Chemical Hygiene Plan

ABSTRACT

The Chemical Hygiene Plan (CHP) is to provide guidance and protocols for the protection of laboratory workers at University of North Texas from health hazards potentially associated with chemicals used in the laboratory. The CHP describes policies, procedures, equipment, personal protective equipment and work practices that are capable of protecting employees from the health hazards presented by many hazardous chemicals used in laboratories.

Risk Management Services

Emergency Telephone Numbers

Department	Phone Number
Chemical Hygiene Officer (CHO)	940-565-4196
Director of Environmental Health and Safety	940-565-2167
Risk Management	940-565-2109
University Police	940-565-3000
University Health Center	940-565-2333
UNT Fire and Emergency	9-911
Denton Fire Department	9-911

After hours or weekends, the University Police (940-565-3000) will assist in contacting Risk Management as necessary.

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1 INTRODUCTION

The University of North Texas (UNT) is dedicated to providing a safe working environment for students and employees and complying with federal and state occupational health and safety standards. Faculty, staff, students, and visitors engaged in the laboratory use of hazardous chemicals, must comply with the provisions of the Occupational Safety and Health Administration (OSHA) standard 29 CFR§1910.1450, "Occupational Exposure to Hazardous Chemicals in Laboratories."

The risks associated with laboratory research are greatly reduced or eliminated when proper precautions and practices are observed in the laboratory. The Chemical Hygiene Plan (CHP) was developed to manage and mitigate these risks and to be the basis of UNT's laboratory safety program. The Chemical Hygiene Plan (CHP) shall be reviewed and evaluated at least annually for its effectiveness and updated as necessary. Ongoing dialogue and feedback are encouraged. The CHP should be made available to all.

All personnel, including principal investigators and laboratory supervisors, employees, and students, have a duty to fulfill their obligations with respect to maintaining a safe work environment. Safety is everyone's responsibility and should be everyone's priority.

1.1 Purpose

The purpose of the Chemical Hygiene Plan (CHP) is to provide guidance and protocols for the protection of laboratory workers at University of North Texas from health hazards potentially associated with chemicals used in the laboratory. The CHP describes policies, procedures, equipment, personal protective equipment, and work practices that are capable of protecting employees from the health hazards presented by many hazardous chemicals used in laboratories. The contents of the CHP are general in nature and specific problems should be referred to the principal investigator or laboratory supervisor, Chemical Hygiene Officer, or appropriate personnel.

1.2 Policy

The CHP applies to all university personnel engaged in the laboratory use of hazardous chemicals. The laboratory use of hazardous chemicals means handling or use of such chemicals in which all of the following conditions are met:

a. chemical manipulations are carried out on a laboratory scale,
b. multiple chemical procedures or chemical substances are used, and
c. "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposures to hazardous chemicals.

A hazardous chemical, according to OSHA, is a chemical for which there is statistically significant evidence, based on at least one study conducted in accordance with established scientific principles, that acute or chronic health effects may occur in exposed employees.

1.3 Responsibilities

All personnel, including principal investigators, laboratory supervisors, laboratory technicians, students, and support staff have the responsibility to maintain a safe working environment.

1.3.1 *Risk Management Services*

Risk Management Services is responsible for the following:

- reviewing the CHP annually and updating the CHP as needed.
- Develop and provide general laboratory safety training. RMS shall maintain training records of appropriate faculty, staff, and students.
- Provide emergency response for large chemical spills.
- Investigate laboratory incidents, including injuries and exposures.
- Conduct periodic laboratory safety audits.

1.3.2 *Chemical Hygiene Officer*

The Chemical Hygiene Officer is responsible for the following:

- Developing, implementing, and updating the CHP;
- Assisting departments and individual laboratories in implementing and complying with the CHP;

- Providing assistance, information, or instruction to all laboratory staff regarding safety issues, identification of chemical hazards or potential chemical hazards, and ensuring that adequate supervision is provided;
- Ensuring proper facilities, equipment, protective devices or services are provided and maintained in good order for safe handling, storage and disposal of chemicals;
- Conducting annual inspections of the laboratories, preparations rooms, and chemical storage rooms, and submit detailed laboratory inspection reports to administration;
- Providing technical guidance and investigation, as appropriate, for laboratory and other types of incidents, injuries, and near-misses;
- Instituting appropriate audit methods to ensure compliance;
- Helping develop and implement appropriate chemical hygiene policies and practices;
- Working with research staff to review existing Standard Operating Procedures (SOPs) and assisting with developing new SOPs for handling hazardous chemicals or processes;

1.3.3 *Principal Investigator*

Principal Investigators (PI) have overall responsibility for the health and safety of all personnel working in their laboratory. The PI may delegate safety duties, but remains responsible for ensuring that any delegated safety duties are adequately performed. The PI has the primary responsibility for establishing a strong safety culture within the laboratory they oversee. New PIs must contact RMS prior to beginning their laboratory operations. RMS should also be contacted by PIs moving into a new lab, when new contacts come into a lab, and before vacating/closing a laboratory. The PI is responsible for the following:

- Knowing all applicable health and safety rules and regulations, training and reporting requirements, and SOPs associated with chemical safety for regulated substances;
- Developing and implementing SOPs and training programs specific to the work being carried out in their laboratories;
- Ensuring effective SOPs (general and protocol specific, chemical and process) are written and followed for lab work involving high hazard materials and activities;
- Ensuring potential hazards of specific projects have been identified and addressed before work is started;
- Identifying and providing necessary safety supplies (e.g., spill kits, first aid kits, etc.) and personal protective equipment (PPE) (e.g., laboratory coats, gloves, eye protection, etc.) to

all laboratory personnel and ensuring the availability of all appropriate PPE and ensuring that PPE is maintained in working order;

- Discussing and reinforcing safe work practices and PPE use, and providing coaching and disciplinary action as necessary;]
- Maintaining an up-to-date and accurate chemical inventory (this includes all hazardous materials and compressed gases) for the laboratory or facility and have safety data sheets (SDSs) readily accessible for all hazardous chemicals stored in their laboratories;
- Ensuring that lab personnel understand and follow the CHP and attend required training from RMS;
- Providing initial and annual training for all laboratory personnel regarding lab-specific hazards in their area and associated with their work and maintaining documentation of initial and annual training for all laboratory personnel;
- Promptly notifying RMS and/or Facilities Management should they become aware that workplace engineering controls (e.g., fume hoods) and safety equipment (e.g., emergency showers/eyewashes, fire extinguishers, etc.) become non-operational;
- Conducting continuous inspection of the research space under the PI's control, and ensuring that unsafe conditions are identified and corrected;
- Ensuring that all injuries, spills, incidents, and near-misses are reported to RMS as soon as possible (within 24 hours);
- Investigating laboratory incidents, identifying root causes, and implementing appropriate solutions in conjunction with EHS personnel;
- Objectively evaluating direct reports on their safety involvement and continuous improvement efforts;
- Identifying and minimizing potential hazards to provide a safe environment for repairs and renovations;
- Actively participating in safety improvement efforts;
- Leaving facilities and equipment in a clean and safe condition when the premises are vacated.

1.3.4 *Laboratory Supervisors*

Laboratory supervisors in charge of lab spaces (including but not limited to research, teaching, and stockrooms) have overall responsibility for the health and safety of those working within their space. The Laboratory Supervisor may delegate safety duties, but remains responsible for ensuring that any delegated safety duties are adequately performed. The Laboratory Supervisor also has the responsibility of establishing a strong safety culture within the laboratory space they oversee. If the Laboratory Supervisor oversees a teaching lab or space involved in teaching, the responsibilities below are designated for both the instructor of record and Laboratory Supervisor. The Laboratory Supervisor is responsible for the following:

- Knowing all applicable health and safety rules and regulations, training and reporting requirements, and SOPs associated with chemical safety for regulated substances;
- Assisting PI or instructor of record in developing and implementing SOPs and training programs specific to the work being carried out in their laboratories;
- Ensuring effective SOPs (general and protocol specific, chemical and process) are written and followed for lab work involving high hazard materials and activities;
- Ensuring potential hazards of specific projects have been identified and addressed before work is started;
- Identifying and providing necessary safety supplies (e.g., spill kits, first aid kits, etc.) and personal protective equipment (PPE) (e.g., laboratory coats, gloves, eye protection, etc.) to all laboratory personnel and ensuring the availability of all appropriate PPE and ensuring that PPE is maintained in working order;
- Discussing and reinforcing safe work practices and PPE use, and providing coaching and disciplinary action as necessary;
- Maintaining an up-to-date and accurate chemical inventory (this includes all hazardous materials and compressed gases) for the laboratory or facility and have safety data sheets (SDSs) readily accessible for all hazardous chemicals stored in their laboratories;
- Ensuring that lab personnel understand and follow the CHP and attend required training from RMS;
- Providing initial and annual training for all laboratory personnel regarding lab-specific hazards in their area and associated with their work and maintaining documentation of initial and annual training for all laboratory personnel;
- Promptly notifying RMS and/or Facilities Management should they become aware that workplace engineering controls (e.g., fume hoods) and safety equipment (e.g., emergency showers/eyewashes, fire extinguishers, etc.) become non-operational;
- Conducting continuous inspection of the space under their control, and ensuring that unsafe conditions are identified and corrected;

- Ensuring that all injuries, spills, incidents, and near-misses are reported to RMS as soon as possible (within 24 hours);
- Investigating laboratory incidents, identifying root causes, and implementing appropriate solutions in conjunction with EHS personnel;
- Objectively evaluating direct reports on their safety involvement and continuous improvement efforts;
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- Actively participating in safety improvement efforts;
- Leaving facilities and equipment in a clean and safe condition when the premises are vacated.

1.3.5 *Laboratory Personnel*

Laboratory personnel, i.e., undergraduate researchers, graduate researchers, post-doctoral researchers, staff scientists, student workers, teaching assistants, and all students in a laboratory setting, are ultimately responsible for following:

- Reviewing and following the requirements of the Chemical Hygiene Plan and completing all required safety training (in-person and online);
- Understanding and following all verbal and written laboratory safety rules, regulations, standard operating procedures, and best practices that apply to the work areas required for the tasks assigned;
- Developing good personal chemical hygiene habits, including but not limited to, keeping the work areas safe and uncluttered;
- Performing a risk assessment of the hazards of materials and processes in their laboratory research or other work procedures and ensuring required safety precautions are in place prior to conducting work;
- Properly identifying/labeling, storing, handling, and disposing of hazardous waste;
- Utilizing appropriate measures to control identified hazards, including consistent and proper use of engineering controls, personal protective equipment, and administrative controls;
- Understanding the capabilities and limitations of PPE issued to them and following University lab dress code and wearing PPE required for procedures;

- Gaining prior approval from the PI or Laboratory Supervisor for the use of restricted chemicals and other materials;
- Consulting with PI and/or Laboratory Supervisor before using any particularly hazardous substances, pyrophoric chemicals, explosives and other highly hazardous materials or conducting certain higher risk experimental procedures;
- Reporting all incidents, injuries, illnesses, spills, unsafe conditions and work practices, and near-misses to the PI and/or Laboratory Supervisor and RMS;
- Completing all required health, safety and environmental training and providing written documentation to their PI and/or Laboratory Supervisor;
- When working autonomously or performing independent research or work:
    - Reviewing the plan or scope of work for their proposed research with the PI and/or Laboratory Supervisor;
    - Notifying in writing and consulting with the PI and/or Laboratory Supervisor, in advance, if they intend to significantly deviate from previously reviewed procedures;
    - Significant change may include, but is not limited to, change in the objectives, change in PI, change in the duration, quantity, frequency, conditions or location, increase or change in PPE, and reduction or elimination of engineering controls;
    - Preparing SOPs for hazardous chemicals and processes and performing literature searches relevant to safety and health that are appropriate for their work;
    - Providing appropriate oversight, training and safety information to laboratory or other personnel they supervise or direct.
    - **NOTE: Undergraduate researchers, student workers, or students within a teaching laboratory space should never be left unsupervised or allowed to work alone within the laboratory space.**

1.4 Non-compliance of Laboratories

Faculty and PIs are ultimately responsible for correcting findings in their laboratory spaces. Environmental Health & Safety will send out pre-survey information before surveys are conducted, including the content of the survey itself, via email to the PIs on record for each space that will be surveyed. Surveys will be conducted in each space by building, and completed surveys will be emailed to the PIs on record for each laboratory as they are completed. The PIs will have 30 days to rectify and/or respond to any issues that have been found during the survey process. If a response has not been received by Environmental Health & Safety after 30 days, a reminder email will be sent requesting a response within 7 days of receipt of the reminder email. If a response has still not been received after 7 days of the reminder email, the issues will be escalated to the director of Environmental Health & Safety and the chair of the PIs department.

1.5 Record of Changes

Change #	Date of Change	Change Entered by	Description
25-01	**02/2025**	**Todd Germain**	**Adding Record of Changes, updating non-compliance escalation, contact list**

2 Employee Information and Training

One of the major provisions of the Laboratory Standard and the OSHA Injury and Illness Prevention Program is a requirement for employee information and training. An essential component of the CHP is providing information and training to all laboratory workers. Providing information and training ensures laboratory workers are aware of the hazards posed by the chemicals in their work areas, and how they may protect themselves from those hazards.

2.1 Employee Information

Laboratory personnel will be informed and provided immediate access to the following documents:

- Contents and appendices of the "OSHA Lab Standard" (29 CFR 1910.1450);
- Contents and appendices of the Chemical Hygiene Plan;
- Mandatory and recommended exposure limits for hazardous chemicals;
- Hazard Communication Standards;
- The location and availability of safety reference materials for hazardous chemicals, including SDSs.

2.2 Employee and Student Training

All laboratory personnel, employees, and students shall be informed and trained about the hazards in their work areas at the time of initial assignment and prior to work involving new exposure situations. Refresher training will occur annually or as otherwise required.

2.3 Information and Training Responsibilities

Laboratory personnel and students must, at a minimum, complete the laboratory safety training provided by RMS. The laboratory safety courses are available on the RMS webpage and other trainings course can be provided upon request by the departments. For information on documentation, see Record keeping.

The PI or Laboratory Supervisor is responsible for identifying laboratory personnel, employees, and students who require training and ensure that those individuals are trained. The PI and/or Laboratory Supervisor shall also conduct laboratory-specific hazard awareness training for each laboratory employee or student before that individual begins working in the lab. It should be noted that depending on the type of research being conducted and associated hazards, there may be additional training requirements.

The OSHA Lab Standard and University policy require that all laboratory personnel receive laboratory safety training and be informed of the potential health and safety risks that may be present in their workplace.

a. General Lab Safety Training: All lab personnel shall be required to take a general laboratory safety course online before beginning work in the lab and annually thereafter.
b. Laboratory-Specific Training: The PI shall conduct laboratory-specific hazard awareness training for all laboratory personnel before they begin working in the lab. The lab-specific training must cover:

- An overview of the OSHA Laboratory Standard.
- The specific chemical and physical hazards in the lab.
- SOPs, including the measures employees can take to protect themselves from the identified hazards, such as appropriate work practices, engineering controls, and personal protective equipment.

- The permissible exposure limits for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard.
- Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory.
- The location and availability of identified reference materials listing the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including, but not limited to SDS's received from the chemical supplier.

2.3.1 *The RMS trainings are listed below:*

If work is done with any chemicals or hazardous materials, the trainings below are required and should be completed annually:

- Chemical Fume Hood Safety
- Chemical Lab Safety
- Hazard Communication Standard Training
- Hazardous Waste Training
- If you work with hydrofluoric acid, please take Hydrofluoric Acid Safety
- If you work with perchloric acid, please take Perchloric Acid Safety
- If you work with gas cylinders or gases under pressure, please take Gas Cylinder Handling Safety

If work is done with biological materials, recombinant DNA, or toxins requiring a BSL-1 or BSL-2 containment, the trainings below are required:

- General Biosafety BSL-1 and BSL-2
- If you work with any animals, please take Animal Biosafety
- If you perform research with HIV or HBV, use human blood, cadaver, body fluids, human cells, human cell lines, work with patients, or handle patient samples, please take Bloodborne Pathogens. See Bloodborne Pathogen Program.

If you are working with any of these items below, you will also need to take the related training.

- electrical equipment: Electrical Safety, Basic Training
- lasers: Laser Safety Training
- radioactive materials: Radiation Safety Training

If you will be shipping research samples or hazardous materials, please contact the Chemical Hygiene Officer to obtain the DOT General Awareness Training prior to shipping.

Emergency Management and Safety Services also has more courses that are not required to take but can be helpful within the scope of work being performed:

- Emergency Readiness Training
- Stop the Bleed Training
- Fire Extinguisher and Automated External Defibrillator Training

It is required that the PI or Laboratory Supervisor provides laboratory specific training for all specific laboratory protocols and procedures. PIs and Laboratory Supervisors are required to document all training including online training taken by all lab personnel. Laboratory specific training should be documented using SOPs. As lab personnel are trained on the procedure or use of chemical(s), the SOP should be signed and dated by each individual who has been trained.

Additional Training

Additional trainings and workshops will be offered and will be posted in the RMS Chemical Safety webpage. Workshop resources will be available online after the workshop has concluded and a certificate of attendance will be given for each workshop attended. If there is a specific training that your lab would like, please contact the Chemical Hygiene Officer to discuss this.

3 SAFE CHEMICAL USE

Safe chemical use includes minimizing exposure to chemicals, understanding chemical hazards, safety data sheets, routes of chemical entry, chemical exposure limits, chemical exposure monitoring, toxicity, chemical labeling, general storage guidelines, transporting chemicals, and chemical segregation.

3.1 Understanding and Communicating Chemical Hazards

Proper hazard communication involves the active participation of the PI and/or Laboratory Supervisor and the CHO, who are each responsible for providing consultation and safety information to personnel working with hazardous chemicals.

List of Hazardous Substances. Every lab group is required to keep an updated copy of their chemical inventory on file, which must be made available to EHS upon request. For each hazardous substance on their inventory, specific information on any associated health or safety hazards must be made readily available to all laboratory personnel. Compressed gases need to be included in the chemical inventory.

The term "hazardous substance" refers to any chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed individuals. Hazardous substances include, but are not limited to, those chemicals listed in the following:

1. Occupational Health and Safety Administration (OSHA) List of Highly Hazardous Chemicals, Toxics, and Reactives
2. National Toxicology Program, Department of Health and Human Services Report on Carcinogens
3. World Health Organization (WHO) Agents Classified by the IARC Monographs

Any novel chemical produced should be presumed hazardous. Chemical derivatives of known materials should be assumed to be at least as hazardous as their known parent compound. Novel compounds should be treated with extreme caution to prevent exposure. Inventory items found on the above lists are subject to the requirements outlined below.

Hazardous materials are also defined in NFPA codes and standards as chemicals or substances that are classified as a physical hazard or a health hazard.

Chemicals can be divided into physical and chemical hazards.

a. Physical hazards include those of fire, explosion or electric shock. Other physical hazards arise from high or low pressure, such as cylinders of compressed gases and experimental vessels, cryogenic equipment, furnaces, refrigerators and glass apparatus.
b. Chemical hazards are associated with health effects and may be sub-classified as acute or chronic. Acute hazards are those capable of producing prompt effects (such as burns, inflammation, or damage to eyes, lungs, or nervous system). Some chemicals are extremely dangerous in this respect and a small amount can cause death or severe injury very quickly. Other toxicological effects of chemicals may be delayed or develop only after exposure over long periods of time and are referred to as chronic hazards.

3.1.1 *Globally Harmonized System (GHS)*

The GHS includes criteria for the classification of health, physical and environmental hazards, as well as specifying what information should be included on labels of hazardous chemicals as well as safety data sheets. GHS classifications are ranked in categories 1-4 with 1 being the most hazardous and 4 being the least hazardous. More details about the classification are provided via H-codes and can be found in the SDS section of the CHP. For more information that is beyond the scope of this section: https://www.osha.gov/hazcom/global

Health hazard

- Carcinogen
- Mutagenicity
- Reproductive Toxicity
- Respiratory Sensitizer
- Target Organ Toxicity
- Aspiration Toxicity

Exclamation Mark

- ❖ Irritant (skin and eye)
- ❖ Skin Sensitizer
- ❖ Acute Toxicity
- ❖ Narcotic Effects
- ❖ Respiratory Tract Irritant
- ❖ Hazardous to Ozone Layer

Flame

- ❖ Flammables
- ❖ Pyrophorics
- ❖ Self-Heating
- ❖ Emits Flammable Gas
- ❖ Self-Reactives
- ❖ Organic Peroxides

Gas Cylinder

- ❖ Gases under pressure

Corrosion

- Skin Corrosion/Burns
- Eye Damage
- Corrosive to Metals

Exploding Bomb

- Explosives
- Self-Reactives
- Organic Peroxides

Skull and Crossbones

- Acute Toxicity (fatal or toxic)

Flame over Circle

- Oxidizers

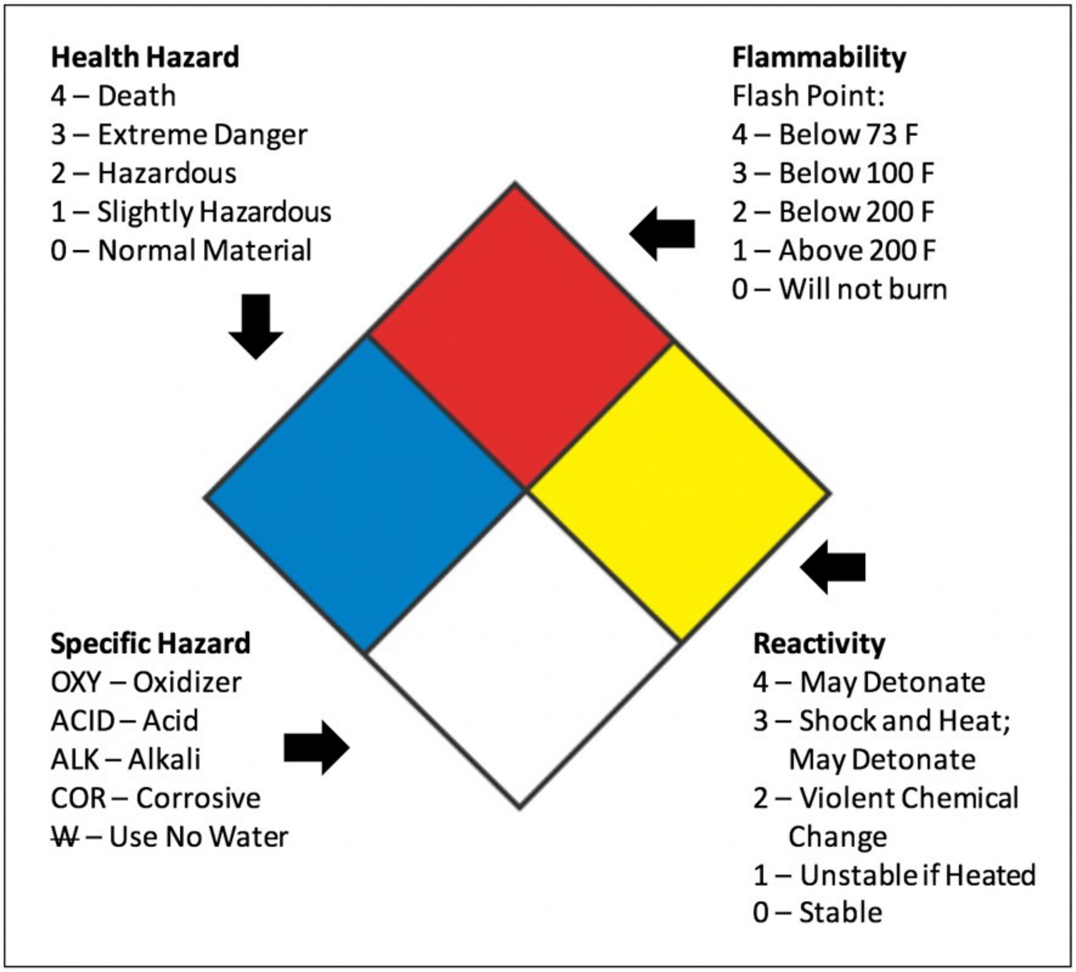
Environment

❖ Environmental or Aquatic Toxicity

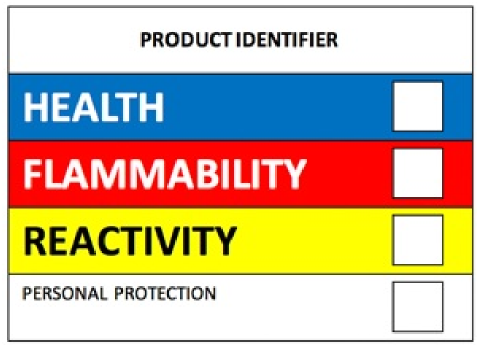
3.1.2 *National Fire Protection Agency (NFPA) Diamond*

NFPA 704, Standard System for the Identification of the Hazards of Materials for Emergency Response, specifies the identification requirements for hazardous materials that provides a simple, readily recognized, and easily understood system of markings that provides a general idea of the hazards of a material and the severity of the hazards as they relate to emergency response. This system is intended to aid first responders.

NFPA 704 hazard identification system is characterized by a diamond. It identifies the degree of severity of the health (blue, 9’oclock position), flammability (red, 12’oclock position), and instability hazards (yellow, 3'oclock position) and any special hazards (white, 6’oclock position). The degree of severity is indicated by a numerical rating ranging from zero (0) indicating a minimal hazard to four (4) indicating a severe hazard. The special or specific hazards is not always filled.



Hazardous Materials Identification System (HMIS) Label is a voluntary-labeling system in the United States intended for workplaces that contain hazardous chemicals. The HMIS label is similar to the NFPA diamond in the coloring of the hazards and the rating of the severity of the hazards (0 through 4). Health is blue, flammability is red, and reactivity or instability is yellow. However, instead of a special hazard, a section for personal protection is included and uses an index of A through K, plus X to indicate what personal protective equipment (PPE) is required. The PPE index is below.



PPE Index

- A = safety glasses
- B = safety glasses + gloves
- C = safety glasses + gloves + apron
- D = face shield + gloves + apron
- E = safety glasses + gloves + dust respirator
- F = safety glasses + gloves + apron + dust respirator
- G = safety glasses + gloves + vapor respirator
- H = splash goggles + gloves + apron + vapor respirator
- I = safety glasses + gloves + dust and vapor respirator
- J = splash goggles + gloves + apron + dust and vapor respirator
- K = air-line hood or mask + gloves + full suit + boots
- X = ask supervisor or safety specialist

3.1.3 *Safety Data Sheets*

Before using any chemical, read the appropriate Safety Data Sheets (SDSs). A current SDS must be available for each hazardous substance in a laboratory's chemical inventory. The SDS has 16 sections which are described below. Sections 1 through 8 contain general information about the chemical, identification, hazards, composition, safe handling practices, and emergency control measures. Section 9 through 11 and 16 contains information on physical and chemical properties, stability and reactivity information, toxicological information, exposure control information, and other information including the date of preparation or last revision. An SDS is a useful resource to aid in identifying the hazards of a chemical and assessing the severity of those hazards. See Appendix H for information on Risk Assessment and identifying hazards and assessing severity of those hazards.

It provides the following information in the listed format:

- **Section 1, Identification** includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.
- **Section 2 Hazard(s) identification** includes all hazards regarding the chemical; required label elements.
- **Section 3, Composition/information on ingredients** includes information on chemical ingredients; trade secret claims.
- **Section 4, First-aid measures** includes important symptoms/ effects, acute, delayed; required treatment.
- **Section 5, Fire-fighting measures** lists suitable extinguishing techniques, equipment; chemical hazards from fire.
- **Section 6, Accidental release measures** lists emergency procedures; protective equipment; proper methods of containment and cleanup.
- **Section 7, Handling and storage** lists precautions for safe handling and storage, including incompatibilities.
- **Section 8, Exposure controls/personal protection** lists OSHA's Permissible Exposure Limits (PELs); Threshold Limit Values (TLVs); appropriate engineering controls; personal protective equipment (PPE).
- **Section 9, Physical and chemical properties** lists the chemical's characteristics.
- **Section 10, Stability and reactivity** lists chemical stability and possibility of hazardous reactions.

- **Section 11, Toxicological information** includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.
- Section 12, Ecological information*
- Section 13, Disposal considerations*
- Section 14, Transport information*
- Section 15, Regulatory information*
- **Section 16, Other information,** includes the date of preparation or last revision.

*These sections are not discussed below.

Each person working with chemicals should have access to the SDS for all chemicals they use. "Access" may be:

- A current hard copy kept in a work area file or binder
- An electronic copy available on RMS website.

How to Use an SDS (Example shown with Isopropanol)

Some key sections to look at are:

Section 2: Hazard(s) Identification

This section identifies the hazards of the chemical presented on the SDS and the appropriate warning information associated with those hazards. This consists of:

- Hazard classification of the chemical
- Signal word
- Hazard statement(s)
- Pictograms
- Precautionary statements
- Description of any hazards not otherwise classified
- For a mixture that contains an ingredient(s) with unknown toxicity, a statement describing how much of the mixture consists of ingredient(s) with unknown acute toxicity.

Globally Harmonized System (GHS) uses three hazard classes: Health Hazards, Physical Hazards and Environmental Hazards. Health hazards present dangers to human health (i.e. breathing or vision) while physical hazards cause damage to the body (like skin corrosion). There are 16 physical hazards and 10 health hazards: each hazard is then further divided according to different severity levels. See this guide on hazard classification for more information.

Note that the GHS 1 – 4 rating system ranks 4 as the **least severe** while National Fire Protection Agency and HMIS rank 4 is most severe.

Signal words provide an immediate indication of severity of the hazard. The chemical label will also only show one signal word indicating the greatest hazard in any class (this is not required if the hazard is low enough)

- **Danger** is used to indicate a greater hazard
- **Warning** is used to indicate a lesser hazard

In particular, *hazard statements* provide further information about the nature of the hazard. Each statement has an H-code associated with it.

- The first number designates the type of hazard the hazard statement is assigned

2 = physical hazard

3 = health hazard

4 = environmental hazard

- The second and third numbers refer to the intrinsic properties of the substance
- Some hazard codes and statements can be combined/ conjoined using a "+" which means "or"
  - Examples:
    - H261: In contact with water releases flammable gas
    - H341: Suspected of causing genetic defects

The relative severity can be gauged by the choice of words.

- H310: **Fatal** in contact with skin
- H311: **Toxic** in contact with skin
- H312: **Harmful** in contact with skin

Precautionary statements describe measures to minimize or prevent exposure and improper handling or storage.

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)

Flammable liquids (Category 2), H225
Eye irritation (Category 2A), H319
Specific target organ toxicity - single exposure (Category 3), Central nervous system, H336

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram 

Signal word Danger

Hazard statement(s)	
H225	Highly flammable liquid and vapor.
H319	Causes serious eye irritation.
H336	May cause drowsiness or dizziness.

Section 3: Composition/Information on Ingredients

This section includes common name and synonyms, the Chemical Abstracts Service (CAS) number which is a unique identifier for the chemical, and impurities and stabilizing additives. Information on the chemical if it is a mixture can be found here. Individual hazards of the components in a mixture are not always listed.

SECTION 3: Composition/information on ingredients

3.1 Substances

Synonyms	:	sec-Propyl alcohol Isopropyl alcohol Isopropanol
Formula	:	C3H8O
Molecular weight	:	60.10 g/mol
CAS-No.	:	67-63-0
EC-No.	:	200-661-7
Index-No.	:	603-117-00-0

Component	Classification	Concentration
2-Propanol		
	Flam. Liq. 2; Eye Irrit. 2A; STOT SE 3; H225, H319, H336	<= 100 %
	Concentration limits: >= 20 %: STOT SE 3, H336;	

Section 4: First-Aid Measures

This section describes initial care given by untrained responders to an individual who has been exposed to the chemical. This section can also sometimes describe symptoms or treatments.

SECTION 4: First aid measures

4.1 Description of first-aid measures

General advice
Show this material safety data sheet to the doctor in attendance.

If inhaled
After inhalation: fresh air. Call in physician.

In case of skin contact
In case of skin contact: Take off immediately all contaminated clothing. Rinse skin with water/ shower.

In case of eye contact
After eye contact: rinse out with plenty of water. Call in ophthalmologist. Remove contact lenses.

If swallowed
After swallowing: immediately make victim drink water (two glasses at most). Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

Section 7: Handling and Storage

This section provides guidance on the safe handling practices and conditions for safe storage of chemicals. This section provides information on hygiene measures.

SECTION 7: Handling and storage

7.1 Precautions for safe handling

Advice on safe handling
Avoid generation of vapours/aerosols.

Advice on protection against fire and explosion
Keep away from open flames, hot surfaces and sources of ignition.Take precautionary measures against static discharge.

Hygiene measures
Change contaminated clothing. Wash hands after working with substance.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities

Storage conditions
Keep container tightly closed in a dry and well-ventilated place. Keep away from heat and sources of ignition.

Handle and store under inert gas. hygroscopic
Storage class (TRGS 510): 3: Flammable liquids

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

Section 8: Exposure Controls/Personal Protection

This section indicates the exposure limits, engineering controls, and personal protective measures that can be used to minimize worker experience. This section will include recommendations for personal protective measures to prevent illness or injury from exposure to chemicals such as personal protective equipment (PPE) and any special requirements for PPE (e.g., type of glove material and breakthrough time of the glove material).

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Ingredients with workplace control parameters

Component	CAS-No.	Value	Control parameters	Basis
2-Propanol	67-63-0	TWA	200 ppm	USA. ACGIH Threshold Limit Values (TLV)
	Remarks	Not classifiable as a human carcinogen		
		STEL	400 ppm	USA. ACGIH Threshold Limit Values (TLV)
		Not classifiable as a human carcinogen		
		TWA	400 ppm 980 mg/m³	USA. NIOSH Recommended Exposure Limits
		ST	500 ppm 1,225 mg/m³	USA. NIOSH Recommended Exposure Limits
		TWA	400 ppm 980 mg/m³	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
		TWA	400 ppm 980 mg/m³	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000
		STEL	500 ppm 1,225 mg/m³	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000
		PEL	400 ppm 980 mg/m³	California permissible exposure limits for chemical

		STEL	500 ppm 1,225 mg/m³	California permissible exposure limits for chemical contaminants (Title 8, Article 107)

Biological occupational exposure limits

Component	CAS-No.	Parameters	Value	Biological specimen	Basis
2-Propanol	67-63-0	Acetone	40 mg/l	Urine	ACGIH - Biological Exposure Indices (BEI)
	Remarks	End of shift at end of workweek			

8.2 Exposure controls

Appropriate engineering controls

Change contaminated clothing. Wash hands after working with substance.

Personal protective equipment

Eye/face protection

Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU). Safety glasses

Skin protection

This recommendation applies only to the product stated in the safety data sheet, supplied by us and for the designated use. When dissolving in or mixing with other substances and under conditions deviating from those stated in EN374 please contact the supplier of CE-approved gloves (e.g. KCL GmbH, D-36124 Eichenzell, Internet: www.kcl.de).
Full contact

Material: Nitrile rubber
Minimum layer thickness: 0.4 mm
Break through time: 480 min
Material tested:Camatril® (KCL 730 / Aldrich Z677442, Size M)

This recommendation applies only to the product stated in the safety data sheet, supplied by us and for the designated use. When dissolving in or mixing with other substances and under conditions deviating from those stated in EN374 please contact the supplier of CE-approved gloves (e.g. KCL GmbH, D-36124 Eichenzell, Internet: www.kcl.de).
Splash contact
Material: Chloroprene
Minimum layer thickness: 0.65 mm
Break through time: 120 min
Material tested:KCL 720 Camapren®

Body Protection
Flame retardant antistatic protective clothing.

Respiratory protection
required when vapours/aerosols are generated. Our recommendations on filtering respiratory protection are based on the following standards: DIN EN 143, DIN 14387 and other accompanying standards relating to the used respiratory protection system.

Control of environmental exposure
Do not let product enter drains. Risk of explosion.

Section 9: Physical and Chemical Properties

This section identifies physical and chemical properties associated with the substance or mixture. This section can be used to determine if the chemical being used can no longer be used (e.g., color or appearance is different than what is indicated).

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: liquid Color: colorless
b)	Odor	alcohol-like
c)	Odor Threshold	1 ppm
d)	pH	at 20 °C (68 °F)neutral
e)	Melting point/freezing point	Melting point/range: -89.5 °C (-129.1 °F)
f)	Initial boiling point and boiling range	82 °C 180 °F
g)	Flash point	12.0 °C (53.6 °F) - closed cup
h)	Evaporation rate	3.0
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or explosive limits	Upper explosion limit: 13.4 %(V) Lower explosion limit: 2 %(V)
k)	Vapor pressure	43 hPa at 20 °C (68 °F)
l)	Vapor density	2.07
m)	Relative density	0.785 g/mL at 25 °C (77 °F)

Section 10: Stability and Reactivity

This section describes the reactivity hazards of the chemical and the chemical stability. This section can be used to determine at what conditions the chemical is stable or unstable and indication of any safety issues that may arise should the product change in appearance. This section also describes any incompatible materials or chemicals.

SECTION 10: Stability and reactivity

10.1 Reactivity
Vapors may form explosive mixture with air.

10.2 Chemical stability
Reacts with air to form peroxides.
The product is chemically stable under standard ambient conditions (room temperature) .
Test for peroxide formation before distillation or evaporation. Test for peroxide formation or discard after 1 year.
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions

Vapors may form explosive mixture with air.

10.4 Conditions to avoid
Warming.

10.5 Incompatible materials
rubber, various plastics, oils

10.6 Hazardous decomposition products
In the event of fire: see section 5

Section 13: Waste Disposal Considerations

This section provides guidance on proper disposal practices. This section may include description of appropriate disposal container to use and recommendation of appropriate disposal methods to employ. This section may also include a description of the physical and chemical properties that may affect disposal activities.

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product
Waste material must be disposed of in accordance with the national and loc No mixing with other waste. Handle uncleaned containers like the product See www.retrologistik.com for processes regarding the return of chemicals and containers, or contact us there if you have further questions.

Where to find an SDS

SDSs' are provided by the manufacturer of the chemical. Generally, the SDS is located on the manufacturer's website or, if not available, can be requested from the manufacturer. It is recommended to look at the SDS from the manufacturer that the chemical was purchased from.

University of North Texas Risk Management Services also provides a database for online SDS and an SDS can always be requested from the Chemical Hygiene Officer.

Beyond an SDS and other resources

An SDS should be used in conjunction with other resources and should not be the sole resource used to identify hazards and assess the severity of those hazards. Other resources include:

- Principal Investigators / Laboratory Supervisors
- Senior members of the laboratory
- Environmental, Health, and Safety staff including the Chemical Hygiene Officer, Laboratory Safety Officer, Radiation Safety Officer, and Biosafety Officer.
- PubChem: 'Open' chemistry database at the National Institutes of Health. Safety information from various sources
- Chemical Safety Library: provides unique crowd sourced data content containing hazardous reactions that can be used to alert scientists to potentially dangerous experiments
- Publications can also be great safety resources (ACS Chemical Health and Safety and other journals publish more articles concerning safety).

3.2 Minimize Exposure to Chemicals

For the general safety of laboratory personnel, all chemical usage must be conducted in adherence with the general safe laboratory practices. In order to minimize chemical exposure always follow these guidelines:

a. Assume that any unfamiliar chemical is hazardous and treat it as such.
b. Substitute less hazardous chemicals in your experiments whenever possible.
    - Micro-scaling the size of the experiment to reduce the amount of chemical usage.

c. Minimize chemical exposures to all potential routes of entry - inhalation, ingestion, skin and eye absorption, and injection through proper use of engineering controls and PPE.
d. Use PPE as appropriate for that chemical.
e. Do not smell or taste chemicals. When it is necessary to identify a chemical's odor, lab personnel should hold the chemical container away from their face and gently waft their hand over the container without inhaling large quantities of chemical vapor.
f. Never underestimate the potential hazard of any chemical or combination of chemicals. Consider any mixture or reaction product to be at least as hazardous as – if not *more* hazardous than – its most hazardous component.
g. In order to identify potential hazards, laboratory personnel should plan out their experiments in advance. These plans should include the specific measures that will be taken to minimize exposure to all chemicals to be used, the proper positioning of equipment, and the organization of dry runs.
h. Know all the hazards of the chemicals with which you work. For example, perchloric acid is a corrosive, an oxidizer, and a reactive. Benzene is an irritant that is also flammable, toxic, and carcinogenic.
i. Follow all chemical safety instructions, such as those listed in Safety Data Sheets or other trusted resources or on chemical container labels, precisely.
j. Clean up spills and leaks immediately.
k. Always wash hands with soap and water after handling chemicals and remove personal protective equipment, such as gloves and lab coats, before leaving the lab.
l. Visitors to the laboratory shall abide by all laboratory safety rules, including requirements for the use of eye protection.
m. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them to contain chemicals and fragments should implosion occur. Use equipment only for its designed purpose.
n. Wash areas of exposed skin thoroughly before leaving the laboratory.
o. Avoid behavior that might confuse, startle or distract another worker.
p. Do not use mouth suction for pipetting or starting a siphon.
q. Avoid working alone in a laboratory while hazardous procedures are being conducted.
r. Warning signs with personnel contact information shall be posted on the door and on equipment where special or unusual hazards exist.
s. Provide for the containment of toxic substances in the event of failure of utility service when operating unattended equipment. Also, ensure that the warning signs are in place.

t. Work areas shall be maintained clean and uncluttered with chemicals and equipment properly labeled and stored; clean up the work area on completion of an operation and at the end of each day.
u. Use a fume hood for operations that might result in release of toxic chemical vapors or dust.
   - Use a fume hood or other local ventilation device when working with any volatile substance with a TLV of less than 50 ppm.
   - Confirm adequate hood performance before use.
   - Keep hood closed when operations are not being performed in the hood. Do not allow materials to block vents or air-flow.
   - Do not store chemicals in the hood.
v. Be aware of unsafe conditions and see that they are corrected when detected.
w. Report any incidents or near-misses to your Principal Investigator and/or Laboratory Supervisor and RMS.

Risk assessments must be performed prior to using any chemicals covered by a standard, carcinogens, and highly toxic materials. Laboratory specific procedures including a work procedure which identifies each workstation/ task involving these chemicals, list of the required controls and equipment that will be needed when handling these chemicals, and information on the exposure limits should be completed prior to using the chemical and documented by the PI and/or Laboratory Supervisor and kept on hand in event of emergency.

3.3 Routes of Chemical Entry

Hazardous chemicals may enter and affect the human body through: Inhalation, Ingestion, Injection, and Eye and Skin Absorption. See Appendix D for more information on specific chemical exposures.

3.3.1 *Inhalation*

Inhalation of aerosols of solid particles (dust, fume) or liquid droplets, or inhalation of gases or vapors is a rapid and highly efficient manner of absorbing hazardous materials. Inhalation of a chemical may cause bronchial irritation, dizziness, central nervous system depression, nausea, headache, coma, or death. Prolonged exposure to excessive concentrations of solvent vapors may cause liver or kidney damage. The consumption of alcoholic beverages can enhance these effects.

The degree of injury resulting from exposure to toxic vapors, mists, gases, and dusts depends on the toxicity of the material and its solubility in tissue fluids, as well as on its concentration and the duration of exposure. Chemical activity and the time of response after exposure are not necessarily a measure of the degree of toxicity. Several chemicals (e.g., mercury and its derivatives) and some of the common solvents (benzene) are cumulative poisons that can produce body damage through exposure to small concentrations over a long period of time.

3.3.2 *Ingestion*

Taking in hazardous materials by mouth is obviously an efficient method of introducing contamination into the body. Mouth pipetting, eating, drinking, smoking, vaping, and applying cosmetics is forbidden in labs to reduce the possibility of ingesting hazardous materials. Food and drink may not be stored or consumed in areas where hazardous chemicals, radioactive materials, or biohazardous materials are being used. Hands must be well washed after laboratory work to prevent hazardous materials being transferred to food, etc., outside the lab. Ingestion of a chemical may cause sever toxicological effects. Seek medical attention immediately.

3.3.3 *Injection*

Piercing the skin with contaminated needles or other sharp objects may introduce hazardous materials into the body. Extreme care must be taken when handling needles and cannulation. Avoid needle poke injuries and exposure by not recapping needles. Place all sharps like needles and razor blades into an appropriate sharps container immediately after use (hard plastic container labeled sharps). Needles or other sharp objects should NEVER go into the trash. Contaminated broken glass should be placed into a separate glass waste container than clean broken glass waste and labeled for broken glass and the contamination. Do not attempt to clean broken glass.

3.3.4 *Eye and Skin Absorption*

Eye contact: eyes are not only very sensitive to damage by hazardous materials, but they also absorb solid, liquid, and gaseous chemicals much faster than skin. If you do get chemicals in your eyes, immediately go to an eyewash station. Once the eyewash has been activated, use your fingers (make sure to take off gloves and that your hands are clean!) to hold your eyelids open and roll your eyeballs in the stream of water so the entire eye can be flushed. After flushing for at least 15 minutes, seek medical attention immediately and complete an Incident Report. The importance of flushing for at least 15 minutes cannot be overstated! If you usually wear contacts, it might be best to talk with your PI to obtain prescription safety glasses. A chemical exposure while wearing contacts can exacerbate injuries. If there is a potential of splashing while working, utilize safety goggles and not glasses, as chemicals can still run down into your eyes while wearing safety glasses.

Skin contact: many chemicals are absorbed through the skin at a significant rate. Although this effect is usually most pronounced with liquids, there are solid chemicals which are hazardous when they come in contact with the skin. Even certain toxic gases may be dangerously absorbed through the skin, but exposure to concentrations of gas able to do this should never be encountered in a research lab. Skin contact with chemicals may lead to defatting, drying, and skin irritation.

For small chemical splashes to the skin, remove any contaminated gloves, lab coats, etc., and wash the affected area with soap and water for at least 15 minutes. For large chemical splashes to the body, it is important to get to an emergency shower and start flushing for at least 15 minutes. Once under the shower, and after the shower has been activated, it is equally important to remove any contaminated clothing. Failure to remove contaminated clothing can result in the chemical being held against the skin and causing further chemical exposure and damage. After flushing for a minimum of 15 minutes, seek medical attention immediately and complete an Incident Report.

3.4 Chemical Exposure Limits

OSHA currently has Permissible Exposure Limits (PELs) for nearly 500 hazardous chemicals as specified in 29 CFR Part 1910, subpart Z.

The PEL is the eight-hour time weighted average concentration of contaminant in air to which a healthy person can be repeatedly exposed without reasonable expectation of adverse health effects.

Another measure of exposure limits is Threshold Limit Values (TLV), which is a reserved term of the American Conference of Governmental Industrial Hygienists (ACGIH). Similar to PELs, TLVs are the average concentration of a chemical that a worker can be exposed to over an 8-hour workday, 5 days per week, over a lifetime without observing ill effects. The difference between PELs and TLVs is that TLVs are advisory guidelines only and are not legally enforceable. Both PELs and TLVs can be found in SDSs.

3.5 Chemical Exposure Monitoring

Employees who may be exposed to hazardous chemicals while working on campus should be kept informed of the nature of the hazards and instructed in methods to protect themselves. RMS can help evaluate the effectiveness of your controls by monitoring exposures to a variety of laboratory materials. Exposure monitoring is the determination of the airborne concentration of a hazardous material in the work environment. Some of the chemicals used in the laboratory are OSHA regulated and have exposure monitoring and medical surveillance requirements. Exposure to chemical substances regulated by OSHA 29 CFR 1910 Subpart Z requires monitoring, either initially or periodically, shall be monitored according to the standard. These requirements are activated when the concentrations of these chemicals meet or exceed exposure levels determined by OSHA.

Medical surveillance is **the systematic assessment of employees exposed or potentially exposed to occupational hazards**. This assessment monitors individuals for adverse health effects and determines the effectiveness of exposure prevention strategies.

If the initial monitoring discloses exposure over the permissible exposure limit (PEL) then immediate compliance with the exposure and medical monitoring provisions of the relevant standard is required. Compliance with the standard may include more frequent monitoring and implementation of additional control measures.

Personnel shall be notified in writing of monitoring data within 15 days of receipt of those monitoring results.

3.6 Toxicity

Toxicity is the degree to which a chemical substance or a particular mixture of substances can damage an organism. The more toxic a material, the smaller the amount necessary to be absorbed before harmful effects are caused. The lower the toxicity, the greater the quantity necessary to be absorbed. Generally, the toxicity of a chemical is determined through experiments on animals (quite often rats), and measured in terms of the amount of material necessary to cause death in 50% of the test animals. These values are called LD50 (lethal dose) or LC50 (lethal concentration), and are usually given in weight of material per kg of body weight or airborne concentration of material per set time period respectively.

3.6.1 *Toxic Effects*

Once a toxic substance has contacted the body it may have either acute (immediate) or chronic (long-term) toxicity.

- Acute toxicity refers to those adverse effects of a substance that result either from a single exposure or from multiple exposures in a short period (usually less than 24 hours).
- Chronic toxicity refers to those adverse effects as the result of long-term exposure to a toxicant, often measured in months or years. It can cause irreversible side effects.

3.6.2 *Evaluating Toxicity Data*

While exact toxic effects of a chemical on test animals cannot necessarily be directly correlated with toxic effects on humans, the LD50 and LC50 can give a good indication of the toxicity of a chemical, particularly in comparison to another chemical. LD50 and LC50 values are often found in safety data sheets, and even if specific values are not quoted, OSHA/GHS hazard categories for acutely toxic materials should be given. Categories of acute toxicity as defined by OSHA are listed below.

Exposure Route	**Category 1**	**Category 2**	**Category 3**	**Category 4**
Oral (mg/kg bodyweight)	≤ 5	> 5 and ≤ 50	> 50 and ≤ 300	> 300 and ≤ 2000
Dermal (mg/kg bodyweight)	≤ 50	> 50 and ≤ 200	> 200 and ≤ 1000	> 1000 and ≤ 2000
Inhalation – gases (ppm by volume)	≤ 100	> 100 and ≤ 500	> 500 and ≤ 2500	> 2500 and ≤ 20000
Inhalation – vapors (mg/L)	≤ 0.5	> 0.5 and ≤ 2.0	> 2.0 and ≤ 10.0	> 10.0 and ≤ 20.0
Inhalation - dusts and mists (mg/L)	≤ 0.05	> 0.05 and ≤ 0.5	> 0.5 and ≤ 1.0	> 1.0 and ≤ 5.0

Note: Substances in Categories 1 and 2 are considered to have a "high degree of acute toxicity." These substances are also referred to as "Highly Acutely Toxic Substances."

3.7 Chemical Labeling

Under the OSHA Hazard Communication Standard (CCR, Title 8, 5194) all chemical containers must be properly labeled – unless a material is temporarily put into a new container for immediate use and is not going to be stored after that immediate use. Proper labeling of chemicals is a way of warning laboratory students and staff of potential hazards that exist, preventing the generation of unknowns, and facilitating emergency responses such as cleaning up spills and obtaining the proper medical treatment. Chemicals purchased from a manufacturer will have labels from that manufacturer that meet the chemical labeling requirements. Labs are responsible for labeling chemicals that are transferred from the primary container (container obtained from manufacturer) to another container (e.g., squirt bottle, beaker, flask, media bottle, vial, etc.).

3.7.1 *Labeling Requirements*

In 2015, OSHA became aligned with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS), which is an international approach to standardizing classification of hazards, and labeling. The GHS standardized label elements, which are not subject to variation and must appear on the chemical label, contain the following elements:

- Product name
- Signal word
- Pictograms
- Hazard statement(s)
- Precautionary statements
- Manufacturer name, address, and telephone number

For chemicals purchased prior to 2015 the labels on primary containers must have at least the following components:

- The name of the chemical as it appears on the Safety Data Sheet.
- Warnings about any physical and health hazards.
- The manufacturers name and address.

When using material directly from the manufacturer bottle, consider adding:

- the date when it was obtained,
- the date when it was opened,
- and if possible, the date of expiration.

When working with peroxide formers, it is also important to add the date the chemical is tested for peroxides. For more information on peroxide formers, see Ch 4.6.

3.7.2 *Non-Original Containers*

Transferring a chemical from an original container into a non-original container such as wash bottles, squirt bottles, temporary storage containers, beakers, flasks, bottles, vials, etc. or any container must be properly labeled. All containers must have a means of communicating their content and the hazards of the content either on the container or in the area where the container is stored. Containers must comply with these labelling requirements if any of the following events occur:

- The material is not consumed within the work shift of the individual who makes the transfer.
- The personnel who made the transfer leaves the work area.
- The container is moved to another work area and is no longer in the possession of the personnel who filled the container.

In general, RMS recommends writing out the full chemical name and any hazards associated with that chemical. Labels on secondary containers must be maintained and not defaced and have at least the following components:

a. The name of the chemical
    a. Either as it appears on the SDS or if using a short-hand name or abbreviation for the chemical, make sure this is documented in a key that is located in your lab or easily accessible in your laboratory notebook. **If you are graduating or leaving your lab, please make sure this key is given to the Chemical Hygiene Officer**.
b. The name or initials of who that chemical belongs to.
c. Warnings about any physical and health hazards, which may be expressed through words, pictures, symbols, or a combination of these.
d. The date it was transferred to that container.

e. Small Containers - For containers, which may be too small to write out a chemical name, structure, or formula, laboratories can:
    a. Place containers in any type of overpack container (beaker, plastic bottle, etc.) and label the overpack with the chemical name and its hazards.
    b. For vials in a rack, label the rack with the chemical name and its hazards.
f. If possible, date of expiration.

Use of abbreviations such as structures, formulas, or acronyms should be avoided whenever possible. However, if abbreviations are used, an abbreviation key in a visible location (preferably close to the chemicals or in laboratory notebook) should be provided. The key must contain the abbreviation and the name of the chemical. It is also useful to include the hazards of the chemical on the "key." **The abbreviation key must be readily available upon request by RMS and emergency responders. If you are graduating or leaving your lab, please make sure this key is given to the Chemical Hygiene Officer**.

- Teaching Samples – For preserved specimens in bottles, bags, or other containment units, the container must list the preservative and its hazards (ex: 70% Ethanol, Flammable and Toxic).
    - Any samples generated for teaching should be disposed of before the end of the semester. Teaching samples should NOT be left in the laboratory. It is the responsibility of the Laboratory Supervisor or Instructor of Record to ensure that these samples are appropriately disposed of.
    - If samples are labelled as "Unknown A," or "Unknown B," for teaching purposes, a key must be kept by both the Laboratory Supervisor or the Instructor of Record. These samples at the end of the semester should be relabeled for their actual chemical name or properly disposed of.
- Research Samples - Should be stored on shelves, in boxes, or racks that are labeled with the preservative and its hazards. If individual samples taken out of storage areas for processing that will be left unsupervised, they must have a label listing the preservative and its hazards.

When synthesizing (both known and novel) compounds and storing samples, individual containers, like vials, should *AT LEAST* contain the name of the chemical or synthesized product and the name or initials of the person who made it.

When synthesizing or storing a large number of samples (of same hazard class and compatibility), consider work area labeling. Work area labeling includes:

- Many samples of vials with the same hazards
- Anything too small to support a label
- Containers of the same hazard class stored together in a bin

The work area label would include similar information as above like the name of chemical (if all samples are the same), name or initials of who it belongs to, and the hazard class associated with those chemicals.

3.8 General Storage Guidelines

Improper chemical storage practices can cause undesired chemical reactions, which may form hazardous products that can lead to employee exposure or possibly fires and property damage. Laboratories should adhere to the following storage guidelines for the proper and safe storage of chemicals. By implementing these guidelines, laboratories can ensure safer storage of chemicals and enhance the general housekeeping and organization of the lab. Proper storage of chemicals also helps utilize limited laboratory space in a more efficient manner.

a. Always segregate and store chemicals according to compatibility and hazard classes. See Appendix B "Chemical Segregation" for recommendations.
b. Do not store acids in flammable liquid storage cabinets. The exceptions are organic acids, such as Acetic acid, Lactic acid, and Formic acid, which are considered flammable/combustible and corrosive and can be stored in flammable or corrosive storage cabinets.
c. Do not store flammable liquids in standard refrigerators or freezers. Due to the potential explosion hazard, only store flammables in units approved by the manufacturer for storage of flammables.
d. Do not store hazardous materials above eye level. Storing glass containers and heavy materials on lower shelves is also recommended.
e. All chemical containers must be labeled. Labels should include the name of the chemical and the hazards the chemical presents to the user.
f. Be sure to check chemical containers regularly and replace any labels that are deteriorating or falling off and/or relabel with another label before the chemical becomes an unknown.
g. Keep all chemical containers closed when not in use.

h. Every chemical should have an identifiable storage place and should be returned to that location after use.
i. The storage of chemicals on bench tops should be kept to a minimum to prevent clutter and possible spills
j. Chemical storage in fume hoods should be kept to a minimum. Excess storage in hoods can interfere with airflow, reduce working space, and increase the risk of a spill, fire, or explosion.
k. Chemicals should not be stored on the floor due to the potential for spills. If it is necessary to store bottles on the floor, then the container should be placed in secondary containment away from aisle spaces.
l. Do not store chemicals in direct sunlight or next to heat sources.
m. Laboratories should keep only the minimum quantity of chemicals necessary.
n. Chemical containers should be dated when they arrive and should be checked regularly and disposed of when they get past their expiration date.
o. Stored chemicals should be periodically inspected for deterioration and container integrity. Chemicals which are no longer used in the laboratory shall be discarded by labeling it with a chemical waste tag. Request a hazardous waste pickup.

Chemicals should NOT be stored alphabetically, however most labs store chemicals this way. However, this does not separate chemicals based on hazards. One suggested way to separate based on hazards is described here by UC Riverside. They can still be stored alphabetically but within the same hazard category.

Secondary Containers

A primary container is the one in which the material was received from the manufacturer. A secondary container is a container in which a chemical or chemical product is transferred or the container in which a new chemical product/reagent is made and stored. A secondary container is also a container in which waste carboys or other chemicals containers are stored for chemical containment. Examples of a primary container and secondary containers are below.

Primary Container

Secondary Container used for transporting chemicals

Secondary container used to store other chemical containers or waste containers.

Secondary containers should be large enough that in the event of a break or spill, it can contain the entire amount in the broken or spilled chemical container. Flammable liquids, corrosive liquids, and all waste should be stored in a secondary container. Make sure that the container being used as storage or secondary containment is compatible with the chemical (e.g., hydrofluoric acid cannot be stored in glass containers since it reacts with glass).

For more information on transportation of chemicals, see below.

Maximum Allowable Quantities

Maximum Allowable Quantities (MAQs) are the maximum amount of hazardous materials allowed to be stored or used within a control area in a building. A control area is a building or portion of a building or outdoor area within which hazardous materials are allowed to be stored, dispensed, used, or handled in quantities not exceeding the MAQ. The MAQs are intended to ensure the quantities of hazardous materials in a building are within the safe operating levels for the fire and life safety elements to which the building is designed and operated. Adhering to these limits is essential for ensuring a building is safe for its occupants and first responders. For more information on MAQs, see NFPA 400.

Determining MAQs is complex and relies on several structural and operational factors. The most common factors that determine MAQ:

- Which floor is your lab located,
- Whether a fire sprinkler system is installed throughout the building,
- And use of approved storage cabinets.

You can use this chart from the NFPA to determine the MAQs per control area and this example to understand how to use the chart. MAQs will be checked by the Chemical Hygiene Officer during annual audits. The PI and/or Laboratory Supervisor is responsible for ensuring that the laboratory is compliant within their MAQ.

3.9 Transporting Chemicals

When moving chemicals between laboratories or other buildings on campus, the following guidelines should be implemented for protection of people and the environment, and to minimize the potential for spills to occur.

- Take precautions to avoid dropping or spilling chemicals.
- Make sure that chemical containers are sealed during transport and that incompatible chemicals are placed in secondary containment away from one another.
- Carry breakable containers in specially-designed bottle carriers or leak-resistant, unbreakable secondary containers.
- When transporting chemicals on a cart, use a cart that is suitable for the load and one that has high edges to contain leaks or spills. The cart should be capable of negotiating uneven surfaces without tipping the chemical container or the cart.
- Transport chemicals by traveling least-trafficked routes. When possible, use freight elevators.
- NEVER transport incompatible chemicals in the same secondary containment.
- While in transit, containers must be labeled with chemical name and corresponding hazards and shall be attended at all times.
- Check containers and lids for damage and cracks. Replace any faulty caps or containers. Damaged containers cannot be transported.
- Individuals transporting chemicals must be familiar with the materials' hazard and should know what to do in the event of a release or a spill.

- Upon arrival at the new location, ensure personnel check contents for damage, remove chemicals from the packing boxes, and place the chemicals in designated storage locations.
- Gas cylinders must be strapped to a hand truck specifically designed for that purpose. Cylinder cover caps must be in place.
- If the chemical is permanently being moved: update the chemical inventory to reflect the new storage location of the chemical.
- Appropriate PPE should be worn when transporting chemicals.
    - To prevent possibility of contamination spreading, only one glove (leaving one clean hand exposed) should be worn.
    - No PPE should be worn when in clean rooms.
- DO NOT transport hazardous chemicals on UNT shuttles or rental vehicles, public transportation, or personal vehicles.
- DO NOT transport a chemical without secondary containment.

If transporting large amounts of chemicals for a laboratory move, (or any amount of chemicals on a public road), contact the RMS at 940-565-2109 and/or askrms@unt.edu for consultation on safe packaging and compliance with federal, state, and local laws.

Note: Shipping of chemicals must be done in compliance with all applicable federal, state, and local laws. Any UNT employee who prepares package containing hazardous materials for shipment or performs any pre-transport function related to shipping hazardous materials must receive training. This includes anyone who:

- Selects packaging for a shipment
- Fills packages
- Marks and Labels Packages
- Prepares shipping papers
- Receives packages

For questions related to shipping or receiving hazardous materials or training on shipping hazardous materials, please contact the Chemical Hygiene Officer.

3.10 Chemical Segregation

When certain hazardous chemicals are stored or mixed together, violent reactions may occur because the chemicals are unsuitable for mixing, or are incompatible. All chemicals must be stored according to chemical compatibility. See Appendix B "Chemical Segregation" for recommendations. Once segregated by chemical compatibility, they can then be stored alphabetically. Information regarding chemical compatibility can be found in:

- the SDS, primarily in Section 7, "Handling and Storage" and Section 10, "Stability and Reactivity".
- Chemical Incompatibility Information Sheet
- CAMEO Chemical Incompatibility Matrix (Database for Hazardous Materials) can see what hazards might occur if chemicals are mixed together.
    - Can add chemicals to a list to always refer back to.

If unsure of proper segregation procedures, contact the PI and/or Laboratory Supervisor or RMS for assistance. Chemical segregation can be achieved by either isolation (e.g., organic solvents stored in a flammable cabinet), physical distance (e.g., acids and bases are stored on opposite sides of a chemical storage room), or secondary containment (e.g., placing oxidizing acids such as nitric acid into a secondary containment to segregate from organic acids such as formic acid. In the most general terms, proper segregation can be achieved by:

- Storing acids away from bases and toxics;
- Storing organic acids away from inorganic acids;
- Storing flammables away from oxidizers and corrosives;
- Storing oxidizers away from organic chemicals; and
- Storing reactive and acutely toxic materials away from all other chemicals.

Segregation of different chemical hazard classes (such as acids and bases) can occur in the same cabinet as long as there is some form of physical separation, such as using trays with high sides or deep trays. However, never store oxidizers and flammables in the same cabinet. Also, do not store compounds such as inorganic cyanides and acids in the same cabinet.

If you need assistance with cleaning out your lab of old and excess chemicals, or would like assistance with segregating your chemicals, contact RMS at 940-565-2109 and/or askrms@unt.edu.

4 CHEMICAL HAZARDS

This section covers the classes of hazardous chemicals and their definitions, physical properties, and information on storage and handling.

4.1 Flammable and Combustible Materials

4.1.1 Flammable and Combustible Liquids

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. Do not heat flammable liquids on a hot plate or open flame. Heat and transfer flammable liquids in well-ventilated areas or fume hoods. These substances should be stored separately from oxidizers and corrosive materials and in a flammable storage cabinet. Lab allowable quantity limits are determined by a complex mixture of data points including the flash point of the liquid, the occupancy classification of the laboratory, the number of fire control areas, the use of flammable cabinets, the presence of sprinklers, and the floor number. A good rule of thumb is that storage of flammable liquids in approved flammable storage cabinets and should not exceed 10 gallons; however, exceptions may apply.

The OSHA Laboratory Standard defines a flammable liquid as any liquid having a flashpoint below 100 °F, except any mixture having components with flashpoints of 100 °F or higher, the total of which make up 99% or more of the total volume of the mixture.

Flashpoint is defined as the minimum temperature at which a liquid gives off enough vapor to ignite in the presence of an ignition source. The risk of a fire requires that the temperature be above the flashpoint and the airborne concentration be in the flammable range above the Lower Explosive Limit (LEL) and below the Upper Explosive Limit (UEL).

The OSHA Laboratory Standard defines a combustible liquid as any liquid having a flashpoint at or above 100 °F, but below 200 °F, except any mixture having components with flashpoints of 200 °F, or higher, the total volume of which make up 99% or more of the total volume of the mixture. OSHA further breaks down flammables into Class I liquids, and combustibles into Class II and Class III liquids. Please note this classification is different than the criteria used for DOT classification. This distinction is important because allowable container sizes and storage amounts are based on the particular OSHA Class of the flammable liquid.

Table 5.A		
Classification	**Flash Point**	**Boiling Point**
Flammable Liquid		

Class IA	<73 °F	<100 °F
Class IB	<73 °F	≥100 °F
Class IC	≥73 °F, <100 °F	>100 °F
Combustible Liquid		
Class II	≥100 °F, <140 °F	--
Class IIIA	≥140 °F, < 200 °F	--
Class IIIB	≥200 °F	--

Flammable and combustible liquids are one of the most common types of chemicals used at the University and are an important component in a number of laboratory processes. In addition to the flammable hazard, some flammable liquids also may possess other hazards such as being toxic and/or corrosive. While common, it is important to remember that these materials can constitute a significant immediate threat and should be treated with particular care.

- Flammable liquids that are not in active use should be stored inside fire resistant flammable storage cabinets or safety cans.
- Flame-resistant laboratory coats must be worn when working with flammable materials and/or with procedures where a significant fire risk is present (e.g., when working with open flame, etc.).
- Always keep flammable liquids stored away from oxidizers and away from heat or ignition sources such as vacuum pumps, radiators, electric power panels, etc.
- When using flammable liquids, keep containers away from open flames; it is best to use heating sources such as steam baths, water baths, oil baths, and heating mantels. Never use a heat gun to heat a flammable liquid.
- Any areas using flammables should have a fire extinguisher present. If a fire extinguisher is not present, then contact RMS at 940-5652109.
- When pouring flammable liquids, it is possible to generate enough static electricity to cause the flammable liquid to ignite. If possible, make sure both containers are electrically interconnected to each other by bonding the containers, and connecting to a ground. See Bonding and Grounding below.
- Always clean up any spills of flammable liquids promptly. Be aware that flammable vapors are usually heavier than air (vapor density > 1). For those chemicals with vapor densities

heavier than air (applies to most chemicals), it is possible for the vapors to travel along floors and, if an ignition source is present, result in a flashback fire.

- Certain flammable solvents such as ethyl ether, isopropyl ether, dioxane, tetrahydrofuran will form peroxides which explode if allowed to concentrate by evaporation or by distillation (See Peroxide Forming Compounds below). Improper handling of most flammable liquids can lead to health hazards - skin reactions and inhalation illnesses.

4.1.2 Flammable Solids

Flammable solids are solids which are readily combustible, or may cause or contribute to a fire through friction. Readily combustible solids are powdered, granular, or pasty substances which are dangerous if they can be easily ignited by brief contact with an ignition source. Flammable solids are more hazardous when widely dispersed in a confined space (e.g., finely divided metal powders).

4.1.3 Storage Guidelines

4.1.3.1 Flammable Storage Cabinets

All flammable liquids not in use should be kept in the flammable liquid storage cabinet. Venting of flammable cabinets is NOT required, however, if a flammable cabinet is vented, it must be vented properly according to the manufacturer's specifications and NFPA 30. Typically, proper flammable cabinet ventilation requires that air be supplied to the cabinet and the air be taken away via non-combustible pipes. If you are planning on venting your flammable storage cabinet, please contact RMS at 940-565-2109 for more information.

Combustible materials like paper and packaging nylon bags should never be stored inside of flammable cabinets or near flammable liquids or solids. Always segregate flammable or combustible liquids from oxidizing acids and oxidizers.

4.1.3.2 Flammable Storage in Refrigerators/Freezers

Standard refrigerators or freezers must **never** be used to store flammable liquids. Standard refrigerators are not electrically designed to store flammable liquids. Store flammable liquids only in specially designed flammable storage refrigerators/freezers or explosion-proof refrigerators/freezers.

Properly rated flammable liquid storage refrigerators/freezers have protected internal electrical components and are designed for the storage of flammable liquids. Explosion-proof refrigerators/freezers have both the internal and external electrical components properly protected and are designed for the storage of flammable liquids. Refrigerators and freezers rated for the storage of flammable materials will be clearly identified as such by the manufacturer.

4.1.4 Handling Guidelines

a. Handle flammable and combustible substances only in areas free of ignition sources and use the chemical in a fume hood whenever practical.
b. Only the amount of material required for the experiment or procedure should be stored in the work area.
c. Always transfer flammable and combustible chemicals from glass containers to glassware or from glass container/glassware to plastic.
d. Flammable liquids in a metal dispending container should always be bonded and grounded when pouring or dispending liquid to prevent the buildup of static electricity and prevent the formation of sparks which will cause a fire.
    a. Dispensing flammable liquids that have a flash point < 100 °F or ignitable liquids > 100 °F when heated above their flashpoint, from one container to another can generate static electricity and must be bonded and grounded.
    b. If you must transfer a Class 1A flammable chemical (e.g., diethyl ether, pentane) from a metal container make sure that the equipment is bonded and grounded (See below for information on bonding and grounding).
e. Flame-resistant laboratory coats must be worn when working with any number of pyrophoric materials, when working with large quantities (1 liter or more) of flammable materials, and/or with procedures where a significant fire risk is present (e.g., when working with open flame, etc.)
    a. Avoid wearing synthetic material clothing when working with any flammable, combustible, explosive, or pyrophoric or self-heating materials.
        i. Synthetic clothing melts when on fire and will adhere to the skin.

4.1.4.1 Bonding and Grounding

Bonding and grounding is defined as providing an electrically conductive pathway between a dispensing container, a receiving container and an earth ground. This pathway helps eliminate the buildup of static electricity by allowing it to safely dissipate into the ground.

Bonding refers to ensuring all components (containers, piping, pumps, funnels) in the dispensing process carry the same electrical potential.

Grounding is the process of carrying the electric charge to “earth” or “ground.” Indoor dispensing locations can tap into grounded building systems, such as the electrical distribution system, to carry the charge to ground.

For bonding and grounding to be effective, a metal-to-metal connection must be maintained between the bonding and grounding wires and the containers. To accomplish this, all paint, dirt, rust, etc., must be removed from the area of connection. These connections can be of two basic types: permanent or temporary. Permanent connections can be made by using solid or braided wires, and must incorporate either screw-type clamps, welding or other similar means. Temporary connections should use only braided wires in conjunction with spring clamps, magnetic clamps or other similar methods of maintaining metal-to-metal contact.

Bonding and grounding configuration for transferring flammable liquid

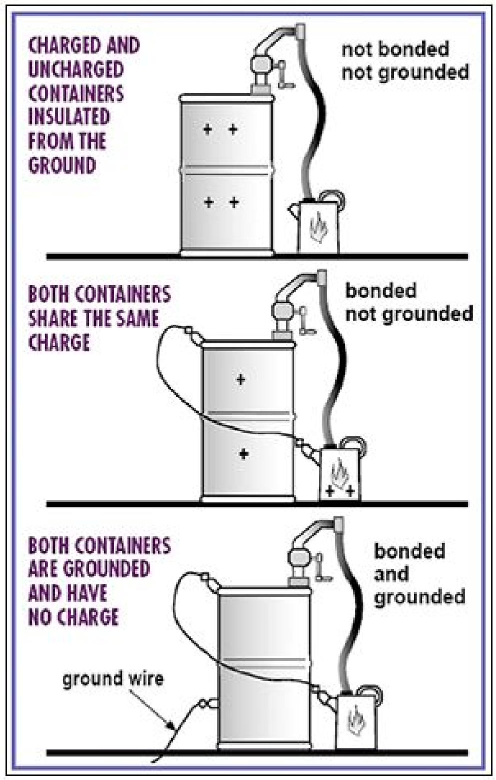


Image courtesy of Farmers Insurance Group.

Quality of Grounding Source

Grounding is accomplished by attaching a ground cable to a ground rod or grounding system designed to provide a continuous ground path to less than 10 ohms (NFPA 77). The ground attachment must be metal-to-metal and must not be painted, and kept clean, free of debris or dirt to ensure a good connection. Grounding systems should be checked annually by an electrician to verify the ground resistance (contact RMS).

Dispensing into Plastic or Glass Containers

Plastic and glass containers larger than 1.3 gallons should not be used for flammable liquid dispensing operations as these materials are non-conductive. Where there is a chemical compatibility issue and metal containers cannot be used, a metal funnel and fill pipe that extends to the bottom of the container or a metal rod inserted into the container can be used for bonding and grounding the operation.

Safety Can (above photo)
Safety cans have a self-closing air tight lid, flexible metal dispensing nozzle and a flame arrestor that protects the contents from an external ignition source, making them safer for storage and dispensing of flammable liquids. However, bonding and grounding is still required when transferring flammable liquids because static electricity generation and accumulation is possible during the transfer. Polyethylene safety cans are equipped with a grounding lug designed to attach to ground wires.

This image shows dispensing into a glass container. Note the ground rod inserted into the funnel.

Dispensing Location

Carefully assess and identify a safe location for flammable liquids transfer. Dispense flammable liquids (< 20 liters) inside a chemical fume hood or in a well-ventilated location. Flammable liquids in quantities > 20 liters must be dispensed inside a room/area specifically designed for dispensing flammable liquids with explosion-proof electrical wiring and equipment, and special ventilation systems. Contact RMS if you have questions. Ensure exit door and egress pathways are not obstructed in the dispensing location. Ensure all ignitions sources (e.g., flames, electrical outlets, etc.) are located at least 3 feet away from dispensing operations.

4.2 Explosive

Explosive chemicals cause sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden adverse conditions. These include shock sensitive chemicals, high-energy oxidizers, and peroxide-formers. Heat, light, mechanical shock, detonation, and certain catalysts can initiate explosive reactions. Compounds containing the functional groups azide, acetylide, diazo, nitroso, haloamine, peroxide, and ozonide are sensitive to shock, heat, and can explode violently. Always date explosive chemicals upon receipt and upon opening.

If you ever come across any chemical that you suspect could be potentially shock sensitive and/or explosive, do not attempt to move the container as some of these compounds are shock, heat, and friction sensitive. In these instances, you should contact RMS at 940-565-2109 immediately.

4.2.1 Handling Guidelines

The following additional procedures are recommended for handling explosive chemicals:

a. Always use the smallest quantity of the chemical possible.
    a. Do **NOT** scale up when using explosive materials. Check with your PI and perform a risk assessment of scaled up reactions, even when not working with explosive materials.
b. Always conduct the experiment within a fume hood and use in conjunction with a properly rated safety (explosion-proof) shield.
    a. Note that fume hoods do not protect entirely against an explosion and blast shields should still be used as a protective barrier.
c. Be sure to notify other people in the laboratory what experiment is being conducted, what the potential hazards are, and when the experiment will be run.
d. Handle shock-sensitive chemicals gently to avoid friction, grinding, and impact. Do not use metal or wooden devices when stirring, cutting, scraping, etc. with potentially explosive compounds. Non-sparking plastic devices should be used instead.
e. Ensure other safety devices such as high temperature controls, water overflow devices, etc., are used in combination to help minimize any potential incidents.

f. Properly dispose of any hazardous waste and note on the hazardous waste tag any special precautions that may need to be taken if the chemical is potentially explosive.
g. Always wear appropriate PPE, including the correct gloves, lab coat or apron, safety goggles used in conjunction with a face shield, and explosion-proof shields when working with potentially explosive chemicals.
    a. Avoid wearing synthetic material clothing when working with any flammable, combustible, explosive, or pyrophoric or self-heating materials.
        i. Synthetic clothing melts when on fire and will adhere to the skin.

Pay particular attention to those compounds that must remain moist or wet so they do not become explosive (ex. Picric acid, 2,4-Dinitrophenyl hydrazine, etc.). Pay particular attention to any potentially explosive compounds that appear to exhibit the following signs of contamination:

- Deterioration of the outside of the container.
- Crystalline growth in or outside the container.
- Discoloration of the chemical.

If you discover a potentially explosive compound that exhibits any of these signs of contamination, contact RMS at 940-565-2109 for more assistance.

4.2.2 Storage Guidelines

Similarly, to flammable materials, these materials must be stored in a separate flame-resistant storage cabinet or, in many cases, in a laboratory grade explosion-proof refrigerator or freezer that are designed for flammable and reactive chemicals.

Check the Section 7 of the materials SDS since some of these materials may need to be stored under inert atmosphere or kept dry and stored in a desiccator.

4.3 Spontaneously Combustible

Spontaneously Combustible material is:

- Pyrophoric Material: A liquid or solid that even in small quantities and without an external ignition source can ignite after coming in contact with the oxygen. Two common examples are tert-Butyllithium under Hexanes and White Phosphorus.
- Self-Heating Material: A liquid or solid, other than a pyrophoric substance, which, by reaction with oxygen and without energy supply, is liable to self-heat.

In addition to the hazard of the spontaneously combustible chemical itself, many of these chemicals are also stored under flammable liquids. In the event of an accident, such as a bottle being knocked off a shelf, the chemical can spontaneously ignite and a fire can occur. Extra care must be taken when handling spontaneously combustible chemicals. Always follow proper procedures to avoid exposing spontaneously combustible materials to air and wear proper PPE, including a fire-resistant lab coat. Special "Class D" fire extinguishers are required for use with spontaneously combustible materials. See Appendix F for information on how to quench spontaneously combustible materials and Ch 8 for Emergency Response.

4.3.1 Handling Guidelines

The following additional procedures are recommended for handling pyrophoric or self-heating materials:

a. Always use the smallest quantity of the chemical possible.
    a. Check with your PI and perform a risk assessment of scaled up reactions.
b. An SOP and Risk Assessment should be prepared for each process involving pyrophoric or water-reactive materials.
c. On-the-job training should be completed and documented.
    a. Perform a dry-run without any chemicals of the experiment.
d. Always conduct the experiment within a fume hood.
e. Be sure to notify other people in the laboratory what experiment is being conducted, what the potential hazards are, and when the experiment will be run.
f. Handle pyrophoric or self-heating materials under inert atmospheres and use the appropriate techniques to avoid exposure to oxygen or air.
    a. If possible, do not use a needle and syringe to handle pyrophoric or self-heating materials in open atmosphere, use a cannula instead to avoid the possibility of the plunger pulling out and exposing the chemical to air.

g. Properly dispose of any hazardous waste and note on the hazardous waste tag any special precautions that may need to be taken.
    a. If possible, quench the pyrophoric or self-heating material prior to disposal.
    b. If the material is in its original container, do not open to air. – submit a hazardous waste pick-up request and note that it is in its original container and the hazard.
h. Always wear appropriate PPE, including the correct gloves, fire resistant lab coat or apron, safety goggles used in conjunction with a face shield, and explosion-proof shields when working with potentially explosive chemicals.
    a. Avoid wearing synthetic material clothing when working with any flammable, combustible, explosive, or pyrophoric or self-heating materials.
        i. Synthetic clothing melts when on fire and will adhere to the skin.
i. It is important to note that any paper towels, Kim wipes, gloves, etc., that have come into contact with these materials need to be quenched prior to disposal.

4.3.2 Storage Guidelines

Spontaneously combustible and self-heating materials must always be stored according to the SDS of the chemical. Due to the fact that these materials can react or ignite upon exposure to air, they should always be stored under an inert atmosphere. Avoid any storage areas near heat/flames, oxidizers, and water sources. Containers with pyrophoric materials must be clearly labeled with the correct chemical name and hazard.

4.4 Dangerous When Wet

Solid substances that produce a flammable gas when wet or react violently with water. Known examples include sodium, calcium, potassium, lithium and calcium carbide. Please note, attempting to put out a fire involving dangerous when wet materials with water will only make the situation worse. Special “Class D” fire extinguishers are required for use with dangerous when wet substance.

4.4.1 Handling and Storage Guidelines

Similarly, to flammable, pyrophoric, and self-heating materials, the same handling guidelines applies to dangerous when wet materials. It is important to note that any paper toweling, Kim wipes, gloves, etc., that have come into contact with these materials need to be quenched with water before disposal. When working with these materials, make sure that all glassware and equipment is completely dry before use. An SOP and Risk Assessment should be prepared for each process involving pyrophoric or water-reactive materials and always perform a dry-run without any chemicals of the experiment.

For storage, always check Section 7 of the SDS for storage guidelines. Keep the container dry and store in appropriate cabinets. Never store near any water sources.

4.5 Oxidizers and Organic Peroxides

Oxidizers can present fire and explosion hazards on contact with organic compounds or reducing agents. Strong oxidizing agents should be stored and used in glass or other inert containers. Cork and rubber stoppers should not be used with these substances.

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.

As with any chemicals, but particularly with oxidizers and organic peroxides, quantities stored on hand should be kept to a minimum. Whenever planning an experiment, be sure to read the SDS and other reference documents to understand the hazards and special handling precautions that may be required, including use of a safety shield. Also be aware of the melting and auto ignition temperatures for these compounds and ensure any device used to heat oxidizers has an over temperature safety switch to prevent the compounds from overheating.

4.5.1 Inorganic Peroxides *(information below taken from: PEROXIDES AND PEROXIDE-FORMING COMPOUNDS)*

Inorganic peroxide compounds are potent oxidizers and are a potential fire or explosion hazard in contact with combustible materials. Inorganic peroxides can react violently with reducing agents and organic compounds to create organic peroxide and hydroperoxide product.

Inorganic peroxides include persalts of alkali metals (M_2O_2), hydrogen peroxide and perchloric acid. If handled properly and not contaminated, hydrogen peroxide has a long shelf life.

Concentrated hydrogen peroxide (>30%) may cause ignition if in contact with fabric, oil, wood, and some resins. Hydrogen peroxide may undergo violent decomposition in the presence of traces of certain catalytic metals (e.g. Fe, Cu, and Cr) or their salts.

Persulfates are highly reactive and may ignite when in contact with metals and perhalogen compounds are extremely shock sensitive. Avoid perhalogen compounds unless absolutely need in research. Perhalogen compounds can react with acids (especially organic acids) to produce near-anhydrous perchloric acid, an extremely hazardous compound.

4.5.2 Handling and Storage Guidelines for Oxidizers and Organic and Inorganic Peroxides

Handle organic peroxides similarly to explosive materials. Avoid using metal objects when stirring or removing oxidizers or organic peroxides from chemical containers. Plastic or ceramic implements should be used instead. If you suspect your oxidizer or organic peroxide has been contaminated (evident by discoloration of the chemical, or if there is crystalline growth in the container or around the cap), then dispose of the chemical as hazardous waste and contact RMS at 940-565-2109.

For storage, always check Section 7 of the SDS. Always store oxidizers and organic and inorganic peroxides **separate** from flammable, combustible, explosive, pyrophoric, or self-heating materials. Always store oxidizers and organic and inorganic peroxides **separate** from corrosive materials. Always store oxidizers and organic and inorganic peroxides **separate** from metals as the majority of these materials react in the presence of metals.

4.6 Peroxide forming compounds

Peroxide forming compounds are among the most hazardous substances commonly handled in laboratories. Several commonly used solvents (e.g. diethyl ether, tetrahydrofuran, dioxane, etc.) can form explosive peroxides through a relatively slow oxidation process in the presence of air and light. Since most peroxide forming chemicals are packaged in atmospheres containing air, even unopened bottles can produce peroxides. Refrigeration does not eliminate peroxide formation and stabilizers only slow down formation. Once peroxides have formed, they can detonate when combined with other compounds or when disturbed by unusual heat, mechanical shock, impact or friction. Visual inspection is the safest way to determine peroxide formation. If a peroxide former has crystals inside or around the cap, precipitation, or cloudiness, do not move or disturb the container and contact RMS immediately at 940-565-2109. Reactive chemicals should be stored on low shelving in secondary containment and never on the floor.

Peroxide forming chemicals are divided into four classes (A-D) which all have different testing and disposal requirements. A list of peroxide formers can be found in here.

- Class A: Chemicals that form explosive levels of peroxides without concentration, even when unopened.
  - Test for peroxides before all procedures and dispose within 3 months of receipt.
    - Ex: isopropyl ether, tetrahydrofuran (without inhibitor)
- Class B: Chemicals that form peroxides when concentrated via evaporation or distillation.
  - Test for peroxides before high-hazard procedures and every 6 months after opening
  - Dispose of by the expiration date or within 2 years of receipt
    - Ex: secondary alcohols, vinyl ethers, tetrahydrofuran (with inhibitor)
- Class C: Chemicals that may autopolymerize without an inhibitor
  - Test for peroxides before high-hazard procedures and every 6 months after opening
  - Dispose of by the expiration date or within 2 years of receipt
    - Methyl methacrylate, acrylic acid
- Class D: Chemicals that may form peroxides and do not fall within A-C
  - Test before high-hazard procedures or within 2 years of receipt

4.6.1 Handling and Storage Guidelines for Peroxide Formers

The following guidelines should be adhered to when using peroxide forming chemicals:

a. Always date peroxide forming compounds upon receipt, upon opening, and the expiration date. Include testing date if the opened bottle has been tested for peroxides.
b. Due to sunlight's ability to promote formation of peroxides, all peroxide forming compounds should be stored in an amber bottle and away from heat and sunlight.

c. As with any hazardous chemical, but particularly with peroxide forming chemicals, the amount of chemical purchased and stored should be kept to an absolute minimum. Only order the amount of chemical needed for the immediate experiment.
d. Never store **opened** peroxide formers in a refrigerator or freezer.
e. Ensure containers of peroxide forming chemicals are tightly sealed after each use and consider adding a blanket of an inert gas, such as N_2, to the container to help slow peroxide formation.
f. A number of peroxide forming chemicals can be purchased with inhibitors added. Unless absolutely necessary for the research, labs should never purchase uninhibited peroxide formers.
g. Before distilling any peroxide forming chemicals, always test the chemical first with peroxide test strips to ensure there are no peroxides present. Never distill peroxide forming chemicals to dryness. Leave at least 10-20% still bottoms to help prevent possible explosions.
h. Certain peroxide-forming chemicals such as diisopropyl ether, divinyl acetylene, sodium amide, and vinylidene chloride must be properly disposed of if they are older than three months. Contact RMS at 940-565-2109 for further instruction if you need to dispose of these substances.
i. Chemicals such as dioxane, diethyl ether, and tetrahydrofuran must be properly disposed of after one year if opened or expired. Contact RMS at 940-565-2109 for further instruction if you need to dispose of these substances.

While no definitive amount of peroxide concentration is given in the literature, a concentration of 50 ppm should be considered dangerous and a concentration of >100 ppm should be disposed of immediately. In both cases, procedures should be followed for removing peroxides formers and should be disposed of as hazardous waste.

4.7 Health Hazards (Poisons, Toxic Chemicals, and Irritants)

4.7.1 *Poisons and Toxic Chemicals*

Poisons, toxic chemicals, can refer to chemicals with acute toxicity or chromic toxicity. In addition, toxicity may target a specific organ. Highly toxic chemicals should be handled only by trained individuals and stored in a dedicated, labeled, and locked Toxics/Poisons cabinet. Experiments must be well planned and take place only in designated areas with limited access.

Symptoms of exposure of these materials may vary. Review each SDS for the specific material being used and take note of the associated symptoms of exposure.

OSHA defines "Toxic" as a chemical falling within any of the following categories:

a. A chemical that has a median lethal dose (LD50) of more than 50 milligrams per kilogram but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.
b. A chemical that has a median lethal dose (LD50) of more than 200 milligrams per kilogram but not more than 1,000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.
c. A chemical that has a median lethal concentration (LC50) in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than two milligrams per liter but not more than 20 milligrams per liter of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.

When working with highly toxic chemicals, you should not work alone. Always wear proper PPE and always wash your hands with soap and water when finished, even if gloves were worn. If you think you may have received an exposure to a poisonous substance, or may have accidentally ingested a chemical, seek medical attention immediately and/or call the Poison Control Center at 1-(800) 222-1222 or call 911 If possible, bring a copy of the SDS with you. Upon completion of seeking medical attention, complete an Incident Report.

4.7.2 *Health hazards with Toxic Effects on Specific Organs*

Substances in this category include:

- Hepatotoxins – i.e., substances that produce liver damage, such as nitrosamines and carbon tetrachloride,
- Nephrotoxins – i.e., agents causing damage to the kidneys, such as certain halogenated hydrocarbons,
- Neurotoxins – i.e., substances which produce their primary toxic effects on the nervous system, such as mercury, acrylamide and carbon disulfide,

- Hematopoietic agents – e.g., carbon monoxide and cyanides which decrease hemoglobin function and deprive the body tissues of oxygen,
- Pulmonary agents – e.g., asbestos and silica.

Symptoms of exposure to these materials vary. Staff working with these materials should review the SDS for the specific material being used and should take special note of the associated symptoms of exposure.

4.7.3 *Irritants and Sensitizers*

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

A sensitizer (allergen) is a substance that causes exposed people to develop an allergic reaction in normal tissue after repeated exposure to the substance. Examples of sensitizers include diazomethane, chromium, nickel, formaldehyde, isocyanates, arylhydrazines, benzylic and allylic halides, and many phenol derivatives. Sensitizer exposure can lead to all of the symptoms associated with allergic reactions, or can increase an individual's existing allergies. Caution should be taken when using these chemicals. Use only in fume hood or gloveboxes. Do not use out in open benches or areas. Never have an open container of a sensitizer outside of a fume hood or space with proper ventilation. If you think you may have become sensitized to a chemical, seek medical attention immediately. If possible, bring a copy of the SDS with you. Upon completion of seeking medical attention, complete an Incident Report.

4.8 Corrosives

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

- Strong acids – e.g., sulfuric, nitric, hydrochloric, and hydrofluoric acids.
- Strong bases – e.g., sodium hydroxide, potassium hydroxide and ammonium hydroxide.

- Dehydrating agents – e.g., sulfuric acid, sodium hydroxide, phosphorus pentoxide and calcium oxide.
- Oxidizing agents – e.g., hydrogen peroxide, chlorine and bromine.

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

Wherever acids and bases are used, an eyewash and emergency shower must be available. If any corrosive chemical is splashed in the eyes, immediately go to an eyewash station and flush your eyes for at least 15 minutes. The importance of flushing for at least 15 minutes cannot be overstated. Once the eyewash has been activated, use your fingers to hold your eyelids open and roll your eyeballs in the stream of water so the entire eye can be flushed. After flushing for at least 15 minutes, seek medical attention immediately and complete an Incident Report. See Ch 8 for more information in Emergency Response.

4.8.1 Handling Guidelines

The following guidelines should be adhered to when using peroxide forming chemicals:

a. Concentrated acids and bases must be added to water to minimize the possibility that the heat of reaction will cause eruption of the corrosive.
    a. **Never** add water to a concentrated acid or base as the water will layer on the top of the more densely concentrated acid or base. The extreme heat produced may boil and project the upper layer.
    b. Always add a concentrated acid or base to water.
b. Since the fumes of concentrated corrosives can cause severe external and internal burns, these solutions should be handled in a fume hood with the employees wearing rubber gloves, rubber apron and safety glasses.
c. If a spill occurs, **neutralize spills of concentrated acid with dry sodium carbonate or bicarbonate, and neutralize spills of concentrated alkali with citric or boric acid.** Keep a supply on hand.

d. Drips of acids or alkalis on the sides of containers are best cleaned off with paper towels.
e. Plastic stoppers are better than glass stoppers for glass bottles holding an alkaline solution. Alkalis tend to bind glass to glass making it sometimes impossible to remove a glass stopper.
f. For safe transportation of corrosives, protective packaging should be used.
g. When a corrosive chemical is to be disposed of, it should first be neutralized before adding to waste containers.
h. Before transporting a carboy of acid or base, check to make certain the neck of the bottle is not broken.
i. Ensure all glassware used to hold corrosive chemicals is well rinsed with water before sending to washup
j. Picric Acid
    a. Picric acid is explosive when dry and must be stored under water and kept out of contact with metals as much as possible. Bottle necks and lids should always be wiped with a moist paper towel to prevent the formation of crystals around them. Picric acid should never be allowed to reach a crystalline state, however, if this should happen - **DO NOT HANDLE ANY PICRIC ACID IN THIS STATE – Contact RMS and PI immediately.**
    b. Metal contamination or storage in metallic containers should be avoided.

4.8.2 Storage Guidelines

- Store corrosive chemicals (e.g., acids, bases) below shoulder level and in secondary containers that are large enough to contain at least 10% of the total volume of liquid stored or the volume of the largest container, whichever is greater.
- Corrosive chemicals are best stored in special ventilated cabinets.
- **Never** store strong acids with bases or either of the two with flammable liquids or oxidizing chemicals.
- Acids must always be segregated from bases and from active metals (e.g., sodium, potassium, magnesium) at all times and must also be segregated from chemicals which could generate toxic gases upon contact (e.g., sodium cyanide, iron sulfide).
    - Keep sealed when not in use.
    - Specific types of acids require additional segregation.
    - Organic acids should be segregated from inorganic acids (mineral acids).
    - Oxidizing acids must be segregated from organic compounds including organic acids, flammable and combustible substances.

- Inorganic acids and organic acids should be stored separately or in separate secondary containers.
- Perchloric acid and hydrofluoric acid should be stored by themselves, away from all other chemicals.
- Picric Acid is reactive with metals or metal salts and explosive when dry and must contain at least 10% water to inhibit explosion (see below for more information on picric acid).
- Perchloric acid that is heated must be used in a specific fume hood to prevent formation of explosive powder residue, if your lab plans to use perchloric acid inform RMS immediately.

4.8.3 *Hydrofluoric acid*

Hydrofluoric acid (HF) is a corrosive material that is dangerous even at low concentrations (50 - 250 ppm) and brief exposure times. Skin contact causes serious skin burns, which may not be immediately apparent or painful since HF interferes with nerve function, initially blocking pain. Symptoms may be delayed 8 hours or longer, resulting in deep acid penetration and severe burns. The fluoride ion readily penetrates the skin causing destruction of deep tissue layers and bone. Systemic fluoride poisoning has been associated with sudden death due to cardiac arrest, which can occur with burns to as little as 2.5% of body surface area. Inhalation of HF vapor may cause ulcers of the upper respiratory tract and can lead to systemic fluoride ion poisoning.

HF should be used in an operational chemical fume hood. In addition to a chemical fume hood, the following personal protective equipment is required for HF use:

a. Rubber or plastic apron
b. Gloves
    - Incidental use - double glove with heavy nitrile exam gloves and re-glove if any exposure to the gloves
    - Extended use – heavy neoprene or butyl over nitrile or silver shield gloves
c. Splash goggles in conjunction with a fume hood sash
d. Closed toed shoes
e. Long pants and a long sleeve shirt with a reasonably high neck (no low cut)

HF is usually stored in polypropylene containers since it attacks glass and other silicon containing compounds. HF reacts with silica to produce silicon tetrafluoride, a poisonous, corrosive gas known to cause pneumonitis and pulmonary edema. Older polypropylene containers can become brittle or start to bubble. If such a container is found, contact RMS immediately. If concentrated HF contacts the skin call 911 immediately and inform medical personnel that a hydrofluoric acid exposure has occurred; and complete an Incident Report.

Labs using hydrofluoric acid must have a supply of either calcium gluconate gel (preferred), or a 10% W/V calcium gluconate solution on hand as an antidote. Topical applications of the gel or solution should be applied frequently and liberally while the victim is awaiting further medical attention. Contact RMS for more information.

4.8.4 *Perchloric acid*

Perchloric acid is a corrosive oxidizer that can be dangerously reactive. At elevated temperatures, it is a strong oxidizing agent and a strong dehydrating reagent. Perchloric acid reacts violently with organic materials. When combined with combustible material, heated perchloric acid may cause a fire or explosion. Cold perchloric acid at less than 70% concentration is not a very strong oxidizer, but its oxidizing strength increases significantly at concentrations higher than 70%. Anhydrous perchloric acid (>85%) is very unstable and can decompose spontaneously and violently. When using perchloric acid, remember the following:

- Be thoroughly familiar with the special hazards associated with perchloric acid before using it.
- If possible, purchase 60% perchloric acid instead of a more concentrated grade.
- Always wear rubber, neoprene, or nitrile gloves and chemical splash goggles while using perchloric acid. Consider also wearing a face shield and rubber apron if splashing is likely.
- Store perchloric acid inside secondary containment (such as a Pyrex dish) and segregated from all other chemicals and organic materials. Do not store bottles of perchloric acid in wooden cabinets or on spill paper.

For any work involving heated Perchloric acid (such as in perchloric acid digestions), the work must be conducted in a special perchloric acid fume hood. Perchloric acid hoods are generally made of non-corrosive materials (stainless steel), and are equipped with a water wash down mechanism in the ductwork. Perchloric acid fume hoods must be clearly labeled and used only for perchloric acid or other mineral acids, such as nitric, hydrochloric, and hydrofluoric. No organic solvents should be stored or used in these hoods. When perchloric acid is heated above ambient temperature, vapor is formed which can condense in the ductwork and form explosive perchlorates. After each use, the fume hood operator shall wash down the hood and ductwork with water.

4.9 Compressed gases

A compressed gas is defined as a gas having pressure in the container of 40 psi or greater at 70°C. Also, any flammable liquid having a Reid vapor pressure (RVP) exceeding 40 psi at 38°C is classified as a compressed gas (RVP – measure of how quickly fuel evaporates). The regulations define the minimum pressure but not the maximum pressure in a cylinder which can be above 6000 psi for non-condensable gases.

The gas pressure within a cylinder depends on its physical state. For example, "permanent" gases exert a pressure proportional to the amount of gas in the cylinder; while gases which are liquified in the cylinder e.g., carbon dioxide, propane, ammonia, etc., exert vapor pressure as long as liquid remains.

4.9.1 Handling Guidelines

For more information, please see Airgas resources.

a. Gas cylinder connections must be inspected frequently for deterioration and must never be used without a regulator.
b. Never use a leaking, corroded or damaged cylinder.
    a. DO NOT attempt to repair a cylinder yourself. Return the cylinder to the manufacturer.
c. Never refill compressed gas cylinders.
d. When stopping a leak between the cylinder and regulator, always close the valve before tightening the union nut.
e. The regulator must be replaced with a safety cap when the cylinder is not in use.
f. When moving gas cylinders, verify first that the safety cap is in place and only use carts designed for this purpose
g. When transporting cylinders of compressed gases, always secure the cylinder with straps or chains onto a suitable hand truck and protect the valve with a cover cap.
    a. Avoid dragging, sliding, or rolling cylinders and use a freight elevator when possible.

4.9.2 Storage Guidelines

For more information, please see Airgas resources.

a. Cylinders of compressed gases are to be strapped or chained to a wall or bench top and are capped when not in use.
b. No more than three cylinders may be chained together with one chain.

c. Cylinders CANNOT be stored in a cart.
d. Do not expose cylinders to excessive dampness, corrosive chemicals or fumes
e. Certain gas cylinders require additional precautions.
f. Flammable gas cylinders must use only flame-resistant gas lines and hoses which carry flammable or toxic gases from cylinders and must have all connections wired.
g. Compressed oxygen gas cylinders must be stored at least 20 feet away from combustible materials and flammable gases.
h. Flammable gases must be stored separated from oxidizing gases.
    a. This is only an exception for gas cylinders used for welding.

4.10 Nanomaterials

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

As is the case with many new technologies, the health effects of nanomaterials have not been thoroughly investigated. Consequently, the uncertainty surrounding the toxicity of nanomaterials merits a cautious approach when working with them.

4.10.1 Handling Guidelines

Below are some general handling guidelines when working with nanomaterials.

- Use engineering controls like source enclosure, local exhaust ventilation, and HEPA filters when working with nanomaterials.
- During any experiment, wear NIOSH-approved personal protective equipment and respirator.
- Cleanup any spill immediately and properly dispose of any Nanomaterials.
- Since there are many different kinds of nanomaterials, always perform a risk assessment of the experiment involving nanomaterials to ensure the proper engineering controls are in place to prevent exposure.

5 PARTICULARLY HAZARDOUS SUBSTANCES

OSHA regulations require that provisions for additional employee protection be made for work with particularly hazardous substances (PHSs). These include carcinogens, reproductive toxins, and substances that have a high degree of acute toxicity.

a. Acute Toxins - OSHA interprets substances that have a high degree of acute toxicity as being substances that "may be fatal or cause damage to target organs as the result of a single exposure or exposures of short duration.” These chemicals, associated chemical waste, and storage containers must be handled with care to prevent cross contamination of work areas and unexpected contact. These chemicals must be labeled as “Toxic.” Empty containers of these substances must be packaged and disposed of as hazardous waste.
b. Reproductive Toxins - These include any chemical that may affect the reproductive capabilities, including chromosomal damage (mutations) and effects on fetuses (teratogenesis).

    i. Reproductive toxins can affect the reproductive health of both men and women if proper procedures and controls are not used. For women, exposure to reproductive toxins during pregnancy can cause adverse effects on the fetus; these effects include embryolethality (death of the fertilized egg, embryo or fetus), malformations (teratogenic effects), and postnatal functional defects. For men, exposure can lead to sterility.
    ii. Examples of embryotoxins include thalidomide and certain antibiotics such as tetracycline. Women of childbearing potential should note that embryotoxins have the greatest impact during the first trimester of pregnancy. Because a woman often does not know that she is pregnant during this period of high susceptibility, special caution is advised when working with all chemicals, especially those rapidly absorbed through the skin (e.g., formamide). Pregnant women and women intending to become pregnant should consult with their laboratory supervisor and EHSRM before working with substances that are suspected to be reproductive toxins.
    iii. Select carcinogens – OSHA defines a “select carcinogen” as a substance that meets one of the following criteria:
        - regulated by OSHA as a carcinogen;

- Is listed under the category "known to be a carcinogen" or "reasonably anticipated to be a carcinogen" in the Annual Report on Carcinogens published by the National Toxicology Program (NTP); or
- Is listed under Group 1 ("carcinogenic to humans") or under Group 2A ('probably carcinogenic to humans") or 2B ("possibly carcinogenic to humans") by the International Agency for Research on Cancer (IARC).

A list of Particularly Hazardous Substances (PHSs) which includes known Select Carcinogens, Reproductive Toxins, and Acute Toxins can be found in Appendix D "Particularly Hazardous Substances". See Appendix N for more information on reproductive toxins.

PIs and Laboratory Supervisors are responsible for assuring that laboratory procedures involving particularly hazardous chemicals have been evaluated for the level of employee protection required. Specific consideration will be given to the need for inclusion of the following:

- Planning;
- Establishment of a designated area;
- Access control;
- Special precautions such as:
    - use of containment devices such as fume hoods or glove boxes;
    - use of personal protective equipment;
    - isolation of contaminated equipment;
    - practicing good laboratory hygiene; and
    - prudent transportation of very toxic chemicals.
- Planning for accidents and spills; and
- Special storage and waste disposal practices.

5.1 Handling and Storage Guidelines

Health Hazards and Toxic Chemicals and Unknown Toxicity

- Designated area(s) for use of particularly hazardous substances must be formally established by developing SOPs and posting appropriate signage.
    - This designated area(s) may be an entire laboratory, a specific work bench, or a chemical fume hood.

- When particularly hazardous substances are in use, access to the designated area shall be limited to personnel following appropriate procedures and who are trained in working with these chemicals.
- Access to areas where particularly hazardous substances are used or stored must be controlled by trained employees.
  - Working quantities of particularly hazardous substances should be kept as small as practical and their use should be physically contained as much as possible, usually within a laboratory fume hood or glove box.
  - It is the responsibility of each PI, or their designee, to train and authorize their staff for these operations and to maintain documentation of this training and authorization.
- Signage is required for all containers, designated work areas and storage locations. Sign wording must state the following, or similar, as appropriate for the specific chemical hazard: "DANGER, CANCER HAZARD – SUSPECT AGENT" "DANGER, CANCER HAZARD – REGULATED CARCINOGEN" "DANGER, REPRODUCTIVE TOXIN" "DANGER, ACUTE TOXIN" Entrances to designated work areas and storage locations must include signage, "AUTHORIZED PERSONNEL ONLY", in addition to the above specific hazard warning wording.

Carcinogens

- It is important to recognize that some substances involved in research laboratories are new compounds and have not been subjected to testing for carcinogenicity.
- When carcinogens are used in a laboratory, access to the laboratory will be clearly restricted to personnel trained in safe handling of highly toxic material.
- Access and use of highly toxic substances and carcinogens shall be controlled and monitored.
- Instructors and graduate students using these materials shall record the amounts used, date and persons working with the materials.
- A separate inventory list of carcinogens, suspected carcinogens, reproductive toxins and highly toxic substances is recommended.
- it is particularly important to review and effectively apply engineering and administrative safety controls as the regulatory requirements for laboratories that may exceed long term (8 hour) or short-term (15 minutes) threshold values for these chemicals are very extensive.
- Any spill, release of, or suspected exposure to a carcinogen must be reported to RMS immediately.

Since there are additional regulations for the use, handling, and storage of carcinogens, the PI and/or Laboratory Supervisor should be notified immediately if there are any changes.

6 CONTROL MEASURES

Safe work with hazardous chemicals can only be accomplished with proper control measures. Proper control measures include the use of engineering controls, appropriate storage and handling of chemicals, the use of personal protective equipment, and proper use and maintenance of safety equipment. Carefully implemented control measures can reduce or eliminate the risk of employee exposure to hazardous chemicals.

6.1 Engineering Controls

Engineering controls include proper laboratory design, adequate ventilation, and the use of other safety devices. These controls offer the first line of protection and are highly effective in that they generally require minimal special procedures.

- Isolation
    - Reduce or remove hazards by separation in time or space. (May be particularly helpful in a shared lab space where different types of chemicals or biohazards are being used.)
- Enclosure
    - Place the material or process in a closed system. (e.g., Schlenk line or glovebox)
- Transportation
    - Move hazardous materials where fewer workers are present.
- Guarding and shielding
    - Install guards to provide protection from moving parts or electrical connections.
    - Shielding provides protection from potential explosions.
- Ventilation
    - Use of fume hoods, snorkels, biological safety cabinets, and air filters.

Ventilation is the most common and most important form of engineering control used to reduce exposures to hazardous chemicals.

6.1.1 *General Lab Ventilation*

The primary functions of laboratory ventilation systems are to provide safe, comfortable, breathable environments for all lab users, and to minimize exposures to hazardous air contaminants. General ventilation must not be relied on to control chemical vapors, gases, and mists.

6.1.2 *Chemical Fume hoods*

Fumes hoods are used for laboratory work with materials that do not require special handling procedures. A general fume hood can be one of four types:

- Constant Air Volume (CAV) or Conventional Hood, the basic hood with a movable sash and baffle. This hood is generally the least expensive and its performance depends mainly on the position of the sash due to the fact that the amount of air exhausted is constant. The face velocity of a CAV hood is inversely proportional to the sash.
- By-Pass Hood, designed to allow some exhaust air to "by-pass" the face of the hood even when the sash is closed. It is designed for use with sensitive and fragile apparatus and/or instruments.
- Auxiliary Air Hood, designed to introduce outside air into the hood and limit the amount of room air that is exhausted.
- Variable Air Volume (VAV) Hood, designed to regulate the hood exhaust and keep the air velocity at a predetermined level. VAV hoods are designed to use less energy than CAV.

The majority of fume hoods on campus are VAV hoods with air flow monitors on the side panels. Some of the older fume hoods are campus are CAV hoods. Make sure that you know which one you are working with and to follow proper protocols while using a fume hood at all times.

6.1.2.1 Fume hood inspection and testing program

RMS performs an annual functional performance test to assure hoods perform as required. The performance test typically includes an evaluation of the face velocity, and airflow monitors. RMS may also note any observed problem with controls, sash, baffles, plumbing, light or corrosion.

Fume hoods tested by RMS will have a label that records its inspection history. If in between the annual testing the fume hood alarm goes off or there are other issues with the fume hood, submit a work request to the UNT facilities and notify RMS.

UNIVERSITY OF NORTH TEXAS®

Risk Management Services

Room: ________ Hood ID: ____________

This Fume hood has been inspected and has a face

Velocity of _______ FPM at sash height of ________

Inspected by: ______ Date: ____________

6.1.2.2 General safety practices

Please see this video explaining the components of a chemical fume hood, how a fume hood works, and how to use it. To ensure safety and proper fume hood performance, follow these guidelines:

- Use a fume hood when working with chemicals or procedures that may produce hazardous fumes or vapors.
- Know how to properly operate a fume hood before beginning work. Inspect the fume hood before starting each operation to ensure it is working.
- Place equipment and chemicals at least six inches behind the fume hood sash. This practice reduces the chance of exposure to hazardous vapors.
- Do not allow paper or other debris to enter the exhaust duct of the hood.

- Do not store excess chemicals or equipment in fume hoods.
- Do not block the baffle area of the fume hood.
- Elevate any large equipment within the hood at least three inches to allow proper ventilation around the equipment.
- When working in a fume hood, set the sash at the height indicated by the arrow. The only time the sash should be completely open is while setting up equipment.
- Do not alter/modify the fume hood or associated ductwork.
- Clean up spills in the hood immediately.
- Do not ignore or defeat fume hood flow alarms. Submit a work request to the UNT facilities and notify RMS.
- Fume hoods may fail for a variety of reasons. Lab personnel should have a contingency plan for hood failure to prevent development of hazardous conditions, and to avoid interruptions in laboratory use.

6.1.3 *Glove Boxes*

A glove box consists of a working enclosure containing a controlled atmosphere, an airlock to enable items to be taken in and out of the box, a transparent front to allow the worker to observe the interior of the box, and gloves (usually butyl rubber) sealed into the front, to allow working access into the interior. Positive pressure glove boxes are good for protecting the items in the box from the external atmosphere, as any leak is out of the box, preventing air from entering.

All personnel using a glove box should follow the following recommendations:

- All personnel must receive documented training from the PI or delegate before any work in a glove box occurs. All trained personnel must understand the design features and limitations of a glove box before use. The training must include detailed instruction on elements such as the ventilation and vacuum controls that maintain a pressure differential between the glove box and outside atmosphere, atmospheric controls (e.g., controlling oxygen concentrations and moisture), etc.
- Prior to use, a visual glove inspection must be performed. Changing of a glove must be documented (date, manufacturer, model of glove, and person performing change). Gloves should not be used until they fail; they should be changed according to the glove box manufacturer's recommendations or whenever necessary.
- Plugging ports that are never or infrequently used is recommended. A properly plugged port should have a stub glove and a glove port cap installed.
- Chemical resistant gloves (e.g., disposable nitrile gloves) should be used under the glove box gloves to protect from contamination.

- The glove box pressure must be checked every day, before use and immediately after gloves are changed. The pressure check must be documented.
- Keep sharps in an approved container while in the glove box.
- Follow all safe work practices for using and handling compressed gas that may be associated with working in the glove box.
- All equipment and chemicals in the glove box must be organized and all chemicals must be labeled. Do not allow items, particularly chemicals to accumulate in the glove box.

For more information on the use of a glovebox, see Appendix L.

6.1.4 *Biosafety cabinets*

A biosafety cabinet is an enclosed, ventilated laboratory workspace for safely working with materials contaminated with (or potentially contaminated with) infectious materials. The primary purpose of a biosafety cabinet is to serve as a means to protect the laboratory worker and the surrounding environment from pathogens. All exhaust air is filtered as it exits the biosafety cabinet, removing harmful particles. Biological safety cabinets are ***not*** designed to be used with chemical applications so the use of chemicals should be kept to a minimum. Applications that involve the use of chemicals should be conducted in chemical fume hoods. Refer to the Biosafety Cabinets (BSC) Guidance for more details on the use of biosafety cabinet.

6.1.5 *Snorkel hoods*

Snorkel hoods are small fume exhaust duct connections. They are designed with flexible ducts and can be positioned directly over a work area at the bench. See this video for demonstration on snorkels. For best performance, the snorkel hood should be placed within six inches of the item needing ventilation. Snorkel hoods should only be used to exhaust heat and nuisance odors. They should never be used with highly toxic or flammable chemicals.

6.2 Personal Protective Equipment

The laboratory environment contains many potential hazards. Most hazards can be reduced or eliminated by substitution and/or engineering controls. Substitution is the reduction or elimination of a hazard by replacing a high hazard material or procedure with a less hazardous one. When hazards cannot be adequately controlled with substitution and/or the implementation of engineering controls, personal protective equipment (PPE) is required. To learn more about other controls, see Appendix H for Hierarchy of Controls.

The PI and/or the Laboratory Supervisor will be responsible for selecting personal protective equipment. PPE issued to laboratory personnel must be appropriate for the task and will depend upon the proper hazard identification and assessment made by the PI and/or laboratory supervisor. Laboratory personnel must understand the use and limitations of the PPE. PPE includes, but is not limited to, laboratory coats and aprons, eye protection (safety glasses, face shields, etc.), and gloves. Laboratory personnel must wear proper PPE when it is required.

6.2.1 *Respiratory protection*

A respirator should only be used when it is not possible to minimize or eliminate exposure to contaminant through other means. All individuals issued respirator must meet the criteria established in the OSHA standard, which include medical screening, training and fit testing. For further information, contact RMS.

6.2.2 *Lab Coats*

Lab coats should be worn by laboratory employees and students whenever there is a reasonable risk of chemical exposure to skin. Lab coats that become contaminated with chemicals must be evaluated on each case. Those that are contaminated with acutely hazardous chemicals must not be laundered or reused. Lab coats that have been grossly contaminated with non-acutely hazardous waste may also be designated for disposal rather than laundering, depending on the chemical nature of the contaminant(s), since laundering may spread contamination and/or result in discharge of effluent that exceeds local limits. Lab coats that have been contaminated due to incidental contact with non-acutely hazardous chemicals or that have become dirty from regular use may be laundered on site or by a commercial vendor that has expertise in cleaning lab coats.

Appropriate clothing should be worn underneath a lab coat and while in the lab at all times. Appropriate clothing is clothing that does not leave any skin exposed like legs or stomach. It is preferred that clothing is made out of natural fibers like cotton, as clothing made with synthetic fibers can potentially melt and adhere to the skin during a fire.

Flame-resistant lab coats must be worn when handling pyrophoric or extremely flammable (flashpoint $<73\ ^{o}F$) substances. These Lab coats must be cleaned by a qualified commercial vendor in order to retain the flame-resistant properties.

Why use a lab coat?

- Provides protection of skin and personal clothing from incidental contact with hazardous materials and small splashes;
- Prevents the spread of contamination outside the lab (provided they are not worn outside the lab);
- Provides a removable barrier in the event of an incident involving a spill or splash of hazardous substances.

Lab coats should not be used as a substitute for engineering controls such as a fume hood, glove box, etc., or a substitute for good work practices and chemical hygiene.

  - For significant chemical handling – you should supplement lab coat use with additional protective clothing I.e.; rubber or vinyl apron for handling large quantities of corrosives or hydrofluoric acid;
  - The use of engineering controls does NOT permit you to forgo PPE like a lab coat.
- Lab coats are not designed to be the equivalent of chemical protection suits for major chemical handling or emergencies.
  - There is little or no information provided by manufacturers or distributors about the capability of a lab coat for a combination of hazards.
    - A coat that is described as "flame resistant", such as treated cotton, may not be chemical resistant or acid resistant.
  - A coat that is advertised as flame resistant has not been tested using criteria involving flammable chemicals on the coat.
      - The term "flame resistant" refers to the characteristic of a fabric that causes it not to burn in air. The flame resistance test criteria were intended to simulate circumstances of a flash fire, or electric arc flash, not a chemical fire.

How do I choose the correct lab coat?

1. Perform a hazard assessment!
2. Consider the following
   a. Does your lab work primarily with chemicals, biological agents, radioisotopes, or a mix of things?
   b. Does your lab work involve animal handling?
   c. Are there large quantities of flammable materials (>4 liters) used in a process or experiment?
   d. Are there water reactive or pyrophoric materials used in the open air, e.g. in a fume hood instead of a glove box?
   e. Are there open flames or hot processes along with a significant amount of flammables?
   f. How are hazardous chemicals used and what engineering controls are available, e.g. a fume hood or glove box?

g. Is there a significant risk of spill, splash or splatter for the tasks being done?
h. What is the toxicity of chemicals used and is there concern about inadvertent spread of contamination?

While there are many different style features, from a protection standpoint the best coats have the following characteristics:

- Tight cuffs (knitted or elastic);
- Snap closures on the front for easy removal in case of contamination;
- Coats with different properties are easy to tell apart (ex: flame resistant (FR) coats should have outer markings clearly identifying them as FR coats and can be ordered in a different color than other coats present in the lab);
- Proper fit - get checked for appropriate size.
  - Use only your designated lab coat. Do not use others lab coats.
- Appropriate material for hazards to be encountered

- One coat may not work for all lab operations.
  - Some people may want to provide a basic poly/cotton blend coat for most operations, but have available lab coats of treated cotton or Nomex for work involving pyrophoric materials, extremely flammable chemicals, large quantities of flammable chemicals, or work around hot processes or operations.
  - If chemical splash is also a concern, use of a rubber apron over the flame resistant lab coat is recommended. Lab coat materials may be made of materials for limited reuse, or disposable one time use.

As a note: Work with pyrophoric, spontaneously combustible, or extremely flammable chemicals presents an especially high potential for fire and burn risks to the skin.

- You should use a fire retardant or fire resistant (FR) lab coat when handling pyrophoric chemicals outside of a glove box.
- An FR lab coat is recommended when working with any flammable materials.
- The primary materials used for FR lab coats are FR-treated cotton or Nomex.
- There is also a newer flame resistant and chemical resistant (FR/CP) lab coat that offers additional protection against many chemicals.
- Consider the use of flame resistant gloves as well.

Type of Lab Coat	Hazards
Polyester/Cotton Blend 80/20 most common (Recommend a minimum of 65% polyester for chemical research lab setting.)	General Chemical, biological, or radioisotopes
Shieldtec (FR/CP)	Corrosives, highly flammable materials, pyrophorics, and/or other chemical splash
Nomex	Highly flammable materials, pyrophorics, welding, arc flash
FR treated cotton	Highly flammable materials, pyrophorics, welding, arc flash
Reusable Fluid Resistant Coats	High contamination (biological)
Polypropylene lab coat.	Intended for protection from dirt, grime, dry particulates in relatively non-hazardous environment such as animal handling and clean rooms.
100% Cotton	Good for labs where acid handling is limited and splash resistance is not a concern, and there is some work with flammables, heat and

	flame. Supplement with an apron for acid handling.

6.2.3 *Hearing protection*

If you work in a high noise area, preventing hearing loss is of utmost importance. Hearing protection (noise attenuating ear muffs or plugs) are required whenever employees and students are exposed to 85 dBA or greater in an eight-hour time weighted average.

6.2.4 *Eye protection*

All eye and face protection devices must meet the requirements in the ANSI Z87 standard. When evaluating the appropriate type of eye protection, it is important to note that more than one type of protection may be appropriate. In addition, multiple layers of eye and face protection may be warranted for higher-hazard operations. During the PPE selection process, the PI should consider the following:

- Safety glasses should be upgraded to splash-resistant chemical goggles whenever pouring liquid chemicals. Chemical goggles offer a much higher degree of eye protection.
- Face shields are not to be worn alone. They must only be used as a secondary means of eye and face protection with appropriate primary eye protection worn underneath. For example, chemical goggles should be worn under a face shield while pouring acids.
- Goggles come in many varieties. The right type of goggle must be selected to ensure the appropriate level of eye protection is achieved. For example, vented goggles protect the wearer from flying chips and are appropriate for cutting operations; however, the vents make them less effective as splash protection.
- How to Choose the Right Safety Eyewear
    - A Guide for Choosing Protective Eyewear
        - Consider work activity and work-related hazards.
        - OSHA Eye and Face Protection Overview

These Z87.1 safety glasses are a popular choice but do not form a tight seal around the eye line.

Z87.1 safety goggles like these offer high-impact resistance and a tight seal around the eye line.

General-purpose safety goggles have a soft, flexible frame and offer only limited protection to the wearer.

6.2.5 *Gloves*

Always wear the appropriate gloves when handling laboratory materials. Gloves must be comfortable, sufficient in length, and made of material that has the appropriate level of chemical resistance for the task to provide adequate protection. Depending on its intended use, a glove may be designed to provide dexterity, strength, low permeability, resistance to penetration by sharp objects, or protection from temperature changes. When using gloves follow these safety procedures:

- Make sure the glove material is resistant to the substances in use.
- Inspect gloves for holes and tears before each use.
- Replace gloves periodically, depending on their permeation and degradation characteristics.
- Disposable gloves designed for single use shall not be reused.
- Abrasion resistant gloves (e.g. leather) should be worn for handling broken glass and other similar materials, but should not be used to handle chemicals.
- Heat resistant gloves shall be used for handling hot objects.

For detailed information on glove selection see Appendix A "Gloves Selection".

- How to Choose the Right Safety Gloves:
    - Glove Selection Guide
    - Identify the hazards and assess the risks of those hazards
        - Consider chemical type, temperature extremes, physical hazards, pH, toxicity, infection potential of biological hazards.
        - Check the SDS section 7 and 8 for guidance on handling and PPE.

- Determine if you will have extended contact.

6.2.6 *Foot protection*

Closed toe shoes must be worn at all times when in the laboratory; open toe shoes and/or sandals are not permitted in any circumstance. Each affected employee must wear protective footwear when working in areas where there is a high risk of objects falling on or rolling across the foot, piercing the sole, and where the feet are exposed to electrical or chemical hazards. If there is a high risk of chemical contamination to the foot (e.g., cleaning up a chemical spill on the floor), then chemical-resistant booties may need to be worn as well.

6.3 Administrative Controls

Administrative controls are measures such as standard operating procedures, rules, supervision, schedules, and training put in place in a workplace with the goal of reducing the duration, frequency, and severity of exposure to hazardous chemical or situations.

6.3.1 *Laboratory specific Standard Operating Procedure*

The PI / Laboratory Supervisor is responsible for providing written laboratory specific Standard Operating Procedures (SOPs) relevant to health and safety for laboratory activities he/she directs involving hazardous chemicals. Laboratory personnel working autonomously or performing independent research are responsible for developing SOPs appropriate for their own work.

Laboratory specific SOP should be developed for any operation involving restricted chemicals, certain higher hazard chemicals such as Particularly Hazardous Substances and Highly Reactive Chemicals, and specified higher risk research procedures. Refer to Appendix E Standard Operating Procedures for a template and guidance for creating laboratory-specific SOPs.

Note that SOPs are **NOT** a replacement for training. SOPs are to supplement training and can be used as a reference later on, prior to performing the process or procedure. All lab personnel **MUST** be trained on the process or procedure by the PI or designated senior lab personnel.

SOPs are only useful if they are used. Reference and review an SOP any time you perform that procedure or process or use an uncommon chemical.

6.3.2 *Chemical Inventory*

Each laboratory is required to maintain a current chemical inventory that lists the chemicals and compressed gases used and stored in the labs to include the quantity of these chemicals. Chemical inventories are used to ensure compliance with storage limits and other regulations and can be used in an emergency to identify potential hazards for emergency response operations. RMS recommends that all laboratories update their chemical inventory at least annually. While no standardized format is required, the inventory should include, at minimum: the chemical name, container size, and the building name and room number. For a chemical inventory template, see Appendix K Chemical Inventory.

6.3.3 *Housekeeping and Maintenance*

Housekeeping is an important element to a laboratory safety program. Keep the work area clean and uncluttered with chemicals and equipment being properly labeled and stored. Clean up the work area upon completion of an experiment or procedure and at the end of each day. The following laboratory housekeeping guidelines should be followed:

- Access to emergency equipment, showers, eyewashes, fire extinguishers, exits and circuit breakers shall never be blocked or obstructed.
- All aisles, corridors, stairs, and stairwells shall be kept clear of chemicals, equipment, supplies, boxes, and debris.
- Keep all areas of the lab free of clutter, trash, extraneous equipment, and unused chemical containers. Areas within the lab that should be addressed include benches, hoods, refrigerators, cabinets, chemical storage cabinets, sinks, trash cans, etc.
- All chemicals should be placed in their proper storage areas at the end of each workday.
- Collection containers for wastes must be clearly labeled including hazard identification.
- In rooms with fire sprinklers, all storage, including both combustible and non-combustible materials, must be kept at least 18" below the level of the sprinkler head deflectors to ensure that fire sprinkler coverage is not impeded.

Laboratory personnel should inspect eyewashes weekly, by operating them until the water runs clear, and to ensure both outlets have sufficient and even supply. RMS coordinates periodic testing of safety showers.

6.3.4 *Eating and drinking in the laboratory*

Do not eat, drink, use tobacco products (smoke, chew, dip), chew gum, or apply cosmetics in areas where laboratory chemicals are present. Remove gloves, wash hands and leave the area before conducting these activities. Do not store food or beverages in refrigerators or glassware that have been used for laboratory operations.

6.3.5 *Laboratory setup and close out*

All facilities designated for use in teaching, research or service activity where chemical agents are used or stored must be registered with RMS. The registration information includes the names and contact information of the PI and alternate contacts, laboratory location(s), and the laboratory hazard information. New PIs must contact RMS prior to beginning their laboratory operations. RMS should also be contacted by PIs moving into a new lab, when new contacts come into a lab, and before vacating/closing a laboratory.

6.3.6 *Graduating Lab Personnel*

Graduating or leaving laboratory personnel should follow the rules below prior to leaving the lab:

1. Label all individual samples and chemicals used in the lab with proper chemical name and hazards.
2. Clean all individual areas and all individual equipment.
3. Submit a hazardous waste pick-up of any samples or chemicals that will NOT be needed or used. *
4. Submit a hazardous waste pick-up for any unknowns made in the lab.

*Check with PI and current lab members that these samples or chemicals will not be needed or used. IF the samples are kept, the PI is responsible for submitting a hazardous waste pick-up of these samples if they are not used.

6.3.7 *Decontamination*

If the lab will have any of the following procedures down below then decontamination of surfaces and equipment is necessary.

- Remodeling or demolition
- Repair by either facilities or an outside contractor
- Vacating rooms or areas during laboratory closeout
- Disposal or recycling of unwanted equipment
- Relocation of equipment
- Returning faulty or damaged equipment for repair or replacement

Decontamination is necessary when hazardous chemical, biological, or radioactive materials are used in the laboratory. Decontamination is necessary to prevent cross contamination or accidental exposures. Consult the Radiation Safety Officer or Biological Safety Officer for decontamination procedures of radioactive or biological materials.

Hazardous Chemicals Decontamination

The area that is being worked on needs to be thoroughly cleaned of chemical residue, including surfaces and equipment. A common way to decontaminate surfaces and equipment with chemicals is to thoroughly wipe down the surfaces and equipment with soap and water using disposable towels. The resulting towels should be placed into a separate solid waste container and a hazardous waste pick-up should be submitted. It is best to review the chemical hazards you are working with to ensure you are wearing necessary PPE and to check for any chemical incompatibility. Some chemicals require special considerations.

- Grease and oil: contamination with greasy residue can be wiped down with a surfactant capable of dissolving grease (i.e., soapy water) or an appropriate solvent or cleaner.
- Solid chemical residue: contamination with solid chemical residue can be cleaned by sweeping or by wetting it with either water (if compatible) or a solvent and wiping the surface with a disposable towel. Take special care not to aerosolize the solid chemical while cleaning (do NOT spray the chemical directly with a squirt bottle and take care when sweeping).
- Mercury: if there is a surface contaminated with mercury, please contact RMS for proper decontamination. Do NOT attempt to clean it.
- Acids and bases: neutralize and/or dilute surfaces contaminated with residual corrosives. If possible, testing the pH of the surface or equipment will help ensure proper decontamination.
- Chemicals in a glovebox: if a glovebox will undergo maintenance, all surfaces and equipment inside the glovebox needs to be cleaned. If there is use of pyrophoric chemicals, these surfaces, equipment, and glassware should be quenched prior to removal and exposure to oxygen. Improper decontamination may result in fires. Quench and decontaminate with solvents that are compatible. If there are solid chemicals, these can be cleaned up using a small broom and dustpan that can be brought into the glovebox (provided it does not react with your chemistry, be sure to pull vacuum on any plastic overnight in a port). Consult PI and senior lab members for proper lab specific protocols when cleaning inside a glovebox.
- Highly toxic chemicals: for areas where use of highly toxic chemicals occurs, these areas should be decontaminated after every use to prevent accidental exposure. Choose a solvent that the material is compatible with and soluble in. Avoid solvents that enhance absorption through the skin like dimethyl sulfoxide. Wear appropriate and necessary PPE when decontaminating the surfaces including correct type of gloves, lab coat, and safety goggles or glasses. Dispose of all materials used to decontaminate the surfaces in the appropriate liquid or solid waste containers.

After decontaminating any surface or equipment, make sure to wash your hands thoroughly and any exposed areas of skin. When working with sensitizers and decontaminating after use, consider changing clothes as well.

6.3.8 *Laboratory Clean-up*

Laboratory Clean-Ups should be done every 6 months to every year. Laboratory clean-ups can include but are not limited to:

- Decontaminating work surfaces,
- Organizing glassware, samples, chemicals within individual spaces,
- Inventorying and organizing chemicals into proper storage spaces,
- Disposing of old, unwanted, or unused chemicals or samples (Legacy Chemicals and Unknowns),
- Disposing and decommissioning of old, unwanted, or broken equipment.

When looking at chemicals to keep, consider these questions:

- Is it likely to be used again?
- How long will the chemical last?
- How hazardous is it?
- Will it generate any new hazards over time?
- How much did it cost?

Legacy Chemicals and Unknowns

Legacy chemicals are unused chemicals that are stored for many years, often inherited chemical stocks from previous lab occupants. These chemicals are often in the back of cabinets, desiccators, or drawers for many years, unnoticed and unused. These chemicals can take up valuable space and some chemicals can become dangerous as they age. Small leaks can go unnoticed and can cause violent reactions and generate toxic fumes. If there are any legacy chemicals or unknowns – discuss with your PI about discarding these and contact RMS for a hazardous waste pick-up request.

To help prevent unknowns and legacy chemicals, please make sure all lab personnel are labeling all samples and chemical bottles.

6.3.9 *Laboratory Inspection*

In order to protect the health and safety of laboratory personnel as well as the environment, RMS conducts laboratory safety inspections to find and correct unsafe conditions and/or instances of non-compliance with applicable rules and regulations. RMS will forward a copy of inspection results to the PI or Laboratory Supervisor for the lab. Follow-up inspections will be performed as necessary, to confirm completion of corrective actions. For a detailed checklist of laboratory inspection see Appendix J Laboratory Inspection.

6.3.10 *Working alone or overnight in Laboratory*

Avoid working alone in a building or laboratory. Prior written approval from the PI or Lab Supervisor is required before working alone in a laboratory. Working alone in a laboratory is prohibited when working with particularly hazardous substances or high-risk physical hazards.

6.3.10.1 Working alone or overnight in laboratory for low or moderate risk procedures

Overnight or late-night experimentation can be quite dangerous since oftentimes the lab personnel working late hours are working alone. Experiments that are left to run overnight have the potential for more dangerous incidents because no one is around. Plan experiments accordingly. If experiments will take a longer time to perform, do not start them late in the evening. It is better to start the next day than to work overnight or late night and alone. *It is recommended to NEVER work alone. It is also best to NOT work when exhausted or tired.* When a lab personnel is exhausted or tired and continues to work, it is more likely for an incident to occur.

Below is a guide to help those who wish to work overnight or those who work late nights stay safe.

- Make multiple people aware that you are working overnight or late.
  - PIs are **required** to be aware of who is working overnight or late nights – get written approval from the PI before working alone.
  - Let a lab member know that you will be working overnight or a late night.
- Set check-in times with a lab member or PI.
- Perform a risk assessment of your experiment (see Appendix H Risk Assessment)
  - **Work through preparing for emergencies if you are the sole person in the lab. This can look very different than usual emergency preparation.**
  - Have the list of emergency numbers for campus on hand.
- Discuss the experiment with your PI to ensure the correct procedures are being performed.
- If an experiment is being performed overnight or is left overnight, post a notice on the door.

- This notice should include hazardous procedures, chemicals being used in the reaction, and any other important information about the reaction (i.e., reflux, sublimation, potentially explosive, etc.)
- This notice should also include name and phone number of the person who set up and is running the experiment.
- This notice should also include all emergency procedures if something were to occur
  - When performing the risk assessment of the experiment, ensure that preparing for emergencies takes into the account that the person discovering the accident is potentially NOT a lab member. Think about all potential possibilities during an incident or emergency and think of all of the steps to respond to possible emergencies or incidents.
- If running any highly exothermic reactions or potentially explosive reactions, make sure that proper engineering controls are in place to minimize the risk of an explosion.
  - Consider discussing these overnight reactions with RMS to ensure that all possible safety measures have been taken.

6.3.11 *Laboratory hazard and Emergency notification*

The University of North Texas (UNT) requires faculty, staff, students, visitors and emergency responders to be aware of the hazards associated with specific laboratory, shop or chemical storage area before entering. The Laboratory Hazard and Emergency Notification signage helps establish a uniform process for informing individuals entering laboratories of the most significant hazards within the space. The signage does not list every possible hazard associated with a laboratory, shop or chemical storage area. The emergency contact information provided are the possible ways of contacting the principal investigator, laboratory supervisor and technicians.

7 PHYSICAL HAZARDS

There are also numerous physical hazards encountered by laboratory personnel on a regular basis. As with chemical hazards, having good awareness of these hazards, good preplanning, use of personal protective equipment and following basic safety rules can go a long way in preventing incidents involving physical hazards.

7.1 Compressed gases

Compressed gas cylinders may present both physical and health hazards. Gases may be oxidizers, flammable, reactive, corrosive, or toxic and these properties must be considered when developing experimental procedures and designing apparatus. Compressed gases, when handled incorrectly, can be very dangerous with a high potential for explosion. Only cylinders designed, constructed, tested, and maintained in accordance with US Department of Transpiration (DOT) specifications and regulations shall be permitted.

OSHA's general requirements for compressed gas cylinders can be found in 29 CFR 1910.101, which incorporates by reference the Compressed Gas Association's Pamphlets C-6-1968, C-8-1962, and P-1-1965. These pamphlets describe the procedures for inspecting, handling, storing, and using compressed gas cylinders. The National Fire Protection Association also provides guidance on the management of cylinders in NFPA 55: Compressed Gases and Cryogenic Fluids Code, which is incorporated by reference into the Uniform Fire Code. Safety procedures that must be followed when handling, storing, and transporting compressed gas cylinders are summarized below:

a. Cylinders must be clearly labeled with their contents.
b. Regulators must be compatible with the cylinder contents and valve.

c. Cylinders must be secured in an upright position by corralling them and securing them to a cart, framework, or other fixed object by use of a restraint.
d. Cylinders must be stored in a cool, well-ventilated area away from ignition and/or heat sources.
e. When not in use, cylinders must always be capped.
f. Cylinder carts must be used to transport cylinders, and cylinders must be capped and properly secured during transport.
g. Cylinders containing flammable gases must not be stored near oxidizers (minimum 20 ft. separation).
h. Cylinders must not be stored near corrosives.
i. Cylinders must be stored away from doors and exits.

All cylinders (new, used, or empty) must be secured at all times. Chains or belts must be used with properly tightened clamps or wall mounts to secure cylinders that are not otherwise secured on carts, or in cylinder cages. Restraints must be kept tight at all times, with no appreciable amount of slack. Do not store gas cylinders in the hallway.

Although cryogenic liquefied gases (e.g. liquid nitrogen) are generally not stored under pressure, laboratory personnel must become familiar with the special hazards associated with the use of these gases.

7.2 Electrical Hazards

There are inherent dangers involved when using any electrical equipment and therefore care must be exercised when operating and especially when installing, modifying, and/or repairing any electrical equipment. Electrical shock - the passage of current through the human body - is the major electrical hazard. The diverse types of electrical equipment used in the chemistry department includes lasers, power supplies, electrophoresis apparatus, electrochemical set ups, X-ray equipment, hot plates and heating mantles. Work involving any of these various classes of equipment can lead to serious injuries if prudent electrical practices are not followed. In order to ensure the safe operation of electrical equipment, all electrical equipment must be installed and maintained in accordance with the provisions of the National Electric Code (NEC) of the National Fire Protection Agency.

Modifications and repairs to the receptacle and wiring in the walls are the responsibility of Facilities Services and should not be attempted or carried out by anyone else. Also, it is strongly advised that all work on electrical equipment be carried out by qualified personnel. Before attempting any minor repairs, modifications, or installations of electrical equipment, it is required that the equipment be deenergized and all capacitors safely discharged. Furthermore, this deenergized and/or discharged condition must be verified before proceeding.

When dealing electrical hazards, remember the following:

- Proper Wiring: The installation, replacement, modification, repair or rehabilitation of any part of any electrical installation must be in compliance with NEC standards, which specify the proper wiring. For any piece of electrical equipment, there must be a switch in a convenient and readily accessible location that will disconnect the main power source to the apparatus in the event of an emergency. Temporary wiring should only be used when absolutely necessary and must be replaced with permanent wiring as soon as possible. Temporary wiring must also comply with NEC codes. Extension cords must be used only as temporary wiring for portable equipment. For permanent equipment, permanent wiring should be installed.
- Grounding: All equipment should be grounded and fused in accordance with NEC codes.
- Insulation: All electrical equipment should be properly insulated. Any power cords that are frayed should be replaced and any exposed hot wires should be insulated to prevent the danger of electrical shock due to accidental contact. When working with high voltage equipment, properly rated gloves and matting for electrical protection should be used.
- Isolation: All electrical equipment or apparatus that may require frequent attention must be capable of being completely isolated electrically. All power supplies must be enclosed in a manner that makes accidental contact with power circuits impossible. In every experimental setup, an enclosure should be provided to protect against accidental contact with electrical circuits. This applies to temporary arrangements as well.
- When installing, replacing, modifying, repairing, or rehabilitating any part of any electrical installation it is considered prudent practice to be with a person trained in CPR who can provide CPR if needed in case of an accidental electrical shock.

7.3 Trip Hazards

Many workers are injured annually due to falls on walking and working surfaces. These injuries account for a significant percentage of lost-time injuries. Not only are trips an economical loss, they also account for a lot of pain and suffering and sometimes even death. It is important to understand how trips happen, how to identify hazards, and how to eliminate or minimize these hazards.

Trips occur when your foot strikes or hits an object which causes you to lose your balance. Common causes of tripping are:

- Clutter on the floor (e.g., power cords, boxes).
- Poor lighting.
- Uneven walking surfaces (e.g., carpeting, steps, thresholds).
- Sudden change in slip resistance properties of walking

surfaces (e.g., wet floor or stepping from tiled to thick pile carpeted floors)

Good housekeeping is very important when working to prevent falls due to slips and trips. Good housekeeping includes:

- Clean up any spills immediately and investigate its cause to prevent reoccurrence.
- Immediately correct any hazard that might cause a fall or report it to a supervisor.
- Keep walkways and floors clear of boxes, extension cords and litter.
- Sweep debris from floors.
- Mark any temporarily made wet areas with signs or limit pedestrian access.
- Secure mats, rugs, and carpets to prevent slippage and overlaps.
- Make sure to always close file cabinet or storage drawers.
- Cover cables that cross over walkways.
- Keep walkways and work areas well-lit for good visibility.

7.4 Pressure and vacuum devices

Pressurized and vacuum operations should never be carried out in, nor heat applied to, an apparatus that is a closed system unless it is designed to withstand the pressure that may be created. Pressurized apparatus shall have an appropriate pressure relief device. When using pressure devices such as autoclaves, some general safety guidelines to follow:

- Any individual that operates the autoclaves must successfully complete a lab-specific or RMS given training on safe operating procedures for autoclaves.
- **Do NOT autoclave any chemicals.**
- Read the owner’s manual before using the autoclave for the first time.
- Operating instructions should be posted near the autoclave.

- Follow the manufacturer's directions for loading the autoclave.
- Do not overload the autoclave compartment and allow for enough space between items for the steam to circulate.
- Be sure to close and latch the autoclave door.
- Be aware that liquids, especially in large quantities, can be superheated when the autoclave is opened. Jarring them may cause sudden boiling, and result in burns.
- At the end of the run, open the autoclave slowly: first open the door only a crack to let any steam escape slowly for several minutes, and then open all the way. Opening the door suddenly can scald a bare hand, arm, or face.
- Large flasks or bottles of liquid removed immediately from the autoclave can cause serious burns by scalding if they break in your hands. Immediately transfer hot items with liquid to a cart; never carry in your hands.
- Wear appropriate PPE, including eye protection and insulating heat-resistant gloves.

When using glass under vacuum, some general guidelines to follow:

- Inspect glassware that will be used for reduced pressure to make sure there are no defects such as chips or cracks that may compromise its integrity.
- Only glassware that is approved for low pressure should be used. Never use a flat bottom flask (unless it is a heavy walled filter flask) or other thin-walled flask that are not appropriate to handle low pressure.
- Use a shield between the user and any glass under vacuum or wrap the glass with tape to contain any glass in the event of an implosion.

7.5 Cryogens

Cryogens are substances used to produce very low temperatures [below -153°C (-243°F)], such as liquid nitrogen which has a boiling point of -196°C (-321°F), that are commonly used in laboratories. Although not a cryogen, solid carbon dioxide or dry ice which converts directly to carbon dioxide gas at -78°C (-109°F) is also often used in laboratories. Cryogens, as well as dry ice, can be hazardous to workers if not handled properly.

General precautions when working with liquid nitrogen or dry ice:

- Avoid eye or skin contact with these substances and never handle dry ice or liquid nitrogen with bare hands.
- Use cryogenic gloves, which are designed specifically for working in freezers below -80°C and for handling containers or vials stored in these freezers.
- Cryogenic gloves need to be loose-fitting so that they can be readily removed if liquid nitrogen splashes into them or a piece of dry ice falls into them.
- Always use appropriate eye protection.
- Do not use or store dry ice or liquid nitrogen in confined areas, walk-in refrigerators, environmental chambers or rooms without ventilation. A leak in such an area could cause an oxygen-deficient atmosphere.
- Never place a cryogen on tile or laminated counters because the adhesive will be destroyed.
- Never store a cryogen in a sealed, airtight container at a temperature above the boiling point of the cryogen; the pressure resulting from the production of gaseous carbon dioxide or nitrogen may lead to an explosion.
- In case of exposure to cryogens or dry ice, remove any clothing that is not frozen to the skin. Do NOT rub frozen body parts because tissue damage may result. Place the affected part of the body in a warm water bath (not above 40°C or 104°F). Never use dry heat. Obtain medical assistance as soon as possible.

7.6 High Temperature Applications

High temperature devices in a laboratory, such as furnaces and ovens, present heat hazards due to their elevated temperatures.

Some simple guidelines can be followed to prevent heat related injuries. These guidelines include:

- Heating devices should be set up on a sturdy fixture and away from any ignitable materials (such as flammable solvents, paper products and other combustibles). Do not leave open flames (from Bunsen burners) unattended.
- Heating devices should not be installed near drench showers or other water spraying apparatus due to electrical shock concerns and potential splattering of hot water.
- Heating devices should have a backup power cutoff or temperature controllers to prevent overheating. If a backup controller is used, an alarm should notify the user that the main controller has failed.
- Provisions should be included in processes to make sure reaction temperatures do not cause violent reactions and a means to cool the dangerous reactions should be available.

- Post signs to warn people of the heat hazard to prevent burns.
- Heating flammables should only be done with a heating mantle or steam bath.
- Heating baths should be durable and set up with firm support. Since combustible liquids are often used in heat baths, the thermostat should be set so the temperature never rises above the flash point of the liquid. Check the SDS for the chemical to determine the flashpoint. Compare that flashpoint with the expected temperature of the reaction to gauge risk of starting a fire.

7.7 Ergonomics

Laboratories provide many opportunities for ergonomic stressors to manifest into injuries or repetitive stress disorders. Major ergonomic issues in the laboratory setting includes static and/or awkward postures and repetitive motions. Use the listed tips to learn a bit more about how to mitigate these stressors. Although the essential job tasks probably cannot change, you can develop important personal strategies that can improve comfort and health.

- If you stand at your workstation, wear comfortable shoes such as sneakers and consider using an anti-fatigue mat. If you are seated, a highly adjustable chair or stool is recommended. Sit against the back of your chair. If your feet come off the ground, lower the chair, adjust the foot ring, or get a footrest.
- Keep frequently used items within close reach. Most frequently used items should be at approximately a forearm's reach away, with lesser-used items up to arm's reach away. Items you are currently working with should be directly in front of the body.
- Adjust the position of your work, your work surface, or your chair or stool so that you can work effectively while maintaining an upright, supported position. Avoid hunching over your work. For precision work, the work surface can be adjusted higher to provide support and reduce bending and hunching. Regular light work generally places the work surface around elbow height or just below. Heavy work places the work surface approximately six inches below elbow height.
- Try to work at a bench cut out with adequate knee clearance. If you are seated, you need room for your legs. If you are standing, a foot rail or foot prop is recommended to encourage and aid shifting positions throughout the workday. Propping a foot up relieves pressure on the back.
- Keep shoulders, arms and hands relaxed and elbows close to the sides while working.

- Try to keep the wrists neutral and aligned while working. Sitting close to your work will help with this.
- Use the lightest pressure possible to use your equipment (e.g. pipettes). Use electronic, automated, or light touch model equipment when possible.
- Remember to take frequent rest breaks.
    - Use the 20/20/20 rule when working in front of a screen – 20 minutes spent looking at a screen, take a break and look at something 20 feet away for 20 seconds.
- Alternate your grip on items like forceps. Vary your tasks.
- Ensure proper lighting for your task.

Tips for the microscope task:

- Ensure that you can view the eyepiece while sitting or standing in an upright position. This includes the shoulders, back and neck. Accomplish this by adjusting your chair (if applicable), the work surface, and/or the microscope eyepiece. An angle stand or extendable eye tube may be available to aid in adjustment.
- Bring the microscope as close to you as possible (this usually means it is pulled to the edge of the workbench).
- Arms should be supported and relaxed while using the microscope with the elbows close to the sides. Wrists should be in a neutral position while making adjustments.
- Keep scopes repaired and clean for easier use.

Tips for the pipetting task:

- Where possible, use electronic, light-touch, or latch mode pipettes for intensive pipetting. Multiple finger (as opposed to thumb-only) pipette designs are preferred. Use the lightest touch possible while pipetting and changing tips.
- Work supplies such as trays and beakers should be placed within easy reach and with no obstructions to their access. Keep work in front of the body to minimize twisting and awkward reaching.
- Strive for straight and neutral wrist position while working.
- Try alternating hands or using both hands to pipet.
- Use low profile tubes, containers, and receptacles to avoid bending and twisting of the wrists, neck, and rolled shoulders.

- Avoid working with winged elbows/arms. Keep arms relaxed and elbows close to the body. Ensure that your work surface is at the appropriate height (see general tips, above).
- Keep head and shoulders in an upright, neutral position.

Tips for hoods and biological safety cabinets:
- Keep arms relaxed and by the sides. Back, shoulders and neck should be upright and neutral in position.
- Keep the sash clean and free of glare so that you can see without tilting your neck or assuming an awkward position. Use diffused lighting to limit glare.
- Use low profile tubes, containers, and receptacles to avoid bending and twisting of the wrists, neck, and rolled shoulders.
- Keep the work area clean and free of clutter. Keep what you are working on directly in front of you, with frequently accessed items within forearm length and lesser-used items at arm's length. Remove unnecessary supplies.
- Perform all work 6 inches inside the hood.
- Strive to keep wrists straight and neutral while working.
- Avoid contact pressure (forearm and wrists in contact with sharp edges). Foam padding may be used on the front sharp edge of the hood and biological safety cabinet.

7.8 Nanomaterials and Related Inhalation Hazards

Nanomaterials are any solid materials with at least one dimension (length, width, or depth) between one and 100 nanometers (nm). Nanomaterials can exhibit unique physical and chemical properties not seen in larger molecules of the same composition. Substantial investments are flowing into the exploration and development of products that can take advantage of the unique properties of nanomaterials. Researchers must consider the potential health, safety, and environmental risks that might result during this research and development boom caused by the promise of nanotechnology.

Nanomaterials divide roughly into two main categories: ambient (or "natural") nanoparticles, and engineered/manufactured nanomaterials. Ambient nanoparticles are also known as "ultrafine" particles in standard industrial hygiene terminology. Sources include diesel engine exhaust, welding fumes, and other combustion processes. Most grinding and crushing processes are incapable of producing nanoparticles, unless fine bead mills are used. Ultrafine/nanoparticles have a larger surface area per unit volume than an equal volume of same composition larger particles. This can lead to different physical, chemical, and biological response properties. Engineered or manufactured nanomaterials are deliberately created and used for a structural/functional purpose. Engineered nanomaterials can include both homogeneous materials and heterogeneous structures with specific applications in computing, medicine, and other disciplines. Examples of engineered nanomaterials include: carbon buckyballs or fullerenes; carbon nanotubes; metal oxide nanoparticles (e.g., titanium dioxide); and quantum dots, among many others.

Nanomaterials have a larger surface area to volume ratio compared to larger materials of the same composition. Nanomaterials, like many other solids, can have biological impacts based on their structure. Inhalation is the most likely exposure route in laboratory settings, and the most extensive health effects studies have involved the inhalation route.

As with all potential exposures, the best place to start is the OSHA "hierarchy of controls", which goes from engineering controls to work practice controls to personal protective equipment. Engineering controls always come first, since they have the potential to remove the exposure from the work area.

Engineering Controls:

- Work with nanomaterials in ventilated enclosures (e.g., glove box, laboratory hood, process chamber) equipped with high-efficiency particulate air (HEPA) filters.
- Where operations cannot be enclosed, provide local exhaust ventilation (e.g., capture hood, enclosing hood) equipped with HEPA filters and designed to capture the contaminant at the point of generation or release.

Work Practice Controls:

- Provide handwashing facilities and information that encourages the use of good hygiene practices.
- Establish procedures to address cleanup of nanomaterial spills and decontamination of surfaces to minimize worker exposure. For example, prohibit dry sweeping or use of compressed air for cleanup of dusts containing nanomaterials, use wet wiping and vacuum cleaners equipped with HEPA filters.

Personal Protective Equipment:

- Provide workers with appropriate personal protective equipment such as respirators, gloves and protective clothing.
- HEPA filtration systems on ventilation systems could remove more than 99.97% of airborne nanomaterials. Similarly, properly fitted elastomeric respirators with HEPA cartridges should be able to prevent respirable exposure to airborne nanomaterials.

All nanomaterial waste should be handled as chemical waste. Contaminated solid waste (paper, gloves, wipes, tips) should be collected and submitted using the online chemical waste pick-up form available on the RMS website.

8 EMERGENCIES AND EXPOSURES

Emergencies can occur at any time, without warning. Careful planning, with an emphasis on safety, can help members of the UNT community handle crises and emergencies with appropriate responses, and could save lives. Every member of the UNT community shares responsibility for emergency preparedness. Unit heads are responsible for ensuring that their units have emergency plans in place, and that all persons – including faculty, staff, and students – are familiar with those emergency plans. Unit heads are also responsible for assigning emergency preparedness and response duties to appropriate staff members.

For OSHA, an "incident" is a workplace event that results in:

- Death
- In-patient hospitalization
- Amputation
- Loss of an eye
- Injuries and illnesses severe enough to cause:
- Days away from work, restricted work, or transfer to another job (even temporarily)
- Medical treatment beyond first aid
- Loss of consciousness
- Some other diagnoses of significant injury or illness by a licensed health care professional

A near-miss is defined as a potential hazard or incident in which no property was damaged, and no personal injury was sustained, but where, given a slight shift in time or position, damage or injury easily could have occurred.

8.1 Emergency Operation Plan

The University has prepared and has made available to appropriate persons an Emergency Operation Plan. Details of the plan may be found here.

8.2 Emergency Response Equipment

All laboratories using hazardous chemicals must have immediate access to emergency response equipment such as safety showers, eyewash stations, first aid kits, spill kits, and fire extinguishers. *ALL Safety Equipment should be clearly marked in the lab. All aisles and surrounding area of the safety equipment must be kept clear at ALL times.*

8.2.1 *Eyewashes*

Eyewash stations are necessary safety equipment utilized in the event of exposure to your eyes or face. An eyewash station is activated by pushing a handle (eyewash station designs can vary). Eyewash stations are required to have a minimum flow rate of 0.4 gallons per minute. The eyewash station should have a controlled flow to both eyes simultaneously at a velocity low enough to be non-injurious. The eyewash station will remain on until intentionally turned off. The water should be at a tepid temperature (above 60 °F (16 °C) and below 100 °F (38 °C)). To turn off the eyewash station, push the lever back into its original position to stop water flow. In the event of an exposure to your eyes or face, flush the area or your eyes for 15 minutes. Avoid placing electrical equipment near the eyewash station. Annual inspections and testing are completed by RMS. This inspection evaluates the basic mechanical functionality of each station. Any deficiencies are repaired by UNT facilities maintenance staff.

Any areas that store or use hazardous materials (especially corrosive materials), are required to have an eyewash station. If an eyewash station is NOT present in your laboratory or an area where chemicals are used, notify RMS immediately. Eyewash stations should be accessible within 10 feet of unimpeded travel distance from the corrosive material hazard.

Laboratory personnel are responsible for monthly activations of all eyewash stations in their laboratory or area. This will keep the system free of sediment and prevent bacterial growth from reducing performance. If an eyewash is not functioning properly (i.e., water velocity is too high or too low, temperature is too cold or too hot, not turning on) please contact facilities and submit a work order.

If lab personnel get a hazardous chemical splashed onto their face or eyes, activate the eyewash station for 15 minutes or until emergency response have personnel arrive and begin treatment. Have someone around call 911, or if you are by yourself, call 911.

- It is important to NOT work alone, as in situations such as splashing a chemical into your eyes – it will be very difficult to navigate and locate an eyewash station while temporarily blinded.
- When using an eyewash station, hold your eyes open in the water for 15 minutes while rolling your eyes around (make sure your hands are clean and you have removed contaminated gloves).
- If you have contacts, rinse your eyes for a few minutes before taking the contacts out and then go back to rinsing your eyes for an additional 15 minutes.
    - If someone else is in the lab with you, have them set a timer for 15 minutes.
    - If possible and can use voice activation with a cell phone and you are alone, try to set a timer for 15 minutes.

8.2.2 *Safety showers*

Safety showers are necessary safety equipment utilized in the event of a larger scale exposure. A safety shower is activated by pulling down on the handle (safety shower designs can vary). Approximately 20 gallons of water per minute comes out of the safety shower when activated. The safety shower will remain on until intentionally turned off. To turn off the safety shower, push the lever back into its original position to stop water flow. The water should be at a tepid temperature (above 60 °F (16 °C) and below 100 °F (38 °C)). In the event of an exposure and your clothing is contaminated with chemicals, remove them, and activate the safety shower and flush the area that was exposed for 15 minutes. Avoid placing electrical equipment near the safety shower. Annual inspections and testing are completed by RMS. This inspection evaluates the basic mechanical functionality of each station. Any deficiencies are repaired either by RMS staff or by UNT facilities maintenance staff.

Any areas that store or use hazardous materials (especially corrosive materials) are required to have a safety shower. If a safety shower is NOT present in your laboratory or an area where chemicals are used, notify RMS immediately. Safety showers should be located within 10 seconds or 55 feet of unimpeded travel distance from the hazard.

If lab personnel are exposed to a hazardous chemical, use the safety shower for 15 minutes or until emergency response have personnel arrive and begin treatment. Have someone around call 911, or if you are by yourself, call 911. Remember to remove all contaminated clothing from the area exposed to the hazardous chemical. Others in the lab should evacuate to allow for privacy. During this time, others in the lab can help by calling 911 and directing the emergency personnel to the lab or area, alerting the PI or supervisor, and alerting RMS to the incident.

8.2.3 *Fire extinguishers*

A fire extinguisher must be present in or near each laboratory area. The extinguisher must be appropriate for the classes of fires possible in a particular laboratory. Each fire extinguisher on campus is inspected on an annual basis by the Facilities Services. If you or your laboratory would like to be trained to use a fire extinguisher, please contact RMS.

When working with flammable substances (or water-reactive or pyrophoric materials that can easily ignite), consider the proper control measures to work with these substances safely including but not limited to, wearing a fire resistant/chemical resistant lab coat, using fire resistant gloves, working in an inert atmosphere glovebox with pyrophoric or water reactive materials, and being trained on using a fire extinguisher.

In all cases, if you or your lab is faced with a fire (no matter the size), if you feel uncomfortable handling it – evacuate the lab, pull the fire alarm, and call 911 and RMS.

It is required for all labs to have a fire extinguisher, five lbs., dry chemical type (at least 10BC rating) suitable for class ABC fires except in areas containing machinery with integrated circuits. Placement should be at the exit of each room, or as required permanently attached to a wall, cupboard or similar. There should be approximately one extinguisher located every 30 feet with discretion used in sharing between one or more rooms. Please refer to 29 CFR 1910.157 and/or Fire Prevention Code regulations to verify compliance with requirements. Area around the fire extinguisher should be kept clear of all items and the fire extinguisher should be clearly marked.

If the lab works with combustible metals or metal alloys, it is required to have a Class D fire extinguisher. Class ABC cannot be used for combustible metal fires. All laboratory personnel should be familiar with the location, use, and classification of the extinguishers in their laboratory.

Table 8.A	
Classification	**Fire Type**
Class A	Ordinary fire (wood and paper)
Class B	Flammable liquids and gases
Class C	Electric fire
Class D	Combustible metal fire
Class K	Kitchen fire

Class D fire extinguishers can be quite large and heavy, consider acquiring a cart for Class D fire extinguisher so that lab personnel can use one with ease.

Some other safety equipment that your lab might have:

- Fire blankets – if your lab has a fire blanket, consider utilizing the stop, drop, and roll method prior to using a fire blanket. NEVER use a fire blanket if not trained to do so. NEVER wrap someone in a fire blanket while they are standing, this can create a 'chimney like' effect and draw more in air while pushing the flames higher on the body.
- Safety cans - flammable chemicals > 4 gallons should be kept in UL approved safety containers having a spring loaded cap and a flame arrester.
- Safety Pumps - must be used when dispensing from containers larger than five gallons.
    - NOTE: Safety pumps with flame arrestors are required when dispensing flammable materials from a metal container to a metal container.

8.2.4 *Spill Kits*

Each laboratory should have a spill response kit available for use. Lab spill kits can either be purchased from a vendor or created by lab personnel. The spill kit needs to accommodate the largest container of each type of hazard present, and be appropriate for the specific hazards present in the lab, such as acids, bases and solvents.

All labs should have a general spill kit inside of the lab. A general spill kit includes:

- Small broom and dustpan (scoop)
- Trash bag (30 gal, 3 mil) or bucket
- Gloves
- Universal spill absorbent
- 1:1:1 ratio of unscented kitty litter, sodium bicarbonate, and sand
- Can also purchase a commercial version

A corrosive spill kit (either for acids or bases) will also include:

- Heavy neoprene gloves
- Sodium Bicarbonate (for acid spills)
- Sodium Bisulfate (for base spills)

A mercury spill kit will also include:

- Absorbent sponges
- Mercury Absorb Powder
- Pump
- Scoop
- Gloves
- Safety glasses
- Baggies
- Labels

A hydrofluoric acid spill kit will also include:

- Polyethylene container

- Calcium carbonate
- Calcium gluconate gel (2.5%) to treat possible exposure

In all cases, if a spill kit is used, all contents should be treated as hazardous material and disposed as hazardous waste. If a spill occurs and a spill kit is used, please contact RMS, report the spill incident, and submit for a hazardous waste request pick-up for all of the contents used in the spill kit. For more information about spills: see Guide for Chemical Spill Response.

8.2.5 *First Aid Kits*

All labs should have a first aid kit in the lab that is easily accessible. First aid kits should include (OSHA 1910.266):

- Gauze pads (at least 4 x 4 inches).
- Two large gauze pads (at least 8 x 10 inches).
- Box adhesive bandages (band-aids).
- One package gauze roller bandage at least 2 inches wide.
- Two triangular bandages.
- Wound cleaning agent such as sealed moistened towelettes.
- Scissors.
- At least one blanket.
- Tweezers.
- Adhesive tape.
- Latex gloves.
- Resuscitation equipment such as resuscitation bag, airway, or pocket mask.
- Two elastic wraps.
- Splint.
- Directions for requesting emergency assistance.

A first aid kit should be available for each separated room for the lab if the lab has multiple rooms or spaces.

8.3 Emergency Response Guide for Laboratories

Each lab should consider the types of incidents that could have an adverse effect on people, research efforts, property, and/or the environment. Planning efforts should be aimed at mitigating the impact of the emergency (for example, arranging for critical laboratory equipment to be maintained on emergency power) and should consider the necessary response for each situation. See Appendix I for UNT Laboratories Emergency Readiness for a guide on power outages, loss of heat, and long breaks or temporary lab closures. It is best to be trained in all types of situations. See https://emergency.unt.edu/personal-preparedness for the types of emergency preparedness trainings that UNT offers. **ALL laboratories and teaching laboratories should have written designated response procedures for all possible emergencies.**

In the laboratory, chemical-related incidents require local emergency response that may involve requesting assistance, local clean up, and incident reporting. For guidance on proper response to various emergencies, see below.

8.3.1 *Life Threatening Emergencies*

- Life Threatening Emergencies - fire, explosion, serious injury/exposure.
  - If fire:
    a. CALL 911
    b. Alert people in the vicinity, activate local alarm systems.
    c. Evacuate the area.
    d. Remain nearby to advise emergency responders.
    e. Once personal safety is established, call RMS at 940-565-2109 and notify the PI or Laboratory Supervisor.

  - If Personnel Exposed:
    a. Remove exposed/contaminated individual from area, unless unsafe to do so because of (a) medical condition of victim, or (b) potential hazard to rescuer.
    b. In all instances, immediately notify Police 911 if immediate medical attention is required.
    c. Administer First Aid as appropriate.
    d. Flush contamination from eyes/skin using the nearest emergency eyewash /shower for a minimum of 15 minutes. Remove any contaminated clothing.

e. Take copy of SDS of chemical to hospital with victim.
f. Notify RMS to report the incident and notify the PI or Laboratory Supervisor.

8.3.2 *Non-life-Threatening Emergencies*

a. Non-life-threatening injuries to personnel (small cut, burns, etc)
    - Notify PI or supervisor and if able to and comfortable with it, perform first aid.
    - Seek medical attention afterwards.
    - Notify RMS at 940-565-2109.
b. Non-life-threatening incidents (i.e., no injury only property damage) or near misses.

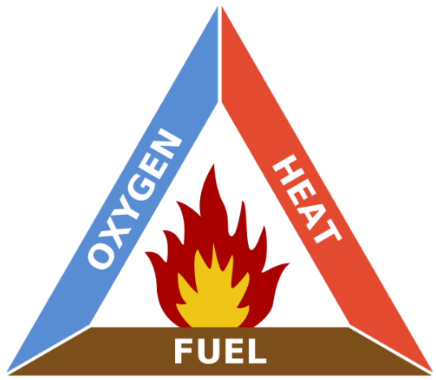
8.3.3 *Fires*

Minor Fires

Minor fires are small fires that do not pose an immediate risk to the health and/or physical safety of those in the immediate area and do not involve human contamination. Minor fire can be handled by laboratory personnel if they feel comfortable doing so.

Prior to working with flammable materials, review the SDS. When working with flammable materials, remove all unnecessary equipment, oxidizers, and other chemicals that can exacerbate a fire in the event of one. If a smaller fire does become larger or out of control, please see Major Fires below for more information.

A minor fire can be handled in multiple ways if it is small enough. Utilize the fire triangle to determine the best method to put out the fire.



The fire triangle depicts the three elements a fire needs to ignite: heat, fuel, oxygen (oxidizing agent). If you are able to do so, removing one or more of the three elements will extinguisher a fire. The easiest two to remove are usually oxygen or oxidizing agent and heat.

Minor fire response procedure:

Consider the scenario, a 25mL beaker with 5mL of ethanol accidentally catches fire.

1) Cover the beaker with a large watch glass or another larger beaker carefully. This will stifle the fire and the fire will slowly go out as the oxygen is burned off. Watch this video for a demonstration.

While attempting to cover the beaker, you have accidentally knocked the beaker over and the fire has now spread to the bench top.

1) If you have sand nearby, this can be used to put out the fire. Sand works like other extinguishing materials by absorbing heat and suffocating the fire by cutting down the oxygen supply.
2) If you have liquid nitrogen nearby, this can also be utilized to put out the fire. Liquid nitrogen will remove the heat from the fire and effectively put out the fire. Note that this should only be used if there is nothing else in the area, liquid nitrogen will freeze the surrounding area and can damage equipment. The initial pouring of the liquid can also knock over other items in the area.
3) Use the ABC fire extinguisher near the exit. Watch this video for a demonstration on the proper use of a fire extinguisher.

If you do not feel 100% comfortable handling a fire, even if it is small, please see the information below for major fires on what to do and how to evacuate.

Once a fire has been put out, call RMS at 940-565-2109 to report the fire, and notify your PI or Laboratory Supervisor.

Major Fires (Emergency)

Major fires are fires that meet these criteria:

1) There is a potential for explosion.
2) The fire poses an immediate danger to life.
3) There is a spill.
4) There are injuries requiring medical attention.
5) You do not know how to or feel comfortable putting out a fire.

Major fire response procedure:

- Stop work, (if possible) turn off any ignition sources, alert others in the immediate area and get away and close lab doors, and evacuate building by pulling fire alarm.
    - If fire is in a fume hood and able to, close fume hood sash.
- Call 911 and describe the details of the incident (chemicals involved, injuries, and any other pertinent information).

If an injury or personal exposure has occurred perform the above and the following as appropriate:

- Move injured persons away from danger zone if you can do so without personal risk.

- Remove any contaminated clothing and flush affected areas with copious amounts of water from a safety shower or eye wash station for at least 15 minutes.
    - If the person is on fire, have them stop, drop, and roll OR stand under the safety shower to extinguisher the fire.
        - If there is a fire blanket nearby and you are TRAINED to use a fire blanket, use one on the person. Never use a fire blanket on someone standing up as this could funnel flames towards their face and head.
- Administer first aid and call 911.
- Notify RMS, your PI or Laboratory Supervisor

8.3.4 *Spills*

Major Spill (Emergency)

Major spills are spills that meet these criteria:

- There is fire or potential for explosion.
- The spill poses an immediate danger to life.
- The spill is greater than 1L
- There are injuries requiring medical attention.
- You do not know the properties of the spilled material.

Major Spill response procedure:

- Stop work, turn off any ignition sources, get away and close lab doors, and evacuate building by pulling fire alarm.
- Call 911 and describe the details of the incident (chemicals involved, injuries, and any other pertinent information).

If an injury or personal exposure has occurred perform the above and the following as appropriate:

- Move injured persons away from danger zone if you can do so without personal risk.
- Remove any contaminated clothing and flush affected areas with copious amounts of water from a safety shower or eye wash station for at least 15 minutes.
- Administer first aid and call 911.

Always notify RMS and your PI or Laboratory Supervisor after following these steps.

Minor Spill (Non-emergency)

Minor spills are spills that involve small volume spill and do not pose an immediate risk to the health and/or physical safety of those in the immediate area and do not involve human contamination. Minor spills can be cleaned up by laboratory personnel if they feel comfortable doing so.

a. Notify personnel in the area and restrict access. Eliminate all sources of ignition.
b. Review the SDS for the spilled material, or use your knowledge of the hazards of the material to determine the appropriate level of protection.
c. Wear gloves and protective eyewear. Clean up using absorbent. Put the contaminated absorbent in a labeled hazardous waste container.
d. If greater than 100 ml, or if it will take longer than 15 minutes for you to clean-up (or a major health or fire hazard), immediately call RMS at 940-565-2109 to report the spill, and notify your PI or Laboratory Supervisor.

Spill response procedure:

- Alert all persons nearby.
- Turn off any heat sources and isolate spill area by closing lab door.
- Open fume hoods in the lab if possible.
- Look at SDS to determine PPE needed for cleanup, then put it on.
- Clean up and contain the chemical as described in SDS, avoid inhaling vapors.
    - Use appropriate kit to neutralize and absorb inorganic acids and bases. Sweep into suitable waste container.
    - Clean spill area with water. Be sure all cleanup tools have been decontaminated.
- Contact RMS for disposal.

Spill Report

Major spills require an incident investigation to be conducted by the supervisor and RMS. Minor spills must be reported in writing to RMS within one working day of the occurrence. This report must include the date, time, location, names of persons involved, material spilled and volume, as well as a detailed description of the incident and any corrective actions taken.

Note: If there is a large quantity spill, or you are not 100% sure how to clean up the spill, contact the RMS for assistance.

8.4 Incident reporting

All work-related injuries or illnesses are to be reported by the supervisor to RMS at 940-565-2109. The injured or ill employee should be present for the call so the employee's injuries or illness may be triaged and the appropriate medical care provided. In case of emergency, call 911 for immediate medical care for the injured or ill employee.

Employee's Responsibility:

- When an incident occurs, the employee must report all injuries or illnesses to his/her supervisor immediately.

PI or Laboratory Supervisor's Responsibility:

- Call RMS at 940-565-2109 to report the injury or illness.
- Reporting of incidents to RMS should be clear and concise, including the following information:
    - Nature of the incident
    - Hazardous material involved
    - Nature of any injuries
    - Location
    - Name of the caller
    - Phone number where caller can be reached
- Within 24 hours, complete the incident report.
- Take prompt action to correct any safety hazards.

Students must report incidents, injuries, and illnesses that occur in laboratories to the appropriately responsible person (i.e., Teaching Assistant, Lab Supervisor, and PI). The responsible person should report the incident to RMS.

8.5 Medical consultations and evaluations

Lab personnel are eligible for medical consultation if they perform work related tasks that might be reasonably anticipated to cause occupational exposure to a potential hazard. Medical evaluations shall be performed by or under the direct supervision of a licensed physician, at a reasonable time and place without cost or loss of pay to the employee. It is the responsibility of the affected Department or PI to contact RMS to arrange for such care.

An opportunity to receive medical attention, including any follow-up examinations which the examining physician determines to be necessary, shall be provided to employees under the following circumstances:

- When an employee develops signs or symptoms associated with occupational exposure to a hazardous chemical.
- When air sampling reveals exposure levels routinely above the action level, or in its absence the PEL for an OSHA regulated substance. Medical surveillance shall comply with the requirements of that particular standard.
- Medical consultation shall be provided whenever an abnormal event such as a spill, leak or explosion takes place in the laboratory. Its purpose shall be to determine whether subsequent medical examination is necessary.

9 ORDER HAZARDS

9.1 Pesticides

Most pesticide incidents result from careless practices or lack of knowledge about safe handling of pesticides. The time employees spend reading the pesticide label will enable them to learn safe pesticide management procedures. Taking time to use pesticides properly is an investment in the health and safety of the employee, his or her family, and others.

The application of pesticides must follow the strict instructions on the container label. Personnel using pesticides shall use only those pesticides that have been registered by the EPA. Being familiar with the EPA-registered product label is the key to safe handling of pesticides.

Before choosing a pesticide, read the label to determine whether:

- The pesticide is the correct one for the job.
- The pesticide can be used safely under the application conditions.

Before mixing the pesticide, read the label and SDS to determine:

- What protective equipment needs to be used.
- What the pesticide can be mixed with (compatibility).
- How much pesticide to use.
- The mixing procedure. To reduce pesticide overuse and waste, always adhere to the mixing ratio on the label.

Before applying the pesticide, read the label to determine:

- What safety measures are to be followed.
- Where the pesticide can be used (livestock, crops, structures, etc.).
- How to apply the pesticide.
- Whether there are any restrictions for use of the pesticide.

Before storing or disposing of the pesticide or pesticide container, read the label to determine:

- Where and how to store the pesticide.
- How to decontaminate and dispose of the pesticide container.
- Where to dispose of surplus pesticides.

9.2 Biohazard

Information about how Biosafety is managed at UNT can be found in the Biosafety Manual.

9.3 Radiation Hazard

Information about how Radiation safety is managed at UNT can be found in the Radiation Safety Manual.

9.4 Laser Hazard

Information about how Laser safety is managed at UNT can be found in the Laser Safety Manual.

10 HAZARDOUS CHEMICAL WASTE DISPOSAL

Hazardous waste is generally defined as waste that is dangerous or potentially harmful to human health and/or the environment. Hazardous waste regulations are strictly enforced by both the Environmental Protection Agency. The PI and/or Laboratory Supervisor is responsible for managing the hazardous waste program in a safe and compliant manner.

Nearly every entity on campus generates some type of waste requiring off-site treatment, disposal, re-use, or recycling. UNT's Environmental Health and Safety group in Risk Management goal is to ensure that each student, graduate student, faculty, and staff are aware of the proper management practices for handling, storing, and disposing of hazardous wastes generated on campus. Every individual that generates waste in their area is responsible for labeling and identifying their waste, appropriate containerization of the waste, and proper storage of waste in their area until removal can occur. **All chemical wastes should be managed as if they are hazardous.**

10.1 Hazardous waste program

University of North Texas is registered with the TCEQ as a Large Quantity Generator (LQG) of hazardous waste and therefore, strict regulations apply. Compliance with these regulations requires partnership and cooperation from all departments involved in the generation and storage of waste on campus.

- LQG's generate >2,200 lbs or ≥1,000 kg PER MONTH of hazardous waste or >2 lbs or 1 kg per month of acute hazardous wastes.
- UNT typically generates approximately 8-15 tons or more of hazardous waste in a calendar year and more than 7 tons of non-hazardous industrial wastes in a calendar year.

Laboratories that generate chemical waste or chemically contaminated lab debris must accurately identify the contents of the waste container on the hazardous waste label. This information is crucial and is required for RMS to properly classify the waste stream for proper disposal. Additional information on identifying hazardous waste and proper disposal of chemical wastes in the lab can be found in the Hazardous Waste Management Program Manual.

10.2 Hazardous Waste Storage Requirements

10.2.1 *Satellite Accumulation Areas*

When waste is generated in your classroom, lab, or work space, it is your responsibility to containerize the waste in an appropriate and compatible container and then label the waste and store it in the Satellite Accumulation Area (SAA) for removal. Every lab or area where waste is generated, with a few exceptions, must have an SAA and SAA signage, and under the control of the person/persons generating the waste. SAA rules must be followed at all times:

- Waste must be stored at or near the point of generation
  - A lab can have multiple SAAs but the location should be as close to the point of generation as possible. It is best not to transfer large quantities of waste between areas.
- For accumulations of small amounts of hazardous wastes (~4L containers or smaller), a fume hood is considered a practical location.

- For amounts greater than 4L such as a 5-gallon container or 15-gallon plastic drum, an area underneath a counter, “near” a fume-hood, and in a low traffic/low use area are also considered practical.
- Waste storage volume should not exceed 55 gallons per SAA
    - Once you notice your waste container approaching 80% (leaving room for headspace expansion), please submit a hazardous waste pick-up request.

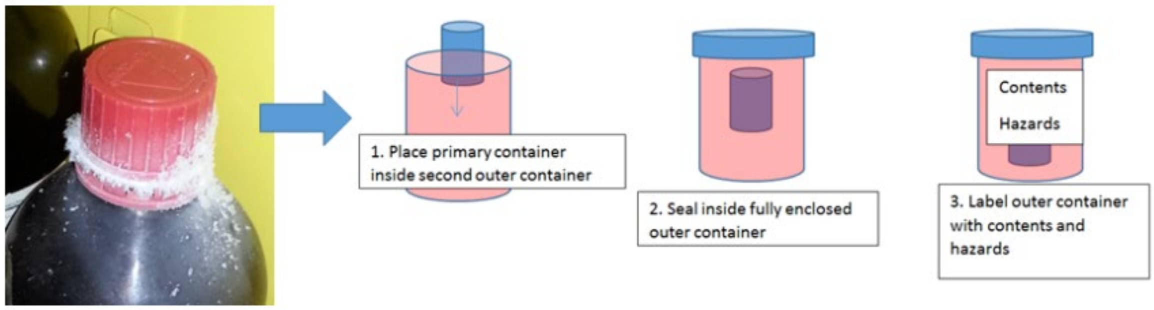
10.2.2 *Hazardous Waste Labeling*

- Containers must be properly labeled from start of generation.
    - Once accumulation of hazardous waste has started, a label must be on the container with the following information:
        - The words “Hazardous Waste,”
        - Date of START of accumulation
        - Chemical composition (all of the chemicals being added – please use full chemical names, NO abbreviations) and the volume percentage of each chemical (an approximation is okay).
        - Generating process
        - Check the hazards associated with the waste
        - Who it was labeled by (PI name is fine).
        - Department and lab phone number
        - Building and room where it is generated.

10.2.3 *Hazardous Waste Containers*

- Make sure waste is stored in a compatible container
    - Consider the type of waste, the amount of waste, and the compatibility of the waste being generated. It may be best to have a 4L glass bottle or a 20L plastic carboy.
- All containers must remain closed at all times except when adding or removing waste.
    - If you must use a funnel for the waste container, consider acquiring a safety funnel which can close and seal.
- Containers must be in good condition and not leaking.
    - If a container has a lot of chemical residues on the outside or the container begins to leak, the waste can be transferred to a container that is in good condition or

over-pack the container that is leaking into a larger, compatible container. A new label should go on the outside of the over-pack container.



- All waste should be stored in secondary containment
    - Secondary containment should be large enough that in the event of a leak or spill of the primary waste container, it should be able to hold all of the primary container contents.
- **ALL** waste containers **MUST** be segregated by chemical compatibility
- **DO NOT** put incompatible chemicals in the same waste container
    - *ALWAYS CHECK CHEMICAL COMPATIBILITY BEFORE COMBINING OR ADDING NEW OR UNFAMILIAR WASTES INTO THE CONTAINER.*
- For liquid wastes: make sure the container is clean and free of contamination, compatible for the type of waste, and has a leak proof cap.
    - Leave a headspace of about 80% to allow for expansion of vapors.
- For dry/solid wastes: make sure the container is clean, free of contamination, and properly tied/taped and sealed.
- For chemically contaminated sharps with no infectious or bio-hazardous contamination: store in a rigid (hard plastic) container with a lid or top that can be sealed with tape.

10.2.4 *Central Accumulation Areas*

Waste removed from an SAA will be moved to a Central Accumulation Area (CAA), a designated area where hazardous waste is stored by the generator until the waste is removed for disposal, treatment, and/or incineration. Depending on the type of generator, there are specific requirements associated with CAAs, such as storage requirements, storage time limits, and additional emergency response plans and training. If you would like to learn more, please contact the Environmental Program Manager.

10.3 Hazardous Waste

All chemical wastes including unwanted or expired chemical that are generated as a result of lab processes are considered hazardous wastes by the University and must be stored in the Satellite Accumulation Area (SAA) near point of generation All SAA's must be audited by the PI and/or Laboratory Supervisor weekly to ensure the following requirements are met:

- All containers must be closed except when waste is actively being added. Caps must be screwed on. If you are concerned about vapor build-up in your container, please contact RMS to discuss options.
- Waste containers must be compatible with the contents. All contents going into the same waste container must be compatible as well. See Appendix B for information on chemical compatibility.
- All wastes must be labeled with the UNT Hazardous Waste label. The contents of the container must be filled out as soon as a waste is added to the container.
- Do not accumulate more than 55-gallons of waste in your SAA. Contact RMS for pick up well before this volume is reached. Visit the RMS webpage (https://riskmanagement.unt.edu/environmental-risk/environmental/waste-management) to find the online Hazardous Material Pickup Request Form.
- Liquid wastes should be stored in secondary containment and incompatible wastes should be stored in separate secondary containment devices.
- Always ensure that you leave at least 20% of head space (80% full) in the waste container. This allows for expansion of any liquids or vapors.

10.4 Non-hazardous waste

Non-hazardous waste should be handled as:

- Sharps (e.g., such as glass or plastic pipettes, broken glass, test tubes, petri dishes, razor blades, needles) waste with no hazardous chemicals contamination must be placed into puncture resistant containers (e.g., sharps container, plastic or metal container with lid) and properly labeled.

- Clean **<u>uncontaminated</u>** broken glassware and plastic sharps should be placed in a corrugated cardboard box or other strong disposable container. When ready for disposal, the box should be taped shut and prominently labeled as “Sharp Objects/Glass – Discard” or similar wording. These are picked up by custodial and disposed with regular trash removal.
- Empty bottles are considered non-hazardous after decontamination and triple-rinsing. After decontamination and triple-rinsing, the hazard warning label shall be defaced and disposed as non-hazardous waste.
    - Triple rinsing – a chemical bottle/container that is empty but has residual chemicals (solid or liquid) should be rinsed with an appropriate solvent (generally isopropanol or acetone) into an compatible liquid chemical waste container. After **<u>ALL</u>** potential chemical residue has been rinsed into a chemical waste container, the chemical bottle/container can then be rinsed with water. This rinseate should go into the appropriate liquid chemical waste container. Afterwards, <u>TWO ADDITIONAL RINSES WITH WATER</u> should be done of the chemical bottle/container and these can be disposed down the drain. This chemical bottle/container can then be left to dry completely of all water and label should be either removed or crossed off of chemical name using a permanent marker. The chemical bottle can be used for waste or other storage – however, it must be properly labelled for this use. These bottles can also be given to RMS.

10.5 Additional Waste Types

Unknown Chemical Waste

If your lab discovers unknown chemicals or samples, please submit a hazardous waste pick-up request. Fill out the form to the best of your ability with the information about the bottle(s) or sample(s). Please label as “unknown chemicals or samples” and take a picture of them and attach it to the form.

In order to prevent unknown chemicals or samples, please make sure that all lab personnel are labeling all containers, samples, flasks, vials, etc. Use chemical names, no abbreviations or codes. All lab personnel should dispose of their samples and chemicals that will not be used when they are leaving or graduating. Please see Ch 6. Graduating Lab Personnel for more information on this topic.

Contaminated labware

Labware contaminated with hazardous chemicals is considered solid hazardous waste. Labware includes Kimwipes, paper towels, plastic pipettes, etc. These can be collected in a solid hazardous waste container, labeled with its contents, and a hazardous waste pickup request can be submitted once full.

Contaminated labware does NOT include uncontaminated containers/vials, sharps (needles or razor blades), pipette tips with no chemical residue, Kimwipes with no chemical residue, paper towels with no chemical residue, and PPE.

Compressed Gas

Compressed gas cylinders should be returned to the original manufacturer or distributer. Submit a hazardous waste pickup request for lecture bottles.

Peroxide Forming Chemical Disposal Requirements

Information on Peroxide Forming Chemicals can be found in Ch 4. If not stored properly, some solvents can form peroxides (ex: tetrahydrofuran). Submit a hazardous waste pickup request for

- If a peroxide forming chemical tests for close to or ABOVE 50 PPM, please contact RMS for disposal.
- If a peroxide forming chemical tests ABOVE 100 PPM, contact RMS immediately for assistance – do **NOT** touch or move the chemical container.
- **DO NOT MOVE CONTAINER AND CONTACT RMS IMMEDIATELY IF**
    - Crystals are visible in or on container or lid,
    - There is visible cloudiness or precipitation in container,
    - container is class A and past expiration date,
    - or class B or class C and has been unopened for more than 1 year and has not been tested

Additional Waste Streams

- Radioactive Waste (contact the Radiation Safety Officer)
- Biohazardous Waste (contact the Biosafety Officer)

- Any broken glass waste should go into broken glass cardboard containers. Contaminated glassware (like vials) should be clean of any chemical residue prior to being placed in glass waste (rinsed with appropriate solvent, and rinse-ate would go into appropriate liquid waste).
    - Plastic caps of vials should NOT go into glass waste.
- For chemically contaminated sharps with no infectious or bio-hazardous contamination: store in a rigid (hard plastic) container with a lid or top that can be sealed with tape.
- Submit a hazardous waste pick up for
    - batteries of all kinds,
    - elemental mercury and mercury-containing equipment (MCE),
        - MCE includes thermostats, barometers, manometers, thermometers, temperature and pressure gauges, mercury switches, mercury-containing lamps, and various medical devices.
    - paint and paint-related wastes,
    - lamps (fluorescent lights, mercury vapor lamps, high-pressure sodium lamps, metal-halide lamps), and incandescent lamps),
    - pesticides/fertilizers,
    - and aerosol cans.
- Electronic Wastes comprise items such as cell phones, computers/monitors, keyboards, cameras, DVD players/recorders, TVs, surge protectors, etc. It should be noted that some electronic wastes are the property of UNT and must have certificates of destruction in order to be picked up. Items that are university assets must be managed through your department's designated inventory coordinator. RMS does not pick up electronic wastes considered assets. Please contact UNT Surplus for pick up and removal.

10.6 Sink disposal

No chemical waste should be poured down the drain unless it is certain that doing so does not violate hazardous waste regulations or the City of Denton wastewater treatment plant's requirements. Please contact RMS at 940-565-2109 for further information regarding non-hazardous chemical waste disposal.

11 RECORD KEEPING

General Requirements:

- RMS must keep an accurate record of any medical consultations or medical examinations.
- Incident records shall be maintained in the organizational unit, as well as by RMS.
- The Chemical Hygiene Officer will manage a database that tracks Laboratory Safety Training.
- The PI/Laboratory Supervisor will manage any documentation for Laboratory Specific Training.

Documentation

It is crucial that all types of training are documented. All training the lab receives should be documented and kept online for easy access to the documents. Training can be documented and kept in the lab as well. Documentation of training includes but is not limited to:

- Certificates from online Bridge training
- Standard Operating Procedures and Process Standard Operating Procedures signage page
- Certificates from outside courses taken for training
- Certificates given from additional training given by RMS

APPENDIX A

Glove Selection

Examples of Chemical Resistance of Common Glove Materials

Table Appendix A					
Chemical	**Notes**	**Natural Rubber**	**Neoprene**	**Nitrile**	**Poly Vinyl Alcohol**
Acetaldehyde	a	P	P	P	P
Acetic Acid	b	F	E	F	P
Acetone	b	P	P	P	P
Acrylonitrile	b	P	P	P	P
Ammonium Hydroxide (sat.)	b	P	E	E	P
Aniline	b	P	P	P	E
Benzaldehyde	b	P	P	P	G
Benzene	a	P	P	P	E
Benzyl Chloride	a	P	P	P	F
Bromine		P	F	-	-
Butane		P	G	P	G
Butyraldehyde	b	P	P	P	P
Calcium Hypochlorite		G	G	G	P
Carbon Disulfide		P	P	P	G
Carbon Tetrachloride	a	P	P	P	E
Chlorine		P	F	-	P
Chloroacetone		F	E	-	P
Chloroform	a	P	P	P	E
Chromic Acid	b	P	P	F	P
Cyclohexane		P	P	E	P

Dibenzyl Ether		P	P	-	P
Dibutyl Phthalate	b	F	F	-	E
Diethanolamine	b	F	E	E	-
Diethyl Ether		P	P	P	E
Dimethyl Sulfoxide	b	P	E	P	P
Ethyl Acetate	b	P	P	P	G
Ethylene Dichloride	a	P	P	P	G
Ethylene Glycol	b	E	E	E	F
Ethylene Trichloride	a	P	P	P	F
Fluorine		P	P	-	P
Formaldehyde	b	P	F	E	P

Excellent, **G**ood, **F**air, **P**oor, "**-**" (No) Resistance to chemical exposure for chemical listed.

Chemical	Notes	Natural Rubber	Neoprene	Nitrile	Vinyl
Formic Acid	b	F	E	F	P
Glycerol		E	E	E	F
Hexane		P	P	E	E
Hydrobromic Acid	b	P	G	F	P
Hydrochloric Acid (conc.)	b	G	G	G	P
Hydrofluoric Acid (30%)	b	F	F	P	P
Hydrogen Peroxide		E	F	E	P
Iodine		G	G	-	G
Methylamine	b	P	G	E	P
Methyl Cellusolve	b	P	P	F	P
Methyl Chloride	a	P	F	-	P
Methyl Ethyl Ketone	b	P	P	P	F
Methylene Chloride	a	P	P	P	E
Monoethanolamine	b	F	E	E	F
Morpholine	b	P	P	P	F

Naphthalene	a	P	P	F	P
Nitric Acid (conc.)	b	P	F	P	P
Perchloric Acid		E	E	E	P
Phenol		P	G	P	P
Phosphoric Acid		E	E	E	P
Potassium Hydroxide (sat.)		E	E	E	P
Propylene Dichloride	a	P	F	-	P
Sodium Hydroxide		E	E	E	P
Sodium Hypochlorite		E	E	E	P
Sulfuric Acid	b	P	F	P	P
Toluene	a	P	P	P	E
Trichloroethylene	a	P	P	P	E
Tricresyl Phosphate	b	P	G	G	E
Triethanolamine		G	E	E	E
Trinitrotoluene		P	F	F	P

Notes:

a. **Aromatic and halogenated hydrocarbons will attack all types of natural and most synthetic glove materials.**
b. **Butyl rubber recommended for handling DMSO.**

For more detailed information concerning glove material selection, consult with the Chemical Hygiene Officer.

APPENDIX B

Chemical Segregation

Table Appendix B			
HAZARD CLASS	**RECOMMENDED STORAGE METHOD**	**EXAMPLES**	**INCOMPATIBILITIES CHECK SDS/MSDS**
Oxidizers	Store inside a noncombustible cabinet, separate from flammable and combustible materials. Store inorganic oxidizers, organic peroxides, separate from each other via secondary containment.	Inorganic oxidizers - Sodium hypochlorite, ammonium nitrate Organic peroxides – methyl ethyl ketone peroxide, allyl compounds, haloalkenes, dienes, monomeric vinyl compounds,	Separate from reducing agents, flammables and combustibles
Flammable Liquids	Store in grounded flammable storage cabinet.	Acetone, benzene, methanol, ethanol, toluene	Separate from acids, bases, oxidizers, and poisons.
Flammable Solids	Store in grounded flammable storage cabinet. Flammable solids must be segregated from flammable liquids using secondary containment.	Phosphorus, lithium, sodium, potassium	Separate from acids and oxidizers.

Corrosives Acids	Store in separate acid storage cabinet. Within the acid cabinet store each of the following groups separately via secondary containment: oxidizing acids, flammable (organic) acids, and mineral acids.	Oxidizing acids - nitric acid, perchloric acid, chromic acid, picric acid Flammable and organic acids – glacial acetic acid, trifloroacetic acid, trichloroacetic acid Mineral acids - Hydrochloric acid, sulfuric acid, phosphoric acid	Separate from flammable liquids, flammable solids, bases, oxidizers.
Corrosives - Bases	Store in separate storage cabinet. Store inorganic bases separate from reducing agents via secondary containment.	Inorganic bases – sodium hydroxide, potassium hydroxide, ammonium hydroxide Reducing agents – Lithium aluminum hydride, sodium borohydride, lithium borohydride	Separate from oxidizers and acids.
General Chemicals Non-reactive	Store on general laboratory benches or shelving preferably below eye level.	Agar, sodium chloride, sodium bicarbonate, and most non-reactive salts	See SDS/MSDS
Water Reactive Chemicals	Store in dry, cool, location, protect from water fire sprinkler. Note: Many water reactive chemicals are flammable solids. If flammable solid,	Sodium metal, potassium metal, lithium metal, lithium aluminum hydride	Separate from all aqueous solutions, and oxidizers.

	store as such. If not, store separately from all other chemicals.		
Poisons (Toxicological Hazard)	If poisons can be categorized as oxidizer, acid, or flammable, store as such. If non-reactive but highly toxic store separately from all other chemicals.	Cyanides, heavy metals compounds (e.g., cadmium, mercury, osmium) methyl iodide, dimethyl sulfate, mercury	Flammable liquids, acids, bases, and oxidizers.

APPENDIX C

Particularly Hazardous Substances

CARC NTP: Listed as a carcinogen by the National Toxicology Program.

CARC IARC: Listed as a carcinogen by the International Agency for Research on Cancer

CARC OSHA: Listed as a regulated carcinogen by the Occupational Safety and Health Administration

REPRO SHEP: Included in the *Catalog of Teratogenic Agents*, T.H. Shepard, 6th Edition, John Hopkins Press, 1989

HTX EPA: Highly toxic, included in EPA's list 'Acutely Toxic Hazardous Waste', P-listed waste 40 CFR261.33, or Included in OSHA's list of highly hazardous chemicals with a threshold 200 pounds 29 CFR 1910.119

Table Appendix C						
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Androgenic hormones	NA					X
Arsenic & compounds	NA		X	X		X
Arsenic, elemental/inorganic cmpds; except arsine	NA	X				X
Beryllium and Beryllium Cmpds	NA		X			
cadmium compounds	NA		X			
Ceramic fibers, respirable size	NA	X				
FChlorobiphenyls	NA				X	
Chromium (VI) compounds, insoluble NOC	NA		X			
Chromium (VI) compounds, water soluble NOC	NA		X			
Coumarin anticoagulants	NA				X	
Creosotes	NA		X			
Cyanides (soluble cyanide salts); NOC	NA					X

Endrin; & metabolites	NA					X
Estrogens; conjugated	NA	X				
Insecticides; nonarsenical spraying	NA		X			
Ionizing radiation	NA				X	
Mercury; organic	NA				X	
Methoxsalen w/ultraviolet A therapy	NA	X				
Methyl mercury substances	NA				X	
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Mineral oils; untreated & mildly treated	NA		X			
MOPP; specified combined therapies	NA		X			
Nickel compounds, essentially sulfate & sulfide	NA		X			
Nicotine; & salts	NA					X
Oestrogens; nonsteriodal	NA		X			
Oestrogens; steriodal (not all in group)	NA		X			
Oestrone replacement therapy	NA		X			
Oral contraceptives; combined & sequential	NA		X			
Panfuran S; containing dihydroxymethylfuratrizine	NA		X			

Petroleum refining	NA		X			
Toxoplasmosis	NA				X	
Ultraviolet Radiation; A,B,& C, including sunlamps	NA		X			
Aziridine	99932-76-0	X	X	X		X
Valproate; see valproic acid	99-66-1				X	
Valproic acid	99-66-1				X	
Benzotrichloride	98-07-7	X				
Aminoazotoluene; o-	97-56-3	X				
Ethylene thiourea	96-45-7	X	X			
Dibromo-3-chloropropane; 1, 2	96-12-8	X	X			
Styrene oxide	96-09-3		X			
Chloro-o-phenylenediamine; 4	95-83-0	X	X			
Diaminotoluene; 2 4	95-80-7	X	X			
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Chloro-o-toluidine; p-; & its salts	95-69-2		X			
Toluidine; o-	95-53-4	X	X			
Safrole	94-59-7	X	X			
Nitrosopyrrolidine; n-	930-55-2	X	X			
Nitrosodi-n-butylamine; n-	924-16-3	X	X			
Polybrominated biphenyls	922-66-0	X				

Nitrodiphenyl; 4	92-93-3			X		
Benzidine	92-87-5	X	X		X	
Aminobiphenyl; 4	92-67-1	X	X			
Dichlorobenzidine salts; 3, 3'	91-94-1			X		
Dichlorobenzidine; 3, 3'	91-94-1	X	X	X		
Naphthylamine; beta	91-59-8	X	X	X		
Iron dextran complex	9004-66-4	X	X			
Ammonium picrate	88-89-1					X
picric acid	88-89-1					X
Dinoseb	88-85-7					X
Trichlorophenol; 2, 4, 6	88-06-2	X				
toluene diisocyanate (mixture of isomers)	86-91-9				X	
ANTU, see Naphthylthiourea	86-88-4					X
Naphthylthiourea; alpha-	86-88-4					X
Amino-2-methyl-anthraquinone; 1	82-28-0	X		X		X
Coal tar	8007-45-2		X			
Cyclosporin	79217-60-0		X			
Nitropropane; 2	79-46-9	X	X			
Dimethylcarbamoyl chloride	79-44-7	X	X			

peracetic acid	79-21-0					X
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Trichloromethanethiol	79-20-9					X
Hydrazinecarbothioamide	79-19-6					X
Thiosemicarbazide	79-19-6					X
chloroacetic acid	79-11-8					X
acrylamide	79-06-1					X
trichloroethylene	79-01-6		X		X	
hydrazine hydrate	7803-57-8				X	
Ammonium vanadate	7803-55-6					X
phosphine	7803-51-2					X
Tetraethyl lead	78-00-2					X
cadmium bromide	7789-42-6		X	X		X
Strontium chromate	7789-06-2	X				
Beryllium sulphate tetrahydrate	7787-56-6	X				
Beryllium fluoride	7787-49-7	X				
Beryllium chloride	7787-47-5	X				

Sodium arsenite	7784-46-5	X				
arsine	7784-42-1		X	X		X
Potassium arsenate	7784-41-0	X				
Lead arsenate	7784-40-9	X				
hydrogen sulfide	7783-06-4					X
chlorine	7782-50-5					
fluorine	7782-41-4					X
Calcium arsenate	7778-44-1	X			X	
Arsenic acid H3AsO4	7778-39-4		X			
Lead chromate	7758-97-6	X				
Asbestos anthopyllite	77536-67-5	X	X			
phosphorus	7723-14-0					X
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Dimethyl sulphate	77-78-1	X	X			

Sulfuric acid; occupational exp., inorg mists	7664-93-9		X			
ammonia (anhydrous)	7664-41-7	X	X			
hydrofluoric acid	7664-39-3					X
hydrochloric acid	7647-01-0					X
Sodium arsenate	7631-89-2	X				
Heptachlor & heptachlor epoxide	76-44-8					X
Nitroso-n-ethylurea; n-	759-73-9	X	X			
Hexaethyl tetraphosphate	757-58-4					X
iodine	7553-56-2					X
Acetone cyanohydrin	75-86-5					X
chlorotrimethylsilane	75-77-4					X
Epoxypropane; 1, 2; see Propylene oxide	75-56-9					X
Propylene oxide	75-56-9	X	X			
Propylene imine	75-55-8					X
phosgene	75-44-5					X
bromodichloromethane	75-27-4	X	X			
Ethylene oxide	75-21-8	X	X			

carbon disulfide	75-15-0					X
formamide	75-12-7		X			
dichloromethane	75-09-2				X	X
acetaldehyde	75-07-0	X	X			
Selenium sulfide	7446-34-6	X				
Lead phosphate	7446-27-7	X				
Thallium(I) sulfate	7446-18-6					X
sulfur trioxide	7446-11-9					X
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
sulfur dioxide	7446-09-5					X
Chromium III	7440-47-3	X	X			
cadmium	7440-43-9	X	X			
beryllium	7440-41-7	X				
Beryllium powder	7440-41-7					X
arsenic	7440-38-2	X				

thallium compounds	7440-28-0					
Lithium	7439-93-2				X	
lead and its inorganic compounds	7439-92-1		X		X	
Hydrogen cyanide	74-90-8					X
Estrogens (not conjugated); mestranol	72-33-3	X				
Endrin	72-20-8					X
Benzene	71-43-2	X	X			
Methyl-N'-nitro-N-nitrosoguanidine; n-; (MNNG)	70-25-7		X			
Arsonous dichloride; phenyl-	696-28-6		X	X		
Dichlorophenylarsine	696-28-6					X
Diethylarsine	692-42-2					X
Methyl-N-nitrosourea; N-	684-93-5		X			
Nitroso-n-methylurea; n-	684-93-5	X				
MeA-a-C(2-amino-3-methyl-9H-pyrido[2,3-b]indole	68006-83-7		X			
Hexamethyl phosphoramide	680-31-9	X	X			
Hexachloroethane	67-72-1	X				
chloroform	67-66-3	X	X		X	
Trichloromethane; see chloroform	67-66-3					

Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Erionite	66733-21-9	X	X			
Uracil mustard	66-75-1		X			
Coal tar pitch	65996-93-2		X			
Dimetilan	644-64-4					X
(N-nitrosomethylamino)-1-(3-pyridyl)-1-butanone; 4	64091-91-4	X	X			
Fluoroacetamide	640-19-7					X
Colchicine	64-86-8					X
Tetracycline hydrochloride; internal use	64-75-5				X	
Diethyl sulfate	64-67-5	X	X			
Cumenyl methylcarbamate; m-	64-00-6					X
Isopropylphenyl N-methylcarbamate; 3	64-00-6					X
Toluidine hydrochloride; o-	636-21-5	X				
Azathioprine	6336-41-0		X			
Selenourea	630-10-4					X
carbon monoxide	630-08-0				X	
Phenoxybenzamine hrdrochloride	63-92-3	X	X			

Mercury fulminate	628-86-4					X
Methyl isocyanate	624-83-9					X
Nitrosodi-n-propylamine; n-	621-64-7	X	X			
Methanamine; N-methyl-N-nitroso-	62-75-9					X
Nitrosodimethylamine; n-	62-75-9	X	X			
Sodium fluoroacetate	62-74-8					X
Thiourea	62-56-6	X	X			
Thioacetamide	62-55-5	X	X			
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
aniline	62-53-3				X	
Ethyl methanesulphonate	62-50-0	X	X			
Phenacetin	62-44-2		X			
Phenacetin, analgesic mixtures containing	62-44-2	X	X			
Phenylmercury acetate	62-38-4					X
Diacetylbenzidine; N,N'-	613-35-4		X			
Dichlorobenzidine dihydrochloriode; 3, 3'	612-83-9	X				
Amino-1,2,4-triazole; 3; see amitrole	61-82-5					X
Amitrole	61-82-5					X
Hexachlorocyclohexane	608-73-1	X				

Dieldrin	60-57-1					X
Methimazole	60-56-0				X	
Tetracycline; internal use	60-54-8				X	
Dimethoate	60-51-5					X
Methyl hydrazine	60-34-4					X
Monomethyl hydrazine; see methyl hydrazine	60-34-4					
Dimethylaminoazo-benzene; 4	60-11-7	X		X		
bromoacetone	598-31-2					X
Dimethylmercury	593-74-8				X	
Vinyl bromide	593-60-2		X			
Calcium cyanide	592-01-8					X
Acetamide; N-(aminothioxomethyl)-	591-08-2	X	X		X	
Nitrosomorpholine; n-	59-89-2	X	X			
5-Bromo-2′-deoxyuridine	59-14-3	X			X	

Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Hexachlorocyclohexane; gamma; see lindane	58-89-9					
Lindane	58-89-9	X				
Progesterone	57-83-0	X				
Chlordane	57-74-9		X			
Physostigmine salicylate	57-64-7					X

Estrogens (not conjugated); ethinylestradiol	57-63-6	X				
Propriolactone; beta	57-57-8	X	X	X		
Physostigmine	57-47-6					X
Phenytoin	57-41-0	X	X		X	
Pentobarbital sodium	57-33-0				X	
Strychnine	57-24-9					X
Dimethylhydrazine; 1, 1	57-14-7	X	X			
Chloro-2-methylpropene; 3	563-47-3	X				
Chloramphenicol	56-75-7		X			
Benzanthracene	56-55-3	X	X			
Diethylstilbestrol	56-53-1	X	X		X	
Parathion	56-38-2					X
carbon tetrachloride	56-23-5	X	X			
Tetrachloromethane; see carbon tetrachloride	56-23-5	X	X		X	
Trans-2-[(dimethylamino)methylamino]-5-[2-(5-ni…	55738-54-0		X			
Nickel cyanide	557-19-7					X
Epoxy-1-propanol; 2, 3; see Glycidol	556-52-5					X
Glycidol	556-52-5	X				
Carbosulfan	55285-14-8					X

Chemical Name	CAS NO.	CARC NTP	CARC IARC	CARC OSHA	REPRO SHEP	HTX EPA
Busulfan; see 1,4-butanediol dimethylsulfonate	55-98-1					
Butanediol dimethanesulfonate; 1,4	55-98-1	X	X		X	
Myleran, see 1,4-Butanediol dimethanesulfonate	55-98-1					
Phosphorofluoridic acid; bis(1-methylethyl) ester	55-91-4					X
Nitroglycerine	55-63-0					X
Nitrosodiethylamine; n-	55-18-5	X	X			
Chlorozotocin	54749-90-5		X			
Copper cyanide	544-92-3					X
Etretinate	54350-48-0				X	
Bis (chloromethyl) ether	542-88-1	X	X	X		X
Chloropropionitrile; 3	542-76-7					X
Dichloropropene; 1, 3; technical grade	542-75-6	X	X			
Barium cyanide	542-62-1			X		X
Dithiobiuret	541-53-7					X
Thioimidodicarbonic diamide [(H2N)C(S)]2NH	541-53-7					X
Aminopterin	54-62-6	X	X	X		

Pyridine; 3-(1-methyl-2-pyrrolidinyl)-; (S)-...	54-11-5					X
Thiourea; (2-chlorophenyl)-	5344-82-1					X
Dinitro-o-cresol; & salts	534-52-1					X
Acetylaminofluorene; 2	53-96-3					X
Dibenz(a,h)anthracene	53-70-3	X				
Dibenzanthracene	53-70-3		X			
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Estrogens (not conjugated); estrone	53-16-7	X				
Calcium arsenite	52740-16-6	X				
Famphur	52-85-7					X
Penicillamine	52-67-5				X	
Thiotepa; see tris (1-aziridinyl) phosphine sul...	52-24-4					
Tris (1-aziridinyl) phosphine sulfide	52-24-4	X	X			
Dimethylvinyl chloride	513-37-1	X				
Urethane	51-79-6	X	X			
Mechlorethamine; see nitrogen mustard	51-75-2					
Nitrogen mustard	51-75-2		X			

Propylthiouracil	51-52-5	X	X			
Epinephrine	51-43-4					X
Dinitrophenol; 2, 4	51-28-5					X
Fluorouracil; 5	51-21-8				X	
Tetranitromethane	509-14-8	X				X
Cyanogen chloride	506-77-4					X
cyanogen bromide	506-68-3					X
Silver cyanide	506-64-9					X
Potassium dicyanoargentate	506-61-6					X
Potassium silver cyanide	506-61-6					X
Mustard gas	505-60-2	X	X			
Aminopyridine; 4	504-24-5				X	
5-fluoro- deoxyuridine	50-91-9	X			X	
Actinomycin D	50-76-0	X	X		X	X
Reserpine	50-55-5	X				
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Thalidomide	50-35-1				X	
Benzopyrene	50-32-8	X	X			
DDT (Dichlorodiphenyl trichloroethane)	50-29-3	X	X			
Estrogens (not conjugated); estradiol-17 beta	50-28-2	X				

Cyclophosphamide; anhydrous	50-18-0	X	X		X	
Phenobarbital	50-06-6		X			
formaldehyde	50-00-0		X		X	X
Methoxypsoralen; 5	484-20-8		X			
Cis-retinoic acid; 13	4759-48-2				X	
Dimethanonaphthalene; 1,2,3,4,10,10-...	465-73-6					x
Isodrin	465-73-6					X
Cyanogen	460-19-5					X
Ethanedinitrile	460-19-5					X
Nitrosomethylvinylamine; n-	4549-40-0	X	X			X
Dacabarzine	4342-03-4	X	X			
Oxymetholone	434-07-1	X	X			
Beryllium zinc silicate	39413-47-3	X				
Thiofanox	39196-18-4					X
Diaminoanisole sulfate; 2 4	39156-41-7	X				
Methyl chrysene; 5	3697-24-3	X				X
Procarbazine hydrochloride	366-70-1	X	X			

fluoroacetylchloride	359-06-8					X
Brucine	357-57-3					X
diazomethane	334-88-3					X
Azacitidine	320-67-2	X				
Hexachlorocyclohexane; beta	319-85-7	X				
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Hexachlorocyclohexane; alpha	319-84-6	X				
Mexacarbamate	315-18-4					X
Diethyl-p-nitrophenyl phosphate	311-45-5					X
Aldrin	309-00-2					X
paraformaldehyde	30525-89-4					X
Chlorambucil	305-03-3	X	X			
Hydrazine	302-01-2	X	X			
Lead acetate	301-04-2	X				
Treosulphan	299-75-2		X			
Methoxypsoralen; 8; plus ultra violet radiation	298-81-7		X			
Disulfoton	298-04-4					X
Phorate	298-02-2					X
Methyl parathion	298-00-0					X

Diethyl O-pyrazinyl phosphorothioate; o o	297-97-2					X
Dibenzo(c,g)carbazole	28641-62-5	X				
(Aminomethyl)-3-isoxazolol; 5	2763-96-4	X	X			
Calcium arsenite	27152-57-4	X				
sodium azide (Na(N3))	26628-22-8					X
toluene diisocyanate	26471-62-5	X				
Dithiolane-2-carboxaldehyde; 2, 4-dimethyl-...	26419-73-8					X
Tirpate	26419-73-8					X
Promecarb	2631-37-0					X
Direct Blue #6	2602-46-2	X	X			
Azoxymethane	25843-45-2	X	X			
Kanechlor 500	25429-29-2	X				
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Hydroxyanisole; butylated	25013-16-5	X	X			

Captafol	2425-06-1		X			
Mirex	2385-85-5		X			
Formetanate hydrochloride.	23422-53-9					X
Adriamycin	23214-92-8	X	X			
Oxamyl	23135-22-0					X
Dibenz(a,h)acridine	226-36-8	X	X			
Dibenz(a,j)acridine	224-42-0	X	X			
Aluminum phosphide	20859-73-8					X
Osmium tetroxide	20816-12-0					X
Benzo(k)fluoranthene	207-08-9	X	X			
Benzo(b)fluoranthene	205-99-2	X	X	X		
Benzo(j)fluoranthene	205-82-3	X	X			
Dimethoxybenzidine dihydrochloride; 3, 3'	20325-40-0	X				
Methiocarb	2032-65-7					X
Direct Black #38	1937-37-7	X	X			
Indeno (1,2,3 cd) pyrene	193-39-5	X	X			

diborane (gas)	19287-45-7					X
Dibenzo(a,e)pyrene	192-65-4	X	X			
Dibenzo(a,l)pyrene	191-30-0	X	X			
Dibenzo(a,h)pyrene	189-64-0	X	X			
Dibenzo(a,i)pyrene	189-55-9	X	X			
Nitrofen	1836-75-5	X				
Benzopyran-2-one; 4-hydroxy-3-(3-oxo-1-…	181-81-2					X
Formparanate.	17702-57-7					X
Tetrachlorodibenzo-p-dioxin (TCDD); 2, 3, 7, 8	1746-01-6	X	X			
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Dimethanonaphth [2,3-b]oxirene…	172-20-8					X
tetrafluoroboric acid	16872-11-0					X
Methomyl	16752-77-5					X
Chlorinated camphene	165820-10-0	X	X			
Toxaphene; see chlorinated camphene	165820-10-0					X

Nitrosonornicotine; n-	16543-55-8	X	X			
Aldicarb sulfone	1646-88-4					X
Direct Brown #95	16071-86-6		X			
Cisplatin	15663-27-1	X	X			
Carbofuran	1563-66-2					X
BCNU; see bis chloroethyl nitrosourea	154-93-8					X
Bis chloroethyl nitrosourea	154-93-8	X	X			
Manganese dimethyldithiocarbamate.	15339-36-3					X
Manganese; bis(dimethylcarbamodithioato-S,S')-...	15339-36-3					X
Octamethylpyrophosphoramide	152-16-9					X
Calcium arsenite	15194-98-6	X				
Potassium cyanide	151-50-8					X
Silica; crystalline; quartz; respirable	14808-60-7	X	X			
Tridymite; see silica	14808-60-7					

Diepoxybutane	1464-53-5	X	X			
Endothall	145-73-3					X
Silica; crystalline; cristobalite	14464-46-1		X			
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
sodium cyanide (Na(CN))	144-33-9					X
Kepone	143-50-0		X			
Aflatoxins	1402-68-2	X	X			
Ethyl acrylate	140-88-5	X	X			
CCNU; methyl	13909-09-6	X	X			
Calcium chromate	13765-19-0	X				
Phenazopyridine hydrochloride	136-40-3	X	X			
Beryllium phosphate	13598-15-7	X				
Beryllium sulphate	13510-49-1	X				
Cupferron	135-20-6	X				
Potassium arsenite	13464-35-2	X				
Nickel carbonyl	13463-39-3					X

gallium trichloride	13450-90-3					X
Naphthylamine; alpha	134-32-7			X		
Anisidene hydrochloride; o-	134-29-2	X				
Polychlorinated biphenyls	1336-36-3	X	X			
ammonium hydroxide	1336-21-6	X	X			
chromium trioxide	1333-82-0	X				
Beryllium hydroxide	13327-32-7	X				
Asbestos	1332-21-4					X
Talc; containing asbestos; see asbestos 1	1332-21-4		X			
Tremolite; asbestiform; see asbestos	1332-21-4					
Arsenic trioxide	1327-53-3	X				X
arsenous oxide	1327-53-3	X				
Nitrososarcosine	13256-22-9	X	X			
Silica; crystalline; tripoli	1317-95-9		X			

Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Vanadium oxide V2O5	1314-62-1					X
phosphorus pentoxide	1314-56-3					X
Thallic oxide	1314-32-5					X
Thorium dioxide	1314-20-1	X				
potassium hydroxide	1310-58-3					X
Cyclohexyl-4;6-dinitrophenol; 2	131-89-5					X
Phenol; 2-cyclohexyl-4, 6-dinitro-	131-89-5					X
Cadmium sulphide	1306-23-6	X				
cadmium oxide	1306-19-0	X				
Beryllium oxide	1304-56-9	X				
Arsenic pentoxide	1303-28-2					X
CCNU	13010-47-4	X	X			
chromium hexacarbonyl	13007-92-6	X		X		

Saccharin	128-44-9	X	X			
Beryllium-alluminum alloy	12770-50-2	X				
Trimethadione	127-48-0				X	
Perchloroethylene	127-18-4	X	X			
Tetrachloroethylene, see perchloroethylene	127-18-4					X
Tris (2;3-dibromopropyl) phosphate	126-72-7	X	X			
ethidium bromide	1239-45-8					X
Dioxane	123-91-1	X				
Hydrazobenzene	122-66-7	X				
Phenyl glycidyl ether (PGE)	122-60-1		X			
Dimethylphenethylamine; alpha, alpha	122-09-8					X
Asbestos, amosite	12172-73-5	X				
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Thallium(I) selenite	12039-52-0					X
Asbestos, chrysotile	12001-29-5	X				
Asbestos, crocidolite	12001-28-4	X				

Cresidine; p-	120-71-8	X	X			
Dimethylbenzidene; 3, 3'	119-93-7	X	X			
Dimethoxybenzidine; 3, 3'	119-90-4	X	X			
Isolan	119-38-0					X
Hexachlorobenzene	118-74-1	X	X			
Di-sec octyl phthalate	117-81-7	X	X			
Aminoanthraquinone; 2	117-79-3	X				
Anisindione	117-37-3	X				
Aldicarb	116-06-3	X	X			
Endosulfan	115-29-7					X
Chlorendic acid	115-28-6	X	X			
Metolcarb	1129-41-5					X
Propane sultone; 1, 3	1120-71-4	X	X			
Nitrosodiethanolamine; n-	1116-54-7	X	X			
glutaraldehyde	111-30-8					X
Aroclor 1254	11097-69-1					X
Aroclor 1260	11096-82-5	X				
tetramethyl ethylenediamine	110-18-9					X
butyl lithium	109-72-8					

Chlorinated paraffins; certain	108171-26-2	X	X			
Phenyl mercaptan	108-98-5					X
Thiophenol; see phenyl mercaptan	108-98-5					
phenol	108-95-2					X
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
toluene	108-88-3				X	
Toluol; see toluene	108-88-3					
Tetraethyl pyrophosphate	107-49-3					X
chloromethyl ether	107-30-2	X	X	X		
Chloroacetaldehyde	107-20-0					X
Propargyl alcohol	107-19-7					X
Allyl alcohol	107-18-6					X
ethylene diamine	107-15-3					X
acrylonitrile	107-13-1	X	X		X	
Propanenitrile	107-12-0					X
Ethylene dichloride	107-06-2	X				
acrolein	107-02-8	X		X		
trimethylin chloride	1066-45-1					X
Butadiene; 1,3	106-99-0	X	X			
Butadine; see 1,3 butadine	106-99-0					

Dibromoethane; 1, 2; see ethylene dibromide	106-93-4	X	X		X	
Ethylene dibromide	106-93-4	X	X			
Chloro-2,3-epoxypropane; 1; see epichlorohydrin	106-89-8					
Epichlorohydrin	106-89-8	X	X			
Dichlorobenzene; p-	106-46-7	X	X			
Phenylthiourea	103-85-5					X
boron tribromide	10294-33-4					X
cobalt carbonyl	10210-68-1					X
Cadmium sulphate	10124-36-4	X				
cadmium chloride	10108-64-2	X				
Nitrogen dioxide	10102-44-0					X
Chemical Name	**CAS NO.**	**CARC NTP**	**CARC IARC**	**CARC OSHA**	**REPRO SHEP**	**HTX EPA**
Nitric oxide	10102-43-9					X
Diglycidyl resorcinol ether	101-90-6	X	X			
Oxydianiline; 4, 4'	101-80-4	X	X			
Methylene-bis(2-chloroaniline) MOCA; 4, 4'	101-14-4		X			

Disodium hydrogen arsenate	10048-95-0	X				
Radon	10043-92-2	X				
Hydrazine sulfate	100-93-2	X				
Nitrosopiperidine; n-	100-75-4	X	X			
Benzyl chloride	100-44-7					X
Vinyl benzene; see stryene	100-42-5					X
Nitroaniline; p-	100-01-6					X
Nitrogen oxide NO2	0102-44-0					X
Nitrogen oxide NO	0102-43-9					X

APPENDIX D

Information on Chemical Exposures from Health Hazards

Information on exposure limits can be found here: OSHA 1910 and NIOSH/CDC Pocket Guide. Some more information on specific types of chemical exposure is detailed below.

Health Hazards

Extreme caution should be taken to prevent exposure to chemicals like carcinogens, toxic chemicals or highly toxic chemicals, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes. Immediate treatment should be sought upon possible exposure to these chemicals.

Corrosive chemicals

- Eye exposures
  - symptoms include pain, blood shot eyes, tearing, and blurring of vision.
- Skin exposures
  - symptoms may include reddening, pain, inflammation, bleeding, irritation, blistering, and burns.
- Inhalation exposure
  - symptoms include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, nausea, and vomiting.
- Acid and Akali Burns

    - The burned areas must be washed with large volumes of water, for a period of five times longer than is necessary to stop the burning sensation. The area must then be covered with sterile dressing and then aluminum foil or plastic wrap to prevent exposure to air.
    - No ointments, creams, baking soda or other substances should be applied. Severe burns should be examined by a physician.

Irritants

- Symptoms of exposure can include reddening or discomfort of the skin and irritation to respiratory systems.

Sensitizers

- Sensitizer exposure can lead to all of the symptoms associated with allergic reactions, or can increase an individual's existing allergies.
- Inhalation of sensitizers can lead to an allergic response
    - It is recommended that sensitizers always be used in a fume hood or with proper ventilation.

Target organs (hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes)

- Symptoms of exposure to these materials vary. Staff working with these materials should review the SDS for the specific material being used and should take special note of the associated symptoms of exposure.

Nanomaterials

- Risk of exposure is lowest when nanomaterials are bound in a solid matrix with little potential to create airborne dust or when in a non-volatile liquid suspension.
- Risk of exposure increases when nanomaterials are used as fine powders, are suspended in volatile solvents or gases, or in procedures in which aerosols may be produced.
- The parent compound of the nanomaterial should also be taken into consideration when evaluating the potential hazards associated with exposure (e.g., a highly toxic compound such as cadmium should be anticipated to be toxic and possibly more toxic when used as a nanomaterial).

- However, some materials that are non-toxic in their bulk phase may display significant toxicity as nanomaterials, always take the necessary precautions to avoid exposure.
- Nanoparticles can cross an alveolar wall into bloodstream. It also can spread to other organs, tissues and brain. Potential nanomaterial exposure routes include inhalation, dermal contact, and ingestion.
- To prevent the exposure, always maintain good work practices like clean work areas, hand washing, and shower use /change of clothes).
- Use engineering controls like source enclosure, local exhaust ventilation, and HEPA filters. During any experiment, wear NIOSH-approved personal protective equipment and respirator.
- Cleanup any spill immediately and properly dispose of any Nanomaterials.
- Metal powders have similar exposure risk to nanomaterials.

Allergens

- Such as diazomethane, isocyanates, and bichromates, require wearing suitable gloves to prevent hand contact with allergens or substances of unknown allergenic activity.
    - Laboratory hoods or glove boxes are a preferred enclosure for allergen work.

Embryo toxins

- Such as organomercurials, lead compounds, and formamide require women of childbearing age to only work with these substances in a hood whose satisfactory performance has been confirmed. Appropriate protective clothing is required to prevent skin contact.
- Procedures for safe handling, use, and storage of allergens and embryo toxins shall be reviewed annually and prior to the introduction of any new material.
- Allergens and embryo toxins shall be properly labeled and stored in unbreakable secondary containers in adequately ventilated areas.
- Spills and incidents of exposure to these materials require immediate notification of supervisor and consultation of a qualified physician when appropriate.
- Chemicals of moderate chronic or high acute toxicity (Appendix A - Acutely Toxic Chemicals) may not exceed TLV50 ppm, e.g. hydrogen cyanide and hydrofluoric acid.

Moderate chronic and high acute toxicity

- Additional precautions are appropriate when working with chemicals of moderate chronic and high acute toxicity (see Appendix A - Acutely Toxic Chemicals).
- Minimize exposure to these toxic substances by any route using all reasonable precautions and appropriate protective equipment, including washing of hands and arms thoroughly after removal of protective equipment.
- Use and store these substances only in areas of restricted access. The storage area containers require special warning signs to alert users of the hazards and safe handling procedures.
- Use in fume hoods that have been previously evaluated to confirm adequate performance. Trap released vapors to prevent their discharge into the fume hood exhaust.
- Maintain records of the amounts of these materials on hand, amounts used, and names of personnel working with the materials.
- Incidents and spills are prevented by preparing the work area prior to chemical handling.
- Assure that at least two people are present at all times when working with highly toxic materials.
- Cover the work area with containment devices such as plastic sheeting and absorbent materials. Prepare a waste disposal receptacle for the waste chemicals and containment material.
- If a major spill occurs outside of the hood, evacuate the area. Assure that cleanup personnel wear suitable protective equipment.

Chemicals with High Chronic Toxicity

- Such as
  - Organic mercury compounds and carcinogens; see Appendix A - Acutely Toxic Chemicals.
  - Carcinogens are those listed in the definition of a carcinogen in Ch 3.
- Restrict all transfers and work with these substances to a "controlled area" such as a restricted access hood, glove box, or a portion of the laboratory designated for use of highly toxic substances.
- All personnel in the laboratory must be made aware of the substances being used and necessary precautions.
- Prior to introduction of highly toxic materials in the laboratory, prepare a plan for the use, disposal and decontamination of equipment.

- The controlled area must be decontaminated after using highly toxic materials.
- Personnel shall remove protective equipment and place it in an appropriate labeled container.
    - Personnel will thoroughly wash hands, forearms, face, and neck after removing protective equipment.
- Laboratory personnel are responsible for cleaning the area when highly toxic materials are used.
- The area must be decontaminated prior to allowing Janitorial personnel to resume normal cleaning procedures.
- *Medical surveillance is required if using significant quantities of a highly toxic material on a regular basis (three times per week). Consult a qualified physician concerning desirability of regular medical monitoring. Only if the SOP (Standard Operating Procedure) for the use of the chemical ensures no exposure to personnel at or above the PEL and/or TLV can the material be used without medical monitoring.*
- Maintain records of the amounts of these materials on hand, amounts used, and names of personnel working with the materials.
- Incidents and spills are prevented by preparing the work area prior to chemical handling.
- Assure that at least two people are present at all times when working with highly toxic materials.
- Cover the work area with containment devices such as plastic sheeting and absorbent. Prepare a waste disposal receptacle for the waste chemicals and containment material.
- If a major spill occurs outside of the hood, evacuate the area. Assure that cleanup personnel wear suitable protective equipment.

<u>Explosive Chemical Management</u>

- An explosive chemical is a gas, solid or liquid chemical which is in itself capable by chemical reaction of producing gas at a temperature and pressure at a speed able to cause damage to the surroundings. This includes chemicals purchased from supplied by vendors or products and by-products generated from experiments or reactions. Examples of explosive chemicals are:
    - organic peroxides
    - oxidizers including? salts containing nitrates
    - chlorates

        - high concentration of perchloric acids
    - Ensure proper control measures and protective barriers are in place when using or working with explosive chemicals or reactions.
        - Labs working with explosive chemicals or reactions should have a blast shield.
        - Follow proper procedures listed below.

<u>Lasers</u>

- No person may use a laser of any type prior to training in laser safety. Contact the Radiation Safety Officer at 940-565-3282 to obtain this training.
- The type and intensity of radiation from lasers varies widely with the instrument design. Prior to working with an instrument, the specifications for operation and protection must be consulted.
- Always wear goggles that offer protection against the specific wavelength of laser in use. If more than one wavelength is being used, additional goggles specific for each wavelength are required. No available spectacles protect against all laser wavelengths.
- Never look directly at the beam or pump source.
- Never view the beam pattern directly; use an image converter or other safe, indirect means. To decrease reflecting hazards, do not aim by looking along the beam.
- Do not allow any objects that cause reflections to be present in or along the beam. Even buttons on clothing and polished screw heads can be dangerous.
- Keep a high general illumination level in areas where lasers are in operation. Low light levels cause dilation of the pupils, thereby increasing the hazard.
- Display warning signs in laser areas.

The following procedures must be followed to minimize the risk of exposure of particularly hazardous substances and risk of explosion.

1. Responsibility
    a. The PI involved in using particularly hazardous substances and/or explosive chemicals must perform a Risk Assessment prior to submitting a research

proposal to the Risk Management Services for approval. Detailed Standard Operating Procedures must be attached with the proposal.

2. Purchasing
    a. All chemicals must be purchased through EIS approval system.
3. Chemical Register
    a. A register of all used/stored chemicals on site shall be generated by the manager of the lab or PI. This list should be submitted to Risk Management Services for review.
4. Chemical User
    a. A list of chemical users includes name, employment status, contact email address, phone number and training status must be submitted with Standard Operating procedures (SOP) to Risk Management Services .
5. New chemical hazard identification and risk assessment
    a. For all new chemicals, a hazard and risk assessment must be performed immediately.
6. Training
    a. Staff and workers must receive related training before handling the chemicals and doing any hands-on experiments.
7. Labeling
    a. The label must be specific and firmly secured on the container with appropriate hazards. See Ch 3.1.1 Labeling.
8. Personal Protective Equipment
    a. Appropriate Personal Protective Equipment must be worn during the experiment.
9. Handling and storage of chemicals
    a. Proper procedures found in the SDS sheets must be used.
10. Waste disposal
    a. Chemical waste must not be mixed with other chemical waste unless the waste is the same type. Users must take "Hazardous Wastes" training prior to handling explosive waste,
11. Updates and records
    a. All SDS's must be updated regularly. Risk Managements Services ensures that new chemicals are entered into the Database inventory.
12. Signage

    a. Warning signage must be posted on the wall or entrance to warn building occupants of any hazards.
13. Emergency phone number
    a. Emergency contact numbers of responsible lab persons, the PI(s), and the UNT Police department must be posted on the outside lab door.
14. Overnight experiments
    a. Describe how to stop the process(es) or turn off the equipment if an emergency happens; also attach a map showing all equipment locations in the lab.
15. Incident report
    a. Principal Investigator or Lab Manager must report any incident to the Risk Management Services within 7 working days. Injuries involving employees require a separate report to Risk Management Services Insurance and Claims, (940) 565-2109.

APPENDIX E: STANDARD OPERATING PROCEDURES GUIDE

Labs that have common or specific practices and procedures with hazardous chemicals or high-risk procedures should have written Standard Operating Procedures (SOPs). Note that SOPs are **NOT** a replacement for training. SOPs are to supplement training and can be used as a reference later on prior to performing the process or procedure. All lab personnel **MUST** be trained on the process or procedure by the PI or designated senior lab personnel. For more information on training, see Ch 5.

SOPs are only useful if they are used. Reference and review an SOP any time you perform that procedure or process or use an uncommon chemical.

Many SOPs can be found online – however, it is best to add the laboratory specific practices to that SOP and make sure that the information that is within the SOP fits for the lab. Please see Resources at the end for some SOP libraries to reference.

SOPs are generally developed for high-risk chemical processes and procedures. These should be able to guide a student through a detailed series of steps to safely achieve a desired result and should eliminate guesswork involved in safety decisions including type of solvents, temperature control, PPE, engineering controls, waste management, and possible emergency scenarios. A risk assessment should be performed on the procedure or process prior to writing an SOP and the risk assessment should be included within the SOP.

SOPs can help standardize best practices for the laboratory. SOPs can also help capture knowledge that generally gets passed down within a research group. This ensures that the group will retain the correct knowledge relating to common processes and procedures despite having a high turnover rate. SOPs also help keep procedures and processes consistent which can help improve research.

SOPs can be designed for both classes of chemicals and specific chemicals involved in procedures or processes. Banded SOPs specify a common set of precautions that apply to chemicals with a specific hazard, or combination of hazards, associated with them. Below is a list of Banded SOPs:

- Flammables / Highly Flammables
- Corrosives and Strong Corrosive Chemicals
- Irritants and Sensitizers
- Gases Under Pressure
- Toxic Chemicals
- Acutely Toxic Chemicals
- Explosive and Potentially Explosive Compounds
- Peroxide Forming Chemicals
- Organic Peroxides and Self-Reactive Chemicals
- Pyrophorics
- Strong Oxidizers
- Toxic Gases
- Water Reactive Chemicals

- Reproductive Toxins
- Sensitizers

The chemicals that fall under these classes also require their own individualized SOPs:

- highly toxic,
- sensitizers,
- carcinogens,
- water reactive,
- pyrophoric,
- or explosive chemicals.

Some specific chemicals that need their own SOP but do not fall into those classes are:

- hydrofluoric acid
- picric acid
- perchloric acid
- osmium tetroxide
- hydrazine

Process SOPs are written for specific procedures and processes performed within the lab. Some examples are:

- Use of Cryogenic Liquids
- Using a Vacuum Pump
- Using a Glovebox
- Using a Schlenk Line
- High Performance Liquid Chromatography
- Quenching Reactive Organometallic Reagents
- Using a Rotary Evaporator
- Use of Pyrophoric Reagents
- Using a Centrifuge
- Using Nanomaterials

Sections of an SOP:

- Title and Information
    - The first section should include title, PI name and signature, who wrote the SOP, and the date it was written. If the SOP was updated, the date it was updated should be included here.
- Type of SOP
    - The type of SOP – is it a banded SOP, specific SOP, or Process SOP.
- Purpose
    - Describe the purpose of the SOP. If it is a banded SOP, the purpose might just be to inform lab personnel about the general hazards and handling. If it is a specific chemical or process SOP, then the purpose would potentially be to guide lab personnel through a specific process used in the lab.
- Properties and Hazards
    - Describe properties of the chemical(s) or process and any hazards associated with the chemical(s) or process. Describe both general and specific hazards.
- PPE
    - Describe the proper type of PPE that should be worn when handling the chemical or performing the procedure. This should include information on glove break through time and if safety goggles should be worn instead of safety glasses.
    - Think about skin and body protection, hand protection, eye protection, and additional hygiene measures (e.g., washing hands after, changing clothes if it is a sensitizer)
- Administrative controls
    - Describe any administrative controls that are in place to help minimize the risk associated with this chemical(s) or process.
- Engineering controls
    - Describe any engineering controls that are utilized to help minimize the risk (i.e., fume hoods, gloveboxes, etc.)
- Special Storage and Handling Requirements
    - Describe any special storage and handling requirements (i.e., handle under inert gas, store under inert gas, incompatible storage with acids, etc.)
- Spill, Incident, and First Aid Procedures

    - Describe emergency procedures for potential spills, incidents (injuries, exposures, fires, etc.), and the first aid procedures to take in the event of exposure.
- Waste Disposal Procedures
    - Describe all waste disposal procedures for the chemical(s) or process. Include incompatible chemicals in this section and if specific or unique waste disposal is required.
- Appendix A: Lab Specific Use Procedures
    - Describe any specific use procedures that is unique to your lab associated with the chemical(s) or processes.
- Signage
    - A section for all lab personnel that when they are trained to use the chemical(s) or perform the process to sign and date certifying that they have read and understand the SOP, and will review it when needed.

Resources to use for SOPs:

- Please see Generating Standard Operating Procedures for the Manipulation of Hazardous Chemicals in Academic Laboratories for more information.
- UC Center for Laboratory Safety SOP library
- UMN SOP library

APPENDIX F: SAFE USE OF PYROPHORIC REAGENTS (UNDER PREPARATION)

In this section is a guidance on the safe use of pyrophoric reagents describing proper handling, disposal, and emergency procedures.

Pyrophoric materials ignite spontaneously upon contact with air, reacting with oxygen and/or moisture in the air. Pyrophoric materials must be handled under inert atmospheres and in ways that? rigorously excludes air and moisture. Most pyrophoric materials are toxic and dissolved in a flammable solvent. When working with pyrophoric materials it is important to have proper training and to not work alone.

Examples of Pyrophoric Materials

- Metal alkyl hydrides and aryls (butyl lithium, trimethylaluminum, triethyl boron)
- Metal carbonyls (nickel carbonyl, iron pentacarbonyl)
- Finely divided metal powders (aluminum powder, zinc dust)
- Metal hydrides (sodium hydride, germane, lithium aluminum hydride)
- Nonmetal hydrides (diethylarsine, diethylphosphine)
- Non-metal alkyls (R_3B, R_3P, R_3As, tetramethyl silane, tributyl phosphine)
- Phosphorus

- Alkali earth metals (sodium, potassium, cesium)
- Gases (arsine, diborane, phosphine, silane)
- Silicon halides (dichloromethylsilane)

Prior to working with pyrophoric materials:

Resources used to create this document:

https://ehs.princeton.edu/book/export/html/529

APPENDIX G: INFORMATION ON CONTROLLED SUBSTANCES

APPENDIX H: RISK ASSESSMENT GUIDE

A thorough risk assessment determines the proper safety and containment precautions given the intrinsic risk of the hazard(s), procedures, and health of laboratory workers. A risk assessment should be completed whenever a new experiment, procedure, or project is developed in the lab. Even something like changing the temperature you are utilizing in an experiment should warrant a risk assessment of the procedure again.

Risk assessment is a guide for the selection of appropriate controls and practices, safety equipment, and facility safeguards that can be used to eliminate or reduce any risks to lab personnel, operations, and/or property. The risk assessment will be used to alert others to the hazards of working in the lab and to the need for developing proficiency in the use of safe practices and containment equipment. Successful control of hazards in the laboratory also protects persons not directly associated with the laboratory, such as other occupants in the building, infrequent visitors (e.g., facilities services), and the public. After control measures are implemented, training and standard operating procedures should be completed for the lab personnel to ensure they are aware of the correct steps and can reference the material (SOPs) as needed.

When conducting an assessment consider things including but not limited to:

- Chemical safety
- Machine safety
- Physical safety
- Biological exposures

When performing a risk assessment, RAMP can be applied. RAMP is a method or thought process used to manage laboratory hazards and risks. When you learn to use RAMP:

- Helps you to prepare for experimental hazards from a variety of reagents, conditions, and/or activities
- Improves your science
- Helps keep you and those around you safe

RAMP stands for:

- Recognize Hazards
- Assess Risks
- Minimize and Manage Risks
- Prepare for Emergencies

Before going through the steps of RAMP, hazard and risk will be explained.

Hazard vs Risk

A hazard is the potential for hard or an adverse effect. Hazard is an inherent property

- Example: Acetone is a hazardous material because it is flammable

Hazards can come in various forms: materials (chemical/biological), processes, tools, conditions, and energy sources.

Risk is the likelihood of adverse effects and the severity of the hazard or: Risk = likelihood of exposure * severity of hazard.

Hazard is an inherent property and therefore cannot be changed. Risk can be managed.

Recognize Hazards

For a risk assessment of a project, it is best to identify general hazards. Make a list of the general hazards for the project.

General hazards can be but are not limited to (a more comprehensive chart):

- Hazardous chemicals and materials
- Biohazards
- Hazardous processes or equipment

For a risk assessment of an experiment, list more specific hazards like:

- Chemical name or biohazardous material
    - Hazards associated with that material

- Processes hazards
    - Temperature, gas usage, glass, equipment hazards

For chemical hazards, Safety Data Sheets (manufacturer) can be utilized. GHS pictograms, hazard statements, and signal words can be used to identify the severity and nature of the hazard. PubChem is an "open" chemistry database at the NIH and can also be used to identify chemical hazards. Publications can also be utilized as new safety data is published.

When recognizing operational hazards, some items to consider are:

- Equipment component failures
- Deviations from the planned/expected critical parameters (e.g., temperature, pressure, time, flow rate)
- Potential human error

Utilize the "What if?" analysis: a structured brainstorming to determine what can go wrong in each step and judge the likelihood and consequences that things will go wrong.

Example: What if the heat controller fails?

Example: Dichloromethane

Identify the hazards associated with dichloromethane.

Looking at the SDS: GHS pictograms show it is a health hazard and irritant. The classifications state that it can cause skin irritation, eye irritation, and it is a carcinogen and has specific target organ toxicity.

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)

Skin irritation (Category 2), H315
Eye irritation (Category 2A), H319
Carcinogenicity (Category 2), H351
Specific target organ toxicity - single exposure (Category 3), Central nervous system, H336

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram

Looking at the signal word: warning, and H-statements provides further information about the hazards.

Signal word	Warning
Hazard statement(s)	
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H336	May cause drowsiness or dizziness.
H351	Suspected of causing cancer.

Assess the Risk

Once a list has been made of all hazards, the risk of each hazard will need to be assessed. Both severity of the hazard and likelihood of exposure will need to be determined. Determining severity of the hazard and likelihood of exposure is somewhat subjective and it is recommended to specify the reasoning/justification. These can be highly dependent on both environment and expertise.

The severity of the hazard can depend on things like the level of toxicity, the concentration, and length of exposure. The likelihood of the exposure will depend on the nature of the experiment, the skill level, and if something will go wrong. If personnel have not been trained on the activity, then the risk would ultimately be higher.

Likelihood/Probability can be low, medium, or high – these definitions are below.

- Low: very unlikely to happen in the near future and no immediate action is needed
- Medium: likely to occur and actions should be taken to reduce or control the risk
- High: very likely to occur or high probability that risk will occur; immediate action plans are required to reduce or control the risk.

You can use the table below to help work out the risk – score your hazard or activity's risk using 'L' for low, 'M' for medium, and 'H' for high when describing your risk.

		Consequence/Severity		
		Low	Medium	High
Likelihood/Probability	High	**Medium**	**High**	**High**
	Medium	**Low/Medium**	**Medium**	**High**
	Low	**Low**	**Low**	**Medium**

Example: Dichloromethane

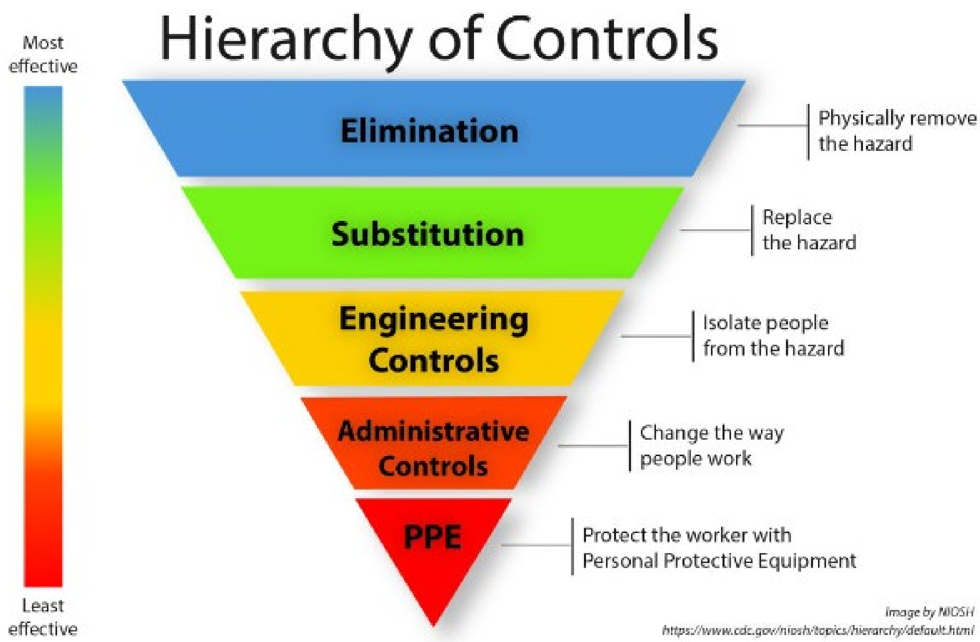
Consider the risk associated with pouring 300mL of dichloromethane from a 4L bottle.

Some potential risks could be exposure to vapors.

The likelihood of exposure (or likelihood that something would go wrong) is high because of the quantity that is being poured. The severity of the hazard is also high because it is a carcinogen and target organ toxin. The overall risk of pouring 300mL of dichloromethane from a 4L bottle is HIGH.

Minimize and Manage Risks

Minimizing and managing risks involves applying control measures. Control measures can be used to either eliminate or lower the risks to an appropriate level. NIOSH's Hierarchy of Controls shows some of the different ways that risks can be managed and how the controls can be applied.



Elimination – removes the hazard at the source. This could potentially be not using a toxic chemical or a more dangerous process, like utilizing a sharp tool.

Substitution – replaces the hazard for something that has a less severe hazard. This could be swapping out a more toxic chemical for a non-toxic one or switching from a razor blade to a scissors or box cutter.

Engineering Controls – reduces or prevents hazards from coming into contact with workers. This can include modifying equipment, using protective barriers, ventilation, and more. According to NIOSH, the most effective engineering controls:

- are part of the original equipment design
- remove or block the hazard at the source before it comes into contact with the workers
- prevent users from modifying or interfering with the control
- need minimal user input for the controls to work
- operate correctly without interfering with the work process or making the work process more difficult.

Some examples of engineering controls are fume hoods, snorkels, glove boxes, bonding and grounding (flammable liquids), use of cannula, and blast shields.

Administrative Controls – establish work practices that reduce duration, frequency, or intensity of exposure to hazards. Some examples of administrative controls are training, standard operating procedures (SOPs), limiting access to hazards, and taking rest breaks.

Personal Protective Equipment (PPE) – is equipment worn to minimize exposure to hazards. PPE includes, but is not limited to, gloves, safety glasses, lab coats, and respirators. When considering the hazards that you are working with, identify the correct types of PPE that should be worn. PPE should not be the sole control measure relied on to protect the worker, but should be used in conjunction with all other controls.

After assessing the risks of the hazards, if there are any HIGH or MEDIUM risks – use the Hierarchy of Controls to minimize or mitigate the risk down to an acceptable risk level (preferably LOW). If you cannot minimize the risk to an acceptable level, consider speaking with your PI or supervisor or even reaching out to RMS to discuss what things can be done.

Consider performing a dry run for complex operation for practicing the experiment or technique (generally done with water or without any chemicals). Consider starting on a smaller scale if working with any kind of potentially explosive or reactive experiments and gradually scale up. Remember to reassess risks as you scale up.

Example: Dichloromethane

Utilize the Hierarchy of Controls to minimize the risks associated with pouring 300mL of dichloromethane from a 4L bottle.

One potential risk is exposure. Working through the Hierarchy of Controls – if dichloromethane is necessary for the experiment, it cannot be eliminated or substituted. The risk can be reduced by pouring the dichloromethane inside of a fume hood. Now the risk of exposure is lower, although the severity is still high. Wearing appropriate gloves, safety goggles, and lab coat would also help lower the risk of exposure.

Although it would be best to lower the risk entirely to eliminate the use of dichloromethane, elimination is not always possible. Think about potentially using a smaller amount of dichloromethane – only taking 10mL from a 500mL bottle. The amount is significantly lower which lowers the risk of exposure as well.

Prepare for Emergencies

It is always possible that something could go wrong when performing an experiment. Human error is still possible and even if everything is accounted for when recognizing hazards, assessing risks, and minimizing those risks – accidents can happen. Preparing for emergencies is a critical step of RAMP for helping ensure your safety and preventing any potential exposure or damage that might occur.

Make sure that your laboratory is equipped with all the required emergency response equipment. All emergency response equipment should be appropriately labelled, and the aisles should be kept clear so that they can be accessed in an emergency. This includes, but is not limited to:

- Fire extinguishers
- Safety eyewashes
- Safety showers

- Spill kits (general, acid, base, HF, mercury)
- Gas shut off valves
- First aid kits

Make sure that all lab personnel know both the location and how to use each piece of equipment. Your lab should have an emergency response plan in place for common emergencies like different types of spills, exposures, fires, etc.

Use the "What if?" statement when preparing and planning for emergencies.

Example: Dichloromethane

Think of emergencies that could occur when pouring 300mL of dichloromethane from a 4L bottle. Write down actions to prepare for these emergencies.

"What if a small spill (less than 1L) occurs?" A spill kit is available to use, all lab personnel are trained on how to respond to a spill. A standard operating procedure on how to clean up a spill is written and available for the lab.

"What if a large spill (more than 1L occurs?" Due to dichloromethanes hazards, it would be best to evacuate the lab to avoid unnecessary exposures while attempting to clean up the spill. Evacuate the lab, call the PI and call RMS to notify about the spill to have someone come clean it up.

"What if a spill occurs and glass breaks and someone cuts themselves?" In the event of any personnel being injured, the injury takes precedence. If it is a life-threatening injury, call 911. If it is NOT a life-threatening injury, seek medical help via the student health center or urgent care. The lab should evacuate and contact the PI and call RMS to notify about the incident and injury.

Reviewing Risk Assessments

Once a risk assessment is completed, it should be reviewed by another lab member. If a project risk assessment is being done, then it should go to review by all of those involved in the project. A review of a risk assessment is important to identify anything that has been missed during the initial risk assessment.

Additional Information for Project Risk Assessments

If you are completing a risk assessment for a project, identify the classes of hazards used in the project and any equipment or process hazards. This includes any hazardous tasks in the project (see Oregon State University example below) Assess the risks of each of those hazards and then discuss the control measures that will be used to mitigate or minimize the risks of those hazards. Please include a plan for different types of emergencies.

Include information about who will be working on this project (graduate, undergraduate, post-doc, etc.) and what kind of training they will receive to help mitigate and minimize their risks.

Please see the specific example done by Oregon State University (pg 6).

Tables for Recognizing Hazards

Table of Hazardous Chemicals and Materials

- Compressed Gases – Flammable
- Compressed Gases – Oxidizing
- Compressed Gases – Toxic
- Compressed Gases – Inert
- Cryogenic Materials
- Organic Peroxides
- Peroxide Formers
- Self-reactive Substances
- Water-reactive Substances
- Pyrophorics
- Oxidizers/Reducing Agents
- Acutely Toxic Chemicals
- Carcinogens
- Nanomaterials
- Reproductive Toxins
- Simple Asphyxiant
- Corrosive Liquid
- DEA/Controlled Substances
- Specific Organ Toxicity
- Explosives
- Flammable Liquids

* SPECIFIC hazards and chemicals, biohazards, and materials should be listed when performing an experimental or procedural risk assessment.

Table of Hazardous Processes or Equipment

• Explosion Hazard	• Hand/power tools	• Centrifuge
• Exothermic, with potential for fire or excessive heat	• Moving equipment or parts	• Working alone/afterhours
• Acid Baths	• Electrical hazards	• Unattended reactions
• Hazardous reaction or products	• Noise > 85 dBa	• Respiratory hazard
• Generation of air contaminants (e.g., gases, aerosols, particulates)	• Hot surfaces	• Vacuum/pressure systems
• Heating chemicals	• Ergonomic hazard	• Refrigerators and freezers
• Large volumes	• Needles/sharps	• Sitting and mixing devices
• Chemical transferring	• Drying oven/furnace	• Laboratory microwave ovens

Table of Shop/Laser/Radiation Hazards

Shop	Laser	Radiation
• Aerial Lift	• Class IIIB Laser	• X-ray machine
• Air Compressor	• Class IV laser	• Magnetic field (e.g., NMR, MRI)
• Crane		• Radioactive materials
• Forklift		• Unsealed source radionucleotides
• Hot Work		• Sealed source radionuclides
• Used/new oil		• Ultraviolet Light/Infra-red Light

Resources

- “What is RAMP?” by ACS Institute
- NIOSH’s Hierarchy of Controls
- Oregon State University Risk Assessment Example
- Lab-HIRA: Hazard identification and risk analysis for the chemical research laboratory. Part 2. Risk analysis of laboratory operations
- Proceedings of the 2018 Laboratory Safety Workshop: Hazard and Risk Management in the Laboratory
- Safe Handling of Cannulas and Needles in Chemistry Laboratories
- Lessons Learned - Fluoride Exposure
- Review of the Performance, Selection, and Use of Gloves for Chemical Protection

APPENDIX I: LABORATORY EMERGENCY READINESS GUIDE

All laboratory personnel must be prepared for emergency situations. The intent of this document is to address potential issues that may arise if there is a disruption or major outage of basic services such as electricity, that could affect lab personnel safety and health. The following pages list potential situations that research departments may encounter and how to prepare to face these problems. Although we cannot predict all potential problems, the information provided below should assist your laboratory in their emergency preparations. For more information on emergencies, please reference the Emergency Response Handbook.

For emergency notifications, be on the lookout for Eagle Alerts and follow UNT Emergency Management and Safety Services (@MeanGreenReady) on Twitter, Facebook, and Instagram for information about the weather on campus and other important safety tips.

WHAT HAPPENS DURING LOSS OF POWER?

During loss of power:

- General ventilation to the labs and local exhaust systems, such as chemical fume hoods, will shut down.
    - The loss of ventilation will exacerbate any problems with spills and prevent the work or use of chemicals.
    - Vented chemical storage cabinets would not operate properly. This could cause vapor to accumulate in the labs and building. This vapor could be both toxic and flammable.
- Chemicals requiring refrigeration may warm.
    - This could cause a potential buildup of vapor in chemical bottles, especially if the decomposition product of a chemical is a gas.
    - Prolonged exposure (more than a few days) to warm conditions could cause bottles to rupture due to over-pressurization. Smaller ampoules containing volatile material could rupture sooner.
- Cold rooms, refrigerators, and freezers containing animal carcasses could warm after a few days (depending on building temperature) causing an odor problem.
    - The frost in freezers could thaw depending on building temperatures producing water that could react with chemicals stored in the freezers.
- Incubators and gloveboxes could be compromised due to loss of power.
- Biological safety cabinets and incubators would shut down.
- Autoclaves would not operate.
- Building Fire Alarm Warning Systems are on emergency power and would operate.

In freezing temperatures and a prolonged loss of power and heat,

- Aqueous chemicals may freeze and crack if the temperatures get below freezing in the lab. These aqueous solutions could contain chemicals, biological material, or radioactive material.
- Water in pipes and in the coils of the HVAC system could freeze and rupture.
    - Water could mix with water-reactive chemicals acids, bases, combustible metals, etc.) and cause significant problems (i.e., fire, release of toxic gases, etc.)

Before Power Fails (UNT Emergency Power Outage Document):

Below are some recommendations to help prepare the lab prior to power failure:

- Designate an emergency contact person for your lab. This person should be available for contact 24 hours a day.
    - The Hazard Notification Signage outside the lab should be updated with PI contact information and someone from the lab for emergency contact information.
- Label lab equipment with emergency contact information, allowing for communication in the event of power outages or equipment failure.
    - Label your items with PI name, lab contact name, and at least one primary email and phone number. Keep the labels posted with current information and update as needed.
- Place a "DO NOT OPEN DURING POWER OUTAGE" sign on the freezer doors.
- Equip your emergency/spill kit with a battery-powered flashlight.
- Do not leave open chemicals in the fume hood when the fume hood is unattended. Always safely store chemicals after use.
- Always close the sash of a chemical fume hood if unattended or not in use.
- Put essential equipment on emergency power circuits.
    - Install appropriately-sized surge protection devices for all sensitive or expensive electronics.
    - Consult with Facilities, (940)-565-2700, if you need to install an uninterruptible power source (ups) or other backup electrical systems or equipment.
    - Check to ensure appropriate personnel have been notified if there are critical areas that need power, such as animal areas, research or other special needs.
- Make a list of equipment that must be reset, reprogrammed, restarted, or recalibrated once power returns.
    - Post the list in a conspicuous place.
    - Program equipment that operates unattended to shut down safely during a power failure and not restart automatically when power returns.
- Identify an emergency source of dry ice, if you have items that must be kept cold.
    - Note: Refrigerators and freezers will maintain their temperature for several hours if they are not opened.
    - Do **NOT** use dry ice in walk-in refrigerators or other confined areas.

When Power Fails:

Report outages immediately to Facility Services at (940)-565-2700 during regular business hours or the after-hours building representative assigned to your building. Building representative list can be found at https://facilities.unt.edu/resources/building-rep Below are some recommendations for when there is a power outage.

- IF PRESENT INSIDE OF LAB AND ABLE:
- Stay calm. Stop and shut down or stabilize experiments that involve hazardous materials.
  - Make sure experiments are stable and won't create uncontrolled hazards.
  - Turn off all heat sources (gas or electric burners) to prevent fires.
- Check fume hoods and biosafety cabinets and take the following precautions, if applicable:
  - Stop any operations that may be emitting hazardous vapors, fumes, or infectious agents.
  - Securely cap any open containers.
  - Close fume hood and biosafety cabinet sashes.
  - Turn off all gas cylinders at the tank valves. If a low flow of an inert gas is being used to "blanket" a reactive compound or mixture, it may be appropriate to leave the flow of gas on.
  - Check all cryogenic vacuum traps (N_2, CO_2 + solvent). The evaporation of trapped materials may cause dangerous conditions.
- Check equipment on emergency power to ensure it is running properly.
  - Note: It may take 20 to 30 seconds for emergency power to activate after a power failure.
- Reduce electrical use and risk of power surges by:
  - Disconnecting unattended equipment and turn off unnecessary equipment.
  - Turning off unnecessary lights

After the following above steps, evacuate the lab as the ventilation and exhaust systems will be off and remain in a safe location (determined by your laboratory procedures). Back-up generators will supply emergency lighting to most areas. Stay clear of all machinery during the power outage.

If you are NOT present inside of the lab while the power goes out *and* it is NOT safe to go into the lab to check on the above list of items – remain in a safe location until the power turns back on. **Discuss these above items with your PI and determine the best course of actions for your laboratory in the event of a power outage.**

After Power Turns On:

Below are some recommendations for after the power turns on:

- Check for unusual odors. Could be the sign of a leak or spill.
  - Contact RMS, (940)-565-2109, or Chemical Hygiene Officer, Laboratory Safety Officer, or Radiation Safety Officer (Environmental, Health, and Safety, EHS contacts) if you need help with a spill or clean up.
- Check equipment.
  - Reset and restart equipment.
    - If building systems, including fume hoods, fail to restart or operate correctly, contact Facilities, (940)-565-2700.
    - If non-building equipment fails to restart or operate correctly, contact the manufacturer or service provider.
  - Confirm air flow in your fume hood is restored before use.
  - Recalibrate and reprogram equipment as necessary.
- Keep doors closed on refrigerators and freezers that failed until they have been repaired and returned to safe working temperature.
  - **Note:** Some refrigerators and freezers require a manual restart.
- Check the temperatures in your cold storage units. Reset alarms if needed.
- Reset or plug in all the equipment as needed and check to make sure they are functioning properly.
- If system or equipment failures create hazardous conditions, immediately notify RMS, (940)-565-2109, or Chemical Hygiene Officer, Laboratory Safety Officer, or Radiation Safety Officer (EHS contacts).

OTHER POTENTIAL EMERGENCIES

Loss of Water

- Water cooling systems for equipment (i.e., distillation apparatus, some cold rooms) would not work.
- Sprinklers, emergency eyewash units, and safety showers would not work.

Some recommendations are:

- Stop and shut down or stabilize experiments that involve a water cooling system
  - Make sure experiments are stable and won't create uncontrolled hazards.
  - Close fume hood and biosafety cabinet sashes.
- Do not allow lab operations involving hazardous chemicals to resume until water returns.

RECOMMENDED PREPARATION PRIOR TO EMERGENCIES

- Departments should develop a call tree to support mitigating efforts. For each laboratory, the names and phone numbers of responsible personnel should be listed. A copy of this list should be made available if necessary, during emergencies.
- Toxic and flammable gases to equipment should be turned off immediately after use.
- All chemical containers must be capped at all times to prevent vapors from escaping.
- Inventory potentially infectious materials in the lab and prepare to decontaminate and dispose of these materials should freezers and/or incubators fail.
  - Do not allow biological waste that needs to be autoclaved to accumulate.
- Identify equipment, such as ultra-low freezers, that must have continuous power. Check with Facilities to ensure these units are on emergency power.
- Ensure that lab door signs have up-to-date information for contact information.
  - If you have not updated your Hazard Notification Signage with contact information and emergency contact information, please contact either the Chemical Hygiene Officer, Laboratory Safety Officer, or Radiation Safety Officer with the updated information.
- Any chemicals that could potentially freeze (i.e., aqueous solutions) should be placed in secondary containers prior to a freeze.
- Remove chemicals from areas where water pipes may freeze overhead prior to a freeze.
  - If these chemicals will be moved, they should still be stored appropriately according to Section 7 of their SDS.

RECOMMENDATIONS FOR DURING AND AFTER EMERGENCIES

- Do **NOT** allow lab operations to resume if power, water, or fire warning systems fail.
- ***If a lab has been without power for more than a few hours, once power resumes: enter any laboratory cautiously***.
    - If an odor is present, allow the ventilation system to operate for a period of time before entering.
- Contact RMS, (940)-565-2109, or Chemical Hygiene Officer, Laboratory Safety Officer, or Radiation Safety Officer (EHS contacts) prior to re-entry if you suspect storage issues relating to hazardous materials or potentially infectious materials.
- Report failure of any storage device (refrigerator, freezer, scintillation counter) that contains radioactive material to the Radiation Safety Officer.

GUIDANCE FOR WINTER BREAK AND OTHER LONG BREAKS

During long breaks (i.e., winter break), most of the lab might be planning on vacation or leaving town. Discuss with your PI about laboratory specific procedures for these situations below.

- *If there will not be anyone* around campus or in the lab during long breaks, please follow the information below under "Temporary Lab Closure or University Closure."
- *If there will be a few people from the lab,* please follow the guidelines below.
    - Try to avoid working alone in the laboratory. If there will be another person staying for over the break, plan work schedules with them.
        - If this is not possible, the PI, Lab supervisor, another lab member, or another member of the department that is close to or on campus, needs to be made aware that you are working alone. Plan for check-ins so that you have someone to check with your that you are okay.
    - Perform risk assessments of all your experiments – try to mitigate your risk as much as possible. Remember that all experiments performed alone is HIGHER RISK just from working alone.
    - Plan for emergencies when working alone and talk with your PI about the proper actions to take. Emergency planning while working alone is VERY different than when working with other people around – take this into consideration.

- **<u>After everyone is finished working in the lab every day, EVERY person should check their own personal spaces. The last person to leave should check that:</u>**
    - Chemical fume hoods and biosafety cabinets sashes are shut properly.
    - All chemicals have been put away and stored in their appropriate places.
    - Turn off all water such as circulating water baths, water aspirators and distillation systems.
    - Turn off and unplug all non-essential electrical devices particularly heat-generating equipment such as hot plates, stir plates, and ovens.
    - If possible, elevate equipment, supplies, electrical wires, and chemicals off the floor to protect against potential flooding (i.e. broken pipes, heavy rain).
    - Check that all essential equipment (refrigerator, freezer, other equipment) are plugged into emergency outlets.
    - Tightly close all refrigerator, freezer and incubator doors.
    - Close all gas and vacuum valves/lines.
    - Secure all gas tanks and close all gas cabinets.
        - Close tanks and if possible, remove regulators and place screw caps on tanks. NOTE: Leave inert gas flowing if it is being used to blanket reactive compounds or used for inert atmosphere gloveboxes.
        - Ensure cryogenic liquids are properly vented.
    - Decontaminate/disinfect all potentially contaminated surfaces.
- Note that hazardous waste pick-up will not occur during Winter break (usually includes the Thursday and Friday prior to break). Plan to have waste requests in three – two weeks prior to a break.

Checking these items after leaving the lab every day will ensure that the lab is prepared in the event of severe weather or power outage that those who are here cannot make it to lab safely. If the weather conditions are unsafe, do NOT go into lab. Your safety and well-being are a priority over everything else.

GUIDANCE FOR TEMPORARY LAB CLOSURE OR UNIVERSITY CLOSURE

In the event of a temporary laboratory closure (e.g. summer field work, group conference, etc.) or a University closure (e.g. severe weather, pandemic disease, etc.), labs must review their critical operations and complete this temporary shutdown checklist according to their specific activities and hazards. Customize the checklist for your specific needs/operations as needed. This list is adapted from University of Arizona Procedure for Temporary Laboratory Closure.

Principal Investigators are ultimately responsible for:

1. Ensuring that all lab operations have been accounted for, and that any hazardous materials/equipment are secured in the event of a planned or unplanned temporary lab closure; and,
2. Identifying personnel able to safely perform any required closure procedure and any critical operation during the temporary closure period.

Preparations for Lab Closure

1. Identify any critical equipment, research materials (biological, chemical or radiological), or processes that building managers should be aware of such as freezers, temperature sensitive areas, etc.
2. Identify/modify all orders of security sensitive materials, plan for the receipt and locked storage of these materials if necessary.
3. Prepare hazardous biological, chemical and/or radiological waste for disposal and arrange for a waste pick-up prior to leaving or closure.
4. Verify that written lab SOPs include steps for shutting down critical equipment or processes including those that are temperature, pressure, or air sensitive – includes glove boxes and distillation equipment.
5. Contact RMS, (940)-565-2109, if you have any questions during temporary closure.

Temporary Lab Closure Checklist

- Experiments

1. Reduce or cease all unattended experiments/processes and all experiments that need monitoring, are temperature or humidity sensitive, or could be affected by loss of electricity, water, or other services.
2. Back up all data and turn off computers. Store lab notebooks and computers in areas that will not be impacted by possible broken water pipes. Secure laptops and other easy to remove electronic devices.

- Equipment
  1. Close sashes on chemical fume hoods and biological safety cabinets.
  2. Turn off biological safety cabinets and UV lights.
  3. Turn off all water such as circulating water baths, water aspirators and distillation systems.
  4. Turn off and unplug all non-essential electrical devices particularly heat-generating equipment such as hot plates, stir plates, and ovens.
  5. If possible, elevate equipment, supplies, electrical wires, and chemicals off the floor to protect against potential flooding (i.e., broken pipes, heavy rain).
  6. Tightly close all refrigerator, freezer and incubator doors.
  7. Secure all gas tanks and close all gas cabinets.
  8. Close all gas and vacuum valves/lines.
     a. Close tanks and if possible, remove regulators and place screw caps on tanks. NOTE: Leave inert gas flowing if it is being used to blanket reactive compounds or used for inert atmosphere gloveboxes.
     b. Ensure cryogenic liquids are properly vented.
- Materials
  1. Properly label, close, and place all hazardous (biological, chemical, and radioactive) materials in appropriate storage areas away from incompatible hazards.
  2. Properly store all air/water reactive chemicals.
  3. Secure all security sensitive material in appropriate storage units that are properly labeled.
  4. Decontaminate/disinfect all potentially contaminated surfaces.
  5. Review storage of biologicals and other perishable items. Place valuable biological research items in temperature-controlled storage units that have backup systems or store items in duplicate locations. Review safety and other issues for the use of alternate cooling methods (e.g., liquid nitrogen, dry ice, etc.).
- Lab Specific Items
  1. Identify any lab specific items that need to be done prior to a temporary laboratory closure.

- Final Checks
    1. Notify appropriate personnel of temporary closure (i.e., department head, building manager, etc.)
    2. Close all doors, including cabinets, storage areas and offices. Lock all exterior lab doors.

CONTACTS

- Emergencies and Life-threatening situations: 911
- Campus Police: (940)-565-3000
- Emergency Management and Safety Services: emergency.management@unt.edu, 940-369-6153
- Risk Management Services: AskRMS@unt.edu, (940)-565-2109

EHS contacts: Chemical Hygiene Officer, Laboratory Safety Officer, or Radiation Safety Officer

RESOURCES

The resources used to create this document:

1. University of Rochester, Environmental Health & Safety Laboratory Safety Unit Emergency Readiness for Research Laboratories
2. UNT Power Outage Information
3. University of Hawaii, Manoa Lab Safety Emergency Procedures During Power Outages
4. Yale Laboratories and Power Outages
5. UC San Diego How to Prepare for a Power Failure in a Lab
6. University of Arizona Procedure for Temporary Laboratory Closure

APPENDIX J: INSPECTION GUIDE (UNDER PREPARATION)

APPENDIX K: CHEMICAL INVENTORY GUIDE

What is a chemical inventory?

A chemical inventory is an overview of all chemical substances and mixtures (including gas cylinders) used in a laboratory.

A complete chemical inventory includes

- ✓ Product name of each chemical,
- ✓ Amount of each chemical,
- ✓ Type of container it is stored in,
- ✓ Date the chemical was received,
- ✓ Location of the chemical,
- ✓ Specific storage area of the chemical,
- ✓ The name of the owner.

Some other items a chemical inventory might include

- ➢ If a chemical was moved or borrowed,
- ➢ When a chemical was received and opened,
- ➢ When a peroxide former was last tested,

- And discard date.

Each laboratory is required to maintain an updated and current chemical inventory.

Why is a chemical inventory important?

There are a few reasons as to why a chemical inventory is important.

1. Ensure compliance with storage limits and fire regulations,
2. Used in emergency situations to identify potential hazards for emergency response operations
    - Without a chemical inventory on hand, emergency responders cannot assess the situation and respond safely for themselves and everyone present
        - See this story about a UC Irvine lab. The responders decided it was safer to let the fire burn out instead since they did not know what was in the lab.
3. *Your chemistry will be easier!*
    - Having an accurate and updated inventory will allow you to know what chemicals you have in your lab and how you can easily find them.

Who is responsible?

The responsibility of a chemical inventory ultimately lies with your principal investigator or laboratory supervisor.

- **HOWEVER,** everyone that works in the lab is responsible for the upkeep and reconciliation of the chemical inventory.

Although a chemical inventory can at first be daunting to start and keep up with, it can be quite easy to maintain if certain steps are taken.

So where do we start?

Starting a chemical inventory can be a HUGE task. Below is a step-wise on how to approach starting a brand-new chemical inventory.

1. Decide on a system to keep your chemical inventory.
    a. Some institutions have their own chemical inventory management software.
    b. Some do not have one (like UNT – although we are working on this!)
    c. One system to use is Excel, others could be free software like Chemical Management System or Quartzy.
    d. Choose something that is best fit for your lab and institution!
2. Organize your document, if using Excel, make a template
    a. Depending on your choice of system, it might already have all the required fields necessary for a chemical inventory.
    b. If you are using Excel, you will have to make a template with all the required fields (discussed above)
        i. RMS already has a template for you to use – contact us for the blank template.
3. Come up with a plan.
    a. Some of our labs have over hundreds of chemicals which is a huge task to inventory.
    b. Start out with a plan for all the lab members.
        i. Choose a day or an hour a week until it's completed and divide up the work evenly.
        ii. Have one person take inventory of a particular cabinet or assign multiple people to a large cabinet or area. Assign people to the areas they use frequently!
        iii. If everyone works together, a chemical inventory can be finished quickly!
        iv. It is a good idea to work in pairs – have one person typing the chemical in, while another is reading out the chemical name, amount, bottle, and locations.
4. Once finished, back it up!
    a. Keep a separate copy of the inventory in case of emergency.
    b. The inventory should also be accessible outside of the lab as well.
        i. This is in case of emergency and you cannot get to the physical copy inside the lab.

        ii. It is best to keep the inventory on a drive like Google drive or One drive so it can be accessed outside of the lab or group computer.

5. *Keep up with it.*
    a. Now that your lab has done all that work – keep up with it.

The next few sections will discuss how to do just that!

Receiving and Using Chemicals

When your lab receives new chemicals…

- Input these into your chemical inventory immediately!
    - This will help you during reconciliation – you won't have to do much work every year to re-do an entire inventory if you've kept up with this!
- Always mark the date the chemical was received.
    - Make sure to keep track of when the chemical was received written on the physical bottle as well as in your inventory.
    - This will enable you to know when the chemical is past shelf-life and should be discarded.
    - If you know the disposal date – mark that too!

Discuss with your PI and Laboratory Supervisor about who has access to the inventory and make a plan on how to update it when receiving and ordering chemicals.

- ➢ If everyone has access to update the inventory, then it might be best if each individual is held responsible for those chemicals.
- ➢ Sometimes if a single individual is doing the ordering – it might be easier for them to always input the chemicals as they are received.

When your lab uses chemicals…

- Ensure that when a chemical container is empty or being disposed of, it is removed from the inventory.
    - Even if you are re-ordering a new bottle – for the time being, that chemical is no longer in your lab.

        - You can update the chemical in the system by removing the amount and received date and mark ‘ordered’ as a place holder instead.
    - Once removed from the inventory – make sure to discard the chemical container appropriately.
        - Make sure to check with your PI, Waste Management, and the SDS (or other resources) about how to properly dispose of the chemical and/or empty container.
- ➢ When you always remove a chemical container as soon as it is empty, you avoid having a false duplicate in your inventory.
- ➢ This will also help you avoid having more chemicals on record than physically accounted for.

Moving Chemicals

If you need to move a chemical between lab spaces, update the location in the inventory!

- This will prevent duplications and will prevent you from having to search for that chemical.
- If the chemical is being borrowed, make sure to mark that in your inventory and who borrowed it.
- This will also ensure that you are aware of where your chemicals are at all times.
    - Always make sure that the chemical that is being borrowed can be used by another lab (<u>check with both PIs and the policy of the labs prior to borrowing chemicals</u>)
- **REMEMBER** to follow proper protocols when transferring chemicals, such as utilizing proper PPE during transport and using a secondary transport container for the chemical bottle.

<u>If all lab members do their part – it makes your yearly reconciliation VERY EASY!</u>

Yearly Reconciliation

<u>Yearly reconciliation</u> is the annual process of comparing your physical inventory counts with records of inventory on hand. This is the yearly chemical inventory update request.

If you have not kept up with your inventory, yearly reconciliation can be a frustrating and difficult task.

- It can be like re-doing a new chemical inventory all over again.
- Some ways to avoid this are
    - Performing a bi-annual reconciliation
        - Take a few days every 6 months to reconcile and go through your physical inventory and compare it to your current and add or remove any chemicals to your inventory list.
    - Keeping a record of purchase orders
        - If you keep a record of your POs with name of chemical and amount, it can be easier to find where that chemical is located to update your inventory.
    - Do small checks throughout the year of certain cabinets.
        - Reconcile (check) a cabinet once a month for the physical inventory vs your record of that cabinet.
        -

Tips and Tricks for Maintenance

A Chemical Inventory is a living document; thus, it requires your work and responsibility to keep it up to date and accurate.

Unfortunately, there are no easy “tips and tricks” for maintenance of your inventory – however, following everything so far, if you take

- 2 minutes inputting a chemical when you receive it,
- 2 minutes removing a chemical when you discard or finish it,
- 2 minutes changing the location of a chemical when you move it,
- And 2 minutes keeping purchase orders organized.

Those 8 minutes are better than many hours and days’ worth of attempting to reconcile your entire inventory every year when you notice that your physical inventory is off from your records.

<u>As a reminder: Chemical Inventory is due annually.</u>

If you are facing difficulties reconciling your inventory, please do not hesitate to reach out to the Chemical Hygiene Officer to talk about what steps your lab can take to make this easier.

Some suggestions are:

- Reconcile a small section with partnered lab mates twice a week.
  - This 'section' should be designated such that it takes less than an hour per day to complete.
- Take a working day to reconcile your inventory with all lab members participating
  - Take one day to complete this. If you have a much larger inventory, you might need two or more days.
- If you notice chemicals that are OLD or past shelf-life OR the integrity of the bottle is weak (rusting, oxidation) – please consider DISCARDING these chemicals and removing it from your inventory. Fill out a Hazardous Waste Pick-up
- If you have LEGACY CHEMICALS – discuss with your PI about discarding, especially if they are unknowns. See below for more information.

Chemicals to be Aware of

- If you notice any chemical bottles that are distorted OR expanded, please do not move or touch them. Submit a waste pick-up request and alert your PI and RMS immediately.
- If you have ANY of the following chemicals, please follow the information below
  - ***Peroxide formers*** (common solvents: IPA, Et_2O, THF, dioxane)
    - if you have peroxide formers and you notice crystallization or cloudiness – DO NOT MOVE OR TOUCH – contact your PI and RMS immediately for a waste pick-up.
    - *Peroxide formers that are cloudy or crystalline are shock-sensitive and can **explode.***
    - When reconciling your inventory - This would be a good time to test your opened bottles for peroxides.
    - Check the specific chemical for which class it falls into – you may need to test the bottle every 6 months.
    - Obtain peroxide test strips

        - Portion out a small amount of the chemical (2 – 3 mL) and immerse the end of the test strip for about 1 second. Allow the test strip color to stabilize (about 30 seconds) and compare the test strip color to the colorimetric scale provided on the test kit bottle.
    - Please see this resource for information on peroxide formers and inorganic peroxides.
        - **<u>Inorganic peroxides (H_2O_2 or M_2O_2)</u>** <u>have special considerations for chemical compatibility and containers.</u>
- ***<u>Picric Acid</u>*** <u>(solid or as part of a premade stain or solution)</u>
    - Pure picric acid is a **shock-sensitive explosive**. For that reason, it is shipped wet (or in solution), and it should be checked for its water content quarterly. Do NOT open a bottle that appears to be dry or that has not been checked for a long time – IMMEDIATELY CONTACT RMS.
    - Keep a running track of when it is checked (can be useful as a part of inventory).
- ***<u>Perchloric Acid</u>***
    - 70% perchloric acid is stable, however many of its salts (perchlorates) are **shock-sensitive explosives**. Old perchloric acid bottles may have formed crystals that are explosives.
        - If you discover an old bottle of perchloric acid, IMMEDIATELY CONTACT RMS. Do **NOT** attempt to move or open.
- ***<u>Hydrofluoric Acid</u>***
    - Hydrofluoric acid is stored in plastic bottles. The plastic material deteriorates with time and becomes brittle.
    - Hydrofluoric acid is highly toxic - a minor exposure can have serious consequences.
    - If your lab has HF – please make sure you have calcium gluconate (Calgonate) on hand – check to make sure it is not expired, if it has, please obtain a new one.
        - Please make sure your lab also has an HF specific spill kit.
    - Do NOT store hydrofluoric acid in glass, it can dissolve glass (do NOT use glass waste containers for hydrofluoric acid).
        - If you discover an older bottle of hydrofluoric acid, do NOT attempt to pick up or move. IMMEDIATELY CONTACT RMS.
- ***<u>Hydrazine</u>***

    - Hydrazine and other corrosives can cause corrosion of the container lid causing a leak that allows toxic vapors to escape.
        - If you notice a corroded bottle, submit a hazardous waste pick-up request.
- ***Legacy Chemicals and Unknowns***
    - Legacy chemicals: unused chemicals that are stored for many years, often inherited chemical stocks from previous lab occupants.
    - These chemicals are often in the back of cabinets, desiccators, or drawers for many years, unnoticed and unused.
        - These chemicals can take up valuable space and some chemical can become dangerous as they age
        - Small leaks can go unnoticed and can cause violent reactions and generate toxic fumes.
    - If you have any legacy chemicals or unknowns – discuss with your PI about discarding these and contact RMS for a hazardous waste pick-up request.

Chemical Storage

- Store chemicals in compatibility groups. Place barriers between groups.
- Store chemicals in a manner that minimizes spilling or leaking. Use secondary containment.
- Minimize the number of chemicals in your lab.
- Be aware of legacy chemicals. If it's likely not going to be used again, dispose through Hazardous Waste Program.
- Some resources are:
    - Chapter 3 CHP
    - Appendix B: Chemical Segregation
    - Chemical Incompatibility Information Sheet
    - Nitric Acid Waste Incompatibility Info

APPENDIX L: LAB EQUIPMENT GUIDE (UNDER PREPARATION)

APPENDIX M: LABORATORY MANAGEMENT GUIDE

Safe work habits and general guidelines that apply to various types of laboratories are included in this section. Principal Investigators and Laboratory Supervisors are encouraged to develop laboratory-specific rules from the general guidelines or the references that have been incorporated into this safety manual.

The general rules are directed primarily toward prevention of toxic exposure and do not include rules and procedures for prevention of physical injury. Safety in Academic Chemistry Laboratories, contains recommended techniques for safety operation of equipment such as: electrical equipment, glassware, distillations, low and high temperature operations, vacuum and high-pressure operations, emergency procedures, etc.

Fundamental Rules for Laboratory Hygiene

- General Lab Rules
  - Do not eat, drink, smoke, chew gum, or apply cosmetics in the laboratory.
    - Do not bring food into the laboratory.
  - All laboratory personnel must also be careful to restrict other actions (such as applying lip balm, rubbing eyes, or using personal electronics such as cell phones) which could inadvertently cause exposure to research materials.
  - Consuming alcohol or taking illegal drugs in a research laboratory are strictly prohibited as such actions potentially endanger the health and safety of not only the user, but everyone in the building. Infractions will be met with serious disciplinary action.
  - Do not put any objects, i.e., pencils, fingers, swabs, etc. in the mouth, ears or nose.
    - Mouth pipetting is forbidden.
  - Cover all cuts, abrasions, open sores and bruises with waterproof tape or disposable gloves and report all injuries to your supervisor.
  - Do only authorized work; no horseplay should take place in the laboratory.
  - Read all labels and warning signs.
  - Keep the work area tidy and free of unnecessary equipment and materials.
  - Clean up all spills and leakages immediately (if you are capable of doing so). See Ch 8 for instructions for spills.

  - All electrical equipment should be grounded and kept in good condition.
  - Keep all corridors, doorways and emergency exits free from hazards and accessible.
  - Acquaint yourself with local procedures in case of fire, incident, explosion or other emergency, by learning the layout of your building.
- Laboratory Dress Code
  - Long pants/skirts and closed toe/heel shoes are required in all areas where hazardous materials are stored and used. Exposed skin should be minimized, especially when working with hazardous material.
    - Shoes that leave the top portion of your foot exposed are NOT acceptable footwear.
  - Synthetic clothing should be avoided, especially around flammables. A flame-resistant hood can be added if using a cotton religious garment is not an option.
  - Before leaving the laboratory, remove lab personal protective equipment/clothing (gloves, lab coat, etc.) and wash hands thoroughly. Do NOT wear laboratory gloves, lab coats, or scrubs in public spaces such as hallways, elevators, or cafeterias.
    - Keep your lab coat buttoned while working in the laboratory.
  - Hair should be tied back, if shoulder length or longer.

<u>Safe Work Habits</u>

<u>Housekeeping</u>

General housekeeping is an integral part of chemical hygiene and a good safety practice. A clean work area is much safer than a cluttered or dirty one. Some appropriate housekeeping measures include:

- Keep all aisles, hallways, and stairs clear of all chemicals.
- Keep all work areas, especially work benches, clear of all clutter and obstructions.
- All working surfaces and floors should be cleaned regularly (if possible).
- Access to emergency equipment, showers, eyewashes and exits should <u>**NEVER**</u> be blocked.
- Wastes should be kept in the appropriate containers and labeled promptly and properly.
- Laboratory personnel should be considerate and aware of housekeeping staff.

- The typical housekeeping staff is not properly trained in the handling of chemicals and should not face situations where they must make decisions regarding the proper handling or storage of chemicals.
- ALL chemicals should be placed in proper storage areas by the end of each workday; all spills should be promptly cleaned up with arrangements made for waste disposal; and all chemicals should be properly labeled.
- OR the regular trash bins and recycling bins should be placed outside of your laboratory at the end of each workday.

Lighting and Noise Levels

Lighting - it is essential that each work area have sufficient lighting.

Noise levels - should not exceed those recommended by OSHA, generally 85 db.

If the noise level is in excess of the standard, efforts must be made to reduce the level. (Possible solutions are: enclosing noisy equipment, acoustical treatment of walls or ceiling, vibration damping of noisy machines, replacing metal to metal contact with synthetic material to material contact).

Electrical and Thermal Equipment

Electrical Equipment

- Always read the instructions before attempting to assemble apparatus or to operate it.
- All equipment must be U.L. approved and have three prong plugs.
- Do not use cords with worn insulation. Replace connections immediately when there is any sign of thinning insulation.
- Make sure the wire is dry before plugging it into any circuit.
- Electrical units which are to be operated in an area where to flammable vapors may be present should be explosion proof.
- Disconnect all electrical equipment before servicing. Electrical service supply should be well grounded with adequate circuit protection.
-
    - Bench tops made of conducting material e.g. (stainless steel) should be grounded.
    - No connections to the main service lines should be made by anyone but a licensed electrician.

- Multiple adapters which can lead to overloading and bad connections should never be used.
- Fuses or circuit breakers of the correct rating should be used on all equipment at all times but "ground" connections must never be fused.
- Labs should have sufficient outlets, suitably spaced to allow for convenient connection of each item of electrical equipment likely to be used at one time.
- The following signals are indicative of electrical hazards and should be corrected if found:
    - Shock received when touching any part of electrical equipment.
    - Power receptacles which are the non-grounded type (two wire instead of three wire) or are cracked or do not hold the plug securely.
    - Power plugs having only two prongs which are connected to a receptacle through a "cheater" (grounding plug to non-grounded receptacle adapter) or have bent or broken pins.
    - Power cords which are frayed, burned, nicked, cracked, or otherwise damaged or are so short that they require an extension cord. Power cords having lengths in excess of the distance between the equipment and the electrical outlet must be <u>neatly</u> coiled. Power cords running across the floor where personnel must walk.
    - Equipment which is dirty or shows evidence of fluid spillages or has been obviously damaged.
    - Multiple electrical equipment attached to an adaptor.
    - Electrical noise shown on meter readings, scope patterns and strip chart recorder traces making them difficult or impossible to read.
    - Wet or moist surfaces on electrical equipment.
- <u>Outlets</u>
    - Should be checked for grounding using a circuit tester every three (3) months as part of routine laboratory inspection.
    - **<u>Electrical Shock</u>** - Turn off electricity first. If the patient is not breathing, begin artificial CPR immediately and then phone for emergency assistance.

<u>Thermal Equipment</u>

- Heating baths
    - Be sure the thermoregulator works properly.
    - Water baths must be checked daily for temperatures and water level.
        - Do **NOT** use a water bath for temperature up greater than 70°C as a dry glass bath can break when used on hot plates at high temperatures.

- Oil baths
  - Mineral or silicone oil is typically used for reactions required heating/reflux temperatures up to 200°C.
  - Provides more uniform heating, however the flask is more slippery to handle and oil can degrade or turn brown over time
  - Oil baths should be used in aluminum or stainless steel pan, heavy porcelain dish or thick walled Pyrex glass to withstand possible breakage or accidental spill.
  - should not be used without a variable autotransformer, known commonly as a variac.
    - Variacs control the voltage and can be adjusted to increase or decrease temperature setting of the oil bath.
    - Heating mantles should **NEVER** be plugged directly into an outlet
    - Inspect variacs thoroughly before use – check for any burnt odor, damaged power cords and connectors.
    - To prevent the static electricity and protect the coils from contacting the enclosure or core, ground the transformer.
- Sand baths
  - Can be used for temperatures up to 500°C.
  - Easier to clean up and reuse and is inert to organic materials.
  - For vacuum distillations – do **NOT** let distillation flask become dry as at high temperatures and vacuum, dry glass flask can become soft and implode.

- Autoclaves/ovens – use appropriate PPE and heat-resistant gloves when handling and using autoclaves and ovens
  - Do **NOT** use or place any flammable, combustible, reactive, corrosive, toxic, or radioactive materials with or inside of autoclaves/ovens.
  - For autoclaves,
    - Check for plastics that are compatible – not all plastics can be autoclaved.
    - Check glassware for cracks – do not autoclave compromised glassware
    - With liquids, leave caps loose or cover with foil to allow steam penetration and prevent explosion
    - For bagged items, loosely tape or tie closed and leave an opening for steam to penetrate the bag.
    - Autoclaves must be tested. Contact with the Biosafety Program Manager for more details.
  - For ovens,

        - If oven is operating outside of normal parameters, it must be taken out of service until repairs can be made. Place “DO NOT USE. OUT OF ORDER” signage.
        - Inspect oven prior to use
            - Check cords for damage
            - Check oven calibration to ensure the temperature read-out is accurate (NEVER use a mercury thermometer for this)
            - Check the door seal
        - Arrange samples evenly throughout oven and do not place too close to interior walls.
        - Do **NOT** load bottom of interior to avoid risk of overheating samples placed there.
        - Check that oven is set to appropriate temperature required for use during either experiment or for drying glassware.
            - **DO NOT** place wet glassware or glassware with solvent inside of oven.
        - Do NOT store combustible materials such as plastics, paper, and cardboard on top, under, behind, or next to the oven.
        - Do NOT store any flammable chemicals near the oven.
- Hot plates
    - Do not use a hot plate for refluxing or distillation – use the appropriate bath for your experiment.
    - Inspect hot plate prior to use
        - Check cords for damage or fraying
        - Check the hot plate is heating appropriately
    - If heating a flask or beaker on a hot plate - Do **NOT** leave unattended.
    - Check experimental set up that any tubing or electrical cords are not in direct contact with the hot plate.
    - Once done with hot plate, UNPLUG and ensure that the hot plate has cooled down prior to moving.
        - **NEVER** leave a hot plate plugged in or on if unattended. Hot plates can sometimes heat uncontrollably regardless of temperature setting or whether controls are in the off position.

Laboratory Ventilation

Laboratory ventilation is a key factor in controlling employee exposure to hazardous substances. Ventilation is provided in two ways: through the facility's heating and air conditioning system, and through fume hoods utilized in the laboratory.

Fume hoods – Details on use of Fume hoods can be found in Ch 7.

- OSHA defines a fume hood as a "device located in the laboratory which is enclosed on five sides with a moveable sash or fixed particle enclosure on the remaining side.
- It is constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory.
- It allows chemical manipulation to be conducted in the enclosure without insertion of any part of the body other than the hand and arm.
- Walk-in hoods with adjustable sashes meet the above requirements if the sashes are adjusted during use so that the airflow and the exhaust of air contaminants are not compromised, and employees do not work inside the enclosure during the release of airborne toxic substances.
- Following are additional requirements applying to fume hoods in the laboratory:
    - Ventilation will not be obstructed or modified except by qualified mechanical engineers.
        - Ventilation in areas where noxious fumes or flammable liquids are handled should provide a minimum of six air changes per hour.
    - Fume hoods are used for the safe handling of noxious, corrosive, or volatile chemicals.
    - Fume hoods are not to be used as a substitute for Biological Safety Cabinets (laminar flow hoods).
- The following policies concerning fume hoods in the laboratory will apply:
    - <u>Toxic fumes</u>: Whenever toxic substances, corrosive aerosols, carcinogens, mutagens or teratogens are handled in a fume hood, the minimum face velocity must be 100 cubic feet per minute (fpm).
        - For effective use, materials should be handled at least six inches away from the hood opening.
    - <u>Inspection</u>: All hoods will be inspected at least annually by a qualified, contracted engineer.
        - Anytime a fume hoods air handling system is altered or serviced, the hood must be inspected before being placed in service.
        - Any new fume hoods installed must be inspected by the contracted engineer before being placed in service.

- Inspected hoods shall have a sign affixed to them stating the inspection interval, last inspection date, average face velocity, location of the fan that serves the hood, and the inspector's name and dated initials.

Signage (Link to online signage upload).

- Signage is required for all containers, designated work areas and storage locations (see chemical labeling).
- Sign wording must state the following, or similar, as appropriate for the specific chemical hazard: “DANGER, CANCER HAZARD – SUSPECT AGENT” “DANGER, CANCER HAZARD – REGULATED CARCINOGEN” “DANGER, REPRODUCTIVE TOXIN” “DANGER, ACUTE TOXIN”
- Entrances to designated work areas and storage locations must include signage, “AUTHORIZED PERSONNEL ONLY”, in addition to the above specific hazard warning wording.
- All labs must have the appropriate signage placed on each lab door including the Principal Investigator name and contact information, a secondary emergency contact that is present on campus, all hazards located within the lab, and required PPE for entry.
- Appropriate signage must be in place if laboratory has lasers or radiation hazards. Please contact the Radiation Safety Officer for more information.
- Signage for medical emergency information and insurance information should be posted in the lab.
- Signage is required for all refrigerators, freezers, and microwaves.
    - If appliance is used for chemicals, chemical signage must be placed with associated hazards and warnings.
    - If appliance is used for food, clean area signage must be placed.

Clean Areas (for labs that have desks inside of them and labs that do not have separated offices)

A clean area is an area within a lab room approved by RMS as safe for the storage and consumption of food and beverage.

To start implementing clean areas,

1. Remove and permanently exclude all chemicals, select agents, and all equipment from area.
    a. If necessary, relocate all hazardous materials use and storage and maintain separation (at least 5 feet) from the area).

2. Ensure newly designated clean area has been cleaned or neutralized.
3. Ensure that radiation exposure rate in the clean area is <0.05 mR/hr
4. Once steps 1-3 are completed, contact RMS to review clean area.
    a. Follow proper chemical hygiene and when entering clean areas, remove gloves and lab coats or other potentially-contaminated PPE and wash hands thoroughly.

Overnight / Late Experimentation

Overnight or late-night experimentation can be quite dangerous since oftentimes the lab personnel working late hours are working alone. Experiments that are left to run overnight have the potential for more dangerous incidents because no one is around. Plan experiments accordingly. If experiments will take a longer time to perform, do not start them late in the evening. It is better to start the next day than to work overnight or late night and alone. *It is recommended to NEVER work alone. It is also best to NOT work when exhausted or tired.* When a lab personnel is exhausted or tired and continues to work, it is more likely for an accident to occur.

Below is a guide to help those who wish to work overnight or those who work late nights stay safe.

- Make multiple people aware that you are working overnight or late.
    - PIs or Lab Supervisors are **required** to be aware of who is working overnight or late nights.
    - Let a lab member know that you will be working overnight or a late night.
- Set check-in times with a lab member or PI.
- Perform a risk assessment of your experiment (see Ch 4. Risk Assessment)
    - Work through preparing for emergencies if you are the sole person in the lab. This can look very different than usual emergency preparation.
    - Have the list of emergency numbers for campus on hand.
- Discuss the experiment with your PI to ensure the correct procedures are being performed.
- If an experiment is being performed overnight or is left overnight, post a notice on the door.
    - This notice should include hazardous procedures, chemicals being used in the reaction, and any other important information about the reaction (i.e., reflux, sublimation, potentially explosive, etc.)
    - This notice should also include name and phone number of the person who set up and is running the experiment.
    - This notice should also include all emergency procedures if something were to occur

        - When performing the risk assessment of the experiment, ensure that preparing for emergencies takes into account that the person discovering the accident is potentially NOT a lab member. Think about all potential possibilities during an incident or emergency and think of all of the steps to respond to possible emergencies or incidents.
    - If running any highly exothermic reactions or potentially explosive reactions, make sure that proper engineering controls are in place to minimize the risk of an explosion.
        - Consider discussing these overnight reactions with RMS to ensure that all possible safety measures have been taken.

APPENDIX N: REPRODUCTIVE HEALTH (UNDER PREPARATION)

RESOURCES AND REFERENCES USED TO CREATE THE CHP

- 29 CFR§1910.1450, "Occupational Exposure to Hazardous Chemicals in Laboratories
- OSHA Injury and Illness Prevention Program
- RMS webpage
- Emergency Readiness Training
- Stop the Bleed Training
- Fire Extinguisher and Automated External Defibrillator Training
- Occupational Health and Safety Administration (OSHA) List of Highly Hazardous Chemicals, Toxics, and Reactives
- National Toxicology Program, Department of Health and Human Services Report on Carcinogens
- World Health Organization (WHO) Agents Classified by the IARC Monographs
- The Globally Harmonized System for Hazard Communication
- NFPA codes
- NFPA 704
- NFPA Diamond
- Hazardous Materials Identification System (HMIS) Label
- database for online SDS
- PubChem
- Chemical Safety Library
- ACS Chemical Health and Safety
- 29 CFR Part 1910, subpart Z
- OSHA Hazard Communication Standard (CCR, Title 8, 5194)
- Chemical Storage Guidelines by UC Riverside
- Chemical Incompatibility Information Sheet
- CAMEO Chemical Incompatibility Matrix
- NFPA 30
- NFPA 77
- Peroxides and Peroxide Forming Compounds Publication
- List of peroxide formers UC Santa Cruz
- Airgas resources
- Definition of a Carcinogen by OSHA
- Annual report on carcinogens published by the National Toxicology Program (NTP)

- List of Group 1 and Group 2A carcinogens by the International Agency for Research on Cancer (IARC).
- Components of Chemical Fume Hood Video
- Biosafety Cabinets (BSC) Guidance Video
- Snorkel hood video
- ANSI Z87 Standard for Safety Glasses and Googles
- Glove Selection Guide
- 29 CFR 1910.101 Compressed Gases
- NFPA 55: Compressed Gases and Cryogenic Fluids Code
- National Electric Code (NEC) of the National Fire Protection Agency
- Emergency operation plan by EMS
- Guide for Chemical Spill Response
- OSHA 1910.266 First Aid Kits
- Biosafety Manual.
- Radiation Safety Manual
- Laser Safety Manual
- Hazardous Waste Management Program Manual.
- Generating Standard Operating Procedures for the Manipulation of Hazardous Chemicals in Academic Laboratories
- UC Center for Laboratory Safety SOP library
- UMN SOP library
- Princeton's Pyrophoric Materials
- "What is RAMP?" by ACS Institute
- NIOSH's Hierarchy of Controls
- Oregon State University Risk Assessment Example
- Lab-HIRA: Hazard identification and risk analysis for the chemical research laboratory. Part 2. Risk analysis of laboratory operations
- Proceedings of the 2018 Laboratory Safety Workshop: Hazard and Risk Management in the Laboratory
- Safe Handling of Cannulas and Needles in Chemistry Laboratories
- Lessons Learned - Fluoride Exposure
- Review of the Performance, Selection, and Use of Gloves for Chemical Protection
- University of Rochester, Environmental Health & Safety Laboratory Safety Unit Emergency Readiness for Research Laboratories
- UNT Power Outage Information
- University of Hawaii, Manoa Lab Safety Emergency Procedures During Power Outages

- Yale Laboratories and Power Outages
- UC San Diego How to Prepare for a Power Failure in a Lab
- University of Arizona Procedure for Temporary Laboratory Closure
- Chemical Incompatibility Information Sheet
- Nitric Acid Waste Incompatibility Info
- Safety in Academic Chemistry Laboratories
- Information on Oil baths
- Information on autoclaves
- Information on ovens
- Hot plates can sometimes heat uncontrollably regardless of temperature setting or whether controls are in the off position.
- UCI Chemical Hygiene Plan
- UMN Chemical Hygiene Plan

(UNDER PREPARATION) GLOSSARY