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### Appendices

- Chemical Hygiene Plan Definitions
- SOP Template
- Example SOP
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- Lab Specific Training Documentation
- Laboratory Assessment Checklist
- Partial List of Chemical Incompatibilities
- Partial List of Particularly Hazardous Substances
Chapter 1
Purpose, Scope, and Responsibilities

Purpose
The purpose of the UNR Chemical Hygiene Plan (CHP) is to establish policies and procedures that when implemented will minimize risks to personnel, facilities, and the environment that arise from laboratory chemical use. These policies and procedures are based on currently accepted good laboratory safety practices in place at academic, government, and industrial research laboratories. Additionally, the CHP is designed to comply with the OSHA Standard (29 CFR 1910.1450), Occupational Exposure to Hazardous Chemicals in the Laboratory, commonly referred to as the OSHA Lab Standard. Laboratories that utilize biological agents and/or radioactive material should refer to the UNR Biosafety Manual and Radiation Safety Manual, respectively.

Scope
The CHP applies only to laboratories; however, it is applicable to all laboratories that utilize chemicals, regardless of the area of research or laboratory activity. For example, research and teaching laboratories that utilize hazardous chemicals are examples of workplaces where the CHP is applicable. Storerooms and stockrooms that stock and supply chemicals in direct support of laboratory operations are also within the scope of this CHP. Non-laboratory workplaces that use or store hazardous chemicals fall under the scope of the UNR Hazard Communication Program, for example: crafts shops, printing shops, and photo labs.

Responsibilities
Laboratory Safety Committee
The Laboratory Safety Committee (LSC) provides guidance and administrative oversight related to broad laboratory safety issues associated with UNR laboratories. The LSC considers all environmental health and safety risks associated with UNR laboratory activities that arise from chemical, biological, radiological, and physical hazards; however, radiation safety and biological safety issues are the primary responsibility of the Radiation Safety Committee and the Institutional Biosafety Committee, respectively.

The LSC is responsible for development of university policies and administrative oversight of laboratory activities. Specific responsibilities of the LSC include:

- Advise the Vice President for Research and Innovation (VPRI) on matters related to laboratory safety.
- Develop, recommend, and oversee policies and procedures for management and reduction of laboratory risks throughout the University.
- Oversee broad laboratory safety issues and regulatory compliance associated with laboratory research and teaching, to include review of assessments of laboratory environmental health and safety issues.
As requested by EH&S or the VPRI, make recommendations on facility design features, laboratory ventilation, utilities, equipment, and services necessary to conduct high quality laboratory teaching and research while minimizing risks. Both “typical” laboratory operations and unique laboratory operations should be considered. Recommendations should include financial and operational responsibilities, including design, construction, purchase, installation, maintenance and repair, and testing and calibration services.

As requested, advise and provide technical expertise on matters regarding laboratory safety to EH&S staff or other members of the UNR community.

Review reported laboratory safety incidents such as personnel exposures, hazardous materials spills, and fires, and provide recommendations to responsible laboratory supervisors and administrators to prevent similar occurrences.

Conduct investigations of serious violations of regulations or university policy, incidents, or operational problems, and make recommendations to the VPRI, Provost, and other appropriate university administrators for the resolution of continued non-compliance or serious infractions.

As an agent of the University, the LSC can recommend to the VPRI that authorization to conduct laboratory activities be suspended or cancelled when training and/or experience, or laboratory facilities and equipment, is deemed inadequate, or in the event of continued non-compliance or serious infractions.

Environmental Health and Safety Department
The Environmental Health and Safety Department (EH&S) is an administrative unit that reports to the Vice President for Research and Innovation. EH&S has responsibility for development and implementation of UNR environmental health and safety policies. A member of the EH&S staff is designated as the University Chemical Hygiene Officer (CHO). Responsibilities of the University CHO include:

- Administering and implementing the UNR CHP.
- Assisting laboratory supervisors in development and implementation of laboratory-specific CHPs and work practices.
- Ensuring that appropriate laboratory assessments are conducted to ensure implementation of this program.
- Reviewing the UNR CHP at least annually.
- Determining if exposure monitoring is necessary.
- Determining if medical surveillance is necessary.
EH&S Chemical Hygiene Contacts

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<tr>
<th>Contact</th>
<th>Phone</th>
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<tr>
<td>Environmental Health &amp; Safety Department</td>
<td>327-5040, answered 24 hrs.</td>
<td></td>
</tr>
<tr>
<td>Ben Owens, University CHO</td>
<td>327-5196</td>
<td><a href="mailto:bowens@unr.edu">bowens@unr.edu</a></td>
</tr>
<tr>
<td>Chet Carpenter, Senior Laboratory Safety Specialist</td>
<td>784-4342</td>
<td><a href="mailto:chestonc@unr.edu">chestonc@unr.edu</a></td>
</tr>
<tr>
<td>Kristin Eliasen, Laboratory Safety Specialist</td>
<td>327-5192</td>
<td><a href="mailto:jkristin@unr.edu">jkristin@unr.edu</a></td>
</tr>
<tr>
<td>Luis Barthel-Rosa, Manager, Chemical Management Services</td>
<td>327-2270</td>
<td><a href="mailto:luisbr@unr.edu">luisbr@unr.edu</a></td>
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Academic Departments and Other Administrative Units
The Chair of each academic department (or other administrative unit) has responsibility for environmental health and safety issues within the department. It is the Chair’s responsibility to ensure that department faculty understand their laboratory safety responsibilities and are committed to implementation of the CHP in research labs and teaching labs. To facilitate this process, it is recommended that each department appoint a safety representative or form a department safety committee.

Each Department is responsible for:

- Implementing this CHP in department laboratories, including development of Standard Operating Procedures (SOPs) and specific laboratory safety training.
- Participating with EH&S in developing an emergency response plan for the Department that is compatible with the University model.
- Participating (with EH&S) in health and safety assessments of department laboratories (and other facilities).
- Reporting laboratory and environmental incidents (e.g., injuries, illnesses, fires, explosions, and release of chemicals to the environment) to EH&S in a timely manner. Incidents requiring immediate response should be reported as soon as possible, including during non-business hours, via the EH&S 24-hour contact number (327-5040). Incidents not requiring immediate response and deemed to be minor should be reported the next business day. Departments are responsible for investigating the cause of each incident and providing a report of the investigation findings to the CHO.
- Informing the Facilities Services Department and/or EH&S of any unsafe conditions, including deficiencies in safety equipment. Anytime safety issues are submitted to, or resolved by, Facilities Services, EH&S should be notified.
- Promoting good environmental health and safety practice in the department.
Laboratory Supervisors

Laboratory Supervisors are responsible for the health and safety of all personnel working in their laboratory (research labs and teaching labs). The UNR CHP serves as a vehicle for improving laboratory safety. Laboratory supervisors are responsible for implementing the UNR CHP in their lab(s); however, specific duties required to meet this obligation can be delegated. Specific responsibilities include:

- Ensuring that all laboratory personnel receive documented training on the specific health and safety hazards to which they are exposed, and that personnel are competent to perform their assigned work. A training documentation form is available as an appendix to this document; however, other formats may be used. This training must communicate laboratory hazards, methods, procedures, and equipment required to work safely in the laboratory, proper emergency response actions, and when and how to obtain treatment for workplace illness or injury.

- Developing written standard operating procedures (SOPs) that address health and safety concerns associated with laboratory operations that involve hazardous chemicals (see Chapter 3).

- Ensuring that Safety Data Sheets (SDSs) and other sources of chemical hazard information are available to laboratory workers, and that workers know how to access this information.

- Upon request from authorized personnel, communicate information regarding hazards and necessary safe work practices to authorized laboratory visitors, including: other laboratory personnel, maintenance workers, custodians, and vendors.

- Provide supervision of laboratory personnel at a level commensurate with the education, experience, and competence level of the personnel. In the event of an extended absence, the Laboratory Supervisor should arrange for a qualified alternate to provide supervision of laboratory operations (generally this will be another qualified faculty member or an experienced member of the research group).

- Ensure that personal protective equipment and any project-specific safety equipment are available, in proper working order, and appropriate for the laboratory and the work being conducted.

- Implement and enforce preventative measures to control hazards and minimize risks to personnel. This includes complying with regulations, University and Departmental laboratory safety policies, and prudent laboratory safety practices.

- Promote environmental health by maintaining compliance with environmental regulations, including minimization and proper management of hazardous wastes, reduction of laboratory water and air effluent, and prudent management of hazardous materials inventories.
• Take active steps to identify laboratory safety deficiencies and ensure remediation. Such deficiencies include those identified during laboratory safety inspections, as described in the UNR Laboratory Safety Assessment Program Policy. This policy also requires that Laboratory Supervisors organize and conduct internal, documented, self-inspections at least annually each year. A sample checklist for laboratory inspections is included in the Appendices. It is recommended that laboratory supervisors tailor checklists for specific activities and hazards.

• Ensure that any deficiencies in facility-associated safety equipment, including laboratory fume hoods, safety showers/eyewashes, fire extinguishers, and emergency egress lighting are reported to the Facilities Services Department for remediation.

• Ensure that laboratory-related injuries and illnesses are reported to the Worker’s Compensation Office, EH&S, and the responsible Department Chair, and necessary forms are filed according to current policy. Similarly, incidents such as fires, explosions, and release of chemicals to the environment are to be reported to EH&S and the responsible Department Chair.

• Implement procedures to avoid hazards resulting from the departure of laboratory personnel. Ensure that departing personnel properly label and store, or dispose of, all chemical solvents, chemical waste, research samples, etc.

**Laboratory Workers**

All laboratory workers (employees and students) are directly responsible for their own safety. Unsafe acts performed by one individual can affect (directly or indirectly) the safety and work productivity of others. Personnel who have health or safety concerns should contact their supervisor and/or EH&S, and should not perform the work until they are confident their concerns have been adequately addressed. Specific responsibilities include:

• Knowing how to access the Chemical Hygiene Plan (this document) and being knowledgeable of requirements and procedures contained in the Plan.

• Conducting all laboratory activities in accordance with the UNR CHP and laboratory-specific standard operating procedures.

• Participating in required training.

• Utilizing engineering controls, safety equipment, and personal protective equipment in an appropriate manner.

• Informing the laboratory supervisor of any safety, health, or environmental incidents and unsafe conditions, including deficiencies in safety equipment.
Chapter 2
General Laboratory Safety

Housekeeping
An unorganized, cluttered laboratory increases the likelihood of chemical spills and splashes due to tripping or knocking over chemical containers. Safety equipment such as fire extinguishers, safety showers, and eyewashes can prevent or minimize harm to personnel; however, they are ineffective if access is blocked. Organize your laboratory so that clear walkways are provided, with designated storage areas for chemicals and hazardous waste; avoid clutter that can prevent access to safety equipment or which can lead to chemical spills or other mishaps.

Laboratory Assessments
EH&S will perform periodic health and safety assessments of chemical laboratories and chemical storerooms. The goal of these assessments is to identify areas where laboratory safety can be improved. Laboratory assessments are most effective when the laboratory supervisor and other laboratory workers participate with EH&S. Written recommendations resulting from these assessments will be given to the laboratory supervisor and Department Chair.

Laboratory Self-Assessments
Each individual laboratory should perform self-assessments of their laboratory at least once per year. A lab assessment checklist is available to assist in this process. The purpose of this self-assessment is to allow each laboratory to self-identify and correct safety and health weaknesses. A record of these laboratory self-assessments should be maintained to document the findings and corrective actions, and so that reoccurring problems can be identified.

Personal Chemical Hygiene
Good personal chemical hygiene habits minimize chemical exposure. Consuming food and beverages in laboratories or chemical storage areas is not permitted since this practice increases the likelihood of chemical exposure by ingestion. For the same reason, do not store food or beverages in laboratories (including refrigerators) or chemical storage areas. Washing your hands frequently will minimize chemical exposure through ingestion and direct contact with the skin. Always wash hands before eating, drinking, smoking, or applying cosmetics.

Basic Chemical Handling Procedures
• KNOW THE HAZARDS OF THE CHEMICALS YOU ARE WORKING WITH! Consult the Safety Data Sheet (SDS) or other appropriate references prior to using a chemical with which you are unfamiliar (see Chapter 15).

• Minimize exposure to all chemicals regardless of toxicity or their familiarity. Most laboratory chemicals have not been fully characterized with respect to their toxicity; therefore, it is prudent to implement procedures that will reduce the likelihood of exposure. Skin contact should always be avoided. Avoid inhalation of chemicals; never "sniff" to test chemicals.
• Wear appropriate eye protection at all times. **At a minimum, safety glasses are required whenever operations involving chemicals are being performed.**

• Minimize chemical exposure through consistent and proper use of **laboratory hoods** and **personal protective equipment**.

• Communicate with others in the building when working alone in the laboratory; let them know when you arrive and leave. Avoid working alone in the laboratory when handling hazardous chemicals, carrying out chemical reactions, or performing other higher risk operations.

• Use cautious judgment when leaving unattended operations: i) post signs to communicate appropriate warnings and precautions, ii) anticipate potential equipment and facility failures and implement mitigative measures, and iii) provide containment and/or shielding for release of hazardous chemicals.

• Assume that unknown materials are toxic, and that a mixture is more toxic than its most toxic compound.

• Know the location and proper use of emergency equipment, such as safety showers and fire extinguishers, and maintain clear access to this equipment.

• Do not use mouth suction for pipetting or siphoning.

• Label all chemical containers with the identity of the contents; primary hazards and chemical concentration must also be included on long term secondary containers.

• Use appropriate safety carriers (secondary containment) when transporting chemicals either inside or outside of the building.

**Prior Approval of Operations**

Each laboratory supervisor should identify operations that require their prior approval before the procedure is initiated. The designated operations will normally be those non-routine operations that are higher risk; however, more routine operations can also be included. Some situations that should be considered for prior approval include:

- A new laboratory procedure that represents greater than routine risk (especially if it differs substantially from procedures already in use).
- New work involving **particularly hazardous substances**.
- Operations where it is likely that there will be significant exposure to a chemical or other hazard (biological, physical, etc.).
- There is a procedural change that significantly increases the overall hazard of the procedure.
- Unattended operations that represent significant likelihood of fire, explosion, or exposure to personnel if a malfunction were to occur (such as a utility outage, runaway reaction, or chemical spill).
Operations that require prior approval should be documented in laboratory-specific standard operating procedures. It is also recommended that approval by the laboratory supervisor be documented through the use of a dedicated “prior approval” form or an entry in a research notebook.

**Laboratory Entrance Signs**
The entrance to each laboratory or chemical storage area must be posted with the name and phone number (office phone number and after-hours number) of the laboratory supervisor, with designation as the primary emergency contact. If there is another faculty (academic or administrative) member who is knowledgeable of laboratory operations, that individual can be listed as an alternate emergency contact, along with his or her office phone number and after-hours phone number. If an alternate emergency contact is not available, EH&S will be listed. Entrance signs must also provide hazard information related to chemicals stored in the room.

EH&S maintains entrance signs for each laboratory that indicate the primary and secondary emergency contacts, chemical hazard information, and other emergency information. Contact one of the EH&S chemical hygiene contacts listed in Chapter 1 to request an entrance sign or to update the entrance sign for your laboratory.
Chapter 3
Written Standard Operating Procedures

Written Procedures
Written Standard Operating Procedures (SOPs) relevant to health and safety concerns are required for laboratory operations involving hazardous chemicals. This document contains SOPs covering various chemical hazards. Laboratory supervisors are responsible for developing additional laboratory-specific SOPs that cover the hazards present in their laboratory. The laboratory-specific SOPs should supplement, rather than duplicate, the general SOPs contained in this document. A risk-based approach should be used to identify laboratory-specific SOP topics. These SOPs should target the use of carcinogens and reproductive toxins, and highly acutely toxic chemicals (see Chapter 9), frequently performed procedures, and chemicals that are used frequently or in relatively large amounts. SOPs for higher risk, non-chemical hazards should also be developed.

Laboratory-specific SOPs are an important component of the laboratory-specific CHP and are to be included in the each laboratory’s written program. All laboratory SOPs must be approved by the laboratory supervisor. Both an SOP template and an example SOP are available to assist laboratories in preparing their own SOPs. The following links provide additional examples of SOPs that have been developed at other institutions. These example SOPs can be used to develop SOPs for UNR laboratories but they must be customized so that they are directly applicable to the UNR laboratory for which they are intended, and fully compatible with this Plan and UNR policies.

- University of California, Los Angeles SOP Library (SOPs for many individual chemicals)
- University of California, Irvine SOPs (many examples)
- Ohio State University, Department of Chemistry: multiple example SOPs.
- Michigan State University SOP guidance and multiple SOP templates)
- University of Pennsylvania: Flammable and Combustible Liquid Storage and Dispensing (example of good use of photos and diagrams)
- University of California, Davis, Department of Chemistry, Osterloh research group SOPs (several examples)

SOPs can be incorporated into lab protocols or they can be written as separate documents. The format of the SOPs can vary depending on need. For example, the scope of an SOP can cover:

- The generic use of a specific chemical or class of chemicals with similar hazards (for example, mineral acids).

- The specific use of a chemical or class of chemicals (such as a specific laboratory procedure).

- A generic procedure (such as distillation) that covers several chemicals.
Regardless of the format, the following issues should be addressed in lab procedures or SOPs:

- Describe the procedure and identify the chemicals to be used (as well as any reaction products or intermediates that are of concern).

- Identify and evaluate health and physical hazards associated with the procedure (for example, reactivity, flammability, routes of exposure, toxicity, target organs, and health effects).

- Identify workers that may be susceptible to any of the chemicals used (such as pregnant workers when teratogens are to be used).

- Select appropriate control methods for the identified hazards (Chapter 12 and Chapter 13).

- Prepare for contingencies such as spills or unexpected reactions (Chapter 19).

- Provide for safe storage and disposal of chemicals (Chapter 16 and Chapter 20).
Chapter 4
Safe Handling of Flammable and Combustible Liquids

Flammable and Combustible Liquids
The International Fire Code and the National Fire Protection Association define flammable and combustible liquids according to their flash point, with flammable liquids having a flash point of less than 100 °F (38 °C) and combustible liquids having a flash point greater than 100 °F (38 °C). It should be pointed out, however, that the Globally Harmonized System for classifying and labeling chemicals that has been incorporated into the OSHA Hazard Communication Standard defines all liquids with a flash point of less than 200 °F (93 °C) as flammable, with an assigned numerical hazard rating to indicate the specific hazard level (see Chapter 15).

Both flammable and combustible liquids are considered fire hazards. The following procedures should be implemented in order to reduce the fire risk associated with these materials.

- Flammable chemicals should be used only in lab hoods (or other well ventilated areas) and away from sources of ignition. Similarly, combustible chemicals should not be used near ignition sources, and it is recommended that they be used in lab hoods whenever possible.
  - Flash point is directly dependent on the total (system) pressure with the flash point at reduced pressures being lower than at ambient pressure. Flash point values reported in the literature should be considered to be determined at ambient conditions unless specified otherwise.

- Do not heat flammable chemicals with an open flame.

- For highly flammable chemicals, static electricity or hot surfaces can serve as ignition sources.
  - Do not use electrical devices with cracked or frayed electrical wiring.

- Transfer flammable liquids from containers of five gallon-capacity or less inside a laboratory hood (or other area with similar ventilation) to prevent accumulation of a flammable concentration of vapors.

- Transfer flammable liquids from containers of greater than five gallon-capacity in a well-ventilated area outside the laboratory building, or in an approved flammable storage room.

- When transferring flammable liquid from a bulk container (generally greater than five gallons), the containers must be electrically bonded and grounded.

- Fire extinguishers appropriate for the fire hazards present must be available in all laboratories and storage areas.
- Class D fire extinguishers must be available in the immediate work area when working with flammable metals such as magnesium, sodium, and potassium.
  - Contact the Fire and Life Safety section of Facilities Maintenance at 784-8020 to inquire about Class D fire extinguishers.
  - When using only small quantities of flammable metals, dry soda lime or sand can be used to smother a fire; however, dry graphite must be used to extinguish lithium fires.

**Storage of Flammable and Combustible Liquids**
Guidelines for the safe storage of flammable and combustible liquids are contained in Chapter 16.
Chapter 5
Highly Reactive Chemicals

General Work Procedures
Highly reactive chemicals include those that have the potential to vigorously polymerize, undergo a vigorous condensation or oxidation-reduction reaction, or become self-reactive due to shock, pressure, temperature, light, or contact with another material. Examples of highly reactive chemicals are explosives, peroxides, water-reactives, and pyrophorics. All work involving highly reactive chemicals should be approved by the laboratory supervisor before initiation of the work.

- Handle reactive chemicals with caution, including segregation in storage and prohibition of mixing even small quantities with other chemicals without consideration of appropriate procedures and use of appropriate personal protective equipment.

- Chemical reactions conducted at temperatures or pressures above or below ambient conditions must be performed in a manner that minimizes hazards such as explosion or vigorous reaction.
  - Provide a mechanism for adequate temperature control and dissipation of excess heat and pressure.
  - Use shielding as appropriate to minimize personnel exposure and injury, and facility damage, resulting from over-pressurization or implosion.

- Minimize the quantity of reactive chemicals used or synthesized to the smallest amount needed.
  - When conducting reactions that involve highly reactive or explosive chemicals, limit the reactants to no more than 0.5 g in the reaction vessel and do not synthesize more than 0.1 g of product in a single run. Exceptions to this must be specifically approved by the laboratory supervisor and appropriate written procedures, training, and mitigation controls must be in place.

- Utilize shields and barricades, and personal protective equipment (such as face shields with throat protectors and heavy gloves) whenever there is a possibility of explosion, implosion, or vigorous chemical reaction.

- Glass equipment operated under vacuum or pressure must be shielded, wrapped with tape, or otherwise protected from shattering.

Organic Peroxides
As a class, organic peroxides are one of the most hazardous chemicals commonly used in the laboratory. Most organic peroxides are sensitive to heat, impact, friction, light and readily react with oxidizing and reducing compounds, and are highly flammable. Since the sensitivity and instability of these compounds vary, always thoroughly review the properties of specific compounds prior to their use.

- Do not use metal spatulas, stirring bars, or other metal items to handle peroxides, as metal contamination can lead to explosive decomposition.
- Avoid friction, grinding, and other types of impact near peroxides (especially solid peroxides).
  - Do not store organic peroxides in glass containers with screw-cap lids or glass stoppers, use polyethylene containers, screw-cap lids, or stoppers.

- After each use, carefully wipe the container neck, cap, and threads with a cloth before resealing.

- Clean up all peroxide spills immediately.

- Contact the CHO for assistance with the disposal of pure peroxides.

**Pyrophoric Chemicals**
The Globally Harmonized System (GHS) of classifying and labeling chemicals that has been adopted by OSHA defines a chemical as pyrophoric if a small quantity of the chemical will ignite within 5 minutes after coming into contact with air. Of particular concern are liquid or gaseous chemicals which very rapidly (immediately) ignite upon exposure to air as they represent the greatest risk for fire and injury to personnel. Additionally, some chemicals that are classified as water reactive can react with water vapor in ambient air to produce flammable gases, which can ignite. For practical laboratory safety purposes, these water reactive chemicals can be grouped with pyrophoric, air-reactive chemicals.

Because of the unique fire risk presented by pyrophoric chemicals, their use requires special handling procedures to avoid contact with air. Laboratories that possess or use pyrophoric chemicals require written SOPs that provide specific guidance on storage, use, and disposal of these chemicals. Additionally, all personnel who handle pyrophoric chemicals must be specifically trained on safe handling procedures and this training must be documented.

**Examples of Pyrophoric Chemicals**
- Grignard Reagents: RMgX (R=alkyl, X=halogen)
- Metal alkyls and aryls: Alkyl lithium compounds; tert-butyl lithium
- Metal carbonyls: Lithium carbonyl, nickel tetracarbonyl
- Metal powders (finely divided): Cobalt, iron, zinc, zirconium
- Metal hydrides: Sodium hydride
- Nonmetal hydrides: Diethylarsine, diethylphosphine
- Non-metal alkyls: R₂B, R₃P, R₃As; tetramethyl silane, tributyl phosphate
- Phosphorus
- Potassium
- Sodium
- Gases: Silane, dichlorosilane, diborane, phosphine, arsine)


**Hazards**
The propensity of pyrophoric chemicals to spontaneously ignite on contact with air and/or water...
represents a high fire risk and requires that they be handled under an inert atmosphere. Strict exclusion of air and/or water requires use of an inert atmosphere glove box and/or special handling techniques. Other hazards may also be associated with pyrophoric chemicals, to include physical hazards such as corrosivity, water reactivity, and formation of peroxides. Pyrophoric chemicals are also generally toxic and health hazards may include liver, kidney, and central nervous system toxicity.

Before Working With Pyrophoric Chemicals

- All personnel who handle pyrophoric chemicals must receive documented laboratory-specific training on the chemicals they will use and the procedures that they will perform. Each individual must demonstrate proficiency in handling pyrophoric chemicals and performing the procedures to be conducted, as appropriate for the particular chemical(s) and procedure(s). Conduct of this training and evaluation of personnel proficiency is the responsibility of the PI; however, these tasks can be delegated to a qualified designated alternate.

- Review Safety Data Sheets, technical bulletins, and other hazard information to identify and understand hazards and risk mitigation procedures. Sigma-Aldrich Technical Bulletin AL-134, Handling Air-Sensitive Reagents, is a widely used reference that should be reviewed by all personnel who use liquid pyrophoric chemicals. Sigma-Aldrich Technical Bulletin AL-164, Handling Pyrophoric Reagents, should also be reviewed prior to working with liquid pyrophoric chemicals.

- Prepare a written SOP that includes procedures for safe storage, use, experimental set up and equipment, disposal, and incident response (fire, etc.) so that associated risks are controlled to a level that is considered to be safe.

- Review any proposed changes to laboratory procedures with the PI or other designated knowledgeable person before implementation. Consider the potential for changes to introduce new hazards or increase risks (e.g., scale up of reactions, change of reactants or reaction conditions) and use appropriate methods to mitigate new hazards or increased risks.

- Consider performing a “dry run” of new procedures involving pyrophoric chemicals to help identify overlooked handling issues or hazards, and to increase users’ proficiency.

Engineered Controls and Safety Equipment

- When available and practical, use an inert atmosphere glove box when handling pyrophoric chemicals.

- When an inert atmosphere glove box is not available or practical, handle pyrophoric chemicals in a chemical lab hood. Pyrophoric chemicals are commonly mixed with flammable solvents or used with flammable solvents, and a lab hood is necessary to exhaust flammable vapors and reduce the likelihood of fire.

- An appropriate fire extinguisher must be readily available in the work area where pyrophoric
chemicals are used. An ABC (standard dry powder) extinguisher is required when using pyrophoric chemicals in flammable solvents. A class D extinguisher is required when using solid pyrophoric metals. Do not use a carbon dioxide extinguisher or water to extinguish a fire involving pyrophoric materials since they can enhance the combustion of some pyrophoric materials. If you are expected to use a fire extinguisher to fight a fire you must complete fire extinguisher training annually.

- Dry soda lime or sand can be used to cover and extinguish small fires resulting from drips or small spills of pyrophoric chemicals or at ends of syringes used to transfer pyrophoric chemicals. Sand should not be used to extinguish lithium fires but dry graphite can be used.

- A working and accessible emergency eye wash and shower must be readily available.

**Personal Protective Equipment**

- Use safety glasses or goggles as appropriate for the chemicals being used and their quantity. Wear a face shield, worn over safety eyewear, whenever there is a risk of explosion or large chemical spray or splash.

- Wear chemical resistant gloves appropriate for the pyrophoric chemical, or in the case of a pyrophoric chemical in solvent, gloves that are appropriate for the solvent. For labs that routinely handle pyrophoric chemicals outside of an inert atmosphere glove box, Nomex pilot gloves are strongly recommended where their use does not increase the risk due to reduced dexterity or other factors. If working with a high toxicity chemical that readily absorbs through skin, the proper chemical resistant glove can be worn underneath (gloves made of nitrile material are generally recommended).

- Flame resistant lab coats should be worn and ideally be made of Nomex or equivalent fire resistant material. For labs that routinely handle pyrophoric chemicals outside of an inert atmosphere glove box, flame resistant lab coats are required.

- Clothing made of synthetic materials should not be worn when handling pyrophoric chemicals.

**General Safety Procedures**

- Never work alone when handling pyrophoric chemicals; always use the buddy system. Whenever possible, avoid working with pyrophoric chemicals outside of normal university business hours when there are few people around to help in the event of an incident.

- Limit the quantity of pyrophoric chemicals acquired in order to minimize the quantity that must be stored, and use the smallest quantity needed to accomplish the scientific goals.

- Before working with pyrophoric chemicals, remove all unneeded and excess chemicals from the lab hood or other immediate work area, especially flammable/combustible chemicals and common combustible materials (e.g., paper).
Handling Pyrophoric Solids
Solid pyrophoric solids are less reactive upon exposure to air than are liquid pyrophoric chemicals; however, safe handling procedures are still required.

- Many pyrophoric solids can release flammable or toxic gases; therefore, they should be handled in a lab hood.
- Store pyrophoric solids under an inert atmosphere and do not store near heat sources, oxidizers, flammable solvents, or water sources.
- Mildly pyrophoric solids such as dispersions of sodium hydride and lithium aluminum hydride in hydrocarbon solvent can be handled in air for short periods of time. The dry, solid forms must be handled under an inert atmosphere.
- The reactivity of pyrophoric metals (e.g., aluminum, magnesium, alkali metals) is proportional to their surface area, with finely divided shavings or powder reacting very rapidly with air/water.
- Solid pieces of sodium, potassium, and lithium are stored under mineral oil (lithium is also stored under argon) to reduce oxidation to oxides/hydroxides and to reduce pyrophoricity. When stored under oil, these materials should be cut under oil and then transferred to a container with hydrocarbon solvent (e.g., hexane) to rinse off the oil.
- Potassium is more reactive than lithium or sodium and during prolonged storage potassium can undergo oxidation to form a potassium superoxide (yellow) coating. Potassium superoxide is shock sensitive and this coating can explode on handling (especially when cutting solid potassium with superoxide coating).

Additional information on general safe handling procedures for solid pyrophoric chemicals is available in the Pacific Northwest National Laboratory documents, *Handling Pyrophoric Reagents*.

Handling and Transfer of Pyrophoric Liquid Chemicals
- When transferring liquid pyrophoric chemicals outside of an inert glove box, a maximum of 50 ml may be transferred using a syringe equipped with a 1 – 2 foot long needle. Transfer of larger quantities should be performed using a cannula technique.
- Procedures for handling and transfer of liquid pyrophoric chemicals must be in agreement with currently accepted safe laboratory practices. Published information on handling and syringe and cannula transfer techniques is available in the Sigma-Aldrich Technical Bulletin AL-134, *Handling Air-Sensitive Reagents*.

Storage
- During prolonged storage the integrity of pyrophoric chemicals, especially liquids, can be compromised due to loss of solvent, decomposition, or reaction with trace contaminants. The quantity of pyrophoric chemicals acquired should be limited to quantities that will be used in planned experiments in order to avoid prolonged storage.
Pyrophoric chemicals are best stored in an inert atmosphere glove box. If it is not possible to store pyrophoric chemicals in an inert glove box, store pyrophorics in an air-tight container (under an inert atmosphere) in a flammable storage cabinet dedicated to storage of pyrophoric chemicals. Do not store pyrophoric chemicals together with flammable chemicals in the same flammable cabinet.

Store pyrophoric chemicals in their original manufacturer container (e.g., Sure Seal bottles) unless experimental work requires transfer to other containers. Septum tops may leak after perforation so inspect them on a regular basis and replace as needed (using an inert glove box).

Pyrophoric chemicals that require refrigeration must be stored in a refrigerator that is designed and constructed for storing flammable liquids. Pyrophorics should be stored in a dedicated refrigerator, not in a refrigerator that also contains flammable liquids.

For pyrophorics stored in protective solvent, kerosene, or oil, check on a regular basis to ensure that there is sufficient liquid.

Do not return pyrophoric chemicals to the original storage container as small quantities of impurities can cause fire or explosion.

Store all liquid pyrophoric chemicals in secondary containers.

Disposal

Unused pyrophoric chemicals and laboratory equipment contaminated with pyrophoric chemicals must be hydrolyzed to non-pyrophoric products as part of each experiment. The end products must then be collected as chemical waste in a properly labeled waste container for disposal through EH&S.

Emptyed containers of liquid pyrophoric chemicals must be triple rinsed with an inert dry solvent under an inert atmosphere. The resulting solvent rinsate must also be hydrolyzed to destroy any residual pyrophoric chemical and then collected for disposal as chemical waste. Allow the empty container to thoroughly air dry (several days) and then triple rinse it again. This rinsate must also be collected for disposal as chemical waste.

References and Additional Information
1. Sigma Aldrich Technical Bulletins:
   a. AL-134, Handling Air-Sensitive Reagents.
   b. AL-164, Handling Pyrophoric Reagents

2. University of California, Irvine, EH&S Department, Standard Operating Procedures (SOPs) Resources.
   Written SOP: Click on Using Pyrophoric Reagents (opens “Procedures for Safe Use of Pyrophoric Reagents (SOP)).

3. University of California, Los Angeles Video: Pyrophoric Liquids

5. University of California, San Diego Videos:
   a. How to Handle Pyrophoric Reagents, Part One: *Getting Ready*
   b. How to Handle Pyrophoric Reagents, Part Two: *Transferring Pyrophoric Liquids*

6. University of Iowa: *Pyrophoric Reagents Handling in Research Labs*
Chapter 6
Peroxide-Forming Chemicals

Identifying Peroxide-Forming Chemicals
Many chemicals can undergo autooxidation to form explosive peroxides (see lists below). Peroxide-forming compounds contain a reactive hydrogen atom that is “activated” by adjacent structural components. Reactive hydrogen atoms are most often found on the following compounds:
- Ethers and acetals with an $\alpha$-hydrogen, especially cyclic ethers and those containing primary and secondary alkyl groups
- Compounds containing benzylic hydrogens
- Compounds containing allylic hydrogens, including most alkene; vinyl and vinylidene compounds; and dienes

Generally, the presence of two or more of these structural features increases the risk of peroxidation. Within a particular class of peroxidizable chemicals, the peroxidation potential decreases with increasing molecular weight of the compound. Compounds with ten or more carbon atoms at a peroxidizable site are normally not considered peroxidation hazards. Additionally, increased volatility of the parent chemical increases the likelihood that dangerous levels of peroxides will form, since evaporation leads to concentration of the peroxide product.

- Use of peroxidizable solvents in distillation or chemical synthesis procedures that involve heating and concentrating contaminating peroxides presents the highest risk of explosion, whereas solvent extraction procedures (or other “gentle” chemical procedures) generally present a low risk.

Potential Peroxide-Forming Chemicals (not all inclusive)

LIST A:
These chemicals form explosive levels of peroxides without concentration. Discard or test for peroxides every 3 months after open date.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS Number</th>
<th>Chemical Name</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divinyl acetylene</td>
<td>821-08-9</td>
<td>Diisopropyl ether</td>
<td>108-20-3</td>
</tr>
<tr>
<td>Potassium metal</td>
<td>7440-09-7</td>
<td>Potassium amide</td>
<td>17242-52-3</td>
</tr>
<tr>
<td>Sodium amide</td>
<td>7782-92-5</td>
<td>Vinylidene chloride</td>
<td>75-35-4</td>
</tr>
</tbody>
</table>

LIST B:
These chemicals produce some peroxides when stored; there is increased risk when concentration occurs. Do not heat, distill, or evaporate without first testing for the presence of peroxides. Discard or test for peroxides at least every 12 months after open date. Some of these chemicals (e.g. some secondary alcohols) may form peroxides more slowly than others, but all should be treated as List B peroxide formers.
<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS Number</th>
<th>Chemical Name</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>75-07-0</td>
<td>Benzyl alcohol</td>
<td>100-51-6</td>
</tr>
<tr>
<td>2-Butanol</td>
<td>78-92-2</td>
<td>Cumene</td>
<td>98-82-8</td>
</tr>
<tr>
<td>Cyclohexanol</td>
<td>108-93-0</td>
<td>2-Cyclohexen-1-ol</td>
<td>822-67-3</td>
</tr>
<tr>
<td>Cyclohexene</td>
<td>110-83-8</td>
<td>Cyclooctene</td>
<td>931-88-4</td>
</tr>
<tr>
<td>Cyclopentene</td>
<td>142-29-0</td>
<td>Decahydroronaphthalene</td>
<td>91-17-8</td>
</tr>
<tr>
<td>Diacetylene</td>
<td>460-12-8</td>
<td>Dicyclopentadiene</td>
<td>77-73-6</td>
</tr>
<tr>
<td>1,1-Diethoxyethane (acetal)</td>
<td>105-57-7</td>
<td>Diethyl ether</td>
<td>60-29-7</td>
</tr>
<tr>
<td>1,4-Dioxane</td>
<td>123-91-1</td>
<td>Diethylene glycol dimethyl ether (diglyme)</td>
<td>111-96-6</td>
</tr>
<tr>
<td>Ethylene glycol dimethyl ether (glyme)</td>
<td>110-71-4</td>
<td>Furan</td>
<td>110-00-9</td>
</tr>
<tr>
<td>4-Heptanol</td>
<td>589-55-9</td>
<td>2-Hexanol</td>
<td>626-93-7</td>
</tr>
<tr>
<td>Methylacetylene</td>
<td>74-99-7</td>
<td>3-Methyl-1-butanol</td>
<td>123-51-3</td>
</tr>
<tr>
<td>Methylcyclopentane</td>
<td>96-37-7</td>
<td>Methyl isobutyl ketone</td>
<td>108-10-1</td>
</tr>
<tr>
<td>4-Methyl-2-pentanol</td>
<td>108-11-2</td>
<td>2-Pentanol</td>
<td>6032-29-7</td>
</tr>
<tr>
<td>4-Penten-1-ol</td>
<td>821-09-0</td>
<td>1-Phenylethanol</td>
<td>98-85-1</td>
</tr>
<tr>
<td>2-Phenylethanol</td>
<td>60-12-8</td>
<td>2-Propanol</td>
<td>67-63-0</td>
</tr>
<tr>
<td>Tetrahydrofuran</td>
<td>109-99-9</td>
<td>Tetrahydronaphthalene</td>
<td>119-64-2</td>
</tr>
<tr>
<td>Dioxanes</td>
<td></td>
<td>Other secondary alcohols</td>
<td></td>
</tr>
<tr>
<td>Vinyl ethers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LIST C:**
These chemicals form peroxides which initiate rapid polymerization. **Uninhibited chemicals are not to be stored longer than 24 hours.**

* Liquids at Room Temperature and Pressure – Discard or test for peroxides within 12 months after open date.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS Number</th>
<th>Chemical Name</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Chloro-1,3,Butadiene (Chloroprene)</td>
<td>126-99-8</td>
<td>Styrene</td>
<td>100-42-5</td>
</tr>
<tr>
<td>Vinyl acetate</td>
<td>108-05-4</td>
<td>Vinyl pyridine</td>
<td>1337-81-1</td>
</tr>
</tbody>
</table>
Gases at Room Temperature and Pressure – If transferred to a secondary container, discard within 12 months after transfer date.

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS Number</th>
<th>Chemical Name</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butadiene</td>
<td>106-99-0</td>
<td>Chlorotrifluoroethylene</td>
<td>79-38-9</td>
</tr>
<tr>
<td>Tetrafluoroethylene</td>
<td>116-14-3</td>
<td>Vinyl acetylene</td>
<td>689-97-4</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>75-01-4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation of Peroxide-Forming Chemicals**

Peroxide-forming liquid chemicals which have not been tested for peroxides within the listed time periods must be evaluated as follows:

1. **Visual Inspection**

Visually inspect all peroxide-forming chemicals before any further evaluation. Containers that exhibit any unusual visual characteristics, such as the examples listed below, should be assumed to contain dangerous levels of peroxides and should not be disturbed (notify EH&S). EH&S will assist in the evaluation of chemicals. If there is any doubt about the safety of handling a chemical container, notify EH&S immediately.

**Liquid Chemicals**

- Crystallization (around the cap or in the liquid)
- Visible discoloration
- Liquid stratification

**Note:** A flashlight or other light source can be used to increase the visibility of the interior of amber bottles.

Diethyl ether is commonly sold in steel containers which prevents visual inspection of the liquid. Therefore, diethyl ether containers whose age and use history are unknown should be assumed to contain dangerous levels of peroxides, and should not be disturbed.

**Solid Chemicals (potassium metal, potassium and sodium amide)**

- Discoloration and/or formation of a surface crust (for example, potassium metal forms a yellow or orange superoxide at the surface)

**Note:** Evaluation of alkali metals and their amides is based on visual criteria only. These substances react strongly with water and oxygen, and standard peroxide tests should not be used.

Materials meeting the above criteria are considered to be high risk and will have to be disposed of by special means (limit handling and movement; notify EH&S). Only chemicals which pass visual inspection should be evaluated further.
2. Opening Container

Only chemicals that meet the below criteria should be opened and tested for peroxides. Chemicals that do not meet one or more of these criteria should be considered to be high risk, and should not be disturbed (limit handling and movement; notify EH&S).

- The identity of the chemical is known.
- The age of the chemical (since manufacture) is known.
- Evaporation of the chemical is thought to be less than 10% - if this is in question, assume that evaporation has occurred and that high peroxide levels may be present.

Note: Never try to force open a rusted or stuck cap on a container of a peroxide-forming chemical.

Additionally, the following classification-specific criteria must be met:

**List A Chemicals**
- Previously opened chemicals which have not been used in the preceding 3 months must be less than 6 months old.
- Chemicals unopened from the manufacturer must be less than 2 years old.
  - If this is in question, assume the container has been opened.

**List B and List C (liquids) Chemicals**
- Opened chemicals not used in the preceding 12 months must be less than 5 years old.
- Chemicals unopened from the manufacturer must be less than 10 years old.
  - If this is in question, assume the container has been opened.

Chemicals not meeting the minimum criteria for opening and testing will be considered to be high risk and must be disposed of by special means (limit handling and movement; notify EH&S). If after opening the container, visual irregularities such as those listed in section 1. are apparent, assume that dangerous levels of peroxides are present. Gently cover the container to minimize evaporation, limit handling and movement, and notify EH&S as soon as possible.

**Safety Precautions**
Personnel handling containers of outdated peroxide-forming chemicals must wear chemical goggles and a face shield, heavy gloves, and a buttoned lab coat. Hearing protection (plugs or muffs) and a rubber apron are also recommended. Suspect chemical containers must be transferred, one at a time, to a clean (no other chemicals) lab hood. When practical, a blast shield should be used when opening or manipulating containers, and testing peroxide levels. Never attempt to force open a stuck cap on a container. Secondary containment for the chemical should also be utilized if practical. Tongs or other forms of remote handling should be used as much as practical. Verify that an operable safety shower/eyewash and fire extinguisher is readily accessible. At least one other person not directly involved in handling of the chemicals should be present.
3. Peroxide testing

For chemicals that have been determined to be safe to open, measure the peroxide concentration using commercial peroxide test strips. Wet chemical detection methods are also available; however, the test strips are gentler, easier, faster, and have greater sensitivity and accuracy, and therefore are recommended for most applications. Laboratory personnel are responsible for performing peroxide testing of chemicals present in their laboratories or storage areas.

- Peroxide test strips (e.g., manufactured by EMD Millipore) are available from many suppliers (such as Fisher Scientific and VWR).
  - Chemicals that contain peroxide levels that exceed the test strip detection range may be diluted with a miscible, peroxide-free, solvent.

4. Dispose of chemical or decontaminate peroxides

Chemicals with a peroxide concentration of less than 30 ppm can be disposed of through EH&S. Laboratory personnel are responsible for decontaminating chemicals that contain greater than 30 ppm peroxides prior to disposal.

- Chemicals with a peroxide concentration greater than 800 ppm are considered high risk, and require disposal by special means (limit handling and movement; notify EH&S).
- Chemicals with a peroxide concentration greater than 100 ppm must be disposed of, or if the peroxide level in a specific container of a chemical on list B is less than 800 ppm, that chemical can be decontaminated and maintained for future use upon the approval of the responsible laboratory supervisor and EH&S. Decontamination and retention of chemicals with this level of peroxide contamination is generally not recommended and would require strong justification for EH&S approval.
  - Peroxides can be removed by chemical treatment or column separation (1, 2).
- Chemicals with a peroxide concentration less than 800 ppm must be decontaminated to reduce the peroxide concentration to less than 30 ppm before disposal (verify treatment with testing). Notify EH&S of treatment and subsequent peroxide concentration when submitting request for waste removal.

Preparation of Peroxide Formers for Disposal

Water-insoluble peroxide formers (ethers, hydrocarbons, etc.) can be decontaminated by shaking with a concentrated ferrous salt solution (5). A solution of 6 g of ferrous sulfate (FeSO₄ • 7H₂O), 6 ml of concentrated sulfuric acid, and 11 ml of water is mixed with 1 L of the peroxide former until the peroxide concentration is reduced to below 30 ppm. Reduction of the peroxides generally takes only a few minutes. Re-test the peroxide former after decontamination to verify that the peroxide concentration is less than 30 ppm. Dispose of the decontaminated peroxide former as soon as possible through EH&S (report final peroxide concentration). An alumina column is used as the standard procedure to decontaminate water-soluble peroxide formers (1, 2). Contact EH&S for guidance on decontamination of these chemicals.
In some instances it may be permissible to dilute the peroxide concentration to below 30 ppm by mixing the peroxide former with a chemically compatible chemical waste stream or chemical solvent. Contact EH&S prior to diluting any peroxide former in preparation for disposal. After diluting the peroxide former, verify that the peroxide concentration of the resulting mixture is less than 30 ppm, and then dispose of the waste mixture through EH&S (report final peroxide concentration).

Safe Storage and Use of Peroxide-Forming Chemicals

Maintenance of peroxide-forming chemicals requires implementation of the following procedures:

- Identify potential peroxide-forming chemicals (see lists above). Prudent practice dictates that laboratories minimize their inventory of peroxide-forming chemicals.

- Label each container with the date it is received and the date it is opened.
  - Labels for peroxide-forming chemicals are available that can be printed on Avery labels #5164 (3-1/3" x 4"); contact Ben Owens (327-5196).

- Store peroxide-forming chemicals in tightly sealed containers to minimize the introduction of air. An inert gas such as nitrogen or argon can be introduced into the container as an inert blanket to minimize available oxygen (inhibited vinyl monomers, List C chemicals, are the exception to this recommendation).

- Ultraviolet light can initiate autooxidation; therefore, it is best to store peroxide-forming chemicals in containers that exclude light.

- Test for peroxides at least as often as recommended in the example lists. Unopened chemicals from the manufacturer must be tested upon reaching the manufacturer’s expiration date, or 18 months, whichever comes first. Chemicals with a peroxide concentration of greater than 100 ppm must be decontaminated or disposed of through EH&S after treatment to reduce peroxides to less than 30 ppm.

- Inspect containers of peroxide-forming chemicals frequently, looking for signs of precipitation, stratification of liquid, crystal formation, or other irregularities. The presence of any of these signs indicates a potential shock sensitive container – do not move the container and contact EH&S as soon as possible.

- Test for peroxides prior to distilling peroxide-forming chemicals (or prior to other heating and concentration procedures), as this is when explosions commonly occur. It is recommended that 10 to 20% residual bottoms be left during distillation. Additionally, a non-volatile organic liquid, such as mineral oil, can be added to minimize concentration of any peroxides.

- Chemical manufacturers often add trace quantities of free radical scavengers (for example, 100 ppm hydroquinone) to inhibit the formation of peroxides. These inhibitors become depleted as peroxides are formed. Additionally, distillation separates the inhibitor from the peroxide-forming chemical. Distilled chemicals and chemicals retained for extended periods should be checked for
inhibitor concentration, and inhibitor added if the concentration is below the manufacturer’s specifications (contact the manufacturer for recommendations).

References and Additional Information
Chapter 7
Corrosive Chemicals and Allergens

Corrosive Chemicals and Allergens
Corrosive chemicals cause destruction of tissue through chemical action at the point of contact. Corrosive chemicals can be liquids, solids, or gases; consequently, corrosive chemicals can affect the skin, eyes, and respiratory tract. Examples of corrosive chemicals include: liquids such as acids and bases, bromine, and hydrogen peroxide; gases such as chlorine and ammonia; and solids such as phosphorous and phenol.

Exposure to a chemical allergen can result in immunological sensitization to the chemical or close structural analogs. Once sensitization to a chemical occurs, subsequent exposure to extremely low doses of the chemical produces an allergic reaction (for example, skin rash or asthma). Examples of compounds that may cause sensitization in some individuals are diazomethane, various isocyanates, formaldehyde, and benzylic and allylic halides.

- Avoid skin contact with chemicals considered to be corrosive or a skin sensitizer.
  - When possible, use mechanical means to handle or transfer these chemicals in order to minimize the likelihood of exposure. Examples include the use of automatic pipettors and other dispensing systems that minimize hands-on contact to replace pouring and other manipulations.
  - Use gloves and other personal protective clothing (lab apron or coat) known to be resistant to permeation and degradation by the chemical. Check gloves and protective clothing for holes.

- Use a properly functioning laboratory hood when handling concentrated acids and bases, or other chemicals that can form mists upon contact with air (often referred to as “fuming”).

- Wear safety eye wear when handling these chemicals, with chemical safety goggles being recommended unless there is very low risk of eye contact (see Chapter 13).
  - Wear a face shield in addition to goggles when there is a likelihood of splash or spray.

Hydrofluoric Acid
Hydrofluoric acid is highly corrosive to body tissue, even in dilute solutions, and higher exposures can produce serious systemic toxicity. Burns involving greater than 25 square inches have the potential to cause serious system toxicity or death due to hypocalcemia. **Avoid exposure to HF by all routes. Personnel using hydrofluoric acid must be specifically trained prior to use, and special work practices must be implemented to prevent exposure to HF** (consult the UNR Chemical Hygiene Officer for assistance). Users of HF should consult the web links below for additional information. Always seek immediate medical attention if skin contact, eye contact, or inhalation occurs.

**Note:** EH&S provides calcium gluconate gel upon request (while supplies last) for first aid treatment of hydrofluoric acid skin burns.
The following documents provide additional information on hydrofluoric acid:
- UNR hydrofluoric acid fact sheet
- American Chemical Society article describing the chemical properties and toxicity of HF, and treatment protocols, *First aid for a unique acid, HF: A Sequel*
- Honeywell HF information page, including *Recommended Medical Treatment for Hydrofluoric Acid Exposure*
Chapter 8
Cryogenic Liquids and Compressed Gases

Cryogenic Liquids
Cryogenic liquids are materials with a boiling point of less than –100 °F (-73 °C); common examples include liquid nitrogen, helium, and argon, and dry ice/alcohol slurries. Cryogenic liquids undergo large volume expansion upon transition to the gas phase, for example, one volume of liquid nitrogen vaporizes to 694 volumes of nitrogen gas. Consequently, the warming of a cryogenic liquid in a sealed container produces high pressure, which can rupture the container.

Hazards of cryogenic liquids include fire (in the case of flammable or oxidizing materials), pressure buildup, explosion, as well as severe frostbite (on contact with skin) and asphyxiation (due to depletion of available oxygen). Additionally, cryogenic liquids such as liquid nitrogen have boiling points below that of oxygen and are capable of condensing atmospheric oxygen, resulting in a localized, oxygen-enriched environment through formation of liquid oxygen. Liquid oxygen in combination with many organic (oxidizable) materials can result in a violent reaction. Systems that incorporate liquid nitrogen traps must never be opened to the atmosphere until the trap is removed from the coolant.

Safe Handling Practices
- The contents of cryogenic dewars and tanks must be clearly labeled to indicate the contents.
- Large tanks of liquid nitrogen and other cryogenic liquids should be secured to prevent sliding or rolling during an earthquake.
- Always wear appropriate personal protective equipment to prevent skin and eye contact. Heavy, loose-fitting gloves (special cryogenic gloves are available), safety glasses and face shield, and lab apron are recommended.
- Handle objects that are in contact with cryogenic liquids with tongs or proper gloves.
- Keep liquid oxygen away from organic materials and ignition sources.
- Only work with cryogenic liquids in well-ventilated areas to avoid localized oxygen depletion or buildup of flammable or toxic gas.
  - Refrigerated rooms generally recycle room air and dangerous atmospheres can result from use of cryogenic liquids or dry ice in these rooms.
  - Rooms containing cryogenic liquids in quantities sufficient to reduce atmospheric oxygen levels below 20% through leaks or catastrophic release should have a continuous oxygen monitor with alarm that will notify personnel inside and outside of the room of low oxygen levels.
- Transfers or pouring of cryogenic liquids should be done carefully to avoid splashing.
• Cryogenic liquid/dry ice baths should be open to the atmosphere to avoid pressure build up.

• Transfer of liquid hydrogen in an air atmosphere can condense oxygen in the liquid hydrogen, creating an explosion hazard.

• Containers and systems containing cryogenic liquids should have pressure relief mechanisms.

• Cryogenic liquid cylinders and other containers (such as Dewar flasks) should be filled no more than 80% of capacity to protect against thermal expansion.

• Shield or affix fiber tape around glass Dewars to minimize flying glass and fragments should an implosion occur.

Note: Plastic mesh will not stop small glass fragments

Compressed Gases
Compressed gases are considered more hazardous to handle than liquids or solids because of the high pressure involved and the ability of the gas to spread rapidly when released. Additionally, many compressed gases are flammable, toxic or corrosive.

Safe Handling Practices
• Each compressed gas cylinder must be clearly labeled to indicate the contents.

• Check connections and hoses regularly for leaks using a specific monitoring instrument or soapy water (or equivalent). When utilizing highly flammable or toxic gas, check the delivery system using an inert gas prior to introducing the hazardous gas.

• When using compressed acetylene: (i) do not exceed a working pressure of 15 psig, and (ii) do not use vessels, piping, or other materials that contain a significant amount of copper (usually considered to be more than 50% copper).

• Replace valve caps when cylinders are not in use.

• Remove damaged or defective cylinders from service (contact the cylinder vendor for assistance).

Transport of Compressed Gases
• Compressed gas cylinders must be transported using hand-trucks or other appropriate means. NEVER TRANSPORT UNSECURED COMPRESSED GAS CYLINDERS!
  - Cylinders should be transported upright whenever possible (always transport and store acetylene in an upright (vertical) position).

• Before transporting any cylinder, remove the pressure regulator and ensure that a safety valve cap is in place.
• Elevators can be a confined space. Due to the potential for exposure to unsafe conditions in the event of a significant leak or catastrophic release, it is recommended that personnel do not ride in an elevator with compressed gas cylinders. Have one person send the elevator and another person receive the elevator.

Storage of Compressed Gases
• Keep compressed gas cylinders secured to prevent falling or rolling. Restraint systems should be sufficiently robust so that cylinders cannot be moved significantly when wiggled by hand or during a small earthquake.

• Liquefied flammable compressed gas cylinders (e.g., acetylene) must always be stored in the upright position so that the pressure relief device is in direct communication with the vapor phase of the cylinder.

• Segregate and clearly mark full and empty cylinders.

• Store compressed gas cylinders away from heat sources, and flammable and highly combustible materials (such as oil and greases).

• Segregate according to hazard class and chemical compatibility.
  - Separate flammable and oxidizing gases.
  - Store flammable gases away from combustible material, ignition sources (including unprotected electrical connections), and oxygen gas cylinders, liquid oxygen, and other oxidizers (at least 20 feet if possible or separated by a fire-rated wall).

• Toxic gases (for example, NFPA health hazard rating of 3 or 4, or OSHA acute hazard rating of 1 or 2) should be stored and used in a ventilated hood or gas cabinet. An area monitor with alarm should be used if a ventilated enclosure is not used, and when the toxic gas has poor warning properties (such as carbon monoxide). **Contact the University CHO for specific guidance.**

Maximum Number of Gas Cylinders
As a State facility UNR is covered by the International Fire Code (IFC). The IFC specifies maximum allowable quantities of hazardous compressed gases per designated fire control area. Fire control areas generally consist of multiple laboratory rooms, making it difficult to assign a maximum allowable quantity for each room. NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, also applies in a regulatory sense to UNR. This standard provides guidance on the maximum number of compressed gas or liquefied gas cylinders per laboratory (500 ft² or less) as shown below. Contact the University CHO for more specific guidance.
### Flammable or Oxidizing Gases

<table>
<thead>
<tr>
<th>Sprinklered</th>
<th>Nonsprinklered</th>
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<tbody>
<tr>
<td>6</td>
<td>3</td>
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### Liquefied Flammable Gases

<table>
<thead>
<tr>
<th>Sprinklered</th>
<th>Nonsprinklered</th>
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<tr>
<td>3</td>
<td>3</td>
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</table>

### Gases with Health Hazard Rating of 3 or 4

<table>
<thead>
<tr>
<th>Sprinklered or Nonsprinklered</th>
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<tbody>
<tr>
<td>2</td>
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</table>

Additional information

Additional information on the safe handling and use of compressed gases is available from the [Compressed Gas Association](https://www.compressedgases.org), [Matheson Tri-Gas](https://www.mathesontrigas.com), and in the [Air Liquide Design and Safety Handbook](https://www.airliquide.com).
Chapter 9
Carcinogens, Reproductive Toxins, and Highly Acutely Toxic Chemicals

Particularly Hazardous Substances
Carcinogens, reproductive toxins, and chemicals with high acute toxicity are considered to be high-risk materials and are classified by OSHA as “Particularly Hazardous Substances.”

Carcinogens
In addition to chemicals classified as known carcinogens, there are many chemicals classified as “suspect carcinogens” since they show carcinogenic activity under certain circumstances but do not demonstrate unequivocal evidence of an increased risk of cancer in humans. In many cases, these suspect carcinogens are regulated by the OSHA Lab Standard as carcinogens, and in all cases, steps must be implemented to minimize exposure to these substances (see “Working with Particularly Hazardous Substances” below).

The following references provide lists of substances classified as carcinogens and suspect carcinogens; however, exclusion from this list does not guarantee that a substance does not possess carcinogenic activity.

- International Agency for Research on Cancer (IARC)
- National Toxicology Program (NTP)
- List of Chemicals Known to the State of California to Cause Cancer or Reproductive Toxicity
- National Institute for Occupational Safety and Health (NIOSH) Carcinogen List
- OSHA regulated carcinogens

Reproductive Toxins and Chemicals with High Acute Toxicity
Reproductive toxins are those chemicals listed as such in SDSs and other recognized sources of chemical hazard information, and highly acutely toxic chemicals are those that meet the definition of “highly toxic.” Unfortunately, there are no definitive listing of chemicals classified as reproductive toxins or highly acutely toxic, so SDSs and other sources of chemical hazard information should be consulted. One listing of chemicals known to cause reproductive toxicity is State of California’s Proposition 65 list of chemicals (which also includes carcinogens).

A listing of several common laboratory chemicals that are known carcinogens, reproductive toxins, or which have high acute toxicity is provided to assist laboratory workers in identifying particularly hazardous substances. Additionally, the following lists can be used to help identify particularly hazardous substances

- Duke University: Particularly Hazardous Substances Lookup Tool
- Medical College of Wisconsin: Particularly Hazardous Substances List

Working with Particularly Hazardous Substances
Extra precaution is required when working with particularly hazardous substances. Although risk varies depending on the specific conditions of use, the procedures described in this section are
generally required when handling any chemical that is a carcinogen or highly acutely toxic. Since the risk associated with reproductive toxins is highly dependent on the specific compound and the conditions of its use, these materials should be assessed on an individual basis. High risk reproductive toxins (those with unequivocal evidence of reproductive risk) should also be handled using the procedures outlined in this section.

Suspect carcinogens (check the IARC and NTP carcinogen lists above) should be handled using these procedures when using toxicologically significant quantities or under conditions with increased likelihood of exposure (such as, generation of vapor or aerosol outside of a laboratory hood, or when skin contact is likely). For the purposes of this section, a toxicologically significant quantity is an amount greater than, or equal to, one-half the quantity reported to produce cancer in a mammalian species, when scaled for a 50 kg (110 pound) person:

**Toxicologically Significant Quantity** (g) = 
\[ \geq \left[ \text{cancer producing dose (mg/kg)} \times 50 \text{ kg} \times \frac{1}{1000} \right] \div 2 \]

Laboratory supervisors can vary these procedures based on a risk assessment of their specific application.

**Designated Areas**

Procedures involving particularly hazardous substances that are thought to have potential for significant exposure to personnel under normal operations must be conducted in a designated area. It is recommended that procedures with lower potential for personnel exposure also be conducted in a designated area. A designated area can be the entire laboratory, a specific laboratory workbench, or a laboratory hood. The designated area is recognized as an area of increased risk where limited access, special procedures, knowledge, and work skills are required. Designated areas must be clearly marked with signs that identify the chemical hazard and include an appropriate warning; for example: WARNING! BENZENE WORK AREA – CARCINOGEN.

**Procedures for Working with Particularly Hazardous Substances**

Laboratory supervisors are responsible for the development of specific SOPs designed to reduce the risk associated with handling particularly hazardous substances. Although the specific SOPs will vary according to the material used, the following guidelines are generally applicable for projects involving these substances:

- Use the smallest amount of chemical that is consistent with the requirements of the work to be performed.

- Use containment devices (such as lab hoods or glove boxes) when: (i) volatilizing these substances, (ii) manipulating substances that may generate aerosols, and (iii) performing laboratory procedures that may result in release of the substance.
  - Use high efficiency particulate air (HEPA) filters, carbon filters, or scrubber systems with containment devices to protect effluent and vacuum lines, pumps, and the environment whenever feasible.
• Use ventilated containment to weigh out solid chemicals. Alternatively, the tare method can be used to prevent inhalation of the chemical. While working in a laboratory hood, the chemical is added to a pre-weighed container. The container is then sealed and re-weighed outside of the hood. If chemical needs to be added or removed, this manipulation is carried out in the hood. In this manner, all open chemical handling is conducted in the laboratory hood.

• Use personnel protective equipment appropriate for the specific hazards when working with these substances.
  - Select chemical resistant gloves that are protective against the specific chemical(s) being used, as well as any carrier or solvent chemical.

• Upon leaving the designated area, remove any personal protective equipment worn and wash hands, forearms, face, and neck.

• After each use (or day), wipe down the immediate work area and equipment to prevent accumulation of chemical residue.

• At the end of each project, thoroughly decontaminate the designated area before resuming normal laboratory work in the area.
Chapter 10
Nanomaterials

Nanomaterials
Nanomaterials are materials with one, two, or three external dimensions in the size range of 1 – 100 nm. Subcategories of nanomaterials include: 1) nanoplates, which have one external dimension at the nanoscale, 2) nanofibers, which have two external dimensions at the nanoscale, with a nanotube defined as a hollow nanofiber, and 3) nanoparticles, which have all three external dimensions at the nanoscale.

The term “nanomaterials” and the subcategory terms listed above are generally used to describe engineered nanoscale materials, while the term “ultrafine particle” is used for airborne particles smaller than 100 nm in diameter that are incidental products of combustion and vaporization. For the purposes of this chapter we are concerned with engineered materials and the “nano” terms will be used.

Toxicity
In addition to the health risks associated with the chemical composition of a particular nanomaterial, the small size of the material poses additional risks. Currently there are gaps in knowledge with regard to routes of exposure, translocation of materials within the body, and interaction of materials with biological systems and cellular components.

It is clear that the very small size of nanoparticles confers unique characteristics relative to larger particles which influence their migration and deposition in the body, and therefore, their toxicity. For example, nanoparticles can cross cell membranes and gain access to organelles such as mitochondria, where they have been shown to cause oxidative damage and impair function of cells in culture. Nanoparticles can cross the blood-brain barrier to gain access to the brain and studies involving mice and rats exposed to metal nanoparticles have shown adverse effects on the brain.

Toxicity information for larger particles provides baseline knowledge about nanoparticles of similar chemical composition. Due to nanoparticles having a greater surface area than an equivalent mass of larger particles, the toxicity of nanoparticles is greater than that of larger particles of similar chemical composition. In addition to surface area, the toxicity of nanoparticles is dependent on its surface chemistry. For example, particle surface reactivity can greatly influence toxicity and particles with greater reactive surface oxidant generation produce more reactive oxygen species and greater pulmonary inflammation. Because of these factors, predicting the toxicity of a nanoparticle based only on its chemical composition may result in underestimation and lead to an inadequate level of protection for exposed personnel.

Primary Health Effects
Like other xenobiotics, the potential health risk associated with exposure to nanoparticles is dependent on the magnitude, duration and frequency of exposure; persistence in the body; ability to be translocated in the body; particle toxicity; and the susceptibility and health status of the exposed individual. The biological persistence and toxicity of particles are in turn dependent on specific
particle characteristics, to include surface chemistry, physical structure, and particle size and tendency of particles to agglomerate. Potential health effects are therefore variable and dependent on the specifics of the nanoparticles.

Animal studies indicate that health effects associated with inhalation of nanoparticles include pulmonary inflammation, lung fibrosis, and lung tumors. Mice exposed to single-walled carbon nanotubes (SWCNTs) via instillation in the lungs developed interstitial inflammation and epitheloid granulomas in a dose-dependent (0.1 or 0.5 mg per mouse) manner, with mortality observed in the high dose group when exposed to SWCNTs that contained nickel. Exposure of mice to SWCNTs via pharyngeal aspiration (10 – 40 µg per mouse) produced transient pulmonary inflammation, oxidative stress, decrease in pulmonary function, decrease in bacterial clearance, and early onset of interstitial fibrosis. Studies involving exposure of mice to multi-walled carbon nanotubes (MWCNT) showed that mice exposed to both a cancer initiator chemical and MWCNT (by inhalation) were significantly more likely to have tumors than mice exposed only to the initiator chemical. This study did not indicate that MWCNT can cause cancer alone but that they increased the risk of cancer in mice also exposed to the initiator chemical.

Studies of workers exposed to ultrafine particles have reported adverse lung effects to include decreased lung function, obstructive lung disease, and fibrotic lung disease. Some studies have also shown elevated lung cancer and neurological effects among exposed workers. The specific relevance of these findings to occupational exposure to nanoparticles is not known with certainty but it is currently thought that nanoparticles produce health effects similar to those produced by ultrafine particles.

**Routes of Exposure**

**Inhalation**

Inhalation is the most common route of exposure for particles and due to their very small size nanoparticles are deposited in the lungs to a greater extent than are larger respirable particles. Nanoparticles deposited in the lungs can enter the bloodstream and be translocated to other organs. Animal studies have shown that nanoparticles deposited in the nasal region can be translocated to the brain via the olfactory nerve, which does not occur with larger particles.

**Skin Absorption**

Studies with human skin samples and dermal exposure of animals have shown that nanoparticles can penetrate skin by passive diffusion through the stratum corneum, analogous to lipophilic liquid chemicals. Although it is not known how these findings relate to occupational skin exposure, it should be assumed that nanoparticles have the ability to pass through intact skin.

**Ingestion**

Ingestion of nanomaterials can occur from hand-to-mouth transfer or may accompany inhalation of nanomaterials since inhaled particles that are cleared from the respiratory tract via the mucociliary escalator may be swallowed. There is currently not much known about potential health effects from ingestion of nanomaterials.
Potential Exposures to Nanomaterials
The potential for exposure to nanomaterials is analogous to that of other particles and is dependent on the form of the nanomaterial, processes involved in manipulation of the nanomaterial, and physiochemical properties of the nanomaterial (e.g., particle size and tendency to agglomerate). Nanomaterials that are in a powder form easily become airborne and present a higher exposure risk than do nanomaterials that are in liquid media as a slurry or suspension. Components or devices made up of nanomaterials present minimal risk of exposure unless disturbed in a manner that can release of nanoparticles (e.g., cutting or grinding). Some situations that increase the potential for exposure to nanomaterials include the following:

- Working with nanomaterials (powders or in liquid media) without adequate skin protection
- Pouring or mixing liquid suspensions or performing other manipulations involving vigorous agitation
- Generating nanomaterials in the gas phase without adequate containment
- Handling nanomaterials powder without adequate containment
- Cleaning up spills of nanomaterials
- Mechanical disruption of nanomaterials

Each use of nanomaterials requires an evaluation of the exposure potential that includes assessment of the material being used, the manipulations to be performed, and exposure control measures to be used. Contact the Chemical Hygiene Officer for assistance with evaluation of nanomaterial exposures and safe work practices.

Exposure Limits for Nanomaterials
Currently there are no specific regulatory occupational exposure limits established for nanomaterials. The National Institute of Occupational Safety and Health (NIOSH) has established a Recommended Exposure Limit (REL) of 1 µg/m³ respirable elemental carbon as an 8-hour time-weighted average for carbon nanotubes and carbon nanofibers, and a REL of 0.3 mg/m³ for ultrafine (including engineered nanoscale) titanium dioxide.

Although exposure limits for larger particles of similar chemical composition may not provide sufficient health protection, they may provide a starting point for additional exposure risk assessment. For example, the REL of 1 µg/m³ for carbon nanotubes corresponds to the lowest airborne carbon nanotube concentration that can be accurately measured by established air sampling methods rather than a protective level based on toxicity. It is recommended that exposures be kept as low as possible below the REL. Limits for exposure to nanomaterials will need to be evaluated based on an assessment of the specific nanomaterial in consultation with the Chemical Hygiene Officer.

Minimizing Exposures to Nanomaterials
Engineered Controls
Exposure to nanomaterials can be controlled using local exhaust ventilation devices and dispersible nanomaterials must always be handled in a ventilated containment device. The effectiveness of a local exhaust ventilation device is dependent on the design of the device, the ventilation
performance of the device, the physical form of the nanomaterial, and the manipulations being performed.

**Glove Boxes and Powder Handling Enclosures**
A glove box or other ventilated full containment device provides the best protection when handling powders. Powder handling enclosures also provide good containment for handling nanomaterial powders. These devices operate at lower air flow rates and velocities than do traditional chemical fume hoods, reducing the potential for loss or ejection of nanomaterials. Flow Sciences is one manufacturer of powder handling enclosures for nanotechnology applications.

**Biological Safety Cabinets**
Although Class II biological safety cabinets (BSCs) are designed to contain infectious aerosols that are produced when handling pathogenic microorganisms, they also provide protection when handling nanomaterials. BSCs can be used when handling powders, although they do not provide as effective containment as do glove boxes or powder handling enclosures. BSCs used for handling nanomaterials should have their exhaust ducted to the outside environment via a thimble connection (Class II, type A1 or A2) or via continuous hard ducting (Class II, type B1 or B2).

**Chemical Lab Hoods (Fume Hoods)**
Traditional chemical lab hoods may not provide adequate containment when handling powders due to higher air flow and turbulence. Lab hoods are generally not appropriate for use with powders but may be adequate for nanomaterials in liquid media or agglomerated form which are not as easily dispersed. It is recommended that the exhaust air from lab hoods that are used for handling nanomaterials pass through a high efficiency particulate air (HEPA) filter prior to release to the environment.

**Safe Work Practices**

**Substitution**
Substitution of nanomaterials is usually not possible for researchers; however, less hazardous options may be available with respect to the form of the nanomaterial used, manipulations performed, and associated chemical use. For example, working with nanomaterials suspended in a liquid rather than as a dry powder reduces the potential for airborne release. Gentler manipulations involving less vigorous agitation should be used whenever possible as this reduces the likelihood of aerosolization. Hazardous chemical use is often required in nanomaterial research and substituting less hazardous chemicals for more hazardous chemicals will reduce the overall risk of the process.

**Prudent Practices**
In addition to the good laboratory safety practices contained in Chapter 2, the following prudent work practices should be implemented to minimize personnel exposure to nanomaterials.

- Minimize access to nanomaterials those personnel who are specifically trained and authorized.

- When working with nanomaterials, limit the number of personnel in the immediate area to only those who are directly needed to perform the work.
- Work in ventilated containment whenever possible.
- Keep containers of nanomaterials closed except when removing or adding material.
- Maintain good housekeeping of nanomaterial work areas.
  - Work on disposable protective covering material ("lab diapers") to reduce contamination of surfaces and to facilitate clean up.
  - Clean all surfaces potentially contaminated with nanomaterials when work is completed or at the end of each day using wet wiping or a HEPA-filtered vacuum that is leak tested annually; never dry sweep.
  - Clean up spills as soon as possible using wet wiping and/or a HEPA-filtered vacuum that is leak tested annually.
- Collect and handle nanomaterial-containing waste in sealed, labeled containers in a manner that minimizes potential exposure during handling and disposal.
- For work involving handling of large quantities of dry powders, and other work with higher risk of contamination, consider use of disposable coveralls, use of dedicated work clothing and showering when work is completed, and other procedures to reduce the likelihood of contaminating other areas (including take-home contamination). Consideration of these special procedures should be justified by risk assessment.

Personal Protective Equipment
Generally, personal clothing and protective equipment that is appropriate for wet-chemistry work (see Chapter 13) is required for work with nanomaterials. This includes clothing that covers legs and closed toes shoes that cover the foot, with a lab coat, appropriate chemical resistant gloves, and eye protection (with face protection as needed). Additional personal protective equipment considerations and requirements are provided below.

Respiratory Protection
Respirators should be worn when there is potential for exposure to airborne nanomaterials. HEPA-filtered respirators (those with N100, P100, or R100 particulate cartridges) provide the highest level of protection against nanoparticles (other than supplied air respirators) and should generally be worn. N95 respirators may be adequate in cases where only low level exposure may be possible or as a supplement where airborne exposures are not expected. The selection of respiratory protection must be based on an assessment of risk. Contact the Chemical Hygiene Officer for assistance.

Gloves
Chemically impervious gloves that are appropriate for the nanomaterials and chemicals being used are required. Selection of gloves must take into account the nanomaterial and liquid that the nanomaterial is suspended in (see Chapter 13). Nanoparticles may be translocated through microscopic breaches in glove material so gloves should be replaced often and immediately upon visible signs of cracks or other visible wear. Gloves should overlap lab coat sleeves to prevent
exposure of lower forearms. Gloves must be removed carefully and using good technique to avoid spreading contamination and aerosolizing nanomaterials.

**Body Protection**
At a minimum, a full laboratory coat must be worn when handling nanomaterials. Procedures involving higher risk of exposure may require use of disposable coveralls or other protective clothing. Used lab coats and other body protective clothing must remain in nanomaterial work areas unless contained in sealed plastic bags. Disposable lab coats and coveralls must be disposed of in sealed plastic bags as advised by EH&S. Non-disposable lab coats must be laundered on a regular basis, with transport in sealed plastic bags.

**Fire and Explosion Control**
Carbon-containing dusts and metal dusts can explode if sufficient airborne concentration is achieved in the presence of adequate oxygen and an ignition source. Because of their greater surface-to-volume ratio, nanoparticles represent a greater risk of explosion than an equivalent concentration of larger particles. Laboratory scale work poses a lower risk of explosion than does larger scale work in pilot plants or manufacturing facilities; however, generation of high airborne concentrations of nanoparticles are to be avoided. Use of ventilated containment, in concert with good housekeeping to prevent accumulation on surfaces, should prevent this possibility.

**Additional Information on Nanomaterials Safety**
National Institute for Occupational Safety and Health (NIOSH), Nanotechnology, Guidance and Publications: [http://www.cdc.gov/niosh/topics/nanotech/pubs.html](http://www.cdc.gov/niosh/topics/nanotech/pubs.html).

**References**
1. *Approaches to Safe Nanotechnology: Managing the Health and Safety Concerns Associated with Engineered Nanomaterials*
2. *General Safe Practices for Working with Engineered Nanomaterials in Research Laboratories*
Chapter 11
Chemical Exposure Limits and Air Monitoring

Airborne Exposure Limits
Many chemicals used in laboratories have significant volatility at room temperature. Consequently, inhalation is generally the most likely route of chemical exposure for laboratory workers. Although airborne exposure limits have been established for many chemicals, these exposure limits are not a strict delineation between safe and unsafe conditions. Nevertheless, exposure to an airborne chemical at a concentration that is below the established exposure limit is generally considered safe. It should be pointed out that many established airborne exposure limits do not take into consideration carcinogenic or reproductive end points, and thus may not provide an adequate level of safety with respect to these toxicological effects.

There are two primary sets of exposure limits used in the United States, the OSHA Permissible Exposure Limits (PELs), and the Threshold Limit Values (TLVs) established by the American Conference of Industrial Hygienists (ACGIH). The OSHA PELs are regulatory exposure limits that are legally enforceable (OSHA will issue a citation if an overexposure occurs), while the ACGIH TLVs are recommended limits. Since TLVs are not regulatory limits, they are revised (based on new information) much more frequently than are PELs and are generally considered to more accurately reflect current knowledge pertaining to the health effects of chemical exposures. Although the OSHA PELs are the regulatory exposure limits, it is recommended that personal exposures be maintained below the lower of the PEL or TLV. Other airborne exposure limits, to include Recommended Exposure Limits (RELs) established by the National Institute for Occupational Safety and Health, may also be used in some circumstances.

Availability of Published Exposure Limits
PELs and TLVs can be found in Safety Data Sheets (SDSs) or they can be obtained from EH&S. Additionally, the OSHA PELs are published in the OSHA regulation, “Air Contaminants.” Many chemicals used in research laboratories do not have established exposure limits, and good laboratory safety practices that minimize exposure to all chemicals should be routinely implemented.

Exceeding Exposure Limits
Exposure limits are most likely to be exceeded when performing operations outside of a lab hood, especially when using highly volatile chemicals, large volumes of chemicals, or chemicals with low exposure limits (for example, less than 50 ppm). Air monitoring is necessary to accurately quantify chemical exposure (see next section, Air Monitoring).

Workers should be familiar with the odor and/or visual characteristics of the chemicals they work with as these characteristics can sometimes be used to detect the presence of chemicals in the laboratory. Do not use chemical odor and/or visual characteristics as a means of determining that inhalation exposure limits are not being exceeded, as sometimes these characteristics are only detected at concentrations far above that which is considered safe. For example, the odor threshold (the concentration at which a chemical can be detected by its odor) of acetonitrile is 1160 ppm, while the exposure limit is 40 ppm!
Air Monitoring

Air monitoring is necessary to quantitatively determine the concentration of airborne chemicals. This information is used to estimate risk to personnel, assess the efficiency of laboratory hoods and other exposure control equipment, and to verify regulatory compliance. To ensure that the air monitoring accurately represents personnel exposure, it must be conducted in accordance with regulatory requirements and accepted professional practice. **EH&S is responsible for performing chemical air monitoring at UNR** and has several direct-reading monitors that can be used to measure the air concentration of many chemicals at near real time. Additionally, air samples can be collected for more detailed laboratory analysis. Generally, consistent use of the good laboratory practices outlined in this manual will keep chemical exposures below established exposure limits; however, if you feel that air monitoring is warranted in your laboratory, contact the University Chemical Hygiene Officer.
Chapter 12
Laboratory Ventilation

Use of Laboratory Hoods
General laboratory room ventilation is designed to provide heating and cooling to the laboratory. General room ventilation does not effectively control personnel exposures to hazardous levels of airborne chemicals. Consequently, laboratory hoods are required to contain chemical vapors and gases at the emission source. Laboratory hoods are the most important control for protecting laboratory workers from chemical exposure.

All chemicals, especially toxic and/or flammable chemicals, should be handled in a laboratory hood whenever it is reasonable to do so. Chemicals that have high acute toxicity, or which are carcinogens or reproductive toxins, must be handled in a laboratory hood, except for situations where the risk is low (such as operations involving very small quantities or very low likelihood of inhalation exposure). As a general guide, chemicals meeting the definition of “toxic,” or which have an exposure limit less than 50 ppm (or 0.25 mg/m$^3$ for airborne particulate), should be used in a laboratory hood or other containment device that effectively controls exposures.

Guidelines for Laboratory Hood Users
Laboratory hoods are designed to contain vapor and gases; however, the hood airflow must compete against external air currents and turbulent internal airflow in order to achieve effective containment. The following guidelines are good practices that will facilitate effective containment of contaminants.

- Verify sufficient inward airflow before using a hood.
  - For hoods with an air velocity monitor, check the monitor. Alternatively, a strip of lightweight paper (such as a Kimwipe) or a piece of yarn should be readily pulled inward when held at the face of the hood.

- Operations that involve heating or volatilizing perchloric acid must be conducted in special perchloric acid hoods. These hoods contain water spray systems to wash down the interior of the hood, ducting, fan, and exhaust stack to prevent accumulation of explosive perchlorate crystalline material. Currently there are no approved perchloric acids hoods on the UNR campus.

- When possible, position the hood sash such that the glass is between the worker (especially the face) and the chemical source. Close the hood sash when not working in the hood.

- Avoid rapid movements at the face of the hood, as they tend to create competing air currents and reduce the ability of the hood to contain air contaminants.

- Keep chemical sources and equipment at least six inches behind the face of the hood.

- Minimize equipment placed in the hood to avoid dead air spaces and/or eddies.
• Equipment used in hoods should be placed on blocks to allow air to flow under and around the equipment.

**Evaluation of Laboratory Hood Performance**
EH&S performs laboratory hood evaluations to ensure that ventilation performance measures are being met. This normally consists of a face velocity measurement and a visual evaluation of the hood’s ability to capture and contain visual smoke.

• EH&S performs laboratory hood performance evaluations at least on an annual basis.
  - Laboratory hood performance should also be evaluated following any maintenance, repair, or modification that could affect ventilation performance.

• After each successful hood performance evaluation a sticker with a red arrow on it is affixed at the side of the hood opening corresponding to a sash height of 16”. This sticker lists the average face velocity of that hood and the date when the next evaluation is due.
  - If the hood evaluation indicates that the hood ventilation is not adequate, a “Do Not Use” sticker is placed on the front of the sash and EH&S will submit a work request for repair of the hood. **Do not use a hood that has been labeled as “Do Not Use.”**

• If a laboratory hood has not been evaluated within the past 12 months (or if the due date is within less than a month) contact the CHO or the EH&S Dept. to request an evaluation of the hood.

• A face velocity of 80-120 fpm is recommended for most laboratory hoods. A face velocity outside of this recommended range should be approved for specific use by EH&S.

• Consult with EH&S and Facilities Maintenance before making any change to a ventilation system (laboratory hood or general room ventilation), or for assistance with unique experimental set-ups.

• Do not use lab hoods to "dispose" of chemicals by evaporation unless the vapors are trapped and recovered for proper waste disposal.

**Repair and Maintenance of Laboratory Hoods**
• If a laboratory hood or other laboratory ventilation device is operating but does not seem to have adequate or normal air flow, call the Chemical Hygiene Officer or call the EH&S Department (327-5040) and request an evaluation.

• Also notify the Chemical Hygiene Officer or call the EH&S Department if a laboratory hood or other laboratory ventilation device is inoperable or needs repair (e.g., a broken sash).

**Laboratory Hood Failure**
In the event of a hood failure during chemical use:
  - Turn off power to all apparatus in the hood.
- Stabilize the chemical source as much as possible to minimize release. Cover chemical containers if it is safe to do so (do not cover containers that may develop internal pressure).
- Close hood sash.
- Notify other occupants of the laboratory.
- Notify the laboratory supervisor and/or the department office and call Facilities Maintenance at 784-8020 to report the problem. Also report the issue to the EH&S Department by calling 327-5040.
- If hazardous chemicals are released from the hood in a quantity that presents an immediate fire or high health hazard, evacuate the area and call Reno City emergency responders at 911. Call EH&S at 327-5040 (24 hour contact number) if the released material presents a lower risk scenario (no fire hazard and/or lower health hazard). See Chapter 19 for additional information on emergency response actions.

Additional Information
- **UNR Ventilation Program** – contains information on topics related to laboratory ventilation, as well as video clips that demonstrate loss of hood containment.
  - See the UNR document *A Guide to Laboratory Ventilation* for additional information on types of laboratory hoods and biological safety cabinets (BSCs), laboratory hood and BSC performance, and safe work practices.
- **UNR Biosafety Manual** – Chapter 8 contains information on biological safety cabinets.
Chapter 13
Personal Protective Equipment

Use of Personal Protective Equipment
Personal protective equipment (PPE) is used to supplement engineering controls (such as laboratory ventilation and laser interlocks) and good work practices, and is an important component of laboratory safety. When properly selected and used, personal protective equipment is effective in minimizing exposure to multiple hazards. Personal protective equipment should always be inspected prior to use, and must not be used if found to be defective.

Eye Protection
- Eye protection (safety glasses or goggles) should be worn at all times in the laboratory, even if you are not currently involved in any “hands on” work. **Eye protection must be worn by all personnel in close proximity of chemical work (chemicals in use, chemical reactions, chemical waste handling, etc.).**

- Normal prescription glasses or sunglasses do not qualify as safety eyewear. Acceptable safety eyewear must meet the requirements of the American National Standards Institute (ANSI) code Z87.1 (“Z87” will be imprinted or labeled on the eyewear).
  - Safety glasses require side shields.

- Chemical splash goggles with indirect venting should be worn when there is a likelihood of chemical splash or spray, explosion/implosion, or other significant eye hazards.

- A face shield should be worn over safety eyewear when working with large quantities of highly corrosive chemicals, operations significantly above or below ambient pressure, or other high risk operations.

Contact Lenses
Historically the wearing of contact lenses has not been allowed in the laboratory since it was believed that contact lenses would exacerbate damage to the eye caused by chemical contact. This policy has been revisited and most experts now agree that contact lenses do not increase the risk of eye damage when handling chemicals. More information on wearing contact lenses in the laboratory is available in the 2005 NIOSH Current Intelligence Bulletin, *Contact Lens Use in a Chemical Environment.*

Contact lenses can be worn by laboratory workers under the following circumstances:
- It is recommended that the laboratory supervisor and other laboratory personnel be notified when contact lenses will be worn in the laboratory.
- Protective eyewear that is appropriate for the hazard is worn. Contact lenses do not provide adequate protection and are not considered protective equipment.
- Contact lenses are removed at the first sign of eye redness or irritation thought to be associated with the laboratory environment. An optometrist or ophthalmologist should be consulted regarding continued use of contact lenses in the laboratory.
Hand Protection
There are a variety of glove materials available; however, **no one glove material is resistant to permeation by all chemicals.** When significant chemical contact (significant because of toxicity, corrosivity, chemical volume or contact time) is expected, specific chemical resistant gloves should be selected based on their resistance to the chemicals in use.

General Use Guidelines
- Gloves should be inspected prior to use and discarded if there are signs of degradation, tears, punctures, or swelling.
- Gloves can be tested for leaks by inflating the glove with air (do not inflate by mouth).
- Always remove gloves when leaving a chemical, biological, or radiological use area to avoid spreading contamination.
- Do not spread chemical contamination by handling common items such as books, phones, and doorknobs.

Disposable Gloves
Disposable (thin) latex gloves are often worn in the laboratory because they provide excellent dexterity and they are inexpensive. These gloves provide protection against dry chemicals but they do not provide adequate protection against the strong acids and bases, and organic solvents commonly used in laboratories. Disposable nitrile and chloroprene gloves provide better chemical resistance than do disposable latex gloves, and are recommended for general laboratory work where significant chemical contact is not expected (available through the UNR Chemical Stores, and most laboratory safety supply vendors). **Regardless of the glove material, disposable gloves only provide protection against incidental chemical contact (occasional splash or spray).** If contact with a chemical of concern occurs, the gloves should be removed immediately, hands washed, and new gloves obtained.

Chemical Resistant Gloves
Thicker, chemical resistant gloves should be worn when skin contact with corrosive or highly toxic chemicals is likely. **When working with highly toxic chemicals, especially those that are absorbed through the skin, wear chemical resistant gloves made of material known to be resistant to permeation by the specific chemical.** If chemical resistant gloves are reused, they should be thoroughly rinsed with clean water after each use and allowed to air dry.

Choosing Chemical Resistant Gloves
The following table provides general recommendations for several chemical resistant glove materials.
Glove Material | Generally Recommended For | Not Recommended For
--- | --- | ---
Butyl Rubber | Acids, bases, ketones, esters, alcohols, and aldehydes | Aliphatic, aromatic, and halogenated hydrocarbons
4H/Silver Shield (North Safety Products) | Good resistance to many chemicals, including chlorinated solvents, hydrocarbons, and ketones | No specific guidance; consult North Safety Products (www.northsafety.com)
Natural (Latex) Rubber | Alcohols, caustics, ketones, and many acids | Aromatics, and hydrocarbons (especially halogenated or aromatic)
Neoprene | Organic acids, caustics, alcohols, ketones, and petroleum hydrocarbons | Aromatic and halogenated hydrocarbons
Nitrile | Many acids, caustics, alcohols, and hydrocarbons | Ketones, halogenated hydrocarbons, and strong acids
Polyvinyl Alcohol | Most organic solvents, including aromatic, halogenated, and petroleum solvents | Inorganic acids, caustics, alcohols, and other aqueous or polar liquids
Viton | Halogenated and aromatic organic solvents | Ketones, ethers, amines, and aldehydes

EH&S has also compiled a list of recommended glove types for several specific laboratory chemicals to assist laboratory workers in identifying the proper glove for their application. EH&S has more detailed information on the chemical resistance and permeation of many glove materials, and laboratory workers should contact the University CHO for specific guidance. Lastly, additional information on recommended chemical resistant gloves is available from glove manufacturers.

- Ansell Chemical Resistant Glove Selection Guide
- Showa Chemical Resistant Glove Guide
- Microflex Chemical Resistance Guide for latex and nitrile gloves

Body Protection
Laboratory workers are expected to always wear a long sleeved (with sleeves rolled down), buttoned lab coat that extends below their mid-thigh when handling hazardous chemicals. It is strongly recommended that all laboratory workers wear clothing that fully covers their legs.

Cotton lab coats are recommended for general laboratory work. The best lab coat material for a specific application can depend on the anticipated hazards. Although cotton lab coats are recommended for general laboratory use, cotton reacts rapidly with acids. Synthetic materials often provide increased chemical resistance but may melt or decompose when exposed to fire or certain chemicals and adhere to skin, increasing damage, but are more resistant to concentrated acids than is cotton. Alternatively, rubberized aprons and chemical resistant sleeves can be used over cotton lab coats when working with concentrated acids or other highly corrosive chemicals.
When working with larger quantities of flammable materials or any quantity of pyrophoric chemicals, a fire resistant lab coat should be worn (also see the section on pyrophoric chemicals in Chapter 5). Additionally, personal clothing composed of synthetic material that is likely to melt and adhere to skin if exposed to fire should not be worn.

Non-disposable lab coats must be laundered on a regular basis, with transport in sealed plastic bags. Lab coats should not be laundered at home but should be laundered using a university washing machine or commercial laundry service.

Foot Protection
Laboratory workers should always wear low-heeled shoes with fully covering “uppers.” Shoes with open toes or with uppers constructed of woven material are not recommended.

Respiratory Protection
Respiratory protection is not normally required during laboratory operations if the work is performed in a properly functioning laboratory hood. Operations involving highly volatile chemicals, large volumes of chemicals, chemicals with low exposure limits (such as less than 10 ppm), or operations that cannot be performed in a hood, may require the use of respiratory protection. Contact the Chemical Hygiene Officer regarding respirator use and approval.

Required Use of Respiratory Protection
Prior approval from EH&S is required whenever personnel are required to wear any respirator (including N95 dust masks/filtering face piece respirators) to prevent exposure to recognized health risks, or when required by regulation or administrative procedure. In these circumstances, all personnel must be medically evaluated, fit-tested, and trained prior to using respiratory protection.

Voluntary Use of Respirators
Some personnel may want to voluntarily wear a dust mask (filtering face piece) or other respirator in the absence of a recognized inhalation risk, regulatory requirement, or administrative requirement. In these circumstances, personnel are permitted to voluntary wear a respirator; however, certain requirements must still be met so EH&S must be contacted prior to voluntary use of respirators.

Voluntary use of N-95 filtering face piece respirators requires only that specific information contained in the applicable OSHA standard (29 CFR 1910.134, Appendix D) be provided to each person. To meet this requirement, each person who plans on wearing a respirator voluntarily much complete the Voluntary Use of Air Purifying Respirators form and send the completed form to the Chemical Hygiene Officer. As a reminder, dust masks are particulate filters and therefore are only effective against particles; they do not provide protection from inhalation of gasses or vapors.

Voluntary use of any respirator other than dust masks (including N-95 filtering face piece respirators) requires that each person be medically evaluated, fit-tested, and trained prior to respirator use. Contact the University Chemical Hygiene Officer at 327-5196 for more information.
Additional Information on Respirators and Regulatory Requirements

- OSHA Respiratory Protection eTool
- UNR Respiratory Protection Program

Personal Protective Equipment Use Summary

The following table provides a hazard assessment summary and corresponding PPE recommendations for general laboratory operations. In some instances, the following PPE recommendations may be inappropriate due to factors such as chemical quantity used, specific chemical toxicological factors, and other variables. These recommendations may be modified (either up or down) following an assessment of the risk associated with the specific procedure and the approval of the responsible laboratory supervisor. Such laboratory-specific guidance should be documented in written Standard Operating Procedures (SOPs) and included in laboratory-specific training.

In all cases, the specific risks associated with particular procedures should be evaluated and PPE selected based on this risk assessment.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Recommended Personal Protective Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any use of chemicals</td>
<td>Safety glasses</td>
</tr>
<tr>
<td>Use of corrosives (other than hydrofluoric acid), strong oxidizers</td>
<td>Chemical splash goggles, Dilute Solutions (&lt;1 N): safety glasses or goggles</td>
</tr>
<tr>
<td></td>
<td>Full face shield and goggles for large liquid volumes (≥ 4 L)</td>
</tr>
<tr>
<td></td>
<td>Chemical resistant gloves and lab coat, with rubber apron suggested for high risk procedures.</td>
</tr>
<tr>
<td></td>
<td>For small volumes (&lt; 250 ml) or dilute solutions (&lt; 1 N): Disposable gloves, lab coat.</td>
</tr>
<tr>
<td>Hydrofluoric Acid</td>
<td>Chemical splash goggles</td>
</tr>
<tr>
<td></td>
<td>Full face shield and goggles for solutions greater than 2%</td>
</tr>
<tr>
<td></td>
<td>Chemical resistant gloves (butyl or neoprene) and lab coat, with rubber apron recommended (with chemical resistant sleeve protectors recommended)</td>
</tr>
<tr>
<td></td>
<td>For solutions less than 2%: chemical resistant gloves and lab coat (rubber apron recommended)</td>
</tr>
</tbody>
</table>
| Use of carcinogens, reproductive toxins, and other highly toxic compounds | Chemical splash goggles  
Small Volumes (<50 ml): safety glasses or goggles | Full face shield and goggles for large liquid volumes (≥ 4 L) | Chemical resistant gloves and lab coat, with rubber apron suggested for large liquid volumes. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryogenic Liquids</td>
<td>Chemical splash goggles</td>
<td>Full face shield and goggles when pouring or other transfers</td>
<td>Lab coat, cryogenic gloves or other insulated gloves that provide cold protection</td>
</tr>
<tr>
<td>Sharp objects (glass, etc.), insertion of glass rods into stoppers</td>
<td>Safety glasses</td>
<td></td>
<td>Heavy cloth barrier or leather gloves, handle broken glass with tongs</td>
</tr>
<tr>
<td>Pressure extremes (high pressure or vacuum systems)</td>
<td>Chemical splash goggles</td>
<td>Full face shield and goggles</td>
<td>Lab coat, with rubber apron suggested if chemical splash is possible</td>
</tr>
</tbody>
</table>
Chapter 14
Eyewash Fountains and Safety Showers

Availability of Eyewashes and Safety Showers
All laboratories and chemical storage areas must have ready access to an operating eyewash, with a safety shower generally required as well. Recommended maximum travel time for an affected individual (assume eyes have been splashed with chemical) is 10 seconds (considered to be approximately 55 feet). Contact the Chemical Hygiene Officer for a determination on the necessity and placement of eyewashes and showers.

Access to Eyewashes and Safety Showers
In the event of a personal contamination, prompt flushing of the affected area is necessary to minimize harm to the affected person. Keep the eyewash/safety shower area free of obstructions, and easily accessible.

Maintenance of Eyewashes and Showers
Individual users (departments or laboratories) should flush eyewashes on a weekly basis to verify performance and to reduce the threat of microbial infection (an operating time of three to five minutes is recommended).

Eye washes and safety showers are checked by EH&S personnel on approximately a monthly basis, with the exception of units located in areas with special access requirements (e.g., BSL-3 laboratories). Laboratory users are responsible for conducting performance checks of units in these locations.

Personal Eyewashes
In some instances it may be prudent to supplement plumbed eyewashes with personal eyewashes (individual plastic water bottles); however, personal eyewashes are not meant to replace plumbed units. Personal eyewashes are to be used only to provide immediate flushing. Once this is accomplished, the affected individual must then perform a thorough flushing of the eyes using a plumbed unit (15 minutes is recommended).

Non-plumbed eye wash units, to include personal eyewash units and portable eye wash units, must be maintained and discarded according to the manufacturer’s instructions and expiration date.
Chapter 15
Communication of Chemical Hazards

Classification of Chemical Hazards
Specific criteria has been established by OSHA for the classification of health and physical hazards, with many hazard classes sub-divided into hazard categories based on the severity of the hazard. The following tables summarize the health and physical hazards to be considered when classifying a chemical.

### Health Hazard Classification
(see [OSHA chemical health hazard criteria](https://www.osha.gov/SLTC/chemicalsafety/accidentprevention.html))

<table>
<thead>
<tr>
<th>Hazard Class</th>
<th>Hazard Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Toxicity: oral, dermal, inhalation</td>
<td>1</td>
</tr>
<tr>
<td>Skin Corrosion/Irritation</td>
<td>1A, 1B, 1C, 2 (irrit)</td>
</tr>
<tr>
<td>Serious Eye Damage/Irritation</td>
<td>1, 2A (irrit), 2B (irrit)</td>
</tr>
<tr>
<td>Respiratory/Skin Sensitization</td>
<td>1A, 1B</td>
</tr>
<tr>
<td>Germ Cell Mutagenicity</td>
<td>1A, 1B, 2</td>
</tr>
<tr>
<td>Carcinogenicity</td>
<td>1A, 1B, 2</td>
</tr>
<tr>
<td>Reproductive Toxicity</td>
<td>1A, 1B, 2, lactation</td>
</tr>
<tr>
<td>Specific Organ Toxicity – single exposure</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Specific Organ Toxicity – repeated exposure</td>
<td>1, 2</td>
</tr>
<tr>
<td>Aspiration Hazard</td>
<td>1</td>
</tr>
<tr>
<td>Simple Asphyxiants</td>
<td>Single category</td>
</tr>
</tbody>
</table>

**HIGH HAZARD** → **LOW HAZARD**
## Physical Hazard Classification
(see [OSHA chemical physical hazard criteria](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10627))

<table>
<thead>
<tr>
<th>Hazard Class</th>
<th>Hazard Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explosives</strong></td>
<td></td>
</tr>
<tr>
<td>Unstable Explosives</td>
<td></td>
</tr>
<tr>
<td>Div. 1.1</td>
<td></td>
</tr>
<tr>
<td>Div. 1.2</td>
<td></td>
</tr>
<tr>
<td>Div. 1.3</td>
<td></td>
</tr>
<tr>
<td>Div. 1.4</td>
<td></td>
</tr>
<tr>
<td>Div. 1.5</td>
<td></td>
</tr>
<tr>
<td>Div. 1.6</td>
<td></td>
</tr>
<tr>
<td>Flammable Gases</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Flammable Aerosols</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Oxidizing Gases</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Gases Under Pressure</td>
<td></td>
</tr>
<tr>
<td>Compressed Gases</td>
<td>Single category</td>
</tr>
<tr>
<td>Liquefied Gases</td>
<td>Single category</td>
</tr>
<tr>
<td>Refrigerated Liquefied Gases</td>
<td>Single category</td>
</tr>
<tr>
<td>Dissolved Gases</td>
<td>Single category</td>
</tr>
<tr>
<td>Flammable Liquids</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Flammable Solids</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Self-Reactive Substances</td>
<td></td>
</tr>
<tr>
<td>Type A</td>
<td></td>
</tr>
<tr>
<td>Type B</td>
<td></td>
</tr>
<tr>
<td>Type C</td>
<td></td>
</tr>
<tr>
<td>Type D</td>
<td></td>
</tr>
<tr>
<td>Type E</td>
<td></td>
</tr>
<tr>
<td>Type F</td>
<td></td>
</tr>
<tr>
<td>Type G</td>
<td></td>
</tr>
<tr>
<td>Pyrophoric Liquids</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Pyrophoric Solids</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Self-Heating Substances</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Chemicals Which, In Contact With Water, Emit Flammable Gases</td>
<td>1</td>
</tr>
<tr>
<td>Oxidizing Liquids</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Oxidizing Solids</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Organic Peroxides</td>
<td></td>
</tr>
<tr>
<td>Type A</td>
<td></td>
</tr>
<tr>
<td>Type B</td>
<td></td>
</tr>
<tr>
<td>Type C</td>
<td></td>
</tr>
<tr>
<td>Type D</td>
<td></td>
</tr>
<tr>
<td>Type E</td>
<td></td>
</tr>
<tr>
<td>Type F</td>
<td></td>
</tr>
<tr>
<td>Type G</td>
<td></td>
</tr>
<tr>
<td>Corrosive to Metals</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Hazard Classifications:***
- **Explosives:** Unstable Explosives
- **Flammable Gases:** Flammable Gases
- **Flammable Aerosols:** Flammable Aerosols
- **Oxidizing Gases:** Oxidizing Gases
- **Gases Under Pressure:** Compressed Gases, Liquefied Gases, Refrigerated Liquefied Gases, Dissolved Gases
- **Flammable Liquids:** Flammable Liquids
- **Flammable Solids:** Flammable Solids
- **Self-Reactive Substances:** Self-Reactive Substances
- **Pyrophoric Liquids:** Pyrophoric Liquids
- **Pyrophoric Solids:** Pyrophoric Solids
- **Self-Heating Substances:** Self-Heating Substances
- **Chemicals Which, In Contact With Water, Emit Flammable Gases:** Chemicals Which, In Contact With Water, Emit Flammable Gases
- **Oxidizing Liquids:** Oxidizing Liquids
- **Oxidizing Solids:** Oxidizing Solids
- **Organic Peroxides:** Organic Peroxides
- **Corrosive to Metals:** Corrosive to Metals

**Hazards Levels:**
- **HIGH HAZARD**
- **LOW HAZARD**
Hazard Ratings
The hazard categories provide information on the severity of the hazard, with some categories including numerical ratings. Under the HCS criteria, the highest hazards are rated as “1” and lower hazards are rated as successively higher numerical or alphabetic ratings. This hazard rating scheme is in contrast to the commonly used National Fire Protection Association (NFPA) 704 and Hazardous Materials Identification System (HMIS) systems which use a hazard rating of “0” for the lowest hazard and “4” for the highest hazard. A comparison of the HCS hazard rating scheme and the NFPA 704 and HMIS schemes is shown below.

<table>
<thead>
<tr>
<th>NFPA/HMIS Hazard Ratings</th>
<th>HCS Hazard Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ~ minimal hazard</td>
<td>Category 1 ~ severe hazard</td>
</tr>
<tr>
<td>1 ~ slight hazard</td>
<td>Category 2 ~ serious hazard</td>
</tr>
<tr>
<td>2 ~ moderate hazard</td>
<td>Category 3 ~ moderate hazard</td>
</tr>
<tr>
<td>3 ~ serious hazard</td>
<td>Category 4 ~ slight hazard</td>
</tr>
<tr>
<td>4 ~ severe hazard</td>
<td>Category 5 ~ minimal hazard</td>
</tr>
</tbody>
</table>

Hazard Definitions
The HCS hazard definitions may differ from other commonly used definitions. Of particular note is the use of the term “flammable liquid.” The International Fire Code (IFC) and the NFPA classify liquids with flash points of less than 100 °F as a flammable liquid, with liquids having flash points greater than 100 °F as combustible liquids. The HCS classifies flammable liquids as those with a flash point of less than or equal to 200 °F.

**IFC/NFPA flammable liquid = flash point < 100 °F (38 °C)**
**HCS flammable liquid = flash point ≤ 200 °F (93 °C)**

Safety Data Sheets
Material Safety Data Sheets (MSDSs) are now known as Safety Data Sheets (SDSs). SDSs are chemical hazard information sheets designed to provide users with the information necessary to handle the chemical safely. OSHA regulations require that chemical manufacturers and vendors supply MSDSs to chemical users, and that workers have ready access to SDSs.

- All Safety Data Sheets (MSDSs) received with incoming hazardous chemicals must be retained.
- A SDS is not required for uncharacterized research material used only by the laboratory that produced it, or for laboratory reagents mixed in the laboratory; however, laboratory workers must be aware of the hazards presented by these chemicals. If the hazards are unknown the chemical must be handled in a manner to minimize exposure to personnel.
• If a chemical substance is prepared for another user outside of the laboratory, the requirements of the OSHA Hazard Communication Standard (29 CFR 1910.1200) must be met, including preparation of a Safety Data Sheet (SDS). Contact EH&S for assistance with preparation of SDSs.

SDS Review and Availability
Before using a new chemical, laboratory workers should review the SDS. Consequently, all laboratory workers must know the location of the SDSs that are maintained by the laboratory, and how to obtain SDSs covering additional chemicals used in the laboratory.

• Copies of many SDSs are forwarded to EH&S by chemical vendors. These SDSs can be accessed from the EH&S SDS Database (http://www.unr.edu/ehs/sds-data).

• EH&S subscribes to an electronic database that includes SDSs and other sources of chemical hazard information. The database is available to the UNR community (via campus computers only) through the EH&S web site as follows:
  - Go to the EH&S Safety Data Sheet (SDS) Retrieval page (http://www.unr.edu/ehs/sds-data)
  - Click on “Search the CCINFOweb SDS Database” to access the database (accessible only via a campus computer)

• Additional sources of SDSs:
  - Vermont Safety Information Resources, Inc. (www.hazard.com)
  - Fisher Scientific – SDSs for Fisher products
  - Sigma-Aldrich – SDSs for Sigma-Aldrich products
  - Avantor Performance Materials (formerly Mallinckrodt Baker) – SDSs for Avantor Performance Materials products

Additional Hazard Information
Since SDSs may not always provide adequate chemical hazard information and do not cover non-chemical hazards, additional sources of hazard information must be available to laboratory workers. The UNR libraries have multiple resources available that discuss laboratory hazards. The following are widely used laboratory safety references that are available at UNR libraries:
  - Prudent Practices in the Laboratory (can download in PDF for free), National Research Council (2011)
  - Laboratory Safety for Chemistry Students, Robert H. Hill, Jr. and David C. Finster (2010)
  - Bretherick’s Handbook of Reactive Chemical Hazards (accessible online for free), seventh edition, P. G. Urben (Ed.) (2007)

Note: older editions of this reference are available from UNR libraries.
Chemical Labeling
Unidentified chemicals represent an increased risk to personnel due to a lack of information on how to properly handle the material. Additionally, unknown chemicals may be a financial burden since they cannot be disposed of without identification, which may involve laboratory analysis. To avoid unidentified chemicals, label all chemical containers as described below.

Original Manufacturer’s Containers
OSHA regulations require that manufacturers’ chemical labels include the following information:
- **Product Identifier:** The name of the chemical or chemical product.
- **Signal Word:** Used to indicate the relative severity of the hazard. Only “Danger” or “Warning” can be used, with “Danger” indicating more severe hazards and “Warning” indicating less severe hazards.
- **Pictogram:** Any number of the eight pictograms shown below will be used to display the major hazard categories associated with the chemical. When a chemical has multiple hazards, different pictograms will be used to display the various hazards.
- **Hazard Statements:** Describe the nature of the hazards associated with the chemical. All applicable hazard statements must appear on the chemical label. Hazard statements should be consistent regardless of the chemical or manufacturer.
- **Precautionary Statements:** Describe recommended measures to prevent adverse effects that may result from exposure to the chemical. When there are similar precautionary statements, the statement providing the most protective information will be listed.
- **Name, Address, and Phone Number:** The name, address, and phone number of the chemical manufacturer or distributor.

- Labels on manufacturers’ containers must not be removed or defaced unless the container has been emptied or the chemical corresponding to the original label has been replaced with a different chemical.

- If the original label is missing or is illegible, it must be replaced with a label containing the above information.

Chemical Hazard Pictograms
The following chemical hazard pictograms are required by OSHA to be included on manufacturers’ chemical labels. Chemical labels will include multiple pictograms as is needed to communicate all hazards associated with the particular chemical.
Secondary Containers
Chemicals that are transferred from their original container to a secondary storage container and which will be stored long term must be labeled to indicate the chemical name, and the primary hazards should be indicated through use of the above pictograms or hazard wording. Likewise, containers of chemical mixtures that have been prepared in the laboratory for use as reagents (such as buffers, or dilute acid or base solutions) must be labeled to indicate the hazardous chemical constituents and the primary hazards should also be indicated. Include chemical concentrations on reagent containers (such as acids and bases) to accurately communicate the hazards associated with the material. The chemical name and hazard information must be consistent with the original manufacturer’s label.

Where practical, chemical names must be spelled out on container labels. Abbreviations and common reagent names may be used for labeling provided that information on the chemical constituents is available in the laboratory, and laboratory personnel are familiar with this information.
Temporary chemical containers (such as beakers, volumetric flasks, and reaction vessels) in active use require only a content identifier label; however, hazard warnings are recommended for reagents that are highly toxic, highly flammable, or which have other significant hazards. If these containers are stored they should also be labeled to indicate the primary hazards.

**Research Materials**
The hazards of chemicals synthesized in the laboratory, and other research materials, are often not completely known and complete hazard labeling is not possible. Nevertheless, research materials must be labeled as completely as possible using the following guidelines:

- Label research materials with the name of the responsible researcher and the identity and hazards (as available). General labeling to indicate chemical identity or class of chemical and hazards can be used when specific information is not known or cannot be included on labels in a practical manner (e.g., a large number of containers of research materials in process).

- References to research notebooks, etc. should be included when necessary to convey identity and hazard information.

**Chemical Delivery Systems**
Inadequate labeling of chemical piping and tubing delivery systems can confuse personnel and lead to chemical exposure, fire, or explosion due to inadvertent cutting of lines or unsafe work practices (such as use of flame near lines containing a flammable chemical).

- All facility piping used for delivery of natural gas, water, and air must be labeled with content identifier labels placed periodically along the length of the delivery system.

- Non-facility delivery systems to include semi-permanent and temporary piping or tubing of compressed gases or other chemicals must also be labeled throughout the delivery system.
Chapter 16
Chemical Storage

General Storage Guidelines
The primary goals of safe chemical storage are to reduce risk by minimizing quantities of chemicals stored, avoiding contact between incompatible chemicals, and preventing hazardous storage conditions (for example, light and heat). Additionally, physical security of chemical storage areas is an increasing concern. **Provide adequate security so that unauthorized personnel do not have access to chemicals.** Chemical storage areas should be locked when authorized personnel are not present.

Selection of Chemicals
The overall risk associated with a particular laboratory is dependent in large part on the chemical inventory; chemical hazards, chemical volume, and storage conditions all influence risk. Whenever possible, choose chemicals that minimize hazards such as toxicity, flammability, and reactivity. In some cases, a less hazardous chemical can be used if laboratory procedures are modified. Ordering only the volume of chemical needed, or that will be used within the shelf life of the chemical, will minimize the chemical inventory within the laboratory. When only a small amount of a chemical is needed it can often be obtained from another laboratory on campus (the Chemical Hygiene Officer can be contacted for assistance). Additionally, determine if adequate storage conditions such as physical space and storage containers (such as flammable storage cabinets) are available prior to obtaining the chemical.

Chemical Inventory and Inspection
- A chemical inventory must be maintained for all chemicals stored in the laboratory. EH&S maintains a chemical inventory of each lab on campus; however, laboratories are encouraged to keep their inventory current by adding and deleting chemicals as they are received or disposed. The chemical inventory database used at UNR is known as ChemTracker. Although ChemTracker is web-based, access to each laboratory inventory is secured to prevent unauthorized viewing. Each laboratory supervisor is granted access to his or her inventory; other laboratory personnel will be provided access only upon approval by the responsible laboratory supervisor. Laboratory supervisors wanting to allow other laboratory personnel to access their lab’s inventory will need to contact EH&S.

- Empty chemical containers must be removed from the chemical inventory as they are disposed of. This can be accomplished by submitting a request for pickup of empty containers to EH&S using the chemical waste forms, or submitting UNR bar code numbers from empty containers to Luis Barthel-Rosa (luisbr@unr.edu). Alternatively, empty containers placed in a designated location will be removed by EH&S waste technicians when they dispose of full waste containers for which a request for disposal has been submitted.

- Each laboratory should perform periodic (at least annually) inspections of their chemical inventory.
  - Chemicals that are no longer needed, or which meet any of the following conditions, should
be disposed of through EH&S: i) safe shelf life has been exceeded, ii) evidence of chemical reaction, iii) identity of chemical is unknown, iv) container and/or cap corroded, leaking, or otherwise in poor condition.

**General Storage Recommendations**

- It is recommended that chemical containers be labeled with the date of receipt and the date opened. This is especially important for peroxidizable chemicals and other chemicals with specific safe storage lifetimes.

- It is recommended that higher risk chemicals (highly toxic, flammable, or reactive) be stored in secondary containment to reduce the likelihood of release.
  - For liquid chemicals, plastic tubs and trays can be used as secondary containment for larger containers or multiple containers, while sealed cans and plastic bags can be used for smaller, individual containers.
  - For solid chemicals, sealed containers or plastic bags can provide secondary containment.

- Generally, chemicals should be stored in cabinets or on shelves.
  - Storage of chemicals in laboratory hoods should be minimized in order to maximize the hood ventilation performance.
  - Storage of chemicals on the floor should be avoided, and if required, glass chemical containers stored on the floor must be in secondary containment.

- Chemical storage cabinets should be secured to a wall or other structure to avoid tipping over (especially likely in an earthquake).
  - Shelving should be secure and able to support the materials placed on them.
  - Shelves should have a barrier or lip to prevent chemical containers from falling off.

**Segregation and Storage of Chemicals**

In order to reduce the likelihood of incompatible mixing during storage, chemicals should be segregated and stored according to their hazard classification and compatibility (see appendix “Partial List of Chemical Incompatibilities”). Incompatible chemicals within hazard classes should also be separated. The ChemTracker chemical inventory management system assigns chemicals to one of eleven storage groups as follows:

<table>
<thead>
<tr>
<th>Storage Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Compatible Organic Bases</td>
</tr>
<tr>
<td>B</td>
<td>Compatible Pyrophoric and Water Reactive Materials</td>
</tr>
<tr>
<td>C</td>
<td>Compatible Inorganic Bases</td>
</tr>
<tr>
<td>D</td>
<td>Compatible Organic Acids</td>
</tr>
<tr>
<td>E</td>
<td>Compatible Oxidizers Including Peroxides</td>
</tr>
<tr>
<td>F</td>
<td>Compatible Inorganic Acids Not Including Oxidizers or Combustibles</td>
</tr>
</tbody>
</table>
The ChemTracker storage groups can be used to assist laboratory workers in segregating chemicals; however, incompatible chemicals may still end up grouped together so laboratory personnel will need to evaluate the compatibility of stored chemicals.

When a chemical fits in more than one hazard category, store the chemical according to the highest risk (based on severity of consequences and likelihood) hazard criteria.

- **Fire is generally considered to be the highest risk category** and flammability/combustibility should be used as the major storage criteria.

**General Chemical Storage (Storage Group G)**

General chemical storage includes low risk chemicals not assigned to another specific hazard group (such as salts, amino acids, buffers, etc.). Store these chemicals using general storage recommendations.

- It is recommended that general chemicals be separated into liquids and solids, and then further segregated into organic and inorganic sections.

**Acids**

- Store oxidizing acids (such as nitric acid, perchloric, and chromic acid) away from organic acids, and organic solvents.
  - Concentrated perchloric acid should be stored in glass or plastic (polyethylene or polypropylene) secondary containers away from combustible materials (such as wooden shelves and paper).

**Note:** Glacial acetic acid has a flash point of approximately 102 °F (39 °C) and is classified as a combustible liquid.

- Store inorganic acids separately from organic acids.
- Concentrated acids should be stored in an acid storage cabinet.
- Separate acids from active metals (such as sodium, magnesium, and potassium) and chemicals that generate toxic gases on contact with acids (such as inorganic cyanides and sulfides).
Separate acids from bases.
  - If necessary, acids and bases can be stored in the same cabinet; however, they should be physically separated by storing in secondary containers (such as bus tubs).

Bases
  - Separate bases from acids.

Flammable and Combustible Liquids

Maximum Flammable and Combustible Liquid Container Size
The maximum allowable (by OSHA) sizes for flammable and combustible liquid storage containers are as follows:

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Flammable Liquid Category</th>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
<th>Category 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass or approved plastic</td>
<td>Category 1</td>
<td>1 pint</td>
<td>1 quart</td>
<td>1 gallon</td>
<td>1 gallon</td>
</tr>
<tr>
<td>Metal (other than DOT drums)</td>
<td>Category 2</td>
<td>1 gallon</td>
<td>5 gallon</td>
<td>5 gallon</td>
<td>5 gallon</td>
</tr>
<tr>
<td>Safety cans</td>
<td>Category 3</td>
<td>2 gallon</td>
<td>5 gallon</td>
<td>5 gallon</td>
<td>5 gallon</td>
</tr>
<tr>
<td>Metal drums (DOT specifications)</td>
<td>Category 4</td>
<td>60 gallon</td>
<td>60 gallon</td>
<td>60 gallon</td>
<td>60 gallon</td>
</tr>
<tr>
<td>Approved portable tanks</td>
<td></td>
<td>660 gallon</td>
<td>660 gallon</td>
<td>660 gallon</td>
<td>60 gallon</td>
</tr>
</tbody>
</table>

Exceptions: Glass or plastic containers up to one gallon capacity can be used for a Category 1 or 2 flammable liquid if the stored liquid would be rendered unfit for its intended use by contact with metal, or would excessively corrode a metal container so as to create a leak hazard. See 29 CFR 1910.106(d)(2)(iii)(a)(1)-(2) for complete exception.

OSHA Flammable Liquid Categories
Category 1 - Flash point < 23°C (73.4°F) and initial boiling point ≤ 35°C (95°F)
Category 2 - Flash point < 23°C (73.4°F) and initial boiling point > 35°C (95°F)
Category 3 - Flash point ≥ 23°C (73.4°F) and ≤ 60°C (140°F)
Category 4 - Flash point > 60°C (140°F) and ≤ 93°C (199.4°F)

Maximum Allowable Quantities in Laboratory Buildings
Contemporary laboratory safety practice dictates that the volume of flammable and combustible liquids stored and used in the laboratory be minimized. Flammable liquids, and to a lesser extent combustible liquids, should always be stored in flammable liquid storage cabinets and safety cans to minimize the risk of fire.

The Nevada State Fire Marshall, through incorporation of the International Fire Code (IFC), regulates maximum storage quantities for flammable and combustible liquids per fire control area. The IFC also limits the number of control areas per building and per floor. The maximum allowable quantities of flammable and combustible liquids per control area (including chemical waste) are:
### Class 1A
- **Quantity - Storage:** 30 gallons
- **Quantity – In Use, Closed System:** 30 gallons
- **Quantity – In Use, Open System:** 10 gallons

### Class 1A, 1B, and 1C combined*
- **Quantity - Storage:** 120 gallons
- **Quantity – In Use, Closed System:** 120 gallons
- **Quantity – In Use, Open System:** 30 gallons

### Class II
- **Quantity - Storage:** 120 gallons
- **Quantity – In Use, Closed System:** 120 gallons
- **Quantity – In Use, Open System:** 30 gallons

### Class IIA
- **Quantity - Storage:** 330 gallons
- **Quantity – In Use, Closed System:** 330 gallons
- **Quantity – In Use, Open System:** 80 gallons

* Quantity limits for Class 1A may not be exceeded.

**IFC Flammable and Combustible Liquid Definitions**
- **Class IA** – Liquids having a flashpoint below 73 °F (23 °C), and having a boiling point below 100 °F (38 °C).
- **Class IB** – Liquids having a flashpoint below 73 °F (23 °C), and having a boiling point at or above 100 °F (38 °C).
- **Class IC** – Liquids having a flashpoint at or above 73 °F (23 °C), and below 100 °F (38 °C).

**Combustible Liquids**
- **Class II** – Liquids having a flashpoint at or above 100 °F (23 °C), but below 140 °F (60 °C).
- **Class IIIA** – Liquids having a flashpoint at or above 140 °F (60 °C), but below 200 °F (93 °C).

Additionally, the number of allowable control areas, and the percentage of the maximum allowable quantity per control area is limited by the floor level within the building as listed below.

<table>
<thead>
<tr>
<th>Floor Level</th>
<th>% of Max. Allowable Quantity Per Control Area</th>
<th>Number Control Areas Per Floor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Above Grade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 9</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>7-9</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>12.5</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>12.5</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>12.5</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Below Grade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>75</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>lower than 2</td>
<td>not allowed</td>
<td>not allowed</td>
</tr>
</tbody>
</table>

**Note 1:** A single control area may be composed of multiple laboratory rooms; thus, the maximum allowable quantity of flammable and combustible liquids in an individual laboratory room will usually be less than the above control area values.
Note 2: The maximum allowable limits for flammable and combustible liquids can be doubled if stored in an approved flammable liquid storage cabinet or approved safety cans, and can be doubled again if the rooms comprising the control area are equipped with automatic fire suppression sprinklers.

It is recommended that quantities of flammable liquids stored outside of a flammable storage cabinet or safety can be limited as follows:

- The maximum quantity of flammable liquids (Class I) and Class II combustible liquids, combined, that can be stored outside of a flammable storage cabinet is 10 gallons; however, this total can be increased to 25 gallons if the flammable and combustible liquids are stored in safety cans.

- All 5 gallon flammable liquid containers should be stored in a flammable liquid storage cabinet.

Storage in Flammable Liquid Cabinets

Maximum Storage Quantities

- Maximum storage quantities per individual flammable liquid storage cabinet are:
  - 60 gallons of flammable or combustible liquid.
  - 120 gallons of flammable and combustible liquid combined.

Ventilation of Flammable Liquid Cabinets

- Flammable storage cabinets should not be vented for fire protection purposes.

- Ventilation of cabinets must be in accordance with fire protection requirements found in NFPA 30, Flammable and Combustible Liquids Code and approved by the State Fire Marshall's Office.
  - Do not remove vent bungs from storage cabinets unless the cabinets are properly ventilated.

  Additional information on venting flammable liquid storage cabinets is available from Grainger.

Labeling of Flammable Liquid Cabinets

- Storage cabinets must be labeled “Flammable-Keep Fire Away.”

Storage in Refrigerators and Freezers

Refrigerators and freezers designed for domestic use contain interior spark sources and should not be used for storage of flammable liquids.

- Do not use a domestic refrigerator or freezer for storage of flammable liquids; use only an approved “laboratory safe” unit (no spark sources in the interior of the unit).
  - The quantity of flammable liquid stored in refrigerators is included in the maximum amount that can be stored outside of an approved flammable liquid cabinet.
Non-Flammable/Combustible Organic Liquids
- Store in a cabinet separated from oxidizing materials.
  - These chemicals can be stored with flammable and combustible liquids.

Oxidizers
- Separate oxidizers from flammable and combustible materials, and reducing agents.

Highly Reactive Chemicals
- Store water reactive chemicals in a secondary container or other protective barrier against accidental exposure to water.
  - Do not store under sinks or near other locations with potential water exposure.

- Store pyrophoric chemicals in an inert atmosphere in accordance with the manufacturer’s (SDS) recommendations or other recognized laboratory safety practices, and away from flammable chemicals and heat sources. Additional information on pyrophoric chemicals is available in Chapter 5.

- Many organic chemicals can undergo autooxidation upon exposure to air and form shock sensitive peroxides. Chapter 6 has information on the proper handling and storage of peroxide forming chemicals.
Chapter 17

Information and Training

Contemporary laboratory safety practice and regulatory requirements require that all laboratory workers are knowledgeable of the hazards that they are exposed to, methods that can be used to minimize exposures, and current regulatory requirements pertaining to laboratory safety. Consequently, laboratory safety training is required for all laboratory workers, including students, faculty, and staff. At UNR, laboratory safety training is comprised of general training that covers general laboratory safety topics and regulatory requirements, and laboratory-specific training.

General Training

All laboratory personnel are required to receive laboratory safety training, including students, faculty, and staff. EH&S provides general laboratory training that covers general laboratory safety topics and regulatory requirements.

General laboratory safety training is composed of two parts. Part 1 is provided as a classroom or online presentation, and Part 2 is hands-on training conducted in the Safety Training for Academic Research (STAR) Lab located in ARF 301. All laboratory personnel must complete Part 1 and Part 2 training, with the following exception. Academic faculty members are not required to complete Part 2 training; however, completion of this training is strongly recommended.

Part 1 training is presented in modular format covering the following topics: 1) chemical hygiene, 2) chemical spill response and waste management, 3) laboratory ventilation, and 4) biosafety. The first three topics are relevant to all laboratory personnel, and biosafety is relevant to those who work with biological agents (microorganisms; cell or tissue culture; recombinant or synthetic nucleic acid, human blood or other body fluids, cells, or unfixed tissue). Part 2 training involves hands-on exercises that supplement and reinforce the laboratory safety principles presented in Part 1 training.

General Training Schedule

EH&S offers general training at the beginning of each semester and other times throughout the year. A calendar of scheduled training is available on the EH&S Training Calendar web page. EH&S will also try and accommodate requests for additional lab safety training sessions for groups of ten or more people. Contact the Chemical Hygiene Officer to inquire about the training schedule.

Laboratory workers must receive laboratory safety training prior to beginning work with hazardous chemicals. If scheduling absolutely does not permit participation in a scheduled training session, contact the University Chemical Hygiene Officer for alternative training options.

The full general laboratory safety training class does not have to be repeated but EH&S will offer an online refresher training class each year and all laboratory personnel, including faculty supervisors, must complete this refresher training each year. Additionally, on-going training is expected through documented, laboratory-specific training and associated laboratory safety updates, which are the responsibility of each laboratory supervisor.
Laboratory-Specific Training

The general training provided by EH&S covers regulatory requirements and general laboratory safety topics; however, this training is not designed to provide adequate training on all the specific hazards that may be encountered in a particular laboratory. Therefore, each laboratory supervisor is responsible for providing supplemental training on hazards specific to their laboratory. This laboratory-specific training is required before personnel are exposed to such hazards, and whenever a new hazard is introduced into the laboratory.

Laboratory-Specific Training Topics

Topics for laboratory-specific training should focus on higher risk operations conducted in the laboratory. Generally, laboratory-specific training topics will coincide with laboratory-specific SOP topics (see Chapter 3). Training topics can be based on specific chemicals, a single chemical class or chemical hazard (such as carcinogens), or specific laboratory procedures. Training should not be limited to chemical hazards, but should also include non-chemical hazards (for example, electricity, high pressure or vacuum, and equipment) as appropriate.

Laboratory-specific training should include the following information:

- Hazards of specific laboratory chemicals and procedures.
- The location of laboratory and department SOPs, and other chemical hazard reference materials.
- How to safely perform laboratory procedures.
- Procedures requiring prior approval from the Laboratory Supervisor.
- Chemical storage and inventory practices.
- Specific use of laboratory hoods and other engineering controls.
- Availability, selection, and use of personal protective equipment such as gloves and protective eye wear.
- Emergency procedures, such as spill response and fires.

Documentation and Maintenance of Training Records

Laboratory-specific training must be documented and the laboratory supervisor or the department must maintain the training records. Training documentation must include the following information: the name of the instructor, the name of the person receiving the training, the date, and the training topic(s). A training documentation form has been developed for documentation of laboratory-specific training; however, other methods may also be used. Laboratory-specific and department-specific training records must be maintained for a minimum of three years after the worker’s entire tenure at UNR has ended.
Chapter 18
Medical Consultations and Examinations

When Medical Attention is Required
Laboratory personnel must be provided the opportunity to receive medical attention at no cost to themselves under the following circumstances:

**Note:** Students who have no employee relationship with UNR (such as a student in a teaching lab) are not covered by Workers’ Compensation and are responsible for payment of medical evaluation and care. Contact the Business Center North Risk Management Office for guidance with student (non-Workers’ Compensation) incidents. Students who are enrolled for 6 or more credits are automatically assessed the Student Health Fee, so many students choose to go to the Student Health Center for evaluation of non-emergency injuries or chemical exposures.

- When personnel develop signs or symptoms that are associated with exposure to a hazardous chemical to which they may have been exposed.
- Air monitoring indicates that airborne exposure levels routinely exceed the action level established by OSHA, or the OSHA PEL if an action level has not been established. One-half the ACGIH TLV (or other exposure limit being used) will generally be used as the action level if an OSHA action level or PEL has not been established.
- An event such as a spill, leak or explosion results in a significant acute exposure to a hazardous chemical.

Medical Surveillance
When toxicologically significant quantities of carcinogens, reproductive toxins, or chemicals with high chronic toxicity are used on a regular basis (such as weekly or multiple times per month), implementation of a medical surveillance program should be considered. Since the specific circumstances determine the need for medical surveillance, consult the University Chemical Hygiene Officer in these instances.

As a general guideline, a toxicologically significant quantity is an amount greater than or equal to one-half the quantity reported to produce the primary toxicological effect expected for the specific chemical in a mammalian species, when scaled for a 50 kg (110 pound) person:

\[
\text{Toxicologically Significant Quantity (g)} = \geq \frac{[\text{toxicological effect dose (mg/kg)} \times 50 \text{ kg} \times \frac{1}{1000}]}{2}
\]

**Note:** If the dosage for the primary toxicological effect is not available, the LD\(_{50}\) can be substituted; however, since the LD\(_{50}\) is based on the endpoint of lethality, it is possible that some risk of non-lethal toxicological effects remain.
Responsibilities of the Laboratory Supervisor

The Workers’ Compensation Office must be notified (784-4394, or at http://www.bcn-nshe.org/hr/wcrm/workerscomp/) when medical evaluation or treatment is needed as a result of an occupational injury or illness (the notification applies to employees and non-employed students). When medical attention is required, the laboratory supervisor is responsible for ensuring that affected personnel are provided with the opportunity to receive medical attention, and that the below information is provided to the attending physician.

- The identity of any chemical(s) to which the affected person may have been exposed (include the SDS or other hazard information).
- The conditions under which any possible exposure occurred, including any exposure data (consult with the University Chemical Hygiene Officer).
- A report of any signs or symptoms the affected person is experiencing.

The employer (generally the Workers’ Compensation Office) must obtain a written opinion from the attending physician that includes the following:

- Any recommendation for medical follow-up.
- The results of the medical examination and any associated tests.
- Any medical condition identified during the examination that may place the affected person at increased risk as a result of exposure to hazardous chemicals found in the workplace.
- A statement that the affected person has been informed by the physician of the results of the examination, and of any medical condition that may require further examination or treatment.

**Note:** This report must not include specific findings of diagnoses unrelated to occupational exposure.

The above information should be shared with the laboratory supervisor as warranted by the situation and as required to ensure the health and safety of the affected person.

**Medical Facilities**

**Employees**

Employees (including students who receive employee compensation through assistantships) who are injured or exposed to chemicals, and require medical attention, should go to one of the following medical facilities that participate in the Workers’ Compensation Program:
For non-life threatening injuries that require medical attention, go to:

**Specialty Health Clinic**
330 E. Liberty Street, Suite 100  
Reno, NV  
(775) 398-3630  
Hours: 8:00 a.m. to 7:00 p.m., M-F

_After Hours or Weekends:_

St. Mary’s Urgent Care  
1595 Robb Drive, Suite #2  
Reno, NV 89523  
(775) 284-5556  
Hours: Monday – Friday, 8:00 a.m. to 6:00 p.m.  
Saturday and Sunday, 9:00 a.m. to 5:00 p.m.

For emergency treatment of non-life threatening injuries, or outside of the Specialty Health Clinic or St. Mary’s Urgent Care business hours, go to:

**St. Mary’s Hospital** or **Northern Nevada Medical Center**
235 W. Sixth Street  
2375 East Prater Way  
Reno, NV  
Sparks, NV  
(775) 770-3000 or (775) 356-4040

_Note:_ Indicate that you are a UNR employee and that the exposure or injury is occupationally related.

For life threatening injuries:
Call 9-911

_Students:_
Students who are injured or exposed to chemicals while performing tasks during which there is no employee relationship with UNR (such as a student in a teaching lab) should go to the [Student Health Center](mailto:studenthealthcenter@unr.edu) or other healthcare facility according to their personal preference (**students are responsible for payment**).

- If the situation requires emergency medical attention, **call 911**.
Additional Information
Additional information on the procedures for providing appropriate medical attention for occupational injuries or illnesses is available from the Workers’ Compensation Office by calling 784-6139, or at http://www.bcn-nshe.org/hr/wcrm/workerscomp/#urgent.
Chapter 19
Emergency Response

Emergency Contacts
Appropriate emergency response is predicated on an accurate assessment of risk. The following examples provide guidelines for appropriate emergency contacts:

**911, Reno City Emergency Dispatch**
Call 911 for fires, medical emergencies (including significant chemical contamination), and major chemical spills.

**327-5040, EH&S (answered 24 hours a day)**
Call 327-5040 for situations that do not warrant a 911 response but where assistance is needed. Examples of these situations include: lower risk spills that require cleanup assistance or materials, situations requiring air monitoring, and technical assistance. **327-5040 is a 24 hours a day, 7 days a week EH&S contact number.**

**784-8020, Facilities Maintenance (emergency after hours)**
Call 784-8020 for facility issues that require immediate assistance, including utilities (power, water, etc.) and laboratory ventilation problems.

Note: Although EH&S does not provide primary response to higher risk incidents (911 calls) or facility issues, report the incident to EH&S as soon as practical by calling 327-5040.

Preplanning
Incidents or emergencies are never planned or expected; therefore, anticipating potential incidents and preplanning an appropriate response is essential to minimizing the occurrence of incidents and their severity. Effective emergency planning requires that laboratory personnel know the hazards of the chemicals and equipment that they are working with, that potential accident scenarios be evaluated, and that appropriate response actions be developed. The emergency response actions that result from this preplanning should be included in the laboratory or department training program.

**Personnel safety is the primary consideration when responding to any laboratory incident. Do not place yourself or others at undue risk when responding to an incident.**

Personnel Contamination
Quick response to personnel contamination is necessary to minimize harm to the affected individual. To reduce response time, be knowledgeable of chemicals that are being used in the laboratory and the location of eyewashes and safety showers. If medical attention is required as a result of a chemical exposure, provide medical personnel with SDSs or other sources of health hazard information for the chemical(s) involved, and the circumstances of the exposure.
Eyes and Face
If chemical contact with the eyes occurs, **immediately** flush the affected area using water (eyewash, emergency shower, or other means available). It is recommended that the eyes be flushed for 15 minutes.

Due to pain and irritation, the eyes may have to be physically held open (by using your hands) during flushing. If the affected person is wearing contact lenses, flush the eyes before attempting to remove the contact lenses. If not removed by the flushing water, contact lenses should be removed as soon as the eyes can be held comfortably open, after which the eyes should continue to be flushed.

After thoroughly flushing the eyes, seek medical attention as soon as possible. **All incidents involving chemical exposure to the eyes require immediate medical attention.**

Skin
Flush the affected area with water as soon as possible. **Do not use solvents or other chemicals in an attempt to rinse off or neutralize the chemical.** Exceptions to this protocol should be discussed with the Chemical Hygiene Officer prior to implementation. Remove clothing and jewelry as necessary to rinse all potentially affected areas.

All incidents involving exposure to hydrofluoric acid, phenol, or other severe skin contact hazards require immediate medical attention. Additionally, seek medical attention if pain, numbness, redness, irritation or other signs are apparent.

Inhalation
Go to fresh air as soon as possible. If coughing, wheezing, or other symptoms of exposure are present, other than minor coughing that quickly subsides, seek immediate medical attention.

**Chemical Spills**
Since each spill scenario is different, the proper response to a particular spill is based on an assessment of risk. The appropriate level of response will vary depending on the specific health and physical hazards associated with the chemical, exposure potential, quantity spilled, and local circumstances such as ventilation and spark sources. Therefore, all laboratory workers must be familiar with the chemicals in the laboratory so that they can properly assess the risk associated with a spill incident. Lab personnel should **preplan**, through the development of written SOPs, their actions in response to spills or personal contamination, with consideration of all chemicals in their laboratory inventory.

**Chemical Spill Risk Assessment**
Chemical spills can be segregated by risk into three categories: high risk, moderate risk, and low risk.
HIGH RISK:
Exists due to the nature of the chemical (highly toxic, flammable, reactive) and quantity involved; extensive measures required to control or contain the spill; unique circumstances of the lab; personnel contamination or injury involved; or other factors. This level of risk necessitates the need for prompt, full scale, professional emergency response action. Follow the emergency response actions outlined in your department’s emergency response plan.

Response: EVACUATE AND CALL RENO CITY EMERGENCY RESPONDERS, 911; notify EH&S (327-5040) as soon as practical

MODERATE RISK:
Exists when there is a "low comfort level" of the lab personnel due to the particular circumstances involved, the need for additional physical support, the need for respiratory protection, or when professional advice or technical information is needed.

Response: CALL EH&S, 327-5040 (24 hr. contact number)

LOW RISK:
Exists when laboratory personnel fully understand the hazards and risks involved; there is no personnel contamination; adequate spill control materials are at hand; proper personal protective equipment is available; and workers have been trained in spill cleanup procedures.

GUIDE:  1 L or less of flammable liquid, concentrated acid or base, or 100 ml or less of a particularly hazardous substance.

Response: LABORATORY WORKERS CLEAN IT UP THEMSELVES

Cleanup of Spills by Laboratory Personnel
Each laboratory is expected to have equipment and procedures necessary for cleanup of the specific chemicals they are using. The following recommendations are presented as general guidelines.

Personal Protective Equipment
The minimum personal protective equipment required for spill cleanup is:
- Splash goggles (safety glasses can be used when there is minimal risk to eyes)
- Lab coat with sleeves rolled down
- Nitrile or neoprene gloves in good condition (other gloves may be required for specific chemicals, check with EH&S if you are unsure).
Spill Cleanup Materials
The following is a minimum recommended list of supplies:
- 5 each absorbent pads
- 1 spray container of liquid acid neutralizer
- 1 spray container of liquid caustic neutralizer
- plastic trash bags
- 3-5 gallon plastic bucket with lid
- 1 each plastic tongs

Spill kits containing the above items are available free of charge from EH&S (while supplies last). It is the responsibility of each laboratory to replenish spill kit items. Most of these items are available at the Chemistry Department Stores. Additionally, these items can be obtained from laboratory supply vendors (such as Grainger) - contact EH&S (327-5040) if specific assistance is needed.

Procedure for Cleanup of a Low Risk Spill
- Decontaminate affected persons using the eyewash, shower, or other appropriate means. If other than minor contact with a hazardous chemical occurs, the incident is not considered low risk (although the spill cleanup may still be low risk).

- Notify others of the spill and control access to the affected area to prevent spreading of the material.

- Clean up spill using proper protective equipment as follows:
  - Ensure ventilation is adequate to prevent accumulation of flammable or toxic vapors.
  - Don personal protective equipment as listed above.
  - Control spread of the spilled chemical by placing absorbent pads around the spill.
  - Use plastic tongs to pick up broken glass and other sharps; dispose of all sharps in a hard-sided container with lid to prevent sticks.
  - Use absorbent pads to pick up the liquid. Start at the perimeter of the spill and work toward the center.
  - Place contaminated absorbent pads in a plastic bag for disposal. Tongs can be used to handle contaminated pads in order to minimize contact with the chemical.
  - For spills involving acids or bases, use liquid acid or base neutralizer to neutralize any residual acid or base. Neutralizer should only be applied after the bulk of the liquid has been absorbed using pads.
  - Moisten an absorbent pad with water and carefully wipe all contaminated surfaces until all chemical residue is removed (soapy water may be required). Place used pad in a plastic bag for disposal.
  - Inspect the area. Carefully check the entire affected area for spill residue, hidden contamination, or unsafe conditions.
  - Place all used absorbent material and contaminated personal protective equipment in a plastic bag; seal the bag, label as chemical waste, and submit a request for waste disposal.
  - Dispose of any broken glass collected as non-hazardous waste (“regular trash”) – assuming only trace chemical is present.
Remove personal protective equipment. Chemical resistant gloves can be reused if they show no signs of deterioration, swelling, cracking, rips, or tears. If gloves will be reused, rinse with water and let air dry.

- Wash hands and arms (and other potentially affected areas) with soap and water.
- Restock the chemical spill cleanup kit.

Fire Safety Services and Fire Extinguisher Training
The Fire and Life Safety section of Facilities Maintenance inspects and services fire extinguishers and evaluates work areas for the proper type and placement of fire extinguishers. The Fire and Life Safety section can be contacted at 784-8020 (ask for the Fire and Life Safety group). Visit the online EH&S Training Calendar to learn more about fire extinguisher training opportunities or contact Brock Young in EH&S at 327-5058.

Small Fires
Laboratory personnel who have received annual fire extinguisher training can extinguish small fires within the capability of the extinguisher, and their own comfort level and ability. Laboratories will normally require a class ABC or BC extinguisher; however, laboratories using flammable metals should also have a Class D fire extinguisher readily available. Contact the Fire and Life Safety section to inquire about a class D (or other) fire extinguisher.

Large Fires
Fires beyond the ability of a portable fire extinguisher are considered large fires. Laboratory personnel should not attempt to extinguish large fires. In the event of a large fire, all personnel are to evacuate immediately.

- If possible, close laboratory doors while evacuating, and notify others.
  - Never use elevators when evacuating a building, always use the stairs.

- Activate the closest fire alarm on your evacuation route.
  - Many buildings (generally newer buildings) do not have manually activated fire alarms; however, fire alarms will be activated in response to heat or smoke.

- Report to the assigned building assembly point so that you can be accounted for.
  - Provide any information pertinent to the fire or evacuation.

Each department should have an emergency response plan; consult your department’s emergency plan for specific guidance. Contact Spencer Lewis (327-5046) in EH&S for assistance in developing building (or department) emergency plans.
Chapter 20
Chemical Waste Management

Management of laboratory waste is a UNR function coordinated by EH&S. Storage and disposal of laboratory waste is highly regulated by the Environmental Protection Agency (EPA), while Washoe County and the City of Reno regulate air and water effluent, respectively. The following information provides general guidelines for management of laboratory waste. Additional information is available at the Chemical Waste Management web page, or by contacting Chad Stephens, the EH&S Regulated Waste Manager at 784-1987.

Hazardous Waste Regulations
Accumulation, storage, and disposal of hazardous waste is highly regulated by the federal EPA and the Nevada Department of Environmental Protection (NDEP). In Nevada, hazardous waste regulations are enforced primarily by the NDEP; however, the federal EPA also has regulatory authority.

The NDEP routinely inspects UNR facilities (at least annually). Significant fines and other regulatory action can result from non-compliance with hazardous waste regulations. Laboratory personnel are responsible for properly accumulating, labeling, storing, and disposing of hazardous waste that is generated during their research activities or academic classes for which they are the responsible instructor.

General Waste Management Practices
- Do not dispose of hazardous chemicals or solutions containing hazardous chemicals in any sink or floor drain.
  - Hazardous chemicals include those that are flammable, reactive, corrosive, or toxic.
  - All material that is discharged to the sanitary sewer must be between pH 5.5 and 9.0.
  - Sewer discharge from university buildings is regulated by the City of Reno through sewer discharge permits that specify allowable chemical concentrations in sewer effluent and other discharge limitations.
- Do not dispose of any hazardous materials as “general waste” to go to the landfill.
- Chemical waste must be under the “control” of the laboratory at all times and must not be stored in general traffic locations such as halls or other areas with general public access.
- Waste collection containers must be kept tightly closed except when being filled.
- If chemical reagent containers are reused to accumulate chemical waste, they must be thoroughly rinsed (triple rinse) and dried so that no chemical residue remains which could react with added chemical waste. Rinsate from hazardous chemical containers must be collected as hazardous waste.
• It is recommended that volatile hazardous chemical containers be rinsed before they are disposed of, with rinsate collected as hazardous waste.

Waste Separation
• Segregate waste by specific hazard class:
  - Halogenated solvents (flammable)
  - Non-halogenated solvents (flammable)
  - Organic acids (corrosive)
  - Inorganic acids (corrosive)
  - Bases (corrosive)
  - Metals
  - Cyanides and sulfides

Be especially vigilant to avoid mixing strong oxidizers such as nitric acid, perchloric acid, and hydrogen peroxide with organic chemicals or other oxidizable chemicals.

Waste Accumulation
- Waste containers must be chemically compatible with the waste.
- Keep containers tightly closed except when being filled (see exception below).
- Provide secondary containment whenever possible.
- Never accumulate more than 55 gallons of chemical waste at any time.
- EH&S provides 1, 3, and 5 gallon poly containers free of charge upon request (sign-in using UNR netID is required).

Exception: venting of containers is allowed when necessary to prevent buildup of internal pressure. EH&S can provide self-venting lids for one-gallon containers, or container lids can be kept loose on the waste container as needed to prevent pressurization of the container.

Waste Labeling
• Label each container of chemical waste by completing the orange “chemical waste” label provided by EH&S, including marking the applicable check boxes and listing the chemical constituents.
  - Waste collected from cleanup of a chemical spill can be labeled by indicating the specific chemical waste (e.g., “mercury spill cleanup waste”).

• List all chemical constituents, their volume (include water) and concentration. This information can be recorded on the orange “chemical waste” label or on a separate piece of paper if the paper is marked with an identifier number that corresponds to the same identifier on the corresponding chemical container, and the paper is kept in close proximity to the waste container.
  - Use a number to identify each container.

Waste containers provided by EH&S come with a chemical waste label that must be filled out by
laboratory personnel. Individual chemical waste labels can be requested from EH&S for use on other waste containers.

**Submitting a Request for Removal of Waste**
Requests for pickup of chemical waste must be initiated electronically using the [Online Waste Submission form](#).

- Submit one form for each container.
  - Fill out the form completely.
  - Account for all constituents (including water) so that the sum of the constituents equals the total volume
  - Use full chemical names – not abbreviations or formulas
- Attach a copy of the completed form to the corresponding container.

**Additional Information**
- [UNR Chemical Waste Management Procedures](#)
Chapter 21
Incident Reporting and Investigation

Incident Reporting
Laboratory workers are to report all occupational injuries or illnesses (or exposure) to their supervisor as soon as practical. Employees are also encouraged to report “near misses” as they are considered a precursor to actual incidents. To encourage reporting of incidents, including near misses, the EH&S “Incident, Near-Miss and Safety Concern Reporting” function can be used.

- All incidents involving occupational injury or illness should be reported to Business Center North Workers’ Compensation Office (BCN) at 784-4394.
  - Affected personnel should complete a C-1 form, which they submit to their supervisor. The C-1 form is routed through the employee’s department to the Worker’s Compensation Office.
  - There are many reasons why it is to the employee’s advantage to file a worker’s compensation claim for occupational injuries or illnesses. For more information, contact the BCN Workers’ Compensation web site, which has links to information documents and contact information.
  - Additional information is available in the Workers’ Compensation document, Employee Procedure When a Work-Related Injury Occurs.

- Student (non-employee) injuries or hazardous materials exposure incidents should be reported to the BCN Risk Management Office using the Potential Liability Incident Report form.

- Incidents that result in personnel illness or injury, or facility or instrument damage must also be reported to EH&S (327-5040) as soon as practical.

- Incidents that involve a fatality, hospitalization, amputation, or loss of an eye must be immediately reported to EH&S (327-5040).

Incident Investigation
All laboratory incidents and “near misses” should be investigated. The goal of the investigation should be to gather information that can be used to prevent a similar type of incident in the future, not to find fault or place blame.

The laboratory supervisor is normally responsible for investigating the incident and submitting a report of their findings to EH&S. In some cases EH&S will lead the investigation of the incident. This will typically occur if the incident involves significant personnel injury or hazardous materials exposure, spill or release of hazardous materials, or regulatory or media attention.

Investigations should be conducted as soon as practical. Personnel who witnessed the incident or who have special knowledge of the circumstances of the incident should be included in the investigation. The supervisor conducting the investigation is responsible for requesting assistance from other UNR groups (EH&S, Facilities Services, etc.) as needed to conduct a thorough investigation. Facts related to the incident, personnel statements, and other pertinent information
should be documented and included in the investigation file.

The laboratory supervisor must complete and submit a Supervisor Accident/Injury/Incident Investigation Report form to the BCN Risk Management Office. A copy of this form and any attachments should also be sent to EH&S.

The Supervisor Accident/Injury/Incident Investigation Report form often does not contain sufficient information to indicate the root cause of the incident or sufficient corrective action to prevent a repeat incident. In these cases, the Chemical Hygiene Officer will ask the laboratory supervisor to conduct a thorough investigation and to submit an investigation report that includes the following information.

- Description of the incident that includes the work that was being performed, safety procedures and precautions implemented at the time of the incident, personal protective equipment worn at the time of the incident, and any other circumstances pertinent to the incident.
- Immediate response actions.
- Any additional or follow up response actions (for example, medical care, hazardous material clean up, etc.).
- Direct cause(s) of the incident.
- Root cause(s) of the incident (what led to the direct cause(s)?).
- Proposed corrective actions to address the direct and root cause(s) and prevent a similar incident from occurring.
- Completion dates for proposed corrective actions.

For other than minor incidents, the incident report and associated information will be reviewed by the university Laboratory Safety Committee. That committee can ask for additional information or corrective action as it feels is appropriate.

**Additional Information**
- UNR policy, Investigation of Laboratory Environmental Health and Safety Incidents.
Chapter 22
Recordkeeping

Training Records
Training records for each laboratory worker must be maintained for a minimum of three years after the worker’s entire tenure at UNR has ended. EH&S maintains training records of general laboratory safety training and other training sessions conducted by EH&S. Laboratory-specific training records should be maintained by individual laboratories or departments. EH&S has prepared a form for documenting laboratory-specific training; however, alternative systems that record the information described in Chapter 17 can be used.

Medical Records
Records of personnel medical records arising from occupational medical monitoring, examinations, treatment, or counseling are maintained by the Business Center North (BCN) Risk Management Office. Original medical records should be forwarded to the Risk Management Office; however, Supervisors and Department Offices may keep copies of these records when permissible by HIPAA and other regulations. These records are confidential and must be maintained as such. Access to medical records must be limited to authorized persons with a legitimate need to access.

Exposure Monitoring Records
Records of exposure monitoring conducted by EH&S are maintained by EH&S. These records are available to personnel or their designated representatives upon request. Records of any personnel or workplace exposure monitoring conducted by other groups must be maintained by the laboratory supervisor or department; however, a copy of the monitoring results must be forwarded to EH&S.

Injury and Illness Records
The BCN Risk Management Office maintains records of reported accidents and illnesses, and associated medical consultations and examinations (individual departments may have alternate procedures).
Chemical Hygiene Plan Definitions

Action Level – The airborne chemical concentration that triggers air monitoring and the implementation of additional control measures. The action level is always lower than the corresponding exposure limit and is designed to protect personnel from overexposure. At UNR, the more conservative of either the OSHA-defined action level (generally one-half the PEL) or one-half the ACGIH TLV is used as the action level.

Carcinogen – Any substance which meets one of the following criteria: (i) it is regulated by OSHA as a carcinogen, (ii) it is listed under the category, “known to be carcinogens,” (Type 1 carcinogen) in the Annual Report on Carcinogens published by the National Toxicology Program (NTP), or (iii) it is listed under Group 1 (“carcinogenic to humans”) by the International Agency for Research on Cancer Monographs (IARC).

Combustible Liquid – Any liquid having a flashpoint at or above 100 °F (38 °C), but below 200 °F (93 °C), except any mixture having components with flashpoints of 200 °F (93 °C), or higher, the total volume of which make up 99 percent or more of the total volume of the mixture. Combustible liquids are divided into the following classes:
(i) Class II – Liquids having a flashpoint at or above 100 °F (38 °C), but below 140 °F (60 °C).
(ii) Class IIIA – Liquids having a flashpoint at or above 140 °F (60 °C), but below 200 °F (93 °C).

Compressed Gas – (i) A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at 70 °F (21 °C); or (ii) A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130 °F (54 °C) regardless of the pressure at 70 °F (21 °C); or (iii) A liquid having a vapor pressure exceeding 40 psi at 100 °F (38 °C).

Corrosive – A chemical that causes visible destruction of, or irreversible alteration in, living tissue by chemical action at the site of contact.

Cryogenic Liquid – A liquefied gas at atmospheric pressure and subzero temperatures (less than –100 °F (-73 °C)).

Designated Area – An administrative area established for work with particularly hazardous substances (carcinogens, reproductive toxins, and chemicals with a high degree of acute toxicity). A designated area may be the entire laboratory, an area within the laboratory, or a device such as a lab hood.

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

Exposure Limit – The air concentration of a specific chemical below which it is believed that most workers will not experience adverse health conditions as a result of the exposure. Exposure limits are defined for specific time periods. See “permissible exposure level” and “threshold limit value.”

Flammable – A chemical which falls into one of the following categories:
(i) Flammable Aerosol – An aerosol that yields a flame projection exceeding 18 inches at full valve opening, or a flashback at any degree of valve opening.
(ii) Flammable Gas – A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less; or that forms a range of flammable mixtures with air wider than 12 percent by volume, regardless of the lower limit.

(iii) Flammable Liquid – Any liquid having a flashpoint below 100 °F, except any mixture having components with flashpoints of 100 °F (38 °C) or higher, the total of which make up 99 percent or more of the total volume of the mixture.

(iv) Flammable Solid – 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 burns so vigorously and persistently as to create a serious hazard.

Flammable Liquid

**OSHA Flammable Liquid Categories**

- **Category 1** - Flash point < 23°C (73.4°F) and initial boiling point ≤ 35°C (95°F)
- **Category 2** - Flash point < 23°C (73.4°F) and initial boiling point > 35°C (95°F)
- **Category 3** - Flash point ≥ 23°C (73.4°F) and ≤ 60°C (140°F)
- **Category 4** - Flash point > 60°C (140°F) and ≤ 93°C (199.4°F)

**International Fire Code Flammable Liquid Classes**

- **Class IA** – Liquids having a flashpoint below 73 °F (23 °C), and having a boiling point below 100 °F (38 °C).
- **Class IB** – Liquids having a flashpoint below 73 °F (23 °C), and having a boiling point at or above 100 °F (38 °C).
- **Class IC** – Liquids having a flashpoint at or above 73 °F (23 °C), and below 100 °F (38 °C).

**Flashpoint** – The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite in the presence of an ignition source.

Hazardous Chemical – Any chemical that is a physical hazard or a health hazard.

Hazard Warning – Any words, pictures, symbols, or combination thereof appearing on a label or other appropriate form of warning which convey the specific physical and health hazards of the chemical in the container.

Health Hazard – 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 personnel. 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.

**HEPA Filter** - High Efficiency Particulate Air (HEPA) filter. A filter material which removes 99.7% or more of particles of 0.3 micrometers or larger under test conditions. Used in applications where toxic dusts must be carefully controlled.
Highly Toxic – A chemical falling within any of the following categories:
(i) A chemical that has a median lethal dose (LD₅₀) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.
(ii) A chemical that has a median lethal dose (LD₅₀) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.
(iii) A chemical that has a median lethal concentration (LC₅₀) in air of 200 parts per million by volume or less of gas of 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.

Irritant – A chemical, which is not corrosive, but which causes a reversible inflammatory effect on living tissue by chemical action at the site of contact.

Laboratory – A facility where the “laboratory use of chemicals” occurs. A facility where relatively small quantities of chemicals are used on a non-production basis.

Laboratory Use of Hazardous Chemicals – Handling or use of such chemicals in which all of the following conditions are met: (i) chemical manipulations are carried out on a “laboratory scale,” (ii) multiple chemical procedures or chemicals are used, (iii) the procedures involved are not part of a production process, and (iv) protective laboratory practices and equipment are available and in common use to minimize the potential for personnel exposure to hazardous chemicals.

LC₅₀ – Lethal Concentration 50. The concentration of a substance in air that on the basis of laboratory tests (inhalation exposure) is expected to kill 50% of a group of test animals when administered as a single exposure in a specific time period (usually one hour).

LD₅₀ – Lethal Dose 50. The single dose of a substance that results in the death of 50% of an animal population from exposure to the substance by any route other than inhalation.

Safety Data Sheet (MSDS) – Formerly known as a material safety data sheet. Written or printed material concerning a hazardous chemical which is prepared in accordance with OSHA specifications.

Organic Peroxide – An organic compound that contains the bivalent –O-O- structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical.

Oxidizer – 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 release of oxygen or other gases.

Particularly Hazardous Substance – Includes carcinogens, reproductive toxins, and substances with high acute toxicity (defined as “highly toxic”).

Permissible Exposure Level (PEL) – An exposure limit promulgated by OSHA and enforceable by law.

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

**Pyrophoric** – A chemical that will ignite spontaneously in air at a temperature of 130 °F (54 °C) or below.

**Reactive Chemical** – A chemical with the ability to react vigorously, decompose or condense under conditions of shock, pressure or temperature.

**Reproductive Toxin** – A chemical that affects the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis). Chemicals identified in the SDS or other accepted hazard information as producing reproductive effects or teratogenesis are considered reproductive toxins.

**Suspect Carcinogen** – Any substance which meets one of the following criteria: (i) it is listed under the category, “reasonably anticipated to be carcinogens,” (Type 2 carcinogen) in the Annual Report on Carcinogens published by the National Toxicology Program (NTP), or (ii) it is listed under Group 2A or 2B (“probably carcinogenic to humans” and “possibly carcinogenic to humans”, respectively) by the International Agency for Research on Cancer Monographs (IARC).

**Sensitizer** – A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical.

**Threshold Limit Value (TLV)** – A recommended exposure limit set by the American Conference of Governmental Industrial Hygienists (ACGIH). A TLV is not enforceable by law.

**Toxic** - A chemical falling within any of the following categories:
(i) 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.
(ii) A chemical that has a median lethal dose (LD$_{50}$) of more than 200 milligrams per kilogram but not more than 1,000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.
(iii) A chemical that has a median lethal concentration (LC$_{50}$) in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas of vapor, or more than 2 milligrams per liter but not more than 20 milligrams per liter of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

**Unstable (reactive)** – A chemical which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shocks, pressure or temperature.

**Water Reactive** – A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.
Standard Operating Procedure

Procedure:
Revision Date:
Prepared By:
Lab Supervisor:

LOCATION:

HAZARDS AND PRECAUTIONS:

ENGINEERING CONTROLS:

ADMINISTRATIVE CONTROLS/DESIGNATED AREA:

PERSONAL PROTECTIVE EQUIPMENT:

SAFETY EQUIPMENT:

TRANSPORT AND STORAGE:

INCIDENT RESPONSE:

EXPERIMENTAL PROCEDURE (indicate if attached):

PRIOR APPROVAL: Is prior approval required before performing this procedure?

Yes ___  No ___

Approved: ____________________________
Laboratory Supervisor

Page 1 of 1
Example of Standard Operating Procedure

Procedure: Inorganic Acids Other Than Hydrofluoric Acid
Revision Date: June, 2009
Prepared By: Joe Public
Lab Supervisor: John Doe

LOCATION:
This procedure is for laboratory operations in Dr. John Doe’s laboratory, Building XX, Room YY.

HAZARDS AND PRECAUTIONS:
Strong inorganic acids are highly corrosive to skin, eyes, and the respiratory system. Avoid skin contact and inhalation of vapors. Dilution with water produces heat. When diluting, always add acid slowly to water (do not add water to acid).

Nitric acid is a powerful oxidizing agent and can react explosively with most organic substances. Nitric acid can also react violently with metals producing flammable hydrogen gas.

ENGINEERING CONTROLS:
Concentrated acids (6 N or greater) must be handled in the laboratory hood. Less concentrated acids should be handled in the hood whenever possible.

ADMINISTRATIVE CONTROLS/DESIGNATED AREA:
No special controls or designated area required.

PERSONAL PROTECTIVE EQUIPMENT:
Concentrated acid:
- Chemical resistant gloves:
  - hydrochloric acid - butyl or nitrile gloves
  - nitric acid – butyl gloves
  - sulfuric acid – butyl gloves
- Safety goggles; with face shield also recommended. Face shield required when using containers with a volume of 4L or greater, or when spray or splash is likely.
- Lab coat; with acid resistant apron also recommended
- Protective equipment can be reduced to lab coat, safety glasses and double disposable latex or nitrile gloves (or chemical resistant as above) when using a small volume (< 250 ml) or when concentration is less than 6N but greater than 1N. If concentration is less than 1 N, lab coat, safety glasses, and single pair of disposable gloves is required.

Note: disposable gloves only provide protection against incidental contact (such as small
splashes). If contact occurs while wearing disposable gloves, immediately remove gloves, wash hands thoroughly, and put on new gloves.

SAFETY EQUIPMENT:
A safety shower and eyewash must be readily available when working with these chemicals.

TRANSPORT AND STORAGE:
Transport concentrated acids (6M or greater) and breakable containers in an unbreakable secondary container. Store inorganic acids in designated acid storage area according to laboratory chemical hygiene plan.

INCIDENT RESPONSE:
Skin Contact: Immediately flush affected area with cold water using sink or safety shower as appropriate. Remove clothing and jewelry as necessary to reach all affected areas. Seek medical attention if burning or redness is present.

Eye Contact: Immediately flush eyes with cold water using eyewash. Physically hold eyes open if necessary. Seek medical attention immediately.

Minor Spill: Wear the following minimum PPE: goggles, butyl or nitrile chemical resistant gloves, and lab coat. Use spill kit located in lab to clean up spill per CHP instructions or laboratory SOP.
- Minor spills are generally considered to be spills that have a risk equivalent less than that of a spill of one liter of concentrated acid.

Decontamination of Materials: Use absorbent pads to collect the bulk of the acid, then neutralize with acid neutralizer provided in chemical spill kit, and rinse affected area with water.

Major Spill:
- Warn others and evacuate area as necessary to reach a safe location.
- Decontaminate personnel (use water) as necessary.
- Call 327-5040 (EH&S) during normal business hours; or 911 when a full hazardous materials response is obvious, when personnel have significant contamination, or when outside normal business hours.
- Isolate area to prevent other personnel from entering.

EXPERIMENTAL PROCEDURE (indicate if attached): see attached procedure.

PRIOR APPROVAL: Is prior approval required before performing this procedure?

Yes ___  No X ___

APPROVED: __________________________
Laboratory Supervisor
Glove Selection Guidelines

The following glove selections are for use when direct chemical contact is expected. Recommendations are based on use of thick (usually 18-28 mil) gloves, not thin (usually 3-8 mil), disposable gloves. Do not use thin, disposable gloves (even those made of the recommended glove material) when direct chemical contact is expected. For incidental contact with organic chemicals, a thin nitrile glove may be used. Use only a recommended glove when using chemicals that are considered particularly hazardous, highly corrosive, skin sensitizers, or which readily absorb through intact skin. Contact EH&S for additional glove recommendations.

<table>
<thead>
<tr>
<th>CHEMICAL</th>
<th>RECOMMENDED GLOVE</th>
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<tbody>
<tr>
<td>Acetic Acid</td>
<td>Butyl</td>
</tr>
<tr>
<td>Acetone</td>
<td>Butyl</td>
</tr>
<tr>
<td>Acetonitrile</td>
<td>Butyl</td>
</tr>
<tr>
<td>Ammonium Hydroxide</td>
<td>Butyl, Nitrile</td>
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<tr>
<td>Benzene (skin)</td>
<td>Viton, 4H</td>
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<tr>
<td>1,4-Butanediol</td>
<td>Butyl, Nitrile</td>
</tr>
<tr>
<td>Carbon Disulfide (skin)</td>
<td>Viton, 4H</td>
</tr>
<tr>
<td>Carbon Tetrachloride (skin)</td>
<td>Viton, 4H</td>
</tr>
<tr>
<td>Chloroform</td>
<td>Viton, 4H</td>
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<tr>
<td>Chromic Acid</td>
<td>Butyl</td>
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<td>Cyclohexanone (skin)</td>
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<td>Dimethyl Formamide (DMF) (skin)</td>
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<tr>
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<td>Isopropyl Alcohol</td>
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<td>Butyl, Nitrile, 4H</td>
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<td>Butyl, Viton</td>
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<td>Methyl Ethyl Ketone (MEK)</td>
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<td>Methyl Isobutyl Ketone (MIBK)</td>
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<td>Methylene Chloride</td>
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<td>Nitric Acid</td>
<td>Butyl, Viton</td>
</tr>
<tr>
<td>Pentane</td>
<td>Nitrile, Viton</td>
</tr>
<tr>
<td>Perchloric Acid</td>
<td>Latex, Nitrile</td>
</tr>
<tr>
<td>Phosphoric Acid</td>
<td>Butyl, Latex, Nitrile</td>
</tr>
<tr>
<td>Potassium Hydroxide</td>
<td>Butyl, Latex, Nitrile</td>
</tr>
<tr>
<td>Sodium Hydroxide</td>
<td>Butyl, Latex, Nitrile</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>Butyl, Viton</td>
</tr>
<tr>
<td>1,1,2,2-Tetrachloroethane</td>
<td>Viton</td>
</tr>
<tr>
<td>Tetrahydrofuran (THF)</td>
<td>4H</td>
</tr>
<tr>
<td>Toluene (skin)</td>
<td>Viton</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>Viton</td>
</tr>
<tr>
<td>Xylene</td>
<td>Viton, 4H</td>
</tr>
</tbody>
</table>

Note 1: Where more than one glove type is listed, all choices provide protection.

Note 2: “Skin” notation designates chemicals which the ACGIH has identified as being able to absorb through intact skin and contribute to overall chemical exposure.
Laboratory Specific Training Documentation

Laboratory Supervisor ________________________________________________

Laboratory Location (Bldg. & Rom) ______________________________________

Name of Laboratory Worker ____________________________________________

I. General Laboratory Safety Training (provided by EH&S)

General laboratory training was completed on ________________

Modules completed:

☐ chemical hygiene  ☐ chemical spill cleanup/waste mgmt.  ☐ lab ventilation
☐ biosafety (as applicable)  ☐ bloodborne pathogens (as applicable)

II. Laboratory Specific Training (provided by laboratory)

<table>
<thead>
<tr>
<th>Topic</th>
<th>Date</th>
<th>Trainer</th>
<th>Worker’s Initials</th>
</tr>
</thead>
<tbody>
<tr>
<td>availability &amp; use of personal protective equip.</td>
<td>__________</td>
<td>_______</td>
<td>__________</td>
</tr>
<tr>
<td>availability of MSDSs &amp; other hazard info.</td>
<td>__________</td>
<td>_______</td>
<td>__________</td>
</tr>
<tr>
<td>waste mgmt. practices (chem. &amp; biol. agents)</td>
<td>__________</td>
<td>_______</td>
<td>__________</td>
</tr>
<tr>
<td>storage of chemical &amp; biological agents</td>
<td>__________</td>
<td>_______</td>
<td>__________</td>
</tr>
<tr>
<td>emergency response (fires, spills, injury, etc.)</td>
<td>__________</td>
<td>_______</td>
<td>__________</td>
</tr>
<tr>
<td>use of personal protective equipment</td>
<td>__________</td>
<td>_______</td>
<td>__________</td>
</tr>
<tr>
<td>use of lab hoods, eyewash, and shower</td>
<td>__________</td>
<td>_______</td>
<td>__________</td>
</tr>
</tbody>
</table>

III. Specific Laboratory Operations (determined by laboratory supervisor)

<table>
<thead>
<tr>
<th>Trainer</th>
<th>Worker’s Initials</th>
<th>Topic</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
Laboratory Assessment Checklist

Date: Inspected By:
Building: Room Number:
Lab Supervisor: Department:

LABORATORY MANAGEMENT
1. Laboratory personnel are familiar with, and know how to access, the chemical hygiene plan, biosafety manual, and radiation safety manual as applicable.
2. Written SOPs have been developed to cover specific laboratory operations.
3. Laboratory-specific safety training is provided and documented.
4. MSDSs and other hazard information are available and personnel know how to access them.
5. A current inventory of chemical, biological, and radiological hazards is readily available.
6. An approval or review process is used prior to the introduction of significant new risks to the laboratory.

GENERAL LABORATORY SAFETY
1. Lab emergency contact information is posted at lab entrance.
2. Warning signs are posted to designate specific hazards.
3. Aisles are clear and without tripping hazards.
4. All exists are free and unobstructed.
5. Appropriate safety eyewear, gloves, lab coats and other personal protective equipment is available and used.

CHEMICAL LABELING AND STORAGE
1. Chemical containers are labeled with the content identity and hazard warnings.
2. Chemicals are segregated by major hazard categories and incompatibles are separated.
3. Peroxide forming chemicals are dated and tested at least annually.
4. Flammable and combustible liquids storage volumes are minimized and stored in flammable storage cabinets or safety cans.
5. Compressed gas cylinders are properly secured.
6. Compressed fuel gases are separated from oxidizing gases.
7. Flammable and toxic gases are stored in a well ventilated area, with highly toxic gases stored in a ventilated enclosure.
## SAFETY EQUIPMENT

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>An operable eyewash and emergency shower is readily available.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>2.</td>
<td>Fire extinguishers are available, unobstructed, and operational.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>3.</td>
<td>Chemical fume hoods are available, operational, and annual inspection is current.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>4.</td>
<td>Biological safety cabinets are available, operational, and annual inspection is current.</td>
<td>___</td>
<td>___</td>
</tr>
</tbody>
</table>

## CHEMICAL WASTE

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chemical waste containers are labeled and lids are closed.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>2.</td>
<td>Chemical waste is segregated by hazard class.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>3.</td>
<td>Storage of waste is minimized and full waste containers are not allowed to accumulate.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>4.</td>
<td>Biohazardous waste containers display the universal biohazard warning label.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>5.</td>
<td>Sharps are collected in puncture-proof, leak proof containers displaying the biohazard warning label.</td>
<td>___</td>
<td>___</td>
</tr>
</tbody>
</table>

## ELECTRICAL SAFETY

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Extension cords are not used as permanent wiring.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>2.</td>
<td>Electrical cords are not frayed or damaged.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>3.</td>
<td>Electrical cords contain a ground wire (three-prong plug).</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>4.</td>
<td>High voltages are shielded and adequately marked and labeled.</td>
<td>___</td>
<td>___</td>
</tr>
</tbody>
</table>

## EMERGENCY RESPONSE

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Personnel have been trained to properly respond to spill, fire, and other incident scenarios.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>2.</td>
<td>Chemical spill cleanup materials are available.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>3.</td>
<td>Biological disinfectant and spill cleanup materials are available.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>4.</td>
<td>First aid kit is available and appropriately stocked.</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>5.</td>
<td>Emergency phone numbers are posted by phone.</td>
<td>___</td>
<td>___</td>
</tr>
</tbody>
</table>

**Comments:**

________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Page 2 of 2
**Partial List of Chemical Incompatibilities**

<table>
<thead>
<tr>
<th>CHEMICAL</th>
<th>INCOMPATIBLE WITH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic Acid</td>
<td>Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates</td>
</tr>
<tr>
<td>Acetone</td>
<td>Concentrated nitric acid and sulfuric acid, and other strong oxidizing agents; very strong bases such as potassium t-butoxide</td>
</tr>
<tr>
<td>Acetylene</td>
<td>Chlorine, bromine, copper, silver, fluorine, mercury</td>
</tr>
<tr>
<td>Alkali and alkaline earth metals (such as powdered aluminum or magnesium, calcium, lithium, sodium, potassium)</td>
<td>Water, carbon tetrachloride or other halogenated hydrocarbons, carbon dioxide, halogens</td>
</tr>
<tr>
<td>Ammonia (anhydrous)</td>
<td>Mercury (e.g., in manometers), chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>Acids, powdered metals, flammable liquids, chlorates, nitrates, sulfur, finely divided organic combustible materials</td>
</tr>
<tr>
<td>Aniline</td>
<td>Nitric acid, hydrogen peroxide</td>
</tr>
<tr>
<td>Arsenic compounds</td>
<td>Any reducing agent</td>
</tr>
<tr>
<td>Azides</td>
<td>Acids. Store azide salts (e.g., sodium and potassium azide) by themselves.</td>
</tr>
<tr>
<td>Bromine</td>
<td>See chlorine</td>
</tr>
<tr>
<td>Calcium oxide</td>
<td>Water</td>
</tr>
<tr>
<td>Carbon (activated)</td>
<td>Calcium hypochlorite, all oxidizing agents</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>Sodium</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Ammonia, acetylene, butadiene, butane, other petroleum gases, hydrogen, sodium carbide, turpentine, benzene, finely divided metals</td>
</tr>
<tr>
<td>Chlorates</td>
<td>Ammonium salts, acids, powdered metals, sulfur, finely divided organic, combustible materials</td>
</tr>
<tr>
<td>Chromic acid and chromium trioxide</td>
<td>Acetic acid, naphthalene, camphor, glycerol, alcohol, flammable liquids in general</td>
</tr>
<tr>
<td>Chlorine dioxide</td>
<td>Ammonia, methane, phosphine, hydrogen sulfide</td>
</tr>
<tr>
<td>Copper</td>
<td>Acetylene, hydrogen peroxide</td>
</tr>
<tr>
<td>Cumene hydroperoxide</td>
<td>Acids (organic or inorganic)</td>
</tr>
<tr>
<td>Cyanides</td>
<td>Acids</td>
</tr>
<tr>
<td>Flammable liquids</td>
<td>Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens</td>
</tr>
<tr>
<td>Chemical</td>
<td>Reactants</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Fluorine</td>
<td>All other chemicals</td>
</tr>
<tr>
<td>Hydrocarbons (such as butane, propane, benzene)</td>
<td>Fluorine, chlorine, bromine, chromic acid, sodium peroxide</td>
</tr>
<tr>
<td>Hydrocyanic acid</td>
<td>Nitric acid, alkali</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, combustible materials</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>Fuming nitric acid, oxidizing gases</td>
</tr>
<tr>
<td>Hypochlorites</td>
<td>Acids, activated carbon</td>
</tr>
<tr>
<td>Iodine</td>
<td>Acetylene, ammonia (aqueous or anhydrous)</td>
</tr>
<tr>
<td>Mercury</td>
<td>Acetylene, fulminic acid, ammonia</td>
</tr>
<tr>
<td>Nitrates</td>
<td>Acids</td>
</tr>
<tr>
<td>Nitric acid (concentrated)</td>
<td>Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids and gases, copper, brass, any heavy metals</td>
</tr>
<tr>
<td>Nitrites</td>
<td>Acids</td>
</tr>
<tr>
<td>Nitroparaffins</td>
<td>Inorganic bases, amines</td>
</tr>
<tr>
<td>Oxalic acid</td>
<td>Silver, mercury</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Oils, grease, hydrogen, flammable liquids, solids and gases</td>
</tr>
<tr>
<td>Perchloric acid</td>
<td>Acetic anhydride bismuth and its alcohol, paper, wood, grease, oils</td>
</tr>
<tr>
<td>Peroxides, organic</td>
<td>Acids (organic or mineral), avoid friction, store cold</td>
</tr>
<tr>
<td>Phosphorus (white)</td>
<td>Air, oxygen, alkalis, reducing agents</td>
</tr>
<tr>
<td>Potassium</td>
<td>Carbon tetrachloride, carbon dioxide, water</td>
</tr>
<tr>
<td>Potassium chlorate</td>
<td>Sulfuric and other acids</td>
</tr>
<tr>
<td>Potassium perchlorate – see also chlorates</td>
<td>Sulfuric and other acids</td>
</tr>
<tr>
<td>Potassium permanganate</td>
<td>Glycerol, ethylene glycol, benzaldehyde, sulfuric acid</td>
</tr>
<tr>
<td>Selenides</td>
<td>Reducing agents</td>
</tr>
<tr>
<td>Silver</td>
<td>Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid</td>
</tr>
<tr>
<td>Sodium</td>
<td>Carbon tetrachloride, carbon dioxide, water</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>Ammonium nitrate and other ammonium salts</td>
</tr>
<tr>
<td>Sodium peroxide</td>
<td>Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural</td>
</tr>
<tr>
<td>Sulfides</td>
<td>Acids</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>Potassium chlorate, potassium perchlorate, potassium permanganate (similar compounds of light metals, such as sodium lithium)</td>
</tr>
<tr>
<td>Tellurides</td>
<td>Reducing agents</td>
</tr>
</tbody>
</table>
Particularly Hazardous Substances
(not all inclusive)

CARCINOGENS — OSHA, IARC Group 1 and NTP Type 1
2-Acetylaminofluorene  Acrylonitrile
Aflatoxins  4-Aminobiphenyl
Arsenic (and As compounds)  Asbestos
Azathioprine  Benzene
Benzidine  Beryllium (and Be compounds)
Bis(chloromethyl)ether  1,3-Butadiene
1,4-Butanediol dimethylsulfonate (myleran)  Cadmium (and Cd compounds)
Chlorambucil  N,N-bis(2-Chloroethyl)-2-naphthylamine
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea  Chromium (VI) compounds
Chloromethylmethyl ether  Coal tars (and volatiles and extracts)
Ciclosporin  1,2-Dibromo-3-chloropropane
Cyclophosphamide  Diethylstilbestrol
3,3'-Dichlorobenzidine (and its salts)  N,N-Dimethylnitrosoamine
4-Dimethylaminoazobenzene  Estrogens (conjugated)
Erionite  Ethylenimine
Ethylene oxide  Formaldehyde
Melphalan
8-Methoxypsoralen plus UV radiation  Methylechloromethylether
4,4'-Methyleneedianiline  Mineral Oils (untreated and mildly treated)
Mustard gas (bis(2-chloroethyl)sulfide)  \( \alpha \)-Naphthylamine
\( \beta \)-Naphthylamine  Nickel (and Ni compounds)
4-Nitrobenzyl  N-Nitrosodimethylamine
Oestrogens (steroidal and non-steroidal)  Oral contraceptives (combined and sequential)
Phenacetin contained in analgesic mixtures  \( \beta \)-Propiolactone
Radon  Shale Oils
Silica (crystalline)  Soots (containing PAHs)
Tamoxifen  2,3,7,8-Tetrachlorodibenzop-\( \alpha \)-dioxin
Thiotepa  Thorium dioxide
Tobacco Smoke (and smokeless tobacco)  Treosulfan
Vinyl Chloride  Wood Dust (certain hard woods)

EXAMPLES OF REPRODUCTIVE TOXINS — not all inclusive
Arsenic (and certain As compounds)  Benzene
Cadmium (and certain Cd compounds)  Carbon disulfide
Ethylene glycol monomethyl and ethyl ethers  Ethylene oxide
Lead compounds  Mercury compounds
Vinyl Chloride  Xylene

EXAMPLES OF CHEMICALS WITH HIGH ACUTE TOXICITY — not all inclusive
Acrolein  Arsine  Chlorine
Diazomethane  Diborane (gas)  Hydrogen cyanide
Hydrogen fluoride  Methyl fluorosulfonate  Nickel carbonyl
Nitrogen dioxide  Osmium tetroxide  Ozone
Phosgene  Sodium azide  Sodium cyanide (and cyanide salts)