NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

LABORATORY SAFETY MANUAL AND CHEMICAL HYGIENE PLAN

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Contents

Purpose of this Manual

The New Mexico Institute of Mining and Technology ("New Mexico Tech", "the University", or "NMT") is committed to providing a safe and healthy work, educational, and living environment, to having a positive impact on the natural environment, and to protecting the University's employees and students.

The purpose of this manual is to meet the basic regulatory requirements of the OSHA Laboratory Standard for the development of a Chemical Hygiene Plan and to provide laboratories with useful recommendations that can help achieve compliance with the intent of the OSHA Lab Standard. Throughout this document, areas where regulatory or University requirements exist will be clearly identified using words such as "must", "required", "shall", and "it is the responsibility", etc. All other information provided within this document are recommendations that New Mexico Tech Research Compliance and Safety ("Research Compliance") encourages laboratories to follow as best management practices. **Departments and individual laboratories are free to establish the guidelines found within this document as required policies for their units or laboratories.**

For the purposes of this Laboratory Safety Manual, the term "Unit" is defined as a College, Department, Division, or Research Group.

Introduction

Research Compliance outlines safety responsibilities and training requirements to ensure individual and institutional compliance with relevant environmental health and safety laws, regulations, policies, and guidelines. This Laboratory Safety Manual includes the University's Chemical Hygiene Plan and recommendations for good laboratory practices to serve as a useful resource and to assist laboratories in designing their own site-specific laboratory safety procedures to meet these requirements.

The Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1910.1450, "Occupational Exposure to Hazardous Chemicals in Laboratories", mandates health and safety practices and procedures in laboratories that use hazardous chemicals. The Standard became effective May 1, 1990 and requires that a Chemical Hygiene Plan be developed for each laboratory workplace. The purpose of the Laboratory Standard is to protect laboratory employees from harm due to chemicals while they are working in a laboratory. This regulation applies to all employers engaged in the laboratory use of hazardous chemicals, which OSHA defines as: "Laboratory" means a facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

"Laboratory scale" means work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.

“Hazardous chemical” means a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term “health hazard” includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems and agents which damage the lungs, skins, eyes, or mucous membranes. Appendix A and Appendix B of The Hazard Communication standard (29 CFR 1910.1200) provides further guidance in defining the scope of health hazards and determining whether or not a chemical is to be considered hazardous for the purposes of this standard.

A complete description of definitions applicable to laboratories can be found in the OSHA Laboratory Standard.

In all other areas that use chemicals, but do not fall under the OSHA definition of a “laboratory”, OSHA regulation 29 CFR 1910.1200 – "Hazard Communication Standard” applies.

Most laboratories at New Mexico Tech using chemicals are subject to the requirements of the Laboratory Standard. In addition to employees who ordinarily work full-time within a laboratory space, other employees (such as office, custodial, maintenance and repair personnel) who regularly spend a significant amount of their time within a laboratory environment as part of their duties, may also fall under the requirements of the Laboratory Standard. OSHA considers graduate students who get paid for working in a lab as employees who are subject to the requirements of the Laboratory Standard.

The OSHA Laboratory Standard requires employers to develop a Chemical Hygiene Plan (CHP), designate a Chemical Hygiene Officer (CHO), and ensure laboratory employees are provided with the proper information and training, including knowing the location of the Chemical Hygiene Plan, and how to work safely in their labs. The main goals of the OSHA Laboratory Standard and the requirement to develop a chemical Hygiene plan are; to protect employees from health hazards associated with use of hazardous chemicals in the laboratory, and keep exposures below the permissible exposure limits as specified in 29 CFR Part 1910, subpart Z – Toxic and Hazardous Substances and other resources such as the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH). In addition to other requirements, the OSHA Lab Standard specifies the Chemical Hygiene Plan to include “criteria the employer will use to determine and implement control measures to reduce employee exposure to hazardous chemicals including engineering controls, the use of personal protective equipment and hygiene practices etc.; particular attention shall be given to the selection of control measures for chemicals that are known to be extremely hazardous.”

Research Compliance has taken responsibility for maintaining an institutional Chemical Hygiene Plan. Each college, center, department, or laboratory may adopt or modify this plan or write their own chemical hygiene plan as long as the requirements of the OSHA Laboratory Standard are met. It is assumed if a college, center, department, or laboratory has not developed their own chemical hygiene plan, then that unit or laboratory has adopted the New Mexico Tech Chemical Hygiene Plan. The New Mexico Tech CHP is maintained by Research Compliance. The campus

CHP is designed to supplement department and laboratory specific safety manuals and procedures that already address chemical safety in laboratories.

Chemical Hygiene Plan (CHP) Accessibility

The OSHA Laboratory Standard requires the CHP to be readily available to employees, employee representatives and, upon request, to the Assistant Secretary of Labor for Occupational Safety and Health, U.S. Department of Labor, or designee. This means laboratory employees working with hazardous chemicals in a laboratory must know the location of the CHP, be familiar with the contents, and be able to produce the CHP for any state or federal regulatory inspectors upon request. While New Mexico Tech recommends a hard copy be kept in the laboratory, electronic access is acceptable and encouraged. The CHP can be found in Appendix A of this manual.

*****It is the responsibility of Principal Investigators and laboratory supervisors to ensure that personnel working in laboratories under their control are familiar with the contents and location of the Chemical Hygiene Plan, including any lab specific standard operating procedures and any department or college level laboratory safety manuals, policies, and procedures.**

1 Laboratory Safety Responsibilities

The ultimate responsibility for health and safety within laboratories lies with each individual who works in the laboratory; however, it is the responsibility of the Principal Investigator, Faculty, and laboratory supervisor to ensure that employees (including visiting scientists, fellows, volunteers, temporary employees, and student employees) have received all appropriate training, and have been provided with all the necessary information to work safely in laboratories under their control. Principal investigators, Faculty, and Lab Supervisors have numerous resources at their disposal for helping to ensure a safe and healthy laboratory that is compliant with state and federal regulations.

It is the responsibility of the Principal Investigator and individual supervisors (and individuals working under their supervision) to be in compliance with the components of the University Chemical Hygiene Plan and any other department or University specific policies.

1.1 New Mexico Tech Office for Research

Office for Research (hereafter referred to as Research Compliance in this manual) will provide technical information and program support to assist in compliance with the OSHA Laboratory Standard. This includes developing policies, recommendations and guidelines (as found in this Laboratory Safety Manual), developing and providing training programs designed to meet regulatory requirements, and serving as consultants in providing health and safety information to laboratory personnel. Research Compliance will maintain the campus Chemical Hygiene Plan (CHP) and the institutional Chemical Hygiene Officer responsibilities.

1.2 Hazardous Materials and Laboratory Safety Specialist

The role of the Hazardous Materials and Laboratory Safety Specialist is to facilitate the implementation of the campus CHP and this Laboratory Safety Manual in laboratories across campus and outlying facilities, and to serve as a technical resource to the campus laboratory community.

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The major duties are:

- Work with campus stakeholders to evaluate, implement, review annually, and make updates as needed to the Chemical Hygiene Plan and Laboratory Safety Manual.
- Provide technical expertise to the laboratory community in the area of laboratory safety and health, and serve as a point of contact to direct inquiries

to other appropriate resources.

- Ensure that guidelines are in place and communicated for particularly hazardous materials regarding proper labeling, handling, use, and storage, selection of proper personal protective equipment, and facilitating the development of standard operating procedures for laboratories using these substances.
- Serve as a resource to review academic research protocols and standard operating procedures developed by Principal Investigators and department personnel for the use, disposal, spill cleanup, and decontamination of hazardous chemicals, and the proper selection and use of personal protective equipment.
- Coordinate the acquisition, annual testing, and maintenance of fume hoods, emergency safety showers, and eyewash stations in all laboratories where hazardous chemicals are used.
- Conduct laboratory safety training sessions for laboratory personnel and upon request, assist laboratory supervisors in developing and conducting hands-on training sessions with employees.
- Review reports for laboratory incidents, accidents, chemical spills, and near misses and recommend follow up actions where appropriate.
- Stay informed of plans for renovations or new laboratory construction projects and serve as a resource in providing code citations and internal standards to assist with the design and construction process.
- Keep the senior administration informed on the progress of continued implementation of the Chemical Hygiene Plan and Laboratory Safety Manual and bring campus-wide issues affecting laboratory safety to their attention.

1.3 Deans, Directors, and Department Chairpersons

The Deans, Directors, and Department Chairpersons are responsible for laboratory safety within their department(s) and must know and understand the New Mexico Tech General Safety and Health Policy from the New Mexico Tech Employee Handbook, and know and understand the guidelines and requirements of this Laboratory Safety Manual.

In addition to the responsibilities outlined within the New Mexico Tech General Safety and Health Policy, the laboratory safety responsibilities of Deans, Directors, and Department Chairpersons, which can be delegated to other authorized personnel within the department, are:

- Be familiar with and implement NMT’s General Safety and Health Policy within units under their control or designate a person in the department with the authority to carry out these requirements.
- Communicate and implement the General Safety and Health Policy and its requirements to faculty, staff (including temporary employees), visiting scholars, volunteers and students working in laboratories within their units.
- Assist the Hazardous Materials and Laboratory Safety Specialist with implementation of the Chemical Hygiene Plan and Laboratory Safety Manual.

- Ensure laboratory personnel develop and adhere to proper health and safety protocols.
- Direct individuals under their supervision, including but not limited to - Principal Investigators, supervisors, regular and temporary employees, visiting professors, and student employees - to obtain any required safety and health training before working with hazardous chemicals, biohazardous agents, radiation, and/or other physical/mechanical hazards found within their working or learning environments.
- Determine and ensure that safety needs and equipment for units/departments are met (e.g., engineering controls, training, protective equipment) and ensure corrective measures for noncompliance items identified in laboratory safety reviews are corrected promptly.
- Encourage the formation of a college and/or department safety committee(s).
- Keep the Building Coordinator, and the Hazardous Materials and Laboratory Safety Specialist informed of plans for renovations or new laboratory construction projects.
- Ensure college and departmental procedures are established and communicated to identify and respond to potential accidents and emergency situations.
- Notify the Hazardous Materials and Laboratory Safety Specialist before a faculty member retires or leaves the University so proper laboratory decommissioning occurs.
- Establish college and departmental priorities, objectives, and targets for laboratory safety and health performance. Obtain assistance and guidance from Research Compliance when necessary.
- Ensure college and departmental laboratory participation in Research Area Inspections as a means to regularly check performance against regulatory requirements and identify opportunities for improvement.

1.4 Principal Investigators, Faculty, and Laboratory Supervisors/Managers

Principal Investigators, faculty, and laboratory supervisors are responsible for laboratory safety in their research or teaching laboratories. In addition to the responsibilities outlined within the New Mexico Tech General Safety and Health Policy, the laboratory safety duties of Principal Investigators, faculty, and laboratory supervisors (which can also be delegated to other authorized personnel within the laboratory) are:

- Implement and communicate New Mexico Tech's General Safety and Health Policy (policy #30 of the NMT Employee Handbook, pg. 58) and all other University safety practices and programs, including the guidelines and procedures found within this Laboratory Safety Manual, in laboratories under your supervision or control.
- Establish laboratory priorities, objectives and targets for laboratory safety, health and environmental performance.
- Communicate roles and responsibilities of individuals within the laboratory relative to environmental, health, and safety according to this Laboratory

Safety Manual.

- Conduct hazard evaluations for procedures conducted in the laboratory and maintain a file of Standard Operating Procedures (SOP) documenting those hazards.
- Ensure that specific operating procedures for handling and disposing of hazardous materials used in their laboratories are written, communicated, and followed and ensure laboratory personnel have been trained in these operating procedures and use proper control measures.
- Attend required health and safety training.
- Require all staff members and students under their direction to obtain and maintain required health and safety training commensurate with their duties and/or department requirements.
- Participate in New Mexico Tech's Laboratory Safety Reviews (LSR) with their laboratory employees or designate someone in the laboratory to conduct these inspections.
- Ensure that all items identified during the annual New Mexico Tech Laboratory Safety Reviews are corrected in a timely manner.
- Ensure that all appropriate engineering controls including chemical fume hoods and safety equipment are available and in good working order in their laboratories. This includes notifying Research Compliance when significant changes in chemical use may require a re-evaluation of the laboratory ventilation.
- Ensure procedures are established and communicated to identify the potential for, and the appropriate response to accidents and emergency situations.
- Ensure that all incidents and near misses occurring in their laboratories are reported to their Director or Department Chairperson, and that an NMT Lab Incident/Near Miss Report is filed with Research Compliance for each injured person.
- Ensure laboratory personnel under your supervision know and follow the guidelines and requirements contained within the Laboratory Safety Manual.
- Follow the guidelines identified within this manual as Principal Investigator and laboratory supervisor responsibilities.
- Keep the Department Chairperson and the Hazardous Materials and Laboratory Safety Specialist informed of plans for renovations or new laboratory construction projects.
- Ensure that research areas under their supervision are registered using HASP in a timely manner upon notification by Research Compliance and updated annually.

1.5 Laboratory Employees

Laboratory employees are those personnel who conduct their work in a laboratory and are at risk of possible exposure to hazardous chemicals on a regular or periodic basis. These personnel include laboratory technicians, instructors, researchers, visiting researchers, administrative assistants, graduate assistants, student aides, student employees, and part time and temporary employees.

In addition to the responsibilities outlined within the New Mexico Tech Safety Policy, the laboratory safety duties of laboratory employees are:

- Comply with New Mexico Tech General Safety and Health Policy and all other health and safety practices and programs by maintaining class, work, and laboratory areas safe and free from hazards.
- Know the location of the CHP and how to access safety data sheets (SDS).
- Attend health and safety training as designated by your supervisor.
- Inform your supervisor or instructor of any safety hazards in the workplace, classroom, or laboratory, including reporting any unsafe working conditions, faulty fume hoods, or other emergency safety equipment to the laboratory supervisor.
- Ensure an SDS is present for all new chemicals you purchase (either sent with the original shipment or available online). Review the SDSs for chemicals you are working with and check with your laboratory supervisor or principal investigator if you ever have any questions.
- Conduct hazard evaluations with your supervisor for procedures conducted in the laboratory and maintain a file of standard operating procedures documenting those hazards.
- Be familiar with what to do in the event of an emergency situation.
- Participate in laboratory self-evaluations and annual New Mexico Tech Laboratory Safety Reviews.
- Follow the standard operating procedures for your laboratory and incorporate the guidelines and requirements outlined in this Laboratory Safety Manual into everyday practice.

2 Engineering Controls

Engineering controls are considered the third line of defense in the laboratory for the reduction or elimination of the potential exposure to hazardous chemicals after Elimination (physically removing the hazard), and Substitution (replacing the hazard with another less hazardous substitute). Examples of engineering controls used in laboratories at New Mexico Tech include dilution ventilation, local exhaust ventilation, chemical fume hoods, glove boxes and other containment enclosures, as well as ventilated storage cabinets.

The OSHA Laboratory Standard requires that "fume hoods and other protective equipment function properly and that specific measures are taken to ensure proper and adequate performance of such equipment." General laboratory room ventilation is not adequate to provide proper protection against benchtop use of hazardous chemicals. Laboratory personnel need to consider available engineering controls to protect themselves against chemical exposures before beginning any new experiment(s) involving the use of hazardous chemicals.

The proper functioning and maintenance of fume hoods and other protective equipment used in the laboratory is the responsibility of a variety of service groups. Facilities Management and Research Compliance collaborate to inspect, test, and service equipment such as fire extinguishers, emergency eyewash and showers, and mechanical ventilation.

Periodic inspections and maintenance by these groups ensure proper functioning and adequate performance of these important pieces of protective equipment. However, it is the responsibility of laboratory personnel to immediately report malfunctioning protective equipment, such as fume hoods, or mechanical problems to their Department Coordinator, and/or their Department Chair as soon as any malfunctions are discovered.

2.1 Chemical Fume Hoods

Fume hoods and other capture devices are used to contain the release of toxic chemical vapors, fumes, and dusts. Benchtop use of chemicals that present an inhalation hazard is strongly discouraged. Fume hoods are to be used when conducting new experiments with unknown consequences from reactions or when the potential for a fire exists.

To achieve optimum performance, the greatest personal protection, and reduce energy usage when using a fume hood:

- Ensure the fume hood is working by checking the air flow monitor (tissue paper hanging from hood sash, manometer, digital gauge, etc.) prior to performing any work in the hood. DO NOT use an improperly working fume hood.
- If the fume hood is not working properly, let other people in the lab know by hanging up a "Do Not Use" sign on the hood.
- Work a minimum of 6 inches from the hood sash inside the hood. This provides for the greatest amount of capture and removal of airborne contaminants. Also, do not place items on the airfoil or work with chemicals at the face of the hood.
- Do not block the baffles at the back of the hood. These allow for proper exhausting of contaminants from the hood. For large equipment, consider the use of Laboratory Jack to raise equipment a minimum of 2 inches, promoting airflow.
- Keeping the hood sash lowered improves the performance of the fume hood by maintaining the internal vortex and containment. It also helps to conserve energy.
- Keep the fume hood sash closed all of the way whenever the fume hood is not being used. Shut the Sash.
- Do not use fume hoods to evaporate hazardous waste. Evaporating hazardous waste is illegal and dangerous.
- For work involving particularly hazardous substances or chemicals that can form toxic vapors, fumes, or dusts, the hood or equipment within the hood may need to be fitted with condensers, traps, or scrubbers in order to prevent the vapors, fumes, and dusts from being released into the environment.
- Do not exhaust items, such as vacuum pumps, through the face of the fume hood as this will disrupt the airflow into the hood and may cause contamination. This will also not allow for the sash to be fully closed.
- As with any work involving chemicals, always practice good housekeeping

and clean up all chemical spills immediately. Be sure to wash both the working surface and hood sash frequently and always maintain a clean and dry work surface that is free of clutter.

In addition to annual fume hood inspection, face velocity testing, and containment testing, Research Compliance also offers training on the safe use of fume hoods. Additional information can be found in the Safe Fume Hood Use Guide (currently under development) available on the NMT HAZMAT Safety Information page at https://www.nmt.edu/research/hazmat.php.

2.1.1 Perchloric Acid and Fume Hood Safety

DO NOT use heated Perchloric acid in a regular fume hood. If heated Perchloric acid is used in a regular fume hood (without a wash down function), shock sensitive metallic perchlorate crystals can form inside the duct work, and could result in causing an explosion during maintenance work on the ventilation system. Use of heated Perchloric acid requires a special perchloric acid fume hood with a wash down function. If you suspect your fume hood has perchlorate contamination or would like more information on perchloric acid fume hoods, then contact the Hazardous Materials and Laboratory Safety Specialist at hazmat@nmt.edu or 575-517-0646.

2.1.2 Fume Hood Inspection and Testing Program

Research Compliance and Facilities Services share the responsibility for the annual testing and inspection of fume hoods on campus. After each inspection, an inspection sticker is affixed to the fume hood. If your fume hood does not have an inspection sticker or if the existing inspection sticker on your fume hood indicates a year or more has passed since the hood was last inspected, or for other questions, please contact Research Compliance at research.compliance@nmt.edu.

Fume hood testing and inspection consists of the following:

- The face velocity will be tested for compliance with American National Standards Institute (ANSI) and American Industrial Hygiene Association (AIHA) standard Z9.5-2012.
- A visual inspection and containment test using either a smoke tube or the dry ice technique will be performed in conjunction with face velocity measurements in accordance with the ANSI/American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standard 110- 1995.
- Hoods will be classified as acceptable or unacceptable based on the average face velocity measurement and result of the containment test.

- If a hood is found to be unacceptable, a warning sign indicating the hood did not pass inspection and does not provide optimum protection will be attached in a conspicuous location. This information will be provided to the building coordinator who will follow through with the repair arrangements with other laboratories for the use of a different hood.

2.1.1 Installation of New Fume Hoods

Installation of a new fume hood requires careful planning and knowledge of the existing building ventilation systems and capabilities. Improperly installed fume hoods or other capture devices can seriously disrupt the existing ventilation system and have a negative impact in the immediate room, other fume hoods, and the ventilation system throughout the building.

All fume hoods and other capture devices must be installed in consultation with Facilities Services and Research Compliance. All new installations of fume hoods must comply with NMT Design approval and be commissioned by Research Compliance to be included in the inspection and testing program.

Research Compliance can provide information regarding the selection, purchase, and inspection requirements for laminar flow clean benches, biosafety cabinets, and portable fume hoods.

2.1.2 Removal of Existing Fume Hoods

Any removal of fume hoods and capture devices requires prior consultation with your Department Coordinator, Department Liaison, Facilities Services, and Research Compliance. This is necessary to ensure building ventilation systems are not affected by removal of fume hoods and capture devices, and so utility services such as electrical lines, plumbing systems, and water and gas supply lines are properly disconnected. For more information about decommissioning of fume hoods, please contact the Hazardous Materials and Laboratory Safety Specialist at hazmat@nmt.edu or at 575-517-0646.

There is an additional concern for the presence of asbestos within the fume hood itself, and potentially in any pipe insulation associated with the ductwork and/or Mercury in cup sinks. Any asbestos must be properly removed and disposed of by a certified asbestos removal company. Research Compliance can assist laboratories with the cleanup of any Mercury contamination. Contact Research Compliance at research.compliance@nmt.edu for more information or questions about potential asbestos or Mercury contamination.

2.2 Other Capture Devices

Engineering controls beside the fume hood include compressed gas cabinets, vented storage cabinets and local exhaust ventilation (LEV) such as capture hoods (canopy and slot), and exhaust snorkels. These work to capture and entrap chemical vapors, fumes and dusts at the point of generation. Examples where these devices would be appropriate are welding operations, atomic absorption units, vacuum pumps, work with dry nanomaterials and many other operations in the laboratory. Installation of any of these must be in the consultation of Research Compliance and may include an engineering design to ensure the proper connection into the ventilation systems ductwork.

2.2.1 Biological Safety Cabinets (Biosafety Cabinets, BSC)

Biological safety cabinets (BSC), or biosafety cabinets, are enclosed and ventilated workspaces in a laboratory that provide protection for personnel and the environment from pathogenic (or potentially pathogenic) agents.

There are 3 different Classes of BSCs (I, II, and III), and each are designed to protect the user and environment, differing only in the level of protection provided and the level of product protection provided.

Classes and Types of BSCs:

- Class I BSCs: Provide personnel and environmental protection, but have limited or no product protection, and the airflow involved may in fact contribute to increased product contamination. These are commonly used to enclose specific equipment and/or procedures that potentially generate aerosols. BSCs in this Class are either connected to the building exhaust system (ducted) or recirculate filtered exhaust back into the lab (un-ducted).
- Class II BSCs: Provide protection to the product as well as the environment and the user, and there are 5 subtypes within this Class as described below:
    - Type A1: Commonly used for biosafety levels (BSL) 1 through 3. Not suitable for handling hazardous chemical vapors.
    - Type A2: Similar to Type A1 BSCs for BSL 1 through 3. Is suitable for use with small amounts of chemicals provided that the chemical vapors are not hazardous, will not interfere with the work when recirculated, and that the system is ducted and exhausts to the outdoors. Type A2 BSCs comprise nearly 90% of all BSCs installed.
    - Type B1: Typically used for BSL 1 through 3. Provides

protection to users from hazardous chemical vapors, and reduces exposure to product and environment. Hard ducted to the building's exhaust system.
    - Type B2: Used for BSL 1 through 3. Provides protection to users and products from chemical vapors, and reduces exposure to the environment. Hard ducted into the building's exhaust system. Most often used for toxicology laboratories.
    - Type C1: Can be configured to use as a Type A-mode recirculating system for standard microbiological work (un-ducted or ducted) or configured as a Type B-mode for handling chemical vapors (ducted).
- Class III BSCs: Provide maximum containment in labs, and are specifically designed for work with BSL 4 pathogenic agents.

Principal Investigators and/or Laboratory Supervisors/Managers are responsible to ensure that BSCs are inspected and certified by a qualified individual or company on an annual basis, at minimum.

2.2.2 Glove Boxes

Glove boxes are sealed enclosures that are designed to protect the user, the process or both, by providing total isolation of the contents from the outside environment. They are usually equipped with at least one pair of gloves attached to the enclosure. The user manipulates the materials inside using the gloves. Typically, a glove box has an antechamber that is used to take materials in and out of the box.

Types of Gloveboxes:

- Controlled Environment (dry box): These create oxygen and moisture free conditions by replacing the air within the box with an inert gas, such as nitrogen, argon or helium, depending on the type of materials to be worked with. A "rotary vane vacuum pump" is used to remove the atmosphere. Additional accessories may be used, such a gas purifier, to further reduce oxygen and moisture levels for particularly sensitive operations. There are 4 types of this type of gloveboxes based on their leak tightness. Class 1 having the lowest hourly leak rate. This should be inspected by a service company during commissioning, when the gloves are changed, or when there appears to be a problem with the functioning of the glovebox.
- Ventilated Glovebox (filtered glovebox): These have filters, either HEPA or ultra-low particulate, on the inlet and outlet ends of the box and a blower to circulate the air. These provide protection to the user through this filtration and also if the exhaust is connected to building exhaust through a thimble connection. These can also serve in cleanroom applications by reversing the airflow in the chamber to

positive pressure.

Regular maintenance and inspection is essential to ensure that a glove box is adequately protecting the user, the environment and/or the product/process. Routine maintenance procedures and the frequency of inspection (or certification) should follow the manufacturers and regulatory recommendations.

There are various tests that can be performed on glove boxes, the suitability of which depends on the glove box and the application. Tests may include pressure decay (for positive pressure), rate of rise (for negative pressure), oxygen analysis, containment integrity, ventilation flow characterization, and cleanliness. The source of a leak can be identified using a Mass Spectrometer Leak Detector, ultrasound, the soap bubble method or use of an oxygen analyzer. For an in-depth discussion of glove boxes and testing, see: AGS (American GloveBox Society) 2007 Guide for gloveboxes – Third Edition. AGS- G001-2007.

2.3 Water Protection in Labs

Laboratory personnel must ensure that any piece of equipment or laboratory apparatus connected to the water supply utilizes backflow protection or is connected to a faucet with a vacuum breaker. The purpose of backflow prevention and vacuum breakers is to prevent water used in an experimental process or with a piece of equipment from back flowing and contaminating the laboratory's and building's water supply system. Examples of situations that can result from improper backflow protection include chemical contamination and/or temperature extremes (i.e. hot water coming from a drinking water fountain).

3 Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) should be considered as the last line of defense in protecting laboratory personnel against chemical hazards after the use of engineering controls and administrative controls (changing the way in which the work is performed; i.e. training, job rotation, limiting access to hazards, etc.). PPE is not a substitute for elimination, substitution, engineering, or administrative controls, but should be used in conjunction with these controls to ensure the safety and health of university employees and students as a good work practice.

The OSHA Personal Protective Equipment standard, 29 CFR 1910 Subpart I has the following requirements:

- Hazard assessment and equipment selection
- Employee training
- Record keeping requirements
- Guidelines for selecting PPE
- Hazard assessment certification

Research Compliance is developing a written Personal Protective Equipment Program (currently in development) in order to be in compliance with the OSHA standard. More information on PPE can be found in the OSHA Safety and Health topics page on Personal Protective Equipment.

3.1 Laboratory Responsibilities for Personal Protective Equipment

Laboratory personnel need to conduct hazard assessments of specific operations occurring in their laboratories to determine what PPE is necessary to safely carry out the operations. PPE must be made available to laboratory workers to reduce exposures to hazardous chemicals in the lab. Proper PPE includes items such as gloves, eye protection, lab coats, face shields, aprons, boots, hearing protection, etc. PPE must be readily available and most equipment is provided at no cost to the employee.

When deciding on the appropriate PPE to wear when performing any operations or experiments, a number of factors must be taken into consideration such as:

- The chemicals being used, including concentration and quantity.
- The hazards the chemicals pose.
- The routes of exposure for the chemicals.
- The material the PPE is constructed of.
- The permeation and degradation rates specific chemicals will have on the material.
- The length of time the PPE will be in contact with the chemicals.

Careful consideration should be given to the comfort and fit of PPE to ensure that it will be used by laboratory personnel.

All personal protective equipment and clothing must be maintained in a sanitary and reliable condition. Only those items that meet NIOSH (National Institute of Occupational Safety and Health) or ANSI standards should be purchased or accepted for use.

There are a number of safety equipment suppliers who sell a wide variety of personal protective equipment. Be sure to check with the Purchasing Department first to find out if there is a supplier that is a preferred vendor that may offer discounted pricing. If you have questions about what PPE is most appropriate for your applications, then contact Research Compliance at research.compliance@nmt.edu.

Please Note: Principal Investigators, laboratory supervisors, departments and colleges are free to set policies that establish minimum PPE requirements that meet or exceed federal and state regulations for personnel working in and entering their laboratories. Check with your Department Chair to see if there are any department specific requirements for PPE.

3.2 Training for Personal Protective Equipment

Laboratory personnel must be trained in the selection, proper use, limitations, care, and maintenance of PPE. Training requirements can be met in a variety of ways including videos, group training sessions, and handouts. Periodic retraining should be offered to both the employees and supervisors as appropriate.

Examples of topics to be covered during the training include:

- When PPE must be worn.
- What PPE is necessary to carry out a procedure or experiment.
- How to properly put on, take off, adjust, and wear PPE.
- The proper cleaning, care, maintenance, useful life, limitations, and disposal of the PPE.

As with any training sessions, PPE training must be documented, including a description of the information covered during the training session and a copy of the sign-in sheet.

Training records must be kept of the names of the persons trained, the type of training provided, and the dates when training occurred. Research Compliance will maintain records of employees who attend Research Compliance training sessions.

Information on the specific PPE required to carry out procedures within the laboratory using hazardous chemicals must also be included in the laboratory's Standard Operating Procedures.

Please note: while Research Compliance can provide information, training, and assistance with conducting hazard assessments and the selection and use of proper PPE, the ultimate responsibility lies with the Principal Investigator or laboratory supervisor.

It is the responsibility of the Principal Investigator or laboratory supervisor to ensure laboratory staff have received the appropriate training on the selection and use of proper PPE, that proper PPE is available and in good condition, and laboratory personnel use proper PPE when working in laboratories under their supervision.

3.3 Eye Protection

Eye protection is one of the most important and easiest forms of PPE to wear. Laboratory personnel should use eye protection for many of the chemical and physical hazards found in laboratories including flying particles, broken glass, molten metal, acids or caustic liquids, chemical liquids, chemical gasses or vapors, or potentially injurious light radiation.

Research Compliance strongly encourages Principal Investigators and laboratory supervisors to make use of eye protection a mandatory requirement for all laboratory personnel, including visitors, working in or entering laboratories under their control.

All laboratory employees and visitors should wear protective eyewear while in laboratories where chemicals are being handled or stored, at all times, even when not working directly with chemicals.

3.3.1 Eye Protection Selection

All protective eye and face devices must comply with ANSI Z87.1-2003, "American National Standard Practice for Occupational and Educational Eye and Face Protection" and be marked to identify the manufacturer. When choosing proper eye protection, be aware there are a number of different styles of eyewear that serve different functions.

Prescription Safety Eyewear
OSHA regulations require that employees who wear prescription lenses while engaged in operations that involve eye hazards shall wear eye protection that incorporates the prescription in its design, or must wear eye protection that can be worn over the prescription lenses (goggles, face shields, etc.) without disturbing the proper position of the prescription lenses or the protective lenses. Any prescription eyewear purchase must comply with ANSI Z87.1-1989.

Note: Contact lenses by themselves are not considered as protective eyewear.

Safety Glasses
Safety glasses provide eye protection from moderate impact and particles associated with grinding, sawing, scaling, broken glass, and minor chemical splashes, etc. Side protectors are required when there is a hazard from flying objects. Safety glasses are available in prescription form for those persons needing corrective lenses. Safety glasses do not provide adequate protection for processes that involve heavy chemical use such as stirring, pouring, or mixing. In these instances, splash goggles should be used.

Splash Goggles
Splash goggles provide adequate eye protection from many hazards, including potential chemical splash hazards, use of concentrated corrosive material, and bulk chemical transfer. Goggles are available with clear or tinted lenses, fog proofing, and vented or non-vented frames. Be aware that goggles designed for woodworking are not appropriate for working with chemicals. These types of goggles can be identified by the numerous small holes throughout the face piece. In the event of a splash, chemicals could enter into the small holes, and result in a chemical exposure to the face. Ensure the goggles you choose are rated for use with chemicals.

Welder's/Chippers' Goggles
Welder's goggles provide protection from sparking, scaling, or splashing metals and harmful light rays. Lenses are impact resistant and are available in graduated lens shades. Chippers'/Grinders' goggles provide protection from flying particles. A dual protective eyecup houses impact resistant clear lenses with individual cover plates.

Face Shields
Face shields provide additional protection to the eyes and face when used in combination with safety glasses or splash goggles. Face shields consist of an adjustable headgear and face shield of tinted or clear lenses or a mesh wire screen. They should be used in operations when the entire face needs protection and should be worn to protect the eyes and face from flying particles, metal sparks, and chemical/biological splashes. Face shields with a mesh wire screen are not appropriate for use with chemicals. Face shields must not be used alone and are not a substitute for appropriate eyewear. Face shields should always be worn in conjunction with a primary form of eye protection such as safety glasses or goggles.

Welding Shields
Welding shields are similar in design to face shields but offer additional protection from infrared or radiant light burns, flying sparks, metal splatter, and slag chips encountered during welding, brazing, soldering, resistance welding, bare or shielded electric arc welding, and oxyacetylene welding and cutting operations.

Equipment fitted with appropriate filter lenses must be used to protect against light radiation. Tinted and shaded lenses are not filter lenses unless they are marked or identified as such.

LASER Eye Protection
A single pair of safety glasses is not available for protection from all LASER outputs. The type of eye protection required is dependent on the spectral frequency or specific wavelength of the laser source. If you have questions on the type of eyewear that should be worn with your specific LASER, contact the NMT LASER Safety Officer at LSO@nmt.edu.

3.4 Hand Protection

Most accidents involving hands and arms can be classified under four main hazard categories: chemicals, abrasions, cuts, and heat/cold. Gloves must be worn whenever significant potential hazards from chemicals, cuts, lacerations, abrasions, punctures, burns, biologicals, or harmful temperatures are present. The proper use of hand protection can help protect from potential chemical and physical hazards. Gloves must be worn when using chemicals that are easily absorbed through the skin and/or

Particularly Hazardous Substances (see section 10) such as "select carcinogens", reproductive toxins, and substances with a high degree of acute toxicity.

***There is not one type of glove that offers the best protection against all chemicals or one glove that totally resists degradation and permeation to all chemicals. All gloves must be replaced periodically, depending on the type and concentration of the chemical, performance characteristics of the gloves, conditions and duration of use, hazards present, and the length of time a chemical has been in contact with the glove.

All glove materials are eventually permeated by chemicals; however, they can be used safely for limited time periods if specific use and other characteristics (i.e., thickness, permeation rate, and time) are known. Research Compliance can provide assistance with determining the resistance to chemicals of common glove materials and determining the specific type of glove material that should be worn for use with a particular chemical.

3.4.1 Selecting Proper Gloves

Before working with any chemical, always read manufacturer instructions and warnings on chemical container labels and SDSs. Recommended glove types are sometimes listed in the PPE section of the SDSs. If the recommended glove type is not listed on the SDS, then laboratory personnel should consult with the manufacturers' glove selection charts. These charts typically include commonly used chemicals that have been tested for the manufacturers' different glove types. Different manufacturers use different formulations so check the glove chart of the specific manufacturer for the glove you plan to use.

If the manufacturers' glove chart does not list the specific chemical you will be using, then call the manufacturer directly and speak with their technical representatives to determine which glove is best suited for your particular application.

It is important to know that not all chemicals or mixtures have been tested by glove manufacturers. It is especially important in these situations to contact the glove manufacturer directly.

In some cases, you may need to consider hiring a testing laboratory that specializes in determining which glove material will be most resistant to the chemical you are using. For more information, contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or at hazmat@nmt.edu, or contact Research Compliance at research.compliance@nmt.edu.

Some general guidelines for glove use include:

- Wear appropriate gloves when the potential for contact with hazardous materials exists. Laboratory personnel should inspect gloves for holes, cracks, or contamination before each use. Any gloves found to be questionable should be discarded immediately.

- Gloves should be replaced periodically, depending on the frequency of use and permeability to the substance(s) handled. Reusable Gloves should be rinsed with soap and water and then carefully removed after use. Discard disposable gloves after each use and whenever they become contaminated.
- Due to potential chemical contamination, which may not always be visible, gloves must be removed before leaving the laboratory. Do not wear gloves while performing common tasks such as answering the phone, grabbing a door handle, using an elevator, etc.

3.4.2 Double Gloving

A common practice to use with disposable gloves is “double-gloving”. This is accomplished when two pairs of gloves are worn over each other to provide a double layer of protection. If the outer glove becomes contaminated, starts to degrade, or tears open, the inner glove continues to offer protection until the gloves are removed and replaced. The best practice is to check outer gloves frequently, watching for signs of degradation (change of color, change of texture, tears, etc.). At the first sign of degradation or contamination, always remove and dispose of the contaminated disposable gloves immediately and double-glove with a new set of gloves. If the inner glove appears to have any contamination or degradation, remove both pairs of gloves, and double gloves with a new pair.

Another approach to double gloving is to wear a thin disposable glove (4 mil Nitrile) under a heavier glove (8 mil Nitrile). The outer glove is the primary protective barrier while the under glove retains dexterity and acts as a secondary barrier in the event of degradation or permeation of the chemical through the outer glove. Alternatively, you could wear a heavier (and usually more expensive and durable) 8 mil Nitrile glove as an under glove and wear a thinner, disposable 4 mil Nitrile glove as the outer glove (which can help improve dexterity). However, remember to change the thinner outer gloves frequently.

When working with mixtures of chemicals, it may be advisable to double glove with two sets of gloves made from different materials. This method can offer protection in case the outer glove material becomes permeated by one chemical in the mixture, while allowing for enough protection until both gloves can be removed. The type of glove materials selected for this type of application will be based on the specific chemicals used as part of the mixture. Check chemical manufacturers glove selection charts first before choosing which type of glove to use.

To properly remove disposable gloves, grab the cuff of the left glove with the gloved right hand and remove the left glove. While holding the removed left glove in the palm of the gloved right hand, insert a finger under the cuff of the right glove and gently invert the right glove over the glove in the palm of your hand and dispose of them properly. Be sure to wash your hands thoroughly with soap and water after the gloves have been removed.

3.4.3 Types of Gloves

As with protective eyewear, there are a number of different types of gloves that are available for laboratory personnel that serve different functions:

Fabric Gloves
Fabric gloves are made of cotton or fabric blends and are generally used to improve grip when handling slippery objects. They also help insulate hands from mild heat or cold. These gloves are not appropriate for use with chemicals because the fabric can absorb and hold the chemical against a user's hands, resulting in a chemical exposure.

Leather Gloves
Leather gloves are used to guard against injuries from sparks, scraping against rough surfaces, or cuts from sharp objects like broken glass. They are also used in combination with an insulated liner when working with electricity. These gloves are not appropriate for use with chemicals because the leather can absorb and hold the chemical against a user's hands, resulting in a chemical exposure.

Metal Mesh Gloves
Metal mesh gloves are used to protect hands from accidental cuts and scratches. They are most commonly used when working with cutting tools, knives, and other sharp instruments.

Cryogenic Gloves
Cryogenic gloves are used to protect hands from extremely cold temperatures. These gloves should be used when handling dry ice and when dispensing or working with liquid nitrogen and other cryogenic liquids.

Chemically Resistant Gloves
Chemically resistant gloves come in a wide variety of materials. The recommendations given below for the specific glove materials are based on incidental contact. Once the chemical makes contact with the gloved

hand, the gloves should be removed and replaced as soon as practical. Often a glove specified for incidental contact is not suitable for extended contact, such as when the gloved hand can become covered or immersed in the chemical in use. Before selecting chemical resistant gloves, consult the glove manufacturers' recommendations or their glove selection charts, or contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 for more assistance.

Some general guidelines for different glove materials include:

- Natural Rubber Latex*** - Resistant to ketones, alcohols, caustics, and organic acids. See note below.
- Neoprene - Resistant to mineral acids, organic acids, caustics, alcohols, and petroleum solvents.
- Nitrile - Resistant to alcohols, caustics, organic acids, and some ketones.
- Norfoil® - Rated for chemicals considered highly toxic and chemicals that are easily absorbed through the skin. These gloves are chemically resistant to a wide range of materials that readily attack other glove materials. These gloves are not recommended for use with Chloroform. Common brand names include: Silver Shield by North Hand Protection, 4H by Safety4, or New Barrier by Ansell Edmont.
- Polyvinyl chloride (PVC) - Resistant to mineral acids, caustics, organic acids, and alcohols.
- Polyvinyl alcohol (PVA) - Resistant to chlorinated solvents, petroleum solvents, and aromatics.

*** A note about latex gloves

The use of latex gloves, especially thin, disposable exam gloves, for chemical handling is discouraged because latex offers little protection from commonly used chemicals. Latex gloves can degrade severely in minutes or seconds, when used with common lab and shop chemicals. Latex gloves also can cause an allergic reaction in a percentage of the population due to several proteins found in latex. Symptoms can include nasal, eye, or sinus irritation, hives, shortness of breath, coughing, wheezing, or unexplained shock. If any of these symptoms become apparent in personnel wearing latex gloves, discontinue using the gloves and seek medical attention immediately.

The use of latex gloves is only appropriate for:

- Most biological materials.
- Non Hazardous chemicals.
- Clean room requirements.
- Medical or veterinary applications.
- Very dilute, aqueous solutions containing <1% for most

hazardous chemicals or less than 0.1% of a known or suspected human carcinogen.

Staff required to wear latex gloves should receive training on the potential health effects related to latex. Hypoallergenic, non-powdered gloves should be used whenever possible. If a good substitute glove material is available, then use non-latex gloves. A general purpose substitute for disposable latex gloves are disposable Nitrile gloves.

See Appendix E of this Laboratory Safety Manual for a list of recommended gloves for specific chemicals, definitions for terms used in glove selection charts, glove materials and characteristics, and a list of useful references.

3.5 Protective Clothing

Protective clothing includes lab coats or other protective garments such as aprons, boots, shoe covers, Tyvek coveralls, and other items that can be used to protect street clothing from biological or chemical contamination and splashes as well as providing additional body protection from some physical hazards.

Research Compliance strongly recommends that Principal Investigators and laboratory supervisors discourage the wearing of shorts and skirts in laboratories using hazardous materials (chemical, biological, and radiological) by laboratory personnel, including visitors, working in or entering laboratories under their supervision.

The following characteristics should be taken into account when choosing protective clothing:

- The specific hazard(s) and the degree of protection required, including the potential exposure to chemicals, radiation, biological materials, and physical hazards such as heat.
- The type of material the clothing is made of and its resistance to the specific hazard(s) that will be encountered. For example, if you will be working with flammable materials, it is far better to wear 100% cotton clothing than polyester blends, due to the fact that polyester can melt and adhere to the skin, causing more damage than fire alone.
- The comfort of the protective clothing, which impacts the acceptance and ease of use by laboratory personnel.
- Whether the clothing is disposable or reusable - which impacts cost, maintenance, and cleaning requirements.
- How quickly the clothing can be removed during an emergency. It is recommended that lab coats use snaps or other easy to remove fasteners instead of buttons.

Laboratory personnel who are planning experiments that may require special protective clothing or have questions regarding the best protective clothing to choose for their experiment(s) should contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or hazmat@nmt.edu for recommendations.

3.6 Respirators

Respiratory protection includes disposable respirators (such as N95 filtering face pieces, commonly referred to as "dust masks"), air purifying, and atmosphere supplying respirators. Respirators are generally not recommended for laboratory workers. Engineering controls, such as dilution ventilation, fume hoods, and other devices, which capture and remove vapors, fumes, and gasses from the breathing zone of the user are preferred over the use of respirators in most laboratory environments. There are certain exceptions to this general rule, such as the changing out of cylinders of toxic gasses and emergency response to chemical spills.

The use of all types of respiratory protection at New Mexico Tech is governed by the OSHA standards and the New Mexico Tech Respiratory Protection Program. A laboratory worker at New Mexico Tech may not purchase a respirator (with the exception of the voluntary usage of N95 filtering face pieces intended for use of limiting and mitigating exposure to respiratory illnesses such as Covid-19) and bring it to their lab for personal use without prior consultation with Research Compliance.

The following are situations where respiratory protection would be appropriate for laboratory workers (after consultation with Research Compliance):

- The use of disposable respirators (e.g., N95 filtering facepieces/dust masks) for weighing powdery or dusty materials. Note: Most disposable respirators do not offer protection against chemical vapors and fumes; they are for use of nuisance dust only. The use of disposable respirators may or may not be regulated by OSHA depending upon the circumstances of use. In order to determine if OSHA regulations apply, please contact Research Compliance at research.compliance@nmt.edu to schedule a hazard assessment prior to using a disposable respirator.
- The voluntary use of N95 respirators in the laboratory is permitted. OSHA requires the following reading: (Mandatory) Information for Employees Using Respirators when not Required Under Standard – 29 CFR 1910.134 Appendix D.
- The use of large volumes of certain hazardous chemicals, such as formaldehyde, in a room where dilution ventilation or capture devices will not be able to offer adequate protection.
- Changing out cylinders of hazardous gasses. (Additional training is required).
- Cleaning up hazardous chemical spills. (Additional training is required.)
- To reduce exposure to some chemicals which certain individuals may be or become sensitive to.
- When mixing chemicals that may result in more hazardous vapors from the combination of chemicals versus the exposure to each chemical alone or when the potential for an unknown exposure exists. However, laboratory staff

should try to conduct such experiments in a fume hood.

Please note: as a measure of coworker protection, when weighing out dusty materials or powders, consider waiting until other coworkers have left the room to prevent possible exposure and thoroughly clean up and decontaminate working surfaces.

There are some situations in which the use of a respirator would be prohibited:

- When the air in a laboratory is severely contaminated and immediately dangerous to life and health (IDLH).
- When the air in a room does not have enough oxygen to support life (less than 19.5%).
- When dangerous vapors are present that have inadequate warning properties (such as odor) should the respirator fail.
- When the air contaminants can penetrate or damage skin and eyes unless other suitable protection is worn.

3.6.1 Respirator Protection Program

New Mexico Tech has established a program for the use of respirators on campus. The program is designed for those University personnel who, during their normal duties are, or could be, exposed to hazardous substances or atmospheres that may affect their health and safety.

The New Mexico Tech Respiratory Protection Program includes the following:

- You will receive a medical evaluation by Bhasker Medical Clinic to ensure you are physically fit to wear a respirator. Wearing any type of respirator puts a large amount of stress on the body. If the use of a respirator is required to perform your job duties, then your department will pay for the medical evaluation.
- You will be shown how to properly put on and take off the respirator, and how to check to make sure it is functioning properly.
- You will be shown how to properly clean and care for your respirator, including proper maintenance.
- You will be shown how to choose the right respirator or respirator cartridge for the specific processes and types of chemicals you will be using. NOTE: As with chemical protective gloves, there is no one universal respirator cartridge that can be used with every chemical.

For more information about the use of respirators at New Mexico Tech, contact Research Compliance at research.compliance@nmt.edu. If you are approved for the use of a respirator after meeting the requirements of the OSHA Standards and the New Mexico Tech Respiratory Protection

Program, then you may purchase a respirator. If the use of a respirator is required to perform your job duties, then your department will pay for the respirator. After the respirator is purchased, a Respiratory Fit Testing will need to be performed by Research Compliance before the respirator can be used in the lab.

3.7 Hearing Protection

Hearing protective devices include earplugs, earmuffs, or similar devices designed to protect your hearing. If occupational noise exposures exceed permissible levels and cannot be reduced through engineering or other controls, then hearing protective devices must be worn. The New Mexico Tech University Hearing Conservation Program (currently in development) protects employees who, during their normal duties experience an Occupational Noise Exposure as defined by the Occupational Safety and Health Administration (OSHA) General Industry Standard "Occupational Exposure to Noise" Part 1910.95 and the Hearing Conservation Amendment. If you have questions about whether you are receiving an occupational noise exposure, or would like to request workplace monitoring or information about the New Mexico Tech University Hearing Conservation Program, then contact Research Compliance at research.compliance@nmt.edu.

Additional information can be obtained from the OSHA Health and Safety Topics page for Noise and Hearing Conservation.

3.8 Foot Protection

Laboratory personnel (and other personnel) must wear foot protection at all times in laboratories, laboratory support areas, and other areas with chemical, biological and physical hazards are present. Laboratory personnel should not wear sandals or similar types of perforated or open toed shoes whenever working with or around hazardous chemicals or physical hazards. This is due to the potential exposure to toxic chemicals and the potential associated with physical hazards such as dropping pieces of equipment or broken glass being present. In general, shoes should be comfortable, and leather shoes are preferable to cloth shoes due to the better chemical resistance of leather compared to cloth. Leather shoes also tend to absorb fewer chemicals than cloth shoes. However, leather shoes are not designed for long term exposure to direct contact with chemicals. In such instances, chemically resistant rubber boots are necessary.

Research Compliance strongly encourages Principal Investigators and laboratory supervisors to require the use of closed toed shoes for all laboratory personnel, including visitors, working in or entering laboratories and laboratory support areas under their supervision.

In some cases, the use of steel-toed shoes may be appropriate when heavy equipment or other items are involved. Chemically resistant boots or shoe covers may be required when working with large quantities of chemicals and the potential exists for large spills to occur.

4 Administrative Controls

Administrative controls include policies and procedures that result in providing proper guidance for safe laboratory work practices and set the standard for behavior within the laboratory. Once developed, administrative controls must be implemented and adhered to by all personnel working in the laboratory.

Colleges and departments are responsible for developing policies and written guidelines to ensure laboratory workers are protected against exposure to hazardous chemicals as outlined in the OSHA Laboratory Standard and physical hazards that may be present, including the development of a written Chemical Hygiene Plan or adoption of this Laboratory Safety Manual.

It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that personnel working in laboratories under their supervision are informed of any and all hazards that may be present in the lab, and that they follow laboratory specific, departmental, and campus wide policies and procedures related to laboratory safety – such as the guidelines and requirements covered in this Laboratory Safety Manual.

***In addition to meeting regulatory requirements identified within this Laboratory Safety Manual, colleges and departments are strongly encouraged to incorporate the recommendations and guidelines identified within this manual. While this Laboratory Safety Manual provides the minimum requirements and recommendations to meet the intent of the OSHA Laboratory Standard, colleges, departments, Principal Investigators, and laboratory supervisors have the authority to implement more stringent policies within laboratories under their supervision and are encouraged to do so.

4.1 Standard Operating Procedures (SOPs)

The OSHA Laboratory Standard requires that Chemical Hygiene Plans include specific elements and measures to ensure employee protection in the laboratory. One such requirement is Standard Operating Procedures (SOPs) "relevant to safety and health considerations to be followed when laboratory work involves the use of hazardous chemicals."

SOPs can be stand-alone documents or supplemental information included as part of research notebooks, experiment documentation, or research proposals. The requirement for SOPs is to ensure a process is in place to document and address relevant health and safety issues as part of every experiment.

At a minimum, SOPs should include details such as:

- The chemicals involved and their hazards.

- Special hazards and circumstances.
- Use of engineering controls (such as fume hoods).
- Required PPE.
- Spill response measures.
- Waste disposal procedures.
- Decontamination procedures.
- Description of how to perform the experiment or operation.

While the OSHA Laboratory Standard specifies the requirement for SOPs for work involving hazardous chemicals, laboratories should also develop SOPs for use with any piece of equipment or operation that may pose any physical hazards. Examples include:

- Safe use and considerations of LASERs.
- Use of cryogenic liquids and fill procedures.
- Connecting regulators to gas cylinders and cylinder change outs.
- Use of equipment with high voltage.

SOPs do not need to be lengthy dissertations and it is perfectly acceptable to point laboratory personnel to other sources of information. Some examples of what to include as part of SOPs are:

- "To use this piece of equipment, see page 4 in the operator's manual (located in file cabinet #4)."
- "The chemical and physical hazards of this chemical can be found in the SDS – located in the SDS binder. Read the SDS before using this chemical."
- "When using chemical X, wear safety goggles, nitrile gloves, and a lab coat."

Research Compliance can assist laboratories with developing general and specific SOPs. Due to the variety of research and the large number of laboratories on the New Mexico Tech campus, it is the responsibility of each laboratory, department, and division to ensure that SOPs are developed and the practices and procedures are adequate to protect lab workers who use hazardous chemicals.

> It is the responsibility of the Principal Investigator and laboratory supervisor to ensure written SOPs incorporating health and safety considerations are developed for work involving the use of hazardous chemicals in laboratories under their supervision and that PPE and engineering controls are adequate to prevent overexposure. In addition, Principal Investigators and laboratory supervisors must ensure that personnel working in laboratories under their supervision have been trained on those SOPs.

4.2 Research Approval Forms

The form(s) should be completed by the Principal Investigator and submitted with all proposals. Of particular note for laboratory personnel, compliance certifications are required for the following areas:

- Human Subjects (Institutional Review Board, IRB. Contact irb@nmt.edu)

- Animal Use (Institutional Animal Care and Use Committee, IACUC. Contact iacuc@nmt.edu)
- Recombinant DNA (See IRB above)
- Genetically Modified Organisms (Contact Research Compliance at research.compliance@nmt.edu)
- Radiation (Radiation Safety Committee, RSC. Contact the Radiation Safety Officer at RSO@nmt.edu)
- Biological Agents and Toxins (Contact Research Compliance at research.compliance@nmt.edu)
- Hazardous Materials (Contact the Hazardous Materials and Laboratory Safety Specialist at hazmat@nmt.edu)
- Conflict of Interests (Required for all research proposals. Contact COI@nmt.edu)

Once Research Compliance receives the form, Research Compliance staff members will contact the Principal Investigator listed to discuss general aspects of the grant proposal and to ensure health and safety aspects have been taken into account. During the review process, Research Compliance staff members will identify any special issues that may need to be addressed to ensure compliance with state or federal regulatory requirements.

4.3 Procedural Controls

Procedural controls incorporate best management practices for working in a laboratory. These practices serve not only to protect the health and safety of personnel, but are a common sense way of increasing productivity in a laboratory. Through implementation of good practices, laboratories can expect an increase in the efficient use of valuable lab space, in the reliability of experiments due to less potential contamination, and an increase in the awareness of health and safety issues by laboratory personnel. Following the practices outlined in this Laboratory Safety Manual should also result in a decrease in the number of accidents, injuries, and spills. This will result in a decrease in the overall liability for the Principal Investigator, laboratory supervisor, and the University.

Procedural controls are fundamental to instilling safe work behaviors and helping to create a culture of safety within the laboratory environment.

4.4 Housekeeping

Housekeeping refers to the general condition and appearance of a laboratory and includes:

- Keeping 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.

- Area walkways and doorways remain clear of any clutter in order to ensure accessible egress from the lab in case of an emergency. A minimum clearance of 28” in walkways and egress routes is recommended.
- Keep all containers of chemicals closed when not in use.
- Cleaning up all chemicals spills immediately, regardless if the chemical is hazardous or not. When cleaning up a chemical spill, look for any splashes that may have resulted on nearby equipment, cabinets, doors, and countertops. For more information on cleaning up spills, see Chemical Spill Procedures Section 5.12 of this document.
- Keeping areas around emergency equipment and devices clean and free of clutter. This includes items such as eyewash/emergency showers, electric power panels, fire extinguishers, and spill cleanup supplies.
- Keeping a minimum of three feet of clearance (as required by fire codes) between benches and equipment. Exits must be clear of obstacles and tripping hazards such as bottles, boxes, equipment, electric cords, etc. Combustible materials may not be stored in exits (including corridors and stairways), exit enclosures, boiler rooms, mechanical rooms, or electrical equipment rooms.
- When storing items overhead, keep heavier and bulkier items closer to the floor. The storage of combustible material (such as paper, boxes, plastics, etc.) within 24" of the ceiling in rooms without sprinklers is strongly discouraged. In rooms with automated sprinkler systems, 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 as per the OSHA Automatic Sprinkler Systems Standard 1910.159(c)(10).
- Always use a stepladder when reaching for overhead items, do not stand on chairs or countertops. If you do not have a stepladder available, then contact your Building Coordinator.

In summary, good housekeeping has obvious health and safety benefits and can have a positive mental effect on laboratory personnel who work in a clean environment, which can lead to increased productivity. Also keep in mind that during an inspection by a state or federal regulatory agency, the general condition of the laboratory observed in the first few minutes of the inspection (the housekeeping of the lab) can have a significant impact (positive or negative) on the rest of the inspection process.

It is the responsibility of Principal Investigators and laboratory supervisors to ensure laboratories under their supervision are maintained in a clean and orderly manner and personnel working in the lab practice good housekeeping.

4.5 Personal Hygiene

Good chemical hygiene practices include the use of personal protective equipment (PPE) and good personal hygiene habits. Although PPE can offer a barrier of protection against chemicals and biological materials, good personal hygiene habits are essential to prevent chemical exposure, even when using PPE.

Some general guidelines that should always be followed include:

- Do not eat, drink, chew gum, or apply cosmetics in a lab or other area where chemicals are used.
- Do not store food or drink in refrigerators that are used to store chemicals.
- Do not ever try starting a siphon or pipette by mouth, doing so can result in ingestion of chemicals or inhalation of chemical vapors. Always use a pipette aid or suction bulb to start a siphon.
- Always confine long hair, loose clothing, and jewelry.
- Wear a lab coat when working with hazardous materials.
- Shorts and sandals should not be worn in a lab when anyone is using corrosives or other chemicals that present a skin contact hazard or where the potential for physical hazards such as dropping pieces of equipment or broken glass are present.
- Remove laboratory coats, gloves, and other PPE immediately when chemical contamination occurs. Failure to do so could result in chemical exposure.
- After removing contaminated PPE, be sure to wash any affected skin areas with soap and water for at least 15 minutes.
- Always remove lab coats, scrubs, gloves, and other PPE before leaving the lab. Do not wear lab coats, scrubs, or other PPE (especially gloves) in areas outside the lab, particularly not in areas where food and drink are served, or other public areas.
- Always wash hands with soap and water after removing gloves and before leaving the lab or using items such as the phone, turning door knobs, or using an elevator.
- Always wash lab coats separately from personal clothing. Be sure to identify contaminated lab coats to commercial laundry facilities to help protect their workers by placing the contaminated lab coat in a separate plastic bag and clearly identifying the bag with a note or label indicating the lab coat is contaminated.
- Smoking is prohibited in all lab areas at New Mexico Tech.

4.6 Eating, Drinking, and Applying Cosmetics in the Lab

Chemical exposure can occur through ingestion of food or drink contaminated with chemicals. This type of contamination can occur when food or drinks are brought into a lab or when food or drinks are stored in refrigerators, freezers, or cabinets with chemicals. When this occurs, it is possible for the food or drink to absorb chemical vapors and thus lead to a chemical exposure when the food or drink is consumed. Eating or drinking in areas exposed to toxic materials is prohibited by the OSHA Sanitation Standard, 29 CFR 1910.141(g)(2).

A similar principle of potential chemical exposure holds true with regard to the application of cosmetics (make-up, hand lotion, etc.) in a laboratory setting when hazardous chemicals are being used. In this instance, the cosmetics have the ability of absorbing chemical vapors, dusts, and mists from the air and when applied to the skin and result in skin exposure to chemicals.

To prevent exposure to hazardous chemicals through ingestion, do not eat, drink, chew gum, or apply cosmetics in areas where hazardous chemicals are used.

Wash your hands thoroughly after using any chemicals or other laboratory materials, even if you were wearing gloves, and especially before eating or drinking.

To help promote awareness, refrigerators and freezers should be properly labeled:

- Refrigerators for the storage of food should be labeled, “Food Only, No Chemicals” or “No Chemicals or Samples”. Please note that food and drinks, and by extension refrigerators or other equipment specifically used for the storage of food and drinks, should never be present in a laboratory that stores or utilizes any hazardous chemicals.
- Refrigerators used for the storage of chemicals should be labeled “Chemicals Only, No Food or Drink”.

Keep in mind that some chemical exposure can result in immediate effects (acute exposure) while other effects may not be seen for some time despite repeated exposure (chronic exposure). Consuming food or drink or applying cosmetics in the lab can result in both types of exposure.

4.7 Working Alone

Whenever possible, laboratory personnel should avoid working alone when conducting research, especially when experiments involve hazardous substances and procedures.

Laboratories should establish specific guidelines and standard operating procedures specifying when working alone is not allowed and develop notification procedures when working alone occurs. All work to be performed by someone working alone, and the monitoring system that is established, must be approved in advance by the Principal Investigator or laboratory supervisor. Check with your department chair to see if your department has specific requirements for working alone.

If a laboratory person determines it is necessary to work alone, consideration should be given to notifying someone else in the area – in an adjacent room, another lab on the same floor, or a lab on a different floor. It is recommended that a “buddy system” be established for regular, routine checks on personnel working alone, such as every 15 – 30 minutes, to ensure no accidents have occurred. This could be accomplished by physically walking to the room where the lab worker is or through the use of a phone. If the person working alone is doing highly hazardous work, then the person checking on the lab worker should not enter the same room. A system of visual checks should be established to indicate there are no problems or to determine if help is needed.

In the event of an emergency that requires the buddy to leave prior to the completion of an experiment involving Particularly Hazardous Substances (see Section 10), the buddy should notify New Mexico Tech Police at 575-835-5555 of the name, location, and end time of the experiment involved. The buddy should also notify the person conducting the experiment. The person conducting the experiment should make an effort to complete the experiment in a safe manner and notify New Mexico Tech Police upon completion of the experiment. Under no circumstances should the New Mexico Tech Police be used in place of a "lab buddy" as this will seriously undermine the safety of all involved.

Please note: For rooms that are locked due to security needs, prior arrangements are required to allow the designated buddy access. However, please be aware that the University does not have a standardized keying system and the New Mexico Tech Emergency Responders and New Mexico Tech Police may not always have immediate access to locked doors - which could result in a delay in response in the event of an emergency. Also understand that if the door to the lab does not have a window, or if the window is covered, then there is a chance that if something happened to a person working alone in a locked lab, then they may not be discovered until someone else from the lab goes into the room (which could be a day or more).

Examples of activities where working alone would be permissible include:

- Office work such as writing papers, calculations, computer work, and reading.
- Housekeeping activities such as general cleaning, reorganization of supplies or equipment, etc., as long as no moving of large quantities of chemicals is involved.
- Assembly or modification of laboratory apparatus when no chemical, electrical, or other physical hazards are present.
- Routine lab functions which are part of a standard operating procedure which has been demonstrated to be safe and not involve hazardous materials.

Examples of activities where working using a "buddy system" should be considered include:

- Experiments involving toxic or otherwise hazardous chemicals, especially poison inhalation hazards.
- Experiments involving high-pressure equipment.
- Experiments involving large quantities of cryogenic materials.
- Experiments involving work with unstable (explosives) materials.
- Experiments involving Class 3b or 4 Lasers.
- Transfer of large quantities of flammable materials, acids, bases, and other hazardous materials.
- Changing out compressed gas cylinders containing hazardous materials.

It is the responsibility of Principal Investigators and laboratory supervisors to ensure procedures for working alone are developed and followed by personnel working in laboratories under their supervision.

4.8 Phones in Labs

All labs are strongly recommended to have a means of communication in the event of an emergency. This can include a phone or cell phone (if service is available) or two-way radio within the lab or access to a central phone located in the hallway. If a phone is not available within the lab, it is advisable to post a sign and/or map indicating where the nearest phone is located.

4.9 Unattended Operations

Whenever it is necessary to have unattended operations occurring in a lab, it is important to ensure safeguards are put into place in the event of an emergency. Laboratory personnel are strongly encouraged to adhere to the following guidelines when it is necessary to carry out unattended operations.

For unattended operations involving Particularly Hazardous Substances (see Section 10), a light should be left on and an appropriate warning sign should be placed on the laboratory door, or in a conspicuous place that could be easily seen without putting someone else in danger in the event of an emergency. The warning sign should list the following information:

- The nature of the experiment in progress.
- The chemicals in use.
- Hazards present (electrical, heat, etc.)
- The name of the person conducting the experiment and a contact number. A secondary name and contact number is also recommended.

When setting up an experiment that will be left unattended, try to take into account potential incidents that could occur if something went wrong. For example:

- Use secondary containment such as trays to contain any spills that may occur.
- Use safety shields and keep the chemical hood sash down low to contain chemicals and glass in case an explosion occurs.
- Remove any chemicals or equipment that are not necessary for the experiment or items that could potentially react with the chemicals or other materials being used in the experiment.
- Whenever possible, use automatic shutoff devices to prevent accidents such as loss of cooling water shutoff, over-temperature shut off, etc.
- Use emergency power outlets for those pieces of equipment that could be negatively affected in the event electric service or other city utilities are interrupted.

It is the responsibility of Principal Investigators and laboratory supervisors to ensure procedures for unattended operations are developed and followed by personnel working in laboratories under their supervision.

4.10 Access to Laboratories

Access to New Mexico Tech University laboratories, workshops and other work areas housing hazardous materials or machinery is restricted to New Mexico Tech faculty, staff, students, or other persons on official business.

It is the responsibility of the Department Chairperson, Principal Investigators, and laboratory supervisors to restrict access of visitors, children and volunteers to areas under their supervision when potential health and physical hazards exist.

4.10.1 Visitors and Children in Labs

Due to the potential hazards and liability issues, other persons, in particular children under the age of 16 are not permitted in hazardous work areas, with the exception of University-sanctioned activity, e.g., tours, open houses, or other University related business as authorized by the Principal Investigator or laboratory supervisor. In these instances, all children under the age of 16 must be under careful and continuous supervision. Check with your Department Chair to see if your department has specific procedures or policies in place for visitors.

4.10.2 Volunteers in Labs

Volunteers in labs are prohibited. Please review this policy for guidance and/or consult with the University's Human Resources for more information.

4.10.3 Visiting Scientists and Other Similar Users

There are potential risks associated with allowing access to labs and equipment by visiting scientists. These risks include theft or questions of ownership for intellectual property, bodily injury, and property damage. Units should verify that all users of the lab have the required safety and health training prior to allowing access to the lab and/or specialized equipment. It is the user's responsibility to have or obtain the appropriate training. Units are advised to consult with the University's Human Resources to obtain contracts and agreements to minimize risks associated with the use of labs and equipment by visiting scientists and others.

4.10.4 Pets, Emotional Support Animals, and Service Animals in Labs

<u>Pets</u>

According to the NMT Service Animal Policy, pets are defined as "an animal kept for ordinary use and companionship". Pets are prohibited from university-controlled buildings.

Emotional Support Animals
According to the NMT Emotional Support Animal (ESA) Policy, an ESA is defined as "an animal that alleviates one or more identified symptoms or effects of a person's mental health disability". ESAs are approved for campus housing only and are not permitted in other university buildings, including NMT laboratory spaces.

Service Animals
According to the NMT Service Animal Policy, Service Animals are defined as "any dog that is individually trained to do work or perform tasks for the benefit of an individual with a disability, including a physical, sensory, psychiatric, intellectual, or other mental disability. Other species of animals, whether wild or domestic, trained or untrained, are not service animals for the purposes of this definition." A service animal must be permitted to accompany their partner everywhere on campus except in situations where safety may be compromised or where the service animal may interfere with the fundamental nature of the activities being conducted. Contact NMT's Office of Student Access Services at access@nmt.edu for more information.

4.11 Chemical Purchasing

Before ordering new chemicals, search your existing inventories and use those chemicals currently in stock. An accurate and up-to-date chemical inventory can help to minimize purchase of chemicals already on hand.

If it is necessary to purchase new chemicals, laboratory personnel should order the smallest size necessary to carry out the experiment. Avoid ordering extra quantities because the chemical might be needed in the future, or to save money by buying bulk quantities. Particularly when dealing with hazardous chemicals, the money saved can increase risk and hazards posed to lab personnel. Try to take advantage of chemical vendors "Just-In-Time" delivery rather than stockpiling chemicals in your lab.

Some chemical purchases may require special approval or permits, such as those chemicals that are Drug Enforcement Agency (DEA) or Alcohol, Tobacco, and Firearms (ATF) listed substances, select agents, or high hazard chemicals. There are also building and fire codes that restrict the amount of flammable materials that can be stored in any one room, floors, and buildings at a time. For more information, contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646.

4.12 Ordering New Equipment

Whenever large pieces of equipment are planned to be purchased and installed in laboratories, especially equipment that is required to be hooked up to building utility services such as electric, water, or gas, laboratory personnel must first consult with Facilities Management, Research Compliance, and the appropriate shops to ensure the building has the necessary resources to support the new piece of equipment. Lab personnel should not assume they can purchase equipment first and then expect the building to be able to handle the service requirements later. By preplanning and communicating well in advance with appropriate campus groups (such as Facilities Management and Research Compliance), any potential issues can be identified ahead of time, which in turn will help make the transition to getting new pieces of equipment up and running quickly after the purchase is made.

Additionally, as with installation of fume hoods, certain pieces of equipment require special installation due to their potential impact on the rest of the building ventilation system and utilities, and cannot be hooked up by laboratory personnel, building managers, or private contractors without first consulting with Facilities Engineering and Research Compliance. Laboratory personnel are strongly encouraged to be proactive and to consult with the appropriate departments ahead of time, before purchasing new pieces of large equipment.

Laboratory personnel are strongly encouraged, as responsible campus members, to give consideration to purchasing "Energy Star" energy efficient pieces of equipment to help conserve natural resources and long-term operating costs. When discussing purchases of equipment with vendors and equipment manufacturers, ask about what "Energy Star" alternatives they carry.

4.13 Work Orders and Ticket Requests

In the event of a maintenance issue or if repairs are needed to equipment, laboratory personnel should first consult with their Department Coordinator, who will submit the appropriate paperwork with Customer Service to have repairs initiated. Please note that due to building codes and liability issues, laboratory personnel must not try to repair utility services (such as electrical, plumbing, or gas issues) by themselves. These repairs must be handled by qualified personnel only.

Whenever maintenance workers will be working on your hood system or in your laboratory, please remove all chemicals, laboratory apparatus, and equipment from the area requiring maintenance work. Ensure the work area is clean and inform the maintenance workers of any potential hazards present in the near vicinity either verbally or by leaving a sign with the appropriate information.

4.14 Changes in Lab Occupancy

Changes in laboratory occupancies can occur when faculty retire, new faculty come to campus, new lab staff are hired, students graduate or leave for another university, or when facility renovations take place. When changes in lab occupancy occur, it is important to address any potential issues BEFORE the occupants leave.

Failure to address the change in occupancy can result in:

- Old, unlabeled chemicals, samples, or hazardous waste being left behind in refrigerators, freezers, and cabinets.
- Valuable furniture or equipment being moved or thrown away.
- Unknown chemical spills or contamination being present.

These issues can result in costly remediation efforts and wasted resources for both the department and the University.

If you are planning to leave your laboratory or if you know of a research group or students that are planning to leave, there are a few simple steps that can be followed to ensure a smooth transition:

- Notify your department chairperson well in advance of the planned move.
- Ensure all chemical containers are properly labeled.
- Properly dispose of any hazardous and chemical waste left in the laboratory.
- Ensure all chemical spills and contamination has been cleaned up.

Research Compliance is currently working on a Laboratory Close-Out Checklist in order to help facilitate these transitions. The completed Laboratory Close-Out Checklist will be posted to NMT's HAZMAT Safety Information page at https://www.nmt.edu/research/hazmat.php

4.15 Ventilation Rates

As part of energy conservation measures, ventilation rates for laboratories are determined based on the occupancy and the type of research being conducted. If the function of a room changes due to new researchers coming to campus, notify Research Compliance. New Mexico Tech will then verify if the ventilation rate for a given room is appropriate for the type of research being conducted.

4.15.1 Room Air Pressure in Labs

Air pressure in Research laboratories should be negative to the hallways and offices. When positive air pressure occurs, more air is being supplied to the room than what is being removed by the fume hood or general exhaust. This can result in air from the laboratory (including chemical vapors and dusts) being blown out into the hallway outside of the lab and chemical odors permeating the hallways and surrounding rooms.

- Ensure the entrance door to the laboratory is closed.
- If you notice odors that seem to be escaping from a lab, then please contact your Building Coordinator for assistance.

4.16 Energy Conservation in Labs

Laboratories are energy intensive facilities, consuming many times the energy use of the average non-lab academic buildings. Laboratories use large quantities of air for ventilation and fume hoods; electricity to operate fans, lighting, and specialized lab equipment; and large quantities of water and process chilled water. Some laboratory facilities also use substantial quantities of natural gas.

There are a number of things that lab occupants can do to reduce the overall consumption of energy:

- Turn off the room lights.
- When possible turn off electrical equipment when not in use.
- Use timers to turn other pieces of equipment on and off automatically.
- Unplug equipment when not in use.
- Turn off your computer’s monitor when not in use. The monitor consumes over half of the energy used by the average computer. Put your computer and monitor into "sleep" mode after 10 minutes and cut power use nearly to zero.
- Keep the sash closed on your fume hood. This promotes both energy conservation and safety.
- Rooms that are too hot or too cool may be due to faulty thermostats or other controls that are malfunctioning or have drifted from set points, resulting in wasted energy as well as uncomfortable conditions for you. If you experience these problems, then contact your Building Coordinator for assistance.
- Report drips of water from sink taps, chilled water connections or Reverse Osmosis (RO) faucets.
- Clean out and consolidate freezers and refrigerators at least once per year.
- Set refrigerator and freezer temperatures at necessary levels instead of the lowest set point the equipment can achieve.
- Consolidate incubator use and freezer storage to minimize the number of appliances used.
- Use shades and blinds as provided to help keep your space cool on sunny days. The shade can reduce the amount of cooling required in a south or west facing room by over 30%.
- Use electric smart strips to minimize electricity used by items on the strip.
- Discourage the use of space heaters.
- Develop maintenance schedules for scientific equipment, such as cleaning compressor coils on cooling devices, to extend the device's life and maintain its energy efficiency.

4.16.1 Green Labs

Green chemistry, also known as sustainable chemistry, is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, and use.

- Substitute hazardous chemicals with less hazardous alternatives or chemicals that are drain disposable.
- Redesign chemical processes to reduce hazardous chemical use and/or exposure to technicians.
- Maintain an ongoing inventory of chemicals and dispose of outdated chemicals on a regular basis.

4.17 Research Area Inspections and Regulatory Bodies

Laboratories and other research areas are subject to regulations by the following entities:

- Occupational Safety and Health administration's (OSHA's) General Industry Regulations: 29 CFR 1910.
    - OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories (commonly known as "The Laboratory Standard"): 29 CFR 1910.1450.
- The Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA): 40 CFR parts 239 through 282.
    - EPA's Non-Hazardous Waste regulations: 40 CFR parts 239 through 259.
    - EPA's Hazardous Waste regulations: 40 CFR parts 260 through 273.
        - EPA's Universal Waste Program concerning Used Oil, Batteries, Lamps, Mercury-Containing Equipment (MCE), Aerosol Cans, and Pesticides: 40 CFR part 273.
- New Mexico Environmental Department (NMED) radioactive materials and hazardous waste regulations: New Mexico Administrative Code (NMAC): Title 20, Chapter 3 (20.3 NMAC) and Chapter 4 (20.4 NMAC).
- Department of Health (DOH) Rules and Regulations.
- National Fire Protection Association (NFPA) Codes and Standards.

Additionally, accreditation and granting agencies such as Centers for Disease Control (CDC), National Institute of Health (NIH), and United States Department of Agriculture (USDA) are increasing scrutiny over researchers and their compliance with state and federal laws.

In order to assist researchers to be in compliance with these regulations and standards, Research Compliance will conduct required inspections, referred to as Laboratory Safety Reviews (LSRs), of all campus laboratory spaces. Please contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or hazmat@nmt.edu for more information on LSRs.

The purpose of the Laboratory Safety Reviews are to assist responsible faculty and staff members in identifying and correcting potential regulatory compliance issues or other issues that could affect granting activities, and identify potential health and safety hazards that could pose an unreasonable risk to laboratory personnel, students, and the campus community. To facilitate the correction of deficient items, a corrective action process has been implemented and will be tracked. Research Compliance will schedule reviews by working with Department Chairs, Department Coordinators, and staff throughout the colleges, departments, and divisions.

4.17.1 Laboratory Self-Evaluations

Principal Investigators and Laboratory Supervisors in Research areas are strongly encouraged to conduct their own inspections of their research area to address any potential issues before Research Compliance performs an LSR, and to provide a training opportunity for research staff. To facilitate the self-inspection process, Research Compliance provides a Laboratory Self-Evaluation Checklist which identifies the same topics covered during a Laboratory Safety Review. This Lab Self-Evaluation Checklist is available at: https://www.nmt.edu/research/hazmat.php

Laboratory Self-Evaluations provide a number of useful benefits and further help to create a culture of safety within the lab.

Benefits of self-evaluations include:
- Raising the level of awareness of laboratory personnel and determining the level of compliance with state and federal regulations.
- Identifying and addressing any potential issues before an inspection by a state or federal regulatory agency.
- Providing an opportunity for lab specific training by identifying potential issues within the lab and then training lab personnel to look for these issues.
- Serving as a regular health and safety check of laboratory facilities.
- Serving as an outlet for faculty, staff, and student concerns.

New Mexico Tech recommends the following frequency for self-evaluations:
- On a daily basis, lab personnel should maintain good housekeeping within their lab.
- Informal weekly lab walkthroughs or “Friday afternoon cleanups”.
- Ideally, self-evaluations should occur once per month. These could include participation of research staff, department chairs, and/or safety committee members, and use of the Self-Inspection Checklist.
- At least once per semester research personnel should perform a formal self-inspection utilizing the Laboratory Self-Evaluation Checklist to ensure that their lab space is in compliance with regulation.

4.17.2 Inspections by Regulatory Agencies

Inspections by state and federal regulatory agencies can occur at any time and can result in citations and significant fines for the university. The best way to be prepared for these inspections is to understand what regulations apply to your area and what you need to do to comply with those regulations. You can obtain this information from resources such as this Laboratory Safety Manual, by conducting your own self-inspections, and by contacting the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or at hazmat@nmt.edu.

If a state or federal inspector shows up in your work area unescorted, ask them to please wait, and then contact the Hazardous Materials and Laboratory Safety Specialist immediately at 575-517-0646.

4.18 Hazard Assessment Signage (HAS) Form

Research Compliance highly recommends using the Hazard Assessment Signage (HAS) form, available at https://www.nmt.edu/research/hazmat.php, to inform individuals of hazards present in rooms to facilitate regulatory compliance, identify training requirements, communicate hazards, and improve emergency response.

Research area hazards should be reviewed on a regular basis and updated when Emergency Contacts or hazard information changes, or upon notification by Research Compliance.

The HAS form includes space for laboratory personnel to indicate the types of hazards present in the room, Department and Room number, and Emergency Contact information. HAS forms should be posted at the exterior entrance for any laboratory that hazardous chemicals, radioactive materials, compressed gasses, or mechanical hazards are present in order to inform individuals of the hazards prior to making entry into the lab space.

4.19 Laboratory Security

Laboratories need to take specific actions in order to provide security against theft of Particularly Hazardous Substances, valuable equipment, and to ensure compliance with state and federal regulations. Research Compliance encourages each unit (College, Department, Division, and Research Group) to review and develop procedures to ensure the security of all hazardous materials in their area of responsibility.

Many laboratories already implement various means of security, including requirements to lock up controlled substances, syringes and needles, and radioactive materials. Research Compliance recommends you review and assess the hazardous materials in your laboratory and consider security issues in protecting those materials. The intent is to minimize the risk of theft, especially targeting the five-minute window when the lab is left unattended.

***One easy way to increase security is to make sure that your laboratory door is locked whenever the lab is left unattended, even for a few minutes.

4.19.1 Security Guidelines

The following are guidelines designed to minimize opportunities for intentional removal of any hazardous materials from your laboratory:

- Recognize that laboratory security is related to, but different from laboratory safety. Security is preventing intrusion into the laboratory and the theft of equipment or materials from the lab.
- Develop a site-specific security policy. Make an assessment of your laboratory area for hazardous materials and particular security issues. Then develop and implement lab security procedures for your lab group and train lab group members on security procedures and assign responsibilities.
- Control access to areas where hazardous chemicals are used and stored. Limit laboratory access to only those individuals who need to be in the lab and restrict off-hours access only to individuals authorized by the Principal Investigator.
- Be sure to lock freezers, refrigerators, storage cabinets, and other containers where stocks of biological agents, hazardous chemicals, or radioactive materials are stored when they are not in direct view of workers (for example, when located in unattended storage areas).
- Do not leave hazardous materials unattended or unsecured at any time. Most importantly, close and lock laboratory doors when no one is present.

Note: If staff work alone and use the buddy system with someone outside of the research group, allowing access for that individual will need to be addressed prior to the initiation of working alone.

5 Emergency Preparation

IN CASE OF AN EMERGENCY: CALL 911 from any campus phone or dial 575-835-5555 from any cell phone, or off campus phone to reach New Mexico Tech Police.

Emergencies can occur at any time, without warning. Careful planning, with an emphasis on safety, can help members of the New Mexico Tech community handle crises and emergencies with appropriate responses, and could save lives. Every member of the New Mexico Tech 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.

5.1 New Mexico Tech Emergency Plan

New Mexico Tech organizes, coordinates, and directs available resources toward an effective response to, and recovery from, emergencies under the NMT Emergency Operations Plan. The effectiveness of this effort is dependent on the development of a comprehensive central plan and individual college/unit plans. The university, therefore, expects colleges, divisions and individual departments to develop detailed emergency plans. This policy includes a chain of command establishing the authority and responsibilities of campus officials and staff members, and requires that colleges, divisions, and individual departments designate emergency coordinators with the authority to make modifications in emergency procedures and to commit resources for emergency preparedness and recovery, as necessary.

5.2 Unit Emergency Planning

Research Compliance can provide clarification and guidance to colleges, divisions, and individual departments in developing detailed unit emergency plans. Effective emergency planning requires that every college and major administrative unit have designated emergency coordinators. The emergency coordinator should be a full-time member of the administrative team, and preferably an experienced employee who is thoroughly familiar with College/Administrative Unit and University procedures. Knowledge of programs and physical facilities in their College/Administrative Unit is also imperative. This person will coordinate their College's/Administrative Unit's emergency plan as well as oversee that the College/Administrative Unit each prepares a unit emergency plan. Each College/Administrative Unit leader (e.g. Dean or Vice President) is responsible for designating an Emergency Coordinator. This person is responsible for gathering and communicating emergency information, coordinating and assisting in evacuations, maintaining emergency response forms and other emergency plan materials.

5.3 Fire Safety Plans

Fire safety planning is very important to the New Mexico Tech community. New Mexico Tech has developed campus-wide procedures to follow in the event of an emergency that must be posted in elevator lobbies, stairwells, and assembly spaces.

5.4 Emergency Evacuation Procedures

Information about Emergency Evacuation Procedures can be found in the Fire Safety Plan document.

5.5 Emergency Procedures

Emergencies can include both fire and non-fire emergencies. Fires are an "expected" emergency in all lab situations and almost all lab staff are trained on emergency steps in the event of a fire. “Non-fire” emergencies can include:

- Loss of electricity, heat, AC, water or other essential utilities.
- Failure of mechanical equipment such as HVAC systems and emergency generators.
- Flooding, tornadoes, earthquakes, or other natural disasters.
- Nearby chemical releases of hazardous materials to the environment (from the lab down the hall or a ruptured tank car one-half mile away).
- Terrorist actions or civil unrest.

5.6 Laboratory Emergency Shutdown Procedures

Each laboratory facility should develop a non-fire emergency plan or incorporate non-fire emergencies into a master emergency response plan. Employees must be trained on the contents of the plan and how to respond in a non-fire emergency. New Mexico Tech has devised a set of simple steps for the shutdown of labs in non-fire emergency situations. These and other steps, based on the requirements of the facility, should be included in the emergency response plan of each unit or facility. This list is by no means complete, but it gives laboratory personnel simple steps to ensure a safe lab shutdown. Please note that these steps should only be implemented if the non-fire emergency is not time dependent, and that no person shall be in a situation that threatens life or health if these steps are implemented.

- Close fume hood sashes.
- Be certain that the caps are on all bottles of chemicals.
- Turn off all non-essential electrical devices. Leave refrigerators and freezers on and make sure the doors are closed. Check the disconnects of large LASERs, radio frequency generators, etc. It may be necessary to check to ensure that essential equipment is plugged into the power receptacles supplied by the emergency generator (usually orange or red).
- Turn off all gas cylinders at the tank valves. Note: If a low flow of an inert gas is being used to "blanket" a reactive compound or mixture, then the lab worker may want to leave the flow of gas on. This should be part of a pre-approved, written, posted standard operating procedure for this material or process.
- Check all cryogenic vacuum traps (Nitrogen, Carbon dioxide, and solvent). The evaporation of trapped materials may cause dangerous conditions. Check all containers of cryogenic liquids to ensure that they are vented to prevent the buildup of internal pressure.
- Check all pressure, temperature, air, or moisture sensitive materials and equipment. This includes vacuum work, distillations, glove boxes used for airless/moisture-less reactions, and all reactions in progress. Terminate all reactions that are in progress, based on the known scope of the emergency.
- If experimental animals are in use, special precautions may need to be taken to secure those areas such as emergency power, alternative ventilation, etc.
- All non-essential staff/students must leave the building. Depending on the nature of the emergency, some staff may need to stay behind to facilitate the start-up of essential equipment once the lab is reopened.

- It is important to remember that some equipment does not shut down automatically, such as large cryogenic magnets, sources of radioactivity, and other pieces of equipment. Be sure to check any special operating procedures for your equipment before an emergency occurs.

5.7 Medical Emergency Procedures

Call 911 from a campus phone (or 575-835-5555 from a cell phone) in any emergency that requires immediate police, fire or medical response to preserve a life.

- Protect the victim from further injury or harm by removing any persistent threat to the victim or by removing the victim to a safe place if needed. However, do not move the injured person unnecessarily. Do not delay in obtaining trained medical assistance if it is safe to do so. Never place yourself in a dangerous situation to provide assistance to an injured person.
- Notify New Mexico Tech Police of the location, nature and extent of the injury by calling 911 from a campus phone, 575-835-5555, or using a Blue Light or Emergency Telephone. Always call from a safe location.
- Provide first aid until help arrives if you have appropriate training and equipment, and it is safe to do so.
- Send someone outside to escort emergency responders to the appropriate location, if possible.

5.8 First Aid Kits

Although there are areas at New Mexico Tech where people work that could be considered hazardous, NMT's main campus has no legal requirements to have first aid kits in work spaces within the campus buildings. This reasoning is addressed by OSHA (29 CFR 1910.151) and cited in the ANSI standard (Z308.1-1998) that states if medical attention can be reached within a reasonable time, or distance, to rely on the professionals and make that part of an emergency plan. New Mexico Tech has fully trained emergency responders on call 24 hours a day, 7 days a week. Injured personnel are encouraged to take advantage of this service by calling 911 from a campus phone or 575-835-5555 from a cell phone.

If you choose to have a first aid kit in your work space, then there are some additional requirements to address. There has to be the appropriate items in the kit to mediate an injury that could happen in your work area. There needs to be a responsible person in your work space that is trained - with their contact information posted on the kit. The kit should be maintained and complete at all times. An NMT Lab Incident/Near Miss Report should be completed when a first aid kit is used due to an injury/illness in a New Mexico Tech University laboratory.

The following is a table listing the minimum required components of both Class A and Class B kits. Class A kits are designed to deal with the most common types of workplace injuries, while Class B kits are designed to handle injuries in high-risk environments, and Class B kits contain more materials, and materials designed for more complex injuries (Source Grainger).

ANSI/ISEA Z308.1 -2021 - Classes of First Aid Kits and Required Contents				
First Aid Supply	Minimum Quantity		Minimum Size or Volume	
	Class A Kits	Class B Kits	U.S.	Metric
Adhesive Bandage	16	50	1 x 3 inches (in)	2.5 x 7.5 centimeters (cm)
Adhesive Tape	1	2	2.5 yards (yds)	2.3 meters (m)
Antibiotic Application	10	25	1/57 ounce (oz)	0.5 gram (g)
Antiseptic	10	50	1/57 oz	0.5 g
Breathing Barrier	1	1	N/A	N/A

Burn Dressing (gel soaked)	1	2	4 x 4 in	10 x 10 cm
Burn Treatment	10	25	1/32 oz	0.9 g
Cold Pack	1	2	4 x 5 in	10 x 12.5 cm
Eye Covering (with means of attachment)	2	2	2.9 square in	19 square cm
Eye/Skin Wash	1	0	1 fluid oz	29 milliliters (ml)
	0	1	4 fluid oz	118.3 ml
Foil Blanket	1	1	52 x 84 in	132 x 213 cm
First Aid Guide	1	1	N/A	N/A
Hand Sanitizer	10	20	1/32 oz	0.9 g

Medical Exam Gloves	2 pair	4 pair	N/A	N/A
Roller Bandage	1	2	2 in x 4 yds	5 cm x 3.66 m
	0	1	4 in x 4 yds	10 cm x 3.66 m
Scissors	1	1	N/A	N/A
Splint	0	1	4 x 2.4 in	10.2 x 61 cm
Sterile Pad	2	4	3 x 3 in	7.5 x 7.5 cm
Tourniquet	0	1	1.5 in (width)	3.8 cm (width)
Trauma Pad	2	4	5 x 9 in	12.7 x 22.9 cm
Triangular Bandage	1	2	40 x 40 x 56 in	101 x 101 x 142 cm

5.9 Fire or Explosion Emergency Procedures

All fires must be reported to New Mexico Tech Police, including those that have been extinguished. Do not hesitate to activate the fire alarm if you discover smoke or fire.

- Alert people in the immediate area of the fire and evacuate the room.
- Confine the fire by closing doors as you leave the room.
- Activate a fire alarm by pulling on an alarm box.
- Notify New Mexico Tech Police of the location and size of the fire by calling 911 from a campus phone, or 575-835-5555 from a cell phone or off campus phone, or using a Blue Light or Emergency Telephone. Always call from a safe location.
- Evacuate the building using the Emergency Evacuation Procedure. Do not use elevators to evacuate unless directed to do so by emergency responders.
- Notify emergency responders of the location, nature and size of the fire once you are outside.

If you have been trained, and it is safe to do so, you may attempt to extinguish the fire with a portable fire extinguisher. Attempt to extinguish only small fires and make sure you have a clear escape path. If you have not been trained to use a fire extinguisher you must evacuate the area.

If clothing is on fire:

- Stop - Drop to the ground or floor and Roll to smother flames.
- Smother flames using a fire blanket.
- Drench with water from a safety shower or other source.
- Seek medical attention for all burns and injuries.

5.10 Fire Extinguishers

All fire extinguishers are inspected regularly (at minimum on an annual basis) and maintained by NMT Facilities Management. Laboratory personnel should perform regular visual checks (at minimum on a monthly basis) to ensure fire extinguishers present in their labs are fully charged. For those fire extinguishers with a readout dial, labs only need to ensure the indicator arrow on the readout dial is within the green zone. If the indicator arrow is on either side of the green zone, which indicates a problem, then call New Mexico Tech Facilities Management to have the fire extinguisher replaced.

Any fire extinguisher that has been used at all, even if it wasn't fully discharged, needs to be reported to New Mexico Tech Facilities Management so a replacement fire extinguisher can be provided in its place.

5.11 Power Outage Procedures

The following is a list of actions that can be implemented in case of a power outage. This list is not a comprehensive list, and is only intended to serve as a guideline, and none of these actions should be performed if there exists a possibility that an individual can be injured or placed in a hazardous situation by performing these actions.

- Assess the extent of the outage in the unit's area.
- Assist other building occupants to move to safe locations. Loss of power to fume hoods may require the evacuation of laboratories and surrounding areas.
- Implement the unit's power outage plan. Evaluate the unit's work areas for hazards created by a power outage.
- Secure hazardous materials.
- Take actions to preserve human and animal safety and health.
- Take actions to preserve research.
- Turn off and/or unplug non-essential electrical equipment, computer equipment and appliances. Keep refrigerators and freezers closed throughout the outage to help keep contents cold.
- If needed, open windows (in mild weather) for additional light and ventilation (this is not always advisable in Biosafety Level 2 labs).

5.12 Chemical Spill Procedures

When a chemical spill occurs, it is necessary to take prompt and appropriate action. The type of response to a spill will depend on the quantity of the chemical spilled and the severity of the hazards associated with the chemical. The first action to take is to alert others in your lab or work area that a spill has occurred. Then you must determine if you can safely clean up the spill yourself.

5.13 Incidental Spills

A spill is considered incidental if the criteria below are met:

- The spill is a small quantity of a known chemical.
- No gasses or vapors are present that require respiratory protection.
- You have the materials and equipment needed to clean up the spill.
- You have the necessary proper personal protective (PPE) equipment available.
- You understand the hazards posed by the spilled chemical.
- You know how to clean up the spill.
- You feel comfortable cleaning up the spill.

If **ANY** of the above items are not met, do not attempt to clean the spill. Instead, contact the Hazardous Materials and Laboratory Safety Specialist immediately at 575-517-0646.

5.13.1 Incidental Spill Cleanup Procedures

The following list of procedures should only be taken if the criteria from Section 5.13 above are all met, including that the individual understands the hazards of the chemicals that were spilled, and that they would not be endangering themselves by performing these procedures. If any doubt exists of these criteria, contact the Hazardous Materials and Laboratory Safety Specialist immediately at 575-517-0646.

The following information is from the American Chemical Society's "Guide for Chemical Spill Response", Section IV: "Recommended Procedures for Cleaning Up Simple Spills" (available at their website at https://www.acs.org/about/governance/committees/chemical-safety/publications-resources/guide-for-chemical-spill-response.html)

A. General Response Guidelines

For simple spills, emergency responders do not need to be notified. However, you should contact the environmental health and safety office or other responsible person within your facility. Most importantly, before cleaning up a simple spill, be sure that you can do so safely. You must have the appropriate personal protective equipment, including, at a minimum, appropriate eye protection, protective gloves, and a lab coat. Additional protective equipment may be required for spills that present special hazards (such as corrosive or reactive spills or spills that have a splash potential). As a rule of thumb, if you need a respirator, you should request outside assistance because you do not have a simple spill.

The following steps should be taken during spill cleanup.

1. **Prevent the spread of dust and vapors.**

   If the substance is volatile or can produce airborne dusts, close the laboratory door and increase ventilation (through fume hoods, for example) to prevent the spread of dusts and vapors to other areas.

2. **Neutralize acids and bases, if possible.**

   Spills of most liquid acids or bases, once neutralized, can be mopped up and rinsed down the drain (to the sanitary sewer). However, be careful because the neutralization process is often vigorous, causing splashes and yielding large amounts of heat. Neutralize acids with soda ash or sodium bicarbonate. Bases can be neutralized with citric acid or ascorbic acid. Use pH paper to determine when acid or base spills have been neutralized. A measured pH of 7 is optimal, but a range of 6 to 8 pH is acceptable.

3. **Control the spread of the liquid.**

Place absorbent materials such as vermiculite, cat litter, or absorbent spill pillows around the spill to contain the spilled liquid.

4. **Absorb the liquid.**

   Add absorbents to the spill, working from the spill's outer edges toward the center. Absorbent materials, such as cat litter or vermiculite, are relatively inexpensive and work well, although they are messy. Spill pillows are not as messy as other absorbents, but they are more expensive. Note that special absorbents are required for chemicals such as hydrofluoric and concentrated sulfuric acids.

5. **Collect and contain the cleanup residues.**

   The neutralized spill residue or the absorbent should be scooped, swept, or otherwise placed into a plastic bucket or other container. For dry powders or liquids absorbed to dryness, double bag the residue using plastic bags. Additional packaging may be required before the wastes can be transported from your laboratory. For spills of powders or solid materials, you may need to add a dust suppressant. Be sure to place descriptive labels on each container.

6. **Dispose of the wastes.**

   Keep cleanup materials separate from normal trash. Contact your environmental health and safety officer for guidance in packaging and labeling cleanup residues. Promptly place cleanup wastes in an appropriate hazardous waste receptacle.

7. **Decontaminate the area and affected equipment.**

   Ventilating the spill area may be necessary. Open windows or use a fan unless the area is under negative pressure. In some instances, your environmental health and safety officer can test the air to ensure that hazardous vapors are gone. For most spills, conventional cleaning products, applied with a mop or sponge, will provide adequate decontamination. If you have any question about the suitability of a decontaminating agent, seek expert advice.

B. Special Precautions

The following precautions apply to chemicals that have hazardous characteristics. Note that some chemicals may exhibit more than one characteristic.

1. **Flammable Liquids**

   Remove all potential sources of ignition. Vapors are what actually burn, and they tend to accumulate near the ground.

   Flammable liquids are best removed through the use of spill pillows or pads. Spill pads backed with a vapor barrier are available from most safety supply companies. Because flammable liquids will probably be incinerated, avoid using inert absorbents such as cat litter. All used absorbent materials should be placed in heavy-duty poly bags, which are then sealed, labeled, and disposed through your facility's hazardous waste management program. Before resuming work, make sure the spill area has been adequately ventilated to remove flammable vapors.

2. **Volatile Toxic Compounds**

   Use appropriate absorbent material to control the extent of the spill. Spill pillows or similar absorbent material usually work best because they do not have the dust associated with cat litter, vermiculite, or corn cobs. Place all used absorbent materials in heavy-duty poly bags. Seal the bags, label them, and hand them over to your facility's hazardous waste management program. Again, make sure the spill area has been adequately ventilated before resuming work.

3. **Direct Contact Hazards**

   Carefully select suitable personal protective equipment. Make sure all skin surfaces are covered and that the gloves you use protect against the hazards posed by the spilled chemical. Often it is a good idea to wear two sets of gloves: one as the primary barrier, the second as a thin inner liner in the event the primary barrier fails. When the cleanup is completed, be sure to wash hands and other potentially affected skin surfaces.

4. **Mercury Spills**

   Mercury spills rarely present an imminent hazard unless the spill occurs in an area with extremely poor ventilation. The main exposure route of mercury is via vapor inhalation. Consequently, if metallic mercury is not cleaned up adequately, the tiny droplets remaining in surface cracks and crevices may yield toxic vapors for years.

When a mercury spill occurs, first cordon off the spill area to prevent people from inadvertently tracking the contamination over a much larger area. Generally, a special mercury vacuum cleaner provides the best method of mercury spill cleanup. DO NOT use a regular vacuum cleaner, because you will only disperse toxic vapors into the air and contaminate your vacuum cleaner. If a special mercury vacuum is not available, first use an appropriate suction device to collect the big droplets, then use a special absorbent (available from most laboratory supply vendors) to amalgamate smaller mercury droplets.

Ideally, mercury spills should be prevented in the first place. Examine all uses of mercury to see if substitutes are available. If substitutes are not available, use trays or other equipment to provide spill containment. Spilled mercury often accumulates in sink traps. Be prepared to contain the mercury when servicing such facilities.

C. Documentation

After cleaning up a spill, a simple write-up should be prepared to document what happened, why, what was done, and what was learned. Such documentation can be used to avoid similar instances in the future. Major incidents are almost always preceded by numerous near misses.

Laboratories seeking to minimize and prevent spills should consider the possible results of their choices and procedures. Such consideration should focus on reducing the likelihood of spills, as well as minimizing spill damage. Experimental plans should only involve chemicals that are actually needed for the desired results. Ideally, laboratories should only store chemicals that will be used within a reasonable period of time. Additionally, correct chemical and experimental equipment choices must be made. Finally, the laboratory worker must not settle for inappropriate laboratory arrangements.

In addition to the above list of procedures from the American Chemical Society, Research Compliance also recommends the following procedures in the event of a simple spill:

- Notify other people in the area that a spill has occurred. Prevent others from coming in contact with the spill (i.e. walking through the spilled chemical). The first priority is to always protect yourself and others.
- Put on the proper Personal Protective Equipment (PPE) such as goggles, gloves, etc. before beginning cleanup. Do not unnecessarily expose yourself to the chemical.
- Stop the source of the spill if possible, and if safe to do so.
- For absorbed hazardous chemicals, label the container and dispose of it through the hazardous waste management program. Contact The Hazardous Materials and Laboratory Safety Specialist at hazmat@nmt.edu or 575-517-0646 for more information.
- Wash the contaminated surface with soapy water. If the spilled chemical is highly toxic, collect the rinse water for proper disposal.
- Report the spill to your supervisor.
- Restock any spill cleanup supplies that you may have used from any spill kits.

5.13.2 Spill Sorbent Materials

Note: The following list containing information based on information available from Cornell University's Environmental Health and Safety website is denoted with an asterisk (*) after the item.

While these materials are recommended spill absorbent materials, they may not be appropriate for every possible chemical spill. When in doubt, contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or hazmat@nmt.edu for advice.

For acid spills (except Hydrofluoric acid):

- Sodium carbonate (soda ash) *
- Sodium bicarbonate (baking soda) *
- Calcium carbonate (limestone)*
- Calcium bicarbonate*
- Vermiculite
- Calcium or Sodium Bentonite (Cat litter)

For Hydrofluoric acid (HF) spills:

- Use Calcium carbonate or Calcium bicarbonate to tightly bind the fluoride ion.*
- PIG ® Hydrofluoric Acid Neutralizer (available at http://www.newpig.com)
- HF ACID EATER Brand Neutralizer (available from Grainger)

NEVER use vermiculite to clean an HF spill, as toxic trifluoride gas is created when vermiculite mixes with HF.

For liquid base spills:

- Use Sodium bicarbonate to lower the pH sufficiently for drain disposal.*

For oil spills:

- Use vermiculite or absorbent clay.

For most aqueous solutions:

- Use vermiculite or absorbent clay. Never use vermiculite or absorbent clay for Hydrofluoric Acid spills as it may release toxic gasses.

For most organic liquid spills:

- Use vermiculite or absorbent clay. If the liquid is flammable, spill pillows or similar absorbent pads.

For oxidizing liquids:

- Use absorbent clay, vermiculite, or some other non reactive absorbent material. Do not use paper towels or any sorbents made from organic material.

For mercury spills:

- Do not dispose of mercury or mercury contaminated spill debris in the regular trash or down the drain.
- While there are several commercially available mercury amalgamation powders (MercAmal, Spilfyter, etc.) there are no mercury spill sorbents. Physical removal processes are best for removing and collecting mercury.
- If you need help collecting Mercury from a spill, contact the Hazardous Materials and Laboratory Safety Specialist by calling 575-517-0646 or emailing at hazmat@nmt.edu.

Note: While powdered sulfur will help reduce mercury vapors, the sulfur greatly complicates the spill cleanup, and should be avoided for this use if possible.

5.13.3 Spill Kits

While commercially available spill kits are available from a number of safety supply vendors, laboratory personnel can assemble their own spill kits to properly clean up chemicals specific to their laboratory. Whether commercially purchased or made in- house, Research Compliance strongly encourages all laboratories to obtain a spill kit for their use. Colleges and departments should give serious consideration to distributing basic spill kits to all laboratories within their units.

The following recommendations for spill kits is from the American Chemical Society's Appendix C for their "Guide for Chemical Spill Response", Section IV: "Recommended Procedures for Cleaning Up Simple Spills" (available at their website at https://www.acs.org/about/governance/committees/chemical-safety/publications-resources/guide-for-chemical-spill-response.html)

Appendix C: Recommended Components of a Laboratory Chemical Spill Kit

Basic Kit

- Kit Container
- Accessible
- Visible
- Securable

Residue Management

- Whisk broom or hand-held brush
- Plastic dust pan
- Metal dust pan
- Large, sealable (e.g., Ziploc) plastic bags
- 5-gallon plastic drum liners
- 5-gallon waste disposal container with lid

Absorbents

- Paper towels (one roll)
- Pillows and brooms
- Sheets and pads
- Loose bulk (e.g., cat litter)

Mercury Spill Kit (unless it is known that there is no mercury in the laboratory)

Personal Protective Equipment (PPE)

- Chemical splash goggles
- Face shields
- Gloves (proper elastomer for the material in the lab)
- Appropriate body protection, such as
- Lab coat
- Elastomeric aprons
- Tyvek suits
- Shoe/foot coverings
- "Saranex" suits

Basic Emergency Equipment (should be close at hand)

- Respirators
- Neutralizers (citric acid, sodium bicarbonate, etc.)
- Special reactants (chelating agents, etc.)
- Decontaminants and biostats (e.g., for blood-borne pathogen cleanup)
- Specialized PPE

In addition to the above information from the American Chemical Society, Research Compliance also recommends the following:

The spill kit should be clearly labeled as "SPILL KIT", with a list of the contents posted on or in the kit. This list should include information about restocking the kit after use and where to obtain restocking materials.

<u>Laboratory personnel must also be properly trained on</u>:

- How to determine if they can or should clean up the spill, or if they should call NMT Campus Police at 911 from a campus phone or 575-835-5555 from a non-campus or cell phone, or if they should contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646.
- Where the spill kit will be kept within the laboratory.
- What items are in the kit and where replacement items can be obtained.
- How to properly use the items in the kit.
- How to clean up the different types of chemical spills.
- How to dispose of spill cleanup material.

Research Compliance can provide assistance and guidance in assembling spill kits for laboratories and offers a training class on "Cleaning Up Small Spills". More information can be obtained by contacting Research Compliance at research.compliance@nmt.edu or by contacting the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or at hazmat@nmt.edu.

5.14 Major Spills

A major spill is any chemical spill for which lab personnel determine they need outside assistance to safely clean up a spill. Whenever New Mexico Tech Police are notified of a spill for this purpose, the Hazmat and Laboratory Safety Specialist is to be notified to assist with spill cleanup. NMT Campus Police can be notified by calling 911 from a campus phone, or by calling 575-835-5555 from a cell phone or non-campus phone. The Hazardous Materials and Laboratory Safety Specialist can be notified by calling 575-517-0646.

5.14.1 Major Spill Cleanup Procedures

When a spill occurs that you are not capable of handling:

- Alert people in the immediate area of the spill and evacuate the room.
- If an explosion hazard is present, do not unplug, or turn electrical equipment on or off – doing so can result in a spark and ignition source.
- Confine the hazard by closing doors as you leave the room.
- Use eyewash or safety showers as needed to rinse spilled chemicals off people or yourself.
- Evacuate any nearby rooms that may be affected. If the hazard will affect the entire building, then evacuate the entire building by pulling the fire alarm.
- Notify New Mexico Tech Police as soon as is safely possible by calling 575-835-5555 or using a Blue Light or Emergency Telephone. Always call from a safe location.

Be prepared to provide New Mexico Tech Police with the following information:

- Where the spill occurred (building and room number).
- If there are any injuries and/or medical attention is needed.
- The identity of the spilled material(s) - be prepared to spell out the chemical names.
- The approximate amount of material spilled.
- How the spill occurred, if known.
- Any immediate actions you took.
- Who first observed the spill and the approximate time it occurred.
- Where you will meet emergency responders, or provide a call back number (if available).

Once outside, notify emergency responders of the location, nature and size of the spill. Isolate contaminated persons and protect yourself and others from chemical exposure.

5.15 Emergency Eyewash and Showers

All laboratories using hazardous chemicals, particularly corrosive chemicals, must have access to an eyewash and/or an emergency shower as per the OSHA standard 29 CFR 1910.151(c) – Medical Services and First Aid. The ANSI Standard Z358.1-2009 - Emergency Eyewash and Shower Equipment provides additional guidance by stating that emergency eyewash and/or emergency showers be readily accessible, free of obstructions and within 10 seconds from the hazard. The ANSI standard also outlines specific requirements related to flow requirements, use of tempered water, inspection and testing frequencies, and training of laboratory personnel in the proper use of this important piece of emergency equipment.

Due to the flow requirements outlined in the ANSI standard, hand held bottles do not qualify as approved eyewashes.

5.15.1 Testing and Inspection of Emergency Eyewash and Showers

The ANSI Standard provides guidance by stating that plumbed emergency eyewash and safety showers should be activated weekly to verify proper operation and inspected annually. Regular activation (weekly flushing) ensures the units are operating properly, helps to keep the units free of clutter, and helps prevent the growth of bacteria within the plumbing lines, which can cause eye infections. It is recommended to allow the water to run for at least 3 minutes. Research Compliance strongly encourages laboratories to post an “Eyewash Testing Sheet” near the eyewash to keep track and document that weekly activation is occurring.

Laboratories are responsible for activating eyewashes in their spaces and ensuring that access to eyewashes and emergency showers are kept free of clutter and ensuring the eyewash nozzle dust covers are kept in place. If nozzle dust covers are not kept on the eyewash nozzles, dust or other particles can clog the nozzles and affect water flow. This could result in dust or other particles being forced into the eyes when the eyewash station is used.

Report any malfunctioning eyewash stations and emergency showers to your Department Coordinator to have the unit repaired. If either the emergency shower or eyewash is not working properly, post a “Do Not Use” sign on the unit to alert others.

Research Compliance performs free annual inspections of eyewashes and emergency showers. Research Compliance will test units for compliance with ANSI Z358.1-2009 including:

- Test the water flow for proper quantity, spray pattern, and good water quality.
- Ensure the unit is the proper height from the floor.
- Ensure the unit is not obstructed.
- Ensure the unit has a tempering valve (if the unit does not have a tempering valve, this will be identified as a recommended repair in the inspection report).
- Ensure valves are working properly.
- Ensure signs are posted.
- Ensure the unit is free of corrosion.

5.15.2 Installation of New Emergency Eyewash and Showers

As with installation of other safety equipment, all new eyewashes and emergency showers must be installed in consultation with Facilities Management and Research Compliance. Before New Mexico Tech will commission any new emergency shower or eyewash, Research Compliance must ensure that the equipment will be in compliance with State and Federal regulations, including the ANSI Standard Z358.1-2009 - Emergency Eyewash and Shower Equipment.

5.15.3 Maintenance Procedures for Emergency Eyewash and Showers

Facilities Management should be contacted in case any Emergency Eyewash or Shower needs to have maintenance performed. If assistance is needed, contact Research Compliance at research.compliance@nmt.edu.

5.15.4 Using Emergency Eyewash and Showers

Preplan your experiments and include emergency procedures. Identify the locations of the nearest emergency shower and eyewash before working with hazardous chemicals and ensure that all personnel know exactly where to find them.

In the event of an emergency (chemical spill or splash) where an eyewash or emergency shower is needed, follow these procedures:

Eyewashes

1. If you get a chemical in your eyes, yell for help if someone else is in the lab.
2. Immediately go to the nearest eyewash and push the activation handle all the way on.
3. Put your eyes or other exposed area in the stream of water and begin flushing.
4. Open your eyelids with your fingers and roll your eyeballs around to get maximum irrigation of the eyes.
5. Keep flushing for at least 15 minutes or until help arrives. The importance of flushing the eyes first for at least 15 minutes cannot be overstated! For accidents involving Hydrofluoric acid, follow the special Hydrofluoric acid precautions.
6. If you are alone, call 911 after you have finished flushing your eyes for at least 15 minutes.
7. Seek medical attention.
8. Complete an NMT Lab Incident/Near Miss Report.

If someone else in the lab needs to use an eyewash, guide them to the eyewash, activate the eyewash for them, and help them get started flushing their eyes using the procedures above and then call 911. After calling 911, go back to assist the person using the eyewash and continue flushing for 15 minutes or until help arrives and have the person seek medical attention.

Emergency Showers

1. If you get chemical contamination on your skin resulting from an accident, yell for help if someone else is in the lab.
2. Immediately go to the nearest emergency shower and pull the activation handle.
3. Once under the stream of water, begin removing your clothing to wash off all chemicals.
4. Keep flushing for at least 15 minutes or until help arrives. The importance of flushing for at least 15 minutes cannot be overstated! If you spill Hydrofluoric acid on yourself, follow the special Hydrofluoric acid precautions.
5. If you are alone, call 911 after you have finished flushing for at least 15 minutes.
6. Seek medical attention.
7. Complete an NMT Lab Incident/Near Miss Report.

If someone else in the lab needs to use an emergency shower (and it is safe for you to do so), guide them to the emergency shower, activate the shower for them, and help them get started flushing using the procedures above and then call 911. After calling 911, go back to assist the person using the shower and continue flushing for 15 minutes or until help arrives and have the person seek medical attention.

NOTE: Although an emergency is no time for modesty, if a person is too modest and reluctant to use the emergency shower, you can assist them by using a lab coat, other piece of clothing, fire blanket, or other barrier to help ease their mind while they undress under the shower.

If you are assisting someone else, you should wear gloves to avoid contaminating yourself. When using an emergency shower, do not be concerned about the damage from flooding. The important thing to remember is to keep flushing for a minimum of 15 minutes. If there is a large quantity of chemical spilled or washed off, please contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 to see if the rinsate needs to be collected as hazardous waste.

5.16 Laboratory Incident/Near Miss Exposure Reporting

All lab accidents, injuries, and near misses, no matter how minor, are **required** to be reported to University officials through the NMT Lab Incident/Near Miss Report. The supervisor of an injured employee, the department head, or a designated individual within the department must complete all sections of this form within **24 hours** after the injury is first reported. The NMT Lab Incident/Near Miss Report can also be accessed through the NMT HAZMAT Safety Information page at https://www.nmt.edu/research/hazmat.php.

It is the responsibility of the Principal Investigator and laboratory supervisor to ensure all injuries are reported to New Mexico Tech officials.

5.17 Medical Consultations

When a chemical exposure occurs, medical consultations and medical examinations will be made available to laboratory workers who work with hazardous chemicals as required. All work related medical examinations and consultations will be performed by or under the direct supervision of a licensed physician and will be provided at no cost to the employee, without loss of pay, and at a reasonable time, through the following service providers:

- If you work in Socorro NM:
    - Bhasker Medical Clinic
      200 Neel Ave
      Socorro, NM 87801
      575-835-2940
    - Presbyterian Medical Group
      Hwy 60
      Socorro, NM 87801
      575-838-4690
    - Socorro General Hospital
      Hwy 60
      Socorro, NM 87801
      575-835-1140
- If you work in Albuquerque, NM:
    - Concentra
      5700 Harper NE
      Albuquerque, NM 87109
      505-823-9166
    - Rehabilitation & Occupational Medicine Services
      3811 Commons Ave NE
      Albuquerque, NM 87109
      505-823-8450
    - Presbyterian Occupational Medicine Clinic
      5901 Harper NE
      Albuquerque, NM 87109
      505-823-8450
- If you work in Playas, NM:
    - Hidalgo Medical Services
      530 DeMoss St

Lordsburg, NM 88045
575-542-8384
- Gila Regional Medical Center
1313 E. 32nd St
Silver City, NM 88061
575-538-4000

The opportunity to receive medical attention, including any follow up examinations, will be provided to employees who work with hazardous chemicals under the following circumstances:

- Whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory.
- Where airborne exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the Permissible Exposure Limit) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements. Action level means the airborne concentration of a specific chemical, identified by OSHA, and calculated as an 8-hour time weighted average (TWA).
- Whenever an event such as a spill, leak, explosion or other occurrence takes place and results in the likelihood of a hazardous exposure. Upon such an event, the affected employee shall be provided an opportunity for a medical consultation. The consultation shall be for the purpose of determining the need for a medical examination.

More information on action levels and Permissible Exposure Limits can be found on the OSHA Health and Safety topics page – Permissible Exposure Limits at https://www.osha.gov/annotated-pels/table-z-1.

5.17.1 Information Provided to the Physician

The physician shall be provided with the following information:

- The identity of the hazardous chemical(s) to which the employee may have been exposed. Such information can be found in the Safety Data Sheet (SDS) for the chemical(s).
- A description of the conditions under which the exposure occurred including quantitative exposure data, if available.
- A description of the signs and symptoms of exposure that the employee is experiencing, if any.

5.17.2 The Physician's Written Opinion

The physician's written opinion for the consultation or examination shall include:

- The results of the medical examination and any associated tests.
- Any medical condition that may be revealed in the course of the

examination, which may place the employee at increased risk as a result of exposure to a hazardous workplace.

- A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.
- The written opinion shall not reveal specific findings of diagnoses unrelated to the occupational exposure.

All records of medical consultations, examinations, tests, or written opinions shall be maintained by NMT's Human Resource Office in accordance with 29 CFR 1910.1020 - Access to employee exposure and medical records. Human Resources is located at Leroy Place, Socorro NM 87801, inside Brown Hall Room 118. Exposure monitoring records of contaminate levels in laboratories will be maintained by Research Compliance. For more information, contact Research Compliance at research.compliance@nmt.edu.

6 Hazard Communication (Hazcom) Requirements

Federal and state laws, as well as New Mexico Tech policy, require all laboratory workers to receive Laboratory Safety and Chemical Waste Disposal training and be informed of the potential health and safety risks that may be present in their workplace. Documentation must be maintained to demonstrate that such training was provided and received. In order to assist laboratory personnel, comply with this requirement, laboratory safety training must be obtained either through New Mexico Tech or documented as having been received from an alternative source.

The OSHA Laboratory Standard requires employers to provide employees with information and training to ensure they are apprised of the hazards of chemicals present in their work area. The Laboratory Standard goes on to state that such information shall be provided at the time of an employee's initial assignment to a work area where hazardous chemicals are present and prior to assignments involving new exposure situations.laboratory workers to receive Laboratory Safety and Chemical Waste Disposal training and be informed of the potential health and safety risks that may be present in their workplace

As per the OSHA Laboratory Standard, information that must be provided to employees includes:

- The contents of the Laboratory Standard and its appendices (Appendix A and Appendix B) shall be made available to employees.
- The location and availability of the employer's Chemical Hygiene Plan.
- 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, SDSs received from the chemical supplier.

The Laboratory Standard goes on to state this training shall include:
- Methods and observations that may be used to detect the presence or release of a hazardous chemical.
- The physical and health hazards of chemicals in the work area.
- The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and PPE to be used.

The employee shall be trained on the applicable details of the employer's written Chemical Hygiene Plan.

While the OSHA Laboratory Standard is specific to working with hazardous chemicals, laboratory employees must also be provided with the proper training and information related to the other health and physical hazards that can be found in their work environment, including the hazards described within this Laboratory Safety Manual (chemical, radioactive, biological, physical, cryogenic, etc.).

It is the responsibility of Principal Investigators and laboratory supervisors to ensure personnel working in laboratories under their supervision have been provided with the proper training, have received information about the hazards in the laboratory they may encounter, and have been informed about ways they can protect themselves.

6.1 Training Options

Principal Investigators and laboratory supervisors have a number of options available to them to ensure laboratory employees under their supervision have received proper training. These options include:
- Training programs provided by Research Compliance
- In-house training programs (provided by the Principal Investigator or laboratory supervisor)
- Training manuals and booklets

The keys to any training programs are:
- The instructor providing the training is technically qualified to provide training on the particular subject.
- The training program(s) address the hazards present in the laboratory and describe ways employees can protect themselves.
- The training program and attendance must be documented using a sign-in sheet and these records must be readily available and accessible upon request.

Training sessions do not have to be hours or half-day sessions, they can be short, 15 minute, half hour, or however long it takes to achieve the training objectives.

Please note that one training class is usually not comprehensive enough to cover all of the hazards found within a laboratory. Principal Investigators and laboratory supervisors will find that it is necessary to use a combination of the options available to ensure their employees are properly trained.

Research Compliance Training Programs

Research Compliance offers a number of training programs on a regular basis and offers a number of programs "Upon Request". For any "Upon Request" training class, Research Compliance can come to your building or laboratory and provide the training program for your laboratory group. All Research Compliance provided training programs and attendance sheets are kept on file in the Research Compliance Office.

In-House Training Programs

In-house training can include department provided training, and training by Principal Investigators and laboratory supervisors. Training sessions can be stand-alone classes, on-the-job training, or short (15 minute) sessions incorporated as part of a laboratory group meeting. The key is to make sure the training is documented with a sign-in sheet.

Training Manuals and Booklets

Principal Investigators and laboratory supervisors can utilize training manuals, booklets, web page downloads, etc., as part of an ongoing training program by simply having laboratory staff review the material, be given an opportunity to ask any questions, and sign off that they read and understood the material.

7 Safe Chemical Use

Safe chemical use includes minimizing exposure to chemicals, proper training, understanding chemical hazards, proper labeling, proper storage and segregation, and proper transport.

7.1 Minimize Exposure to Chemicals

The best way laboratory personnel can protect themselves from chemical hazards is to minimize their exposure to them. In order to minimize chemical exposure:

- Substitute less hazardous chemicals in your experiments whenever possible.
- Always use the smallest possible quantity of chemical for all experiments. Consider microscale experiments and activities.
- Minimize chemical exposures to all potential routes of entry - inhalation, ingestion, skin and eye absorption, and injection through proper use of engineering controls and personal protective equipment.

- Be sure to select the proper PPE and regularly inspect it for contamination, leaks, cracks, and holes. Pay particular attention to gloves.
- Do not pipette or apply suction by mouth.
- 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.
- Do not underestimate the risk of exposure to chemicals - even for substances of no known significant hazard.
- 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.
- Chemicals that are particularly hazardous substances require prior approval from your supervisor and special precautions to be taken.
- When working with mixtures of chemicals, laboratory personnel should assume the mixture to be more toxic than the most toxic component in the mixture.
- Consider all substances of unknown toxicity to be toxic until proven otherwise.
- Request exposure monitoring to ensure the Permissible Exposure Limits (PELs) of OSHA and the current Threshold Limit Values (TLVs) of the American Conference of Governmental Industrial Hygienists are not exceeded.
- Promptly clean up all chemical spills regardless of whether the chemical is considered hazardous or nonhazardous. When cleaning up spills, remember to clean up any splashes that may have occurred on the sides of cabinets and doors in the immediate area.
- When working in cold rooms, keep all toxic and flammable substances tightly closed as cold rooms have recirculated atmospheres.
- Be aware of the potential asphyxiation hazard when using cryogenic materials and compressed gasses in confined areas such as cold rooms and environmental chambers. If necessary, install an oxygen monitor/oxygen deficiency alarm and/or toxic gas monitor before working with these materials in confined areas. Contact the Hazmat and Lab Safety Specialist at 575-517-0646 for more assistance.
- Do not eat, drink, chew gum, or apply cosmetics in areas where hazardous chemicals are being used.
- Keep all food and drink out of refrigerators and freezers used to store chemicals. Refrigerators used to store chemicals should be labeled as "Chemicals Only – No Food". Refrigerators used to store food should be labeled as "Food Only – No Chemicals". Please note: no food or drink should be stored in a lab that stores hazardous chemicals. If there are any items that can be construed as food or drink (e.g. distilled water bottles, strawberries used for DNA analysis experiments, vinegar, etc.), those items should be labeled "For Lab Use Only", "Not for human consumption", or similarly

worded signage that clearly distinguishes that the items are not to be consumed as food or drink.

- Always wash hands with soap and water after handling chemicals and especially before leaving the lab and eating – even if gloves were worn during chemical handling.
- Always remove personal protective equipment, such as gloves and lab coats, before leaving the lab.
- Do not attempt to scale up experiments until after you have run the experiment according to published protocols and you are thoroughly familiar with the potential hazards. When scaling up an experiment – change only one variable at a time, i.e. don't change the heat source, the volumes, and the glassware all at once. It is also advisable to let one of your other lab group members check your setup prior to each run.

7.2 Understanding Chemical Hazards

Chemicals pose both health and physical hazards. For the purposes of this document, health hazard will be used interchangeably with chemical hazard and health effects on the body will be used interchangeably with chemical effects on the body.

According to OSHA, health hazard means "a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term 'health hazard' includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system and agents which damage the lungs, skin, eyes, or mucous membranes."

According to OSHA, physical hazard means "a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive." Physical hazards are covered in Section 15 of this document.

7.3 Chemical Hazard Information

As part of the employers Chemical Hygiene Plan, the OSHA Laboratory Standard requires that "the employer shall provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work area…Such information shall be provided at the time of an employee's initial assignment to a work area where hazardous chemicals are present and prior to assignments involving new exposure situations."

It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that staff and students under their supervision are provided with adequate training and information specific to any hazards (chemical, physical, radioactive, cryogenic, etc.) found within their laboratories.

In addition to required health and safety training as per the OSHA Lab Standard, other sources of information on chemical and physical hazards include:

- This Laboratory Safety Manual
- Known reference materials (New Mexico Tech maintains a reference library)
- Other department's safety manuals
- Safety Data Sheets (SDSs)
- Websites
- NMT training programs
- Departmental Safety Committees
- Container labels
- Laboratory Standard Operating Procedures
- Laboratory signage and postings
- Publications such as the American Chemical Society – Safety in Academic Chemistry Laboratories

7.3.1 Safety Data Sheets (SDSs)

Safety Data Sheets (SDSs) are an important part of any laboratory safety program in communicating information to chemical users. SDSs provide useful information such as:

- The identity of the chemical substance.
- Physical and chemical characteristics.
- Physical and health hazards.
- Primary routes of entry.
- OSHA Permissible Exposure Limits (PELs)
- Carcinogenic and reproductive health status.
- Precautions for safe handling and use (including PPE).
- Spill response procedures.
- Emergency and first aid questions.
- Date the SDS was prepared.

Any chemical shipment received should be accompanied by an SDS (unless one has been shipped with a previous order). If you do not receive an SDS with your shipment, check the chemical manufacturers website, call the manufacturer directly, or contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or by email at hazmat@nmt.edu to request assistance in obtaining the SDS.

If you have questions on how to read SDSs, or questions about the terminology or data used in SDSs, you can contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 for more information.

It is the responsibility of Principal Investigators and laboratory supervisors to ensure that staff and students working in laboratories under their supervision have obtained required health and safety training and have access to SDSs (and other sources of information) for all hazardous chemicals used in laboratories under their supervision.

SDSs must be accessible at all times. Access to SDSs can mean access to paper copies or electronic access via the internet. Research Compliance maintains links to a number of SDS websites and other sites with chemical health and safety information.

Research Compliance strongly encourages paper copies of SDSs be kept in the laboratory, however, having SDS websites bookmarked is acceptable as long as all employees in the workplace know where to find the SDSs and are trained on the use of computers to access SDSs. If a laboratory chooses to use electronic access, then Research Compliance recommends the SDS website link be posted on the computer or in another conspicuous location, and the SDS links are checked periodically to ensure that the link is still active. Providing a QR code to the SDS links in a conspicuous place is also an option for providing electronic access. Some departments maintain three ring binders - “Big Red Books” - with SDSs. Check with your PI or Lab Manager for the location of the departmental SDS collection. Please note that while electronic access to SDS information is allowable, paper copies are still preferable due to situations where electrical power to computers storing SDS information, or internet access to SDS links can be interrupted.

Please note: any accidents involving a chemical will require an SDS being provided to emergency response personnel and to the attending physician so proper treatment can be administered.

The general “rule of thumb” is that a person working in a laboratory should be able to produce an SDS for any hazardous chemical found in the lab within at most five minutes.

7.3.2 SDSs and Newly Synthesized Chemicals

Principal Investigators will be responsible for ensuring that newly synthesized chemicals are used exclusively within their laboratories and are properly labeled. If the hazards of a chemical synthesized in the laboratory are unknown, then the chemical must be assumed to be hazardous and the label should indicate the potential hazards of that substance have not been tested and are unknown.

The Principal Investigator must ensure a SDS is prepared for newly synthesized chemicals if:

The chemical is hazardous according to the OSHA definition of hazardous (if the hazards are not known, then the chemical must be assumed to be hazardous).

AND

The newly created chemical or intermediate compound is going to be transferred to a different researcher or testing lab on or off of the New Mexico Tech University campus.

OR

The newly created chemical or intermediate compound is going to be kept in the lab for an on-going basis for use by current and/or future researchers in the lab where it was originally made.

OR

The newly created chemical or intermediate compound is going to be provided to another research group at New Mexico Tech University.

7.4 Routes of Chemical Entry

The potential health effects that may result from exposure to chemicals depends on a number of factors. These factors include the properties of the specific chemical (including toxicity), the dose and concentration of the chemical, the route of exposure, duration of exposure, individual susceptibility, and any other effects resulting from mixtures with other chemicals.

In order to understand how chemical hazards can affect you, it is important to first understand how chemicals can get into your body and do damage. The four main routes of entry are inhalation, ingestion, injection, and absorption through the skin and eyes.

7.4.1 Inhalation

Inhalation of chemicals occurs by absorption of chemicals via the respiratory tract (lungs). Once chemicals have entered into the respiratory tract, the chemicals can then be absorbed into the bloodstream for distribution throughout the body. Chemicals can be inhaled in the form of vapors, fumes, mists, aerosols and fine dust.

Symptoms of exposure to chemicals through inhalation include eye, nose, and throat irritation, coughing, difficulty in breathing, headache, dizziness, confusion, and collapse. If any of these symptoms are noted, leave the area immediately and get fresh air. Seek medical attention if symptoms persist and complete an NMT Lab Incident/Near Miss Report.

Laboratory workers can protect themselves from chemical exposure via inhalation through proper use of a functioning fume hood, use of dust masks and respirators when a fume hood is not available, avoiding benchtop use of hazardous chemicals, ensuring chemical containers are kept tightly capped, and ensuring all chemical spills are promptly cleaned up.

7.4.2 Ingestion

Chemical exposure through ingestion occurs by absorption of chemicals through the digestive tract. Ingestion of chemicals can occur directly and indirectly. Direct ingestion can occur by accidently eating or drinking a chemical; with proper housekeeping and labeling, this is less likely to occur. A higher probability of receiving a chemical exposure can occur by way of indirect ingestion. This can occur when food or drink is brought into a chemical laboratory. The food or drink can then absorb chemical contaminants (vapors or dusts) in the air and result in a chemical exposure when the food or drink is consumed. This can also occur when food or drink is stored with chemicals, such as in a refrigerator. Ingestion can occur when a laboratory worker who handles chemicals does not wear gloves or practice good personal hygiene, such as frequent hand washing, and then leaves the laboratory to eat, drink, or smoke. In all cases, a chemical exposure can result, although the effects of chronic exposure may not manifest itself until years later.

Symptoms of chemical exposure through ingestion include metallic or other strange tastes in the mouth, stomach discomfort, vomiting, problems swallowing, and a general ill feeling. If you think you may have accidentally ingested a chemical, seek medical attention immediately and/or call the Poison Control Center at 1-(800)-222-1222 or New Mexico Tech Police at 575-835-5555 from a cell phone or off campus phone. After seeking medical attention, complete an NMT Lab Incident/Near Miss Report.

The best protection against ingestion of chemicals is to properly label all chemical containers, never consume food or drink or chew gum in laboratories, always wear PPE (such as gloves), and practice good personal hygiene, such as frequent handwashing (especially after removing gloves).

7.4.3 Injection

Chemical exposure via injection can occur when handling chemically contaminated items such as broken glass, plastic, pipettes, needles, razor blades, or other items capable of causing punctures, cuts, or abrasions to the skin. When this occurs, chemicals can be injected directly into the bloodstream and cause damage to tissue and organs. Due to direct injection into the bloodstream, symptoms from chemical exposure may occur immediately.

Laboratory workers can protect themselves from an injection hazard by wearing proper PPE such as safety glasses/goggles, face shields, and gloves. Inspect all glassware for chips and cracks before use, and immediately discard any glassware or plastic-ware that is damaged. To help protect coworkers in the lab and building care staff, all broken glass should be disposed of in a puncture resistant container labeled as “Broken Glass”. This can be a commercially purchased “broken glass” container or simply a cardboard box or other puncture resistant container labeled as “Broken Glass”. If using a cardboard box for these purposes, it is advisable to line the box with a plastic bag and/or taping the boxes corners prior to placing any broken glass in the box, to minimize the likelihood of small particles of broken glass from escaping the box.

Whenever cleaning up broken glass or other sharp items, always use a broom, scoop or dustpan, or devices such as pliers, before using your hands to pick up broken pieces. If you have to use your hands, it is best to wear leather gloves when handling broken glass.

For other items that can cause cuts or puncture wounds, such as needles and razor blades, never leave these items out in the open where someone could come into contact with them. Research Compliance recommends using a device such as a piece of Styrofoam or similar item to secure them for later use. For disposal, use an appropriate “sharps” container.

If you do receive a cut or injection from a chemically contaminated item, if possible, gently try to remove the object and immediately rinse under water while trying to flush the wound and remove any chemical contamination, administer first aid and seek medical attention if necessary, and then complete an NMT Lab Incident/Near Miss Report.

7.4.4 Eye and Skin Absorption

Some chemicals can be absorbed by the eyes and skin, resulting in a chemical exposure. Most situations of this type of exposure result from a chemical spill or splash to unprotected eyes or skin. Once absorbed by these organs, the chemical can quickly find its way into the bloodstream and cause further damage, in addition to the immediate effects that can occur to the eyes and the skin.

Symptoms of eye exposure can include itchy or burning sensations, blurred vision, discomfort, and blindness. The best way to protect yourself from chemical splashes to the eyes is to always wear safety glasses in the laboratory whenever eye hazards exist (chemicals, glassware, lasers, etc.). If you are pouring chemicals, then indirectly vented splash goggles are more appropriate than safety glasses. Whenever a severe splash hazard may exist, the use of a face shield, in combination with splash goggles is the best choice for protection.

Please note, wearing a face shield by itself does not provide adequate eye protection.

If you do get chemicals in your 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 NMT Lab Incident/Near Miss Report.

Symptoms of skin exposure to chemicals include dry, whitened skin, redness, swelling, rashes, blisters, itching, chemical burns, cuts, and defatting. Please note that some chemicals can be readily absorbed by the skin.

Laboratory workers can protect their skin from chemical exposure by selecting and wearing the proper gloves, wearing a lab coat and other personal protective equipment for special hazards (such as protective sleeves, face shields, and aprons), and not wearing shorts and sandals in areas where chemicals are being used - even if you are not using chemicals, but someone else in the lab is using chemicals nearby.

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. Seek medical attention afterward, especially if symptoms persist.

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 NMT Lab Incident/Near Miss Report.

Please note that some chemicals, such as Hydrofluoric acid, require use of a special antidote (such as Calcium gluconate gel) and special emergency procedures. Be sure to read SDSs for any chemical you work with to determine if a special antidote is needed when chemical exposure occurs.

7.5 Chemical Exposure Limits

The OSHA Laboratory Standard requires that laboratory employee exposure of OSHA Regulated Substances do not exceed the Permissible Exposure Limits as specified in 29 CFR Part 1010, subpart Z.

The Permissible Exposure Limits (PEL) are based on the average concentration of a chemical to which workers can be exposed to over an 8-hour workday, 5 days per week, for a lifetime without receiving damaging effects. In some cases, chemicals can also have a Ceiling (C) limit, which is the maximum concentration that cannot be exceeded. OSHA has established PELs for over 500 chemicals. Permissible Exposure Limits are legally enforceable.

Another measure of exposure limits are Threshold Limit Values (TLV) which are recommended occupational exposure limits published by 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. TLVs also have Ceiling (C) limits, which are the maximum concentration a worker can be exposed to at any given time. The ACGIH has established TLVs for over 800 chemicals.

A main point of difference between PELs and TLVs is that TLVs are updated annually by ACGIH based on new data and information, while the vast majority of PELs have not been updated since they were first introduced shortly after the adoption of the Occupational Safety and Health Act in 1970.

Another good resource for information concerning PELs and TLVs is the National Institute for Occupational Health and Safety (NIOSH). NIOSH, in association with the Department of Health and Human Services (DOH) and Centers for Disease Control (CDC), produces the "NIOSH Pocket Guide to Chemical Hazards", an immensely useful book for finding information on individual chemicals. The NIOSH Pocket Guide contains information on many hazardous chemicals and their PELs and Recommended Exposure Limits (RELs). The physical book is an invaluable resource, as is its digital counterpart which is available for most smartphones and tablets through the App Store or Google Play Store.

A major point of difference between PELs, TLVs, and RELs is that while PELs are legally enforceable, TLVs and RELs are advisory guidelines only and are not legally enforceable. Both PELs and TLVs can be found in SDSs, while RELs are not usually included.

7.5.1 Chemical Exposure Monitoring

As a laboratory worker, you may use a variety of potentially hazardous materials on a daily basis. Safe use of these materials depends heavily on following proper laboratory work practices and the utilization of engineering controls. In certain circumstances, it is necessary to verify that work practices and engineering controls are effective in limiting exposures to hazardous materials. Research Compliance 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. Exposure monitoring data is compared to existing OSHA and ACGIH exposure guidelines and is often used to make recommendations concerning engineering controls, work practices, and PPE.

If you think you are receiving a chemical exposure in excess of OSHA exposure limits, such as feeling symptoms commonly associated with exposure to hazardous materials, or work with any of the chemicals listed below, contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 and we can use a variety of sampling methods to monitor for any potential exposures.

In some cases, OSHA substance specific standards actually require that the employer conduct initial exposure monitoring. Examples of chemicals that fall into this category include:

- Formaldehyde
- Vinyl chloride
- Methylene chloride
- Benzene
- Ethylene oxide

Other substances that have exposure monitoring requirements include:

- Lead
- Cadmium
- Silica

7.6 Chemical Labeling

The simple rule for chemical labeling is - if a container looks like it contains a chemical (even a clear liquid), then it must be labeled with the contents. Proper labeling of chemicals is one way of informing people who work in laboratories 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. Even a container of water needs to be labeled properly!

New chemical containers have the proper labeling information on the chemical label.

The OSHA Laboratory Standard requires that labels on all incoming containers must be maintained and not defaced. As part of laboratory good housekeeping and self-inspections, if any chemical labels appear to be falling off, then laboratory personnel should tape the label back on the container or relabel with a permanent label.

7.6.1 Non-Original Containers

Non-original containers (secondary use containers) such as wash bottles, squirt bottles, temporary storage containers, beakers, flasks, bottles, vials, etc. or any container that a chemical from an original container is transferred into, must be properly labeled. In general, Research Compliance recommends writing out the full chemical name and any hazards associated with that chemical. Laboratory personnel are strongly encouraged to use commercially available pre-labeled containers (such as squirt bottles) for chemicals that get used frequently. However, labs can also choose to label chemical containers in other ways such as:

Abbreviations – Structures and Formulas

Use of abbreviations such as structures, formulas, or acronyms is acceptable. However, if you use any abbreviations, you must hang up a key to the abbreviations in a visible location since the same abbreviations are used for different chemicals (for example "BA" is a common abbreviation for both Benzyl Alcohol as well as Butyl Acetate). The key must contain the abbreviation and the name of the chemical and should be placed in a conspicuous place, preferably by the chemical and/or by the door. Including the hazards of the chemical on the key is also useful information. The abbreviation key must be readily available upon request by visitors, emergency responders, and state and federal regulatory agencies such as EPA and OSHA.

Small Containers and Sample Storage

For small containers, such as vials and eppendorf tubes, which may be too small to write out a chemical name, structure, or formula, laboratories can implement other systems to identify the chemicals such as:

- Placing the vial or small container in a Ziploc bag or other type of over-pack container (beaker, plastic bottle, etc.) and labeling the over-pack container with the chemical name.
- Laboratories can use "price tag" style labels in which the chemical name is written out on a tag, and the tag is then attached to the small container with string or a rubber band.
- For vials in a test tube rack – laboratory personnel can simply label the rack with the chemical name, and then label the vials with an abbreviation, color, number, or letter code that corresponds to the label on the test tube rack. For example, if a lab had 10 small vials

of ethanol in one rack, the rack could be labeled a 1-E = Ethanol. All of the vials would then be labeled as 1-E. Be sure that the number or letter code is clearly identifiable and would not be confused with other chemicals in the lab.

- For preserved specimens, bottles should be labeled with the preservative (i.e. ethanol or formaldehyde). A large number of these labels could easily be produced on the computer using Avery style mailing labels.
- For sample storage in refrigerators, laboratory personnel should label sample containers with one of the above methods, including labeling boxes that hold the small vials or chemical containers. Laboratories should include a key to any abbreviations on the outside of the refrigerator and label the key as "Sample Storage abbreviation = chemical name".

Number, Letter, and Color Codes

For vials and other small containers, laboratory personnel can make use of number, letter, and color-coded systems as long as a key is hung up which clearly identifies the chemical name that the number, letter, or color code represents. While this type of system is available for laboratory personnel to use, Research Compliance does not recommend using such a system for hazardous chemicals. Such a system would be more appropriate for non-hazardous compounds such as agar and buffer solutions.

***Please keep in mind that some laboratory workers may be color-blind: red-green and blue-yellow. This fact needs to be taken into consideration, BEFORE a color-coding system is used.

7.6.2 Labeling Requirements

In all cases, regardless of the labeling system used, the following labeling requirements must be followed:

- All chemical containers (both hazardous and non-hazardous) MUST be labeled. Chemical names must be written out in English. If a label is starting to fall off a chemical container or is becoming degraded, then the container needs to be relabeled (using tape, permanent marker, etc.) or the chemical needs to be transferred to another properly labeled container.
- If abbreviations such as formulas, structures, or acronyms are used, then a key to the abbreviations must be hung up in a conspicuous location.
- All personnel working in the laboratory must be fully trained on how to label chemicals using the system and how to understand the labeling system. Training must occur when a new person begins working in the laboratory, when new chemicals are introduced, and

should occur on a regular basis or annually.

8 Chemical Storage

Chemical storage areas in the academic laboratory setting include central stockrooms, storerooms, laboratory work areas, storage cabinets, refrigerators, and freezers. There are established legal requirements as well as recommended practices for proper storage of chemicals. Proper storage of chemicals promotes safer and healthier working conditions, extends the usefulness of chemicals, and can help prevent contamination.

Chemicals that are stored improperly can result in:
- Degraded containers that can release hazardous vapors that are detrimental to the health of laboratory personnel.
- Degraded containers that allow chemicals to become contaminated, which can have an adverse effect on experiments.
- Degraded containers that can release vapors, which in turn can affect the integrity of nearby containers.
- Degraded labels that can result in the generation of unknowns.
- Chemicals becoming unstable and/or potentially explosive.
- Unwanted chemical reactions.
- Citation and/or fines from state and federal regulatory agencies.

8.1 General Storage Guidelines

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.

To help ensure the proper storage of chemicals, the following guidelines are recommended:
- All chemical containers MUST be labeled. Labels should include the name of the chemical constituent(s) and any hazards present. 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.
- Keep all containers of chemicals closed when not in use.
- Every chemical should have an identifiable storage place and should be returned to that location after use.
- The storage of chemicals on bench tops should be kept to a minimum to help prevent clutter and spills, and to allow for adequate working space.
- Chemical storage in fume hoods should be kept to a minimum, and limited to the experiment actively being conducted. Excess storage of chemical containers in hoods can interfere with airflow, reduce working space, and

increase the risk of a spill, fire, or explosion.

- For chemical storage cabinets, larger chemical bottles should be stored towards the back and smaller bottles should be stored up front where they are visible. Chemical bottles should be turned with the labels facing out so they can be easily read.
- Chemicals should not be stored on the floor due to the potential for bottles to be knocked over and result in a spill. If it is necessary to store bottles on the floor, then the bottles should be placed in secondary containment, such as trays, and the bottles should be placed away from aisle spaces. Secondary containment trays must be compatible with the chemicals that are being stored inside.
- For multiples of the same chemical, older containers should be stored in front of newer chemicals and containers with the least amount of chemical should be stored in front of full containers. This allows for older chemicals to get used up first and helps to minimize the number of chemical containers in the storage area.
- Do not store chemicals in direct sunlight or next to heat sources.
- Laboratories should strive to keep only the minimum quantity of chemicals necessary. When ordering new chemicals, laboratories should only order enough stock needed for the experiment or the quantity that will get used up within 1 or 2 years at most.
- Liquid chemical containers should be stored in secondary containment, such as trays, to minimize the potential for bottle breakage and minimize the potential for spills. Secondary containment trays must be compatible with the chemicals stored inside.
- Chemical containers should be dated when they arrive and should be checked regularly and disposed of when they get past their expiration date. Please Note: Due to the potential explosion hazard, peroxide forming chemicals are required to be tested and dated.
- Flammable liquids in excess of quantities for specific flammability classes must be stored in approved flammable liquid storage cabinets.
- Do not store corrosive or other chemicals that can be injurious to the eyes above eye level. In general, and where practical, no chemicals should be stored above eye level.
- Do not store flammable liquids in standard (non-explosion proof) refrigerators or freezers. Due to the potential explosion hazard, only store flammables in refrigerators or freezers approved by the manufacturer for storage of flammables. Household refrigerators equipped with an interior light that turns on when the door is opened should never be used to store flammable chemicals, because the light can potentially be an ignition source for flammable vapors present in the refrigerator. Household refrigerators also do not have adequate shielding from other internal mechanisms that can also provide a possible ignition source.
- Highly toxic chemicals such as inorganic cyanides should be stored in locked storage cabinets. Always keep the quantities of highly toxic chemicals to an absolute minimum. See Particularly Hazardous Substances in Section 10 of

this document, for more information.
- Be aware of any special antidotes or medical treatment that may be required for some chemicals (such as cyanides and Hydrofluoric acid).
- Always keep spill kits and other spill control equipment on hand in areas where chemicals are used. Ensure all personnel working in the lab have been properly trained on the location and use of the spill kit.
- For reagent shelves, it is recommended to use shelves with anti-roll lips, to prevent bottles from falling off.

8.2 Transporting Chemicals

When transporting 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.

- Whenever transporting chemicals by hand, always use a secondary container such as a rubber acid carrying bucket, plastic bucket, or a 5-gallon pail). If necessary, a small amount of packing material (shipping peanuts, vermiculite, or cardboard inserts), that is compatible with the chemical(s), should be used to prevent bottles from tipping over or breaking during transport. You should have proper PPE accessible in the event of a spill.
- Wheeled carts with lipped surfaces (such as Rubbermaid or Uline carts) should be used whenever feasible.
- Whenever possible, do not use passenger elevators when transporting chemicals, only freight elevators should be used. If it is necessary to use a passenger elevator, use should be restricted to low-use times such as early in the morning or late in the afternoon. If this is not possible, be sure to warn passengers, or prohibit passengers from riding with you. Depending on the hazards of the chemicals (especially inhalation hazards of acutely toxic or Particularly Hazardous Substances), it may be prudent to station qualified personnel that have means of communication with each other at both entrances of the elevator in order to "send" and "receive" the materials without being inside the confined space of the elevator to avoid potential exposure.
- When transporting compressed gas cylinders, always use a proper gas cylinder hand truck with the cylinder strapped to the cart and keep the cap in place. NEVER roll or drag a compressed gas cylinder.
- Avoid riding in elevators with cryogenic liquids or compressed gas cylinders. If this is necessary, consider using a buddy system to have one person send the properly secured dewars or cylinders on the elevator, while the other person waits at the floor by the elevator doors where the dewars or cylinders will arrive.
- NEVER transport chemicals in your personal vehicle. Contact Research Compliance for assistance if chemicals need to be transported across campus grounds.
- Please note: If you plan on transporting or shipping any hazardous chemicals off the main campus, be aware there are specific procedures, training and

other legal requirements that must be followed. For more information, refer to Shipping Hazardous Materials in Section 12 of this document.

8.3 Chemical Segregation

Chemicals should be stored according to hazard classification and compatibility rather than alphabetically, by physical state, etc. Research Compliance recommends that you segregate chemicals using the Globally Harmonized System (GHS) of hazard classification first, and then further sort the chemicals by compatibility.

The potential hazards of storing incompatible chemicals together, and when an emergency occurs, include:

- Generation of heat.
- Possible fires and explosions.
- Generation of toxic and/or flammable gasses and vapors.
- Formation of toxic compounds.
- Formation of shock and/or friction sensitive compounds.
- Violent polymerization.

The benefits of chemical segregation by hazard class include:

- Safer chemical storage.
- Understanding what hazards a chemical exhibits will increase your knowledge about the chemical.
- Identifying potentially explosive chemicals.
- Identifying multiple containers of the same chemical.

There are a number of segregation schemes recommended in the literature by government agencies, chemical manufacturers, safety supply companies, and other universities. However, there is no one system that solves all problems, therefore Research Compliance has developed the following system based on the Hazard Communication Standard (HCS) developed by OSHA, which utilizes Pictograms developed by the "Globally Harmonic System of Classification and Labeling of Chemicals (GHS)"

The system described below is less complicated than other segregation schemes and the information to make decisions of which hazard classes to use can easily be found in SDSs, container labels, container markings and stickers, and other resources.

Keep in mind that chemicals do not always fall neatly into one hazard class and can pose multiple hazards – including both physical and health hazards (such as flammable liquid, corrosive or flammable liquid, poison).

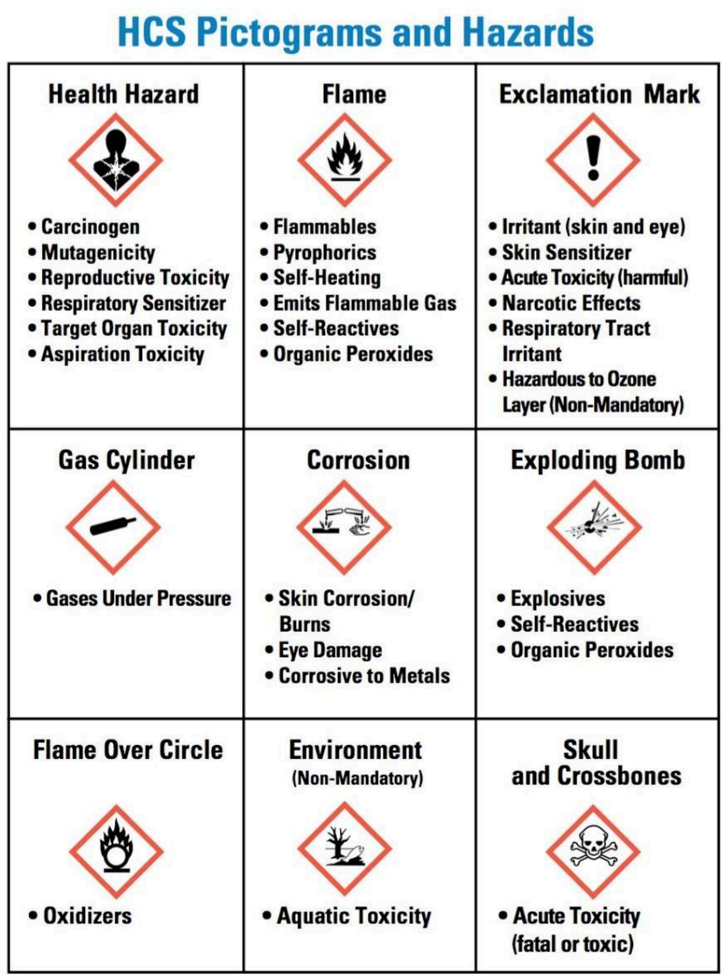
When you are making decisions on how to segregate, keep in mind the following:

- Physical hazards of the chemical.
- Health hazards of the chemical.
- The chemical form (solid, liquid or gas).

- Concentration of the chemical.

The following graphic is a depiction of the Hazard Communication Standard (HCS) and Globally Harmonized System of Classification and Labeling of Chemicals (GHS) Pictograms (Source: OSHA® Quick Card™. https://www.osha.gov/sites/default/files/publications/OSHA3491QuickCardPictogram.pdf)

> "The Hazard Communication Standard (HCS) requires pictograms on labels to alert users of the chemical hazards to which they may be exposed. Each pictogram consists of a symbol on a white background framed within a red border and represents a distinct hazard(s). The pictogram on the label is determined by the chemical hazard classification."



8.3.1 NMT Research Compliance Classification System

NMT Research Compliance has developed the following system for the classification of hazardous chemicals based on information from HCS and

GHS classification systems:

- **<u>Toxics</u>**
    - Health Hazards
    - Exclamation Point
    - Skull and Crossbones
- **<u>Corrosives</u>**
    - Acids
        - Inorganic Acids
        - Organic Acids
    - Bases
- **<u>Oxidizers</u>**
- **<u>Flammables</u>**

*** Please note that special storage considerations are required for the following materials:

- **<u>Self-Reactive, Water Reactive, Pyrophoric, and Peroxide Forming Chemicals</u>**
    - Grignard Reagents
    - Alkyl metal hydrides
        - Butyl Lithium
    - Metal hydrides
        - Calcium Hydride
        - Sodium Hydride
        - Lithium Aluminum Hydride
    - Alkali Earth Elements
        - Potassium
        - Lithium
        - Sodium
    - Peroxide Forming Chemicals (often classified with "Flammable" GHS and HCS pictograms. Look at the "Hazards Not Otherwise Classified" section of the SDS for information on peroxide crystal formation)
- **<u>Explosive and Potentially Explosive Chemicals</u>**
    - Perchlorate Salt
    - Chemicals containing the following functional groups:
        - Azide
        - Acetylide
        - Diazo
        - Nitroso
        - Haloamine
        - Peroxide
        - Ozonide
    - Di-nitro compounds
    - Tri-nitro compounds
    - Picric Acid (dry)

Always segregate and store chemicals according to compatibility and hazard classes. The following list of chemical hazard classes should be separated in storage:

- Organic acids and Inorganic acids. Many organic acids exhibit flammable characteristics, and many inorganic acids act as oxidizing agents. In the event of a fire, storing organic and inorganic acids together can provide both fuel and excess oxygen, increasing the strength of the fire.
- Oxidizers and Flammables. In the event of a fire, storing organic and inorganic acids together can provide both fuel and excess oxygen, increasing the strength of the fire.
- Acids and Bases. Acids and bases should be stored separately because, in the event of a leak or spill, the mixture of the two chemicals can result in a violent neutralization reaction, producing heat and/or toxic gasses.
- Flammables and Inorganic Acids. Flammables should be stored separate from inorganic acids due to the fact that many inorganic acids act as oxidizers. In the case of a fire, the presence of both flammables and inorganic acids can provide both fuel and excess oxygen, increasing the strength of a fire.
- Flammables and Inorganic Bases. Flammables should be stored separately from inorganic bases due to the corrosive nature of the inorganic bases. In addition, the fact that while most bases act as reducing agents, some have oxidizing properties as well (Sodium hypochlorite for example).
- Oxidizers and Bases. Oxidizers should be separated from bases due to the fact that bases often act as reducing agents, and the reactions between oxidizers and reducing agents can often be violent, cause unexpected results, or even liberate toxic gasses.
- Solid and Liquid Chemicals. Solid and liquid chemicals should be stored separately to minimize the involvement of chemicals in the event of a liquid spill.
- Unknown Chemicals. Unknowns should be stored separately from any other material if possible because the hazards and incompatibilities cannot be determined, and therefore the highest potential hazard must be assumed to exist.

***Please Note: 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.

Once chemicals have been segregated, ensure everyone in the lab knows the process and what system is being used. It is best to clearly identify where chemicals in each hazard class will be stored by labeling cabinets with signs, or hazard class labels. These can be purchased from a safety supply company, or you can create your own.

If you need assistance with cleaning out your lab of old and excess chemicals, or would like assistance with segregating your chemicals, contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or at hazmat@nmt.edu.

9 Chemical Hazards

Chemicals can be broken down into hazard classes and exhibit both physical and health hazards. It is important to keep in mind that chemicals can exhibit more than one hazard or combinations of several hazards.

Several factors can influence how a chemical will behave and the hazards the chemical presents, and the severity of the response may need to be adjusted depending on the following factors:

- Concentration of the chemical.
- Physical state of the chemical (solid, liquid, gas).
- Physical processes involved in using the chemical (cutting, grinding, heating, cooling, etc.).
- Chemical processes involved in using the chemical (mixing with other chemicals, purification, distillation, etc.).
- Other processes (improper storage, addition of moisture, storage in sunlight, refrigeration, etc.).

The following sections describe general information and safety precautions about specific hazard classes. The chemical hazards listed are based on the GHS and HCS Hazard Classification Systems from Section 8.3.

It is important to note that the following sections are general guidelines. Laboratory personnel should always review SDSs and other resources FIRST, before working with any chemical.

9.1 Toxicity

Toxicity refers to the ability of a chemical to cause harmful effects to the body. As was described by Paracelsus (1493-1541):

> "What is it that is not poison? All things are poison and nothing is without poison. It is the dose only that makes a thing not a poison."

There are a number of factors that influence the toxic effects of chemicals on the body. These include, but are not limited to:

- The quantity and concentration of the chemical.
- The length of time and the frequency of the exposure.

- The route of the exposure.
- If mixtures of chemicals are involved.
- Physical aspects and lifestyle of the person being exposed to the chemical.

9.1.1 Toxic Effects

Toxic effects are generally classified as acute toxicity or chronic toxicity. For the purpose of this Laboratory Safety Manual and chemical segregation practices recommended by Research Compliance in the NMT Research Compliance Classification System (Section 8.3.1), chemicals classified with the GHS pictograms Health Hazard, Exclamation Mark, Skull and Crossbones, and Environment are considered "Toxic".

- Acute toxicity is generally thought of as a single, short-term exposure where effects appear immediately and are often reversible. An example of acute toxicity relates to the over consumption of alcohol and "hangovers".
- Chronic toxicity is generally thought of as frequent exposures where effects may be delayed (even for years) and are generally irreversible. Chronic toxicity can also result in acute exposures, with long term chronic effects. An example of chronic toxicity relates to cigarette smoking and lung cancer.

9.1.2 Evaluating Toxicity Data

SDSs and other chemical resources generally refer to the toxicity of a chemical numerically using the term Lethal Dose 50 (LD_{50}). The LD_{50} describes the amount of chemical ingested or absorbed by the skin in test animals that causes death in 50% of test animals used during a toxicity test study. Another common term is Lethal Concentration 50 (LC_{50}), which describes the amount of chemical inhaled by test animals that causes death in 50% of test animals used during a toxicity test study. The LD_{50} and LC_{50} values are then used to infer what dose is required to show a toxic effect on humans.

As a general rule of thumb, the lower the LD_{50} or LC_{50} number, the more toxic the chemical. Note there are other factors (concentration of the chemical, frequency of exposure, etc.) that contribute to the toxicity of a chemical, including other hazards the chemical may possess.

While exact toxic effects of a chemical on test animals cannot necessarily be directly correlated with toxic effects on humans, the LD_{50} and LC_{50} can give a good indication of the toxicity of a chemical, particularly in comparison to another chemical. For example, when making a decision on what chemical to use in an experiment based on safety for the lab worker, a chemical with a high LD_{50} or LC_{50} would be safer to work with, assuming the chemical did not possess multiple hazards and everything else being equal.

The resource "Prudent Practices in the Laboratory" Table 4.1 (pg. 59 of the Updated Edition, Copyright 2011) lists the following table for evaluating the Acute Toxicity Hazard of a chemical:

Hazard Level	**Toxicity Rating**	**Oral LD_{50} (rats, per kg)**	**Skin Contact LD_{50} (rabbits, per kg)**	**Inhalation LC_{50} (rats, ppm for 1h)**	**Inhalation LC_{50} (rats, mg/m^3 for 1h)**
High	Highly Toxic	<50mg	<200mg	<200	<200
Medium	Moderately Toxic	50 to 500mg	200mg to 1g	200 to 2,000	2,000 to 20,000
Low	Slightly Toxic	500mg to 5g	1 to 5 g	2,000 to 20,000	20,000 to 200,000

"Prudent Practices in the Laboratory" Table 4.2 (pg. 60 of the Updated Edition, Copyright 2011) lists the following table for evaluating the Probable Lethal Dose for Humans:

Toxicity Rating	**Animal LD_{50} (per kg)**	**Lethal Dose When Ingested by 70kg (150lb) Human**
Extremely Toxic	<5mg	A taste (<7 drops)
Highly Toxic	5 to 50mg	Between 7 drops and 1 tsp
Moderately Toxic	50 to 500mg	Between 1 tsp and 1 oz.
Slightly Toxic	500mg to 5g	Between 1 oz. and 1 pint
Practically nontoxic	>5g	>1 pint

In the preceding tables, there is an overlap between the dosages in determining Hazard Levels and Toxicity Ratings. Best practices would be to assume the greater hazard is present when evaluating chemicals that fall between these dosage levels.

In addition to having a toxic effect on the body, some chemicals can be carcinogenic, mutagenic, teratogenic, and acutely toxic. These specific chemical hazards are covered in more detail under Particularly Hazardous Substances, Section 10 of this document.

9.1.3 OSHA Definitions Regarding Toxic Chemicals

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

- A chemical that has a median lethal dose (LD_{50}) 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.

- A chemical that has a median lethal dose (LD_{50}) of more than 200 milligrams per kilogram, but not more than 1000 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.
- A chemical that has a median lethal concentration (LC_{50}) in air of more than 200 parts per million, but not more than 2000 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, dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

It is important to note that OSHA draws a distinction between toxic chemicals and acutely toxic chemicals. For more information on acutely toxic chemicals, see Particularly Hazardous Substances. OSHA also provides definitions for other health hazards on their website.

As a general rule of thumb, all chemicals should be treated as potentially toxic, and proper procedures such as maintaining good housekeeping, use of proper PPE, good personal hygiene, etc., should be followed. When working with known toxic chemicals, it is very important to have thought an experiment through, addressing health and safety issues before working with the toxic chemical. Safety Data Sheets (SDS) and other chemical references should be consulted before beginning the experiment.

Some questions to ask before working with toxic chemicals:

- Do I need to use the poisonous chemical or can a less toxic chemical be substituted?
- What are the routes of entry into the body for the poison (inhalation, ingestion, injection, or skin absorption)?
- What are the signs and symptoms of potential chemical exposure?
- What are the proper PPE required (type of glove, safety glasses vs. splash goggles, face shield, etc.)?
- Does the chemical require any special antidote?
- What are the emergency procedures to be followed?

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 are worn. Be aware that toxic mixtures, vapors, and gasses can be formed during an experiment. Be sure to research both the reactants and products of the chemicals you will be working with first. Additional information can be found in the Routes of Chemical Entry (Section 7.4) and Chemical Exposure Limits (Section 7.5) sections of this manual.

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 the University Police at 911 from a campus phone or 575-835-5555 from a cell phone or off campus phone. If possible, bring a copy of the SDS with you. Upon completion of seeking medical attention, complete an NMT Lab Incident/Near Miss Report.

9.2 Corrosives

OSHA defines a corrosive as "a chemical that causes visible destruction of, or irreversible alterations in living tissue by chemical action at the site of contact."

Corrosive chemicals can be subdivided into acids and bases, and acids can further be subdivided into inorganic and organic acids. Corrosives can be in the liquid, solid, or gaseous state. Corrosive chemicals can have a severe effect on eyes, skin, respiratory tract, and gastrointestinal tract if an exposure occurs. Corrosive solids and their dusts can react with moisture on the skin or in the respiratory tract and result in an exposure.

Whenever working with concentrated corrosive solutions, indirectly vented splash goggles should be worn instead of safety glasses. Splash goggles used in conjunction with a face shield provides better protection. Please note that a face shield alone does not provide adequate protection. Use of rubber gloves such as butyl rubber and a rubber apron may also be required.

Corrosive chemicals should be handled in a fume hood to avoid breathing corrosive vapors and gasses.

When mixing concentrated acids with water, remember the mnemonic AAA: Always Add Acid. Add the acid slowly to the water (specifically, add the more concentrated acid to the dilute acid). Never add water to acid, this can result in a boiling effect and cause acid to splatter. Do not pour the acid directly into the water; it should be poured in a manner that allows it to run down the sides of the container. Never store corrosive chemicals above eye level and always use a protective bottle carrier when transporting corrosive chemicals. These dilution considerations also apply to concentrated bases as well.

Some chemicals can react with acids and liberate toxic and/or flammable vapors. When working with corrosive materials, ensure spill cleanup material is available for neutralization, such as Calcium carbonate for acids and Citric acid for bases.

Wherever acids and bases are used, an eyewash and emergency shower must be available. If any corrosive chemical gets 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 NMT Lab Incident/Near Miss Report.

For small splashes of corrosives to the skin, remove any contaminated gloves, lab coats, etc., and wash the affected area with soap and water for at least 15 minutes. Seek medical attention afterward, especially if symptoms persist.

For large splashes of corrosives 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 NMT Lab Incident/Near Miss Report.

***Please note some chemicals, such as Hydrofluoric acid, require the use of a special antidote (such as Calcium gluconate gel) and special emergency procedures. Read the SDSs for any chemical(s) you work with to determine if a special antidote is needed if a chemical exposure occurs.

***Please note that most inorganic acids tend to act more like oxidizers and most organic acids tend to act as flammables. Special care should be taken to separate inorganic and organic acids in storage to prevent incidents.

9.2.1 Hydrofluoric Acid (HF)

Hydrofluoric Acid (HF) is one of the most hazardous chemicals used at New Mexico Tech. Small exposures to HF can be fatal if not treated properly. The critical minutes immediately after an exposure can have a great effect on the chances of a victim's survival.

HF is a gas that is dissolved in water to form Hydrofluoric acid. The concentration can vary from very low such as in store bought products up to the most concentrated 70% form (anhydrous), with the most common lab use around 48%. The liquid is colorless, non-flammable and has a pungent odor. The OSHA permissible exposure limit is 3 ppm, but concentrations should be kept as low as possible. HF is actually a weak acid by definition and not as corrosive as strong acids such as Hydrochloric (HCl), however, corrosivity is the least hazardous aspect of HF. The toxicity of HF is the main concern.

HF is absorbed through the skin quickly and is a severe systemic toxin.

The fluoride ion binds calcium in the blood, bones and other organs and causes damage to tissues that is very painful and can be lethal. At the emergency room, the victim is often given calcium injections, but pain medication is not generally given since the pain subsiding is the only indication that the calcium injections are working. Do not take over-the-counter pain medication (Advil, Tylenol, Aleve, etc.) to lessen the pain of an exposure to HF.

Due to the serious hazard of working with HF, the following requirements and guidelines are provided:

- A Standard Operating Procedure (SOP) must be written for the process in which HF is used. This SOP should be posted or readily available near the designated area where HF use will occur.
- HF should only be used in a designated fume hood and the fume hood should be identified by posting a HF Designated Area sign.
- First Aid - A HF first aid kit must be available that includes 2.5% calcium gluconate gel. The Calcium gluconate gel can be obtained at the Gannett Health Services dispensary with a department charge number and should be replaced with new stock annually. The Hydrofluoric Acid First Aid sign should be posted in a prominent place where the Calcium gluconate gel is located.
- Spill Kits - An HF spill kit must be available with calcium compounds such as Calcium carbonate, Calcium sulfate or Calcium hydroxide. Sodium bicarbonate should never be used since it does not bind the fluoride ion and can generate toxic aerosols. Vermiculite should not be used due to the generation of toxic gas.
- Prior approval - Before anyone uses HF they must have prior approval from the Principal investigator. The names of lab personnel should be added to an HF Prior Approval form showing that they have are familiar with the following:
    - Has read the SDS for HF
    - Has read the HF Use SOP developed by the lab
    - Has read the Hydrofluoric acid section in this Lab Safety Manual
    - Is aware of the designated area for HF use
    - Knows the first aid procedure in case of an HF exposure
    - Knows what to do in case of an HF spill
- Personal Protective Equipment (PPE) – The following PPE is required for HF use:
    - Rubber or plastic apron
    - Plastic arm coverings 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

    - Splash goggles in conjunction with a fume hood sash
    - Closed toed shoes
    - Long pants and a long sleeve shirt with a reasonably high neck (no low cut)
- The following are safe practice guidelines when working with HF:
    - Never work alone with HF but have a buddy system.
    - Use a plastic tray while working with HF for containment in case of a spill.
    - Keep containers of HF closed. HF can etch the glass sash and make it hard to see through (if the hood sash becomes fogged and hard to see though due to etching, then contact Research Compliance at research.compliance@nmt.edu about installing a polycarbonate sash)
    - Safety Data Sheet (SDS) – A SDS for HF must be available.
    - All containers of HF must be clearly labeled. Secondary labels for all non-original containers are available from Research Compliance inside the Foyer of the Research Office Building (R.O.B.), or by contacting Research Compliance at research.compliance@nmt.edu.
    - The stock HF should be stored in plastic secondary containment and the cabinet should be labeled. HF should be stored in lower cabinets near the floor.
    - Wash gloves off with water before removing them.

Additional information on the safe use and handling of Hydrofluoric acid (HF) can be found on the Honeywell (the world's largest manufacturer of hydrofluoric acid) website at https://www.honeywell-hfacid.com/literature/. This website contains useful information on HF such as:

- Safety Data Sheets
- Technical Data Sheets
- Recommended Medical Treatment for HF exposure
- HF Properties charts
- Online Training

9.2.2 Nitric Acid

Nitric acid is a highly corrosive mineral acid and strong oxidizer used primarily for nitration of organic molecules and washing glassware or metal equipment. Nitric acid reacts violently with alcohols, alkalis, reducing agents, combustible materials, organic materials, metals, acids, cyanides, terpenes, charcoal, and acetone. It produces exothermic reactions, as well as toxic, corrosive, and flammable vapors. Nitric acid can be extremely hazardous in cases of inhalation (lung corrosive), skin contact (corrosive, irritant, permeator), eye contact (corrosive), or ingestion.

Nitric acid guidelines for safe usage include the following:

- Minimize or eliminate use and storage of nitric acid whenever possible.
- Use in ventilated areas and in proximity to eyewash and safety shower stations, while wearing compatible gloves, safety goggles, and a lab coat.
- Avoid contact with metals! Nitric acid is extremely corrosive in the presence of aluminum, copper, and oxides and attacks all base metals.
- Store in glass containers that are secured, dry, cool (<23'C/73.4'F), away from sources of ignition, combustible materials, other acids, bases, cyanides, and acetone. Use secondary containers to segregate nitric acid from other acids in your acids cabinet.
- Storage containers must be dry, as nitric acid can react with water or steam to produce heat, and toxic, corrosive, and flammable vapors.
- Pre-labeled and dated safety-coated glass bottles (PTFE) may be used for nitric acid waste; avoid using empty organic solvent bottles.
- Proper waste segregation can help avoid laboratory accidents and explosions. Do not mix nitric acid waste with any other waste streams, including other inorganic acids.
- Segregation of nitric acid waste from different processes or experiments is recommended.
- In the case of a spill, absorb nitric acid with an inert dry material (earth, sand, or other non-combustible material), place in an appropriate waste container, and neutralize with dilute sodium carbonate.
- Principal investigators planning to use nitric acid should develop an SOP and provide documented training to all of their respective personnel.
- Principal investigators and/or lab managers are responsible for ensuring all laboratory personnel understand and adhere to safety requirements in the laboratory.

9.2.3 Perchloric Acid

Perchloric acid is a strong oxidizing acid that can react violently with organic materials. Perchloric acid can also explode if concentrated above 72%. For any work involving heated Perchloric acid (such as in Perchloric acid digestion), the work must be conducted in a special Perchloric acid fume hood with a wash down function. If heated Perchloric acid is used in a standard fume hood, the hot Perchloric acid vapors can react with the metal in the hood ductwork to form shock sensitive metallic perchlorates. When working with Perchloric acid, be sure to remove all organic materials, such as solvents, from the immediate work area. Due to the potential danger of Perchloric acid, if possible, try to use alternate techniques that do not involve the use of Perchloric acid. If you must use Perchloric acid in your experiments, only purchase the smallest size container necessary.

Because Perchloric acid is so reactive, it is important to keep it stored separate from other chemicals, particularly organic solvents, organic acids, and oxidizers. All containers of Perchloric acid should be inspected regularly for container integrity and the acid should be checked for discoloration. Discolored Perchloric acid should be discarded as hazardous waste. Perchloric acid should be used and stored away from combustible materials, and away from wooden furniture. Like all acids, but particularly with Perchloric acid, secondary containment should be used for storage.

9.3 Oxidizers

The OSHA Laboratory Standard defines an oxidizer as "a chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gasses."

As a reminder of the fire triangle (now referred to as the fire tetrahedron), in order to have a fire, you need:

- A fuel source.
- An oxygen source.
- An ignition source.
- A chemical reaction.

Oxidizers can be solids, liquids, or gasses, and they can react strongly with organic material and reducing agents. Most oxidizers will readily give off oxygen, but a few can give off other oxidizing gasses such as chlorine or fluorine. In addition to intensifying a fire, oxidizers can also make a fire start more easily by expanding the flammability range and lowering the ignition temperatures of combustible materials.

The National Fire Protection Association (NFPA) defines four categories of oxidizer classes, based on the severity of the risk. These classes are described as follows (in order of increasing severity):

- **Class 1**: An oxidizer that does not moderately increase the burn rate of another material.
- **Class 2**: An oxidizer that will moderately increase the burn rate.
- **Class 3**: An oxidizer that will cause a severe increase in the burn rate.
- **Class 4**: An oxidizer that has the potential to lead to an explosive oxidation when combined with other materials.

Examples of strong oxidizing agents and their respective Classes include (source: Standard Operating Procedures – Strong Oxidizers, Yale Environmental Health & Safety):

- Ammonium perchlorate (Class 4)
- Ammonium permanganate (Class 4)
- Chromic acid (Class 2)
- Hydrogen peroxide (>27.5 - 52%: Class 2; >52 - 91%: Class 3)
- Magnesium peroxide (Class 1)
- Nitric acid (40% or greater: Class 1; >40 - 86% Class 2)
- Perchloric acid (>50 - 60%: Class 2; >60 - 72%: Class 3; >72%: Class 4)
- Potassium bromate (Class 3)
- Potassium chlorate (Class 3)
- Sodium chlorate (Class 3)
- Sodium chlorite (>40%: Class 3)

As with any chemicals, but particularly with oxidizers, 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 a safety switch to prevent the compounds from overheating.

Laboratory staff should be particularly careful when handling oxidizers (especially high surface area oxidizers such as finely divided powders) around organic materials.

Avoid using metal objects when stirring or removing oxidizers from chemical containers. Plastic or ceramic implements should be used instead. Laboratory personnel should avoid friction, grinding, and impact with solid oxidizers.

9.4 Flammables

Flammable materials comprise a large majority of the chemicals that are utilized by New Mexico Tech Research Groups, Departments, Divisions, and Laboratories. This Section will discuss both flammable liquids and solids, as well as storage considerations and special handling measures for specific types of flammable materials.

9.4.1 Flammable and Combustible Liquids

The OSHA Laboratory Standard defines a flammable liquid as any liquid having a flashpoint below 100℉ (37.8℃), except any mixture having components with flashpoints of 100 degrees F (37.8 degrees C) 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 degrees F (37.8 degrees C), but below 200 degrees F (93.3 degrees C), except any mixture having components with flashpoints of 200 degrees F (93.3 degrees C), 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.

Flammable Liquids		
Classification	**Flash Point**	**Boiling Point**
Class IA	<73 degrees F	<100 degrees F
Class IB	<73 degrees F	>=100 degrees F
Class IC	>=73 degrees F, <100 degrees F	>100 degrees F

Combustible Liquids		
Classification	**Flash Point**	**Boiling Point**
Class II	>=100 degrees F, <140 degrees F	--
Class IIIA	>=140 degrees F, < 200 degrees F	--
Class IIIB	>=200 degrees F	--

Flammable and combustible liquids are one of the most common types of chemicals used at New Mexico Tech and are an important component in a number of laboratory processes. However, in addition to the flammable hazard, some flammable liquids also may possess other hazards such as being toxic and/or corrosive.

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 Facilities Management for more assistance.

Always keep flammable liquids stored away from oxidizers and away from heat or ignition sources such as radiators, electric power panels, etc.

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.

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.

9.4.2 Flammable Storage in Refrigerators/Freezers

It is important to store flammable liquids only in specially designed flammable storage refrigerators/freezers or explosion-proof refrigerators/freezers. Do not store flammable liquids in standard (non-flammable rated) refrigerators/freezers. Standard refrigerators are not electrically designed to store flammable liquids. If flammable liquids are stored in a standard refrigerator, the buildup of flammable vapors can be in sufficient quantities to ignite when the refrigerator's compressor or light turns on, resulting in a fire or an explosion.

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.

For most laboratory applications, a flammable storage refrigerator/freezer is acceptable. However, some operations may require an explosion-proof refrigerator/freezer. In the case of limited funding where a laboratory cannot purchase a flammable storage refrigerator for the laboratory's own use, Research Compliance strongly encourages departments and laboratory groups on each floor to consider purchasing a communal flammable storage refrigerator for the proper and safe storage of flammable liquids.

9.4.3 Flammable Storage Cabinets

The requirements for use of flammable storage cabinets are determined by the classification of the flammable liquids, the quantities kept on hand, the building construction (fire wall ratings), and the floor of the building the flammables are being stored on. As a general rule of thumb, if you have more than 10 gallons of flammable liquids, including materials in use, then you should store the flammable liquids in a properly rated flammable liquid storage cabinet. All flammable liquids not in use should be kept in the flammable liquid storage cabinet. For stand-alone flammable cabinets (as opposed to cabinets underneath fume hoods), there are vent holes on each side of the cabinet (called bung holes) that must have the metal bungs screwed into place for the cabinet to maintain its fire rating. 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 Research Compliance at research.compliance@nmt.edu for more information.

9.4.4 Flammable Solids

The OSHA Laboratory Standard defines a flammable solid as a "solid, other than a blasting agent or explosive, that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited, burn so vigorously and persistently to create a serious hazard." An example of a flammable solid is gun powder.

Many of the same principles for handling and storage of flammable liquids apply to flammable solids. Always keep flammable solids stored away from oxidizers, and away from heat or ignition sources such as radiators, electric power panels, etc.

9.4.5 Self-Reactive, Water Reactive Chemicals, Pyrophoric, and Peroxide Forming Chemicals

Self-reactive, water-reactive, pyrophoric, and peroxide forming chemicals need to be stored and handled with extreme caution and forethought. Planning prior to working with these materials is a must, and SOPs on these materials and lab work should be developed for them before they are introduced into the lab space. Many of these reactive chemicals are classified as "Flammables" in the GHS system, hence their inclusion in this Section of the Laboratory Safety Manual.

9.4.6 Self-Reactive Chemicals

Self-reactive chemicals are thermally unstable materials that are liable to undergo a strongly exothermic decomposition reaction, even without the presence of oxygen in the air. A self-reactive chemical can be regarded as having explosive properties when, in laboratory testing, the formulation is liable to detonate, deflagrate rapidly, or to show a violent effect when heated under confinement.

Classes of chemicals often identified as self-reactive chemicals include, but are not limited to the following (Source: University of Michigan, Self-Reactive and Self-Heating Chemicals Standard Operating Procedures):

- Chemicals with weak and/or strained bonds
  - Azo, Diazo, Azido, Hydrazine, and Azide compounds
  - Acetylides
  - Epoxides
  - High nitrogen compounds, tetrazoles
  - Nitrides
  - Nitroso compounds
- Chemicals that can polymerize (monomers)
  - Unsaturated carbon bonds
  - Nitrile groups
  - Vinyl groups
  - Cyanate groups
- Chemicals with high oxygen content
  - Nitro-group substituted organics
  - Organic nitrates or organic nitrites

9.4.7 Water-Reactive Chemicals

Water-reactive chemicals are substances that react readily with water or moisture that releases gasses that are either flammable, toxic, or both. The heat of reaction is typically sufficient enough to cause spontaneous combustion or even explosion.

Examples of water-reactive chemicals include, but are not limited to, the following (Source: University of Pennsylvania Environmental Health and Radiation Safety – SOP Water-Reactive Chemicals):

- Alkali metals
  - Lithium
  - Sodium
  - Cesium
  - Potassium
- Alkaline earth metals
  - Magnesium
  - Barium
  - Calcium
- Metal Hydrides
  - Lithium aluminum hydride
  - Calcium hydride

    - Potassium hydride
- Alkyl and Aryl Magnesium Halides
    - Grignard Reagents

Please note, attempting to put out a fire involving water-reactive materials with water will only make the situation worse. Special "Class D" fire extinguishers are required for use with water-reactive chemicals.

If you are using water-reactive compounds and do not have a Class D fire extinguisher present, then please contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 for more assistance.

9.4.8 Pyrophoric Chemicals

Pyrophoric chemicals are a class of chemicals that are spontaneously ignitable in the presence of air, are reactive with water vapor (in the air or otherwise), and/or are reactive with oxygen. To receive the pyrophoric classification under GHS, a chemical must be shown to ignite within 5 minutes of exposure to air. However, chemicals that can ignite in the presence of air outside of that 5-minute designation also pose a significant risk to the health and safety of users, and should be handled as pyrophorics are. Many pyrophoric chemicals are often used in a flammable solvent solution in chemical research settings, increasing the risk of fire.

Examples of pyrophoric chemicals include, but are not limited to the following (Source: Stanford University Information on Pyrophoric Compounds):

- Organolithium reagents
    - Alkyl and aryl lithiums
    - Lithium acetylide
    - Lithium amide
- Organohalogen or Grignard Reagents
    - Compounds in the form of RMgX, where R=alkyl and X=halogen
- Alkyl metal bases
    - Butyllithium
    - Trimethylaluminum
    - Triethylboron
- Metal hydrides
    - Sodium hydride
    - Germane
    - Lithium aluminum hydride
- Finely divided metals
    - Raney nickel
    - Aluminum powder
    - Zinc dust

- Used hydrogenation catalysts
    - Palladium on carbon
- Metal carbonyls
    - Nickel carbonyl
    - Iron pentacarbonyl
- Organozincs
    - Diethylzinc
- Aluminum alkyls
    - Trimethylaluminum
- Silicon halides
    - Dichloromethylsilane
- Red and white phosphorus

***Please note that the preceding list of pyrophoric materials include items from the examples of "Water-Reactive Chemicals" previously mentioned in this section. This overlap is intentional and is due to the fact that many pyrophoric chemicals are reactive to the water vapor and moisture in the air.

One notable example of a pyrophoric chemical is tert-butyllithium (often shortened to t-BuLi). Tert-butyllithium is often kept under hexanes (a flammable liquid) to prevent exposure to air, due to its extreme reactive potential in air. In December 2008, an incident in a research lab at the University of California - Los Angeles (UCLA) involving a research student using tert-butyllithium, resulted in severe burns and the subsequent death of the young research student.

As previously mentioned, in addition to the hazard of the pyrophoric 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 pyrophoric chemicals. When transporting these chemicals, it is best to use a bottle carrier and carts.

9.4.9 Peroxide Forming Chemicals

Peroxide forming chemicals (PFCs) pose a unique hazard in laboratories, while not initially an explosive hazard, these compounds can develop potential explosive characteristics over time, evaporation, exposure to oxygen in the air, or distillation. Many commonly used chemicals, organic solvents in particular, can form shock, heat, or friction sensitive peroxides upon exposure to oxygen.

Once peroxides have formed, an explosion can result during routine handling, such as twisting the cap off a bottle if peroxides are formed in the threads of the cap. One of the major concerns about PFCs is that the shock sensitive peroxide crystals do not need an external ignition source, and can ignite spontaneously with sources of physical concussion or friction. Since these chemicals are often flammable organic solvents, the risk of fire resulting from an incident involving these explosive events presents additional hazards.

Explosions are more likely when concentrating, evaporating, or distilling these compounds if they contain peroxides. When these compounds are improperly handled and stored, a serious fire and explosion hazard exists.

Many institutions categorize PFCs in four different classes, based on the severity and conditions of the materials.

- **Class A**: Severe peroxide hazard. These chemicals can spontaneously decompose and become explosive with exposure to air without concentration.
- **Class B**: Concentration hazard. These chemicals require external energy for spontaneous decomposition, and can form explosive peroxides when distilled, evaporated, or otherwise concentrated.
- **Class C**: Shock and heat sensitive. These chemicals are often highly reactive and can auto-polymerize as a result of internal peroxide accumulation. The peroxides formed in these reactions are extremely shock and heat sensitive.
- **Class D**: Potential peroxide forming chemicals. These chemicals may form peroxides, but cannot be clearly categorized in Class A, B, or C.

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

- Each peroxide forming chemical container MUST be dated with both a received and an opened date.
- Each peroxide forming chemical container must be tested for peroxides when opened and at least every 6 months thereafter. The results of the peroxide test and the test date must be marked on the outside of the container. There are sample peroxide labels on the Signs and Labels webpage.
- Peroxide test strips can be purchased from a variety of safety supply vendors, such as VWR and Grainger. Research Compliance highly recommends Quantofix Peroxide 100 testing strips. An alternative to peroxide test strips is the KI (potassium iodide) test. References such as Prudent Practices in the Laboratory and the American Chemical Society booklet “Safety in Academic Chemistry Laboratories” outline ways to test for peroxides and ways to remove them if discovered. When using the test strips, if the strip turns blue, then peroxides are present. Light blue test results may be acceptable for use if your procedure does not call for concentrating, evaporating or distilling. Containers with darker

blue test results must be deactivated or disposed of. You can test older test strips for efficacy with a dilute solution of hydrogen peroxide.

- Due to sunlight's ability to promote formation of peroxides, all peroxidizable compounds should be stored away from heat and sunlight.
- Peroxide forming chemicals should not be refrigerated at or below the temperature at which the peroxide forming compound freezes or precipitates as these forms of peroxides are especially sensitive to shock and heat. Refrigeration does not prevent peroxide formation.
- 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.
- Ensure containers of peroxide forming chemicals are tightly sealed after each use and consider adding a blanket of an inert gas, such as Nitrogen, to the container to help slow peroxide formation.
- 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.
- 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.

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. However, compounds that are suspected of having very high peroxide levels because of age, unusual viscosity, discoloration, or crystal formation should be considered extremely dangerous. If you discover a container that meets this description, DO NOT attempt to open or move the container. Notify other people in the lab about the potential explosion hazard and notify the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 immediately.

Examples of peroxide forming chemicals include, but are not limited to, the following (Source University of California – Santa Cruz, Environmental Health and Safety Laboratory Safety Manual):

- **Class A: Severe Peroxide Hazard**
    - Butadiene (liquid monomer)
    - Chloroprene (liquid monomer)
    - Divinyl ether

    - Isopropyl ether
    - Potassium amide
    - Potassium metal
    - Sodium amide
    - Tetrafluoroethylene (liquid monomer)
    - Vinylidene chloride
- **Class B: Concentration Hazard**
    - Acetal
    - Acetaldehyde
    - Cyclohexene
    - Diethylene glycol dimethyl ether (diglyme)
    - Dioxanes
    - Diethyl ether (ether)
    - 4-Heptanol
    - Tetrahydrofuran
    - Vinyl ethers
- **Class C: Shock and Heat Sensitive**
    - Acrylonitrile
    - Butadiene (gas)
    - Chlorobutadiene
    - Methyl methacrylate
    - Styrene
    - Vinylidene chloride
- **Class D: Potential Peroxide Forming Chemicals**
    - Acrolein
    - Allyl ethyl ether
    - n-Amyl ether
    - Chloromethyl methyl ether
    - 1-Ethoxy-2-propyne
    - 2,5-Hexadiyn-1-ol
    - Tetrahydropyran
    - Vinylene carbonate

***Please note: the preceding list only lists some of the chemicals provided by UCSC's Laboratory Safety Manual, which itself is not a complete listing of possible PFCs. Always check a chemical's "Hazards Not Otherwise Classified" section of the SDS for more information on a chemical's potential to form peroxide crystals. Please see Appendix I for more information on peroxide forming chemicals.

9.5 Explosive Materials

The OSHA Laboratory Standard defines an explosive as a chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.

Fortunately, most laboratories do not use many explosives; however, there are a number of chemicals that can become unstable and/or potentially explosive over time due to contamination with air, water, other materials such as metals, or when the chemical dries out (see Sections 9.4.5 – 9.4.9 Self-reactive, Water-reactive, Pyrophoric, and Peroxide Forming Chemicals for more information on these potentially explosive materials).

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 the Hazardous Materials and Laboratory Safety Specialist at 575-0517-0646 immediately.

Explosives can result in damage to surrounding materials (hoods, glassware, windows, people, etc.), generation of toxic gasses, and fires. If you plan to conduct an experiment where the potential for an explosion exists, first ask yourself the question; "Is there another chemical that could be substituted in the experiment that does not have an explosion potential?" If you must use a chemical that is potentially explosive, or for those compounds that you know are explosive, (even low powered explosives) you must first obtain prior approval from the Principal Investigator to use such chemicals. After obtaining prior approval from your Principal Investigator, thoroughly read the SDSs and any other chemical resources related to the potentially explosive compound(s) to ensure potential incidents are minimized.

Whenever setting up experiments using potentially explosive compounds:

- Always use the smallest quantity of the chemical possible.
- Always conduct the experiment within a fume hood and use it in conjunction with a properly rated safety shield.
- Be sure to remove any unnecessary equipment and other chemicals (particularly highly toxic and flammables) away from the immediate work area.
- 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.
- Do not use metal or wooden devices when stirring, cutting, scraping, etc. with potentially explosive compounds. Non-sparking plastic devices should be used instead.
- Ensure other safety devices such as high temperature controls, water overflow devices, etc., are used in combination to help minimize any potential incidents.
- 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.
- 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.

- For storage purposes, always date chemical containers when received and opened. 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 the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 for more assistance.

Examples of explosive and potentially explosive chemicals include:
- Compounds containing the functional groups azide, acetylide, diazo, nitroso, haloamine, peroxide, and ozonide
- Nitrocellulose
- Di- and Tri-nitro compounds
- Peroxide forming compounds
- Picric acid (dry)
- 2,4-Dinitrophenylhydrazine (dry)
- Benzoyl peroxide (dry).

9.6 Controlled Substances

Controlled substances are any drugs or chemical substances whose possession and use are regulated under the United States Controlled Substances Act. The U.S. Department of Justice (DOJ) and the Drug Enforcement Administration (DEA) administer the federal law, while the New Mexico Board of Pharmacy administers state law. Controlled substances have stimulant, depressant, or hallucinogenic effects on the higher functions of the central nervous system, and tend to promote abuse or physiological/psychological dependence.

9.6.1 Schedules of Controlled Substances

Substances regulated under the U.S. Controlled Substances Act (CSA) are in one of five schedules. Schedule I substances have the most restrictions, and Schedule V substances the least. The CSA defines the schedules as follows:

- Schedule I: Drug or other substance with a high potential for abuse, no currently accepted medical use in treatment in the United States, and a lack of accepted safety protocols for use under medical supervision.
- Schedule II: High potential for abuse; a currently accepted use in treatment in the United States, or currently accepted medical use with severe restrictions; abuse may lead to severe psychological or physical dependence.

- Schedule III: Potential for abuse less than Schedule I or II substances; currently accepted medical use in treatment in the United States; abuse may lead to moderate or low physical dependence or high psychological dependence.
- Schedule IV: Low potential for abuse relative to Schedule III; currently accepted medical use in treatment in the United States; abuse may lead to limited physical or psychological dependence relative to Schedule III.
- Schedule V: Low potential for abuse relative to Schedule IV; currently accepted medical use in treatment in the United States; abuse may lead to limited physical or psychological dependence relative to Schedule IV.

9.6.2 Registration, Acquisition, and Disposal of Controlled Substances

Researchers planning to use any controlled substances in their research must have a current DEA license on file with Research Compliance, or must have applied for such a license before research will be approved by Research Compliance. Contact Research Compliance at research.compliance@nmt.edu for more information on the registration, acquisition, and disposal of controlled substances.

10 Particularly Hazardous Substances

The OSHA Laboratory Standard requires as part of the Chemical Hygiene Plan that provisions for additional employee protection be included for work involving particularly hazardous substances (PHSs). These substances include “select carcinogens”, reproductive toxins, and substances which have a high degree of acute toxicity. Each of these categories will be discussed in detail in later sections. Please see New Mexico Tech’s HAZMAT Safety Information website for a list of PHSs commonly found in labs.

The OSHA Laboratory Standard states for work involving particularly hazardous substances, specific consideration be given to the following provisions where appropriate:

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

Research Compliance can assist researchers by providing information on working with PHSs. General guidelines and recommendations for the safe handling, use, and control of particularly hazardous substances can be found in SDSs and other references such as “Prudent Practices in the Laboratory” and “Safety in Academic Chemistry Laboratories”.

Appendix C contains a list of chemicals that are considered “Particularly Hazardous Substances” by Research Compliance.

10.1 Establishment of Designated Area

For work involving particularly hazardous substances, laboratories should establish a designated area where particularly hazardous substances can only be used. In some cases, a designated area could be an entire room out of a suite of rooms, or it could mean one particular fume hood within a laboratory. The idea is to designate one area that everyone in the laboratory is aware of where the particularly hazardous substances can only be used.

In certain cases of establishing designated areas, Principal Investigators and laboratory supervisors may want to restrict use of a particularly hazardous substance to a fume hood, glove box or other containment device. This information should be included as part of the laboratory's SOPs and covered during in-lab training.

Establishing a designated area not only provides better employee protection, but can help minimize the area where potential contamination of particularly hazardous substances could occur. If a designated area is established, a sign should be hung up (on a fume hood for example) indicating the area is designated for use with particularly hazardous substances. Most designated areas will have special PPE requirements and/or special waste and spill cleanup procedures as well. These and other special precautions should be included within the lab's SOPs.

10.2 Safe Removal of Contaminated Materials and Waste

Some particularly hazardous substances may require special procedures for safe disposal of both waste and/or contaminated materials. When in doubt, contact Research Compliance to determine proper disposal procedures. Once these disposal procedures have been identified, they should be included as part of the laboratory's SOPs and everyone working in the lab should be trained on those procedures.

10.3 Decontamination Procedures

Some particularly hazardous substances may require special decontamination or deactivation procedures (such as Diaminobenzidine waste or Ethidium bromide) for safe handling. Review SDSs and other reference materials when working with particularly hazardous substances to identify if special decontamination procedures are required. If they are required, then this information should be included in the laboratory's SOPs and appropriate training needs to be provided to laboratory personnel who work with these chemicals.

10.4 Guidelines for Working with Particularly Hazardous Substances

Laboratory staff should always practice good housekeeping, use engineering controls, wear proper PPE, develop and follow SOPs, and receive appropriate training when working with any chemicals. The following special guidelines should be adhered to when working with particularly hazardous substances:

- Substitute less hazardous chemicals if possible to avoid working with particularly hazardous substances and keep exposures to a minimum.
- Always obtain prior approval from the Principal Investigator before ordering any particularly hazardous substances.
- Plan your experiment out in advance, including layout of apparatus and chemical and waste containers that are necessary.
- Before working with any particularly hazardous substance, review chemical resources for any special decontamination/deactivation procedures and ensure you have the appropriate spill cleanup materials and absorbent on hand.
- Ensure that you have the appropriate PPE, particularly gloves (check glove selection charts or contact Research Compliance at research.compliance@nmt.edu).
- Always use the minimum quantities of chemicals necessary for the experiment. If possible, try adding a buffer directly to the original container and making dilutions directly.
- If possible, purchase premade solutions to avoid handling powders. If you have to use powders, it is best to weigh them in a fume hood. If it is necessary to weigh outside of a fume hood (because some particles may be too light and would pose more of a hazard due to turbulent airflow) then wear a dust mask when weighing the chemical. It is advisable to surround the weighing area with wetted paper towels to facilitate cleanup.
- As a measure of coworker protection when weighing out dusty materials or powders, consider waiting until other coworkers have left the room to prevent possible exposure and thoroughly clean up and decontaminate working surfaces.
- Whenever possible, use secondary containment, such as trays, to conduct your experiment in and for storage of particularly hazardous substances.
- Particularly hazardous substances should be stored by themselves in clearly marked trays or containers indicating what the hazard is i.e. “Carcinogens,” Reproductive Toxins”, etc.
- Always practice good personal hygiene, especially frequent hand washing, even if wearing gloves.
- If it is necessary to use a vacuum for cleaning particularly hazardous substances, only High Efficiency Particulate Air (HEPA) filters are recommended for best capture and protection. Be aware that after cleaning up chemical powders, the vacuum bag and its contents may have to be disposed of as hazardous waste
- Ensure information related to the experiment is included within any SOPs.

10.5 Prior Approval

The OSHA Laboratory Standard requires Chemical Hygiene Plans to include information on “the circumstances under which a particular laboratory operation, procedure or activity shall require prior approval”, including “provisions for additional employee protection for work with particularly hazardous substances" such as "select carcinogens," reproductive toxins, and substances which have a high degree of acute toxicity.

Prior approval ensures that laboratory workers have received the proper training on the hazards of particularly hazardous substances or with new equipment, and that safety considerations have been taken into account BEFORE a new experiment begins.

While Research Compliance can provide assistance in identifying circumstances when there should be prior approval before implementation of a particular laboratory operation, the ultimate responsibility of establishing prior approval procedures lies with the Principal Investigator or laboratory supervisor.

Principal Investigators or laboratory supervisors must identify operations or experiments that involve particularly hazardous substances (such as "select carcinogens," reproductive toxins, and substances which have a high degree of acute toxicity) and highly hazardous operations or equipment that require prior approval. They must establish the guidelines, procedures, and approval process that would be required. This information should be documented in the laboratory's or department's SOPs. Additionally, Principal Investigators and laboratory supervisors are strongly encouraged to have written documentation, such as "Prior Approval" forms that are completed and signed by the laboratory worker, and signed off by the Principal Investigator or laboratory supervisor and kept on file.

Examples where Principal Investigators or laboratory supervisors should consider requiring their laboratory workers to obtain prior approval include:

- Experiments that require the use of particularly hazardous substances such as "select carcinogens," reproductive toxins, and substances that have a high degree of acute toxicity, highly toxic gasses, cryogenic materials and other particularly hazardous substances or experiments involving radioactive materials, high powered lasers, etc.
- Where a significant change is planned for the amount of chemicals to be used for a routine experiment such as an increase of 10% or greater in the quantity of chemicals normally used.
- When a new piece of equipment is brought into the lab that requires special training in addition to the normal training provided to laboratory worker
- When a laboratory worker is planning on working alone on an experiment that involves particularly hazardous substances or operations.

10.5.1 Campus Prior Approval

There are some circumstances where prior approval from a campus research related committee is required before beginning an operation or activity. These include:

- Research using live vertebrate animals

- Recombinant DNA use – contact Research Compliance at research.compliance@nmt.edu.
- Use of Radioactive Materials – contact the New Mexico Tech Radiation Safety Officer (RSO) at rso@nmt.edu
- Use of Human Subjects - contact the NMT Institutional Review Board (IRB) at irb@nmt.edu.
- Controlled Substances

10.6 Select Carcinogens

A carcinogen is any substance or agent that is capable of causing cancer – the abnormal or uncontrolled growth of new cells in any part of the body in humans or animals. Most carcinogens are chronic toxins with long latency periods that can cause damage after repeated or long duration exposures and often do not have immediate apparent harmful effects.

The OSHA Lab Standard defines a "select carcinogen" as any substance which meets one of the following criteria:

- (i) It is regulated by OSHA as a carcinogen; or
- (ii) It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or
- (iii) It is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer Monographs (IARC) (latest editions);
- (iv) It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:
    - (A) After inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m^3;
    - (B) After repeated skin application of less than 300 (mg/kg of body weight) per week; or
    - (C) After oral dosages of less than 50 mg/kg of body weight per day.

With regard to mixtures, OSHA requires that a mixture "shall be assumed to present a carcinogenic hazard if it contains a component in concentrations of 0.1% or greater, which is considered to be carcinogenic." When working with carcinogens, laboratory staff should adhere to Guidelines for Working with Particularly Hazardous Substances.

Note that the potential for carcinogens to result in cancer can also be dependent on other "lifestyle" factors such as:

- Cigarette smoking
- Alcohol consumption
- Consumption of high fat diet
- Geographic location – industrial areas and UV light exposure

- Therapeutic drugs
- Inherited conditions

More information on carcinogens, including numerous useful web links such as a listing of OSHA regulated carcinogens, can be found on the OSHA Safety and Health Topics for Carcinogens webpage. The State of California has developed an extensive list of "Carcinogens Known to the State of California through Prop 65". Please note, this list is being provided as supplemental information to the Occupational Safety and Health Administration (OSHA), National Toxicology Program (NTP) and International Agency for Research on Cancer (IARC) chemical lists and is not legally mandated by New Mexico State.

10.6.1 Reproductive Toxins

The OSHA Lab Standard defines a reproductive toxin as a chemical "which affects the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis)".

A number of reproductive toxins are chronic toxins that cause damage after repeated or long duration exposures and can have long latency periods. Women of childbearing potential should be especially careful when handling reproductive toxins. Pregnant women and women intending to become pregnant, or men seeking to have children, should seek the advice of their physician before working with known or suspected reproductive toxins.

It is important to be aware of the threats to reproductive health and prevent potential reproductive hazard exposures for male and female employees and students who work with known and suspected reproductive toxins including chemical, biological, radiological, and physical agents. Research Compliance is available to respond to concerns or questions on reproductive hazards, conduct workplace hazard assessments, and provide recommendations to address or eliminate specific reproductive risks. This free service can be requested by contacting Research Compliance at research.comliance@nmt.edu. As with any high hazard chemical, work involving the use of reproductive toxins should adhere to the Guidelines for Working with Particularly Hazardous Substances in Section 10.4 of this Laboratory Safety Manual.

More information on reproductive toxins, including numerous useful web links, can be found on the OSHA Safety and Health Topics for Reproductive Hazards webpage. The State of California has developed an extensive list of "Reproductive Toxins Known to the State of California through Prop 65". Please note, this list is being provided as supplemental information to the Occupational Safety and Health Administration (OSHA), National Toxicology Program (NTP) and International Agency for Research on Cancer (IARC) chemical lists and is not legally mandated by New Mexico State.

10.6.2 Acute Toxins

OSHA defines a chemical as being highly toxic if it falls within any of the following categories:

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

Information on determining whether or not a chemical meets one of these definitions can be found in SDSs and other chemical references. As with any particularly hazardous substance, work involving the use of acute toxins should adhere to the Guidelines for Working with Particularly Hazardous Substances (Section 10.4 of this document). In addition to following the Guidelines for Working with Particularly Hazardous Substances, additional guidelines for working with acute toxins include:

- Consider storing highly toxic materials in a locked storage cabinet.
- Be aware of any special antidotes that may be required in case of accidental exposure (Hydrofluoric acid and inorganic cyanides for example).
- Give particular attention to the selection of gloves and other personal protective equipment.
- Do not work with highly toxic chemicals outside of a fume hood, glove box or ventilated enclosure.

More information on acute toxins, including numerous useful web links, can be found on the OSHA Safety and Health Topics for Hazardous and Toxic Substances webpage.

11 Hazardous Chemical Waste Disposal

Hazardous chemical waste storage and disposal is regulated by the U.S. Environmental Protection Agency (EPA). In New Mexico State, the New Mexico Environmental Department

(NMED) regulates chemical waste management activities. All University chemical wastes are subject to inspection and enforcement actions by the EPA or the NMED.

New Mexico Tech provides the following chemical waste compliance services:

- Management of University main hazardous waste accumulation area.
- Collection of chemical waste.
- General compliance assistance.

11.1 Hazardous Chemical Waste Container Requirements

Within your work area, the following practices must be followed for proper management of hazardous waste:

- Determine if your unwanted materials pose a significant risk requiring management as hazardous waste.
- Determine if chemical deactivation or drain disposal is an option. If any doubt exists, assume that the waste is hazardous and that drain disposal is not an option.
- Label with a New Mexico Tech Hazardous Waste label. Labels are available in the office of the Administrative Assistant to the Vice President of Research (Brown Hall 200), inside the foyer of the Research Office Building (R.O.B.), or by request by contacting the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646.
    - Alternatively, you may label containers of hazardous chemical wastes with the identity of the chemical(s) AND the words "Hazardous Waste", however, NMT Hazardous Waste Labels are preferred.
        - Hazardous Waste labels must include the following information, legibly written:
            - Name of the generator (or the individual that knows the most about the waste)
            - Location the waste was generated (Building and Room number)
            - Contents (name of the chemical, not abbreviations)
            - Hazards of the contents (see Section 8.3.1, NMT Research Compliance Classification System for hazard classes commonly encountered; hazard classes should be determined from the materials SDS)
            - Accumulation Start Date (this refers specifically to Central Accumulation Areas, CAA, and will be filled out by the Hazardous Materials and Laboratory Safety Specialist when the hazardous waste is removed from the Satellite Accumulation Area, SAA)
            - 90/180 Pickup Date (timeframe that the waste is allowed to be stored in the CAA by state and federal regulations; this will be filled out by the Hazardous Materials and Laboratory Safety Specialist at the time of removal)
- Keep containers of hazardous chemical wastes closed at all times when they are not in use.

- Store hazardous waste containers within the room in which they are generated.

Recommended practices that should be followed:
- Always maintain a neat and orderly workplace
- Use secondary containment bins or trays to store your chemical waste containers in.
- Store your waste containers in a designated place with the appropriate Satellite Accumulation Area (SAA) signage (see Appendix N for more information).

It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that personnel working in laboratories under their supervision are familiar with and follow hazardous chemical waste container requirements and have attended New Mexico Tech Chemical Waste Disposal training.

11.2 Types of Hazardous Waste Streams

New Mexico Tech generates three different types of hazardous waste streams as described as follows:

<u>Chemical Hazardous Waste</u>
Research Compliance defines Chemical hazardous waste as any liquid, gaseous, or solid chemical that is ignitable, corrosive, reactive, toxic, or persistent, and is no longer deemed to be useful or wanted.

<u>Universal Hazardous Waste</u>
Research Compliance defines Universal Hazardous Waste as any wastes that are commonly generated by a wide variety of establishments that have either inherent or potential hazardous characteristics.

The federal universal waste regulations are found in 40 CFR 273 and apply to the following five types of universal waste:

1. Batteries
2. Pesticides
3. Mercury Containing Equipment
4. Lamps
5. Aerosol Cans

All of the above five universal wastes must be disposed of properly by Research Compliance. Even alkaline batteries like AAA batteries must be disposed of by following the Hazardous Waste Pick Up Procedures in the following Section (11.3).

<u>Radioactive Hazardous Waste</u>
Research Compliance defines Radioactive Hazardous Waste as any waste that contains or emits radioactive particles.

11.3 Hazardous Waste Pick Up Procedures

To have your hazardous waste picked up by New Mexico Tech Safety, please complete the following procedures:

- Place a New Mexico Tech Hazardous Waste label on each container. Labels are available inside Brown Hall 200, inside the foyer of the Research Office Building, or by contacting the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or at hazmat@nmt.edu.
- Fill out the waste label and list all of the ingredients (no trade names or chemical formulas, please).
- Contact the Hazardous Materials and Laboratory Safety Specialist for waste containers.

For Chemical Hazardous Waste

- Fill out the "Chemical Waste Pick Up Request Form" at www.nmt.edu/research/hazmat.php and email the completed form to hazmat@nmt.edu.

For Universal Hazardous Waste (batteries, fluorescent bulbs, used oil, etc.)

- Fill out the "Universal Waste Pick Up Request Form" at www.nmt.edu/research/hazmat.php and email the completed form to hazmat@nmt.edu.

For Radioactive Hazardous Waste

- Fill out the "Radioactive Waste Pick Up Request Form" at www.nmt.edu/research/hazmat.php and email the completed form to hazmat@nmt.edu.

The following types of materials have different requirements for disposal. Contact Research Compliance for more information:

- Biohazardous materials
- Construction debris (such as asbestos and lead)
- CRTs (computer monitors and televisions)
- Scrap electronics (circuit boards)

12 Shipping Hazardous Materials

The transport of hazardous materials is regulated by the U.S. Department of Transportation (DOT) and the International Civil Aviation Organization. An additional regulatory body formed by the airlines is called the International Air Transport Association (IATA); however, their regulations are only enforceable by the airlines. All University transportation (including shipping) of hazardous materials off University owned property is subject to DOT enforcement.

Research Compliance provides the following hazardous material shipping compliance services:

- Compliance training
- Maintenance of training records

- University DOT certification program
- General compliance assistance
- Oversight of shipping stations (where untrained/uncertified individuals may have hazardous material shipped for them).

12.1 Regulated Hazardous Materials

The following materials are regulated as hazardous materials for transportation:

- Alcohol solutions
- Compressed gasses
- Corrosives
- Dry Ice (air shipments only)
- Explosives
- Flammable liquids and solids
- Formaldehyde - solutions between 0.1% and 25% (air shipments only)
- Infectious substances (animals and humans only)
- Oxidizers
- Poisons
- Radioactive materials

12.2 Hazardous Materials Transportation Requirements

The following must be adhered to for all shipments involving hazardous materials:

- All shipments of hazardous materials from the University must be prepared by individuals trained and certified by the Department of Transportation (DOT).
- Anyone who classifies, packages, marks, or labels hazardous materials for shipment must be DOT trained and certified.
- Transport of hazardous materials by New Mexico Tech University members for University business requires the preparer and the driver to be DOT trained and certified.
- Shipments of hazardous materials received by New Mexico Tech University do not require a DOT trained and certified individual unless they help unload the truck.

It is the responsibility of the Principal Investigator or laboratory supervisor to ensure any employee working under their supervision who ships or prepares shipments of hazardous materials has received the proper training. For additional guidance and help in obtaining DOT certifications, please contact Research Compliance at research.compliance@nmt.edu.

13 Radiation Hazards

Ionizing radiation is a form of energy. Unlike some other types of energy, such as heat (infrared radiation) or visible light, the human body cannot sense exposure to ionizing radiation. Nonetheless, absorption of ionizing radiation energy by body tissues causes changes to the chemical makeup of living cells.

The type and thickness of material needed to make an effective barrier or shield around a source of ionizing radiation varies a great deal depending on the type of ionizing radiation. Beta radiation is a stream of tiny charged particles that can be stopped by a thin layer of plastic, glass, wood, metal and most other common materials. X-rays and Gamma rays are very similar to sunlight in that they are not particles, just electromagnetic waves. While sunlight will pass through only a few materials, such as window glass, X-rays and Gamma rays penetrate easily through most materials. However, even they can be blocked by a sufficient thickness of lead.

Ionizing radiation is also similar to other forms of radiation in that the intensity of the radiation exposure decreases very quickly as you move away from the radiation source. Just as moving a short distance closer to or farther from a fireplace causes a large change in how warm you feel; keeping just a few feet away from where someone is handling radioactive material will almost eliminate your exposure.

13.1 Where Ionizing Radiation is Used

Small amounts of radioactive material are used and stored in a multitude of laboratory rooms around the campus. Some of the material is contained in small sealed capsules. Examples of these "sealed sources" include test sources for radiation detectors and ionization detectors in gas chromatographs. Most often radioactive material is found in small vials of radioactively labeled chemicals in solution. These labeled chemicals are widely used in research and in veterinary medicine. With very few exceptions, only very small amounts of radioactive material are used and levels of radiation exposure are quite low.

Ionizing radiation can also be produced by certain electrical equipment, including X-ray machines and particle accelerators. There are approximately one hundred pieces of radiation producing equipment on the campus. Radiation levels produced by this equipment are also very low because of shielding.

You can tell if a room contains a source of ionizing radiation because each entrance is plainly marked by warning labels. Within the room, additional labels and warning tape will be found on each piece of radiation producing equipment and on all areas used to work with or store radioactive material.

13.2 Potential Hazards

Like any form of energy, ionizing radiation can be harmful if a person is exposed to an excessive amount. Exposure to ionizing radiation causes chemical damage to body tissues and can be harmful. Just as with exposure to any toxic chemical, the human body can tolerate exposure to ionizing radiation up to a point without producing any immediate injury. However, just as with toxic chemicals, high levels of exposure can cause serious injuries including skin burns, hair loss, internal bleeding, anemia and immune system suppression. In addition, exposure to high levels of ionizing radiation has been proven to cause an increased lifetime risk of cancer.

13.3 How to Protect Yourself

Responsibility for protecting themselves, co-workers and others from exposure to ionizing radiation is delegated by the Radiation Safety Committee to the Principal Investigator or area supervisor and to each of the individual users. Appropriate safety requirements, that are specific to each use and location, are written into each approval granted by the Committee. Every user must be trained in radiation safety principles and on the specific safety requirements of their operations before they are allowed to begin working with radioactive material.

Other individuals in these areas, who are not trained to use radioactive material or radiation producing equipment, need to follow the safety procedures established for those working with ionizing radiation. Primarily this means:

- Never operate equipment that produces ionizing radiation.
- Never handle items or containers that are labeled with radioactive material warnings or that are within areas marked as storage or use areas for radioactive material.

13.4 Control of Ionizing Radiation

All use of material or equipment that produces ionizing radiation requires prior approval by the New Mexico Tech University Radiation Safety Committee. This group of faculty members set policies and personally reviews each operation to ensure safety and compliance with state and federal regulations. The University Radiation Safety Officer and the Radiation Safety Group within New Mexico Tech provide training and other services to help individuals work safely. In addition, they perform routine inspections of all use areas and require correction of all violations of radiation safety requirements. Detailed information on the university radiation safety program is available in the New Mexico Tech University Radiation Safety Manual (updated manual is currently in development).

The performance of the New Mexico Tech Radiation Safety Program is reviewed continuously. The Radiation Safety Officer keeps policies up-to-date, resolves problems and compliance issues and monitors the level of radiation exposure to individuals on campus. Self-audits are done by New Mexico Tech programs and services (Research Compliance). In addition, the New Mexico State Department of Health performs an on campus assessment of our program every two years.

The information presented here is only a brief overview of how sources of ionizing radiation are used at New Mexico Tech University. While New Mexico Tech has demonstrated that it has a solid and consistent safety program, it is important not to take safety for granted. If you have questions or concerns about the use of ionizing radiation where you work, you are entitled to answers and information. The Principal Investigator, area supervisor or any authorized user is willing and able to help you and you should feel free to speak with them. They understand that many individuals have never had formal training about radiation safety. If you need additional assistance or have any other questions, please contact Research Compliance at research.compliance@nmt.edu.

13.5 Radioactive Waste Disposal

Radioactive material cannot be disposed of in the regular trash. New Mexico Tech provides services to pick up radioactive waste upon request. Radioactive waste is divided into several distinct categories and should be separated accordingly. Please read the Radiation Safety Manual, Disposal of Radioactive Material section, for proper procedures in preparing your radioactive waste for pickup. A radioactive waste pickup may be requested by emailing a completed Radioactive Waste Pick Up Request Form found at www.nmt.edu/research/hazmat.php to hazmat@nmt.edu. For more information or if you have any questions, please contact the Hazardous Materials and Laboratory Safety Specialist at hazmat@nmt.edu or by phone at 575-517-0646.

14 Laser Hazards

New Mexico Tech University has a Laser Safety Program designed to establish guidelines to protect students and employees from the potential hazards associated with laser devices and systems used to conduct laboratory, educational, or research activities at New Mexico Tech University. To achieve this goal, New Mexico Tech recognizes the American National Standard for the Safe Use of Lasers, ANSI Z136.1-2000.

ANSI Z136.1-2007 requires that all class 3b and 4 laser users must attend laser safety training. New Mexico Tech offers training to meet this requirement, which includes topics such as laser hazards, laser classifications, signage/labeling, medical monitoring, safety guidelines, and what to do in case of an exposure incident. The Laser Safety Training class is offered on a monthly basis by submitting a request to Research Compliance.

Additionally, any class 3b and 4 lasers that are in use must be registered with Research Compliance. If your user group has not completed this process, please complete the LASER registration form and return it to New Mexico Tech to the Hazardous Materials and Laboratory Safety Specialist at Research Office Building (R.O.B.) room 113. Laser safety reviews, control recommendations, and medical monitoring are also available by submitting a request to NMT Safety.

Additional information can be found on the OSHA Safety and Health topics webpage for laser hazards.

It is the responsibility of the Principal Investigator or laboratory supervisor with class 3b or 4 LASERs in laboratories under their supervision to ensure the class 3b or 4 LASERs have been registered with New Mexico Tech and employees using these LASERs have received the appropriate training.

For more information, contact NMT's Laser Safety Officer at LSO@nmt.edu.

15 Physical Hazards

In addition to the chemical hazards found in laboratories, there are also numerous physical hazards encountered by laboratory staff on a day-to-day 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 accidents involving physical hazards.

It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that staff and students in laboratories under their supervision are provided with adequate training and information specific to the physical hazards found within their laboratories.

15.1 Machine Guarding

Common machine hazards occurring around moving parts include:
Pinch Points

- Where two parts move together and at least one of the parts moves in a circle; also called mesh points, run-on points, and entry points. Examples include: Belt drives, chain drives, gear drives, and feed rolls.
- When shields cannot be provided, operators must avoid contact with hands or clothing in pinch point areas. Never attempt to service or unclog a machine while it is operating or the engine is running.

Wrap Points

- Any exposed component that rotates.
- Examples include: Rotating shafts such as a PTO shaft or shafts that protrude beyond bearings or sprockets. Watch components on rotating shafts, such as couplers, universal joints, keys, keyways, pins, or other fastening devices. Splined, square, and hexagon-shaped shafts are usually more dangerous than round shafts because the edges tend to grab fingers or clothing more easily than a round shaft, but round shafts may not be smooth and can also grab quickly. Once a finger, thread, article of clothing, or hair is caught it begins to wrap; pulling only causes the wrap to become tighter.

Shear Points

- Where the edges of two moving parts move across one another or where a single sharp part moves with enough speed or force to cut soft material.
- Remember that crop cutting devices cannot be totally guarded to keep hands and feet out and still perform their intended function. Recognize the potential hazards of cutting and shear points on implements and equipment that are not designed to cut or shear. Guarding may not be feasible for these hazards.

Crush Points

- Points that occur between two objects moving toward each other or one object moving toward a stationary object. Never stand between two objects moving toward one another. Use adequate blocking or lock-out devices when working under equipment.

Pull-In Points

- Points where objects are pulled into equipment, usually for some type of processing. Machines are faster and stronger than people. Never attempt to hand-feed materials into moving feed rollers. Always stop the equipment before attempting to remove an item that has plugged a roller or that has become wrapped around a rotating shaft. Remember that guards cannot be provided for all situations - equipment must be able to function in the capacity for which it is designed. Freewheeling parts, rotating or moving parts that continue to move after the power is shut off are particularly dangerous because time delays are necessary before service can begin. Allow sufficient time for freewheeling parts to stop moving. Stay alert! Listen and Watch for Motion!

Thrown Objects

- Any object that can become airborne because of moving parts.
- Keep shields in place to reduce the potential for thrown objects. Wear protective gear such as goggles to reduce the risk of personal injury if you cannot prevent particles from being thrown. All guards, shields or access doors must be in place when equipment is operating. Electrically powered equipment must have a lock- out control on the switch or an electrical switch, mechanical clutch or other positive shut-off device mounted directly on the equipment. Circuit interruption devices on an electric motor, such as circuit breakers or overload protection, must require manual reset to restart the motor.

15.2 Electrical Hazards

Electricity travels in closed circuits, and its normal route is through a conductor. Shock occurs when the body becomes a part of the electric circuit. Electric shock can cause direct injuries such as electrical burns, arc burns, and thermal contact burns. It can also cause injuries of an indirect or secondary nature in which involuntary muscle reaction from the electric shock can cause bruises, bone fractures, and even death resulting from collisions or falls. Shock normally occurs in one of three ways. The person must be in contact with ground and must contact with:

- Both wires of the electric circuit, or
- One wire of the energized circuit and the ground, or
- A metallic part that has become energized by being in contact with an energized wire.

The severity of the shock received when a person becomes a part of an electric circuit is affected by three primary factors:

- The amount of current flowing through the body (measured in amperes).
- The path of the current through the body.
- The length of time the body is in the circuit.

Other factors that may affect the severity of shock are the frequency of the current, the phase of the heart cycle when shock occurs, and the general health of the person prior to shock. The effects of an electrical shock can range from a barely perceptible tingle to immediate cardiac arrest. Although there are no absolute limits or even known values that show the exact injury from any given amperage, the table above shows the general relationship between the degree of injury and the amount of amperage for a 60-cycle hand-to-foot path of one second's duration of shock.

The following table indicates the effects of electrical current on the human body (Source: OSHA Basic Electricity Safety):

EFFECTS OF ELECTRICAL CURRENT IN THE HUMAN BODY	
Current	**Reaction**
Below 1 Milliamp	Generally not perceptible.
1 Milliamp	Faint tingle.
5 Milliamps	Slight shock felt. Not painful but disturbing. Average individual can let go. Strong involuntary reaction can lead to other injuries.
6 to 25 Milliamps	Painful shocks. Loss of muscle control.
9 to 30 Milliamps	The freezing current or “let go” range. If extensor muscles are excited by shock, the person may be thrown away from the power source. Individuals cannot let go. Strong involuntary reactions can lead to other injuries.
50 to 150 Milliamps	Extreme pain, respiratory arrest, severe muscle reactions. Death is possible.
1.0 to 4.3 Amps (1000 Milliamps to 4,300 Milliamps)	Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death is likely
10 Amps (10,000 Milliamps)	Cardiac arrest, severe burns, death is probable.

As this table illustrates, a difference of less than 100 milliamps exists between a current that is barely perceptible (1 milliamp) and one that can potentially kill (50 to 150 milliamps). Muscular contraction caused by stimulation may not allow the victim to free himself/herself from the circuit, and the increased duration of exposure increases the dangers to the shock victim. For example, a current of 100 milliamps for 3 seconds is equivalent to a current of 900 milliamps applied for 0.03 seconds in causing fibrillation. The so-called low voltages can be extremely dangerous because, all other factors being equal, the degree of injury is proportional to the length of time the body is in the circuit. Simply put, low voltage does not mean low hazard.

In the event of an accident involving electricity, if the individual is down or unconscious, or not breathing: CALL New Mexico Tech University Police at 575-835-5555 from a cell phone or off campus phone immediately. If an individual must be physically removed from an electrical source, it is always best to eliminate the power source first (i.e.: switch off the circuit breaker) but time, or circumstance may not allow this option - be sure to use a nonconductive item such as a dry board. Failure to think and react properly could make you an additional victim. If the individual is not breathing and you have been trained in CPR, have someone call New Mexico Tech University Police and begin CPR IMMEDIATELY!

15.2.1 Common Electrical Hazards and Preventive Steps

Many common electrical hazards can be easily identified before a serious problem exists.

- Read and follow all equipment operating instructions for proper use. Ask yourself, "Do I have the skills, knowledge, tools, and experience to do this work safely?"
- Do not attempt electrical repairs unless you are a qualified electrical technician assigned to perform electrical work by your supervisor. Qualified individuals must receive training in safety related work practices and procedures, be able to recognize specific hazards associated with electrical energy, and be trained to understand the relationship between electrical hazards and possible injury. Fixed wiring may only be repaired or modified by Facilities Services.
- All electrical devices fabricated for experimental purposes must meet state and University construction and grounding requirements. Extension cords, power strips, and other purchased electrical equipment must be Underwriters Laboratories (UL) listed.
- Remove all jewelry before working with electricity. This includes rings, watches, bracelets, and necklaces.
- Determine appropriate personal protective equipment (PPE) based on potential hazards present. Before use, inspect safety glasses and gloves for signs of wear and tear, and other damage.
- Use insulated tools and testing equipment to work on electrical equipment. Use power tools that are double-insulated or that have Ground Fault Circuit Interrupters protecting the circuit. Do not use aluminum ladders while working with electricity; choose either wood or fiberglass.
- Do not work on energized circuits. The accidental or unexpected starting of electrical equipment can cause severe injury or death. Before any inspections or repairs are made, the current must be turned off at the switch box and the switch padlocked or tagged out in the off position. At the same time, the switch or controls of the machine or the other equipment being locked out of service should be securely tagged to show which equipment or circuits are being worked on. Test the equipment to make sure there is no residual energy before attempting to work on the circuit. Employees must follow lock- out/tag-out procedures (for more information, please

see OSHA’s Lockout-Tagout eTool).

- If you need additional power supply, the best solution is to have additional outlets installed by Facilities Services. Do not use extension cords or power strips ("power taps") as a substitute for permanent wiring.
- Extension cords and power strips may be used for experimental or developmental purposes on a temporary basis only. Extension cords can only be used for portable tools or equipment and must be unplugged after use. Do not use extension cords for fixed equipment such as computers, refrigerators/freezers, etc.; use a power strip in these cases. In general, the use of power strips is preferred over use of extension cords.
- Power strips must have a built-in overload protection (circuit breaker) and must not be connected to another power strip or extension cord (commonly referred to as daisy chained or piggy-backed). As mentioned above though, extension cords and power strips are not a substitute for permanent wiring.
- Ensure any power strips or extension cords are listed by a third-party testing laboratory, such as Underwriters Laboratory (UL). Make sure the extension cord thickness is at least as big as the electrical cord for the tool. For more information on extension cords, see the Consumer Product Safety Commission - Extension Cords Fact Sheet (CPSC Document #16).
- Inspect all electrical and extension cords for wear and tear. Pay particular attention near the plug and where the cord connects to the piece of equipment. If you discover a frayed electrical cord, contact your Building Coordinator for assistance. Do not use equipment having worn or damaged power cords, plugs, switches, receptacles, or cracked casings. Running electrical cords under doors or rugs, through windows, or through holes in walls is a common cause of frayed or damaged cords and plugs.
- Do not use 2-prong ungrounded electrical devices. All department-purchased electrical equipment must be 3-prong grounded with very limited exceptions.
- Never store flammable liquids near electrical equipment, even temporarily.
- Keep work areas clean and dry. Cluttered work areas and benches invite accidents and injuries. Good housekeeping and a well-planned layout of temporary wiring will reduce the dangers of fire, shock, and tripping hazards.
- Common scenarios that may indicate an electrical problem include: flickering lights, warm switches or receptacles, burning odors, sparking sounds when cords are moved, loose connections, frayed, cracked, or broken wires. If you notice any of these problems, have a qualified electrician address the issue immediately.
- To protect against electrical hazards and to respond to electrical

emergencies it is important to identify the electrical panels that serve each room. Access to these panels must be unobstructed; a minimum of 3’ of clearance is required in front of every electrical panel. Each panel must have all the circuit breakers labeled as to what they control. Contact your Building Coordinator for assistance.

- When performing laboratory inspections, it is a good idea to verify the location of the power panel and to open the door to ensure any breakers that are missing have breaker caps in its place. If no breaker is present and no breaker cap is covering the hole, contact your Building Coordinator for assistance.
- Avoid operating or working with electrical equipment in a wet or damp environment. If you must work in a wet or damp environment, be sure your outlets or circuit breakers are Ground Fault Circuit Interrupter (GFCI) protected. Temporary GFCI plug adapters can also be used, but are not a substitute for GFCI outlets or circuit breakers.
- Fuses, circuit breakers, and Ground-Fault Circuit Interrupters are three well-known examples of circuit protection devices.
- Fuses and circuit breakers are overcurrent devices that are placed in circuits to monitor the amount of current that the circuit will carry. They automatically open or break the circuit when the amount of the current flow becomes excessive and therefore unsafe. Fuses are designed to melt when too much current flows through them. Circuit breakers, on the other hand, are designed to trip open the circuit by electro-mechanical means.
- Fuses and circuit breakers are intended primarily for the protection of conductors and equipment. They prevent overheating of wires and components that might otherwise create hazards for operators.
- The Ground Fault Circuit Interrupter (GFCI) is designed to shut off electric power within as little as 1/40 of a second, thereby protecting the person, not just the equipment. It works by comparing the amount of current going to an electric device against the amount of current returning from the device along the circuit conductors. A fixed or portable GFCI should be used in high-risk areas such as wet locations and construction sites.
- Entrances to rooms and other guarded locations containing exposed live parts must be marked with conspicuous warning signs forbidding unqualified persons to enter.

Live parts of electric equipment operating at 50 volts or more must be guarded against accidental contact. Guarding of live parts may be accomplished by:

- Location in a room, vault, or similar enclosure accessible only to qualified persons.
- Use of permanent, substantial partitions or screens to exclude

unqualified persons.
- Location on a suitable balcony, gallery, or platform elevated and arranged to exclude unqualified persons, or
- Elevation of 8 feet or more above the floor.

Additional resources for electrical safety can be found in OSHA's Pamphlet 3075, "Controlling Electrical Hazards" as well as OSHA's "Electrical Regulations and Standards", comprised of 29 CFR 1926 Subpart K, Subpart V, 29 CFR 1910 Subpart R, Subpart S, 1910.137 and 1910.147.

15.2.2 Safe Use of Electrophoresis Equipment

Electrophoresis units present several possible hazards including electrical, chemical, and radiological hazards. All of these hazards need to be addressed before using the units. Research Compliance has prepared these guidelines to assist researchers in safely operating electrophoresis units.
- Hazards associated with particular machines.
- How the safeguards provide protection and the hazards for which they are intended.
- How and why to use the safeguards.
- How and when safeguards can be removed and by whom.
- What to do if a safeguard is damaged, missing, or unable to provide adequate protection.

Hazards to machine operators that can't be designed around must be shielded to protect the operator from injury or death. Guards, decals and labels which identify the danger must be kept in place whenever the machine is operated. Guards or shields removed for maintenance must be properly replaced before use. Moving parts present the greatest hazard because of the swiftness of their action and unforgiving and relentless motion.

15.2.3 Lighting

Having a properly lighted work area is essential to working safely. A couple of key points to remember about proper lighting:
- Lighting should be adequate for safe illumination of all work areas (100-200 lumens for laboratories).
- Light bulbs that are mounted low and susceptible to contact should be guarded.
- If the risk of electrocution exists when changing light bulbs, practice lock-out tag-out procedures (for more information, please see OSHA's Lockout-Tagout eTool).
- For proper disposal of fluorescent bulbs ("universal waste"), please fill out and email a completed "Universal Waste Pick Up Request

Form" found at www.nmt.edu/research/hazmat.php to hazmat@nmt.edu.
- As an energy conservation measure, please remember to turn off your lights when you leave your lab.

15.3 Compressed Gas Cylinders

Compressed gasses are commonly used in laboratories for a number of different operations. While compressed gasses are very useful, they present a number of hazards for the laboratory worker:

- Gas cylinders may contain gasses that are flammable, toxic, corrosive, asphyxiants, or oxidizers.
- Unsecured cylinders can be easily knocked over, causing serious injury and damage. Impact can shear the valve from an uncapped cylinder, causing a catastrophic release of pressure leading to personal injury and extensive damage.
- Mechanical failure of the cylinder, cylinder valve, or regulator can result in rapid diffusion of the pressurized contents of the cylinder into the atmosphere; leading to explosion, fire, runaway reactions, or burst reaction vessels.

15.3.1 Handling Compressed Gas Cylinders

There are a number of ways that compressed gasses can be handled safely. Always practice the following when handling compressed gasses:

- The contents of any compressed gas cylinder must be clearly identified. Such identification should be stenciled or stamped on the cylinder, or a label or tag should be attached. Do not rely on the color of the cylinder for identification because color-coding is not standardized and may vary with the manufacturer or supplier.
- When transporting cylinders:
  - Always use a hand truck equipped with a chain or belt for securing the cylinder.
  - Make sure the protective cap covers the cylinder valve.
  - Never transport a cylinder while a regulator is attached.
  - Always use caution when transporting cylinders – cylinders are heavy.
- Avoid riding in elevators with compressed gas cylinders. If this is necessary, consider using a buddy system to have one person send the properly secured cylinders on the elevator, while the other person waits at the floor by the elevator doors where the cylinders will arrive.
- Do not move compressed gas cylinders by carrying, rolling, sliding, or dragging them across the floor.
- Do not transport oxygen and combustible gasses at the same time.
- Do not drop cylinders or permit them to strike anything violently.

15.3.2 Safe Storage of Compressed Gas Cylinders

Procedures to follow for safe storage of compressed gas cylinders include:

- Gas cylinders must be secured to prevent them from falling over. Chains are recommended over clamp-plus-strap assemblies due to the hazards involved in a fire and straps melting or burning. Be sure the chain is high enough (at least half way up) on the cylinder to keep it from tipping over.
- Do not store incompatible gasses right next to each other. Cylinders of oxygen must be stored at least 20 feet away from cylinders of hydrogen or other flammable gas, or the storage areas must be separated by a firewall five feet high with a fire rating of 1/2 hour.
- All cylinders should be stored away from heat and away from areas where they might be subjected to mechanical damage.
- Keep cylinders away from locations where they might form part of an electrical circuit, such as next to electric power panels or electric wiring.
- The protective cap that comes with a cylinder of gas should always be left on the cylinder when it is not in use. The cap keeps the main cylinder valve from being damaged or broken.

15.3.3 Operation of Compressed Gas Cylinders

The cylinder valve hand wheel opens and closes the cylinder valve. The pressure relief valve is designed to keep a cylinder from exploding in case of fire or extreme temperature. Cylinders of very toxic gasses do not have a pressure relief valve, but they are constructed with special safety features. The valve outlet connection is the joint used to attach the regulator. The pressure regulator is attached to the valve outlet connector in order to reduce the gas flow to a working level. The Compressed Gas Association has intentionally made certain types of regulators incompatible with certain valve outlet connections to avoid accidental mixing of gasses that react with each other. gasses should always be used with the appropriate regulator. Do not use adaptors with regulators. The cylinder connection is a metal-to-metal pressure seal. Make sure the curved mating surfaces are clean before attaching a regulator to a cylinder. Do not use Teflon tape on the threaded parts, because this may actually cause the metal seal not to form properly. Always leak test the connection.

<u>Basic operating guidelines include</u>:

- Make sure that the cylinder is secured.
- Attach the proper regulator to the cylinder. If the regulator does not fit, it may not be suitable for the gas you are using.
- Attach the appropriate hose connections to the flow control valve. Secure any tubing with clamps so that it will not whip around

when pressure is turned on. Use suitable materials for connections; toxic and corrosive gasses require connections made of special materials.

- Install a trap between the regulator and the reaction mixture to avoid backflow into the cylinder.
- To prevent a surge of pressure, turn the delivery pressure adjusting screw counterclockwise until it turns freely and then close the flow control valve.
- Slowly open the cylinder valve hand wheel until the cylinder pressure gauge reads the cylinder pressure.
- With the flow control valve closed, turn the delivery pressure screw clockwise until the delivery pressure gauge reads the desired pressure.
- Adjust the gas flow to the system by using the flow control valve or another flow control device between the regulator and the experiment.
- After an experiment is completed, turn the cylinder valve off first, and then allow gas to bleed from the regulator. When both gauges read "zero", remove the regulator and replace the protective cap on the cylinder head.
- When the cylinder is empty, mark it as "Empty", and store empty cylinders separate from full cylinders.
- Attach a "Full/In Use/Empty" tag to all of your cylinders, these tags are perforated and can be obtained from the gas cylinder vendor.

<u>Precautions to follow</u>:

- Use a regulator only with gas for which it is intended. The use of adaptors or homemade connectors has caused serious and even fatal accidents.
- Toxic gasses should be purchased with a flow-limiting orifice.
- When using more than one gas, be sure to install one-way flow valves from each cylinder to prevent mixing. Otherwise accidental mixing can cause contamination of a cylinder.
- Do not attempt to put any gas into a commercial gas cylinder.
- Do not allow a cylinder to become completely empty. Leave at least 25 psi of residual gas to avoid contamination of the cylinder by reverse flow.
- Do not tamper with or use force on a cylinder valve.

15.3.4 Hazards of Specific gasses

<u>Inert gasses</u>: Examples include Helium, Argon, and Nitrogen

- Can cause asphyxiation by displacing the air necessary for the support of life.
- Cryogens are capable of causing freezing burns, frostbite, and

destruction of tissue.

- Cryogenic liquids are extremely cold and their vapors can rapidly freeze human tissue.
- Boiling and splashing will occur when the cryogen contacts warm objects.
- Can cause common materials such as plastic and rubber to become brittle and fracture under stress.
- Liquid to gas expansion ratio: one volume of liquid will vaporize and expand to about 700 times that volume, as a gas, and thus can build up tremendous pressures in a closed system. Therefore, dispensing areas need to be well ventilated. Avoid storing cryogenics in cold rooms, environmental chambers, and other areas with poor ventilation. If necessary, install an oxygen monitor/oxygen deficiency alarm and/or toxic gas monitor before working these materials in confined areas.

<u>Oxidizers</u>: Examples include Oxygen, Chlorine

- Oxidizers vigorously accelerate combustion; therefore, keep away from all flammable and organic materials. Greasy and oily materials should never be stored around oxygen. Oil or grease should never be applied to fittings or connectors.

<u>Flammable gasses</u>: Examples include Methane, Propane, Hydrogen, Acetylene

- Flammable gasses present serious fire and explosion hazards.
- Do not store near open flames or other sources of ignition.
- Cylinders containing Acetylene should never be stored on their side.
- Flammable gasses are easily ignited by heat, sparks, or flames, and may form explosive mixtures with air. Vapors from liquefied gas often are heavier than air, and may spread along ground and travel to a source of ignition and result in a flashback fire.

<u>Corrosive gasses</u>: Examples include Chlorine, Hydrogen Chloride, Ammonia

- There can be an accelerated corrosion of materials in the presence of moisture.
- Corrosive gasses readily attack the skin, mucous membranes, and eyes. Some corrosive gasses are also toxic.
- Due to the corrosive nature of the gasses, corrosive cylinders should only be kept on hand for 6 months (up to one-year maximum). Only order the smallest size needed for your experiments.

<u>Toxic gasses</u>: Examples include Arsine, Phosphine, Phosgene

- Toxic gasses can be extremely dangerous, and present a serious

hazard to laboratory staff.
- Toxic gasses require special ventilation systems and equipment and must only be used by properly trained experts. There are also special building code regulations that must be followed with regard to quantities kept on hand and storage.
- The purchase and use of toxic gasses require prior approval from Research Compliance.

15.4 Battery Hazards

Lead acid batteries contain corrosive liquids and also generate Hydrogen gas during charging which poses an explosion hazard. The following guidelines should be followed for battery charging areas:

- A "No smoking" sign should be posted.
- Before working, remove all jewelry from hands and arms and any dangling jewelry to prevent accidental contact with battery connections (this can cause sparks which can ignite vapors).
- Always wear appropriate PPE such as rubber or synthetic aprons, splash goggles (ideally in combination with a face shield), and thick Neoprene, Viton, or Butyl gloves.
- A plumbed emergency eyewash station must be readily available near the station (please note, hand held eyewash bottles do not meet these criteria.)
- A class B rated fire extinguisher must be readily available. If none is available, contact Facilities Management.
- Ensure there is adequate ventilation available to prevent the buildup of potentially flammable and explosive gasses.
- Keep all ignition sources away from the area.
- Stand clear of batteries while charging.
- Keep vent caps tight and level.
- Only use the appropriate equipment for charging.
- Store unused batteries in secondary containment to prevent spills.
- Have an acid spill kit available. The waste from a spill may contain lead and neutralized wastes may be toxic. Contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 for hazardous waste disposal.
- Properly dispose of your used batteries. Fill out the "Universal Waste Pick Up Request Form" found at www.nmt.edu/research/hazmat.php and email the completed form to hazmat@nmt.edu.

15.5 Hazards of Heat and Heating Devices

Heat hazards within laboratories can occur from a number of sources; however, there are some simple guidelines that 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.

When using ovens, the follow additional guidelines should be followed:

- Heat generated should be adequately removed from the area.
- If toxic, flammable, or otherwise hazardous chemicals are evolved from the oven, then only use ovens with a single pass through design where air is ventilated out of the lab and the exhausted air is not allowed to come into contact with electrical components or heating elements.
- Heating flammables should only be done with a heating mantle or steam bath.

When using heating baths, these additional guidelines should be followed:

- 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.

15.5.1 Heat Stress

Another form of heat hazard occurs when working in a high heat area. Under certain conditions, your body might have trouble regulating its temperature. If your body cannot regulate its temperature, it overheats and suffers some degree of heat stress. This can occur very suddenly and, if left unrecognized and untreated, can lead to very serious health effects.

Heat stress disorders range from mild disorders such as fainting, cramps, or prickly heat to more dangerous disorders such as heat exhaustion or heat stroke. Symptoms of mild to moderate heat stress can include: sweating, clammy skin, fatigue, decreased strength, loss of coordination and muscle control, dizziness, nausea, and irritability. You should move the victim to a cool place and give plenty of fluids. Place cool compresses on the forehead, neck, and under their armpits.

Heat stroke is a medical emergency. It can cause permanent damage to the brain and vital organs, or even death. Heat stroke can occur suddenly, with little warning. Symptoms of heat stroke may include: no sweating (in some cases victims may sweat profusely), high body temperature (103℉ or more), red, hot, and dry skin, rapid and strong pulse, throbbing headache, dizziness, nausea, convulsions, delirious behavior, unconsciousness, or coma.

In the case of heat stroke, call 911 & get medical assistance ASAP! In the meantime, you should move the victim to a cool place, cool the person quickly by sponging with cool water and fanning, and offer a conscious person 1/2 glass of water every 15 minutes.

There are a number of factors that affect your body's temperature regulation:

- Radiant heat sources such as the sun or a furnace.
- Increased humidity causes decreased sweat evaporation.
- Decreased air movement causes decreased sweat evaporation.
- As ambient temperature rises, your body temperature rises and its ability to regulate decreases

You should be especially careful if:

- You just started a job involving physical work in a hot environment.
- You are ill, overweight, physically unfit, or on medication that can cause dehydration.
- You have been drinking alcohol.
- You have had a previous heat stress disorder.

In order to prevent heat stress, please follow these recommendations:

- Acclimatize your body to the heat. Gradually increase the time you spend in the heat. Most people acclimate to warmer temperatures in 4-7 days. Acclimatization is lost when you have been away from the heat for one week or more. When you return, you must repeat the acclimatization process.
- Drink at least 4-8 ounces of fluid every 15-20 minutes to maintain proper balance during hot and/or humid environments. THIRST IS NOT A GOOD INDICATOR OF DEHYDRATION. Fluid intake must continue until well after thirst has been quenched.
- During prolonged heat exposure or heavy workload, a carbohydrate-electrolyte beverage is beneficial.
- Alternate work and rest cycles to prevent an overexposure to heat. Rest cycles should include relocation to a cooler environment.
- Perform the heaviest workloads in the cooler part of the day.
- There should be no alcohol consumption during periods of high heat exposure.
- Eat light, preferably cold meals. Fatty foods are harder to digest in hot weather.

15.6 Cold Traps

<u>Cold traps</u>:

- Because many chemicals captured in cold traps are hazardous, care should be taken and appropriate protective equipment should be worn when handling these chemicals. Hazards include flammability, toxicity, and cryogenic temperatures, which can burn the skin.
- If liquid nitrogen is used, the chamber should be evacuated before charging the system with coolant. Since oxygen in air has a higher boiling point than nitrogen, liquid oxygen can be produced and cause an explosion hazard.
- Boiling and splashing generally occur when charging (cooling) a warm container, so stand clear and wear appropriate protective equipment. Items should be added slowly and in small amounts to minimize splash.
- A blue tint to liquid nitrogen indicates contamination with oxygen and represents an explosion hazard. Contaminated liquid nitrogen should be disposed of appropriately.
- If working under vacuum see the "reduced pressure" section.
- See "cryogenics" for safety advice when working with cryogenic materials.

15.7 Autoclaves

Autoclaves have the following potential hazards:

- Heat, steam, and pressure.
- Thermal burns from steam and hot liquids.
- Cuts from exploding glass.

Some general safety guidelines to follow when using autoclaves:

- All users should be given training in proper operating procedures for using the autoclave.
- 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.
- Be sure to close and latch the autoclave door.
- Some kinds of bottles containing liquids can crack in the autoclave, or when they are removed from the autoclave. Use a tray to provide secondary containment in case of a spill, and add a little water to the tray to ensure even heating.
- Only fill bottles halfway to allow for liquid expansion and loosen screw caps on bottles and tubes of liquid before autoclaving, to prevent them from shattering.
- Do not overload the autoclave compartment and allow for enough space between items for the steam to circulate.
- 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 with 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.
- Wait at least five minutes after opening the door before removing items.
- 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.

15.8 Centrifuges

Some general safety guidelines to follow when using centrifuges:

- Be familiar with the operating procedures written by the manufacturer. Keep the operating manual near the unit for easy reference. If necessary, contact the manufacturer to replace lost manuals.
- Handle, load, clean, and inspect rotors as recommended by the manufacturer.
- Pay careful attention to instructions on balancing samples -- tolerances for balancing are often very restricted. Check the condition of tubes and bottles. Make sure you have secured the lid to the rotor and the rotor to the centrifuge.
- Maintain a logbook of rotor use for each rotor, recording the speed and length of time for each use.
- To avoid catastrophic rotor failure, many types of rotors must be "de-rated" (limited to a maximum rotation speed that is less than the maximum rotation speed specified for the rotor when it is new) after a specified amount of use, and eventually taken out of service and discarded.
- Use only the types of rotors that are specifically approved for use in a given centrifuge unit.
- Maintain the centrifuge in good condition. Broken door latches and other problems should be repaired before using the centrifuge.
- Whenever centrifuging biohazardous materials, always load and unload the centrifuge rotor in a Biosafety cabinet.

15.8.1 Centrifuge Rotor Care

Basic centrifuge rotor care includes:

- Keep the rotor clean and dry, to prevent corrosion.
- Remove adapters after use and inspect for corrosion.
- Store the rotor upside down, in a warm, dry place to prevent condensation in the tubes.
- Read and follow the recommendations in the manual regarding: Regular cleaning
- Routine inspections
- Regular polishing
- Lubricating O-rings
- Decontaminating the rotor after use with radioactive or biological materials

- Remove any rotor from use that has been dropped or shows any sign of defect, and report it to a manufacturer's representative for inspection.

15.9 Cryogenic Safety

A cryogenic gas is a material that is normally a gas at standard temperature and pressure, but which has been super-cooled such that it is a liquid or solid at standard pressure. Commonly used cryogenic materials include the liquids nitrogen, argon, and helium, and solid carbon dioxide (dry ice).

Hazards associated with direct personal exposure to cryogenic fluids include:

- Frostbite - Potential hazards in handling liquefied gasses and solids result because they are extremely cold and can cause severe cold contact burns by the liquid, and frostbite or cold exposure by the vapor.
- Asphyxiation - The ability of the liquid to rapidly convert to large quantities of gas associated with evaporation of cryogenic liquid spills can result in asphyxiation. For instance, nitrogen expands approximately 700 times in volume going from liquid to gas at ambient temperature. Total displacement of oxygen by another gas, such as Carbon dioxide, will result in unconsciousness, followed by death. Exposure to oxygen-deficient atmospheres may produce dizziness, nausea, vomiting, loss of consciousness, and death. Such symptoms may occur in seconds without warning. Death may result from errors in judgment, confusion, or loss of consciousness that prevents self-rescue.
- Toxicity - Many of the commonly used cryogenic gasses are considered to be of low toxicity, but still pose a hazard from asphyxiation. Check the properties of the gasses you are using, because some gasses are toxic, for example, Carbon monoxide, Fluorine, and Nitrous oxide.
- Flammability and Explosion Hazards - Fire or explosion may result from the evaporation and vapor buildup of flammable gasses such as hydrogen, carbon monoxide, or methane. Liquid oxygen, while not itself a flammable gas, can combine with combustible materials and greatly accelerate combustion. Oxygen clings to clothing and cloth items, and presents an acute fire hazard.
- High Pressure Gas Hazards - Potential hazards exist in highly compressed gasses because of the stored energy. In cryogenic systems, high pressures are obtained by gas compression during refrigeration, by pumping of liquids to high pressures followed by rapid evaporation, and by confinement of cryogenic fluids with subsequent evaporation. If this confined fluid is suddenly released through a rupture or break in a line, a significant thrust may be experienced. Over- pressurization of cryogenic equipment can occur due to the phase change from liquid to gas if not vented properly. All cryogenic fluids produce large volumes of gas when they vaporize.
- Materials and Construction Hazards - The selection of materials calls for consideration of the effects of low temperatures on the properties of those materials. Some materials become brittle at low temperatures. Brittle materials

fracture easily and can result in almost instantaneous material failure. Low temperature equipment can also fail due to thermal stresses caused by differential thermal contraction of the materials. Over-pressurization of cryogenic equipment can occur due to the phase change from liquid to gas if not vented properly. All cryogenic fluids produce large volumes of gas when they vaporize.

Working with cryogenic substances in confined spaces, such as walk-in coolers, can be especially hazardous. Where cryogenic materials are used, a hazard assessment is required to determine the potential for an oxygen-deficient condition. Controls such as ventilation and/or gas detection systems may be required to safeguard employees. Asphyxiation and chemical toxicity are hazards encountered when entering an area that has been used to store cryogenic liquids if proper ventilation/purging techniques are not employed.

15.9.1 Cryogenic Safety Guidelines

Responsibilities

- Personnel who are responsible for any cryogenic equipment must conduct a safety review prior to the commencement of operation of the equipment. Supplementary safety reviews must follow any system modification to ensure that no potentially hazardous condition is overlooked or created and that updated operational and safety procedures remain adequate.

Personal Protective Equipment

- Wear the appropriate PPE when working with cryogenic materials. Face shields and splash goggles must be worn during the transfer and normal handling of cryogenic fluids. Loose fitting, heavy leather or other insulating protective gloves must be worn when handling cryogenic fluids. Shirt sleeves should be rolled down and buttoned over glove cuffs, or an equivalent protection such as a lab coat, should be worn in order to prevent liquid from spraying or spilling inside the gloves. Trousers without cuffs should be worn.

Safety Practices

- Cryogenic fluids must be handled and stored only in containers and systems specifically designed for these products and in accordance with applicable standards, procedures, and proven safe practices.
- Transfer operations involving open cryogenic containers such as dewars must be conducted slowly to minimize boiling and splashing of the cryogenic fluid. Transfer of cryogenic fluids from open containers must occur below the chest level of the person pouring the liquid.
- Only conduct such operations in well-ventilated areas, such as the laboratory, to prevent possible gas or vapor accumulation that may

produce an oxygen- deficient atmosphere and lead to asphyxiation. If this is not possible, an oxygen meter must be installed.

- Equipment and systems designed for the storage, transfer, and dispensing of cryogenic fluids need to be constructed of materials compatible with the products being handled and the temperatures encountered.
- All cryogenic systems including piping must be equipped with pressure relief devices to prevent excessive pressure build-up. Pressure reliefs must be directed to a safe location. It should be noted that two closed valves in a line form a closed system. The vacuum insulation jacket should also be protected by an over pressure device if the service is below 77 degrees Kelvin. In the event a pressure relief device fails, do not attempt to remove the blockage; instead, call the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646.
- The caps of liquid nitrogen dewars are designed to fit snugly to contain the liquid nitrogen, but also allow the periodic venting that will occur to prevent an over pressurization of the vessel. Do not ever attempt to seal the caps of liquid nitrogen dewars. Doing so can present a significant hazard of over pressurization that could rupture the container and cause splashes of liquid nitrogen and, depending on the quantity of liquid nitrogen that may get spilled, cause an oxygen deficient atmosphere within a laboratory due to a sudden release and vaporization of the liquid nitrogen.
- If liquid nitrogen or helium traps are used to remove condensable gas impurities from a vacuum system that may be closed off by valves, the condensed gasses will be released when the trap warms up. Adequate means for relieving resultant build-up of pressure must be provided.

<u>First Aid</u>

- Workers will rarely, if ever, come into contact with cryogenic fluids if proper handling procedures are used. In the unlikely event of contact with a cryogenic liquid or gas, a contact “burn” may occur. The skin or eye tissue will freeze. The recommended emergency treatment is as follows:
- If the cryogenic fluid comes in contact with the skin or eyes, flush the affected area with generous quantities of cold water. Never use dry heat. Splashes on bare skin cause a stinging sensation, but, in general, are not harmful
- If clothing becomes soaked with liquid, it should be removed as quickly as possible and the affected area should be flooded with water as above. Where clothing has frozen to the underlying skin, cold water should be poured on the area, but no attempt should be made to remove the clothing until it is completely free.
- Contact NMT campus Police 575-835-5555 for additional

treatment if necessary.
- Complete an NMT Lab Incident/Near Miss Report.

15.9.2 Cryogenic Chemical Specific Information

Liquid Helium
Liquid helium must be transferred via helium pressurization in properly designed transfer lines. A major safety hazard may occur if liquid helium comes in contact with air. Air solidifies in contact with liquid helium, and precautions must be taken when transferring liquid helium from one vessel to another or when venting. Over-pressurization and rupture of the container may result. All liquid helium containers must be equipped with a pressure-relief device. The latent heat of vaporization of liquid helium is extremely low (20.5 J/gm); therefore, small heat leaks can cause rapid pressure rises.

Liquid Nitrogen
Since the boiling point of liquid nitrogen is below that of liquid oxygen, it is possible for oxygen to condense on any surface cooled by liquid nitrogen. If the system is subsequently closed and the liquid nitrogen removed, the evaporation of the condensed oxygen may over-pressurize the equipment or cause a chemical explosion if exposed to combustible materials, e.g., the oil in a rotary vacuum pump. In addition, if the mixture is exposed to radiation, ozone is formed, which freezes out as ice and is very unstable. An explosion can result if this ice is disturbed. For this reason, air should not be admitted to enclosed equipment that is below the boiling point of oxygen unless specifically required by a written procedure.

Any transfer operations involving open containers such as wide-mouth Dewars must be conducted slowly to minimize boiling and splashing of liquid nitrogen. The transfer of liquid nitrogen from open containers must occur below the chest level of the person pouring the liquid.

Liquid Hydrogen
Anyone proposing the use of liquid hydrogen must first obtain prior approval of Research Compliance at research.compliance@nmt.edu

Because of its wide flammability range and ease of ignition, special safety measures must be invoked when using liquid hydrogen.

Liquid hydrogen must be transferred by helium pressurization in properly designed transfer lines in order to avoid contact with air. Properly constructed and certified vacuum insulated transfer lines should be used.

Only trained personnel familiar with liquid hydrogen properties, equipment, and operating procedures are permitted to perform transfer operations. Transfer lines in liquid hydrogen service must be purged with helium or gaseous hydrogen, with proper precautions, before using.

The safety philosophy in the use of liquid hydrogen can be summarized as the following:

- Isolation of the experiment
- Provision of adequate ventilation
- Exclusion of ignition sources plus system grounding/bonding to prevent static charge build-up.
- Containment in helium purged vessels.
- Efficient monitoring for hydrogen leakage.
- Limiting the amount of hydrogen cryo-pumped in the vacuum system.

Liquid Oxygen

Anyone proposing the use of liquid oxygen must first obtain prior approval of Research Compliance at research.compliance@nmt.edu.

Liquid oxygen does not burn; however, it greatly accelerates fire. Adequate ventilation to avoid oxygen enrichment of the air is necessary. A room with combustible materials, oils and grease, electrical equipment, an ignition source, or flammable liquids and vapors should be avoided.

OSHA defines an oxygen enriched atmosphere as being more than 22% oxygen. Oxygen enriched atmospheres present a significant fire and explosion risk.

In the event of saturation of clothing with liquid oxygen, stay away from ignition sources for at least 30 minutes or change clothing.

15.9.3 Extractions and Distillations

Extractions

- Do not attempt to extract a solution until it is cooler than the boiling point of the extractant due to the risk of over pressurization, which could cause the vessel to burst.
- When a volatile solvent is used, the solution should be swirled and vented repeatedly to reduce pressure before separation.
- When opening the stopcock, your hand should keep the plug firmly in place.
- The stopcock should be lubricated.
- Vent funnels away from ignition sources and people, preferably into a hood.
- Keep volumes small to reduce the risk of overpressure and if large volumes are needed, break them up into smaller batches.

Distillations

- Avoid bumping (sudden boiling) since the force can break apart the apparatus and result in splashes. Bumping can be avoided by even heating, such as using a heat mantle. Also, stirring can prevent bumping. Boiling stones can be used only if the process is at atmospheric pressure.
- Do not add solid items such as boiling stones to liquid that is near boiling since it may result in the liquid boiling over spontaneously
- Organic compounds should never be allowed to boil to dryness unless they are known to be free of peroxides, which can result in an explosion hazard.

Reduced pressure distillation

- Do not overheat the liquid. Superheating can result in decomposition and uncontrolled reactions.
- Superheating and bumping often occur at reduced pressures so it is especially important to abide by the previous point on bumping and to ensure even, controlled heating. Inserting a nitrogen bleed tube may help alleviate this issue.
- Evacuate the assembly gradually to minimize bumping.
- Allow the system to cool and then slowly bleed in air. Air can cause an explosion in a hot system (pure nitrogen is preferable to air for cooling).
- See "reduced pressure" for vacuum conditions.

15.10 Glass and Glassware Hazards and Guidelines

Some general guidelines for glass, glassware, glass under pressure of vacuums, washing glassware, and general glass equipment set up are provided in the following subsections.

Any broken glass or glassware should be placed in a plastic lined cardboard box, a cardboard box that has had its corners taped, or a plastic container to prevent small broken glass particles from escaping. If the broken glass is contaminated (or potentially contaminated) with hazardous materials, please contact the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646 or hazmat@nmt.edu.

15.10.1 Glass Under Vacuum

Reduced pressure

Some general guidelines for glass under vacuum include:

- 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 flasks 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.

Vacuum pumps

- Cold traps should be used to prevent pump oil from being contaminated which can create a hazardous waste.
- Pump exhaust should be vented into a hood when possible.
- Ensure all belts and other moving parts are properly guarded.
- Whenever working on or servicing vacuum pumps, be sure to follow appropriate lock- out procedures.

15.10.2 Glassware Washing

In most cases laboratory glassware can be cleaned effectively by using detergents and water. In some cases, it may be necessary to use strong chemicals for cleaning glassware. Strong acids should be avoided unless necessary. In particular, Chromic acid should not be used due to its toxicity and disposal concerns. One product that may be substituted for Chromic acid is "Nochromix Reagent". The Fisher catalog describes this material as: "Nochromix Reagent. Inorganic oxidizer chemically cleans glassware. Contains no metal ions. Rinses freely—leaving no metal residue, making this product valuable for trace analysis, enzymology, and tissue culture work. (Mix with sulfuric acid)." Unused Nochromix Reagent can be neutralized to a pH between 5.5 and 9.5 and drain disposed. Acid/base baths should have appropriate labeling and secondary containment. Additionally, a Standard Operating Procedure (SOP), proper personal protective equipment (PPE), and spill materials should be available. Proper disposal for spent acid/base bath contents is neutralization and drain disposal.

When handling glassware, check for cracks and chips before washing, autoclaving or using it. Dispose of chipped and broken glassware immediately in an approved collection unit. DO NOT put broken glassware in the regular trash. Instead, a plastic bag lined cardboard box, or cardboard box with its corners taped, should be used. Handle glassware with care – avoid impacts, scratches or intense heating of glassware. Make sure you use the appropriate lab-ware for the procedures and chemicals. Use care when inserting glass tubing into stoppers: use glass tubing that has been fire-polished, lubricate the glass, and protect your hands with heavy gloves.

If your department/building has a glass washing service, there are certain protocols that must be followed before sending the glassware to be washed. It is the responsibility of the lab to empty and rinse all glassware before it leaves the lab. Although the contents may not be hazardous, the washroom support staff cannot be certain of the appropriate PPE to wear, disposal regulations or possible incompatibilities with items received from other researchers. Be aware that labeling for lab personnel is not sufficient for areas outside the lab as per the OSHA Hazard Communication Standard. It is the responsibility of the glassware washing staff to reject or return glassware that is not acceptable due to breakage or containing chemicals. For this reason, glassware should be labeled with the name of the person who is responsible for it.

15.10.3 General Equipment Set Up

The following recommended laboratory techniques for general equipment set up was taken from the American Chemical Society's booklet – "Safety in Academic Chemistry Laboratories."

<u>Glassware and Plastic-ware</u>

- Borosilicate glassware (i.e. Pyrex) is recommended for all lab glassware, except for special experiments using UV or other light sources. Soft glass should only be used for things such as reagent bottles, measuring equipment, stirring rods and tubing.
- Any glass equipment being evacuated, such as suction flasks, should be specially designed with heavy walls. Dewar flasks and large vacuum vessels should be taped or guarded in case of flying glass from an implosion. Household thermos bottles have thin walls and are not acceptable substitutes for lab Dewar flasks.
- Glass containers containing hazardous chemicals should be transported in rubber bottle carriers or buckets to protect them from breakage and contain any spills or leaks. It is recommended to transport plastic containers this way as well since they also can break or leak.

<u>Preparation of Glass Tubing and Stoppers</u>

To cut glass tubing:

- Hold the tube against a firm support and make one firm quick stroke with a sharp triangular file or glass cutter to score the glass long enough to extend approximately one third around the circumference.
- Cover the tubing with cloth and hold the tubing in both hands away from the body. Place thumbs on the tubing opposite the nick 2 to 3 cm and extend toward each other.
- Push out on the tubing with the thumbs as you pull the sections apart, but do not deliberately bend the glass with the hands. If the tubing does not break, re- score the tube in the same place and try again. Be careful to not contact anyone nearby with your motion or

with long pieces of tubing.

- All glass tubing, including stir rods, should be fire polished before use. Unpolished tubing can cut skin as well as inhibit insertion into stoppers. After polishing or bending glass, give the tube ample time to cool before grasping it.

When drilling a stopper:

- Use only a sharp borer one size smaller than that which will just slip over the tube to be inserted. For rubber stoppers, lubricate with water or glycerol. Holes should be bored by slicing through the stopper, twisting with moderate forward pressure, grasping the stopper only with the fingers, and keeping the hand away from the back of the stopper.
- Keep the index finger of the drilling hand against the barrel of the borer and close to the stopper to stop the borer when it breaks through. Preferably, drill only part way through and then finish by drilling from the opposite side.
- Discard a stopper if a hole is irregular or does not fit the inserted tube snugly, if it is cracked, or if it leaks.
- Corks should have been previously softened by rolling and kneading. Rubber or cork stoppers should fit into a joint so that one-third to one–half of the stopper is inserted.
- When available, glassware with ground joints is preferable. Glass stoppers and joints should be clean, dry and lightly lubricated.

Insertion of Glass Tubes or Rods into Stoppers

The following practices will help prevent accidents:

- Make sure the diameter of the tube or rod is compatible with the diameter of the hose or stopper.
- If not already fire polished, fire polish the end of the glass to be inserted; let it cool.
- Lubricate the glass. Water may be sufficient, but glycerol is a better lubricant.
- Wear heavy gloves or wrap layers of cloth around the glass and protect the other hand by holding the hose or stopper with a layered cloth pad.
- Hold the glass not more than 5 cm from the end to be inserted.
- Insert the glass with a slight twisting motion, avoiding too much pressure and torque.
- When helpful, use a cork borer as a sleeve for insertion of glass tubes.
- If appropriate, substitute a piece of metal tubing for glass tubing.
- Remove stuck tubes by slitting the hose or stopper with a sharp knife.

Assembling Apparatus

Following these recommendations will help make apparatus assembly easier and equipment safer:

- Keep your work space free of clutter.
- Set up a clean, dry apparatus, firmly clamped and well back from the edge of the lab bench making adequate space between your apparatus and others work. Choose sizes that can properly accommodate the operation to be performed. As a rule, reserve 20% of the area around your work as free space.
- Use only equipment that is free from flaws such as cracks, chips, frayed wire, and obvious defects. Glassware can be examined in polarized light for strains. Even the smallest crack or chip can render glassware unusable. Cracked or chipped glassware should be repaired or discarded.
- A properly placed pan under a reaction vessel or container will act as secondary containment to confine spilled liquids in the event of glass breakage.
- When working with flammable gasses or liquids, do not allow burners or other ignition sources in the vicinity. Use appropriate traps, condensers, or scrubbers to minimize release of material to the environment. If a hot plate is used, ensure the temperatures of all exposed surfaces are less than the auto-ignition temperature of the chemicals likely to be released and that the temperature control device and the stirring / ventilation motor (if present) do not spark.
- Whenever possible, use controlled electrical heaters or steam in place of gas burners.

  Addition and separatory funnels should be properly supported and oriented so that the stopcock will not be loosened by gravity. A retainer ring should be used on the stopcock plug. Glass stopcocks should be freshly lubricated. Teflon stopcocks should not be lubricated.
- Condensers should be properly supported with securely positioned clamps and the attached water hoses secured with wire or clamps.
- Stirrer motors and vessels should be secured to maintain proper alignment. Magnetic stirring is preferable. Only non-sparking motors should be used in chemical laboratories. Air motors may be an option.
- Apparatus attached to a ring stand should be positioned so that the center of gravity of the system is over the base and not to one side. There should be adequate provision for removing burners or baths quickly. Standards bearing heavy loads should be firmly attached to the bench top. Equipment racks should be securely anchored at the top and bottom.
- Apparatus, equipment, or chemical bottles should not be placed on the floor. If necessary, keep these items under tables and out of aisle ways to prevent creating a tripping hazard.
- Never heat a closed container. Provide a vent as part of the

apparatus for chemicals that are to be heated. Prior to heating a liquid, place boiling stones in unstirred vessels (except test tubes). If a burner is used, distribute the heat with a ceramic-centered wire gauze. Use the thermometer with its bulb in the boiling liquid if there is the possibility of a dangerous exothermic decomposition as in some distillations. This will provide a warning and may allow time to remove the heat and apply external cooling. The setup should allow for fast removal of heat

- Whenever hazardous gasses or fumes are likely to be evolved, an appropriate gas trap should be used and the operation confined to a fume hood.
- Fume hoods are recommended for all operations in which toxic or flammable vapors are evolved as is the case with many distillations. Most vapors have a density greater than air and will settle on a benchtop or floor where they may diffuse to a distant burner or ignition source. These vapors will roll out over astonishingly long distances and, if flammable, an ignition can cause a flash back to the source of vapors. Once diluted with significant amounts of air, vapors move in air essentially as air itself.
- Use a hood when working with a system under reduced pressure (which may implode). Close the sash to provide a shield. If a hood is not available, use a standing shield. Shields that can be knocked over must be stabilized with weights or fasteners. Standing shields are preferably secured near the top. Proper eye and face protection must be worn even when using safety shields or fume hoods.

15.11 Mercury Containing Equipment

Elemental Mercury (Hg) or liquid Mercury is commonly seen in thermometers, barometers, diffusion pumps, sphygmomanometers, thermostats, high intensity microscope bulbs, fluorescent bulbs, UV lamps, batteries, Coulter Counter, boilers, ovens, welding machines, etc.

Most of these items can be substituted with equipment without Mercury, thus greatly decreasing the hazard potential. Larger laboratory equipment may be more difficult to identify as “Mercury containing” due to the fact that mercury can be hidden inside inner components such as switches or gauges.

The concerns surrounding mercury containing equipment are:

- It is difficult to identify exposures or cross-contamination due to Mercury leaks or spills.
- The amount of Mercury used is usually much greater than the New Mexico Environmental Department (NMED) reportable quantities for releases to the environment.
- People may be unaware of the Mercury and thus may not be properly trained

for use, maintenance, spills, transport or disposal or may not use the appropriate engineering controls or Personal Protective Equipment (PPE).
- There is legal liability if human health and the environment are not properly protected to minimize the potential for Mercury spills and possible exposures, laboratory personnel are strongly encouraged to follow these recommendations.
- Identify and label "Mercury Containing Equipment".
- Write a Standard Operating Procedure (SOP).
- Train personnel on proper use, maintenance, transport and disposal.
- Conduct periodic inspections of equipment to ensure no leaks or spills have occurred.
- Consider replacing Mercury with electronic or other replacement components.
- Have available proper PPE such as nitrile gloves.
- Use secondary containment, such as trays as a precaution for spills.
- Plan for emergencies such as a spill or release of mercury.
- Decontaminate and remove Mercury before long-term storage, transport or disposal.
- For new equipment purchases, please attempt to procure instruments with no or little Mercury

15.12 Ergonomics

Many lab tasks such as looking through microscopes, working in exhaust hoods, pipetting, and continuously looking down for bench tasks require both significant repetitive movements and sustained awkward posturing. Often there is no leg room when sitting at counters or hoods, which causes more leaning and reaching. Although the essential job tasks probably cannot change, you can develop important personal strategies that can improve comfort and health. There may also be equipment changes you can make.

The section below outlines some steps you can take to reduce your risk for injury from this demanding work. Links to product ideas and additional related information are provided. Product links do not imply endorsement.

Seating
- Take the time to adjust the seat depth and chair back height and tilt in order to maximize individual back support. Consider a slightly reclined position to promote better support.
- Try using chairs "backward", supporting the torso when leaning forward to do bench/hood/microscope work, as a means for changing positions throughout the day.
- Make sure the feet reach the floor, foot ring or separate footrest comfortably. The stabilization of both feet makes it easier to sit back in a supported manner. Some lab chairs have adjustable foot rings—consider this feature when buying new chairs. For lower surfaces use office-style footrests.
- Seat height—be sure lab chairs have adequate height adjustment. Extended

cylinder heights (32 inch) may provide additional adjustment that will help employees comfortably reach/perform work at counter height.
- Pull your torso close to the work surface and then sit back. This technique will help avoid ‘perching’ on the edge of the chair.
- Select benches where there is leg room under the surface.

Extended Standing

Standing all day for bench work, particularly on concrete/tile flooring, is difficult. The body requires time to recover from these demands, even within a given shift.

Recommendations to minimize risks from extended standing include:
- Micro breaks--allow time (as little as 30 seconds - 1 minute every 20 minutes) and a chair/stool so spinal structures and joints can recover from extended standing.
- Consider anti-fatigue matting in areas where it is practical.
- Proper footwear is important and using a foam/gel insole can also reduce fatigue. Remember, they need to be replaced before they appear worn out.
- Provide a footrest so you can elevate one foot, then the other. This will reduce static fatigue. If safe/appropriate, try opening cabinets to create a footrest.

Microscope Station
- Be cognizant of neutral postures while working. Adjust the chair or microscope as needed to maintain an upright head position. Elevate, tilt or move the microscope closer to the edge of the counter to avoid bending your neck.
- Avoid leaning on the hard edges on the table - consider padding the front lip of the microscope table (AliEdge or similar) or using forearm pads. A simple, versatile solution is a variety of foam pads, like Wedge-Ease. Be sure these supports do not cause awkward wrist postures when focusing/adjusting the stage.
- Keep scopes repaired and clean.
- Spread microscope work throughout the day and between several people, if possible.
- Observe seating adjustment and support techniques.

Additional resources can be found at Nikon MicroscopyU.

15.13 Pipetting

Below are some general guidelines to reduce the physical impact of pipetting.
- Sit or stand close to your work at the bench. If safe/appropriate, try opening cabinets to create legroom.
- Work at appropriate heights to minimize twisting of the neck and torso. Elevate your chair rather than reaching up to pipette.
- Alternate or use both hands to pipette.
- Select a lightweight pipette sized for your hand. Hold the pipette with a

relaxed grip and use minimal pressure while pipetting.
- Avoid standing or sitting for long periods. Alternating between sitting and standing provides relief and recovery time for fatigued body structures.

<u>Hood Work</u>
- Observe seating recommendations to promote supported postures.
- Position work supplies as close as possible in order to avoid awkward leaning/reaching while working. Consider turntables to rotate materials closer to the user. Be sure that only essential materials are in the hood to avoid unnecessary reaching around clutter
- Consider lower-profile sample holders, solution containers, waste receptacles to prevent awkward bending of wrist, neck and shoulders. Reduced repetitive movement also means increased efficiency.

<u>Other Tips</u>
- Gloves— Wear slightly snug gloves to reduce forces on hands and improve accuracy during fine manipulation. Wearing loose gloves during pipetting and other tasks makes manipulating small materials more forceful and difficult.
- Rotate tasks throughout the work day and among several people, whenever possible. Take frequent small rest breaks (1-2 minutes in duration) every 20 minutes. Every 45-60 minutes, get up to stretch and move.
- Take vision breaks during intensive computer and fine visual work. Every 20 minutes, close eyes or focus on something in the distance.

Appendix A: Chemical Hygiene Plan

CHEMICAL HYGIENE PLAN

The Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1910.1450, "Occupational Exposure to Hazardous Chemicals in Laboratories" mandates the development of a Chemical Hygiene Plan which is capable of protecting employees from health hazards associated with hazardous chemicals in the laboratory and capable of keeping exposures below OSHA Permissible Exposure Limits (PELs).

The New Mexico Tech Chemical Hygiene Plan is developed and coordinated by New Mexico Tech's Office of Research Compliance. This Chemical Hygiene Plan is designed to supplement department and laboratory specific safety manuals and procedures that already address chemical safety in laboratories.

As per the OSHA Laboratory Standard, the following are elements of the Chemical Hygiene Plan:

1) Standard Operating Procedures

There are a multitude of research and teaching laboratories at New Mexico Tech and most of these use hazardous chemicals. Many departments have developed comprehensive safety and health manuals. These manuals address specific safety rules, regulations and standard operating procedures for laboratory workers in the department or college.

Research Compliance will assist laboratories in developing general and specific standard operating procedures for chemical use in laboratories. Due to the large variety of research and the number of laboratories involved, it will be the responsibility of each laboratory, department or college to ensure that their practices and procedures are robust enough to protect workers who interact with hazardous chemicals.

It will be up to the Principal Investigator or department head to ensure that written safety procedures are developed for work in their labs and that controls and protective equipment are capable of preventing overexposure. In many cases, standard operating procedures for laboratory safety have already been developed and implemented for years; as such, few changes will be necessary to comply with the OSHA Lab Standard. Existing standard operating procedures may need to be reevaluated to ensure that they address the health and safety requirements for the chemicals in use.

2) Control Measures

The exposure to hazardous chemicals in the laboratory shall be controlled through the use of engineering controls, personal protective equipment, good general laboratory practices, and standard operating procedures specific to an individual laboratory or department.

- Engineering controls: There are a variety of engineering controls that can be used in the laboratory to control exposures to hazardous chemicals. Some of the engineering controls that will be used in laboratories at New Mexico Tech may include dilution ventilation, local exhaust ventilation (fume hoods), and proper storage facilities.
- Personal protective equipment: Personal protective equipment (PPE) will be available to laboratory workers for use to reduce exposures to hazardous chemicals in the laboratory. Common PPE such as goggles, gloves, face shields, and aprons are recommended for use with hazardous chemicals. Other PPE such as respirators will be available and recommended for use if necessary. Research Compliance can assist in the proper selection, use, and care of PPE. PPE will be readily available and most equipment is provided at no cost to the employee.
- General laboratory practices: Research Compliance provides laboratories with information about general laboratory work practices and rules that are recognized as effective control measures to minimize exposure to hazardous chemicals in the laboratory. The information is referenced from Prudent Practices in the Laboratory, Safety in Academic Chemistry Laboratories, and other references. These general procedures include guidelines on use of chemicals, accidents and spills, personal protection, use of fume hoods and other good laboratory practice information.
- Specific laboratory practices: Individual departments or laboratories must develop additional written safety procedures whenever necessary to protect laboratory workers from specific chemical hazards that are unique to their particular area of research. Particular attention should be given to control measures for operations that involve the use of particularly hazardous substances such as select carcinogens, reproductive toxins, or acutely toxic chemicals. Research Compliance can assist researchers in developing safety procedures for specific hazards.
- Other: Other control methods that will be used to determine and reduce employee exposures to hazardous chemicals in the laboratory may include exposure monitoring, testing eyewash and emergency shower facilities, developing emergency procedures, proper container selection, and substitution of less toxic chemicals whenever possible.

3) Fume Hoods and Other Protective Equipment

Fume hoods, emergency eyewash stations, and safety showers are inspected annually by Research Compliance and Facilities. Research Compliance will coordinate the inspection and repairs with the Facilities and Campus Services shops to ensure a timely and accurate repair process.

The proper functioning and maintenance of other protective equipment used in the lab is the responsibility of a variety of service groups. Facilities Management, Research Compliance, and other groups provide and service equipment such as fire extinguishers, eyewash/shower facilities, spill response equipment and mechanical ventilation. Periodic inspections and maintenance by these groups ensure proper functioning and adequate performance of the equipment.

4) Information and Training

Federal, state, and local laws along with New Mexico Tech policy require all laboratory workers to receive Laboratory Safety and Chemical Waste Disposal training and be informed of the potential health and safety risks that may be present in their workplace. Documentation must be maintained to demonstrate that such training was provided and received. In order to assist laboratory personnel comply with this requirement, laboratory safety training must be obtained either through Research Compliance (classroom or web- based sessions) or documented as having been received from an alternative source. Laboratory personnel who attend Research Compliance training classes will have documentation entered and maintained for them in a training database. Laboratory personnel who have not attended the New Mexico Tech Laboratory Safety Training program must submit documentation of training received from alternative sources for verification by Research Compliance.

It is the responsibility of Principal Investigators and laboratory supervisors to ensure personnel working in laboratories under their supervision have been provided with proper training, have received information about the hazards in the laboratory they may encounter, and have been informed about ways the employees can protect themselves.

New Mexico Tech will provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work area. Research Compliance regularly provides a variety of training programs for laboratory workers such as Laboratory Safety, EPA – Chemical Waste Disposal, Radiation Safety, Biological Safety, Spill Response, and other training programs, including providing laboratory workers with information on how to obtain additional safety information.

Individual laboratories maintain notebooks or electronic access to Safety Data Sheets (SDSs) for chemicals used in the lab. Employees are encouraged to consult the SDSs before working with new chemicals, or to call or write to Research Compliance for additional information. Research Compliance also maintains a webpage with links to a variety of internal and external websites for SDS and other chemical safety related information.

Research Compliance will provide information to laboratories, including the Chemical Hygiene Plan, the Laboratory Safety Manual, SDSs, OSHA Permissible Exposure Limits, and specific topical information from employee requests. Research Compliance personnel are available on a daily basis to answer questions and provide information to employees about chemical safety in laboratories.

Other sources of information and training may come from informal group or individual discussions with a supervisor, posted notices, fliers, web documents, and other written materials. Properly labeled containers, such as those using Right-To-Know labels, will give immediate warning information to workers about specific chemical hazards. Many departments have safety committees and safety manuals that provide information on laboratory safety. Employees are encouraged to contact Research Compliance for more information about safety in laboratories.

5) Prior Approval for High Hazard Work

Research Compliance can assist in identifying circumstances when there should be prior approval before implementation of a particular laboratory operation. Due to the large variety of research being conducted in laboratories at the University, it is impossible to apply one prior approval process that can apply to all laboratories. Instead, high hazard types of activities should be identified by the Principal Investigator or person responsible for the work, and any type of approval process should be addressed in the laboratory's or department's standard operating procedures.

New Mexico Tech will assist in providing information to researchers about work with select carcinogens, reproductive toxins, and acute toxins. General guidelines and recommendations for the safe handling, use and control of high hazard materials can be provided through SDSs, and reference sources such as "Prudent Practices in the Laboratory", "Safety in Academic Chemistry Laboratories", and other resources.

6) Personnel Responsible for the Chemical Hygiene Plan

Research Compliance will provide technical information and program support to assist laboratories comply with the OSHA Laboratory Standard. Research Compliance will maintain the campus Chemical Hygiene Plan (CHP) and the institutional Chemical Hygiene Officer responsibilities will reside within Research Compliance. However, it will be the responsibility of the Principal Investigator or individual supervisor, department or college to be in compliance with the components of the CHP.

Each college, center, department, or laboratory may adopt or modify this CHP or write their own chemical hygiene plan as long as the requirements of the OSHA Laboratory Standard are met. It is assumed if a college, center, department, or laboratory has not developed their own chemical hygiene plan, then that unit or laboratory has adopted the New Mexico Tech University Chemical Hygiene Plan.

7) Provisions for Additional Employee Protection for Work with High Hazard Chemicals and/or Particularly Hazardous Substances

The Chemical Hygiene Plan includes provisions for additional employee protection for work with particularly hazardous substances. Research involving the use of particularly hazardous substances, such as select carcinogens, reproductive toxins, or acute toxins may require prior review to ensure adequate controls are in place which will protect the worker. Research Compliance will assist with the review and make recommendations for additional employee protection.

Additional employee protection may require the use of additional provisions such as:

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

The provision for additional controls may require the expertise and recommendations of various groups including Research Compliance, Facilities Engineering, technical committees, and outside consulting companies. These groups have all been previously involved with review and implementation of controls for high hazard research. All additional provisions for work with particularly hazardous substances must be incorporated into the lab's standard operation procedures for those materials.

- It is the responsibility of Principal Investigators and laboratory supervisors to ensure that personnel working in laboratories under their control are familiar with the contents and location of the Chemical Hygiene Plan, including any lab specific standard operating procedures and any department or college level laboratory safety manuals, policies, and procedures. (Section 1.1 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator and individual supervisors (and individuals working under their supervision) to be in compliance with the components of the University's Chemical Hygiene Plan, the University Employee Handbook, and any other department or University specific policies. (Section 1.4 of the NMT Laboratory Safety Manual)
- It is the responsibility of laboratory personnel to immediately report malfunctioning protective equipment, such as fume hoods, or mechanical problems to their Building Coordinator as soon as any malfunctions are discovered. (Section 1.5 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator or laboratory supervisor to ensure biological safety cabinets within laboratories under their supervision are certified annually. (Section 2.2.1 of the NMT Laboratory Safety Manual)
- Principal Investigators, laboratory supervisors, departments and colleges are free to set policies that establish minimum PPE requirements for personnel working in and entering their laboratories. Be sure to check with your Department Chair to see if there are any department or college specific requirements for PPE. (Section 3.1 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator or laboratory supervisor to ensure laboratory staff have received the appropriate training on the selection and use of proper PPE, that proper PPE is available and in good condition, and laboratory personnel use proper PPE when working in laboratories under their supervision. (Section 3.2 of the NMT Laboratory Safety Manual)
- Research Compliance strongly encourages Principal Investigators and laboratory supervisors to make use of eye protection a mandatory requirement for all laboratory personnel, including visitors, working in or entering laboratories under their control. (Section 3.3 of the NMT Laboratory Safety Manual)
- Research Compliance strongly recommends that Principal Investigators and laboratory supervisors discourage the wearing of shorts and skirts in laboratories using hazardous materials (chemical, biological, and radiological) by laboratory personnel, including visitors, working in or entering laboratories under their supervision. (Section 3.5 of the NMT Laboratory Safety Manual)
- Research Compliance strongly encourages Principal Investigators and laboratory supervisors to require the use of closed toed shoes for all laboratory personnel, including visitors, working in or entering laboratories and laboratory support areas

under their supervision. (Section 3.8 of the NMT Laboratory Safety Manual)

- It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that personnel working in laboratories under their supervision are informed and follow laboratory specific, departmental, and campus wide policies and procedures related to laboratory safety – such as the guidelines and requirements covered in this Laboratory Safety Manual. (Section 4.1 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator and laboratory supervisor to ensure written SOPs incorporating health and safety considerations are developed for work involving the use of hazardous chemicals in laboratories under their supervision and that PPE and engineering controls are adequate enough to prevent overexposure. In addition, Principal Investigators and laboratory supervisors must ensure that personnel working in laboratories under their supervision have been trained on those SOPs. (Section 4.1 of the NMT Laboratory Safety Manual)
- It is the responsibility of Principal Investigators and laboratory supervisors to ensure laboratories under their supervision are maintained in a clean and orderly manner and personnel working in the lab practice good housekeeping. (Section 4.4 of the NMT Laboratory Safety Manual)
- It is the responsibility of Principal Investigators and laboratory supervisors to ensure procedures for working alone are developed and followed by personnel working in laboratories under their supervision. (Section 4.7 of the NMT Laboratory Safety Manual)
- It is the responsibility of Principal Investigators and laboratory supervisors to ensure procedures for unattended operations are developed and followed by personnel working in laboratories under their supervision. (Section 4.9 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Department Chairperson, Principal Investigators, and laboratory supervisors to restrict access of visitors and children to areas under their supervision when potential health and physical hazards exist. (Section 4.10.1 and 4.10.3 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator and individual supervisors to ensure research areas under their supervision utilize Hazard Assessment Signage (HAS) on the laboratory door exterior to communicate the hazards within the lab, as well as to identify emergency contacts for the lab space. (Section 4.18 of the NMT Laboratory Safety Manual)
- It is the responsibility of laboratory personnel to activate (flush) emergency showers and eyewash units on a regular basis. (Section 5.15.1 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator and laboratory supervisor to ensure all injuries are reported to University officials through the use of the New Mexico Tech University Laboratory Incident/Near Miss Report within 24 hours of the event. (Section 5.16 of the NMT Laboratory Safety Manual)
- It is the responsibility of Principal Investigators and laboratory supervisors to ensure personnel working in laboratories under their supervision have been provided with the proper training, have received information about the hazards in the laboratory they may encounter, and have been informed about ways they can protect themselves. (Section 6 and 6.1 of the NMT Laboratory Safety Manual)

- It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that staff and students under their supervision are provided with adequate training and information specific to the hazards found within their laboratories. (Section 7.3 of the NMT Laboratory Safety Manual)
- It is the responsibility of Principal Investigators and laboratory supervisors to ensure that staff and students working in laboratories under their supervision have obtained required health and safety training and have access to SDSs (and other sources of information) for all hazardous chemicals used in laboratories under their supervision. (Section 7.3.1 of the NMT Laboratory Safety Manual)
- While Research Compliance can provide assistance in identifying circumstances when there should be prior approval before implementation of a particular laboratory operation, the ultimate responsibility of establishing prior approval procedures lies with the Principal Investigator or laboratory supervisor. (Section 10.5 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that personnel working in laboratories under their supervision are familiar with and follow hazardous chemical waste container requirements and have attended New Mexico Tech's Chemical Waste Disposal training. (Section 11.1 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator or laboratory supervisor to ensure any employee working under their supervision who ships or prepares shipments of hazardous materials has received the proper training and certification. (Section 12 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator or laboratory supervisor with class 3b or 4 LASERs in laboratories under their supervision to ensure that the class 3b or 4 LASERs have been registered with New Mexico Tech and employees using these LASERs have received the appropriate training. (Section 14 of the NMT Laboratory Safety Manual)
- It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that staff and students in laboratories under their supervision are provided with adequate training and information specific to the physical hazards found within their laboratories. (Section 16 of the NMT Laboratory Safety Manual)

8) Medical Examinations and Consultations

Medical consultations and medical examinations will be made available to laboratory workers who work with hazardous chemicals as required. All work related medical examinations and consultations will be performed by or under the direct supervision of a licensed physician and will be provided at no cost to the employee through the following service providers:

- If you work in Socorro NM:
    - Bhasker Medical Clinic
      200 Neel Ave
      Socorro, NM 87801
      575-835-2940

    - Presbyterian Medical Group
      Hwy 60
      Socorro, NM 87801
      575-838-4690
    - Socorro General Hospital
      Hwy 60
      Socorro, NM 87801
      575-835-1140
- If you work in Albuquerque, NM:
    - Concentra
      5700 Harper NE
      Albuquerque, NM 87109
      505-823-9166
    - Rehabilitation & Occupational Medicine Services
      3811 Commons Ave NE
      Albuquerque, NM 87109
      505-823-8450
    - Presbyterian Occupational Medicine Clinic
      5901 Harper NE
      Albuquerque, NM 87109
      505-823-8450
- If you work in Playas, NM:
    - Hidalgo Medical Services
      530 DeMoss St
      Lordsburg, NM 88045
      575-542-8384
    - Gila Regional Medical Center
      1313 E. 32nd St
      Silver City, NM 88061
      575-538-4000

The opportunity to receive medical attention, including any follow up examinations, will be provided to employees who work with hazardous chemicals under the following circumstances:

- Whenever an employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory.
- Where airborne exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the Permissible Exposure Limit) for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements. Action level means the airborne concentration of a specific chemical, identified by OSHA, and calculated as an 8-hour time weighted average (TWA).
- Whenever an event such as a spill, leak, explosion or other occurrence takes place and results in the likelihood of a hazardous exposure. Upon such an event, the affected employee shall be provided an opportunity for a medical consultation. The consultation shall be for the purpose of determining the need for a medical

examination.

All records of medical consultations, examinations, tests, or written opinions shall be maintained at NMT's Human Resource Office in accordance with 29 CFR 1910.1020 - Access to employee exposure and medical records. Human Resources is located at Leroy Place, Socorro NM 87801, inside Brown Hall Room 118. For more information, contact Research Compliance at 575-517-0646 or research.compliance@nmt.edu.

This Chemical Hygiene Plan is reviewed annually. Last Date Reviewed: 6/25/2024

Appendix B: Compiled List of Lab Safety Responsibilities

1. The ultimate responsibility for health and safety within laboratories lies with each individual who works in the laboratory; however, it is the responsibility of the Principal Investigator, Faculty, and laboratory supervisor to ensure that employees (including visiting scientists, fellows, volunteers, temporary employees, and student employees) have received all appropriate training, and have been provided with all the necessary information to work safely in laboratories under their control (Section 1 Laboratory Safety Responsibilities).
2. It is the responsibility of the Principal Investigator and individual supervisors (and individuals working under their supervision) to be in compliance with the components of the University Chemical Hygiene Plan and any other department or University specific policies (Section 1 Laboratory Safety Responsibilities).
3. The Deans, Directors, and Department Chairpersons are responsible for laboratory safety within their department(s) and must know and understand the New Mexico Tech General Safety and Health Policy from the New Mexico Tech Employee Handbook, and know and understand the guidelines and requirements of this Laboratory Safety Manual (Section 1.3 Deans, Directors, and Department Chairs).
4. Principal Investigators, faculty, and laboratory supervisors are responsible for laboratory safety in their research or teaching laboratories (Section 1.4 Principal Investigators, Faculty, and Laboratory Supervisors/Managers).
5. The proper functioning and maintenance of fume hoods and other protective equipment used in the laboratory is the combined responsibility of Facilities Management and Research Compliance (Section 2 Engineering Controls).
6. It is the responsibility of laboratory personnel to immediately report malfunctioning protective equipment, such as fume hoods, or mechanical problems to their Department Coordinator, and/or their Department Chair as soon as any malfunctions are discovered (Section 2 Engineering Controls).
7. Research Compliance and Facilities Services share the responsibility for the annual testing and inspection of fume hoods on campus (Section 2.1.2 Fume Hood Inspection and Testing Program).
8. Principal Investigators and/or Laboratory Supervisors/Managers are responsible to ensure that BSCs are inspected and certified by a qualified individual or company on an annual basis, at minimum (Section 2.2.1 Biological Safety Cabinets (Biosafety Cabinets,BSC)).
9. It is the responsibility of the Principal Investigator or laboratory supervisor to ensure laboratory staff have received the appropriate training on the selection and use of proper PPE, that proper PPE is available and in good condition, and laboratory personnel use proper PPE when working in laboratories under their supervision (Section 3.2 Training for Personal Protective Equipment).
10. Colleges and departments are responsible for developing policies and written guidelines to ensure laboratory workers are protected against exposure to hazardous chemicals as outlined in the OSHA Laboratory Standard and physical hazards that may be present, including the development of a written Chemical Hygiene Plan or adoption of this Laboratory Safety Manual (Section 4 Administrative Controls).
11. It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that personnel working in laboratories under their supervision are informed of any and all

hazards that may be present in the lab, and that they follow laboratory specific, departmental, and campus wide policies and procedures related to laboratory safety – such as the guidelines and requirements covered in this Laboratory Safety Manual (Section 4 Administrative Controls).

12. It is the responsibility of each laboratory, department, and division to ensure that SOPs are developed and the practices and procedures are adequate to protect lab workers who use hazardous chemicals (Section 4.1 Standard Operating Procedures (SOPs)).
13. It is the responsibility of the Principal Investigator and laboratory supervisor to ensure written SOPs incorporating health and safety considerations are developed for work involving the use of hazardous chemicals in laboratories under their supervision and that PPE and engineering controls are adequate to prevent overexposure (Section 4.1 Standard Operating Procedures (SOPs)).
14. It is the responsibility of Principal Investigators and laboratory supervisors to ensure laboratories under their supervision are maintained in a clean and orderly manner and personnel working in the lab practice good housekeeping (Section 4.4 Housekeeping).
15. It is the responsibility of Principal Investigators and laboratory supervisors to ensure procedures for working alone are developed and followed by personnel working in laboratories under their supervision (Section 4.7 Working Alone).
16. It is the responsibility of Principal Investigators and laboratory supervisors to ensure procedures for unattended operations are developed and followed by personnel working in laboratories under their supervision (Section 4.9 Unattended Operations).
17. It is the responsibility of the Department Chairperson, Principal Investigators, and laboratory supervisors to restrict access of visitors, children and volunteers to areas under their supervision when potential health and physical hazards exist (Section 4.10 Access to Laboratories).
18. Laboratories are responsible for activating eyewashes in their spaces and ensuring that access to eyewashes and emergency showers are kept free of clutter and ensuring the eyewash nozzle dust covers are kept in place (Section 5.15.1 Testing and Inspection of Emergency Eyewash and Showers).
19. It is the responsibility of Principal Investigators and laboratory supervisors to ensure personnel working in laboratories under their supervision have been provided with the proper training, have received information about the hazards in the laboratory they may encounter, and have been informed about ways they can protect themselves (Section 6 Hazard Communication (Hazcom) Requirements).
20. It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that staff and students under their supervision are provided with adequate training and information specific to any hazards (chemical, physical, radioactive, cryogenic, etc.) found within their laboratories (Section 7.3 Chemical Hazard Information).
21. It is the responsibility of Principal Investigators and laboratory supervisors to ensure that staff and students working in laboratories under their supervision have obtained required health and safety training and have access to SDSs (and other sources of information) for all hazardous chemicals used in laboratories under their supervision (Section 7.3.1 Safety Data Sheets (SDSs)).
22. Principal Investigators will be responsible for ensuring that newly synthesized chemicals are used exclusively within their laboratories and are properly labeled (Section 7.3.2 SDSs and Newly Synthesized Chemicals).

23. Principal investigators and/or lab managers are responsible for ensuring all laboratory personnel understand and adhere to safety requirements in the laboratory (Section 9.2.2 Nitric Acid).
24. While Research Compliance can provide assistance in identifying circumstances when there should be prior approval before implementation of a particular laboratory operation, the ultimate responsibility of establishing prior approval procedures lies with the Principal Investigator or laboratory supervisor (Section 10.5 Prior Approval).
25. It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that personnel working in laboratories under their supervision are familiar with and follow hazardous chemical waste container requirements and have attended New Mexico Tech Chemical Waste Disposal training (Section 11.1 Hazardous Chemical Waste Container Requirements).
26. It is the responsibility of the Principal Investigator or laboratory supervisor to ensure any employee working under their supervision who ships or prepares shipments of hazardous materials has received the proper training (Section 12.2 Hazardous Materials Transportation Requirements).
27. Responsibility for protecting themselves, co-workers and others from exposure to ionizing radiation is delegated by the Radiation Safety Committee to the Principal Investigator or area supervisor and to each of the individual users (Section 13.3 How to Protect Yourself).
28. It is the responsibility of the Principal Investigator or laboratory supervisor with class 3b or 4 LASERs in laboratories under their supervision to ensure the class 3b or 4 LASERs have been registered with New Mexico Tech and employees using these LASERs have received the appropriate training (Section 14 Laser Hazards).
29. It is the responsibility of the Principal Investigator and laboratory supervisor to ensure that staff and students in laboratories under their supervision are provided with adequate training and information specific to the physical hazards found within their laboratories (Section 15 Physical Hazards).
30. Personnel who are responsible for any cryogenic equipment must conduct a safety review prior to the commencement of operation of the equipment (Section 15.9.1 Cryogenic Safety Guidelines).
31. It is the responsibility of the lab to empty and rinse all glassware before it leaves the lab. Although the contents may not be hazardous, the washroom support staff cannot be certain of the appropriate PPE to wear, disposal regulations or possible incompatibilities with items received from other researchers (Section 15.10.2 Glassware Washing).
32. It is the responsibility of the glassware washing staff to reject or return glassware that is not acceptable due to breakage or containing chemicals (Section 15.10.2 Glassware Washing).
33. Due to the large variety of research and the number of laboratories involved, it will be the responsibility of each laboratory, department or college to ensure that their practices and procedures are robust enough to protect workers who interact with hazardous chemicals (Appendix A: Chemical Hygiene Plan, Standard Operating Procedures).
34. It is the responsibility of Principal Investigators and laboratory supervisors to ensure personnel working in laboratories under their supervision have been provided with proper training, have received information about the hazards in the laboratory they may encounter, and have been informed about ways the employees can protect themselves

(Appendix A: Chemical Hygiene Plan, Information and Training).

35. It will be the responsibility of the Principal Investigator or individual supervisor, department or college to be in compliance with the components of the Chemical Hygiene Plan. (Appendix A: Chemical Hygiene Plan, Personnel Responsible for the Chemical Hygiene Plan)

Appendix C: Standard Operating Procedures (SOPs) Template and SOP Examples

Below is the NMT Standard Operating Procedure (SOP) Template (also available here). Examples of SOPs are available following the Template.

NEW MEXICO TECH
SCIENCE • ENGINEERING • RESEARCH UNIVERSITY

Laboratory-Specific Standard Operating Procedures

TITLE: SOP for the safe use of ___________

Date:

Review Date:

Revised:

Principle Investigator:

Authors (Names):

Department, Building, Room(s):

Contact Phone Number:

This SOP must be kept on file for all laboratory employee training and review.

Section 1: (Check One)

There are three methods that can be used to write SOPs. They are: by process (distillation, synthesis, chromatography, etc.); by individual hazardous chemical (benzene, phenol, arsenic, etc.); and by hazardous chemical class (flammable, corrosive, oxidizer, etc.).

_____ Process _______ Chemical _____ Hazard Chemical Class

Section 2: Describe Process, Hazardous Chemical or Hazard Class

Provide a general description of what activities are covered under this SOP.

Section 3: Potential Hazards

Describe the potential hazards for each process, hazardous chemical or hazard class. Include physical and health hazards.

Section 4: Personal Protective Equipment

Identify the required PPE. If a respirator is required, contact the Hazardous Materials and Laboratory Safety Specialist before using.

Section 5: Engineering Controls

Describe engineering controls that will be used to prevent or reduce employee exposure to hazardous chemicals.

Section 6: Special Handling and Storage Requirements

List storage requirements for hazardous chemicals involved with the SOP, including specific area, and policies regarding access to chemicals. Special procedures such as dating peroxide formers are appropriate here. Is a special "designated area" required?

Section 7: Spill and Accident Procedures

Indicate how spills or accidental release will be handled. List the location of appropriate emergency equipment. Any special requirements for protection of personnel from exposure should be identified here.

- For Accidents:
- For Spills:

List where the chemical spill kit is located. For all spills, large or small, refer to Laboratory Safety Manual Section 5.12 Chemical Spill. For large spills and accidents, place absorbent material on the spill, evacuate, and contact Campus Police (575-835-5555) or the Hazardous Materials and Laboratory Safety Specialist (575-517-0646).

Section 8: Decontamination Procedures

Specify decontamination procedures to be used for equipment, glassware, and clothing: including equipment such as hoods, lab benches, and controlled (special "designated area") areas within the lab.

Section 9: Waste disposal Procedures

Waste must be disposed in accordance with New Mexico Tech's Hazardous Chemical Waste Disposal Procedures (Section 11 of the NMT Laboratory Safety Manual)

· Waste storage:

· To schedule a chemical waste pick-up, download the Chemical Waste Pick Up Request Form available at https://www.nmt.edu/research/hazmat.php and email the completed form to hazmat@nmt.edu

Section 10: Laboratory Specific Protocol(s)

Attach laboratory protocol for specific handling and operational practices.

Section 11: Documentation of Training

- Prior to conducting any work with nitric acid, designated personnel, i.e. approved users listed below, must provide training to his/her laboratory personnel specific to the hazards involved in working with this substance, work area decontamination, and emergency procedures.
- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.
- The Principal Investigator must ensure that their laboratory personnel have attended appropriate laboratory safety training and are current with any refresher training as required by Research Compliance.

Name	Signature	Trainer	Date

Example SOPs

Nitric Acid SOP

Perchloric Acid SOP

Peroxide Forming Chemicals

Appendix D: Lab Close Out Procedures

Laboratories that are vacated or abandoned without first being cleared of all hazards is a common cause of lab accidents, incidents and near-misses. The responsible party leaving the institution, relocating a laboratory, terminating laboratory research activities, or temporarily relocating during a renovation project must first ensure that all hazards are identified and removed. Prior to transferring a lab to a new department or occupant, the responsible party and their department are responsible for ensuring that the space, including shared space, is cleared of all hazards belonging to the responsible party, and that all biological, chemical, and radiological materials are removed prior to vacating the space. All remaining equipment, including biosafety cabinets and storage cabinets, must be properly decontaminated, including all surfaces, such as counters, drawers, floors, fume hoods, etc. All New Mexico Institute of Mining and Technology (New Mexico Tech , NMT) laboratory rooms, chemical storage areas, and areas where hazardous equipment or materials are used or stored will be inspected and evaluated by staff from the Research Compliance and Safety Office before being vacated.

Below are links to the NMT Laboratory Close-Out Procedure, NMT Laboratory Close-Out Checklist, and NMT Laboratory Close-Out Survey.

- NMT Laboratory Close-Out Procedure
- NMT Laboratory Close-Out Checklist
- NMT Laboratory Close-Out Survey

Appendix E: Glove Selection Guide

The following Glove selection chart is from OSHA's Personal Protective Equipment pamphlet (available at http://www.osha.gov/Publications/osha3151.pdf).

Chemical and Liquid-Resistant Gloves

Chemical-resistant gloves are made with different kinds of rubber: natural, butyl, neoprene, nitrile and fluorocarbon (viton); or various kinds of plastic: polyvinyl chloride (PVC), polyvinyl alcohol and polyethylene. These materials can be blended or laminated for better performance. As a general rule, the thicker the glove material, the greater the chemical resistance but thick gloves may impair grip and dexterity, having a negative impact on safety. Some examples of chemical-resistant gloves include:

- **Butyl gloves** are made of a synthetic rubber and protect against a wide variety of chemicals, such as peroxide, rocket fuels, highly corrosive acids (nitric acid, sulfuric acid, hydrofluoric acid and red-fuming nitric acid), strong bases, alcohols, aldehydes, ketones, esters and nitro compounds. Butyl gloves also resist oxidation, ozone corrosion and abrasion, and remain flexible at low temperatures. Butyl rubber does not perform well with aliphatic and aromatic hydrocarbons and halogenated solvents.
- **Natural (latex) rubber gloves** are comfortable to wear, which makes them a popular general purpose glove. They feature outstanding tensile strength, elasticity and temperature resistance. In addition to resisting abrasions caused by grinding and polishing, these gloves protect workers' hands from most water solutions of acids, alkalis, salts and ketones. Latex gloves have caused allergic reactions in some individuals and may not be appropriate for all employees. Hypoallergenic gloves, glove liners and powderless gloves are possible alternatives for workers who are allergic to latex gloves.
- **Neoprene gloves** are made of synthetic rubber and offer good pliability, finger dexterity, high density and tear resistance. They protect against hydraulic fluids, gasoline, alcohols, organic acids and alkalis. They generally have chemical and wear resistance properties superior to those made of natural rubber.
- **Nitrile gloves** are made of a copolymer and provide protection from chlorinated solvents such as trichloroethylene and perchloroethylene. Although intended for jobs requiring dexterity and sensitivity, nitrile gloves stand up to heavy use even after prolonged exposure to substances that cause other gloves to deteriorate. They offer protection when working with oils, greases, acids, caustics and alcohols but are generally not recommended for use with strong oxidizing agents, aromatic solvents, ketones and acetates.

The following table from the U.S. Department of Energy (Occupational Safety and Health Technical Reference Manual) rates various gloves as being protective against specific chemicals and will help you select the most appropriate gloves to protect your employees.

The ratings are abbreviated as follows: **VG**: Very Good; **G**: Good; **F**: Fair; **P**: Poor (not recommended). Chemicals marked with an asterisk (*) are for limited service.

Chemical	**Neoprene**	**Natural Latex or Rubber**	**Butyl**	**Nitrile**
Acetaldehyde*	VG	G	VG	G
Acetic Acid	VG	VG	VG	VG
Acetone*	G	VG	VG	P
Ammonium hydroxide	VG	VG	VG	VG
Amyl Acetate*	F	P	F	P
Aniline	G	F	F	P
Benzaldehyde*	F	F	G	G
Benzene*	P	P	P	F
Butyl acetate	G	F	F	P
Butyl alcohol	VG	VG	VG	VG
Carbon disulfide	F	F	F	F
Carbon tetrachloride*	F	P	P	G
Castor oil	F	P	F	VG
Chlorobenzene*	F	P	F	P
Chloroform*	G	P	P	F
Chloronaphthalene	F	P	F	F
Chromic acid (50%)	F	P	F	F
Citric acid (10%)	VG	VG	VG	VG
Cyclohexanol	G	F	G	VG
Dibutyl phthalate*	G	P	G	G
Diesel fuel	G	P	P	VG
Diisobutyl ketone	P	F	G	P
Dimethylformamide	F	F	G	G
Dioctyl phthalate	G	P	F	VG
Dioxane	VG	G	G	G
Epoxy resins, dry	VG	VG	VG	VG
Ethyl acetate*	G	F	G	F
Ethyl alcohol	VG	VG	VG	VG
Ethyl ether*	VG	G	VG	G
Ethylene dichloride*	F	P	F	P
Ethylene glycol	VG	VG	VG	VG
Formaldehyde	VG	VG	VG	VG
Formic acid	VG	VG	VG	VG
Freon 11	G	P	F	G
Freon 12	G	P	F	G
Freon 21	G	P	F	G

Freon 22	G	P	F	G
Furfural*	G	G	G	G
Gasoline, leaded	G	P	F	VG
Gasoline, unleaded	G	P	F	VG
Glycerin	VG	VG	VG	VG
Hexane	F	P	P	G
Hydrazine (65%)	F	G	G	G
Hydrochloric acid	VG	G	G	G
Hydrofluoric acid (48%)	VG	G	G	G
Hydrogen peroxide (30%)	G	G	G	G
Hydroquinone	G	G	G	F
Isooctane	F	P	P	VG
Kerosene	VG	F	F	VG
Ketones	G	VG	VG	P
Lacquer thinners	G	F	F	P
Lactic acid (85%)	VG	VG	VG	VG
Lauric acid (36%)	VG	F	VG	VG
Lineolic acid	VG	P	F	G
Linseed oil	VG	P	F	VG
Maleic acid	VG	VG	VG	VG
Methyl alcohol	VG	VG	VG	VG
Methylamine	F	F	G	G
Methyl bromide	G	F	G	F
Methyl chloride*	P	P	P	P
Methyl ethyl ketone*	G	G	VG	P
Methyl isobutyl ketone*	F	F	VG	P
Methyl methacrylate	G	G	VG	F
Monoethanolamine	VG	G	VG	VG
Morpholine	VG	VG	VG	G
Naphthalene	G	F	F	G
Napthas, aliphatic	VG	F	F	VG
Napthas, aromatic	G	P	P	G
Nitric acid*	G	F	F	F
Nitric acid, red and white fuming	P	P	P	P
Nitromethane (95.5%)*	F	P	F	F
Nitropropane (95.5%)	F	P	F	F

Octyl alcohol	VG	VG	VG	VG
Oleic acid	VG	F	G	VG
Oxalic acid	VG	VG	VG	VG
Palmitic acid	VG	VG	VG	VG
Perchloric acid (60%)	VG	F	G	G
Perchloroethylene	F	P	P	G
Petroleum distillates (naphtha)	G	P	P	VG
Phenol	VG	F	G	F
Phosphoric acid	VG	G	VG	VG
Potassium hydroxide	VG	VG	VG	VG
Propyl acetate	G	F	G	F
Propyl alcohol	VG	VG	VG	VG
Propyl alcohol (iso)	VG	VG	VG	VG
Sodium hydroxide	VG	VG	VG	VG
Styrene	P	P	P	F
Styrene (100%)	P	P	P	F
Sulfuric acid	G	G	G	G
Tannic acid (65)	VG	VG	VG	VG
Tetrahydrofuran	P	F	F	F
Toluene*	F	P	P	F
Toluene diisocyanate (TDI)	F	G	G	F
Trichloroethylene*	F	F	P	G
Triethanolamine (85%)	VG	G	G	VG
Tung oil	VG	P	F	VG
Turpentine	G	F	F	VG
Xylene*	P	P	P	F

Note: When selecting chemical-resistant gloves be sure to consult the manufacturer's recommendations, especially if the gloved hand(s) will be immersed in the chemical.

Appendix F: Particularly Hazardous Substances (PHS)

The following list is a non-comprehensive list of particularly hazardous substances.

CHEMICAL	CAS #	DESCRIPTION	REASON FOR LISTING AS PHS
Acetonitrile	75-05-8	Colorless, limpid liquid; aromatic odor	Toxic action by skin absorption and inhalation. Questionable carcinogen
Acrylamide	79-06-1	Colorless, odorless crystal	Toxic by skin absorption. Present in particulate and vapor phases. Irritant to skin and mucous membranes. Central nervous system impairment. Probable carcinogen.
Arsenic	7440-38-2	Silver-gray, brittle, crystalline solid that darkens in moist air.	Confirmed carcinogen and mutagen.
5-Bromo-2′-deoxyuridine*	59-14-3	White powder	May cause genetic defects. Suspected of damaging fertility or the unborn child.
Chloroform	67-66-3	Colorless, highly refractive, heavy, volatile liquid	Possible carcinogen. Toxic by inhalation. Anesthetic
Cyanide	74-90-8	Colorless gas, highly water-soluble, slight odor of bitter almonds	Cellular asphyxiation, respiration inhibition, highly toxic
Cyclophosphamide	50-18-0	Crystalline solid	Confirmed Carcinogen.
Diaminobenzidine	91-95-2	Solid	Carcinogen
Dimethylformamide	68-12-2	Water-white liquid	Moderate fire risk. Toxic by skin absorption. String irritant to skin and tissue. Liver Damage. Questionable carcinogen
Ethidium Bromide*	1239-45-8	Dark-red liquid	Acutely toxic if inhaled; Germ cell mutagenicity; suspected of causing genetic defects.
Formaldehyde	50-00-0	(Gas) Strong pungent odor,	Moderate fire risk, Toxic by inhalation, strong irritant, carcinogen
N-Nitrosodiethylamine	55-18-5	Slightly yellow oil	Possible carcinogen, mutagen, neoplastigen, tumorigen, poison, teratogen
Nitric Acid	7697-37-2	Transparent, colorless, or yellowish fuming	Dangerous fire risk in contact with organic materials. Highly toxic by inhalation, corrosive to skin and mucous membranes, strong oxidizing agent. Eye and upper respiratory tract irritant and dental erosion
Osmium Tetroxide	20816-12-0	A colorless dimorphic compound with both crystalline and amorphous, pungent, disagreeable odor	Toxic by inhalation, strong irritant to eyes and mucous membranes, upper respiratory tract and skin irritant

Perchloric Acid	7601-903	Colorless, fuming, hygroscopic liquid, unstable in concentrated form	Strong oxidizing agent, will ignite vigorously in contact with organic material, or detonate by shock or heat. Toxic by ingestion and inhalation, strong irritant
Phenol	108-95-2	White, crystalline mass that turns pick or red if not perfectly pure or if under influence of light. Absorbs water from air and liquefies. Distinctive odor. Sharp burning taste. When in a very weak solution it has a sweetish taste.	Toxic by ingestion, inhalation and skin absorption. Strong irritant to tissue and upper respiratory tract. Toxic by skin absorption. Lung damage and central nervous system impairment. Questionable carcinogen.
Phenylmethylsulfonyl Fluoride*	329-98-6	White Crystalline solid	Acutely toxic if swallowed. Causes severe skin burns and eye damage. Strong hydrogen fluoride releaser.
Picric Acid	88-89-1	Yellow crystals, very bitter taste	Severe explosion risk when shocked or heated, especially reactive with metals or metallic salts. Toxic by skin absorption. Skin sensitization, dermatitis and eye irritant
Sodium Azide	26628-22- 8	Colorless, hexagonal crystals, decomposes at about 300C, hydrolyzes to form hydrazoic acid, combustible	Highly toxic. Lung damage and cardiac impairment. Questionable carcinogen
Streptozotocin*	18883-66-4	White, light yellow, powder.	Flammable solid. Suspected of causing genetic defects. Suspected of causing cancer.
Strychnine	57-24-9	Hard white crystals or powder, bitter taste.	Toxic by ingestion and inhalation. Central nervous system impairment
Tamoxifen*	10540-29-1	Solid; Off-white powder.	May cause cancer. May damage fertility or the unborn child. Very toxic to aquatic life with long lasting effects.

Chemical information was obtained from Hawley's Condensed Chemical Dictionary, Sixteenth Edition, except for items with the * symbol after the chemical name, which information was obtained from the chemical's Safety Data Sheets.

Appendix G: How To Understand Safety Data Sheets SDSs

Chemical manufacturers are required by law to supply "Safety Data Sheets" (OSHA Form 174 or its equivalent) upon request by their customers. These sheets have nine sections giving a variety of information about the chemical.

*Following is a section-by-section reproduction and explanation of an SDS originally prepared and distributed by Cornell University's Environmental Health and Safety Department.

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration
SAFETY DATA SHEET
Required For compliance with OSHA Act of 1970
Public Law 91-596 (CFR 1910)

SECTION I	
Product Name	Size
Chemical Name	
Formula	
Manufacturer	
Address	
For Information on Health Hazards Call	
For Other Information Call	
Signature and date	

This section gives the name and address of the manufacturer and an emergency phone number where questions about toxicity and chemical hazards can be directed. Large chemical manufacturers have 24-hour hotlines manned by chemical safety professionals who can answer questions regarding spills, leaks, chemical exposure, fire hazard, etc. Other information that may be contained in Section I includes:

Trade Name: This is the manufacturer's name for the product.

Chemical Name and Synonyms: This refers to the generic or standard names for the chemical.

Chemical Family: This classification allows one to group the substance along with a class of similar substances, such as mineral dusts, acids, caustics, etc. The potential hazards of a substance can sometimes be gauged by experience with other chemicals of that hazard class.

SECTION II - HAZARDOUS INGREDIENTS OF MIXTURES		
Principal Hazardous component(s)	%	TLV (Units)

This section describes the percent composition of the substance, listing chemicals present in the mixture. It lists Threshold Limit Values for the different chemicals that are present. Threshold Limit values (TLV's) are values for airborne toxic materials that are used as guides in the control of health hazards. They represent concentrations to which nearly all workers (workers without special sensitivities) can be exposed to for long periods of time without harmful effects. TLV's are usually expressed as parts per million (ppm), the parts of gas or vapor in each million parts of air. TLV's are also expressed as mg/m3, the milligrams of dust or vapor per cubic meter of air.

SECTION III - PHYSICAL DATA			
Boiling Point (℉)		Specific Gravity (H_2O=1)	
Vapor Pressure (mm Hg)		Percent Volatile By Volume (%)	
Vapor Density (Air=1)		Evaporation Rate (Butyl Acetate=1)	
Solubility in Water			
Appearance and Odor			

This section gives information about the physical characteristics of the chemical. This information can be very useful in determining how a chemical will behave in a spill situation and what appropriate steps should be taken.

Vapor Pressure: Vapor pressure (VP) can be used as a measure of how volatile a substance is…how quickly it evaporates. VP is measured in units of millimeters of mercury (mm Hg). For comparison, the VP of water (at 20o Centigrade) is 17.5 mm Hg. The VP of Vaseline (a nonvolatile substance) would be close to zero mm Hg, while the VP of diethyl ether (a very volatile substance) is 440 mm Hg.

Vapor Density: Vapor density describes whether the vapor is lighter or heavier than air. The density of air is 1.0. A density greater than 1.0 indicates a heavier vapor, a density less than 1.0 indicates a lighter vapor. Vapors heavier than air (gasoline vapor for instance) can flow along just above the ground and can collect in depressions where they may pose a fire and explosion hazard.

Specific Gravity: Specific gravity describes whether the liquid is lighter or heavier than water. Water has a specific gravity of 1.0.

Percent Volatile by Volume: Describes how much of the substance will evaporate.

SECTION IV - FIRE AND EXPLOSION HAZARD DATA			
Flash Point (℉)	Flammable Limits in Air (% by Vol.)	Lower	Upper
Extinguisher Media		Autoignition Temperature (℉)	
Special Fire Fighting Procedures			
Explosion Hazards			

This section gives information, which is important for preventing and extinguishing fires and explosions. If a fire does occur, this information should be made available to fire fighters.

Flash Point: Flash point is the lowest temperature at which a liquid gives off enough vapor to ignite when a source of ignition is present. A fire or explosion hazard may exist if the substance is at or above this temperature and used in the presence of spark or flame.

Flammable Limits: In order to be flammable, a substance must be mixed with a certain amount of air (as in an automobile carburetor). A mixture that is too "lean" (not enough chemical) or too "rich" (not enough air) will not ignite. The Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL) define the range of concentration in which combustion can occur. The wider the range between the LEL and UEL, the more flammable the substance is.

SECTION V - HEALTH HAZARD DATA
Threshold Limit Value
Effects of Overexposure
Acute Overexposure
Chronic Overexposure
Emergency and First Aid Procedures
Inhalation
Eyes
Skin
Ingestion

This section describes the potential health effects resulting from overexposure to the chemical and gives emergency and first aid procedures. The symptoms and effects listed are the effects of exposure at hazardous levels. Most chemicals are safe in normal use and the vast majority of workers never suffer toxic effects. However, any chemical can be toxic in high concentrations, and the precautions outlined in the MSDS should be followed.

The health hazards section often contains information on the toxicity of the substance. The data most often presented are the results of animal experiments. For example, "LD50 (mouse) = 250 mg/kg." The usual measure of toxicity is dose level expressed as weight of chemical per unit body weight of the animal-usually milligrams of chemical per kilogram of body weight (mg/kg). The LD50 describes the amount of chemical ingested or absorbed by the skin in test animals that causes death in 50% of test animals used during a toxicity test study. Another common term is LC50, which describes the amount of chemical inhaled by test animals that causes death in 50% of test animals used during a toxicity test study. The LD50 and LC50 values are then used to infer what dose is required to show a toxic effect on humans.

As a general rule of thumb, the lower the LD50 or LC50 number, the more toxic the chemical. Note there are other factors (concentration of the chemical, frequency of exposure, etc.) that contribute to the toxicity of a chemical, including other hazards the chemical may possess.

Health hazard information may also distinguish the effects of acute and chronic exposure. Acute toxicity is generally thought of as a single, short-term exposure where effects appear immediately and the effects are often reversible. Chronic toxicity is generally thought of as frequent exposures where effects may be delayed (even for years), and the effects are generally irreversible. Chronic toxicity can also result in acute exposures, with long term chronic effects.

SECTION VI - REACTIVITY DATA			
Stability		Unstable	Conditions to avoid
		Stable	
Incompatibility (Materials to Avoid)			
Hazardous Decomposition Products			
Hazardous Polymerization			Conditions to Avoid
May Occur	Will Not Occur		

This section gives information on the reactivity of the chemical – with other chemicals, air, or water which is important when responding to a spill or fire. Chemical substances may be not only hazardous by themselves, but may also be hazardous when they decompose (break down into other substances) or when they react with other chemicals.

Stability: Unstable indicates that a chemical can decompose spontaneously under normal temperatures, pressures, and mechanical shocks. Rapid decomposition may be hazardous because it produces heat and may cause a fire or explosion. Stable compounds do not decompose under normal conditions.

Incompatibility: Certain chemicals should never be mixed because the mixture creates hazardous conditions. Incompatible chemicals should not be stored together where an accident could cause them to mix.

Hazardous Decomposition Products: Other chemical substances may be created when a chemical burns or decomposes.

Hazardous Polymerization: Some chemicals can undergo a type of chemical reaction (rapid polymerization) which may produce enough heat to cause containers to explode. Conditions to avoid are listed in this section.

SECTION VII - SPILL OR LEAK PROCEDURES
Steps to be Taken in Case Material is Released or Spilled
Waste Disposal Method

This section can provide specific information about how to clean up a spill of the chemical and how the chemical should be properly disposed of.

<table>
<tr><td colspan="4">SECTION VIII - SPECIAL PROTECTION INFORMATION</td></tr>
<tr><td colspan="4">Respiratory Protection (Specify type)</td></tr>
<tr><td>Ventilation</td><td colspan="2">Local Exhaust</td><td>Special</td></tr>
<tr><td></td><td colspan="2">Mechanical (general)</td><td>Other</td></tr>
<tr><td colspan="2">Protective Gloves</td><td colspan="2">Eye protection</td></tr>
<tr><td colspan="4">Other Protective clothing or Equipment</td></tr>
</table>

This section gives information for any special protection that needs to be taken when handling this chemical including ventilation requirements and the type of personal protective equipment that should be worn.

SECTION IX - SPECIAL PRECAUTIONS
Precautions to be Taken in Handling and Storing
Other Precautions

This section describes other precautionary measures that may need to be taken. Some of the precautions presented are intended for large-scale users and may not be necessary for use with small quantities of the chemical. Any questions about precautions or health effects should be referred to the Hazardous Materials and Laboratory Safety Specialist at 575-517-0646.

Appendix H: Hazards of Functional Groups

The following information gives a basic overview of the hazards of functional groups. This information is not meant to replace material safety data sheets for the specific chemical(s) used in your experiments. While these functional groups are listed alphabetically for convenience, chemicals should be segregated and stored by hazard classes – see the Research Compliance Segregation Scheme in Appendix M for more information.

*Following is a reproduction and explanation of functional group hazards originally prepared and distributed by Cornell University's Environmental Health and Safety Department.

Alcohols:

- The lower aliphatic alcohols are low to moderately toxic and usually have low vapor pressures, therefore inhalation toxicity is low.
- Vapors may be an irritant to the eyes and mucous membranes.
- Ingestion and absorption of the liquids through the skin can be a major health hazard.
- Lower alcohols containing double or triple bonds exhibit a greater degree of toxicity and irritation.
- Fatty alcohols (derived from oils, fats, and waxes) are almost non-toxic.
- Lower alcohols are flammable or combustible liquids.
- Flammability decreases with an increase in the carbon number.
- Solubility of alcohols decrease with increase in carbon chain length.
- Toxicity tends to decrease with an increase in carbon number.
- Examples:
  - Allyl alcohol
  - 1-Butanol
  - Cyclohexanol
  - 1,2-Ethanediol
  - Ethanol
  - Methanol
  - 1-Propanol
  - 2-Propyn 1-ol

Aldehydes:

- Aldehydes are intermediate products in the conversion of primary alcohols to carboxylic acids or vice versa.
- The low molecular weight aldehydes are more toxic than the higher ones.
- Toxicity decreases with increase in the carbon chain length.
- Aromatic aldehydes are less toxic than low molecular weight aliphatic aldehydes.
- Low molecular weight aldehydes are highly flammable, with flammability decreasing with increasing carbon chain length.
- Low aromatic aldehydes are combustible or nonflammable liquids.
- Examples:
  - Acetaldehyde
  - Acrolein
  - Benzaldehyde

    - Formaldehyde
    - Glutaraldehyde
    - 1-Hexanal
    - Isobutyraldehyde
    - Propenal

Aliphatic Amines:

- The toxicity of most aliphatic amines may fall in the low to moderate category.
- The health hazard from amines arises primarily from their caustic nature.
- All lower aliphatic amines are severe irritants to the skin, eyes, and mucous membranes.
- All of these compounds have a strong to mild odor of ammonia and their vapors produce irritation of the nose and throat.
- Aliphatic amines, especially the lower ones, are highly flammable liquids, many which have flashpoints below 0 degrees Celsius.
- The vapors are heavier than air.
- They react vigorously with concentrated mineral acids.
- The flammability decreases with an increase in the carbon number.
- The reactivity of amines in general is low.
- Examples:
    - Aminocyclohexane
    - Ethyleneimine
    - Methylamine
    - 2-Propylamine

Aliphatic and Alicyclic Hydrocarbons:

- Organic compounds composed solely of carbon and hydrogen.
- Hydrocarbons may be classified into 3 broad categories:
    - Open-chain aliphatic compounds
    - Cyclic or alicyclic compounds of naphthalene type
    - Aromatic ring compounds
- Open chain aliphatic hydrocarbons constitute alkanes, alkenes, alkynes, and their isomers. Alkenes or olefins are unsaturated compounds, characterized by one or more double bonds between the carbon atoms. Alkynes or acetylenic hydrocarbons contain a triple bond in the molecule and are highly unsaturated. An alicyclic hydrocarbon is a cyclic ring compound of 3 or more carbon atoms. Aromatics are ring compounds too, but are characterized by a 6 carbon atom unsaturated benzenoid rings.
- The toxicities of aliphatic and alicyclic hydrocarbons in humans and animals are very low.
- The gaseous compounds are all nontoxic and are simple asphyxiants.
- Lower hydrocarbons are highly flammable substances, an increase in the carbon number causes a decrease in flammability.
- It is the flammable properties that make hydrocarbons hazardous.
- The reactivity of alkanes and cycloalkanes is very low.
- Alkenes and alkynes containing double and triple bonds are reactive.
- Examples:
    - Butane

    - Cyclohexene
    - Cyclopentane
    - Methane
    - n-Pentane

Alkali and Other Reactive Metals:

- Alkali metals constitute Group IA of the periodic table.
- Alkaline-earth metals constitute Group IIA and are less active than the alkali metals.
- These can be water and/or air reactive.
- Several of these metals are flammable, too, but only in a finely divided state.
- Reactions with water produce strong bases.
- Examples:
    - Aluminum
    - Calcium
    - Lithium
    - Magnesium
    - Potassium
    - Sodium

Alkalis:

- Water-soluble bases, mostly the hydroxides of alkali- and alkaline-earth metals.
- Certain carbonates and bicarbonates also exhibit basic properties but are weak bases.
- These compounds react with acids to form salts and water.
- The health hazard from concentrated solutions of alkalies arises from their severe corrosive actions on tissues.
- These compounds are bitter to taste, corrosive to skin and a severe irritant to the eyes.
- The toxicity of alkalies is governed by the metal ions.
- Hydroxides and carbonates of alkali-and alkaline-earth are noncombustible.
- Strong caustic alkalies react exothermically with many substances, including water and concentrated acids, generating heat that can ignite flammable materials.
- Examples:
    - Lithium hydroxide
    - Potassium hydroxide
    - Potassium carbonate
    - Sodium hydroxide

Aromatic Amines:

- Compounds that contain one or more amino groups attached to an aromatic ring.
- These amines are similar in many respects to aliphatic amines.
- These amines are basic, but the basicity is lower to aliphatic amines.
- The health hazard from aromatic amines may arise in two ways:
    - Moderate to severe poisoning, with symptoms ranging from headache, dizziness, and ataxia to anemia, cyanosis, and reticulocytosis.
    - Carcinogenic, especially cancer of the bladder.
- Many amines are proven or suspected human carcinogens, among aromatic amines, ortho-isomers generally exhibit stronger carcinogenic properties than those of the para-

and meta-isomers.

- Unlike aliphatic amines, the aromatic amines do not cause severe skin burn or corneal injury.
- The pure liquids (or solids) may produce mild to moderate irritation on the skin.
- Lower aromatic amines are combustible liquids and form explosive mixtures with air.
- Amines may react violently with strong oxidizing compounds.
- Examples:
    - Aniline
    - Benzidine
    - o-Toluidine

Aromatic Hydrocarbons:

- Aromatics are a class of hydrocarbons having benzene-ring structures.
- Many polyaromatics are carcinogens.
- The acute toxicity of mononuclear aromatics is low.
- Inhalation of vapors at high concentrations in air may cause narcosis with symptoms of hallucination, excitement, euphoria, distorted perception, and headache.
- Benzene is the only mononuclear aromatic with possible human carcinogenicity and other severe chronic effects.
- With a greater degree of substitutions in the benzene ring and/or increase in the carbon chain length of the alkyl substituents, the flammability decreases.
- Examples:
    - Benzene
    - Benzo[a]pyrene
    - Pyrene
    - Toluene
    - Xylene

Azides, Fulminates, Acetylides, and Related Compounds:

- These compounds form highly explosive shock- and heat-sensitive salts with many metals.
- Structurally they differ from each other, but have similar detonating characteristics.
- While alkali metal azides are inert to shock, the salts for copper, silver, lead, and mercury are dangerously shock sensitive.
- Fulminates of heavy metals are powerful explosives.
- These compounds are highly sensitive to impact and heat.
- Acetylides of heavy metals are extremely shock sensitive when dry, whereas the salts of alkali metals are fairly stable.
- Most azides, fulminates, acetylides, nitrides and related compounds are highly unstable and constitute an explosion hazard.
- Salts of Group IB and IIB metals are especially explosive.
- Azides of nonmetals, such as those of halogens or organic azides such as that of cyanogen, are also extremely shock sensitive.
- Some of these compounds may even explode on exposure to light.
- Examples:
    - Cuprous acetylide

- Hydrazoic acid
- Lead azide
- Mercury fulminate
- Silver fulminate
- Silver nitride
- Sodium azide

Carboxylic Acids:

- Weak organic acids, their strength is much weaker than mineral acids.
- Toxicity of monocarboxylic acids is moderate to low and decreases with carbon chain length.
- Some lower dicarboxylic acids are moderate to high toxicity, becoming less toxic with increasing carbon chain length.
- Low molecular weight carboxylic acids are combustible liquids.
- Aromatic acids are of low toxicity.
- Examples:
    - Acetic acid
    - Butyric acid
    - Formic acid
    - Methacrylic acid
    - Oxalic acid
    - Propionic acid
    - Succinic acid
    - Valeric acid

Epoxy Compounds:

- Epoxides, also called oxiranes and 1,2-epoxides.
- Exposure to epoxides can cause irritation of the skin, eyes, and respiratory tract.
- Low molecular weight epoxides are strong irritants and more toxic than higher ones.
- Inhalation can produce pulmonary edema and affect the lungs, central nervous system and liver.
- Many epoxy compounds have been found to cause cancer in animals.
- Lower epoxides are highly flammable.
- They also polymerize readily in the presence of strong acids and active catalysts, this reaction generates heat and pressure that may rupture closed containers.
- Therefore contact with anhydrous metal halides, strong bases, and readily oxidizable substances should be avoided.
- Examples:
    - Butylene oxide
    - Epichlorohydrin
    - Ethylene oxide
    - Glycidaldehyde
    - Glycidol
    - Isopropyl glycidyl ether

Esters:

- Lower aliphatic esters have a pleasant fruity odor.
- The acute toxicity of esters is generally of low order, they are narcotic at high concentrations.
- Vapors are an irritant to the eyes and mucous membranes.
- Toxicity increases with an increase in the alkyl chain length.
- Lower aliphatic esters are flammable liquids, some have low flash points and may cause flashback to an open container.
- The vapors form explosive mixtures with air.
- The flash point increases with increase in the alkyl chain length.
- The reactivity of esters is low.
- Aromatic esters are similar in effects as aliphatic esters.
- Examples:
    - Ethyl acetate
    - Ethyl formate
    - Methyl acrylate
    - Methyl formate
    - n-Propyl acetate
    - (Aromatics) Methyl benzoate
    - Methyl salicylate

Ethers:

- Widely used as solvents.
- They have a high degree of flammability.
- They tend to form unstable peroxides, which can explode spontaneously or upon heating.
- The flash point decreases with increase in carbon chain.
- Lower aliphatic ethers are some of the most flammable organic compounds and can be ignited by static electricity or lightning.
- The vapor densities are heavier than air.
- They form explosive mixtures with air.
- Aromatic ethers are noncombustible liquids or solids and do not exhibit the flammable characteristics common to aliphatic ethers.
- Ethers react with oxygen to form unstable peroxides, this reaction is catalyzed by sunlight, when evaporated to dryness, the concentrations of such peroxides increase, resulting in violent explosions.
- The toxicity of ethers is low to very low, at high concentrations these compounds exhibit anesthetic effects.
- Examples:
    - Butyl vinyl ether
    - Ethyl ether
    - Isopropyl ether
    - Methyl propyl ether
    - Vinyl ether

Glycol Ethers:

- Also known by the name Cellosolve.
- The toxic effects are mild, however, moderate to severe poisoning can occur from

excessive dosage.
- The routes of exposure are inhalation, ingestion, and absorption through the skin.
- Compounds with high molecular weights and low vapor pressures do not manifest an inhalation hazard.
- Low molecular weight alkyl ethers are flammable or combustible liquids forming explosive mixtures with air.
- The reactivity of glycol ethers is low.
- There is no report of any violent explosive reactions.
- The high molecular weight compounds are noncombustible.
- Examples:
    - Ethylene glycol monobutyl ether
    - Ethylene glycol monomethyl ether
    - 2-Isopropoxyethanol

Haloethers:
- Haloethers are ethers containing hydrogen atoms.
- Halogen substitutions make ether molecules less flammable or nonflammable.
- The explosion hazards of low aliphatic ethers due to peroxide formation are not manifested by the haloethers. The halogens inhibit the ether oxidation to peroxides.
- Inhalation of Fluoroethers can produce anesthesia similar to that of the lower aliphatic ethers. Lower aliphatic chloro- and bromo- ethers can be injurious to the lungs.
- Many of these are cancer causing to the lungs in animals or humans.
- Aromatic chloro-ethers are toxic by inhalation, ingestion, and skin absorption only at high doses. These effects can be attributed to the chlorine content and to a lesser extent on the aromaticity of the molecule.
- Examples:
    - Bis(chloromethyl)ether
    - 2-Chloroethyl vinyl ether
    - Pentachloro diphenyl oxide

Halogenated Hydrocarbons:
- The flammability of these compounds shows a wide variation.
- Bromo compounds are less flammable than their Chloro- counterparts, the difference in flammability is not great though.
- An increase in the halo- substitutions in the molecule increases the flash point.
- The flammable hydrocarbons are stable compounds with low reactivity.
- These compounds, however, may react violently with alkali metals and their alloys or with finely divided metals.
- Violent reactions may occur with powerful oxidizers, especially upon heating.
- Volatile halocarbons may rupture glass containers due to simple pressure build up or to exothermic polymerization in a closed vessel.
- Halogenated hydrocarbons in general exhibit low acute toxicity.
- Inhalation toxicity is greater for gaseous or volatile liquid compounds.
- The health hazard from exposure to these compounds may be due to their anesthetic actions; damaging effects on liver and kidney; and in case of certain compounds, carcinogenicity.

- The toxic symptoms are drowsiness, lack of coordination, anesthesia, hepatitis, and necrosis of the liver.
- Vapors may cause irritation of the eyes and respiratory tract.
- Death may result from cardiac arrest due to prolonged exposure to high concentrations.
- Ingestion can produce nausea, vomiting, and liver injury.
- Fluorocarbons are less toxic than the chloro-, bromo-, and iodo- compounds, the toxicity increases with increase in the mass number of the halogen atoms.
- Some of the halogenated hydrocarbons cause cancer in humans.
- Examples:
    - Benzyl chloride
    - Carbon tetrachloride
    - Chloroform
    - 1,2-Dichlorobenzene
    - Ethyl bromide
    - Fluorobenzene
    - Methylene chloride

Hydrides:

- The single most hazardous property of hydrides is their high reactivity toward water.
- The reaction with water is violent and can be explosive with liberation of hydrogen.
- Many hydrides are flammable solids that may ignite spontaneously on exposure to moist air.
- Many ionic hydrides are strongly basic; their reactions with acids are violent and exothermic, which can cause ignition.
- Hydrides are also powerful reducing agents, they react violently with strong oxidizing substances, causing explosions.
- Covalent volatile hydrides such as arsine, silane, or germane are highly toxic.
- Ionic alkali metal hydrides are corrosive to skin, as they form caustic alkalies readily with moisture.
- Examples:
    - Decarborane
    - Lithium aluminum hydride
    - Potassium hydride
    - Sodium borohydride
    - Sodium hydride

Industrial Solvents:

- The toxic effects of most of the solvents are of low order, chronic exposures or large doses can produce moderate to severe poisoning.
- Most organic solvents are flammable or combustible liquids, the vapors of which can form explosive mixtures with air.
- Many of the common solvents can cause flashback of the vapors, and some form peroxide on prolonged storage, especially those compounds containing an ether functional group, some also can form shock-sensitive solvated complexes with metal perchlorates.
- Examples:

- Acetamide
- Acetone
- Benzene
- Carbon tetrachloride
- Chloroform
- Methyl acetate
- Pyridine
- Tetrahydrofuran

Inorganic Cyanides:

- Inorganic cyanides are the metal salts of Hydrocyanic acid.
- Cyanides of alkali metals are extremely toxic.
- In addition to being extremely toxic by ingestion or skin absorption, most metal cyanides present a serious hazard of forming extremely toxic Hydrogen cyanide when they come into contact with acids.
- Examples:
  - Barium cyanide
  - Cyanogen chloride
  - Cyanamide cyanogen
  - Hydrogen cyanate
  - Sodium cyanide
  - Potassium cyanide

Ketones:

- Similar to aldehydes.
- In general, the toxicity is much lower than that of other functional groups, such as cyanides or amines.
- Unlike aldehydes and alcohols, some of the simplest ketones are less toxic than the higher ones.
- Beyond 7 carbons, the higher ones are almost non-toxic.
- Substitution of other functional groups can alter toxicity significantly.
- The simplest ketones are highly flammable.
- The flammability decreases with increase in the carbon number.
- Examples:
  - Acetophenone
  - Acetone
  - Ketene
  - Mesityl oxide
  - Methyl Ethyl Ketone

Mineral Acids:

- Acid strengths vary widely.
- Sour in taste.
- React with a base to form salt and water.
- Produce hydrogen when reacting with most common metals.
- Produce carbon dioxide when reacting with most carbonates.

- All mineral acids are corrosive.
- Noncombustible substances.
- Some are highly reactive to certain substances, causing fire and/or explosions.
- Examples:
    - Hydrochloric acid
    - Hydrofluoric acid
    - Hydroiodic acid
    - Phosphoric acid
    - Nitric acid
    - Sulfuric acid

Organic Cyanides (Nitriles):

- These are organic derivatives of Hydrocyanic acid or the cyano-substituted organic compounds.
- Nitriles are highly reactive, the CN group reacts with a large number of reactants to form a wide variety of products, such as amides, amines, carboxylic acids, aldehydes, ketones, esters, thioamides, and other compounds.
- Nitriles are highly toxic compounds, some of them are as toxic as alkali metal cyanides.
- Lower aliphatic nitriles are flammable and form explosive mixtures with air. The explosive range narrows down with an increase in the carbon chain length.
- Examples:
    - Acrylonitrile
    - Acetonitrile
    - Butyronitrile
    - Cyanohydrin

Organic Isocyanates:

- Organic groups attached to the isocyanate group.
- These compounds are highly reactive due to the high unsaturation in the isocyanate functional group.
- Isocyanates in general are highly reactive toward compounds containing active hydrogen atoms.
- Most isocyanates are hazardous to health.
- They are lachrymators and irritants to the skin and mucous membranes.
- Skin contact can cause itching, eczema, and mild tanning.
- Inhalation of isocyanate vapors can produce asthma-like allergic reactions, with symptoms from difficulty in breathing to acute attacks and sudden loss of consciousness.
- Toxicities of isocyanates vary widely, in addition, health hazards differ significantly on the route of exposure but occur primarily via inhalation exposure.
- Most isocyanates have high flash points, therefore the fire hazard is low.
- However, closed containers can rupture due to the pressure built up from carbon dioxide, which is formed from reaction with moisture.
- Examples:
    - n-Butyl isocyanate
    - Hexamethylene diisocyanate
    - Methyl isocyanate

- Phenyl isocyanate

Organic Peroxides:

- Compounds containing the peroxide group bound to organic groups.
- In general the toxicity is low to moderate.
- Peroxides are a hazardous class of compounds, some of which are extremely dangerous to handle.
- The dangerous ones are highly reactive, powerful oxidizers, highly flammable and often form decomposition products, which are more flammable.
- Many organic peroxides can explode violently due to one or a combination of the follow factors:
  - Mechanical shock, such as impact, jarring, or friction
  - Heat
  - Chemical contact
- Short chain alkyl and acyl peroxides, hydroperoxides, peroxyesters, and peroxydicarbonates with low carbon numbers are of much greater hazard than the long chain peroxy compounds.
- The active oxygen content of peroxides is measured as the amount of active oxygen (from peroxide functional group) per 100 gm of the substance. The greater the percentage of active oxygen in formulation, the higher is its reactivity. An active oxygen content exceeding 9% is too dangerous for handling and shipping.
- Examples:
  - Benzoyl peroxide
  - Cumene hydroperoxide
  - Diacetyl peroxide
  - Diisopropyl peroxydicarbonate
  - Hydroperoxy Ethanol

Oxidizers:

- Include certain classes of inorganic compounds that are strong oxidizing agents, evolving oxygen on decomposition.
- These substances are rich in oxygen and decompose violently on heating.
- The explosion hazard arises when these substances come into contact with easily oxidizable compounds such as organics, metals, or metal hydrides.
- When the solid substances are finely divided and combined, the risk of explosion is enhanced.
- The unstable intermediate products, so formed, are sensitive to heat, shock, and percussion.
- The health hazard from the substances arises due to their strong corrosive action on the skin and eyes.
- The toxicity depends on the metal ions in these molecules.
- Examples:
  - Bromates
  - Chlorites
  - Dichromates
  - Hypochlorites

  - Inorganic peroxides
  - Iodates
  - Nitrates
  - Periodates
  - Perchlorates
  - Permanganates

<u>Peroxy Acids:</u>

- There are 2 types: Peroxycarboxylic acids and Peroxysulfonic acids.
- Peroxycarboxylic acids are weaker acids than the corresponding carboxylic acids.
- Lower peroxy acids are volatile liquids, soluble in water.
- Higher acids with greater than 7 carbons are solids and insoluble in water.
- These compounds are highly unstable and can decompose violently on heating.
- May react dangerously with organic matter and readily oxidizable compounds.
- Among organic peroxides, peroxy acids are the most powerful oxidizing compounds.
- The lower acids are also shock sensitive, but less than some organic peroxides.
- Health hazard primarily due to their irritant actions.
- Examples:
  - Peroxyacetic acid
  - Peroxybenzoic acid
  - Peroxyformic acid

<u>Phenols:</u>

- Phenols are a class of organic compounds containing hydroxyl groups attached to aromatic rings.
- The hydroxyl group exhibits properties that are different from an alcoholic hydroxyl group.
- Phenols are weakly acidic, forming metal salts on reactions with caustic alkalies.
- In comparison, acid strengths of alcohols are negligibly small or several orders of magnitude lower than those of phenols.
- In comparison with many other classes of organic compounds, phenols show relatively greater toxicity.
- Examples:
  - Cresol
  - 2-Naphthol
  - Pentachlorophenol
  - Phenols
  - Resorcinol

<u>Phthalate Esters:</u>

- These are esters of Phthalic acid.
- They are noncombustible liquids.
- Some are EPA-listed priority pollutants.
- The acute toxicity is very low.
- High doses may produce somnolence, weight loss, dyspnea, and cyanosis.
- The pure liquids are mild irritants to the skin.

- These are relatively harmless and are among the least toxic organic industrial products.
- Examples:
  - Dibutyl phthalate
  - Diethylhexyl Phthalate (DEHP)

Reference: Patnaik, Pradyot, A Comprehensive Guide to the Hazardous Properties of Chemical Substances, Van Nostrand Reinhold, 1992.

Appendix I: Peroxide Forming Chemicals

The following tables are a non-comprehensive list of known peroxide forming chemicals. Table A lists chemicals that can form explosive levels of peroxides without concentration or distillation. Table B lists chemicals that can form explosive levels of peroxides by being concentrated or distilled. Table C lists chemicals that may auto-polymerize as a result of peroxide accumulation. Table D lists chemicals that may form peroxides, but cannot be clearly categorized in Class A, B, or C.

Many institutions categorize PFCs in four different classes, based on the severity and conditions of the materials.

- **Class A**: Severe peroxide hazard. These chemicals can spontaneously decompose and become explosive with exposure to air without concentration.
- **Class B**: Concentration hazard. These chemicals require external energy for spontaneous decomposition, and can form explosive peroxides when distilled, evaporated, or otherwise concentrated.
- **Class C**: Shock and heat sensitive. These chemicals are often highly reactive and can auto-polymerize as a result of internal peroxide accumulation. The peroxides formed in these reactions are extremely shock and heat sensitive.
- **Class D**: Potential peroxide forming chemicals. These chemicals may form peroxides, but cannot be clearly categorized in Class A, B, or C.

Table A Class A: Chemicals that form explosive levels of peroxides without concentration. Peroxide Testing/Disposal Recommendations: 3 Months or less			
CHEMICAL	**CAS #**	**SYNONYMS**	**DESCRIPTION**
Diethyl Ketene	96-22-0	2 ethyl 1 butene 1 one	Clear, colorless liquid
Divinyl acetylene	0821-08-09	n/a	Yellowish oil, liquid
Divinyl Ether	109-93-3	Divinyl Oxide; Vinyl Ether	Clear, colorless liquid
Isopropyl ether	108-20-3	Diisopropyl Ether, Diisopropyl Oxide	Clear, colorless liquid
Potassium Amide	17242-52-3	Potassamide	Yellowish brown solid
Potassium Metal	7440-09-07	Potassium	Silver/White solid metal
Sodium Amide	7782-92-5	Sodamide	Gray/white crystalline powder
Vinylidene Chloride	75-35-4	1,1,-dichloroethylene, 1,1-dichloroethane	Clear, colorless liquid
Sodium Ethoxyacetylide	73506-39-5		White crystalline powder

Table B Class B: Chemicals that form explosive levels of peroxides on concentration. Peroxide Testing/Disposal Recommendations: 12 Months inhibited, 3 months if uninhibited.			
CHEMICAL	**CAS #**	**SYNONYMS**	**DESCRIPTION**
Acetal	105-57-7	1,1 diethoxyethane, diethyl acetal	Clear, colorless liquid
Acetaldehyde	75-07-0	Ethanal, ethyl aldehyde	Clear, colorless liquid
Cumene	98-82-8	Isopropyl benzene	Clear, colorless liquid
Cyclohexene	110-82-7	1,2,3,4 tetrahydrobenzene	Clear, colorless liquid
Cyclopentene	142-29-0	n/a	Clear, colorless liquid
Decalin	91-17-8	Decahydronapthalene	Clear, colorless liquid
Dicyclopentadiene	77-73-6	Cyclopentadiene dimer	Clear, colorless liquid
Diethylene glycol dimethyl ether	111-96-6	Diglyme	Clear, colorless liquid
Dioxane	111-96-6	1,4 dioxane, diethylene dioxide	Clear, colorless liquid
Ethyl ether	60-29-7	diethyl ether, ethoxyethane	Clear, colorless liquid
Ethylene glycol dimethyl ether	110-71-4	1,2, dimethoxy ethane, glyme	Clear, colorless liquid
Furan	110-00-9	Divinylene oxide	Clear, colorless liquid

Methylcyclopentane	96-37-7	MCP	Light yellow liquid
Methyl isobutyl ketone	0108-10-1	MIBK, Isopropylacetone	Clear, colorless liquid
Tetrahydrofuran	109-99-9	Butylenes oxide, diethylene oxide	Clear, colorless liquid
Tetrahydronaphthalene	119-64-2	Tetraline	Clear, colorless liquid
1,3 butadiene	106-99-0	Vinylethylene, divinyl	Clear compressed liquefied gas

Table C Class C: Chemicals that may auto-polymerize as a result of peroxide accumulation. Peroxide Testing/Disposal Recommendations: 12 Months inhibited, 3 months if uninhibited.			
Acrylic Acid	79-10-7	2-Propenoic acid, vinyl formic acid	Clear, colorless liquid
Acrylonitrile	107-13-1	Propenenitrile; Vinyl cyanide; Cyanoethylene	Clear, colorless liquid
Chlorobutadiene	109-69-3	Chloroprene	Clear, colorless liquid
Methyl Methacrylate	80-62-6	Propenoic acid, Methacrylic acid	Clear, colorless liquid
Styrene	100-42-5	Vinylbenzene; Phenylethylene; Styrol	Clear to yellow oily liquid
Vinyl acetate	0108-05-04	Ethenyl acetate; Ethenyl ethanoate	Clear, colorless liquid
Vinyl acetylene	689-97-4	Buten-3-yne	Colorless gas or liquid
Vinyl chloride	75-01-4	Chloroethylene, ethylene monochloride	Colorless gas or liquid
Vinyl pyridine	100-69-6	4-Ethenylpyridine	Yellow to brown liquid

Table D Class D: Potential peroxide forming chemicals. These chemicals may form peroxides, but cannot be clearly categorized in Class A, B, or C. Peroxide Testing/Disposal Recommendations: 12 Months inhibited, 3 months if uninhibited.			
Acrolein	Allyl Ether	Allyl Ethyl Ether	n-Amyl ether
1,2-Diethoxyethane	1-Pentene	1-Ethoxy-2-propyne	Ethyl vinyl ether
Chloromethyl methyl ether	b-Methoxypropionitrile	n-Methylphenetole	Isoamyl ether
n-Hexyl ether	tert-Butyl methyl ether	n-Butyl vinyl ether	Sodium ethoxyacetylide
Tetrahydropyran	2-Ethylbutanol	Triethylene glycol dipropionate	2-Ethoxyethyl acetate
o,p-Ethoxyphenyl isocyanate	1,2-Epoxy-3-isopropoxypropane	Dimethoxymethane	Diethyl ethoxymethylenemalonate

Appendix J: Incompatible Materials

Substances in the left-hand column should be stored and handled so they cannot contact corresponding substances in the right-hand column. The following list contains some of the chemicals commonly found in laboratories, but it should not be considered exhaustive. Information for the specific chemical you are using can usually be found in the "REACTIVITY" or "INCOMPATIBILITIES" section of the Safety Data Sheet. Research Compliance has a copy of Wiley Guide to Chemical Incompatibilities, by Pohanish and Greene, which lists the incompatibilities of hundreds of chemicals.

*Following is a reproduction and explanation of chemical incompatibility hazards originally prepared and distributed by Cornell University's Environmental Health and Safety Department.

Incompatibility Reference Table

Chemical Class or Chemical Name	Incompatible Chemicals
Alkaline and alkaline earth metals, such as Sodium, Potassium, Cesium, Lithium, Magnesium, Calcium	Carbon dioxide, Carbon tetrachloride and other chlorinated hydrocarbons, any free acid or halogen. Do not use water, foam or dry chemicals on fires involving these metals.
Acetic acid	Chromic acid, Nitric acid, hydroxyl compounds, Ethylene glycol, Perchloric acid, peroxides, permanganates.
Acetic anhydride	Chromic acid, Nitric acid, hydroxyl-containing compounds, Ethylene glycol, Perchloric acid, peroxides and permanganates.
Acetone	Concentrated Nitric and Sulfuric acid mixtures.
Acetylene	Copper, Silver, Mercury and halogens, Fluorine, Chlorine, Bromine.
Alkali & alkaline earth metals (such as powdered Aluminum or Magnesium, Calcium, Lithium, Sodium, Potassium)	Water, Carbon tetrachloride or other chlorinated hydrocarbons, Carbon dioxide, and halogens.
Aluminum alkyls	Halogenated hydrocarbons, water.
Ammonia (anhydrous)	Silver, Mercury, Chlorine, Calcium hypochlorite, Iodine, Bromine, Hydrogen fluoride, Chlorine dioxide, Hydrofluoric acid (anhydrous).
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, Sulfur, finely divided organics or combustibles.
Aniline	Nitric acid, Hydrogen peroxide.

Arsenical materials	Any reducing agent.
Azides	Acids.
Benzoyl peroxide	Chloroform, organic materials.
Bromine	Ammonia, Acetylene, Butadiene, Butane and other petroleum gasses, Sodium carbide, Turpentine, Benzene and finely divided metals, Methane, Propane, Hydrogen.
Calcium carbide	Water (see also Acetylene).
Calcium hypochlorite	Methyl carbitol, Phenol, Glycerol, Nitromethane, Iron oxide, Ammonia, activated carbon.
Calcium oxide	Water.
Carbon, activated	Calcium hypochlorite, all oxidizing agents.
Carbon tetrachloride	Sodium.
Chlorates	Ammonium salts, acids, metal powders, Sulfur, finely divided organics or combustibles.
Chlorine	Ammonia, Acetylene, Butadiene, Butane, Propane, and other petroleum gasses, Hydrogen, Sodium carbide, Turpentine, Benzene and finely divided metals, Methane.
Chlorine dioxide	Ammonia, Methane, Phosphine and Hydrogen sulfide.
Chlorosulfonic acid	Organic materials, water, powdered metals.
Chromic acid & Chromium trioxide	Acetic acid, Naphthalene, Camphor, Glycerin, Turpentine, alcohol and other flammable liquids, paper or cellulose.
Copper	Acetylene, Hydrogen peroxide, Ethylene oxide.
Cumene hydroperoxide	Acids, organic or mineral.
Cyanides	Acids.
Ethylene oxide	Acids, bases, Copper, Magnesium perchlorate.
Flammable liquids	Ammonium nitrate, Chromic acid, Hydrogen peroxide, Nitric acid, Sodium peroxide, halogens.
Fluorine	Almost all oxidizable substances.
Hydrocarbons (such as Bromine, Butane)	Fluorine, Chlorine, Chromic acid, Sodium peroxide.

Hydrocyanic acid	Nitric acid, alkalis.
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous).
Hydrogen peroxide	Copper, Chromium, Iron, most metals or their salts, any flammable liquid, combustible materials, Aniline, Nitromethane, alcohols, Acetone, organic materials, Aniline.
Hydrides	Water, air, Carbon dioxide, chlorinated hydrocarbons.
Hydrofluoric acid, anhydrous (Hydrogen fluoride)	Ammonia (anhydrous or aqueous), organic peroxides.
Hydrogen sulfide	Fuming Nitric acid, oxidizing gasses.
Hydrocarbons (Benzene, Butane, Propane, Gasoline, Turpentine, etc.)	Fluorine, Chlorine, Bromine, Chromic acid, Sodium peroxide, fuming Nitric acid.
Hydroxylamine	Barium oxide, Lead dioxide, Phosphorus pentachloride and trichloride, Zinc, Potassium dichromate.
Hypochlorites	Acids, activated Carbon.
Iodine	Acetylene, Ammonia (anhydrous or aqueous), Hydrogen.
Maleic anhydride	Sodium hydroxide, Pyridine and other tertiary amines.
Mercury	Acetylene, Fulminic acid, Ammonia, Oxalic acid.
Nitrates	Acids, metal powders, flammable liquids, chlorates, sulfur, finely divided organics or combustibles, Sulfuric acid.
Nitric acid (concentrated)	Acetic acid, Aniline, Chromic acid, Hydrocyanic acid, Hydrogen sulfide, flammable liquids, flammable gasses, organic peroxides, chlorates, Copper, brass, any heavy metals.
Nitroparaffins	Inorganic bases, amines.
Oxygen	Oil, grease, Hydrogen, flammable liquids, solids, or gasses.
Oxalic acid	Silver, mercury, organic peroxides.
Perchlorates	Acids.
Perchloric acid	Acetic anhydride, Bismuth and its alloys, alcohol, paper, wood, grease, oil, organic

	amines or antioxidants.
Peroxides, organic	Acids (organic or mineral); avoid friction, store cold.
Phosphorus (white)	Air, Oxygen, alkalis, reducing agents.
Phosphorus pentoxide	Propargyl alcohol.
Potassium	Carbon tetrachloride, Carbon dioxide, water.
Potassium chlorate	Acids, Sulfuric acid (see also chlorates).
Potassium perchlorate	Sulfuric & other acids (see also Perchloric acid, & chlorates).
Potassium permanganate	Glycerin, Ethylene glycol, Benzaldehyde, any free acid, Sulfuric acid.
Selenides	Reducing agents
Silver	Acetylene, Oxalic acid, Tartaric acid, Fulminic acid, ammonium compounds.
Sodium	Carbon tetrachloride, Carbon dioxide, water. See alkaline metals (above).
Sodium amide	Air, water.
Sodium nitrate	Ammonium nitrate and other ammonium salts.
Sodium oxide	Water, any free acid.
Sodium peroxide	Any oxidizable substance, such as Ethanol, Methanol, glacial Acetic acid, Acetic anhydride, Benzaldehyde, Carbon disulfide, Glycerine, Ethylene glycol, Ethyl acetate, Methyl acetate and Furfural.
Sulfides	Acids.
Sulfuric acid	Chlorates, perchlorates, permanganates, organic peroxides. Potassium chlorate, Potassium perchlorate, Potassium permanganate (similar compounds of light metals, such as Sodium, Lithium).
UDMH (1,1-Dimethylhydrazine)	Oxidizing agents such as Hydrogen peroxide and fuming Nitric acid.
Zirconium	Prohibit water, Carbon tetrachloride, foam and dry chemical on zirconium fires.

Appendix K: Research Compliance Reference Library

Chemical Safety References

The following is a list of some of the reference materials that Research Compliance uses to develop and update the NMT Laboratory Safety Manual, Chemical Hygiene Plan, and other safety documents.

- Prudent Practices in the Laboratory, Handling and Management of Chemical Hazards. There is a free downloadable version available here. A physical copy is available at the Research Office Building room 113 by appointment. Contact Ben Thomas at ben.thomas@nmt.edu for more information. Prudent Practices in the Laboratory is especially useful for research labs, but also valuable for teaching labs.
- Hawley's Condensed Chemical Dictionary. There is an online copy available through Skeen Library. Physical copies are available in the reference section of Skeen Library, as well as at the Research Office Building in room 113 by appointment. Contact Ben Thomas at ben.thomas@nmt.edu for more information. Hawley's Condensed Chemical Dictionary is a useful resource for individuals requiring technical data and/or descriptive information on chemicals often used in lab settings.
- CRC Handbook of Laboratory Safety. There is a physical copy of the 4th Edition available in the reference section of Skeen Library, as well as a copy of the 5th Edition available at the Research Office Building in room 113 by appointment. Contact Ben Thomas at ben.thomas@nmt.edu for more information. The Handbook of Laboratory Safety is a great resource for research and teaching labs.
- Wiley Guide to Chemical Incompatibilities. There are physical copies available in the reference section at Skeen Library, and at the Research Office Building in room 113 by appointment.Contact Ben Thomas at ben.thomas@nmt.edu for more information. Wiley Guide to Chemical Incompatibilities is a great resource for any individual working with or near hazardous chemicals.
- Safety in Academic Chemistry Laboratories, Vol 1. There is a free online version available here. This resource is written for student use.

Appendix L: Phenol First Aid Guide

*Following is a reproduction and explanation of Phenol information, hazards, first aid methods, and personal protective equipment originally prepared and distributed by Cornell University's Environmental Health and Safety Department.

Phenol is a common chemical used for activities such as tissue preservation and DNA/RNA extraction. Phenol can be a component in a commercial reagent (e.g. QIAzol, TRIzol) or prepared as part of a mixture in the laboratory (e.g. chloroform: phenol). Because phenol solutions are an integral part of routine life science applications, their hazards may be taken for granted. Make no mistake about it, however. Phenol can be very dangerous and the hazards are not just those of a typical corrosive.

The hazards of phenol are two-fold. It is both corrosive (can cause severe burns) and toxic (absorbed phenol acts as a systemic toxin). In one case, death resulted from ingestion of as little as 15 mL (pg 12 & 13 of Acute Exposure Guideline Levels). Liquid phenol can penetrate the skin with efficiency approximately equal to that of inhalation. Deaths have been reported for exposures of 25% or more of body surface area. Phenol has an anesthetic effect and can cause severe burns that may not be immediately painful or visible. The threshold concentration of human skin damage from phenol is 1.5%. It can cause permanent eye injury, blindness and scarring.

Recommendations are that laboratories working with phenol use polyethylene glycol 300 or 400 (PEG-300 or PEG-400), rather than water, for immediate first aid treatment of dermal exposures. In addition, all laboratory groups using phenol should take the need for appropriate personal protective equipment (PPE) seriously and require its use as part of the laboratory operations when using phenol and documented in the Standard Operating Procedures (SOPs). This document can be added as a supplement to existing phenol SOPs.

Symptoms of Phenol Exposure

The most common route of occupational exposure for phenol is skin contact and absorption. Phenol does not readily form a vapor at room temperature and is unlikely to pose an inhalation hazard unless it is heated or misted. Additionally, it has a distinct, sweet, acrid, odor that is detected by most people at levels well below the OSHA airborne permissible exposure limit (PEL).

Phenol burns and intoxications can be life-threatening. Symptoms include:

- **Eye Contact:** Severe irritation, permanent damage, blindness.
- **Inhalation:** Respiratory irritation, sore throat, headache, and shortness of breath.
- Ingestion: Phenol is very toxic; death can occur rapidly following ingestion. Symptoms include irritation, swelling, burns and damage to the mouth, throat and stomach, internal bleeding, vomiting, diarrhea, decreased blood pressure, shock, collapse, coma and death.
- **Skin Contact:** Initial exposure can cause numbness or slight tingling, so contact may not be immediately apparent. However, even minor contact can result in burns, blisters, and permanent skin damage. Absorption of phenol through skin can result in phenol toxicity

with symptoms including muscle weakness, tremors, loss of coordination, shock, sudden collapse, coma, convulsions, organ damage and death. When phenol contacts the skin, a white covering of precipitated protein forms. It soon turns red and eventually sloughs off, leaving the surface stained slightly brown. If phenol is left on the skin, it will penetrate rapidly and lead to cell death and gangrene.

Exposure Control and Personal Protective Equipment

- **Emergency Showers and Eyewashes:** Any laboratory using phenol (or any corrosive/caustic chemical) must have an emergency eyewash station accessible within 10 seconds and located in the same room the hazard is being used. Emergency showers must be accessible within 10 seconds and can be located within the room or in the hallway.
- **Administrative Controls:** Never work alone when using phenol. Procedures requiring the use of phenol should have written safety SOPs associated with them, including the location of emergency equipment.
- **Engineering Controls:** Phenol must be used in a fume hood when working with stock solutions and making formulations and dilutions. Even when working with small amounts of dilute phenol, the best practice is to work in a fume hood because of the splash protection the sash provides and the ability of the hood to contain emissions especially in the event of a spill.
- **Eye/Face Protection:** Eye protection is required when working with phenol. Chemical splash goggles are best practice and a face shield (in addition to goggles) may also be necessary, depending on concentration and amount. Safety glasses can be worn if working with small quantities of phenol in a fume hood with the sash properly positioned to provide splash, spray and mist protection. Consider that small facial burns caused by splatter may not be life threatening but can result in permanent scarring/disfigurement
- **Skin Protection:** Lab coat, long sleeves, impervious full foot/closed toe shoes and long pants at a minimum. If body splash potential exists, wear a butyl rubber or neoprene apron.
- **Hand Protection:** Hand protection needs to be selected based on projected use (concentration and exposure). For working with phenol at concentrations >70%, butyl rubber, Viton, Barrier and Silver Shield gloves provide good resistance. Neoprene and polyvinyl alcohol are suitable for short term work (resistance to breakthrough within 1-4 hours) but should be thicker than 0.3 mm (11.8 mil).

  Thin disposable gloves are generally for splash protection only and should immediately be removed if phenol gets on them. Ansell recommends "NeoTouch®" (neoprene) or DermaShield (proprietary poly-chloroprene blend) for splash protection when working with 10% phenol solutions. A good practice is to use a heavy weight disposable (0.2 mm; 8 mil) and double glove. In general, nitrile is not recommended as a material of choice when working with phenol.

    - **Chloroform and Phenol Mixtures:** Phenol is often used in combination with chloroform in nucleic acid purification procedures. Unfortunately, chloroform rapidly degrades both neoprene and nitrile. Ansell has recently developed a relatively thin glove (ChemTek® 380214T) consisting of a 4 millimeter outer layer of Viton® rubber over a 4 millimeter layer of butyl rubber which provides >90 minutes breakthrough resistance to chloroform/phenol solutions. The request to develop this glove was initiated by the University of California, San Francisco as a result of a phenol/chloroform laboratory accident.

The gloves demonstrated below (Viton Butyl) may be purchased from VWR, and although they are more expensive than nitrile, they may be reused after incidental contact (always inspect them before use and discard if holes are evident or contamination is apparent).

First Aid

- **Eye:** Rapid and immediate decontamination is critical. Flush with copious amounts of water using the emergency eyewash for at least 15 minutes, lifting eyelids occasionally. Remove contact lenses if easily removable without additional trauma to the eye. Do not interrupt flushing. Get medical attention immediately
- **Inhalation:** Remove to fresh air. Get medical attention immediately.
- **Ingestion:** Do not induce vomiting. If the victim is conscious and able to swallow, give 4-8 oz (1 c) of milk or water. Get medical attention immediately. Never give anything by mouth to an unconscious person or while in the laboratory.
- **Skin Contact:** Rapid and immediate skin decontamination is critical to minimize phenol absorption. Anyone assisting the victim should wear protective clothing and gloves.
    - **Small Exposures:** Rapidly remove contaminated clothing (including anything leather like belts or watch bands) and either irrigate or wipe exposed areas immediately and repeatedly with low-molecular-weight polyethylene glycol (PEG 300 or PEG 400). Treatment should be continued until there is no detectable odor of phenol. If PEG is not available, a glycerin solution can be used instead. If neither of these are available, irrigation with a source of high-density drenching water (such as an emergency shower) will reduce phenol uptake, but lesser amounts of water will merely dilute the phenol and expand the area of exposures.

If using the shower or other, shower for at least 15 min.

- **Large Exposures:** First aid treatment is similar to that for small exposures except the amount of surface area to be decontaminated must be considered. If the amount of phenol on the skin is more than can be quickly removed by swabbing or irrigating with PEG, then an emergency shower should be used and 911 should be called immediately. A high-density shower is preferable to reduce phenol uptake. Lesser amounts of water will merely dilute the phenol and expand the area of exposure. If possible, use PEG after the initial decontamination. Otherwise, the victim should stay in the shower until the emergency responders arrive to provide assistance.

For any exposure, double-bag contaminated clothing and personal belongings. Get medical attention. Even if the exposure is small, it is still important to be evaluated by a medical professional to determine if follow-up treatment is necessary.

Phenol First Aid Kit

Laboratories that use phenol are advised to assemble a kit for first aid treatment of dermal exposure. The kit should be located in a visible area where the phenol work is being done (for instance, in the fume hood), or nearby with the location clearly posted. The principal investigator or laboratory manager should train all persons working with phenol on how to respond to a phenol exposure and how to use the kit.

Research Compliance recommends a simple kit that can fit in a plastic zip-lock bag that laboratories can assemble themselves. Included in the kit is a 500 mL bottle of PEG 300 or PEG 400. Pharmaceutical grade (USP or NF) PEG is recommended and available from most chemical suppliers. A 500 mL bottle is meant to treat small areas of exposure, such as might occur when using DNA/RNA extraction kits. For work involving larger amounts of phenol, contact Research Compliance for help designing a kit and a response plan suitable for the amount of phenol being used.

The recommended contents of the kit and instructions for use are listed below (the list of the contents of the kit can be taped to the outside of the large zip lock bag while the instructions for use should be kept in the bag). Date the bag with the expiration date of the PEG and replace the bottle when it expires (use the opportunity to inspect the integrity of the other items in the kit, such as gloves, and replace as necessary).

Contents

Phenol Skin (Dermal) Exposure First Aid Kit:

- Pre-packaged gauze pads, 4” x 4” (~10)
- Polyethylene Glycol 300 or 400, 500 mL (~ 1 pint) USP or NF
- Silver Shield gloves (1-2 pairs)
- Instructions for use
- Small plastic bag (for collecting waste gauze pads)
- Large plastic zip lock bag big enough to hold items above

Instructions Phenol Skin (Dermal) Exposure First Aid
Emergency Numbers:

- NMT Campus Police: 5555 from a Campus phone, 575-835-5555 from a cell phone or off-campus phone.
- NMT Hazardous Materials and Laboratory Safety Specialist: 575-517-0646
- Poison Control: 1-800-222-1222

NOTE: This procedure is NOT for eye exposure. For eye exposure, flush with water in an eyewash station for at least 15 minutes and call 911 immediately.

1. Remove contaminated clothing, including any leather items such as watch bands or belts.
2. Put on safety glasses and silver shield gloves (but don't put on the gloves if you are treating yourself and your hands are contaminated with phenol).
3. Open up a few packages of gauze pads.
4. Pour polyethylene glycol liberally on to one of the gauze pads.
5. Gently wipe off excessive phenol on the exposed area. Discard the gauze pad in the small plastic bag in the kit.
6. Take a new gauze pad, add polyethylene glycol, and continue to clean off the exposed area. Discard the pad. Repeat with a new gauze pad and application of polyethylene glycol until all visible traces of phenol have been removed from the skin.
7. Continue to gently wipe skin (do not scrape or irritate the affected skin area) with polyethylene glycol soaked gauze pads until no odor of phenol remains, changing the gauze pad frequently.
8. Follow-up: Even if you feel it is unnecessary to get emergency help, please go for evaluation to determine if follow-up treatment is necessary. Don't forget to fill out an NMT Lab Incident/Near Miss Report.
9. Double bag any contaminated clothing. Label both the bag and the small zip-lock

bag for collecting the used gauze wipes as “Hazardous Waste – Phenol Contamination”. Contact hazmat@nmt.edu for proper disposal.
10. Replace the contents of the kit with new, unused items

References

Agency for Toxic Substances and Disease Registry Medical Management Guidelines for Phenol.

Monteiro-Riviere, N. A., A. O. Inman, H. Jackson, B. Dunn and S. Dimond. 2001. Efficacy of topical phenol decontamination strategies on severity of acute phenol chemical burns and dermal absorption: in vitro and in vivo studies in pig skin and Industrial Health. Toxicology and Industrial Health. 17:95-104

Appendix M: Information on Methylene Chloride (Dichloromethane, DCM)

On April 30th 2024, The Environmental Protection Agency finalized a rule to mitigate the unreasonable risk of injury to health of methylene chloride, a dangerous chemical known to cause several kinds of cancer as well as other health hazards.

The following links provide information on methylene chloride and how research and academic laboratories will be affected by the new ruling.

- New Jersey Department of Health Right to Know Hazardous Substance Fact Sheet
- NIOSH Methylene Chloride Hazards for Bathtub Refinishers
- A Guide to Complying With the 2024 Methylene Chloride Regulation Under the Toxic Substances Control Act (TSCA)
- Methylene Chloride Safety Data Sheet (SDS)
- How the EPA Ban of Methylene Chloride Will Impact Laboratories
- What the Dichloromethane Ban Might Mean for University Labs in the US
- Federal Register Methylene Chloride; Regulation Under the Toxic Substances Control Act (TSCA)
- Final Risk Evaluation for Methylene Chloride
- What Does the New EPA Methylene Chloride Rule Mean for Academic Labs?
- Biden-Harris Administration Finalizes Ban on Most Uses of Methylene Chloride, Protecting Workers and Communities from Fatal Exposure

Appendix N: Regulations Governing Satellite Accumulation Areas

Hazardous waste on the New Mexico Institute of Mining and Technology campus is to be placed in a Satellite Accumulation Area (SAA) at or near the location where the hazardous waste is generated.

The following is information regarding SAA regulations:

Regulations Governing Satellite Accumulation Areas

RCRA (40 CFR 262)

Waste is accumulated at or near the point of generation under the control of the operator	262.15(a)
Container/s have less than 55 gallons of HW	262.15(a)
Container/s have less than 1 qt/1Kg of acutely hazardous waste	262.15(a)
Container/s are in good condition and non-leaking	262.15(a)(1)
Waste is compatible with the container it is stored in	262.15(a)(2)
Only compatible wastes are accumulated in each container and the container is separated from nearby incompatible materials	262.15(a)(3)
Container is closed except when adding, removing, or consolidating waste or when temporary venting is necessary	262.15(a)(4)
Container is marked with the words “Hazardous Waste” and an indication of the hazards of the contents	262.15(a)(5)
Satellite area complies with all preparedness and prevention requirements noted below	262.15(a)(8)
Area is maintained to prevent fire, explosions, and spills	262.16(b)(8)(i)
Area must be equipped with: 1.Internal communications to signal emergency to facility personnel 2. Communication device to alert local emergency response personnel 3. Fire extinguishers, spill control equipment, and decontamination equipment 4. Fire suppression, adequate water supply or foam producing equipment	262.16(b)(8)(ii)
Testing and maintenance of equipment	262.16(b)(8)(iii)
Immediate access to communication equipment when handling hazardous waste	262.16(b)(8)(iv)
Adequate aisle space	262.16(b)(8)(v)
Emergency information posted next to telephones or in areas directly involved in the generation and accumulation of hazardous waste.	262.16(b)(9)(ii)