazard class. You will need to develop a segregation scheme to fit your specific needs; but, do not store chemicals alphabetically until you have them properly segregated. Use the following broad hazard classes as a guide for segregating your hazardous chemicals. Storing solids above and liquids below is a good practice.

CLASS OF CHEMICALS	**RECOMMENDED STORAGE METHOD**	**CHEMICAL EXAMPLES**	**INCOMPATIBLES SEE MSDS IN ALL CASES**
Compressed Gases - Flammable (Includes Combustible)	Store in a cool, dry area, at least **20 feet** away from oxidizing gases. Securely strap or chain cylinders to a wall or bench top. Some gases may require a sprinklered and/or ventilated gas storage cabinet.	Methane, Acetylene, Hydrogen	Oxidizing and toxic compressed gases, oxidizing solids
Compressed Gases - Liquefied Flammable	Store in a cool, dry area, at least **20 feet** away from oxidizing gases. Securely strap or chain cylinders to a wall or bench top. Some gases may require a sprinklered and/or ventilated gas storage cabinet. Limit storage inside buildings to **16 oz.** containers or less. Larger cylinders are for day use only inside buildings. Permanent storage should be located outside of the building.	Propane, Butane	Oxidizing and toxic compressed gases, oxidizing solids

Compressed Gases - Reactive (includes Oxidizing)	Store in a cool, dry area, at least 20 feet away from flammable gases and liquids. Securely strap or chain cylinders to a wall or bench top. Some gases may require a ventilated gas storage cabinet.	Oxygen, Chlorine, Bromine	Flammable gases
CLASS OF CHEMICALS	**RECOMMENDED STORAGE METHOD**	**CHEMICAL EXAMPLES**	**INCOMPATIBLES SEE MSDS IN ALL CASES**
Compressed Gases - Threat to Human Health (includes Toxic and Corrosive)	Store in a cool, dry area, away from flammable gases and liquids. Securely strap or chain cylinders to a wall or bench top. Some gases may require a ventilated gas storage cabinet.	Carbon monoxide, Hydrogen sulfide	Flammable and/or oxidizing gases
Corrosives - Acids INORGANIC	Store in a separate, lined/protected acid storage cabinet or plastic secondary container	**Inorganic (mineral) acids** - Hydrochloric acid, Sulfuric acid, Chromic acid, Nitric acid. *Note: Nitric acid is a strong oxidizer and should be stored by itself. Separate nitric acid from other acids by storing in a secondary container or a separate acid cabinet.*	Flammable liquids, flammable solids, bases, and oxidizers. **Organic acids**
Corrosives - Acids ORGANIC	Store in a separate, lined/protected acid storage cabinet or plastic secondary container	**Organic acids** - Acetic acid, Trichloroacetic acid, Lactic acid	Flammable liquids, flammable solids, bases, and oxidizers. **Inorganic acids**
Corrosives - Bases	Store in a separate storage cabinet	Ammonium hydroxide, Potassium hydroxide, Sodium hydroxide	Oxidizers and Acids
Explosives	Store in a secure location away from all other chemicals. Do not store in an area where they can fall.	Ammonium nitrate, Nitro Urea, Sodium azide, Trinitroaniline, Trinitroanisole, Trinitrobenzene, Trinitrophenol/Picric Acid, Trinitrotoluene (TNT).	All other chemicals.

Flammable Liquids	Store in a flammable storage cabinet. *Note: Peroxide forming chemicals must be dated upon opening, e.g., ether, tetrahydrofuran, dioxane*	Acetone, Benzene, Diethyl ether, Methanol, Ethanol, Hexanes, Toluene	Oxidizers and Acids
Flammable Solids	Store in a separate dry cool area away from oxidizers, corrosives	Phosphorus, Carbon, Charcoal	Oxidizers and Acids
Water Reactive Chemicals	Store in a dry, cool location. Protect from water and the fire sprinkler system, if applicable. Label location - WATER REACTIVE CHEMICALS -	Sodium metal, Potassium metal, Lithium metal, Lithium Aluminum hydride	Separate from all aqueous solutions, and oxidizers
CLASS OF CHEMICAL S	**RECOMMENDED STORAGE METHOD**	**CHEMICAL EXAMPLES**	**INCOMPATIBLES SEE MSDS IN ALL CASES**
Oxidizers	Store in a spill tray inside a non-combustible cabinet, separate from flammable and combustible materials.	Sodium hypochlorite, Benzoyl peroxide, Potassium permanganate, Potassium chlorate, Potassium dichromate. *Note: The following chemical groups are considered oxidizers: Nitrates, Nitrites, Chromates, Dichromates, Chlorites, Permanganates, Persulfates, Peroxides, Picrates, Bromates, Iodates, Superoxides.*	Separate from reducing agents, flammables, combustibles and organic materials.
Toxics (Poisons)	Store separately in a vented, cool, dry, area in chemically resistant secondary containers	Cyanides, heavy metal compounds, i.e. Cadmium, Mercury, Osmium	See MSDS
General Chemicals Non-Reactive	Store on general laboratory benches or shelving. Use upper shelving for non-hazardous chemicals only.	Agar, Sodium chloride, Sodium bicarbonate, and most non-reactive salts	See MSDS

The following gases will require ventilated storage: Ammonia, Arsenic pentafluoride, Arsine, Boron trifluoride, 1,3-Butadiene, Carbon monoxide, Chlorine trifluoride, Chloroethane, Cyanogen, Diborane, Dichloroborane, Dichlorosilane, Dimethylamine, Ethylamine, Ethylene, Ethylene oxide, Fluorine, Formaldehyde, Germane, Hydrogen chloride, Hydrogen cyanide, Hydrogen fluoride, Hydrogen selenide, Hydrogen sulfide, Methylamine, Methyl bromide, Methyl chloride, Methyl mercaptan, Nitrogen oxides, Phosgene, Phosphine, Silane, Silicon tetrafluoride, Stibine, Trimethylamine, Vinyl chloride

APPENDIX C – EMERGENCY INSTRUCTIONS

CONTACT NUMBERS

	Landline	**Cell**
UT Police	911	471-4441
EHS	1-351	471-3511
OHP (HealthPoint)	1-4647	471-4647

Location Information

Building: ______________________________
Room Number: _________________________
Address: ______________________________
Lab Phone: ____________________________
PI: ___________________________________
Building Manager
Name___________________________
Office Location___________________
Phone #_________________________

Is the situation and immediate threat to life and health?

YES			NO			NOT SURE	
Spill/Leak/Release	**Medical Emergency**	**Fire or Flammable Gas**	**Spill/Leak/Release**	**Medical Emergency**	**Fire or Flammable Gas**	**Chemical Odor?**	**Possible Fire / Natural Gas**
(including chemicals and bio agents")	(not including chemicals or bio agents)		(including chemicals and bio agents")	(not including chemicals or bio agents)		Report the incident to your building manager, lab director, principal investigator, or department administrator	Turn off flames and other ignition sources if safe to do so
Use safety shower or eyewash- remove affected clothing and rinse for a minimum of 15 minutes	Assist the victim, if possible, while someone calls UT Police	Turn off flames and other ignition sources if safe to do so	Alert your neighbors	Assist the victim, if possible	Turn off flames and other ignition sources if safe to do so	Contact EHS	Report the incident to your building manager, lab director, principal investigator, or department administrator
Shut doors to the spill area and evacuate the area (if necessary)	Report the incident to your building manager, lab director, principal investigator, or department administrator	Evacuate the area if necessary	Report the incident to your building manager, lab director, principal investigator, or department administrator	Report the incident to your building manager, lab director, principal investigator, or department administrator	Use extinguisher as appropriate for fire	Stay in area to inform EHS response	Contact EHS
Call UT Police	Report incident to EHS	Shut doors to the area and alert others	Contact EHS	Report incident to EHS	Report the incident to your building manager, lab director, principal investigator, or department administrator		Stay in area to inform EHS response
Report the incident to your building manager, lab director, principal investigator, or department administrator	Report incident to OHP	Pull the nearest fire alarm and call UT Police	Follow steps in Lab Safety Manual or in spill kit	Report incident to OHP	Report incident to EHS		
Contact EHS		Report the incident to your building manager, lab director, principal investigator, or department administrator					
Contact OHP		Report incident to EHS					

APPENDIX D- LAB INSPECTION CHECKLIST

THE UNIVERSITY OF TEXAS AT AUSTIN

Environmental
Health & Safety

Lab Safety Evaluation

Bldg/Room ______________________	PI ______________________
Date ______________________	Department ______________________
Lab Contact ______________________	Phone ______________________
Inspector ______________________	Inspection Type Regular

Chemical Storage		Y	N	O	N/A	Comments/Notes
1	Chemicals segregated by hazard class					
2	Chemical containers in good condition					
3	Chemical containers properly labeled					
4	Chemical containers closed					
5	Glass chemical containers are not stored on the floor					
6	Lab safe refrigerator used for cold flammable storage					
7	Flammable storage cabinets used for flammable storage >10 gal					
8	Peroxide forming chemicals not expired or peroxide testing evident					
9	Acids stored in acid cabinet or secondary containment					
10	Gas cylinders properly secured					
11	Gas cylinder safety caps in place					
12	Toxic and hazardous gas cylinders properly ventilated					
13	Fume hood not used as permanent storage/ no clutter in fume hood					
14	Fume hood sash at or below 18”					
Ignition Sources						
15	Vacuum pumps and other ignition sources are segregated from flammables/combustibles					
16	Electrical cords are in good condition					
Chemical/Sharps/Glass Waste						
17	Less than 55 gallons of chemical waste in area					
18	Chemical waste containers properly labeled					
19	Chemical waste containers closed					
20	Glass waste disposal box properly used					
21	Sharps containers properly used/properly disposed when full **					
Good Practices						
22	Excess clutter was not present in the lab					
23	Food/drinks were not in the lab					
Emergency Equipment and Egress						
24	Exits and aisles clear of obstruction					
25	Emergency equipment clear of obstruction					
26	Doors not propped open					
27	Chemical spill supplies available					
28	Hazardous materials/equipment in hall secured					
29	Electrical panels/disconnects clear of obstruction/ panel doors closed					
30	Lab personnel know emergency equipment shutdown procedures **					

Emergency Preparedness

31 Eyewash tested within the past week/documented in the past month					
32 Lab personnel have attended required training ** (OH 101, OH 102, OH 201, FF 205)					
33 Lab personnel know how to get MSDS **					
34 Lab personnel have protective clothing available **					
35 Lab personnel wear/use proper protective equipment while in lab (Lab coat, gloves, glasses, etc.)/ short/sandals are not worn in the lab					

Other (Describe)

36 Miscellaneous

**Lab personnel must be present to answer questions

*****Entered into database ☐ Entry Number ___________________ *****

Lab Facility Evaluation

Emergency Equipment	Y	N	O	N/A	Comments/Notes
37 Eyewash available					Actually needed? Identify a place for it. Prioritize: High,Med,Low
38 Emergency shower available					Actually needed? Identify a place for it. Prioritize: High,Med,Low
39 Emergency shower has been tested within the past year					
40 Fire extinguisher is available, mounted and clearly marked					
41 Fire extinguishers are charged and have safety pins and seals					
Lab Design					
42 No penetrations in walls, floor, or ceiling/ all ceiling tiles in place					
43 Fire separation was adequate (Class A only*)					
44 Doors swing in direction of egress (Class A only*)					
45 Appropriate number of exits (Class A only*)					
Labeling/Signage/ Lab Usage					
46 Refrigerators/cooling equipment properly labeled					
47 Lab does not use RAM, lasers, or biological materials **					
48 Signs identifying unusual hazards posted at lab entrance					
49 Emergency instructions posted near phones					
50 Current chemical inventories posted near door					
Chemical Ventilation Control					
51 Ventilated storage available for toxic and hazardous gas cylinders					
52 Fume hood electrical disconnects located within 50 ft, accessible and clearly marked (**ONLY** if electrical services/controls in fume hood)					
53 Fume hood has been tested within the past year					

* FPS participates in Class A evaluations

Mercury Thermometers

Does the lab use mercury thermometers?					

****Reminder: Ask lab contact for a list of their lab staff.****

Notes:

Environmental Health & Safety

Standard Operating Procedures Template for Highly Hazardous Chemicals

- **Title of Procedure:**
- **Date:**
- **Date of Last Review:**
- **Principal Investigator:**
- **Lab Location:**
- **Lab Personnel who have reviewed SOP/Date:**

Risk Assessment

Hazardous Chemicals: *(List chemicals used. Include chemical name, common name and abbreviation)*

Potential Hazard(s): *(Describe the potential hazards associated with the chemicals or the procedure.)*

Examples include:

1) *Chemical hazards such as carcinogenic, irritant, corrosive, acutely toxic*
2) *Reproductive hazards such as teratogens or mutagens*
3) *Allergies or chemical sensitivities that may be associated with the chemical*
4) *Physical hazards such as reactive, unstable, pyrophoric, implosion, exothermic, use of high energy equipment*

Routes of Exposure: *(As applicable, describe the potential routes of exposure associated with the procedure such as inhalation, injection, skin/eye contact)*

Exposure Limit: *(As applicable, list the Permissible Exposure Limit (PEL) or Threshold Limit Value (TLV) of the chemical(s) if known)*

Quantity/Concentration Hazards: *(As applicable, describe if the quantity/concentration of the chemical(s) used increases the risk of exposure to the chemical.)*

Substitution of Less Hazardous Chemicals: *(As applicable, describe the potential use of less hazardous chemical substitutes)*

Control Measures

Personal Protective Equipment (PPE): *(List all applicable personal protective equipment needed for procedure)*

For example, describe use of:

1) *Gloves (what type)*
2) *Lab Coats, Suits, Aprons*
3) *Safety Glasses, Goggles, Faceshields*
4) *Respirators, Hearing Protection*
5) *Special Equipment (such as blast shields)*
6) *Other PPE*

Engineering Controls: *(As applicable, describe the engineering controls used for the procedure)*

Examples:

1) *Use of fume hoods or glove boxes*
2) *Special ventilation*
3) *HEPA filtered vacuum lines*
4) *Non-reactive containers*
5) *Temperature control*
6) *Bench paper, pads, chuks, plastic-backed paper*
7) *Special signage*
8) *Safe sharp devices*
9) *Other safety devices used*

Work Practice Controls: *(As applicable, describe work practice controls used for the procedure)*

Examples:

1) *Designated areas(for highly toxic chemicals)*
2) *Performing procedure with at least two people present*
3) *Rotating workers*
4) *Restricting access; locks*
5) *Housekeeping*

Monitoring: *(As applicable, describe any monitoring needed for the procedure)*

Examples:

1) *Personnel exposure monitoring*
2) *Gas/spill release monitoring*

Use in Animals: *(As applicable, describe how the chemical will be safely used in animals)*

Examples:

1) *Dosing administration procedures*
2) *Animal restraining*
3) *Information on shedding/excretion of chemical*
4) *Aerosol suppression practices*
5) *Handling animals*
6) *Special cage handling/washing instructions*

Cleanup/Decontamination Procedures: *(Describe the process for cleaning the work area during and after the procedure.)*

Storage Procedures: *(Describe how and where the chemical will be safely stored)*

Example:

Reviewing expiration dates on peroxide formers

Transportation Procedures: *(If the chemical will be transported on campus, describe procedure)*

Waste Disposal Procedures: *(Description of how waste will be disposed)*

Examples:

1) *Animals: include bedding, cages and carcasses*
2) *Chemicals*
3) *Radioactive*
4) *Sharps*

Emergency Procedures: *(Describe what procedures should be followed in the event of an emergency)*

Spills or Releases: *(Provide specific instructions on what personnel should do in the event of a spill or gas release. Include location of spill kits.)*

Fire: *(Provide specific instructions on what personnel should do in the event of a fire)*

Emergency Shut Offs: *(If applicable, describe procedures for shutting down equipment in an emergency)*

Signs and Symptoms of Exposure: *(Describe the specific signs and symptoms of an exposure to the chemical such as visual cues or odors)*

Exposures: *(Provide specific instructions on what personnel should do in the event of an exposure)*

First Aid: *(If first aid for exposure is available, describe procedure. If not, describe what steps should personnel take if injured.)*

Occupational Health Requirements: *(Describe any Occupational Health requirements necessary that are associated with the procedure. Examples include medical evaluation, baseline serum samples and respiratory fit testing)*

Material Safety Data Sheets (MSDS): *(Describe how personnel will access MSDS in the lab. Include a copy of the MSDS with this SOP)*

Training Requirements: *(Describe what training personnel must complete before using chemical/procedure. This training should be documented)*

Review of Procedure: *(Describe the frequency for reviewing the SOP document)*

Protocol:

Description of how to safely perform the experiment or operation.

SAVE PRINT RESET SUBMIT