Environmental Health and Safety
Chemical Hygiene Plan

Updated September 2024

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Introduction and purpose

Arizona State University strives to provide a learning, teaching and research environment free from recognized hazards. The Occupational Safety and Health Administration requires universities to establish a chemical hygiene plan to protect employees and students from potential health hazards associated with the handling, using, and storing of hazardous chemicals in laboratories and to certify personal protective equipment requirements. The ASU CHP includes methods designed to protect employees from the health hazards presented by hazardous chemicals and other materials used in laboratories and maker spaces, known hereafter as laboratories.

Scope and application

The CHP meets the requirements of ASU EHS 104: Laboratory Use of Hazardous Chemicals. The safe storage, use and disposal of chemicals in the laboratory requires policies for protecting students, employees and the environment. ASU and its employees are responsible for being well-informed regarding hazardous chemicals and the risks associated with using them in a laboratory environment.

This document serves as the institution-wide compliance with OSHA and all ASU-owned and operated laboratories. At locations not identified as ASU-owned or operated facilities but are occupied by ASU employees, employees are directed to follow the safety and security practices and procedures established by the host location. They should use this document to identify best laboratory management practices.

The primary objective of this document is to provide a general guide for handling hazardous chemicals in laboratories. This plan establishes basic safety principles for laboratory procedures, equipment and work practices that can protect the ASU community from physical and health hazards of hazardous chemicals in laboratories. Where this document does not adequately address the scope of hazards, the principal investigator should develop specific standard operating procedures.

The CHP aims to minimize or eliminate occupational exposure to hazardous chemicals. The hierarchy of controls defines exposure prevention and control methods.

References

- 42 CFR 43.
- 7 CFR 331.
- 9 CFR 121.
- ASU Bloodborne Pathogens Program.
- ASU Hazard Communication Program.
- OSHA 1910.101(b).
- OSHA 29 CFR 1910.132.
- OSHA 29 CFR 1910.1450(e).

Permissible Exposure Limits

The ASU CHP outlines processes to ensure laboratory use of OSHA-regulated substances does not exceed permissible exposure limits specified in 20 CFR 1910, Subpart Z, prohibition of skin and eye contact where specified by any OSHA standard in other instances where this standard does not adequately address the scope of hazards. ASU Environmental Health and Safety staff will review and apply consensus standards and recommendations for evaluating and controlling potential exposure to hazardous materials. Guidance from the National Institute of Occupational Safety and Health recommended exposure limits, and the American Conference of Governmental Industrial Hygienists Threshold Limit Values® will be applied where applicable.

Responsibilities

Environmental Health and Safety

ASU EHS is responsible for assuring ASU compliance with state and federal standards and preparing required documentation. In this capacity, EHS oversees and ensures regulatory compliance with the OSHA Laboratory Standard and the chemical hygiene plan needed and will develop the appropriate provisions.

Chemical hygiene officer

EHS will appoint a chemical hygiene officer. The CHO and EHS will assist all academic units, principal investigators, laboratory managers and supervisors, and other individuals, as necessary, in implementing and carrying out the provisions of the CHP. EHS and the CHO will serve as on-campus authorities and sources of information for the OSHA Laboratory Safety Standard.

Academic unit leadership

As the Employee Information and Training section outlines, academic unit leadership may include deans, directors and chairs. It is responsible for establishing and implementing department-centered guidance and training programs for their respective areas. If acceptable, academic unit leadership may delegate responsibility to the principal investigator, laboratory manager, compliance officer or safety committee member.

Academic unit leadership is also responsible for assuring that laboratories are appropriately registered according to EHS 005: Management Policy and EHS 104: Laboratory Use of Hazardous Chemicals. Leadership must ensure deficiencies identified during consultations are addressed within the required 30-day timeframe. Leaders are responsible for assuring that each PI who sets up, moves, remodels or vacates a laboratory contacts EHS to ensure the proper transportation and disposition of hazardous materials. Delegation of these responsibilities to the PI, laboratory manager, graduate or post-doctoral student, compliance officer or safety committee member is acceptable.

Principal investigators

PIs ensure compliance with this plan, including:

- Chemical inventory management.
- Compliance with EHS requirements, including federal and state requirements.
- Corrective action findings noted after laboratory consultations, including:
    a. Biosafety reviews.
    b. Chemical reviews.
    c. Fire safety reviews.
    d. Radiation safety reviews.
- Employee training plan.
- Hazardous waste regulations.
- Laboratory operating procedures.
- Laboratory registrations or reregistration.
- Laboratory-specific SOPs.
- Laboratory-specific training on SOPs and laboratory operations.
- PPE hazard assessments.

PIs also ensure contractors and vendors comply with requirements while working in the laboratory. PIs ensure all assigned laboratories and hazardous materials are kept secure by locking doors while the laboratory is unattended.

PIs are responsible for understanding the provisions of this plan and ensuring employees are aware of the dangers involved in handling and using hazardous chemicals or materials. The PI shall notify EHS if there is reason to believe an employee is showing signs or symptoms of over-exposure to a hazardous chemical.

They must also ensure that safety data sheets are available for every chemical in the workplace and that employees are trained in their use. PIs are also responsible for informing any visitor, contractor or vendor of the chemical hazards used in the laboratory they are working in or visiting.

Interdisciplinary research

Interdisciplinary research is encouraged at ASU. In conducting this type of research, researchers are expected to be trained primarily in a single discipline, such as biology or physics, and conduct research requiring expertise from several fields. In those cases, it is recommended that the PI leading that research involve a PI from each discipline involved in that research in the review and design of safety protocols.

Compliance officers

ASU EHS 005: Management Policy requires the university to be a quality model in environmental health and safety. Compliance officers are the principal liaison between the departments, colleges and schools with ASU EHS. College and departmental COs, by their special training and relationship with the EHS, serve as the primary source of coordination for activities that support ASU policies and the activities of the policy and operations committees.

Compliance officers serve as the primary source of coordination for those activities that support the ASU policies and the activities of the policy and operations committees. The CO has authority delegated from the provost, dean, director or chair to manage environmental health and safety activities on campus or in the institute or department. It includes the authority to establish processes, investigate complaints or incidents and audit the performance of ASU employees.

Safety committees

The ASU EHS operations committee provides oversight for all EHS programs at ASU as outlined in the management policy. The departmental safety committee’s primary function should be to provide peer review of all internal safety audits, training reviews, accident investigations and other safety-related actions as deemed necessary by the department and following regulatory and EHS mandates. Each department’s safety committee should consist of faculty or other department representatives appointed by the dean, director or chair.

Each department’s safety committees may implement laboratory safety practices specific to their department while maintaining the ASU CHP requirements and all applicable EHS policies. Established safety committees should consult the CHO on interpreting and applying EHS policies to laboratories.

Employees

Employees are paid personnel, including graduate students on stipends and paid undergraduates. Employees are responsible for understanding the hazards involved with the chemicals they use. They must be familiar with the location and contents of the SDS file in their work area. They must consult their PI or laboratory manager if they need clarification on the safe handling, use or storage of hazardous chemicals. All applicable safety training must occur before the employee begins working in the laboratory or any area where hazardous materials are used. Employees must follow standard operating procedures and wear the appropriate personal protective equipment designated for the task.

Vendors, contractors and visitors

Vendors and contractors are responsible for providing SDSs for the materials they are using in the laboratory. They will provide the necessary PPE to their employees. Vendors, contractors, and visitors are responsible for following applicable safety standards, regulations, best practices and ASU policies.

Incident reporting

PIs or laboratory managers must submit accident/near miss reports to EHS for any accident or near miss situation per Arizona Administrative Code R2-10-205. Employees will be free from any reprisals for reporting accidents. Accident/near-miss reports, corrective actions, and suggestions regarding possible improvements can help safety committees strive to improve laboratory safety in the future.

ASU EHS 115: Incident Reporting and Investigation requires reporting all incidents. Electronically report incidents related to an employee, visitor or student. **Fill out the accident/near miss/quality improvement report** regarding near misses.

Hazardous material incidents

A hazardous materials incident is considered a spill involving biologicals, chemicals or radioactive materials. Only trained and authorized personnel are permitted to respond to a hazardous materials incident. Please refer to the ASU Emergency Response Guide located in your laboratory.

Employee rights

The employee’s right is to receive information about the known physical and health hazards of hazardous chemicals in their work areas and to receive adequate training and equipment to work safely with these substances.

Employee’s right-to-know, the OSHA Hazard Communication Standard, covers potential job hazards and protections, including label and material safety data sheet information and other required safety training per 29 CFR 1910.1200. Rights to information and equipment needed to work safely are included in many OSHA regulations on specific tasks, equipment and substances.

ASU complies with the OSHA standard that requires employees to be trained on the new label elements and SDS format. The Globally Harmonized System is an international approach to hazard communication, providing agreed criteria for the classification of chemical hazards and a standard approach to labeling elements on safety data sheets.

Laboratory procedures

Laboratory registration

Laboratory registration is the process the university uses to maintain emergency laboratory contacts and information, develop and maintain chemical inventories and ensure regulatory compliance. Registrations serve as an operating permit to use hazardous materials in the location.

The laboratory registration process requires the PI or acceptable designee to verify the current chemical inventory annually. When personnel, operations, or locations, including laboratory transfers or changes in the registered space, the PI is responsible for updating the registration or emailing revisions to EHS.

Shared laboratories

A shared laboratory is considered a laboratory room shared by multiple research groups. General guidelines on registering shared laboratory space:

- Each PI or their designee must submit a separate registration for their group.
- PIs or their designee can collaborate and submit a cumulative chemical inventory for the open laboratory. This is the preferred method. Alternatively, each researcher can submit their separate chemical inventories.

The laboratory registration webpage provides additional information on laboratory registration.

Laboratory start-up and close-out procedure

ASU EHS must be notified in the event of a laboratory move, relocation or vacating a laboratory for any reason. Each department is responsible for removing hazards from the laboratory before any PI departure. Before the move, EHS will conduct a laboratory close-out assessment and offer guidance and assistance to ensure all hazardous material regulations are addressed and satisfied.

EHS must also be notified before a new laboratory is occupied. EHS will conduct a laboratory start-up assessment and provide guidance and assistance to ensure regulatory compliance and adherence to EHS policies. Laboratory start-up consultations are only sometimes performed on existing laboratory renewals or transfers. Review ASU EHS 405: Laboratory Start-up/Close-out and Equipment Relocation for more information.

EHS laboratory registration reminders

EHS sends reminder notices related to updating the laboratories annually; however, the annual update is the responsibility of the PI. The laboratory's annual registration review and update allows each laboratory to self-assess.

Chemical inventory

The chemical inventory must include a complete account of the chemicals used or stored in the work area or laboratory, including but not limited to the following:

- Aquarium products.
- Cleaning products.
- Compressed gases.
- Fertilizers.
- Herbicides.
- Insecticides.
- Oils.
- Paints.

EHS 408: Purchasing of Chemicals requires chemicals to be purchased through the ASU-designated chemical purchasing system, Workday. A chemical inventory shall be maintained and available to employees in the laboratory. The ASU Chemical Environmental Management System maintains the chemical inventory at ASU. Review the CEMS webpage for resources, tutorials and more information.

Maximum allowable quantities of hazardous materials

A control area is defined as a space within a building that is enclosed and bounded by exterior walls, fire walls, fire barriers, and roofs, or a combination thereof, where quantities of hazardous materials not exceeding the maximum allowable quantities per control area are stored, dispensed, used or handled. The storage, use and handling of all hazardous materials shall follow the maximum allowable quantities per control area as defined by table 5003.1.1(1) of the International Fire Code, 2018 revision.

Chemical hygiene plan requirements

Provisions of the ASU CHP are as follows:

- Individual departments or colleges may develop their version of a CHP, provided that it meets the requirements of the ASU CHP.
- The OSHA standard requires the CHP to be available for all employees.

Standard operating procedures

Standard operating procedures are written instructions that detail the steps to perform during a given experimental process and include information about potential hazards and how these hazards will be mitigated. SOPs relevant to safety and health considerations must be developed and followed when laboratory work involves using hazardous chemicals, equipment and conditions, especially for particularly hazardous substances. Refer to Appendix C for examples of particularly hazardous substances.

SOPs shall be written by the most knowledgeable laboratory personnel involved with the experimental process. SOP templates are available to download. The PI and all personnel responsible for performing the procedures detailed in the SOP shall sign the SOP acknowledging the contents, requirements and responsibilities outlined in the SOP.

Updates to the SOP shall be reviewed and amended by qualified personnel and approved by the PI. The updated SOP shall be signed by all users acknowledging the contents, requirements and responsibilities outlined in the SOP.

Laboratory safety consultations

EHS or designated safety officers will conduct laboratory safety consultations to determine individual laboratory compliance with the CHP as identified in Appendix B. Consultations may be performed with the PI, laboratory manager, compliance officer or safety committee members. Any immediate safety concerns will be addressed during the consultation.

A report identifying deficiencies and areas of improvement will be directed to the laboratory's PI and may include the laboratory manager, compliance officer, or safety committee members. Follow-up consultations may be conducted based on the severity of the findings. Refer to Appendix B for more information on laboratory safety consultations.

Program evaluation

CHP and laboratory safety program evaluation will be conducted annually by the CHO and reviewed with the ASU EHS operations committee, along with any metrics maintained related to the program. This review will be in the form of a system audit and will be based on the effectiveness of the CHP. The EHS operations committee may direct the CHO to propose modifications or initiate new policies.

Record keeping

Required documentation and records are kept in compliance with applicable laboratory standards. These records may include reports, questionnaires, and permits required by various federal, state and local agencies. EHS keeps forms and the associated information collected through laboratory consultations and submittals.

Departments or PIs must maintain the records this plan requires, including consultation reports, corrective actions, documentation that corrective actions have been remedied, training records, safety meetings, or one-on-one job safety training sessions. Safety committees should maintain records of their activities and meeting minutes.

EHS maintains records detailing employee exposure monitoring. These records provide an accurate account of the measurements to monitor potential employee exposures to any chemical contaminant above the action level. The documents must be kept for 30 years after the employee ceases to work at ASU. These records are available from EHS.

ASU Employee Health maintains records detailing employee medical consultations, including an accurate report of examinations, tests and written opinions by attending medical personnel. These records must be kept for 30 days after the employee ceases to work at ASU.

Records must be available to employees and their representatives only. The medical personnel's written opinion concerning occupational exposure is available to ASU.

Employee information and training

Laboratory employees must complete the following training annually, at a minimum:

- Fire Prevention.
- Hazardous Waste Management.
- Laboratory Safety.

Additional training courses may be required depending on the hazards present in the laboratory. Employees must complete all the necessary training identified in the ASU EHS Training Determination Tool. EHS 108: Environmental Health and Safety Training outlines employee safety training requirements.

Visit the EHS training webpage for more information regarding safety training for employees, students, volunteers and minors.

The PI must ensure that the safety training of all laboratory employees is completed annually. Training must be provided for new employees before working in the laboratory or when a new hazardous chemical or procedure is introduced into the work area. PIs or laboratory managers must provide additional laboratory-specific safety training to employees and non-employees, like students and volunteers, relative to the specific hazards associated with their laboratory, such as chemicals and equipment. Refer to Appendix D for the laboratory-specific training checklist.

Employees with special needs will be provided training when necessary. A department can perform special needs training in their emergency preparedness plan.

Laboratory-specific training plan

The OSHA Laboratory Safety Standard and the university's CHP require all laboratory employees to participate in Laboratory-specific training. Refer to the Laboratory-specific Training Plan template for assistance in developing laboratory-specific training. The PI trains all research laboratory personnel, such as employees, students and visitors.

This training must be provided initially, annually and any time a significant procedural change occurs in the laboratory. The checklist can be used as a framework for discussing material during training. You must address all hazards to your research, including chemical, biological and radiological safety. An open section in the checklist can be used to describe these specific hazards.

Please keep a signed copy as the training record for the employee's duration of employment in the laboratory.

Communication

Each department should establish a system for communicating health and safety issues to employees. The CO program should be considered as one method to ensure effective communication of EHS issues and programs. ASU EHS will publish information related to laboratory safety so that COs can communicate with their respective groups.

Shared laboratory spaces

Shared laboratory space has become a common practice for research at ASU and other institutions as it allows for easy collaboration and lowers costs associated with building and maintaining laboratory research space. However, shared laboratory space may lead to problems when users leave shared resources unclean, fail to label containers or leave the space in a generally unsafe condition.

Refer to the Shared Laboratory Space guidelines for more information on addressing these potential issues.

Minors in laboratories

EHS 116: Minors in Laboratories prohibits anyone under 18 from entering an ASU laboratory unless specific exceptions have been made and the appropriate approvals are received. This policy aims to ensure that persons under 18 years old have authorization to be in a laboratory, are under proper supervision and receive the appropriate training.

A request for minor access to the ASU laboratories form is required for minors working in a laboratory. Exceptions include minors participating in an organized educational program approved by the head of the academic unit where the program will take place. EHS must approve additional exceptions. Additional requirements are necessary when the minor is under 16 years of age.

Employee exposure determination

If there is a reason to believe employees are being overexposed to hazardous materials, please call EHS to determine if exposure monitoring is required. The decision to conduct monitoring is based on a review of procedures undertaken in individual laboratories, equipment setup, ventilation or other information obtained during the laboratory registration or consultation process.

OSHA has specific mandates for several substances that may pose serious health risks to employees. Hazard assessments and employee exposure monitoring are required for OSHA-regulated chemicals such as arsenic, benzene, chromium, cadmium, ethylene oxide, formaldehyde and methylene chloride.

For use of chemicals where a specific OSHA health standard exists, EHS may monitor for potential exposures if:

- A request for monitoring is made by the laboratory or employee when there is reason to believe that the exposure levels for that substance routinely exceed the action level or, in the absence of an action level, the PEL.
- There is a reason to believe that the exposure levels for that substance routinely exceed the action level or, in the absence of an action level, the PEL.

Medical consultations and examinations

Employees working with hazardous chemicals will be provided medical attention, including any follow-up examinations that the examining physician determines necessary, under the following circumstances:

- Examinations must be conducted under the direct supervision of a licensed physician and provided at no cost or loss of pay to the employee.
- Whenever an employee develops signs or symptoms associated with a hazardous chemical exposure that may have occurred in the laboratory.
- Whenever a spill, leak or other release results in an employee's potentially hazardous chemical exposure above PEL or action level.
- Where monitoring reveals an exposure level routinely above the action level, or in the absence of an action level, the PEL — for an OSHA-regulated substance — or any Threshold Limit Values® or recommended exposure limit for which there are prescribed exposure monitoring and medical surveillance requirements.

ASU will provide the physician with the following:

- A description of the conditions under which the exposure occurred, including any quantitative data if applicable.
- A description of the signs and symptoms the employee is exhibiting.
- The identity of the hazardous chemicals to which the employee may have been exposed.

After the examination, the physician will submit a written opinion to ASU EHS that must include the following:

- A statement by the physician that the employee has been informed of the examination results and any medical condition that may require further treatment or examination.
- Any medical condition revealed that would place the employee at increased risk due to exposure to a hazardous chemical found in the workplace.
- Any recommendations for medical follow-up.
- The results of the medical examination and associated tests.
- The written opinion will not reveal specific diagnosis findings unrelated to the occupational exposure.

Process hazard analysis

A hazard analysis is a step-by-step review of the procedures used by a laboratory and functions to predict hazards and risks to personnel, property or the environment. PIs and laboratory managers should conduct process hazard analysis on any new hazardous materials, processes or procedures. This analysis assists in defining control methods to prevent exposure to hazards.

The analysis should include the following:

- Chemical use evaluation.
- Evaluation of the need for a Prior Approval Assessment Form.
- Laboratory use evaluation.
- Personal protective equipment evaluation.
- Pollution prevention analysis.

Prior approval

A prior approval assessment process is recommended for all new uses of chemical sand and is required for processes involving particularly hazardous substances and hazardous materials. Submit a Prior Approval Assessment form to ASU EHS for prior approval consideration.

Select agent toxins

Select agent toxins are of biological origin and are subject to stringent regulatory requirements under 42 CFR Part 73 for their potential to pose a severe threat to the public, animal or plant health, or animal or plant products. These toxins, along with specified biological agents such as viruses, bacteria or fungi listed in 42 CFR Part 73, 9 CFR Part 121 and 7 CFR Part 331, fall under the oversight of the Federal Select Agent Program, which requires registration for the possession, use and transfer of select agents.

Possession of amounts of select agent toxins under the permissible toxin limits, as described in ASU's Biological Safety Manual, is exempt from registration with the FSAP Program. An SOP must use quantities under the permissible toxin limits and meet the Federal Select Agent Program due diligence requirements.

Personal protective equipment

PPE is always required while in the laboratory. Before each use, verify the PPE is in good working condition. The PPE listed below are the minimum necessary items:

- Appropriate gloves. Closed-toe shoes that protect the entire foot.
- Suitable clothes that cover all the skin include long pants or dresses that are full length.
- Laboratory coats and safety glasses are always required when working with hazardous materials.

Due to specific hazards in the laboratory, additional PPE may be required. This additional PPE is based on the laboratory's PPE hazard assessment. Additional PPE may include flame-resistant laboratory coats, face shields, acid aprons, hearing protection, respirators or other specialty PPE.

With the assistance of the ASU EHS, the PI should perform a PPE hazard assessment to determine specific PPE requirements for each laboratory task. PPE requirements are reviewed during laboratory safety training and must be followed by all who enter the laboratory.

Consider the following when conducting PPE hazard assessments:

- Approved respirators without adequate ventilation, like glove boxes or fume hoods.
- Hearing protection devices may be required if noise hazards are present in the laboratory.
- Specific PPE for handling potentially hazardous chemicals such as reproductive toxins, carcinogens and sensitizers.
- Standard operating procedures should include the required PPE.

Review the OSHA personal protective equipment standard 29 CFR § 1910.132 for more information.

OSHA required PPE

- Eye and face protection: 29 CFR 1910.133.
- Foot protection: 29 CFR 1910.136.
- Head protection: 29 CFR 1910.135.

Laboratory coats

EHS recommends always wearing laboratory coats with potentially hazardous materials in laboratories. PIs must ensure their staff and students wear laboratory coats as outlined in the PPE hazard assessment. Laboratory coats must not be removed from the laboratory into any meeting room, break area or dining facility.

Use the following guidelines for proper laboratory coat use and storage:

- Do not access pant pockets via side slits.
- Hang laboratory coats on hooks or hangers in designated areas.
- If you need to transport your laboratory coat to another location, verify it is not contaminated and carry it to the next place in a bag or backpack.
- Laboratory coats should fit properly and be buttoned entirely.
- Remove the laboratory coat before leaving the laboratory.
- Remove the laboratory coat before sitting in an in-laboratory office area or designated food, drink or workspace.
- Sleeves must extend beyond the wrist.
- Store clean laboratory coats separately from used ones.

EHS recommends using flame-resistant laboratory coats for any use or potential exposure to pyrophoric liquids or gases. Laboratory coats used for flammable materials should be made of 100% cotton or flame-resistant-rated materials. Many laboratory coats are made from cotton and polyester fabric blends. These materials should not be used with open flames or pyrophoric materials.

If a hazardous material is splashed on a laboratory coat, the wearer must remove it to prevent the splash from encountering the wearer's clothes or skin. If a splash occurs, remove the laboratory coat immediately and determine if clothes or skin have been contaminated.

If clothes are contaminated with corrosives or toxic materials by skin absorption, remove clothing and immediately wash the affected area(s) in an emergency safety shower, seek medical attention, report the incident to your supervisor, and follow your laboratory's emergency procedures.

Laboratory coat laundering

ASU provides a laboratory coat laundering service. Laboratory coats must not be taken home or to public laundry facilities to be cleaned.

Before sending to laundering services, complete the following steps:

- Check laboratory coats daily. Launder at regular intervals or when they are dirty, whichever is earlier.
- If the laboratory coat cannot be safely decontaminated or made safe to be handled by the laundry, it should be disposed of accordingly.
- If the laboratory coat is heavily stained with chemical or biological materials, it should be discarded immediately via the appropriate waste route.
- Place laboratory coats for laundering in the special plastic bags for collection by the contracted laundering service.
- Replace torn or old laboratory coats.
- The laboratory coat should be free from obvious contamination or autoclaved before being sent to the laboratory coat laundering program.

Contaminated laboratory coat pre-laundry guidelines	
Contaminant	**Decontamination process**
Biological contaminants or microorganisms like blood, urine or sputum	Autoclave.
Chemical contaminant	Launder or dispose of as hazardous waste.
Particularly hazardous substances	Contact EHS at 480-965-1823.

Radioactive isotope	Contact Radiation Safety at 480-965-1823.
Solvent	Fume hood.

Respirator use

Respirator use may be necessary to maintain exposure levels below permissible or short-term exposure limits. ASU EHS can help you determine the necessity for respirator use by evaluating your circumstances. Employees may request an evaluation by contacting ASU EHS at 480-965-1823 or through your department's safety committee.

Respiratory protection users must comply with the ASU Respiratory Protection Plan, which includes compliance related to all types of respirators and dust masks. The specific laboratory or department will provide respirator equipment at no cost to employees.

Hearing protection devices

Hearing protection devices like earmuffs or earplugs may be necessary to maintain employee exposure to noise below OSHA's PELs. Departments may request a noise evaluation by contacting EHS. Employees using hearing protection devices must comply with the ASU Hearing Conservation Program.

Laboratory safety equipment

Laboratory work is prohibited where room ventilation is inadequate. All laboratory fume hoods, glove boxes, special ventilation areas and biological safety cabinets must meet the required performance criteria. General laboratory ventilation and special ventilation devices such as snorkel exhaust, glove box and biological safety cabinet guidelines are within the ASU CPMG design guidelines and ANSI\AIHA Z9.5 American National Standard Laboratory Ventilation guidelines.

Fume hoods

Refer to the ASU EHS Chemical Fume Hood User Guide for properly using chemical fume hoods. Fume hoods should be performance tested by qualified personnel at least annually. Daily fume hood monitoring must be conducted by laboratory personnel and is accomplished by consultation with the hood before use to ensure the hood works correctly. Proper use of hoods equipped with an on/off switch must be addressed in laboratory-specific training or other standard operating procedures. Immediately report problems with fume hoods to ASU FDM or call 480-965-3633.

The chemical fume hood shall be equipped with a flow-measuring device. This device may be a flow indicator, flow alarm or face velocity alarm indicator to alert users of improper exhaust flow or hood failure. The responsible party, PI, designee or the department in possession of a fume hood not equipped with a flow-measuring device should contact EHS for a risk assessment of the fume hood. Using a ductless fume hood is prohibited without prior review and approval by EHS.

Walk-in hoods

These hoods are designed so laboratory personnel can walk into the hood to set up large equipment. It is not intended that personnel stay in the hood while equipment operates. Profile sticker sash height settings must be followed when using this hood type.

Emergency eyewashes and showers

All laboratories in which corrosive chemicals are used should have direct access to eyewash stations and safety showers or have SOPs in place that have been approved by the PI to minimize the potential risks of injury until a suitable emergency eyewash and safety shower can be accessed. PIs should consider adding procedures or providing a solution for showers not equipped with curtains. This could include a partition or other laboratory workers as a barrier and a clean extra laboratory coat or fire blanket to cloak the exposed individual afterward.

General guidelines are located within the ASU CPMG design guidelines. American National Standards Institute, ANSI Z358.1 2009 and National Research Council Prudent Practices in the Laboratory provide detailed information regarding installing, operating and testing emergency eyewash and shower equipment. Refer to the EHS safety equipment webpage for more details.

General information

- Emergency eyewash and shower equipment should be available for immediate use, but it should not take an individual longer than 10 seconds, or approximately 50 feet, to reach the nearest facility. A door is considered to be an obstruction.
- Emergency eyewashes and showers shall be located on the same level as the hazard, and the path of travel shall be free of obstructions that may inhibit the immediate use of the equipment.
- Employees exposed to hazardous materials shall be instructed at the location to use the emergency shower and eyewash units properly.
- For a strong acid or caustic — pH <1 or >12 — the eyewash should be immediately adjacent to the hazard.
- Personal wash units — portable or squeeze bottle type eyewashes — and drench hoses are considered supplemental to emergency eyewash and shower equipment and should be tagged or labeled. Laboratory-specific training programs and SOPs should identify the nearest suitable emergency eyewash and safety shower if not located within the laboratory.
- Plumbed shower and eyewash equipment should be inspected and tested. Eyewashes may be activated weekly or monthly for a long enough time to verify operation and ensure that flushing fluid is available. Guidance for routine testing is available from EHS. Contact EHS at 480-965-1823 or your department’s compliance officer for questions about testing frequency or if laboratory personnel need advice for setting up routine testing.
- The water flow valve shall remain open without using the operator’s hands until intentionally closed. The valve shall be simple to operate and go from **off** to **on** in one second or less.
- Where the hazard is not corrosive, one intervening door can be present if the door opens in the same direction of travel as the person attempting to reach the emergency equipment and the door is equipped with a closing mechanism that cannot be locked to impede access to the equipment.

Privacy concerns should also be considered. If an employee is splashed with a hazardous substance, they must quickly disrobe for a drench shower to thoroughly flush all chemicals or contaminants from the skin. Privacy curtains around drench showers or combination shower/eyewash units can address privacy issues and are encouraged. Additionally, enclosures for safety showers offer privacy in a larger space and include a shower basin and drain to collect the water. The enclosure protects the safety fixture from dust, debris or accidental damage.

Eyewash stations

- Eyewash nozzles shall be protected from airborne contaminants. Whatever means is used to afford such protection, the operator shall not require a separate movement when activating the unit.
- Plumbed and self-contained eyewash equipment shall deliver flushing fluid at a minimum of 1.5 liters per minute — 0.4 gallons per minute — for a minimum of 15 minutes.
- The eyewash unit shall be designed, manufactured and installed so that, once activated, it can be used without requiring the operator’s hands.
- The eyewash units shall provide flushing fluid to both eyes simultaneously.

Safety showers

- Plumbed and self-contained shower equipment shall deliver flushing fluid at a minimum of 75.7 liters per minute — 20 gallons per minute — for a minimum of 15 minutes.
- Showers should be checked routinely to ensure access is not restricted and the pull-down bar to start water flow is within user reach.

Eyewash and safety shower alarms

In some situations, it may be appropriate to install a local alarm to notify laboratory occupants that the unit is in use and that assistance may be needed. When a local alarm is used, the following guidance should be followed.

- Local alarms must have a distinct difference in audibility from the fire alarm system.
- Local alarms must not be tied into building automation or fire alarm systems.
- Noise levels should not exceed 85 dB(A) to ensure that the use of the unit is not deterred.
- The alarm must be capable of being silenced or disabled for routine testing and by anyone assisting the injured party using the unit.

Fire safety equipment

Fire safety equipment, including an available fire extinguisher — type ABC — must be easily accessible to the laboratory staff. Fire extinguishers are routinely inspected. Fire blankets or automatic extinguishing systems may be available in the laboratory. Laboratory personnel shall maintain fire sprinkler clearance requirements of 18 inches as outlined in the International Fire Code.

Laboratory standards and resources

Compressed gases

Compressed gas cylinders can present a variety of hazards due to their pressure and or contents. In addition to the standard required work practices for inert gases, hazardous gases may require additional controls and work practices including, but not limited to, the use of gas cabinets, gas monitors, emergency shutoffs, proper equipment design, leak testing procedures and the use of air supplying respirators for certain highly toxic gases.

The ASU Compressed Gas Safety Program document has been developed to guide the storage, training, use, and handling of gases in pressurized portable containers and gas systems. The program is designed to meet regulatory requirements: 29 CFR 1910.101-111, the Compressed Gas Association CGA P-1-2008 Safe Handling of Compressed Gases in Containers, and ASU EHS: 122 Compressed Gases.

Laboratory managers and PIs must ensure all users of compressed gases have completed compressed gas safety training and follow the standard operating procedures and the laboratory-specific training plan.

Do not use glass containers for experiments and processes that may become pressurized without conducting a hazard assessment. Understand the pressure levels and use containers rated for the application or other engineering safeguards, like a pressure relief device. EHS is available to assist with hazard assessments or for consultation with pressurized systems.

Container labeling

Hazardous chemical containers in the laboratory must be properly labeled. PIs or laboratory managers must ensure all chemical containers have labels with legible writing indicating the following:

- If the material is a peroxide former, the label should include the date the container was opened or the date of the most recent peroxide test. Refer to Appendix G for more information.

- Name of contents — the label must be written in English using acceptable International Union of Pure and Applied Chemistry chemical names.
- Primary health and physical hazards, including NFPA or GHS hazard warnings, include corrosives, oxidizers, acids, alkalis, radiation, etc.

Chemical containers received from the manufacturer must also include these items, as well as the name and address of the chemical manufacturer or distributor. A new label must meet the requirements when containers are repurposed for new materials. Laboratories must maintain a legend near the container that addresses abbreviations used on labels.

Small containers used for samples with potentially hazardous materials need only be labeled with the sample number or other designation, providing a key to identifying the sample contents, such as water samples in 0.1 N sulfuric acid. This information must be available to emergency responders. If it is not practical to label the container, appropriate information may be placed on a sign next to it.

Use these procedures for chemical substances developed by the laboratory and for which there is no known written hazard information:

- If another company produces the chemical developed by the laboratory for use, the laboratory must develop an SDS for that chemical substance.
- If the chemical developed by the laboratory is produced exclusively for the laboratory’s use — new compounds and drugs — the laboratory must determine if the substance is hazardous.
- If the laboratory cannot determine the hazards, it must label the chemical as hazardous.
- If the substance is hazardous, the laboratory must label the containers as such and indicate those hazards on the label.

Eating, drinking, smoking, chewing and cosmetic use

Many respected institutions, including the National Research Council, Bureau of Radiation Control and the Centers for Disease Control and Prevention, agree that eating, drinking, smoking gum or tobacco, chewing, applying cosmetics, and taking medicine in laboratories where hazardous chemicals and materials, including unsealed sources of radioactive materials, are used must be strictly prohibited.

Food, beverages, cups and other drinking and eating utensils are not to be stored in areas where hazardous chemicals and materials or radioactive materials are handled or stored. ACD 805: Eating and Drinking in Academic Areas prohibits eating and drinking in the laboratory. Each department dean, director, chair or designee may designate areas within laboratory facilities where these activities are permitted. Prohibitions related to using hazardous materials in these locations must be communicated to all laboratory personnel, and the requirement must be enforced.

Refrigerators, freezers, ovens, microwaves, and similar appliances in laboratories not intended for use with food or beverage to be used for human consumption must be labeled **as not food, drink, or ice for human consumption** or equivalent. Similar appliances in designated laboratory locations intended for use with food or beverage for human consumption must be labeled **for food use only** or equivalent. Areas with refrigerated food for animal use must be labeled as **food for animal use only** or equivalent.

Emergency procedures

Laboratory personnel must be aware of the provisions for emergency procedures and preparedness. Emergency procedures and preparedness include actions or contingencies for:

- Evacuations due to fires, chemical spills, and other situations.
- First aid.
- Location of emergency equipment to include showers and eyewashes.
- Procedures for the use of particular ventilation areas.
- Shut down and lock out during evacuations.

Protocols for handling chemical emergencies are outlined in the ASU Emergency Response Guide and EHS 403: Chemical Release Emergency Response. Laboratories must have a written plan detailing their specific emergency procedures.

Guidelines for transporting chemicals — including gas cylinders and cryogenic containers

When transporting chemicals on campus malls, the following additional precautions apply:

- Be prepared for action in the event of an incident. If there is a minor spill and ASU EHS assistance is needed, call 480-965-1823 from a cell phone and be prepared to provide your location. If there is a significant incident, contact the ASU PD by calling 911 from a cell phone or blue call box.
- Before transporting autoclaved materials, please refer to the Autoclave Safety Manual for chemical information.
- Bring PPE, such as safety glasses, laboratory coats and appropriate gloves, in case of a spill. Also, bring a spill kit.
- Contact ASU EHS at 480-965-1823 if additional guidance is needed.
- Do not transport hazardous materials to the malls during class change times.
- If transporting more than one container, use a heavy-duty cart and secondary containment — do not carry multiple containers. Acceptable secondary containers include plastic bottle carriers with closed tops and handles or non-metal liquid-tight carts with lips on all four sides. Never transport incompatible chemicals in the same secondary containment. Use plastic tubs or separate bottle carriers to prevent potential mixing if spilled.
- If transporting off campus, hazardous materials must not be transported in personal vehicles. The material’s SDS will assist you in determining if the material is hazardous. Contact EHS at 480-965-1823 if you need assistance in this determination. Hazardous material transportation must be done only by EHS or employees authorized to transport hazardous materials. Contact EHS if a chemical must be transported onto or off campus. Avoid transporting non-hazardous materials in a passenger vehicle, but do not place the materials in the passenger compartment if necessary. Place the containers in the trunk or cargo bed and ensure they are adequately packaged and firmly secured. Never leave these materials unattended or stored in a vehicle.
- Materials that are unstable, explosive, or unusually hazardous due to size or toxicity should not be moved without contacting EHS, like outdated peroxide formers such as THF, dry Picric Acid, and >20 gal containers of flammable or corrosive liquids.
- Refer to Appendix K for safe handling and transportation procedures for cryogenic materials.
- Segregate materials according to hazard classification for transportation. Each hazard class should have a separate secondary container. For example, do not transport concentrated acids and organic solvents. Additional guidance on chemical containers and compatibility can be found in Appendix G.
- Transport on paved paths and sidewalks rather than streets or roads. Two people must attend to prevent the cart from tipping as it is moved over uneven terrain and elevation changes.
- Transport compressed gas cylinders using special compressed gas cylinder handcarts. The cart should be pushed in front of the transporter and not pulled. Two people must be in attendance when transporting cylinders across asphalt or uneven terrain to prevent tipping and unanticipated jolting of the gas cart. Cylinders must be securely attached to the cart, and valve protection caps must be in place.
- Where possible, transport chemicals in their shipping package. Use an approved chemical carrier and ensure it is appropriately labeled if it is not possible to transport chemicals in their shipping package.

When transporting chemicals on campus between laboratory rooms within the building, like hallways, elevators, etc., these precautions apply:

- Acceptable secondary containers include plastic bottle carriers with closed tops and handles or non-metal liquid-tight carts with lips on all four sides. Never transport incompatible chemicals in the same secondary containment. Use plastic tubs or separate bottle carriers to prevent incompatibles from mixing.
- All chemicals should be transported within secondary containers capable of holding all materials in the event of a spill. Any corrosive or heated material transport requires secondary containment unless exempted by EHS.
- Carry or wear appropriate PPE. Minimum PPE includes safety glasses, laboratory coats or other appropriate laboratory attire, and closed-toe shoes. Hazardous chemicals must always be attended to while being transported.
- Individuals transporting chemicals must ensure containers are appropriately labeled and know what to do in the event of a release or spill. Safety Data Sheets are a good source for this information.
- Materials that are unstable, explosive, or unusually hazardous due to size or toxicity should not be moved without contacting EHS, like outdated peroxide formers such as THF, dry Picric acid, and >20 gal containers of flammable or corrosive liquids.
- Transport compressed gas cylinders using special compressed gas cylinder handcarts. The cart should be pushed in front of the transporter and not pulled. When transporting cylinders across asphalt, uneven terrain or between buildings, two people must attend to prevent tipping and unanticipated jolting of the gas cart. Cylinders must be securely attached to the cart, and valve protection caps must be in place.
- For transporting cryogenic materials, refer to Appendix K.
- Use freight elevators to move chemicals between floors. If freight elevators are not available, use unoccupied passenger elevators. Stairs should be used only if elevators are not available.

Hazardous waste management

Laboratory operations that produce waste chemicals are considered to create hazardous waste. The Arizona Department of Environmental Quality regulates hazardous waste. All laboratory personnel who produce hazardous waste must manage it according to ASU’s Hazardous Waste Management Compliance Guidelines. State and federal law require the university to manage its hazardous waste. Failure to manage hazardous waste properly may result in criminal prosecution and heavy fines.

All laboratory employees who physically place hazardous waste into designated hazardous waste containers must complete the Hazardous Waste Management training.

Broken glass

These guidelines should be followed in case of broken glass in the laboratory. If broken glass is the only issue, the glass should be carefully picked up using forceps or broom and dustpan and placed in a container such as a cardboard box or other designated substantial container, such as a plastic container designated for broken glass, and clearly labeled as broken glass. Please do not place broken glass in ordinary trash containers, as it presents a potential risk to those who need to handle it. Broken glass that is not contaminated may be recycled.

Please review the Biowaste Compliance Guidelines if the waste involves broken glass with blood, microorganisms or bioresearch materials.

Hydrogen generators

A hydrogen generator may be installed to reduce the amount of flammable compressed hydrogen gas within a laboratory or space. Hydrogen generators are beneficial when small amounts of gas are needed for a process. The use of, size and output, intended location, process to be connected to, and installation shall be reviewed and approved by the ASU fire marshal or their designee before installation.

Typical hydrogen generator installations may not require additional local exhaust ventilation, enclosures such as gas cabinets, and gas detection. Hydrogen generators will not impact the maximum allowable quantities of flammable gases in the control area where they are installed when approved by the ASU fire marshal.

These requirements shall be followed for installation:

- The distance between the generator and the tool or equipment using the gas shall be as short as possible and no more than 20 feet.
- The piping between the generator and the equipment shall be a single continuous non-combustible tubing — braided steel preferred — with no fittings or connections except for the connection to the equipment.
- Piping shall not penetrate walls or run above ceilings or below floors.

Laboratory safety manual

The Laboratory Safety Manual is compiled of important information from various regulatory areas into a single source repository of laboratory-specific compliance topics that PIs are required to keep concerning the operation of their laboratory. The LSM helps PIs organize and develop laboratory-specific information necessary for their research laboratory. It reduces the administrative time needed for future laboratory consultations, incident investigations, and answering questions related to regulatory compliance.

EHS provides the initial LSM and regular updates through communication with the manual holders. The LSM should be in an easy-to-find location during possible regulatory inspections, laboratory-specific training, or anyone needing to reference the information. The PIs must ensure that the appropriate information is added and included in each section of the LSM.

Laboratory use of anesthetics

Anesthesia commonly used in some research laboratories includes nitrous oxide, halothane, enflurane, trichloroethylene and urethane. Exposure to waste anesthetic gases and vapors during surgical procedures harms researchers. Open bench surgeries involving gaseous anesthetics should employ waste gas scavenging systems connected to non-recirculating exhaust systems.

- Consult the ASU Anesthetic Gas Usage program for procedures to minimize exposure to waste anesthetic gases.
- Exhaust systems must be used in conjunction with scavenger systems. Contact EHS at 480-965-1823 before installing scavenger systems to existing building ventilation.

Physical hazards

Physical hazards associated with each laboratory process must be assessed to determine potential risks and identify necessary engineering controls, training and required PPE. Physical hazards include noise, use of compressed gas, explosive or highly reactive chemicals, non-ionizing and ionizing radiation, machine shop equipment and potential energy, like springs and hydraulic systems.

Physical hazards must be assessed during the PPE hazard assessment. EHS is available to assist with evaluations.

All equipment manufacturers' signage related to physical hazards must be left intact, and employees must be informed to adhere to all manufacturers' warning labels. In situations where the manufacturer's label becomes illegible or missing, physical hazards are to be marked with signage and warnings consistent with the requirements of ANSI Z535.2 Specifications for Accident Prevention Signs and ANSI Z535.1-6 Safety Color Code for Marking Physical Hazards as follows. Refer to the EHS chemical safety webpage for university-branded printable signs.

Please ensure the following equipment types have warning labels associated with physical hazards.

- Robots, pneumatic lifts, and material handling devices are not equipped with physical barriers or interlocks and are engineered to prevent exposure to physical hazards.
- The presence of bare electrical conductors greater than 50 volts as defined in EHS 118: Electrical Safe Work Practices.

EHS surveillance is required for equipment generating excessive noise levels per the ASU Hearing Conservation Program. Signage shall be used to identify areas where hearing protection may be necessary or recommended.

Radiation-producing equipment, materials, radio frequency-generating equipment, and lasers must be labeled. Contact the radiation safety officer if the equipment manufacturer did not provide labels.

Pollution prevention analysis

Pollution prevention analysis is the systematic review of laboratory procedures that use hazardous chemicals to reduce waste volume and toxicity and prevent substance release into the environment. Replacing hazardous chemicals with less hazardous or non-hazardous chemicals is the most efficient way to reduce waste and minimize pollution potential. **No chemicals are allowed in the trash or down the drain**.

All laboratories must be accountable for all hazardous chemicals and materials to ensure they are not released into the air, sewer or ground. Evaporation is not permitted as a method of disposal. The safest and most efficient way to dispose of hazardous chemicals is to have wastes picked up on-campus by hazardous waste management services.

Pollution prevention analysis requires the researcher to review all processes and identify less hazardous chemicals that can be substituted. Researchers must be able to justify to EHS and ADEQ the use and volumes of hazardous chemicals used in their laboratories.

Shipping and receiving hazardous materials or dangerous goods

No person may receive hazardous materials or dangerous goods without function-specific training. Training must be documented and included in the employees' training records. No person may ship or offer for shipment HM/DG unless that person has received certified 16-hour U.S. Department of Transportation training for hazardous materials. Shipping materials with dry ice requires dry-ice shipper training.

EHS will help classify your shipment and complete the shipper's declaration forms, commercial invoices and FedEx airway bills. EHS can also help with package selection and consult about international shipments and customs requirements. Before submitting the completed form, email the Office of Industry Research and Collaboration to see if a material transfer agreement is required.

International shipments may require export permits, and the recipient may require import permits; please plan accordingly. Email the ASU Office of Research Integrity for international shipments only.
Dry ice shipments must complete the EHS Dry Ice Shipper training before shipping. Refer to EHS 406: Shipping and Receiving Hazardous Materials.

Shop equipment

OSHA requires that machine guarding and other safeguards be provided and maintained to protect employees who may operate machines, typically shop equipment, and other persons in machine areas from potential hazards per OSHA 29 CFR 1910.212.

Hazards include those created by points of operation, in-going nip points, rotating parts, flying chips, sparks, moving belts, meshing gears, cutting teeth, or by any parts that impact or shear or have reciprocating, transverse, cutting, punching, shearing, boring or bending actions.

The risk of injuries such as crushed hands and arms, severed fingers, skin lacerations, scalping, hot metal burns, eye injuries and blindness must be anticipated and addressed.

Responsibilities for ensuring machine safety through hazard identification and evaluation, safeguarding, training and safe operating procedures fall under the PI for individual laboratories and under shop supervisors for designated machine shops. To assist with fulfilling these responsibilities, EHS offers web-based training. EHS also conducts consultations of machine shops at least annually and is available to arrange special training sessions upon request.

Any employee who services equipment in such a way as to potentially be exposed to hazardous sources of energy such as electricity or who needs to remove guards or panels exposing moving parts must be trained in the ASU Lockout/Tag Out program.
To prevent potential hazards from exposure to toxic metals such as beryllium, machining any metal alloy not stocked in shop supplies must be approved through a Prior Approval Form.

OSHA also requires that hand and power tools be used in safe conditions per 29 CFR 1910.242. The hazards encountered when using portable tools include striking or contacting part of the body with the tool or the workpiece and projectiles flying off the tool or workpiece in the eyes. SOPs may be developed to address these potential hazards.

Working alone procedures

Hazard assessments will be conducted whenever employees and volunteers work alone, as required in EHS 123: Working Alone with Hazardous Materials, Processes or Equipment. Working alone with hazardous materials, equipment, or processes is prohibited unless authorized by the PI or their designee per this policy or as approved by ASU EHS.

EHS is responsible for providing EHS 123 and a Working-Alone Checklist for use in conjunction with this policy. The Working-Alone Checklist should be used to assess tasks under this policy. EHS will also provide guidance and consultation regarding situations or circumstances where working alone may occur.

Colleges, departments and units shall assess their operations and activities to identify any situations when members of the ASU community may be exposed to hazardous materials, equipment or processes as defined in this policy. Each PI shall ensure that safe working procedures are established to prevent one from working alone with hazardous materials, hazardous equipment, or hazardous processes and develop strategies and training that eliminate or minimize the risks of working alone. Each PI, or designee, is responsible for ensuring that alternative working procedures are at least as effective as the working alone procedures.

Appendix A

Definitions

***Other regulations or associated definitions may apply.**

ACGIH — American Conference of Governmental Industrial Hygienists: An organization of professional personnel in governmental agencies or educational institutions engaged in occupational safety and health programs. ACGIH develops and publishes recommended occupational exposure limits — refer to TLV — for hundreds of chemical substances and physical agents.

Action level: A concentration designated in OSHA 29 CFR § 1910 for a specific substance, calculated as an eight-hour time-weighted average, initiates certain required activities such as exposure monitoring and medical surveillance.

Acute: Severe, often dangerous conditions in which relatively rapid changes occur.

Acute exposure: A single, brief exposure to toxic substances. If applicable, adverse effects on the human body are evident soon after exposure and can quickly lead to a crisis.

Alloys: A mixture of metals, such as brass, sometimes a metal and a non-metal.

Ambient temperature: Temperature of the immediate surroundings.

Appearance or odor: The color, physical state at room temperature, size of particles and characteristics of the material. Odor is described in comparison to ordinary familiar "smells."

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

Aspiration hazard: This is the danger of drawing fluid into the lungs, causing an inflammatory response.

Assistant Secretary: The Assistant Secretary of Labor for the Occupational Safety and Health Administration, U.S. Department of Labor, or designee.

Autoignition temperature: The lowest temperature at which a flammable gas or vapor-air mixture will ignite from its own or other contacted heat sources.

Boiling point: The temperature at which the vapor pressure of a liquid equals atmospheric pressure.

CAS number: The number assigned to chemicals or products by the Chemical Abstracts Service.

Carcinogen: A substance or agent capable of causing or producing cancer.

Catalyst: A substance that changes the speed of a chemical reaction but undergoes no permanent change. An example of a catalyst is the platinum used in automotive catalytic converters on the exhaust system.

Chemical hygiene officer: An employee designated by the employer and qualified by training or experience to provide technical guidance in the development and implementation of the provisions of the CHP. This definition does not limit the position description or job classification the designated individual must hold within the employer's organizational structure.

CHP — Chemical Hygiene Plan: A written program developed and implemented by the employer. It sets forth procedures, equipment, PPE and work practices that:

- Can protect employees from the health hazards of hazardous chemicals used in that workplace.
- Meet the requirements of CFR 29 1910.1450.

Chronic effect: An adverse effect on a human or animal in which symptoms develop slowly over a long period or recur frequently.

Combustible: A substance capable of fueling a fire. Also, a term used to classify certain liquids based on their flashpoints. Also, see "flammable.”

Combustible liquid: Any liquid having a flashpoint at or above 100° Fahrenheit (37.8˚ C) but below 200° Fahrenheit (93.3°C). Combustible liquids are further subdivided in the IFC.

Compressed gas:

- A gas or mixture of gases in a container, having an absolute pressure exceeding 40 psi at 70° Fahrenheit (21.1˚C).
- A gas or mixture of gases in a container, having an absolute pressure exceeding 104 psi at 130° Fahrenheit (54.4^{0}C) regardless of the pressure at 70 degrees Fahrenheit (21.1^{0}C).
- A liquid having a vapor pressure exceeding 40 psi at 100° Fahrenheit (37.8^{0}C) as determined by ASTM D-323-72.

Corrosive or corrosive material: A liquid or solid that causes visible destruction or irreversible alterations in human skin tissue at the site of contact or in the cases of leakage from its packaging as defined by the IFC. This liquid has a severe corrosion rate on steel. Liquids with a pH ranging from <1 to >12 shall be considered corrosive.

Cutaneous: About or affecting the skin.

Decomposition: Breakdown of a material or substance — by heat, chemical reaction, electrolysis, decay or other processes — into simpler substances.

Dermal: About or affecting the skin.

Designated area: An area that may be used for work with "select carcinogens," reproductive toxins, or substances with a high degree of acute toxicity. A designated area may be the entire laboratory, a space or a device such as a laboratory hood.

Dyspnea: Shortness of breath, difficulty or labored breathing.

Emergency: Any occurrence such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment, which results in an uncontrolled release of a hazardous chemical into the workplace.

Emergency eye-wash and safety shower: Equipment provided in the laboratory for emergency use in treating splashes of corrosive materials meeting the requirement of ANSI Z358.1 2009.

Employee: An individual in a laboratory workplace may be exposed to hazardous chemicals during their assignments.

Erythema: A reddening of the skin.

Evaporation rate: The ratio of time required to evaporate the same volume of a reference liquid — ether. A high ratio means a slower evaporation rate.

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

Exposure limit: The limit set to minimize occupational exposure to a hazardous substance. Recommended occupational exposure limits used are ACGIH Threshold Limit Values® and Occupational Safety and Health Administration Permissible Exposure Limits.

Extinguishing agents: Agent(s) suitable for controlling or putting out a fire.

Extremely hazardous activities: A short list of chemicals and activities that are difficult to control and have lethal potential or could trigger a life-shortening disease in one low-level exposure or cause a lethal event like an explosion. This list is evolving but will likely include highly toxic, pyrophoric, and carcinogenic gases, toxic gases with poor warning properties, beryllium, methyl mercury, etc.

Flammable limits: The range of a vapor and gas concentration in air that will burn or explode if an ignition source is present.

Flammable: A chemical that falls into one of the following categories:

- Aerosol, flammable means an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening or a flashback — a flame extending back to the valve — at any degree of valve opening.
- Gas, flammable:
    - A gas that forms a flammable mixture with air at a concentration of 13% by volume or less at ambient temperature and pressure.
    - A gas that forms a range of explosive mixtures at ambient temperature and pressure with air more expansive than 12% by volume, regardless of the lower limit.
- Liquid, flammable: Any liquid having a flashpoint below 100° Fahrenheit (37.7^{0}C), except any mixture having components with flashpoints of 100° Fahrenheit (37.7^{0}C) or higher, the total of which makes up 99% or more of the total volume of the mixture.
- Solid, flammable: A solid, other than a blasting agent or explosive as defined in § 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a severe hazard. A chemical must be considered a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.

Flashpoint: The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite.

General exhaust: Removal of contaminated air from a large area by an air circulation or exchange system.

Generic substance: Identified by its general chemical name and formula.

Hazard communication program: The written program employers must develop and use. This program specifies employee training for routine and emergency use of all potentially hazardous chemicals in the workplace and is covered under EHS 103: Hazard Communication Program. It also specifies details about chemical laboratories, chemical storage, SDSs and the complete list of all hazardous chemicals in the workplace.

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

Health hazard: Any chemical for which at least one scientific study shows may cause acute or chronic health symptoms. This includes carcinogens, toxic or highly toxic chemicals, irritants, corrosives, sensitizers, or chemicals that affect target organs, including the lungs, kidneys, nervous system, pulmonary system, reproductive system, skin and eyes.

Highly toxic: A chemical that has been found through testing of laboratory animals to cause death when exposed at certain levels. Refer to the IFC for additional information.

Ignition source: Anything that provides heat, sparks or flame sufficient to cause combustion or explosion.

Incompatible: Materials that could cause dangerous reactions from direct contact with one another.

Ingestion: The drawing of a substance into the body — stomach — through the nose, mouth and breathing passages in the form of gas, vapor, fume, mist or dust.

Inhalation: The drawing of a substance into the body — lungs — through the nose, mouth, and breathing passages in the form of gas, vapor, fume, mist or dust.

Irritant: A substance that will cause an inflammatory response or reaction of the eye, skin, or respiratory system following single or multiple exposures.

Laboratory: A space where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis.

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

Laboratory startup and closeout: Process to ensure laboratory operations adhere to the Chemical Hygiene Program requirements.

Laboratory-type hood: A device located in a laboratory, enclosed on five sides with a moveable sash or fixed partial enclosed on the remaining side, constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms. Walk-in hoods with adjustable sashes meet the above definition, provided that the sashes are adjusted during use so that the airflow and the exhaust of air contaminants are not compromised, and employees do not work inside the enclosure during the release of airborne hazardous chemicals.

Laboratory use of hazardous chemicals: Handling or use of such chemicals in **which all** the following conditions are met:

- Chemical manipulations are carried out on a laboratory scale.
- Multiple chemical procedures or chemicals are used.
- Protective laboratory practices and equipment are available and commonly used to minimize potential employee exposure to hazardous chemicals.
- The procedures involved are not part of a production process nor in any way simulate a production process.

LC50: Lethal concentration 50 is the concentration in the air that causes the death of 50% of the test animals. The concentration is expressed in mg/liter, mg/m^3.

LD50: Lethal dose 50 is a single dose of material that, based on laboratory tests, is expected to kill 50% of a group of test animals. The material may be administered by mouth — oral — or applied to the skin — dermal or cutaneous. The dose is expressed in g\kg of body weight.

LEL — lower explosive limit: The minimum concentration of vapor in air that can produce ignition or explosion.

Local exhaust: A local exhaust system is used to capture and exhaust contaminants from the air to the point where the contaminants — gases and particulates- are released. Not to be confused with general exhaust.

Medical consultation: A consultation between an employee and a medical professional to determine what medical examinations or procedures are appropriate in cases where significant exposure to a hazardous chemical may have occurred.

Mechanical exhaust: Mechanical exhaust systems use a powered device, such as a motor-driven fan or air/street venturi tube, for exhausting contaminants from a workplace, vessel or enclosure.

Neutralize: To render chemically neutral or harmless, neither acid nor base, to counteract the activity or effect, the addition of a base — sodium hydroxide — to an acid — hydrochloric acid — results in water and a salt — sodium chloride; thus, the acid has been neutralized or rendered harmless.

Odor threshold: An odor threshold is the minimum concentration of an airborne, toxic substance whose odor is detectable to the average individual. Depending on whether it is above or below the substance’s TLV, it may be indicative of whether additional ventilation is required.

Oral: Of, through, about or affecting the mouth.

Organic peroxide: An organic compound containing the bivalent -O-O- structure may be considered a structural derivative of hydrogen peroxide where an organic radical has replaced one or both hydrogen atoms.

OSHA — Occupational Safety and Health Administration of the U.S. Department of Labor: A federal agency with safety and health enforcement authority for most U.S. industries and businesses.

Oxidizer: Materials that readily yield oxygen or other oxidizing gas or that readily react to promote or initi ate combustion of combustible materials and, if heated or contaminated, can result in vigorous self-sustained decomposition.

Particularly hazardous substances: Include select carcinogens, reproductive toxins and substances with a high degree of acute toxicity.

PEL — Permissible Exposure Limit: OSHA's regulatory authority established an exposure limit. PELS may be expressed as a time-weighted average or maximum concentration exposure limit.

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

Polymerization: A chemical reaction in which many relatively simple molecules combine to form a sizeable chainlike molecule. A hazardous polymerization is a reaction that takes place at a rate that releases large amounts of energy.

PPM — parts per million: A unit for measuring the concentration of a gas or vapor in contaminated air. PPM is also used to indicate the concentration of a particular substance in a liquid or solid.

Protective laboratory practices and equipment: Those laboratory procedures, practices, and equipment accepted by laboratory health and safety experts as effective, or that the employer can show to be effective, in minimizing the potential for employee exposure to hazardous chemicals.

Pyrophoric: A chemical that ignites spontaneously with air at 130° Fahrenheit or less.

Regulated carcinogen: Cancer-causing agents that are adopted and regulated by OSHA.

Respiratory protection: Devices for use in conditions exceeding set exposure levels, when properly selected, maintained, and worn by the user, will protect the user's respiratory system from exposure to airborne contaminants by inhalation.

Reproductive toxins: Chemicals that affect the reproductive capabilities, including chromosomal damage — mutations — and effects on fetuses — teratogenesis.

Safety data sheet — SDS: Written or printed material about a chemical that specifies its hazards, safe use and other information. It is prepared by the chemical manufacturer and is required by federal law.

SCBA: Self-contained breathing apparatus.

Select carcinogen: Any substance which meets one of the following criteria:

- OSHA regulates it as a carcinogen.
- It is listed under the category **known to be carcinogens** in the Annual Report on Carcinogens published by the National Toxicology Program latest edition.
- It is listed under group 1 **as carcinogenic to humans by the International Agency for Research on Cancer Monographs'** latest editions.
- It is listed in either group 2A or 2B by IARC or under the category **reasonably anticipated to be carcinogens** by NTP. It causes statistically significant tumor incidence in experimental animals by any of the following criteria:
    a. After inhalation, exposure is 6–7 hours per day, five days per week, for a significant portion of a lifetime, and dosages of less than 10 mg/m^3.
    b. After repeated skin application of less than 300 mg/kg of body weight per week.
    c. After oral dosages of less than 50 mg/kg of body weight daily.

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.

Solubility in water: The percentage of a material, by weight, that will dissolve in water at a specific temperature:

- Appreciable: More than 10%.
- Complete soluble in all proportions.
- Moderate: 1 to 10%.
- Negligible: Less than 0.1% to 1.0%.

Solvents: A substance that dissolves another substance.

Special ventilation areas: A special ventilation area is an environmental room, isolation room, cold room, clean room or incubator.

Specific gravity: The ratio of the weight of a volume of material to the weight of an equal volume of water, usually at 60 degrees Fahrenheit.

Systemic: Spread throughout the body, affecting many or all body systems or organs, not localized in one spot or area.

TLV — **Threshold Limit Value®:** The exposure limit for a specific substance per ACGIH. TLV is a measure of inhalation exposure only.

TLV skin: The skin designation refers to the potential contribution to the overall exposure by the cutaneous route, including mucous membranes and the eye. Exposure can be either by airborne or direct contact with the substance. This designation indicates that appropriate measures should be taken to prevent skin absorption. Refer to OSHA guidance for more information.

This designation sometimes appears alongside a TLV or PEL. It refers to the possibility of absorption of a particular chemical through the skin and eyes. Thus, protecting large surface areas of skin should be considered to prevent skin absorption so that the TLV is not invalidated.

Target organ: The specific organs or body systems that sustain hazardous effects from a toxic chemical, either long or short-term. Target organs include the liver, kidneys, central nervous system or skin.

Toxic: A substance that has a median lethal dose (LD50) of 50 to 500 mg/kg for ingestion, from 200 to 1,000 mg/kg within 24 hours for contact and from 200 to 2,000 PPM gas or vapor for inhalation.

UEL — upper explosive limit: The air's highest gas or vapor concentration can produce ignition or explosion.

Unstable-reactive: An unstable or reactive chemical can undergo vigorous polymerization, decomposition or condensation. This process occurs when the chemical undergoes shock or changes in pressure or temperature.

Vapor density: The ratio of a substance's vapor density to that of another, usually air. A vapor density of greater than one means the substance is heavier than air.

Vapor pressure: The pressure exerted by vapor, in confinement, over its liquid as it accumulates at a constant temperature.

Water-reactive: A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

Appendix B

EHS laboratory inspection process

The ASU EHS operations committee and the University Laboratory Safety Committee approved the following laboratory consultation process:

- **Purpose**: To define the roles, responsibilities and processes for the ASU EHS general laboratory safety consultation at ASU campuses.
- **References and regulations**.
    - EHS 104: Laboratory Use of Hazardous Chemicals.
    - OSHA 29 CFR part 1910.1450.
    - Prudent Practices in the Laboratory Handling and Management of Chemical Hazards, National Research Council of the National Academies.
- **Equipment — materials**.
    - ASU EHS Laboratory Safety Consultation Checklist.
    - Personal protective equipment.
- **Responsibility**.
    - **Environmental Health and Safety**.
        - Consult with laboratories and provide results.
        - Coordinate consultations of ASU laboratories.
        - Designate laboratories to be visited.
        - Maintain consultation database.
        - Oversee communication of consultation results to laboratory managers, principal investigators, department heads, etc.
        - Provide support to laboratory managers where applicable.
        - Report metrics of consultations.
        - Track completed consultations.
    - **Laboratory managers**: Correct and respond to consultation findings as determined by consultation reports under the guidance of the laboratory PI.
    - **Compliance officers**: Assist with correcting administrative deficiencies determined by consultation reports and follow-ups.
- **Inspection ranking guidelines**: ASU EHS ranks laboratory safety inspection findings based on the risk and severity of the results. Inspection/consultation findings are ranked from one to three, with three being the most severe or highest risk finding. The ranking system is used to assist in resolving open results from consultations.
    - **Inspection findings ranked No. 1**: Administrative conclusions that can be resolved by email and closed without a follow-up consultation with the laboratory staff or PI.
    - **Inspection findings ranked No. 2**: Consist of more hazardous infractions. These consultation findings can be closed by conducting a physical follow-up consultation. Compliance officers, laboratory managers, or ASU EHS laboratory consultants can conduct follow-up consultations.
    - **Inspection findings ranked No. 3**: Consists of severe hazards and high-risk regulatory infractions. These infractions consist of noncompliance with regulatory policies and procedures. Examples include imminent threats, exposure compliance, hazardous waste procedures, compressed gas processes, and OSHA regulations. These findings can only be resolved through a physical follow-up consultation by the initial laboratory consultant or their supervisors.
- **Follow-up inspection**: EHS performs laboratory safety consultations and reports to the PI. The consultation report will advise the PI to provide a written corrective action plan or proof of corrected findings within 30 days.

    - If no response is received within **30 days** of the report, EHS may, as a courtesy, contact the laboratory's PI with a reminder. Additional parties, such as the safety committee, compliance officer or department designee, may also be notified.
    - If no response is received or findings remain open after **60 days** of receiving the initial follow-up consultation report, the information will be forwarded to the CHO for review to determine if an additional follow-up is required.
- **Repeat findings**: Repeat inspection findings ranked No. 3 may be communicated with academic unit leadership and placed on a quarterly consultation schedule. A quarterly consultation schedule can assist the laboratory in resolving these repeat findings. The CHO and EHS leadership will determine when repeat findings are resolved, and a regular schedule can resume.
- **Self-assessments**: PIs are encouraged to perform laboratory self-assessments during the annual registration. Refer to the laboratory self-inspection checklist for more information. **Inspection-finding trends and recordkeeping**: EHS maintains consultation records and generates reports to identify consultation-finding trends and determine corrective actions.

Risk categories

All categories required applicable EHS training and PI-provided laboratory-specific safety training. Risks in categories 2 and 3 require SOPS for particularly hazardous substances.

Risk category	Areas defined — not an all-inclusive list
1: Low	Areas with general hazardous chemicals that do not have unique risks: • Biosafety level one laboratories. • Classroom reaching laboratories — academic teaching. • Laboratories with small, useable amounts of chemicals. • Lasers — Class 1, 2 and 3A.
2: Moderate	Areas considered special risk laboratories. This defines most laboratories. These laboratories use and store particularly hazardous substances, such as: • All radioisotopes for use and storage. • Biosafety level two containment laboratories with non-select agents. • Drug Enforcement Agency controlled substances. • High voltage electrical equipment < 600 volts. • Large volumes of stored chemicals like flammable cabinets, etc. • Lasers — Class 3B and 4. • Radiation-producing equipment — X-rays and accelerators. • The laboratory is performing research with vertebrate animals.
3: High	Areas with extremely hazardous activities and chemical or material use, including highly sensitive areas with the highest risk conditions, such as: • Areas whose grant application requires environmental and safety certification. • Highly toxic gases, pyrophoric materials or any quantity of gases. • Laboratories with security-related equipment requiring passwords or entries — select agents and other highly sensitive or regulated areas. • Select agent laboratories and biosafety level three facilities.

Appendix C

List of particularly hazardous substances — dangerous chemicals

Particularly hazardous substances fall into the following three categories: Acute toxins, reproductive toxins and carcinogens. All materials in this section require the development and use of laboratory-specific SOPs. For more information, refer to Appendix F.

EHS maintains a list of particularly hazardous substances, including acutely toxic chemicals, acutely toxic gases, air-reactive chemicals, carcinogens, reproductive toxins and water-reactive chemicals.

Acute toxins: Substances with a high degree of acute toxicity may be fatal or damage target organs due to a single exposure or exposures of short durations. Refer to Appendix A for definitions and the SDS.

Reproductive toxins: Any chemical affecting reproductive capabilities, including chromosomal damage — mutations — and effects on fetuses — teratogenesis. Refer to the SDS.

Carcinogens: Chemical or physical agents that cause cancer. Generally, they are chronically toxic substances; that is, they cause damage after repeated or long-duration exposure, and their effects may only become evident after a long latency period. Refer to the complete definition of select carcinogen in Appendix A. OSHA regulates the following 13 listed carcinogens and have specific use and handling requirements per 29 CFR 1910.1003:

- 2-Acetylaminofluorene.
- 3,3'-Dichlorobenzidine — and its salts.
- 4-Aminodiphenyl.
- 4-Dimethylaminoazobenzene.
- 4-Nitrobiphenyl.
- Alpha-Naphthylamine.
- Benzidine — and its salts.
- Beta-Naphthylamine.
- Beta-propiolactone.
- Bis-chloromethyl ether.
- Ethyleneimine.
- Methyl chloromethyl ether.
- N-Nitroso dimethylamine.

Air-reactive chemicals: Air-reactive chemicals can spontaneously and violently react with air; most are pyrophoric, meaning they spontaneously ignite with air. These chemicals should be stored tightly in an inert atmosphere or an inert liquid.

Water-reactive chemicals: Certain chemicals react with water to evolve heat and flammable or toxic gases and should be stored and handled so that they do not encounter liquid water or water vapor.

Shock-sensitive chemicals: Common classes of shock-sensitive laboratory chemicals, which have the potential to produce a violent explosion when subjected to shock or friction, are listed below:

- Acetylenic compounds, especially polyacetylenes, halo acetylenes, and heavy metal salts of acetylenes — copper, silver and mercury salts are particularly sensitive.
- Acyl nitrates.
- Alkyl nitrates, particularly polyol nitrates such as nitrocellulose and nitroglycerine.
- Ammine metal oxo salts — metal compounds with coordinated ammonia, hydrazine, or similar nitrogenous donors and ionic perchlorate, nitrate, permanganate, or another oxidizing group.
- Azides, including metal, nonmetal, and organic azides.
- Chlorite salts of metals, such as silver chloride or mercuric chloride.
- Diazo compounds such as cyanamide.
- Diazonium salts when dry.
- Fulminates such as mercury fulminate.
- Hydrogen peroxide becomes increasingly treacherous as the concentration rises above 30 percent, forming explosive mixtures with organic materials and decomposing violently in the presence of traces of transition metals.
- N-halogen compounds such as difluoroamino compounds and halogen azides.
- N-nitro compounds such as N-trimethylamine, nitrourea, nitroguanidine, and nitric amide.
- Oxosalts of nitrogenous bases: perchlorates, dichromates, nitrates, iodates, chlorites, chlorates, and permanganates of ammonia, hydroxylamine, guanidine, etc.
- Perchlorate salts. Most metal, nonmetal and amine perchlorates can be detonated and may react violently in contact with combustible materials.
- Peroxides and hydroperoxides, organic.
- Peroxides — solid — that crystallize from or are left from evaporation of peroxidizable solvents.
- Peroxides, transition-metal salts.
- Picrates, especially salts of transition and heavy metals, such as nickel, lead, mercury, copper, and zinc.
- Polynitroalkyl compounds such as tetranitromethane and dinitroacetonitrile.
- Polynitroaromatic compounds, especially polynitro hydrocarbons, phenols and amines, such as dinitrotoluene, trinitrotoluene and picric acid.

Appendix D

Standard operating procedures template

Suppose your laboratory research involves using particularly hazardous substances or physically reactive materials such as the ones defined in Appendix C. In that case, you must develop laboratory-specific SOPs to supplement the information in the CHP and the material's safety data sheet.

Below are instructions for completing the SOP using the corresponding template. Please email EHS with any questions or comments while completing your SOPs. Completed SOPs shall be reviewed by the PI and each laboratory employee before working with the material or procedure. Before work, the PI must approve changes to the procedure, and all laboratory employees shall again review the newly revised SOP. Download a sample template.

Include the following in your standard operating procedures:

- **Type of SOP**.
    - **Process**: Identifies a process such as distillation, synthesis, etc.
    - **Hazardous chemical**: Identifies an individual chemical such as arsenic, formaldehyde, nitric acid, etc.
    - **Hazard class**: Identifies the hazard class of chemicals such as oxidizers, flammables, corrosives, etc.
- **Purpose**: Provide a brief description of the chemical used in the laboratory and any information that explains why an SOP is necessary for the chemical of interest.
- **Physical and chemical properties and definition of the chemical group**: Provide the CAS number and essential information on the chemical of interest.
- **Potential hazards or toxicity**.
    - Describe all the potential hazards for each process, hazardous chemical or hazard class.
    - Describe the potential for physical and health hazards.
        - Health hazards include carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic systems and agents that damage the lungs, skin, eyes or mucous membranes.
    - State the potential for the chemicals' chronic or acute health hazard effects.
        - Physical hazards include radioactivity, cryogen, high temperature, electrical, compressed gas or other pressure systems, UV light, laser, flammable or combustible, corrosive, water-reactive, unstable, oxidizer and pyrophoric, explosive, or peroxide-forming chemicals.
- **PPE**: Identify the required PPE for the process, hazardous chemical or hazard class. PPE includes but is not limited to gloves, aprons, laboratory coats, safety glasses, goggles, masks, respirators or face shields.
- **Engineering controls**: Describe or list engineering controls that will be used to prevent or reduce employee exposure to hazards. Examples of engineering controls include fume hoods, glove boxes, interlocks on equipment and shielding.
- **First aid procedures**:
    - Describe any emergency first aid procedures that should be followed in case of chemical exposure.
    - Provide specific details on responses under specific exposure circumstances, such as inhalation, ingestion, skin contact, etc.
- **Special handling and storage requirements**:
    - Describe the storage requirements for hazardous substances, including special containment devices, temperature requirements, storage areas or cabinets, chemical compatibility storage requirements, etc.
    - State the policy regarding access to the substance(s).

  - Provide the exact storage location in the laboratory.
  - Describe any special procedures, such as dating peroxide forming chemicals on receipt, opening, and disposal or testing after an appropriate time.
  - Describe safe methods of transport, such as in a secondary container using a low, stable cart or two hands to carry the chemical container.
- **Spill and accident procedures**:
  - Describe special procedures for spills, releases or exposures such as neutralizing agents, use of fluorescence to detect materials, etc.
  - Indicate how spills, accidental releases and exposures will be handled.
  - List the location of the following emergency equipment:
    - Chemical spill clean-up kit.
    - Emergency shower.
    - Eyewash.
    - Fire extinguisher.
    - First aid kit.
  - Indicate the designated area for experiments using PHSs. A portion of a laboratory bench, equipment, the fume hood or the entire laboratory may be considered a designated area for PHS experiments.
- **Decontamination and waste disposal procedures**:
  - Describe specific decontamination procedures for equipment, glassware or work areas.
  - Describe the anticipated waste products and how waste will be collected and disposed of.
- **Safety data sheet location**: Indicate where the SFSs are kept for the chemicals or hazardous substances used in the laboratory.
  - Indicate the location of other pertinent safety information such as references, equipment manuals, etc.
- **Protocols**: Insert a copy of your specific laboratory procedures for the process, hazardous chemical or chemical hazard class.
- **Documentation of training**: A list of personnel who have reviewed the SOP. A signature and the training date are needed to complete the table.

Appendix E

PPE hazard assessment

All managers and supervisors must survey the work areas and activities under control to determine where PPE may be required. Complete the following instructions:

1. Identify the workplace location.
2. Conduct a walkthrough survey of the workplace and list the tasks or job functions that require PPE.
3. Ensure PPE has an acceptable ANSI rating. Contact EHS if you have any questions.
4. Conduct interviews with employees while performing field observations when necessary and complete this form.
5. The completed assessment should remain on file in your area and additional areas required by your department.

Note: When determining if a potential hazard exists, consideration should be given to the following:

- Employees' perception of hazards.
- History of employee complaints or concerns.
- History of injuries or illnesses related to the workplace or job.

Task	Potential hazard	PPE required

Observation		
Are employees wearing PPE appropriate to tasks? ☐ Yes ☐ No	Is PPE worn and adjusted correctly? ☐ Yes ☐ No	Is PPE maintained in good condition? ☐ Yes ☐ No

If no, describe the corrective action taken:

PPE criteria

*ANSI criteria for protective equipment. The table has been adapted from the Arizona State Risk Management training handout OSHA 1910.132: Personal Protective Equipment.

Protective equipment *Not an all-inclusive list.	**ANSI standard**
Eye and face protection	ANSI Z87
Head protection	ANSI Z89
Foot protection	ANSI Z41

Signature of assessor: ____

Date: ____

Location: ____

Department: ____

Appendix F

Hazardous material storage guide

General rules and principles

Stock containers of chemicals in ASU laboratories must be organized and stored following this guidance. The primary purpose of this guide is to provide hazardous material users guidance regarding how to control health or physical hazards posed by hazardous materials during storage in the laboratory. The hazardous material storage guide aims to do the following:

- Minimize the potential of exposure to poisons.
- Protect flammables from ignition.
- Segregate incompatible materials to prevent accidental mixing.

Designated storage

Stock chemical containers should have a designated storage place for each compound and be returned to that location after each use. Storage locations can be marked on containers.
Do not store excess supplies of chemicals on laboratory bench tops where they are unprotected from ignition sources or potentially damaged. Only chemicals in use or low hazard, like salts and buffers, are permitted on bench tops.

Do not store in a chemical fume hood

Do not keep excessive supplies of chemicals or waste in chemical fume hoods where they clutter space, interfere with the hood's airflow, and contribute to materials that could become involved in a fire or accidental release of hazardous materials.

Close or seal all chemical containers

All chemical containers must be closed except when adding or removing material, including bottles used for hazardous waste chemicals. Hazardous waste containers must remain closed except when filling the container. Potential pressure build-up inside containers sometimes poses a significant hazard; written SOPs should warn users about such a hazard and provide alternative guidance.

Determining the correct storage group

You can determine the correct storage group by the hazard information on the chemical container label and chemical safety data sheet or by contacting EHS.

Chemical and waste storage groups

Chemicals must be stored in the groups and corresponding facilities described on the following pages. This guide demonstrates nine storage groups. Seven of these groups are for the storage of liquids because of the variety of hazards these chemicals pose.

Specific instructions must be followed for metal hydrides — group 8 — and certain individual compounds; otherwise, all dry solids are in group 9.

Do not store chemicals in alphabetical order except within a storage group. The alphabetical arrangement of randomly collected chemicals often increases the likelihood of dangerous reactions by bringing incompatible materials into close proximity.

Heat and sunlight

Storage areas should not be exposed to extremes of heat or sunlight.

Under the sink storage

Do not store any chemicals except compatible general cleaning agents under the sink. Chemicals can be stored in a cabinet under a fume hood if the cabinet is designed and manufactured for hazardous material storage.

Labeling chemicals and hazardous waste

All containers within the laboratory must be labeled according to the instructions in the ASU CHP. Suspect and known carcinogens must be labeled as such and segregated within secondary trays to contain leaks and spills. Hazardous waste containers must be labeled with the words **hazardous waste** and must include a description of the contents.

Liquid chemicals

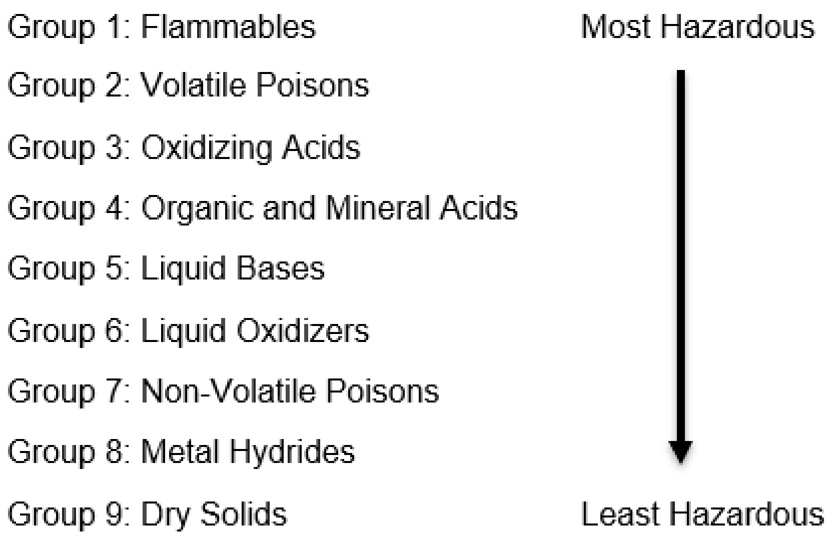
Storage of liquid chemicals is more hazardous than solids and is subject to numerous and varied storage requirements.

Safeguard against theft

This plan does not require security measures, like locked cabinets, to prevent theft, but laboratory workers should ensure laboratory doors are locked when unattended.

Multi-hazard liquids

Many liquid chemicals pose hazards that correspond to more than one storage group. Liquid storage groups are shown in descending order of hazard. The correct storage group for a multi-hazard chemical represents the most significant storage hazard or the group appearing highest in this list.



Group 1: Flammables — Most Hazardous
Group 2: Volatile Poisons
Group 3: Oxidizing Acids
Group 4: Organic and Mineral Acids
Group 5: Liquid Bases
Group 6: Liquid Oxidizers
Group 7: Non-Volatile Poisons
Group 8: Metal Hydrides
Group 9: Dry Solids — Least Hazardous

Storage group definitions

Group 1: Flammable liquids

Includes liquids with flashpoints < 100 degrees Fahrenheit. Examples include all alcohols, acetone, acetaldehyde, acetonitrile, amyl acetate, benzene, cyclohexane, dimethyl dichlorosilane, dioxane, ether, ethyl acetate, histoclad, hexane, hydrazine, methyl butane, picoline, piperidine, propanol, pyridine, some scintillation liquids, all silanes, tetrahydrofuran, toluene, triethylamine, and xylene.

- **Acceptable storage facilities and methods:**
    - Explosion-proof refrigerator or freezer.
    - Flammable cabinet.
    - In-use containers such as properly labeled squirt bottles may be on benchtops.
- **Compatible storage groups:** Flammables may be with either group 2 volatile poisons or group 5 liquid bases, but not with both.
- **Primary storage concern**: To protect from ignition.

Group 2: Volatile poisons

This includes poisons, toxins, and "select" and suspected carcinogens with strong odors or an evaporation rate greater than 1 — butyl acetate = 1. Examples include carbon tetrachloride, chloroform, dimethylformamide, dimethyl sulfate, formamide, formaldehyde, halothane, mercaptoethanol, methylene chloride and phenol.

- **Acceptable storage facilities and methods**: Flammable cabinets or refrigerators for containers less than one liter.
- **Compatible storage groups**: If bases are absent, volatile poisons may be stored with flammables.
  Primary storage concern: To prevent inhalation exposures.

Group 3: Oxidizing acids

All oxidizing acids are highly reactive with most substances and each other. Examples include nitric, sulfuric, perchloric, phosphoric, and chromic acids.

- **Acceptable storage facilities and methods:**
    - Each oxidizing acid must be double-contained — the primary container must be kept inside a canister, tray or tub.
    - Safety cabinet.
- **Primary storage concern:** Preventing contact and reaction with each other and other substances and corrosive action on surfaces.

Group 4: Organic and mineral acids

Examples of organic and mineral acids include acetic, butyric, formic, glacial acetic, hydrochloric, isobutyric, mercaptopropionic, propionic, and trifluoroacetic acids.

- **Acceptable storage facilities and methods**: Storage cabinet.
- **Compatible storage groups**: Small amounts of double-contained oxidizing acids can be stored in the same compartment as organic acids if the oxidizing acids are stored on the bottom shelf.
    - **Exceptions**: Acetic anhydride and trichloroacetic anhydride are corrosive. These acids are very reactive with other acids and should not be stored in this group. It is better to store these with organic compounds.
- **Primary storage concern**: To prevent containing, reacting with bases, oxidizing acids, and corrosive action on surfaces.

Group 5: Liquid bases

Examples of liquid bases included sodium hydroxide, ammonium hydroxide, calcium hydroxide and glutaraldehyde.

- **Acceptable storage facilities and methods**: In tubs and trays in a standard or safety cabinet.
- **Compatible storage groups**: Liquid bases may be stored with flammables in the flammable cabinet if volatile poisons are not stored in the same cabinet.
- **Primary storage concern**: Preventing contact and reaction with acids.

Group 6: Liquid oxidizers

Oxidizing liquids react with everything, potentially causing explosions or corrosion of surfaces. Examples include ammonium persulfate and hydrogen peroxide if greater than or equal to 30%.

- **Acceptable storage facilities and methods**:
    - Smaller quantities must be double-contained when stored near other chemicals, such as refrigerators.
    - Total quantities exceeding three liters must be kept in a cabinet housing no other chemical.
- **Compatible storage groups**: None.
- **Primary storage concern**: To isolate from other materials.

Group 7: Non-volatile liquid poisons

Includes highly toxic — LD50 oral rat < 50 mg/kg — and toxic chemicals — LD50 oral rat < 500 mg/kg, "select carcinogens," suspected carcinogens and mutagens. Examples include acrylamide solutions, Coomassie blue stain, diethylpyrocarbonate, diisopropyl fluorophosphate, uncured epoxy resins, ethidium bromide and triethanolamine.

- **Acceptable storage facilities and methods**:
    - Cabinet or refrigerator — must be enclosed.
    - Do not store on open shelves in the laboratory or cold room.
    - Liquid poisons in containers larger than one liter must be stored below bench level on shelves closest to the floor. Smaller containers of liquid poison can be stored above bench level only if behind sliding — non-swinging — doors.
- **Compatible storage groups**: Non-hazardous liquids like buffer solutions.
    - Exceptions: Anhydrides — acetic and trichloroacetic — are organic acids. However, storing them with this group is better since they are highly reactive with other acids.
- **Primary storage concern**: To prevent contact and reaction with other substances.

Group 8: Metal hydrides

Most metal hydrides react violently with water; some ignite spontaneously in air — pyrophoric. Examples include sodium borohydride, calcium hydride and lithium aluminum hydride.

- **Acceptable storage facilities and methods**:
    - Secure, waterproof double-containment according to label instructions. Isolate from other storage groups.
- **Compatible storage groups**: If securely double-contained to prevent contact with water or air, metal hydrides may be stored in the same area as group 9 dry solids.
- **Primary storage concern**: To prevent contact and reaction with liquids and, in some cases, air.

Group 9: Dry solids

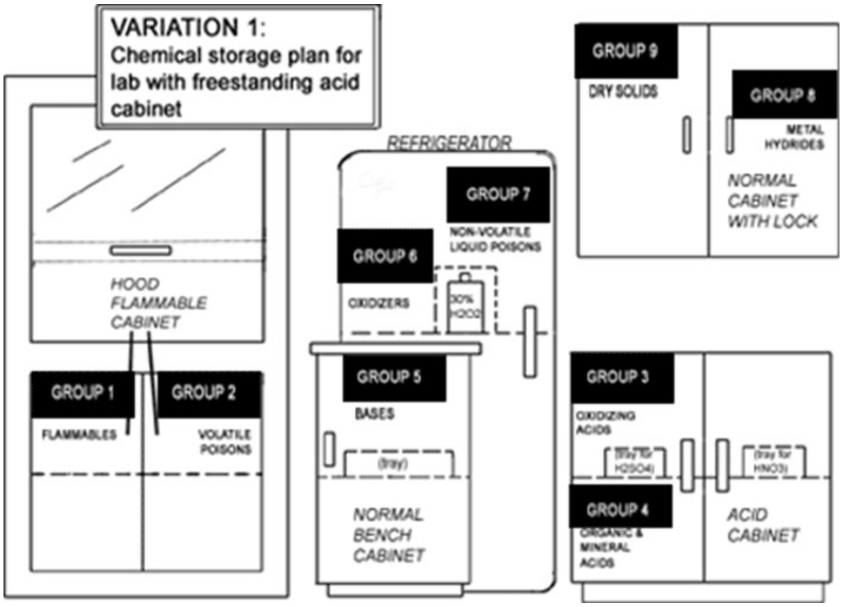
Includes all powders, hazardous and non-hazardous. Examples include benzidine, cyanogen bromide, ethylmaleimide, oxalic acid, potassium cyanide and sodium cyanide.

- **Acceptable storage facilities and methods**:
    - Cabinets are recommended, but open shelves are acceptable if not available. Store above liquids.
    - It is recommended that the most hazardous substances in this group be segregated. It is essential to keep liquid poisons below cyanide- or sulfide-containing poisons — solids; a spill of aqueous liquid onto cyanide- or sulfide-containing poisons would cause a reaction that would release poisonous gas.
    - Warning labels on highly toxic powders should be inspected, highlighted or amended to stand out against less toxic substances in this group.
- **Compatible storage groups**: Metal hydrides may be stored in the same area if properly double-contained.
- **Exceptions**: Solid picric or picric sulfonic acid can be stored with this group but should be checked regularly for dryness. When completely dry, picric acid is explosive and may detonate upon shock or friction.
- **Primary storage concern**: To prevent contact and potential reaction with liquids.

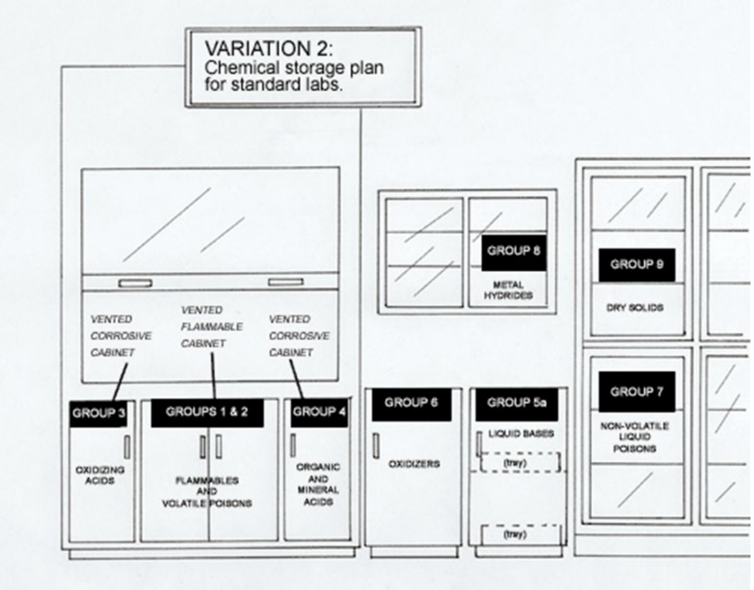
Storage plan variations for different laboratory facilities

On the following pages are illustrations of possible — non-mandatory — chemical storage arrangements for two types of laboratory facilities. They are provided merely as examples of layouts that satisfy the requirements of the chemical storage plan. They are not intended to restrict storage to the arrangements and facilities depicted. Refer to the storage group definitions for segregation and facility requirements.

Variation one: Chemical storage plan for a laboratory with a freestanding acid cabinet.



Variation two: The chemical storage plan for standard laboratories.



Examples of incompatible chemicals

Always use the SDS to identify chemical compatibility so that it works safely in the laboratory. The following list contains some common incompatible materials and is not all-inclusive.

Chemical	Incompatible chemicals
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides and permanganates.
Acetic anhydride	Hydroxyl-containing compounds such as ethylene glycol and perchloric acid.
Acetone	Concentrated nitric, sulfuric acid mixtures and hydrogen peroxide.
Acetylene	Chlorine, bromine, copper, fluorine, silver and mercury.
Alkali and alkaline earth metals, such as powdered magnesium, sodium and potassium	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide and halogens.
Ammonia — anhydrous	Mercury, halogens, calcium hypochlorite and hydrofluoric acid.
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur and finely divided organic or combustible materials.
Aniline	Nitric acid and hydrogen peroxide.
Arsenical materials	Any reducing agent.
Azides	Acids, heavy metals and their salts, and oxidizing agents.
Calcium oxide	Water.
Carbon — activated	All oxidizing agents and calcium hypochlorite.
Carbon tetrachloride	Sodium.
Chlorates	Ammonium salts, acids, metal powders, sulfur and finely divided organic or combustible material.
Chlorine dioxide	Ammonia, methane, phosphine and hydrogen sulfide.
Chromic acid and chromium trioxide	Acetic acid, alcohol, camphor, glycerol, naphthalene and flammable liquids in general.
Copper	Acetylene and hydrogen peroxide.
Cumene hydroperoxide	Acids are organic or inorganic.
Cyanides	Acids.

Chemicals	Incompatible chemicals
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens and other oxidizing agents.
Fluorine	All other chemicals.
Hydrides	Water.
Hydrocarbons, such as butane, propane and benzene	Fluorine, chlorine, bromine, chromic acid and peroxides.
Hydrocyanic acid	Nitric acid and alkalis.
Hydrofluoric acid — anhydrous	Ammonia — aqueous or anhydrous.
Hydrogen peroxide	Copper, chromium, iron, most metals or salts, flammable liquids like alcohols or acetone, combustible materials, aniline and nitromethane.
Hydrogen sulfide	Fuming nitric acid and oxidizing gases.
Hypochlorites	Acids and activated carbon.
Iodine	Acetylene, ammonia — aqueous or anhydrous — and hydrogen.
Mercury	Acetylene, fulminic acid and ammonia.
Metal hydrides	Acids and water.
Nitrates	Acids.
Nitric acid — concentrated	Acetic acid, acetone, alcohol, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, gases, copper, brass and heavy metals.
Nitrites	Acids.
Nitroparaffins	Inorganic bases and amines.
Oxalic acid	Mercury, silver and their salts.
Oxygen	Oils, grease, hydrogen and flammable liquids, solids or gases.
Perchloric acid	Acetic anhydride, alcohol, bismuth, paper, wood, grease and oils.
Permanganates	Concentrated sulfuric acid, glycerol, ethylene glycol and benzaldehyde.
Peroxides — organic	Acids — organic or mineral: Avoid friction and store them cold.
Phosphorus — white	Air, oxygen, alkalis and reducing agents.
Potassium	Carbon tetrachloride, carbon dioxide and water.
Potassium chlorate	Sulfuric and other acids, ammonium salts, metal powders, sulfur and finely divided organics or combustibles.
Potassium perchlorate — see chlorates	Sulfuric and other acids.
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde and sulfuric acid.
Silver and silver salts	Acetylene, oxalic acid, tartaric acid, ammonium compounds and fulminic acid.
Sodium	Carbon tetrachloride, carbon dioxide, other chlorinated hydrocarbons and water.
Sodium nitrate	Ammonium nitrate and other ammonium salts.
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide glycerin, ethylene glycol, ethyl acetate, methyl acetate and furfural.
Sulfides	Acids.
Sulfuric acid	Chlorates, perchlorates and permanganates.

Basic chemical segregation

Chemical hazard class	Recommended storage method	Examples	Incompatibilities
Compressed gases — flammable	Store in a cool, dry area away from oxidizing gases. Securely strap or chain cylinders to a wall or bench.	• Acetylene propane. • Methane hydrogen.	• Oxidizing and toxic compressed gases. • Oxidizing solids.
Compressed gases — oxidizing	Store away from flammable gases and liquids in a cool, dry area. Securely strap or chain cylinders to a wall or bench.	• Bromine. • Chlorine. • Oxygen.	• Flammable gases.
Compressed gases — poisonous	Store away from flammable gases and liquids in a cool, dry area. Securely strap or chain cylinders to a wall or bench.	• Carbon monoxide. • Hydrogen sulfide. • Nitrogen dioxide.	• Flammable gases. • Oxidizing gases.
Corrosives — acids	Store separately in an acid storage cabinet. Segregate oxidizing acids from organic acids, such as chromic, nitric, sulfuric, and perchloric acids.	• Acetic acid. • Chromic acid. • Hydrochloric acid. • Nitric acid. • Perchloric acid. • Phenol. • Sulfuric acid.	• Bases. • Flammable liquids. • Flammable solids. • Oxidizers.
Corrosives — bases	Store in a separate corrosive storage cabinet. Store solutions of inorganic hydroxides in labeled polyethylene containers.	• Ammonium hydroxide. • Calcium hydroxide. • Sodium hydroxide.	• Acids. • Flammable liquids. • Oxidizers. • Poisons.
Flammable liquids	Store in a flammable storage cabinet and away from sources of ignition. Store highly volatile flammable liquids in an explosion-proof refrigerator.	• Acetone. • Benzene. • Diethyl ether. • Ethanol. • Glacial acetic acid. • Methanol. • Toluene.	• Acids. • Bases. • Oxidizers. • Poisons.
Flammable solids	Store in a separate, dry, cool area away from oxidizers, corrosives and flammable liquids.	• Benzoyl peroxide. • Calcium carbide. • Phosphorus, yellow. • Picric acid.	• Acids. • Bases. • Oxidizers. • Poisons.
General chemicals — non-reactive	Sore on general laboratory benches or shelving, preferably behind glass doors and below eye level.	• Agar. • Most non-reactive salts. • Sodium bicarbonate. • Sodium chloride.	Refer to the SDS.

Chemical hazard class	**Recommended storage method**	**Examples**	**Incompatibilities**
Water-reactive chemicals	Store in a dry, cool location with protection from water fire sprinklers.	• Lithium aluminum hydride. • Lithium metal. • Potassium metal. • Sodium metal.	Separate from all aqueous solutions and oxidizers.
Oxidizers	Store in a spill tray inside a chemical storage cabinet. Separate from flammable and combustible materials.	• Ammonium persulfate. • Ferric chloride. • Benzoyl peroxide. • Iodine. • Potassium dichromate. • Potassium permanganate. • Sodium hypochlorite. The following are generally considered oxidizing substances: • Bromate. • Chlorates. • Nitrates. • Perchlorates. • Peroxides. • Super oxides.	Separate from reducing agents, flammables and combustibles.
Poisons and toxic compounds	Store separately in a vented, cool, dry area in unbreakable chemically resistant secondary containers and following the hazardous nature of the chemical.	• Aniline. • Carbon tetrachloride. • Chloroform. • Formic acid. • Heavy metal compounds like cadmium, mercury and osmium. • Oxalic acid. • Phenol.	• Acids. • Bases. • Flammable liquids. • Oxidizers. Refer to the SDS.
Carcinogens	Label all containers as **cancer suspect agents**. Store according to the hazardous nature of the chemical, using appropriate security when necessary.	• Benzene. • Benzidine. • Beta-naphthylamine. • Beta-propiolactone. • Methylene chloride.	Refer to the SDS.
Teratogens	Label all containers as **suspect reproductive hazard**. Store according to the hazardous nature of the chemical, using appropriate security when necessary.	• Aniline. • Benzene. • Lead and mercury compounds.	Refer to the SDS.

Chemical hazard class	**Recommended storage method**	**Examples**	**Incompatibilities**
Peroxide-forming chemicals	Store in airtight containers in a dark, cool and dry area. Refer to the suggested storage time limits table below.	• Acetaldehyde. • Acrylonitrile. • Diethyl ether.	Refer to the SDS.
Strong reducing agents	Store in a cool, dry, well-ventilated location. Water reactive. Segregate from all other chemicals.	• Acetyl chloride. • Ferrous sulfide. • Maleic anhydride. • Thionyl chloride.	Refer to the SDS.

Suggested storage time limits for common peroxide crystal-forming compounds

Peroxide formation occurs when certain laboratory chemicals react with air at ordinary temperatures to form peroxyl compounds, which are violently reactive or explosive. Organic peroxides are classified as hazardous low-power explosives because they are sensitive to shock, sparks or other ignition sources. Additionally, they are sensitive to heat, friction, impact, light and strong oxidizing and reducing agents.

All organic peroxides are flammable and have a specific decomposition rate under a given set of conditions. Due to unusual stability problems, bulk quantities of peroxides should be cautiously approached because they may generate enough heat to auto-accelerate up to ignition. Peroxides or peroxide-forming chemicals include but are not limited to, the following lists.

Suggested storage time limits		
Most dangerous	**Dangerous**	**Dangerous**
Discard after three months. The following chemicals are a peroxide formation hazard during storage: • Chloride. • Disopropyl ether. • Divinyl acetylene. • Isopropyl ether. • Potassium metal. • Sodium amide vinylidene.	**Discard after one year**. The following chemicals are a peroxide formation hazard during storage and on concentration — distillation — of the compound: • 1,4-Dioxane. • Acetal acetaldehyde. • Cumene cyclohexene. • Diacetylene. • Dicyclopentadiene. • Diethyl ether. • Dimethyl ether. • Ethylene glycol. • Methyl acetylene. • Methyl cyclopentane. • Methyl isobutyl ketone. • Tetrahydrofuran. • Tetrahydronaphthalene. • Vinyl ethers.	**Discard after one year**. The peroxide formation of the following chemicals causes the initiation of hazardous polymerizations: • 1,3-Bitadiene. • 2-Butanol. • 2-Propanal. • Acrylic acid. • Acrylonitrile. • Chloroprene. • Chlorotrifluoroethylene. • Methyl methacrylate. • Styrene. • Tetrafluoroethylene. • Vinyl acetate. • Vinyl acetylene. • Vinyl chloride. • Vinyl pyridine.

Appendix G

Guidelines for nanotechnology-related research

Nanotechnology is an emerging industry and research area involving the engineering of items on a molecular level. For years, experts have been heralding science as a field with enormous promise. Considerable advancements in nanotechnology have already been made, and this is a growing area of research at ASU. Nanotech products can already be found in many consumer products, including food, makeup and other products.

Reasons for concern related to potential EHS risks associated with nanotechnologies, and in particular, carbon nanotubes, have recently surfaced. For this reason, EHS's department recommends an approach referred to as control banding to address the potential risks associated with research in nanotechnologies.

Control banding is a strategy for qualitative risk assessment and management of workplace hazards. The method involves grouping workplace risks into control bands based on hazard and exposure information combinations. CB strategies are not intended to be predictive exposure models.

The table below provides general guidelines for specific nanotechnologies already used in many research areas. It is recommended that this table be used as a guideline for developing an SOP for all nanotechnology-related research. At a minimum, any new research involving nanotechnologies must follow the prior approval process identified in this CHP.

Green — NSL1 — Nanomaterials consist of little to no harm and are known to be inert.	
Scenario description	**Name or description of nanomaterial**
Gold nanoparticles are used to test the carbon nanotube filter.	Gold nanoparticles.
Mixed polystyrene spheres with buffer, etching nanostructures onto semiconductors.	Polystyrene spheres and nanostructures.
Deposition of liquid-suspended nanoparticles onto surfaces using low-voltage electric fields.	Polymer latex, gold, platinum, and palladium nanoparticles.
Preparation of examples. Activities include cutting, slicing, grinding, lapping, polishing, chemical etching, electrochemical polishing and ion etching.	Carbon black, aluminum oxide, magnesium oxide, polycrystalline diamond suspension, colloidal silica, palladium power and carbon nanotubes.
Sample preparation and characterization.	Gold, silver nanoparticles, iron oxide, silicon dioxide, aluminum oxide, carbon, ceramic aerogels, and nanopowders.
Synthesis of aerogel.	Silica, iron, chromium, copper, zinc nanoparticles and titanium nanoparticles.
Required engineering controls	**Required PPE**
General ventilation/HVAC.	Laboratory cost, safety glasses and goggles, and single nitrile gloves.

Yellow — NSL 2 — nanomaterials consist of potential hazards	
Scenario description	**Name or description of nanomaterial**
Synthesis of metal oxide nanowires on substrates within a tube furnace.	Zinc oxide, tin oxide, titanium oxide, lead zirconium titanium oxide, barium titanium oxide and strontium titanium oxide nanowires.
Synthesis of silver and copper oxide nanoparticles.	Silver oxide nanoparticles and copper oxide nanoparticles.
Addition of quantum dots onto porous glass.	Cadmium selenide and lead sulfide.
Growth of palladium nanocatalyst.	Palladium nanocatalyst.
Water is poured into a container with liquid-suspended carbon nanotubes.	Carbon nanotubes.
Analysis of nanomaterial waste samples in the laboratory.	Various.
Purification and functionalization of carbon nanotubes.	Carbon nanotubes.
Synthesis and optical characterization of nanoparticles.	Cadmium selenium quantum dots, germanium quantum dots, iron oxide, gold and lead sulfide nanoparticles.
Sample preparation and characterization of cadmium selenium nanodots.	Cadmium selenium quantum dots.
Sample preparation and characterization of carbon diamonds.	Carbon diamonds.
Sample preparation and characterization using laser microscopy.	Gold and silver nanoparticles.
Preparation of nanofoams sample for microscopy.	Gold, copper, aluminum and nickel nanoparticles.
Preparation of carbon nanotube sample for microscopy.	Carbon nanotubes.
Machining — turning or milling — of aerogels and nanofoams for target assembly.	Nanofoams, copper and gold, and carbon nanofoams.
Sitewide waste sampling activities.	Various.
Waste accumulation area activities, including waste management, waste packaging, etc.	Various.
Radioactive and hazardous waste management field tech activities, including waste management, waste packaging, waste sampling, etc.	Various.
Required engineering controls	**Required PPE**
Fume hood or BSL	Laboratory coat, safety glasses, goggles and single nitrile gloves.

Orange — NSL 3 nanomaterials — limited information is known	
Scenario description	**Name or description of nanomaterial**
Activities related to operating and maintaining a vertical tub quench furnace and a horizontal tube furnace.	Gold, copper, nickel, brass, silver and platinum nanoparticles.
Required engineering controls	**Required PPE**
Glove box and fume hood with HEPA or hard ducted BCA.	Laboratory coat, safety glasses or goggles and double nitrile gloves.

Red — NSL 4 — nanomaterials information is unknown, inhalation hazard	
Scenario description	**Name or description of nanomaterial**
Nanomaterial is attached to a carcinogenic chemical, etc.	
Required engineering controls	**Required PPE**
Glove box and fume hood with HEPA or hard ducted BSC.	Laboratory coat, safety glasses and goggles, double nitrile gloves and an N95 or N100 respirator.

Appendix H

Maximum allowable storage quantities

For more information, refer to International Fire Code, 2018 revision, table 5003.1.1(1). ASU and surrounding jurisdictions adhere to the 2018 version of the IFC.

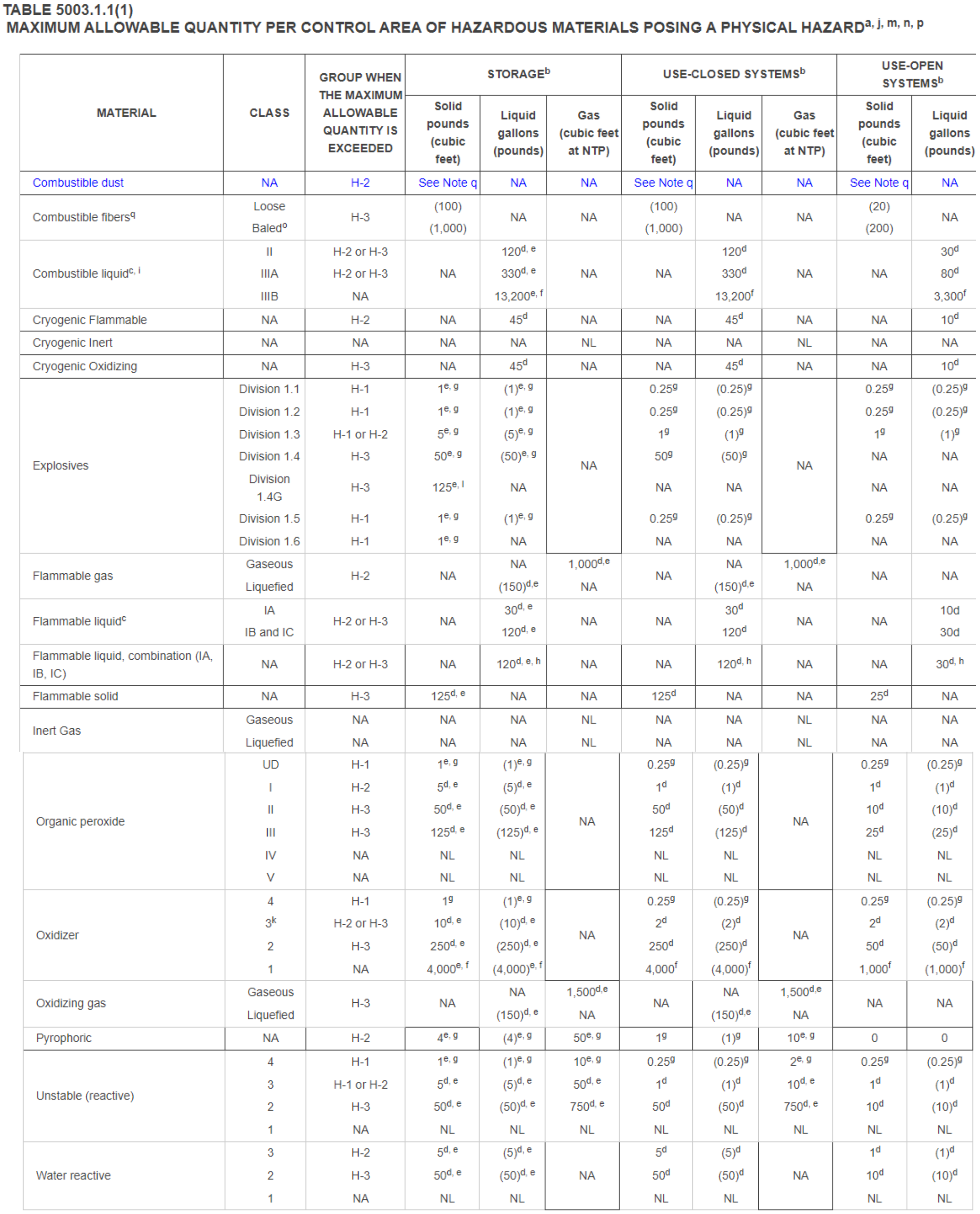
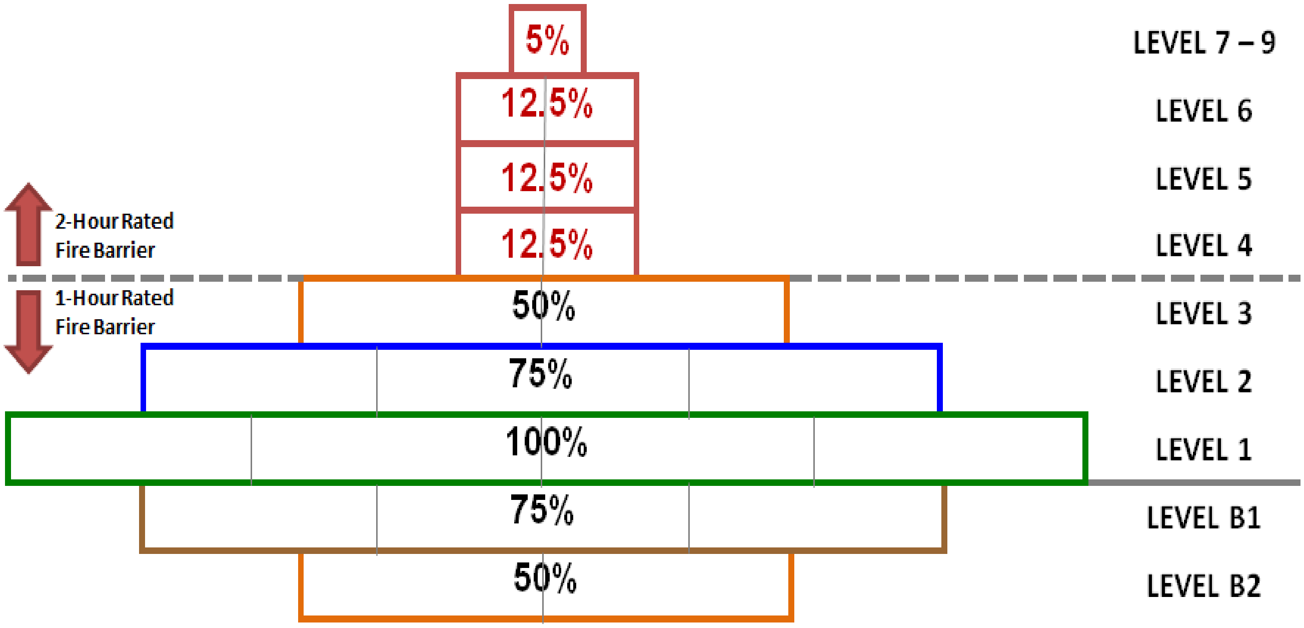


TABLE 5003.1.1(1)
MAXIMUM ALLOWABLE QUANTITY PER CONTROL AREA OF HAZARDOUS MATERIALS POSING A PHYSICAL HAZARD[a, j, m, n, p]

MATERIAL	CLASS	GROUP WHEN THE MAXIMUM ALLOWABLE QUANTITY IS EXCEEDED	STORAGE[b]			USE-CLOSED SYSTEMS[b]			USE-OPEN SYSTEMS[b]	
			Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet at NTP)	Solid pounds (cubic feet)	Liquid gallons (pounds)	Gas (cubic feet at NTP)	Solid pounds (cubic feet)	Liquid gallons (pounds)
Combustible dust	NA	H-2	See Note q	NA	NA	See Note q	NA	NA	See Note q	NA
Combustible fibers[q]	Loose	H-3	(100)	NA	NA	(100)	NA	NA	(20)	NA
	Baled[o]		(1,000)			(1,000)			(200)	
Combustible liquid[c, i]	II	H-2 or H-3	NA	120[d, e]	NA	NA	120[d]	NA	NA	30[d]
	IIIA	H-2 or H-3		330[d, e]			330[d]			80[d]
	IIIB	NA		13,200[e, f]			13,200[f]			3,300[f]
Cryogenic Flammable	NA	H-2	NA	45[d]	NA	NA	45[d]	NA	NA	10[d]
Cryogenic Inert	NA	NA	NA	NA	NL	NA	NA	NL	NA	NA
Cryogenic Oxidizing	NA	H-3	NA	45[d]	NA	NA	45[d]	NA	NA	10[d]
Explosives	Division 1.1	H-1	1[e, g]	(1)[e, g]	NA	0.25[g]	(0.25)[g]	NA	0.25[g]	(0.25)[g]
	Division 1.2	H-1	1[e, g]	(1)[e, g]		0.25[g]	(0.25)[g]		0.25[g]	(0.25)[g]
	Division 1.3	H-1 or H-2	5[e, g]	(5)[e, g]		1[g]	(1)[g]		1[g]	(1)[g]
	Division 1.4	H-3	50[e, g]	(50)[e, g]		50[g]	(50)[g]		NA	NA
	Division 1.4G	H-3	125[e, l]	NA		NA	NA		NA	NA
	Division 1.5	H-1	1[e, g]	(1)[e, g]		0.25[g]	(0.25)[g]		0.25[g]	(0.25)[g]
	Division 1.6	H-1	1[e, g]	NA		NA	NA		NA	NA
Flammable gas	Gaseous	H-2	NA	NA	1,000[d,e]	NA	NA	1,000[d,e]	NA	NA
	Liquefied			(150)[d,e]	NA		(150)[d,e]	NA		
Flammable liquid[c]	IA	H-2 or H-3	NA	30[d, e]	NA	NA	30[d]	NA	NA	10d
	IB and IC			120[d, e]			120[d]			30d
Flammable liquid, combination (IA, IB, IC)	NA	H-2 or H-3	NA	120[d, e, h]	NA	NA	120[d, h]	NA	NA	30[d, h]
Flammable solid	NA	H-3	125[d, e]	NA	NA	125[d]	NA	NA	25[d]	NA
Inert Gas	Gaseous	NA	NA	NA	NL	NA	NA	NL	NA	NA
	Liquefied	NA	NA	NA	NL	NA	NA	NL	NA	NA
Organic peroxide	UD	H-1	1[e, g]	(1)[e, g]	NA	0.25[g]	(0.25)[g]	NA	0.25[g]	(0.25)[g]
	I	H-2	5[d, e]	(5)[d, e]		1[d]	(1)[d]		1[d]	(1)[d]
	II	H-3	50[d, e]	(50)[d, e]		50[d]	(50)[d]		10[d]	(10)[d]
	III	H-3	125[d, e]	(125)[d, e]		125[d]	(125)[d]		25[d]	(25)[d]
	IV	NA	NL	NL		NL	NL		NL	NL
	V	NA	NL	NL		NL	NL		NL	NL
Oxidizer	4	H-1	1[g]	(1)[e, g]	NA	0.25[g]	(0.25)[g]	NA	0.25[g]	(0.25)[g]
	3[k]	H-2 or H-3	10[d, e]	(10)[d, e]		2[d]	(2)[d]		2[d]	(2)[d]
	2	H-3	250[d, e]	(250)[d, e]		250[d]	(250)[d]		50[d]	(50)[d]
	1	NA	4,000[e, f]	(4,000)[e, f]		4,000[f]	(4,000)[f]		1,000[f]	(1,000)[f]
Oxidizing gas	Gaseous	H-3	NA	NA	1,500[d,e]	NA	NA	1,500[d,e]	NA	NA
	Liquefied			(150)[d, e]	NA		(150)[d,e]	NA		
Pyrophoric	NA	H-2	4[e, g]	(4)[e, g]	50[e, g]	1[g]	(1)[g]	10[e, g]	0	0
Unstable (reactive)	4	H-1	1[e, g]	(1)[e, g]	10[e, g]	0.25[g]	(0.25)[g]	2[e, g]	0.25[g]	(0.25)[g]
	3	H-1 or H-2	5[d, e]	(5)[d, e]	50[d, e]	1[d]	(1)[d]	10[d, e]	1[d]	(1)[d]
	2	H-3	50[d, e]	(50)[d, e]	750[d, e]	50[d]	(50)[d]	750[d, e]	10[d]	(10)[d]
	1	NA	NL	NL	NL	NL	NL	NL	NL	NL
Water reactive	3	H-2	5[d, e]	(5)[d, e]	NA	5[d]	(5)[d]	NA	1[d]	(1)[d]
	2	H-3	50[d, e]	(50)[d, e]		50[d]	(50)[d]		10[d]	(10)[d]
	1	NA	NL	NL		NL	NL		NL	NL

For more information, refer to the Maximum Allowable Quantity per Building Level of Hazardous Materials Posing a Physical Hazard Table 5003.8.3.2, International Fire Code 2018. The table appearance was modified for the ASU CHP.



Appendix I

Vacuum pump and vacuum system safety guidance

This appendix covers general safety practices for utilizing vacuum pumps and house vacuum systems with chemical solutions.

Vacuum pumps

1. Inspect all laboratory vacuum pumps used with chemicals and verify they do not vent into general room air. If the system vents into general room air and cannot be vented into the laboratory hood or local exhaust system, contact EHS at 480-965-1823 for an evaluation.
2. Verify oil condensers are in place for vacuum pumps utilizing oil as a lubricant.
3. Utilize cold traps to protect pumps from corrosive materials and, whenever evaporating, flammable solvents with pumps that are not intrinsically safe. After completion, immediately disconnect and empty the cold trap into a designated hazardous waste container. Also, please ensure that the cold trap is not set up to allow chemicals to drain or be washed into any drains. This may represent a regulatory compliance issue.
4. Verify that all employees and students working with vacuum equipment are trained and understand how to use it safely and that cold traps must be monitored to ensure they do not go dry.

House vacuum pumps

House vacuum systems are evaluated by EHS and CPMG during installation and are designed to vent potentially hazardous materials in a controlled manner to prevent potential exposure to laboratory personnel. However, this does not eliminate users’ responsibility to protect the house vacuum system from potential chemical contaminants. When evacuating potentially flammable, toxic, or corrosive materials, always use a liquid collection and a cold trap to remove any potentially hazardous material from contaminating the house vacuum system.

Contamination of the house vacuum system may lead to vacuum system downtime and impact all laboratories in the building.

Procedure for working on contaminated laboratory vacuum pumps and systems

The following information is provided as guidance to minimize potential chemical exposure while performing maintenance or repair on laboratory vacuum pumps. This is a brief overview only. For more information, contact EHS.

Contamination of the sealing liquids in vacuum pumps can occur because the liquid — often oil — has direct contact with any contaminant passing through the vacuum system.

Depending on the chemistry of the sealing liquid and the contaminant, chemical residues or a byproduct of a chemical reaction between the two may be present. **As a result of this contamination, facility personnel could be exposed to small amounts of various hazardous materials during the removal, maintenance or reconfiguration of vacuum systems.**

The following guidelines have been developed to minimize risk when working on laboratory vacuum systems:

Small vacuum systems using portable pumps

1. Attempt to identify specific hazardous chemicals entering the system by conferring with laboratory personnel regarding the uses of vacuum systems and the extent to which traps or other control devices have been used.
2. Disconnect the pump and conduct all service operations within a laboratory fume hood if the usage history indicates that a dangerous material has been used in the system and may have potentially left residue or hazardous byproducts.
3. Contact EHS if you cannot follow these steps.

Central vacuum systems

Chemical-specific information will not be available. In cases where work is conducted on central vacuum systems or where the use of the vacuum system is unknown, assume that the system components are contaminated with chemical residues and follow this procedure:

- Always wash hands after service activities.
- Close appropriate valves to isolate affected parts of the system.
- Ensure proper ventilation in the work area, particularly in small spaces. Portable ventilation systems or closed systems designed to route displaced air to a safe location are recommended.
- If applicable, remove the sealing liquid carefully. Avoid splashing or excessive pouring. Place in a sealed container. The liquid should be containerized and disposed of as hazardous waste. Smaller vacuum pumps or systems can be drained into laboratory hoods to avoid exposure.
- If cutting or other work generates dust, safety glasses with side shields are indicated. Goggles are needed if work generates mist or the possibility of a liquid splash.
- Latex or nitrile gloves are adequate for most applications. Specialty gloves may be needed if extreme contamination is present. If cut protective gloves are indicated, they should be worn over chemical protective gloves.
- Notify affected personnel if the system maintenance will affect the central vacuum system. Control energy sources when required using appropriate lock-out or tag-out procedures.
- Reusable gloves, drop cloths, and coveralls may be rinsed, laundered, and reused. Disposable or damaged personal protective equipment can be disposed of as regular trash.
- Sealing liquid removed during service must be disposed of as hazardous waste. If you have any questions regarding hazardous waste, call ASU EHS Hazardous Waste.
- Where possible, purge the system with clean air before beginning work.

Important: Reactions involving highly reactive compounds such as acetylene, butadiene, dioxane, ethylene oxide, oxygen and all potent oxidizing agents must be handled cautiously.

Pressure vessels

Pressure vessels contain internal or external pressure per ASME Code Section VIII. This pressure may be obtained from an external source or by applying heat directly or indirectly. Generally, a pressure vessel is a storage tank or vessel designed to operate at pressures above 15 PSIG.

Examples include glassware, autoclaves, compressed gas cylinders, compressors, refrigeration, vacuum chambers and custom-designed laboratory vessels.

Hazards associated with pressure vessels

The potential hazards are the pressure differential — whether created from a chemical reaction, compressed gas, heating, chilling, or vacuum, cracked or damaged vessels, or leakage from vessels. Two consequences result from a complete rupture:

- Blast effects due to sudden expansion of the pressurized fluid.
- Fragmentation damage and injury if the vessel ruptures.

For a leakage failure, the hazard consequences can range from no effect to severe effects:

- Chemical and thermal burns from contact with process liquids.
- Fire and explosion — physical hazards for a flammable fluid.
- Suffocation or poisoning, depending on the nature of the contained fluid, if the leakage occurs in a closed space.

How to use and handle pressure vessels safely

1. Select a reactor or pressure vessel with the capacity, pressure rating, corrosion resistance and design features suitable for its intended use.
2. When working with pressurized systems that are not specially constructed and certified to contain the pressure or systems that may develop pressure due to heat or reaction, or if the system is unknown or the potential for pressure is not expected but possible, take the following steps to prevent personal injury:
    a. Consider all conditions affecting the pressure vessel — gas versus liquid, heated or cooled, corrosion, etc.
    b. Ensure the regulator is appropriate or designed for the system.
    c. Periodically inspect the setup for physical damage or stress. If you are unsure what to look for, contact EHS.
    d. Use a lower pressure or a different system, like a pump, if it will not adversely affect research.
    e. Use a metal or shatterproof glass or plastic screen to protect personnel from physical injury.
    f. Use a pressure relief valve if the device is connected to an external source — gas cylinder, compressor, pump, etc. — that creates a pressure above 15 psi. The pressure relief valve should be configured to relieve pressure below the pressure rating for the specific vessel.
    g. Use appropriate safety accessories to install and operate the equipment within suitable barricades.
3. Establish training procedures to ensure that anyone handling the equipment knows how to use it properly.
4. Maintain the equipment in good condition and establish procedures for periodic testing to ensure the vessel remains structurally sound.

Ventilation

The room where a pressure vessel will be operated must be well-ventilated. This is particularly important when working with flammable or toxic material. Laboratories are considered well-ventilated rooms. The reactors should be located close to a laboratory hood or exhaust fan to discharge any released gases safely. Lock or tag out electrical equipment if flames are in adjacent areas. Gases and effluent purposely discharged from pressure vessels must be routed through a fume hood or other local exhaust ventilation system.

Load limits

One of the subtlest and most frequently overlooked hazards that can arise in pressure vessel operation is produced by overfilling the vessel. A vessel must never be filled to more than three-fourths of its available free space, and in some cases, the charge must be reduced even further for safe operation. Dangerous pressures can develop suddenly when a liquid is heated in a closed vessel if the available free space cannot accommodate the expanding liquid.

This is particularly true of water and water solutions, which may increase to as much as three times their initial volume when heated from room temperature to the critical point at 374° Celsius. If the vessel's free space cannot accommodate this expansion, destructive pressures will develop suddenly and unexpectedly.

Maintenance and training

The user must realize that it is their responsibility to keep the vessel in good condition and to use it only within the prescribed temperature and pressure limits. Users must be constantly aware of the severe consequences of such things as opening the wrong valve, mixing combustible vapors with air or oxidizing gases, adding reactants too fast, or failing to observe and prevent a sudden increase in temperature or pressure. Supervisors should make frequent checks to ensure all safety rules are being followed.

For more information, refer to the Arizona Division of Occupational Safety and Health Section R20-5-404 and the Standards for Boilers, Lined Hot Water Heaters and Pressure Vessels.

Appendix J

Safe handling procedures for cryogenic materials

This appendix outlines the general precautions for using liquid nitrogen and other cryogenic materials.

Liquid nitrogen and all other cryogenic materials can cause significant burns. Hand protection and goggles—not safety glasses—must always be worn when handling liquid nitrogen. When handling large quantities, a full-length apron will minimize the chance of a spill entering your shoes, which might destroy several cubic centimeters of flesh before you can get your shoes and socks off.

Persons using a tipper to dispense liquid nitrogen and other Cryogenic Materials must wear a full-face shield over goggles, cryogenic gloves, full-length trousers or pants or a full-length apron, and footwear that covers the entire foot.

Properties

- Liquid nitrogen is a colorless, odorless liquid with a boiling point of -19˚ Celsius. At low temperatures, the gas or vapor is heavier than air.
- Nitrogen gas is invisible — the cloudy vapor that appears when liquid nitrogen is exposed to air is condensed moisture, not the gas itself.
- Small amounts of liquid vaporize rapidly to produce large volumes of gas — 1 liter of liquid nitrogen will produce 0.7m^3 of gas.

Hazards

Asphyxiation: One of the main dangers associated with liquid nitrogen is the risk of asphyxiation when used or stored in poorly ventilated areas. Liquid nitrogen evolves into nitrogen gas, which is inert and non-toxic. Still, asphyxiation is risky when high concentrations accumulate and displace air from the room. Short exposures to cold gas vapor lead to discomfort in breathing, while prolonged inhalation can cause severe effects on the lungs and could also result in death.

Cryogenic burns: Liquid nitrogen can cause cryogenic burns if the substance itself or surfaces that have been in contact with it, like metal transfer hoses, encounter the skin. Local pain may be felt as the skin cools, though intense pain can occur when cold burns thaw, and if the area affected is large enough, the person may go into shock.

Explosions-chemical: Cryogenic fluids with a boiling point below that of liquid oxygen can condense oxygen from the atmosphere. Repeated system replenishment can cause oxygen to accumulate as an unwanted contaminant. Similar oxygen enrichment may occur where condensed air accumulates on the exterior of cryogenic piping. Violent reactions, like rapid combustions or explosions, may occur if the materials that contact the oxygen are combustible.

Explosion-pressure: Heat flux into the cryogen from the environment will vaporize the liquid and potentially cause pressure buildup in cryogenic containment vessels and transfer lines. On vaporization, liquid nitrogen expands by a factor of 696; one liter of liquid nitrogen becomes 24.6 cubic feet of nitrogen gas. All system parts must provide adequate pressure relief to permit this routine out-gassing and prevent explosion.

Frostbite: Continued exposure of unprotected flesh to cold atmospheres can result in frostbite. Local pain usually provides sufficient warning when the freezing action occurs.

Hypothermia: Low air temperatures arising from the proximity of liquefied gases can cause hypothermia. Susceptibility depends upon temperature, exposure time and the individual concerned — older people are more likely to succumb.

Personal protective equipment

Always wear proper PPE when handling liquid nitrogen:

- Body: A laboratory coat or overalls should always be worn. Non-absorbent cryogenic aprons are also commercially available. Open pockets and turn-ups where liquid could be collected should be avoided.
- Face: A full face visor should protect the eyes and face where splashing or spraying may occur.
- Feet: Sturdy shoes with a reinforced toecap are recommended for handling liquid nitrogen vessels. Open-toed shoes should not be worn under any circumstances.
- Guard against pressure build-up using a pressure relief vessel or a venting lid. Remove metallic jewelry or watches on your hands and wrists.
- Hands: Non-absorbent insulated gloves must always be worn when handling recent contact with liquid nitrogen. Cryogenic gloves are designed to be used in the vapor phase only and should not be immersed in liquid nitrogen under any circumstances. They should be loosely fit to facilitate easy removal. Gauntlet-style gloves are not recommended for some liquid handling uses as the liquid can drip into them and become trapped against the skin. Sleeves should cover the ends of gloves, or a ribbed cuff style may be used.
- Trouser bottoms should overlap boots or shoes for the same reason.
- When not in use, all PPE should be stored appropriately, like visors on wall-mounted hooks, to ensure it is not damaged or contaminated.

Training

Before handling liquid nitrogen, all users must be aware of its properties and hazards and fully trained in the local departmental procedures for usage, storage and transportation.

First aid

- Where contact has occurred, the aim should be to slowly raise the temperature of the affected area back to normal. For minor injuries, clothing should be loosened, and the person made comfortable.
- Clothing should not be pulled away from burned or frozen skin. The affected area should be doused with copious quantities of tepid water at 40° Celsius for at least 15 minutes, and a sterile burn dressing should be applied to protect the injury until the person can be taken to receive hospital treatment.
- Where inhalation has occurred, the victim — who may be unconscious — should be removed to a well-ventilated area. Rescuers should not put themselves at risk. A contaminated area should not be entered unless considered safe. Breathing apparatus may be required but should only be used by trained personnel. The person should be kept warm and rested while medical attention is obtained. If breathing has stopped, a trained first aider should commence resuscitation.

Do not:

- Give analgesics like paracetamol or aspirin.
- Use a direct source of heat, such as a radiator.

For major injuries, first aid should be applied as far as practicable and arrange for the victim to receive medical attention.

Storage and use

Ventilation is a crucial issue. Large-scale vacuum-insulated tanks are usually stored outside buildings because of the quantities of stored liquid. Where smaller pressurized containers and non-pressurized dewars are stored within buildings, the following points should be considered:

- Do not leave vessels unattended when filling.
- Do not overfill vessels.
- Do not use brittle plastics that may shatter with cold liquid.
- Do not use hollow dipsticks - use solid metal or wood.
- Ensure appropriate hazard warning signs are displayed — yellow triangle with exclamation symbol and text liquid nitrogen.
- Handle in well-ventilated areas.
- Handle the liquid slowly to minimize boiling and splashing. Use tongs to withdraw objects immersed in a cryogenic liquid - Boiling and splashing always occur when charging or filling a warm container with cryogenic liquid or inserting objects into these liquids.
- Never tamper or modify safety devices such as cylinder valves or regulators of the tank.
- Only correctly specified equipment is used for storing liquid nitrogen.
- Store below 50° Celsius in a well-ventilated place.
- Use only proper transfer equipment.

General use

Do not plug the entrance of non-pressurized containers with any device that would interfere with gas venting. Use only the loose-fitting neck tube core or an approved accessory. Departments monitor all procedures to ensure that laboratory rules are followed.

When working with liquid nitrogen in cold rooms, the following points should be considered:

- Do people spend significant periods working in the cold room — on unrelated tasks?
- Is the door fitted with a viewing panel?
- Is the room fitted with an oxygen deficiency monitor or alarm?
- Is there a panic button within the room?
- Ventilation.
  - Is it adequate? Most cold rooms do not have an air supply or extract system, so there is little or no air change.
    - Can the door be left open to allow gas to dissipate when vessels are being filled?

Maintenance

Complete a written standard operating procedure. The periodic examination is usually done by trained personnel. Any apparent damage sustained by vessels — either static or transportable — must be reported immediately to the laboratory supervisor, and if necessary, the vessel should be taken out of use. Forced ventilation systems and oxygen deficiency alarms should be maintained in good working order.

Rules for decanting liquid nitrogen storage tanks

- All users must be trained and authorized to dispense liquid nitrogen from the storage vessel.
- Always wear proper PPE — gloves and eye or face protection—during the dispensing process. People filling dewars should wear full-length trousers/pants or a full-length apron, footwear covering the entire foot, goggles, face shield, hearing protection and cryo-gloves. Individuals filling must be constantly aware of the filling operation. To prevent splashing, place the filling hose

at or below the mouth of the receiving vessel.

- If it is raining, warn people of possible slippery surfaces.
- If liquid leaks from a delivery hose or joints, stop filling and report the problem. If liquid nitrogen from the pressurized storage dewar is handled outside of office hours, 8 a.m.–5 p.m., it must be carried out by two trained members of staff working together to allow for the alarm to be raised if there is an incident/accident.
- Liquid nitrogen and other cryogenic materials are to be dispensed only into smaller dewars, which either have carrying handles or are on wheels and have pressure relief valves or pressure venting lids. A wide-base Dewar, which is stable on a wheeled cart, qualifies as on wheels.
- Liquid nitrogen may only be dispensed into containers designed for liquid nitrogen use.

Transportation of vessels within the department

If vessels must be maneuvered between locations and there is a risk or possible risk of injury, then an assessment must be carried out. In the case of the larger pressurized cylinders, it should be done by two people, mainly if there is a requirement to move between differing levels using a lift.

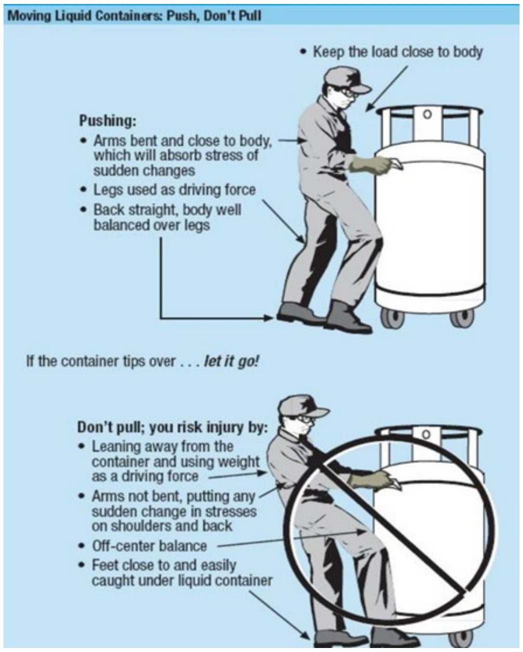
Large mobile dewars or liquid nitrogen refrigerators, or the trolleys carrying these used for transporting cryogens within or between buildings, should be equipped with a braking mechanism.

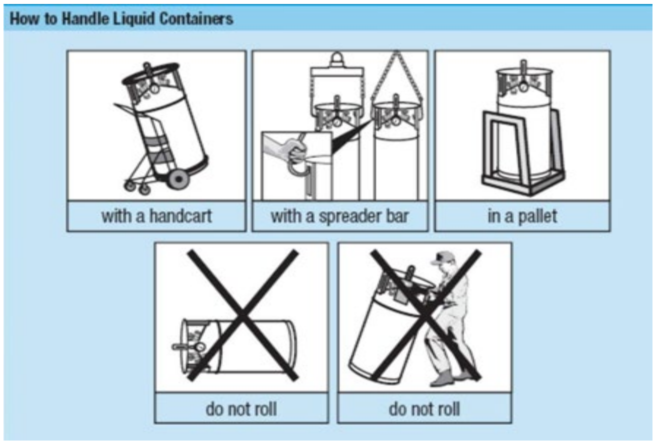
Do not use feet to brake wheels. Avoid crushing hands or fingers between the vessel and walls or doorframes. Do not transport liquid nitrogen or other cryogenic materials in open containers. Before moving transportable containers, the route should be assessed to consider:

- Curbs.
- Floor surfaces — are they sound and even?
- Lifts.
- Movement through populated work areas.
- Possible obstructions and clutter.
- Rest stops.
- Stairs — hazardous due to potential slips and trips, which could result in spillages from small hand-held dewars.
- Whether the destination for the gas is ready to accept it.

The transportation of liquid nitrogen across public roads is prohibited. Gas services arrange for pickup and delivery of LN2 dewars requiring transportation across public roads. Do not transport chemicals on golf carts across public streets unless approved in writing by ASU EHS. Small quantities of chemicals, like one box, may be transported in their original shipping container on a pushcart.

Two people should be involved when crossing public streets, one observing traffic and the other moving the cart with hazardous materials. Inside buildings, the best transport from room to room is by using a dewar equipped with carrying handles or on wheels with pressure relief valves or pressure venting lids.





Note: A wide-based dewar stable on a wheeled cart qualifies as on wheels.

For short distances in hallways, it is acceptable to hand-carry a quart or smaller Dewar of liquid nitrogen or other cryogenic materials that have no handles, as long as:

- The dewar is your only load — no books, coffee or other items.
- The vessel has a venting lid — a cork or loose stopper is fine.
- The vessel is carried with both hands and as far away from your face as comfortably as possible.
- You are carefully watching for people who will run into you.
- You are wearing appropriate PPE.

Transport of nitrogen and other cryogenic materials on an elevator

When transporting pressurized liquid cryogenic material containers on an elevator, care must be exercised. Due to the elevator's confined nature, a nitrogen gas or other cryogenic material leak from a pressurized container could quickly produce an oxygen-deficient atmosphere through oxygen displacement.

- All elevator doors should be observed to prevent entry or signage placed on the dewar to deter riders from entering the elevator.
- Do not transport a pressurized container of liquid nitrogen or cryogenic material in an elevator with any other person(s) in the elevator car.
- If the elevator cannot be operated to prevent unauthorized entry, a sign must be posted on the dewar itself to warn anyone observing it in the elevator not to enter.
- The sender should remain outside the elevator and activate it to the desired floor. Another person should be available on the receiving floor to take the liquid container off the elevator at its destination.
- When a pressurized container has been placed on an elevator, the elevator must travel between floors unoccupied.

Emergency procedures

In the event of a large spillage or accidental release, follow these procedures:

1. Call 911.
2. Do not re-enter the area unless it is proven safe by EHS or an oxygen-deficiency monitor. If present, oxygen deficiency monitors will indicate the oxygen levels nearby.
3. Evacuate the area. Alert the others in the area but do not attempt any rescue. Deploy warning signs as necessary.
4. Prevent liquid nitrogen from entering drains, basements, pits or any confined space where accumulation may be dangerous.
5. If possible and only when it's safe, try to stop the release, such as turning off valves. Always wear protective clothing.
6. Ventilate the area. Open doors and windows or activate forced ventilation, allowing spilled liquid to evaporate and the resultant gas to disperse.
7. Notify EHS of any spills or accidental releases and complete the incident reporting process.

Appendix K

Nanoparticles and nanomaterials

Nanoparticles and nanomaterials have different reactivates and interactions with biological systems than bulk materials and understanding and exploiting these differences is an active area of research. However, these differences also mean the risks and hazards associated with exposure to engineered nanomaterials are unknown. Because this is an area of ongoing research, consult trusted sources for the most up-to-date information available.

Note that the higher reactivity of many nanoscale materials suggests that they should be treated as potential ignition, accelerants and fuel sources that could result in fire or explosion. Easily dispersed dry nanomaterials may pose the most significant health hazard because of the risk of inhalation.

Operations involving these nanomaterials deserve more attention and more stringent controls than those where the nanomaterials are embedded in solid or suspended in liquid matrixes.

All possible routes of exposure to nanomaterials should be considered, such as inhalation, ingestion, injection and dermal contact, including eye and mucous membranes. Avoid handling nanomaterials in the open air in a free-particle state. Whenever possible, handle and store dispersible nanomaterials in closed, tightly sealed containers, whether suspended in liquids or a dry particle form. Unless cutting or grinding occurs, nanomaterials not in a free form — encapsulated in a solid or a nanocomposite — typically will not require engineering controls. If a synthesis is being performed to create nanomaterials, it is not enough to consider only the final material in the risk assessment but the hazardous properties of the precursor materials as well.

To minimize laboratory personnel exposure, conduct any work that could generate engineered nanoparticles in an enclosure that operates at a negative pressure differential compared to the laboratory’s breathing zone. Limited data exist regarding the efficacy of PPE and ventilation systems against nanoparticle exposure. However, until further information is available, it is prudent to follow standard chemical hygiene practices.

Conduct a hazard evaluation to determine PPE appropriate for the hazard level according to the requirements outlined in OSHA's Personal Protective Equipment Standard.

Appendix L

Glove box safety tips

A glove box is a sealed container that manipulates materials where a separate atmosphere is desired. They are commonly used to protect workers from hazardous materials or chemicals and materials that may be sensitive to air or water vapor. Glove boxes may be used under either positive or negative pressure. Glove boxes operated under positive pressure usually contain materials sensitive to outside contaminates such as air or water vapor.

Exposure to outside contaminates can lead to degradation or a violent reaction with these compounds. Negative-pressure glove boxes protect workers and are used for hazardous materials such as toxic gases or pathogens.

Daily inspections

When using glove boxes, perform daily inspections before use. As part of your daily checklist, perform the following:

- Ensure all pressure gauges and indicators are within acceptable ranges.
- Check the condition of the gloves. Look for holes, areas of discoloration representing compromised integrity, and the connection to the exterior.
- If your box has a solvent scrubber and solvent delivery system, ensure the scrubber cartridges are within operating parameters.
- Inspect the condition of the window, paying particular attention to the area where the window is connected to the rest of the box.
- Inspect the vacuum pump exhaust oil-mist filter and ensure it is still within operating parameters.
- Perform a vacuum pump inspection and ensure that all lines are in good condition and that the oil — if applicable — has been changed recently.

Other considerations

- Avoid abruptly extending gloves into the box; this can severely stress the system and cause over-pressurization.
- Contact EHS before using flammable gases in a glove box.
- Ensure proper backup measures are in place for a loss of power or the loss of the source of the inert atmosphere.
- If it is a shared glove box, assign one or two senior people in the laboratory to ensure all maintenance on the box and components are updated.
- Maintain a log of the users and require each user to record the date and time of use and any pertinent parameters that ensure proper glove box operation.
- Maintain service contracts with the manufacturer and have them perform routine maintenance on the system.
- Train all individuals working in the glove box. Document this training in a laboratory-specific training file.
- Use nitrile gloves on the glove box gloves. This extends the life of the glove box gloves, helps avoid cross-contamination and makes cleanup easier.

Appendix M

Guidelines for Bunsen burner safety

Bunsen burners may be used in laboratories to heat samples or to boil water rapidly. A well-adjusted flame will have two distinct cones: An outer aqua cone and an inner blue cone. The temperature of the hottest part of the flame — the tip of the inner blue cone — is about 1200° Celsius. Take a moment to look at the burner. You will see a barrel with a removable tip at one end and a band of holes at the other. These holes adjust the amount of air entering the barrel and serve as a mixing chamber for fuel and air. On the bottom is a needle valve, which, when turned tight into the barrel, blocks all gas from entering the barrel.

Before using a Bunsen burner, check the hose for cracks and ask your instructor to replace a faulty hose. Use only hoses approved for Bunsen burners and strikers explicitly designed for lighting them. Use a Bunsen burner when there’s at least 12 inches of overhead clearance. In other words, please don't use it under a shelf, light fixture or other equipment unless there are at least 12 inches of space. The heat from the flame could ignite nearby objects, especially if those objects are within 12 inches of the Bunsen burner. Before using a flame, tie back loose hair and remove or confine scarves.

Ask your supervisor for instructions on how to adjust the burner. Refer to the Guide for Bunsen Burner Use for more information on potential hazards, required PPE and safe operating procedures.

Note: Heat sources such as Bunsen burners are strictly prohibited inside the BSCs as they significantly disrupt the laminar flow of air. The flame and heat can also damage the HEPA filter inside the cabinet.

Appendix N

Guidelines for mineral oil baths

Take the following precautions when using an oil bath:

- Always ensure you know the location and usage of the nearest safety shower and eyewash in case you need it. Ensure that they have been tested annually.
- Always make sure the bath is on a flat and stable surface.
- Always wear proper personal protective equipment or PPE, including a fireproof laboratory coat, gloves, safety glasses, long pants, and closed-toe shoes.
- Always work inside a properly operating fume hood with the hood sash as low as possible. The fume hood must be clean and uncluttered. Chemical fume hoods are not intended for storage. Remove chemical containers that are not used and return them to their proper storage locations.
- Avoid leaving the bath unattended whenever possible. Set the temperature below the oil's flash point if you must leave the bath unattended.
- Before the first use of the oil bath, a dry run or test experiment must be conducted with your principal investigator or supervisor.
- Before using an oil bath, ensure an appropriate spill kit is readily accessible to contain spills safely. In the event of a spill, allow the oil to cool before cleaning.
- Change the oil if it becomes contaminated or shows signs of discoloration or turbidity.
- Clamp the reaction flask with an adjustable clamp. Avoid using small open reaction vessels to avoid spilling and contaminating the bath.
- Dispose of used oil as hazardous waste. Do not dispose of down the drains. Do not overfill the bath.
- Follow your laboratory-specific training and any standard operating procedures for working with oil baths.
- Have the safety data sheet for the oil in the laboratory and ensure you know the contents.
- Hot oil can cause severe burns. Allow the oil to cool to near room temperature before handling or disassembling the apparatus.
- Inspect the water-cooling apparatus to ensure water will not lead into the hot oil baths. Water can cause hazardous popping and splattering.
- Never overheat oil. Always know the safe working temperature of the oil you will use and set the bath temperature below the oil's flash point. A thermometer or thermistor is used to monitor the oil temperature.
- Observe for signs of smoke. Smoke indicates that the oil has been heated beyond its safe temperature range and can easily ignite.
- Store the oil away from all heat sources. Label your oil container with the safe working temperature range as soon as you get the oil in the laboratory.

Appendix O

Hydrogen gas safety guidelines

Hydrogen is a colorless, odorless, tasteless, non-toxic gas flammable over various concentrations. Some of the unique hydrogen properties that contribute to the potential hazards — flammability and explosivity — are:

- Due to its small molecular size, hydrogen can easily pass through porous materials and be absorbed by some containment materials. This can eventually result in loss of ductility or embrittlement and reduce the performance of some containment and piping materials, such as carbon steel. Loss of ductility or embrittlement is accelerated at elevated temperatures.
- Hydrogen burns with a nonluminous, invisible flame under bright light.
- Hydrogen has deficient ignition energy.
- Hydrogen is highly flammable over a wide range of concentrations. Depending on the mixture, it is flammable by volume at atmospheric pressure of 3% to 100%.

General precautions when handling hydrogen gas:

- A standard operating procedure should be developed if you use hydrogen in a research laboratory.
- All electrical connections should be outside chemical fume hoods or gas cabinets.
- All electronic equipment used near hydrogen gas must be grounded.
- Always use regulators that have been designed to be used with hydrogen. Never attempt to repair a regulator or force connections that do not readily fit together. Avoid cracking hydrogen cylinder valves to remove dust or dirt from fittings, as this practice could result in self-ignition.
- Be aware of leaks. Hydrogen has a low viscosity, which results in a high leakage rate. Check that the pressurized system does not leak hydrogen with a leak detection solution or pressure sensing.
- Clean up any spills near hydrogen gas generation, use or storage to reduce impact in case of fire. Clean-up must be done when spills happen. This is especially important with catalyst reactors.
- Close the cylinder valve when not in use. Do not leave the piping pressurized if not in use.
- Due to hydrogen's low molecular weight, this gas will diffuse rapidly in a room and collect near the ceiling. It is essential only to use hydrogen in well-ventilated locations. Hoods must have unrestricted airflow and cannot be overly crowded with reactors or equipment.
- Ground all equipment and piping used with hydrogen, and ensure you are properly grounded before working with hydrogen. Rubber-soled shoes prevent you from being grounded, so you should touch a grounded object to discharge built-up static electricity before beginning work.
- Hydrogen cylinders must be stored in a flammable gas cabinet with appropriate gas monitoring systems. Shut-off systems with pneumatic valves should be considered to avoid using electricity inside the gas cabinet.
- Hydrogen cylinders must be stored more than 20 feet away from cylinders of oxygen or other PPE, including a fireproof laboratory coat, gloves, safety glasses, long pants, and closed-toe ending not less than 18 inches above and to the sides of the stored material.
- Hydrogen cylinders must be stored with the valve's protective cap. If the cap has been removed, the cylinder must be stored upright and secured with noncombustible straps or chains.
- Hydrogen gas cylinders must be secured in an upright position to avoid being knocked over
- Never open the cylinder valve before ensuring all your connections are secure, as the static discharge from flowing gas may cause hydrogen to be ignited.
- Never use adapters.
- Open flames and smoking are prohibited in areas where hydrogen is used or stored. All combustible material shall be removed from the area.

- Remove electrical equipment or electronic devices from the vicinity of hydrogen gas unless the device is certified intrinsically safe. Even invisible tiny sparks from electronic devices could ignite hydrogen.
- Use metal piping with hydrogen. Do not use non-conductive or plastic tubing. Be sure to dissipate static charge when flowing hydrogen gas by electrical bonding and grounding the cylinder, metal piping and apparatus used.
- Wear appropriate laboratory safety gear, such as safety glasses and goggles, laboratory coat, gloves and preferably a face shield.
- Where feasible, discontinue using hydrogen tanks and switch to hydrogen generators with automatic shut-off when a leak is detected.
- Work in an area with plenty of ventilation. Work in a fume hood or use a canopy hood as fugitive vapors; if not captured, they may collect near the ceiling.

Hydrogen is incompatible with many materials and situations. Check the SDS for a complete list of incompatibles:

- It forms hydrides when heated with alkalis, alkaline earth and other elements.
- It ignites easily with oxygen and could explode when heated.
- It is incompatible with copper (II) oxide, difluorodiazene, iodine heptafluoride, lead trifluoride, liquid nitrogen, lithium perchlorate trihydrate, metals, nitrogen trifluoride, nitryl fluoride, palladium (II) oxide, palladium trifluoride, polycarbon monofluoride, potassium tetrafluoro hydrazine, xenon hexafluoride.
- It reacts violently or explosively or forms heat-sensitive explosive mixtures with oxidizers, halogens, halogen compounds, acetylene, bromine pentafluoride, chlorine oxides, fluorine perchloride and nitrogen oxides. Check the SDS for a list of incompatibles.
- Mixtures with chlorine may explode on exposure to light.
- Mixtures with oxygen may explode in the presence of a platinum catalyst.

Appendix P

Guidelines for handling dry ice

Dry ice: Handling, storage and transportation

Dry ice is the solid form of carbon dioxide, with a temperature of -78.5° Celsius or -109.3° Fahrenheit. It undergoes sublimation, changing directly from a solid to a gas, releasing carbon dioxide. The rapid gas release can cause hazardous conditions, making proper handling crucial. Dry ice, solid carbon dioxide, is widely used for various purposes, but special precautions are required to ensure safety.

Potential hazards

- Asphyxiation: Carbon dioxide gas can displace oxygen in enclosed spaces, leading to suffocation.
- Frostbite: Direct contact with dry ice can cause severe frostbite or cold burns to the skin.
- Pressure buildup: Inadequate ventilation may cause pressure to build up in sealed containers.

Personal protective equipment

- Always wear insulated gloves when handling dry ice to protect against frostbite.
- Safety goggles or a face shield should be used to shield your eyes from potential splashes or contact with dry ice.
- Wear long pants and closed-toe shoes when handling dry ice.

Handling precautions

- Avoid inhaling carbon dioxide gas; work in well-ventilated areas.
- Never put dry ice in your mouth or swallow it, as it can cause severe injury.
- Never touch dry ice with bare hands; use insulated gloves or tongs.

Storage recommendations

- Avoid airtight containers to prevent pressure buildup.
- Ensure proper ventilation to allow carbon dioxide gas to escape.
- Store dry ice in insulated containers, such as coolers or chests.

Transporting dry ice

- Do not store dry ice in the passenger compartment of vehicles.
- Keep car windows partially open during transport to maintain ventilation.
- Use well-ventilated containers when transporting dry ice.

Packaging guidelines

- Insulate dry ice with materials like newspapers, but avoid airtight packing.
- Use sturdy containers designed for low temperatures and pressure changes.

Disposal instructions

- Allow dry ice to sublimate in a well-ventilated area to avoid a harmful buildup of CO_2 or return it to the supplier.
- Avoid putting dry ice directly on tile or laminated countertops. The cold can weaken adhesives and cause cracking.
- Do not leave dry ice unattended in public places.

- Never dispose of dry ice in a trash can.
- Never dispose of dry ice in sinks, toilets or confined spaces.

Emergency preparedness

1. In case of skin contact, remove contaminated clothing and rinse with lukewarm water.
2. Seek medical attention immediately if frostbite occurs.
3. If exposed to high levels of carbon dioxide gas, move to fresh air and seek medical help.

Appendix Q

Peroxide-forming chemicals

A peroxide is a chemical containing an oxygen-oxygen single bond — R-O-O-R. The two most serious hazards associated with peroxides are fires and explosions when exposed to heat, shock, or friction. Peroxide decomposition can initiate explosive polymerization reactions. Peroxides can also oxidize human tissue, cotton, and other materials.

Peroxide use and storage shall follow the approved Maximum Allowable Quantities per Control Area following the International Fire Code 2018 edition, chapter 50 Hazardous Materials — general provisions, table 5003.1.1(2).

Many solvents and chemicals can form peroxides over time due to oxidation upon exposure to air, resulting in unexpected fires and explosions. These peroxide-forming chemicals can pose a significant hazard, as the concentration of peroxides increases upon prolonged exposure to air. Due to their reactivity, even small amounts can interfere with experiments by oxidizing reagents or damaging biological material.

The oxidation mechanism involving oxygen and peroxide-forming compounds is a radical process where a hydrogen atom is first abstracted. A good indication of a chemical being a peroxide former is if it has hydrogen atoms that create stabilized radicals once removed. Light can initiate radical processes, so these chemicals should be stored away from light sources. Some of the common oxidizable functional groups include:

- Aldehydes, including acetaldehyde and benzaldehyde; and
- Compounds containing hydrogen atoms that can be heterolytically cleaved to form stable radicals, including hydrogen atoms bound to benzylic, allylic and tertiary carbon atoms.
- Ethers, acetals, and ketals, especially cyclic ethers or ethers where the oxygen atom of the ether functional group is bound to a primary or secondary alkyl group(s).
- Hydrocarbons with benzylic, allylic or propargylic hydrogens.
- Hydrocarbons with exposed tertiary hydrogens.

Many known peroxide formers contain low concentrations of additives such as butylated hydroxytoluene as autoxidation inhibitors to prevent the oxidation of the chemical. If the inhibitor does not interfere with the use of the chemical, it is suggested that peroxide formers be purchased with the inhibitor present. However, peroxides will form as the inhibitor depletes over time. **Note**: Distilling the chemical will remove the inhibitor.

Peroxide-forming chemicals are grouped into three categories depending on the tendency to form peroxides and the associated hazards: Class A, B and C.

Class A: Severe peroxide hazard after prolonged storage, especially after exposure to air. Chemicals in this group can form amounts of peroxides that can cause an explosion without concentration. All listed chemicals have been responsible for fatalities. EHS provides additional information on Class A peroxide-forming chemicals.

Class A chemicals	
Butadiene *	Potassium metal
Chlorobutadiene — chloroprene *	Sodium amide
Divinyl acetylene	Tetrafluoroethylene *
Isopropyl ether	Vinylidene chloride
Potassium amide	

*When stored as a liquid monomer.
**When stored as a gas.

Note: Potassium metal turns yellow when peroxides are present and should be discarded.

Test liquids for peroxide formation before using, and discard when peroxides are present. Discard three months after opening. Discard unopened chemicals after storing for 12 months or the expiration date, whichever comes first.

Class B: Chemicals in this group form amounts of peroxides that generally do not cause an explosion but can pose an explosion hazard when concentrated by evaporation or distillation. Most of these solvents are sufficiently volatile that multiple openings of a single container can result in a significant and dangerous peroxide concentration. Store in a dark location. Test for peroxide formation before using. If peroxides are detected, discard the chemical.

Class B chemicals	
1-Phenylethanol	Cyclopentene
2-Butanol	Decahydronaphthalene
2-Cyclohexene-1-ol	Diacetylene — butadiene
2-Hexanol	Dicyclopentadiene
2-Pentanol	Diethyl ether
2-Phenylethanol	Diethylene glycol dimethyl ether
3-Methyl-1-Butanol	Dioxane
4-Heptanol	Ethylene glycol ether acetates
4-Methyl-2-Pentanol	Furan
4-Penten-1-ol	Isopropanol
Acetal	Methyl acetylene
Acetaldehyde	Methyl cyclopentane
Benzyl alcohol	Methyl-isobutyl ketone
Chlorofluorothylene	Other secondary alcohols
Cumene — isopropyl benzene	Tetrahydrofuran
Cyclohexene	Tetrahydronaphthalene
Cyclooctene	Vinyl ethers

Class C: Peroxide formation can initiate explosive auto-polymerization. The peroxide-forming potential is higher for liquids than for gases in this group. Store in a dark location and test for peroxide formation before use. If peroxides are detected, discard the chemical as hazardous waste.

Class C chemicals	
Acrylic acid	Tetrafluoroethylene **
Butadiene **	Vinyl acetate
Chloroprene **	Vinyl acetylene
Chlorotrifluoroethylene	Vinyl chloride
Ethyl acrylate	Vinyl pyridine
Methyl methacrylate	Vinylidene chloride
Styrene	

*When stored as a liquid monomer.
**When stored as a gas.

Purchasing of peroxides

Prior approval from EHS is required before ordering peroxides. Log in to the ASU CEMS portal to access the chemical approval form.

Proper storage of peroxides

If you are still evaluating, consider any container as open. EHS requires prompt disposal of peroxide-forming chemicals past the manufacturer's expiration date.

Class A

- **Opened container**: Three months, or up to the manufacturer's expiration date, if tested every three months and is peroxide-free.
- **Solid chemical**: Manufacturer's expiration date, if the chemical is stored appropriately and frequently visually inspected for peroxide formation.
- **Unopened container:** Manufacturer's expiration date if the chemical is stored appropriately, unused, and frequently visually inspected for peroxide formation. Refer to the visual signs of peroxide formation section below for more information.

Class B and C

- **Opened container**: Six months or up to the manufacturer's expiration date, whichever comes first.
- **Unopened container**: Manufacturer's expiration date if the chemical is stored appropriately, unused, and frequently visually inspected for peroxide formation. Refer to the visual signs of peroxide formation section below for more information.

Other storage requirements

- Because distillation of a stabilized solvent will remove the stabilizer, the distillate must be stored carefully and closely monitored for peroxide formation.
- Do not allow open flames, other heat sources or sparks, friction, grinding or impact near peroxides.
- Do not store large quantities.
- Do not store peroxidizable chemicals in open, partially empty or transparent containers.
- Do not use secondary glass containers with screw-cap lids or glass stoppers for extended storage. Use polyethylene containers with screw caps or stoppers.
- It is also good practice for researchers to store these chemicals under inert gas and, if possible, flow some inert gas into the container head space before putting it away.
- Label potential peroxide formers, including the date received and opened.
- Protect from heat and light. Store peroxide formers in airtight containers — preferably the container furnished by the supplier — in cool, dry, dark locations, preferably in dark amber glass with a tight-fitting cap.
- Purchase peroxide-forming chemicals with an added inhibitor or stabilizer and store them under an inert gas.

Safe handling

- Chemicals that can form peroxides must be dated upon receipt from the manufacturer and upon opening.
- If containers of unknown age are found, it is recommended that they be disposed of by contacting EHS.
- Never attempt to twist caps, move, or open bottles of liquid ethers containing crystallized materials. If crystals are observed, contact EHS immediately for pick up and leave the container untouched.
- Periodically test peroxide-forming chemicals for the presence of peroxides according to the tables above. Inspect the chemical and container's physical state to ensure no crystals have formed.
- Store the peroxide formers in a dark place and purge the headspace with an inert gas to prolong the chemical's shelf life.
- To avoid prolonged storage of peroxide-forming chemicals, they should be purchased in small quantities.

Visual signs of peroxide formation

Visual inspection can help determine if your compound has begun forming peroxides. A non-hazardous light source, like a flashlight, can provide a backlight or side light to the bottle to make indicators visible.

- Appearance of cloudiness.
- Clear liquid containing suspended wisp-like structures.
- Discoloration or formation of a surface crust — for example, potassium metal forms yellow or orange superoxide at the surface.
- Gross contamination.
- Precipitated crystal formation appearing as chips, ice-like structures and solid mass.
- Solid chemicals — potassium metal, potassium and sodium amide.
- Visible discoloration.
- White crystal under the rim of the cap.

Additional notes

- Do not move or disturb any container if there is any question about the presence of peroxides.
- Evaluation of alkali metals and their amides is based only on visual criteria. These substances react violently with water and oxygen, so standard peroxide tests should not be used.
- If these indicators are observed, avoid additional testing or handling and call EHS immediately.

Precautions

Before starting work, complete the following steps:

- Always read the SDS for the specific chemical.
- Ensure that a written SOP is readily available in the laboratory.
- Identify the location of the Emergency Response Guide in the laboratory. Ensure you are familiar with general university emergency procedures.
- Identify the location of the nearest eyewash and shower and verify that they are accessible. The laboratory personnel must know how to use the safety shower and eyewash.
- Test for peroxides before experiments if performing a distillation or evaporation. Never distill to dryness.
- Verify that the product you are ordering includes safety precautions unless the stock chemical cannot contain an inhibitor. Most commonly sold peroxide formers contain inhibiting chemicals and are shipped under nitrogen or another inert gas within their supplied containers.
- Visually inspect containers for crystallization before opening or handling them.

During work:

- Conduct all procedures inside a fume hood or behind a protective shield.
- Do not return unused peroxide-forming chemicals to the stock container.
- Do not use metal-containing utensils for weighing or working with peroxide formers.
- Do not use volatile solvents that contain peroxides.
- Ensure the syringe is entirely depressed to prevent air from entering the bottle when removing the peroxide former from the septum cap. This could promote peroxide formation.
- Use only the minimum quantity required.

Disposal

Dispose of all used or unwanted chemicals as hazardous waste. If a liquid peroxide former looks cloudy, shows crystals, or a solid mass, immediately call EHS. The hazardous waste pickup can be requested by logging in to the ASU CEMS portal with your ASU credentials.

Appendix R

Guidelines for pyrophoric materials

The International Fire Code 2018 Edition definition of pyrophoric is a chemical with an autoignition temperature in air, at or below a temperature of 130° Fahrenheit — 54° Celsius. Pyrophoric materials use and storage shall follow the approved Maximum Allowable Quantities per Control Area per the International Fire Code 2018 Edition and Chapter 50 Hazardous Materials — General Provisions. Table 5003.1.1(2).

Pyrophoric materials react with air or moisture in the air. Typical reactions are oxidation and hydrolysis, and the heat generated by the reactions may ignite the chemical. In some cases, these reactions liberate flammable gases, which makes ignition a certainty and an explosion a real possibility.

Other common hazards include corrosivity, teratogenicity, organic peroxide formation, and liver, kidney, and central nervous system damage. Examples include metal hydrides, finely divided metal powders, nonmetal hydrides and alkyl compounds, white phosphorus, alloys of reactive materials, and organometallic compounds, including alkylithiums.

The floors of storage areas containing pyrophoric liquids shall be liquid-tight. Silane gas and gas mixtures with a silane concentration of 1.37% or more by volume shall be used following CGA G-13.

References

- IFC chapter 64, Pyrophoric Materials.
- IFC section 6404, Storage.
- IFC section 6405, Use.
- International Fire Code 2018 Edition.

Failure to follow proper handling techniques could result in severe injury or death.

Controlling the hazards

- A dry run of the experiment should be performed using low-hazard materials, such as water or solvent.
- A PI must authorize the personnel and the procedure when using pyrophoric chemicals.
- All glassware used for pyrophorics should be oven-dried and free of moisture.
- An SOP should be prepared and reviewed for each pyrophoric material process. A copy of the SOP must be present in the laboratory.
- Before working with pyrophoric materials, read the SDS. The SDS must be reviewed before using an unfamiliar chemical and periodically as a reminder.
- If possible, use safer chemical alternatives.
- In-laboratory training should be completed before working with pyrophorics.
- Keep an appropriate fire extinguisher or extinguishing material close at hand.
- Limit the amount purchased and the amount stored. Do not accumulate unneeded pyrophoric materials.
- Review the location of the safety shower, eyewash, telephone, and fire extinguisher.
- Use the buddy system. Working alone with pyrophorics is strongly discouraged.

Additional controls when handling liquid pyrophoric materials

- Avoid transfer of large volumes — >20 mL — using a syringe.
- Secure the pyrophoric reagent bottle to stand.
- Secure the syringe so the contents will not splash anyone if the plunger blows out of the syringe's body. To prevent blowouts of the plunger, syringes should be twice the volume of liquid to be transferred.

Personal protective equipment

Always wear the proper PPE when handling pyrophoric materials.

Eye protection

- A face shield is required whenever there is a risk of explosion, significant splash hazard or a highly exothermic reaction. Portable shields are also acceptable. A face shield is recommended when handling larger quantities of pyrophorics.
- Chemical splash goggles or safety glasses must be worn whenever handling pyrophoric chemicals. Ordinary prescription glasses will not provide adequate protection.

Skin protection

- Avoid wearing synthetic clothing, such as nylon or polyester, while working with pyrophorics. A laboratory coat, apron made from Nomex, or other unique fire-resistant material must be worn.
- Gloves must be worn when handling pyrophoric chemicals. Nitrile gloves should be adequate for handling most of these in general laboratory settings, but they are combustible. Be sure to use adequate protection to prevent skin exposure. Sigma-Aldrich recommends the use of nitrile gloves underneath neoprene gloves.
- Long pants and closed-toe shoes must always be worn in the laboratory.

Designated areas

Fume hood

Many pyrophoric chemicals release toxic or flammable gases and should be handled in a laboratory hood with the sash down at the lowest feasible working position. Before handling pyrophoric materials, all other flammable materials and clutter should be removed from the hood. In addition, some pyrophoric materials are stored under kerosene or other flammable solvents; therefore, a fume hood or glove box is required to prevent the release of flammable vapors into the laboratory.

Glove box

Glove boxes or dry boxes are excellent devices to control pyrophoric chemicals when inert or dry atmospheres are required. When using a disposable plastic syringe, glove boxes are also recommended. Personnel must be trained, and SOPs must be reviewed for the box before beginning work.

Storage

- Avoid areas with heat or flames, oxidizers and water sources.
- Ensure that sufficient protective solvent remains in the container while in storage.
- Never return excess chemicals to the original container. Small amounts of impurities introduced into the container may cause a fire or explosion.
- Pyrophoric chemicals should be stored under an inert gas atmosphere or kerosene, as the SDS recommends.
- Store reactive materials as recommended in the SDS. An inert gas-filled desiccator or glove box may be a suitable storage location for most materials.

- Use and store minimal amounts of pyrophoric chemicals. Do not store pyrophoric chemicals with flammable materials or in a flammable cabinet.

Disposal

- A container with residual pyrophoric material must never be opened to the atmosphere.
- All materials containing or contaminated with pyrophoric chemicals must be disposed of as hazardous waste.
- Submit a hazardous waste pick-up request or call EHS.

Emergency procedures

Do not use water on any pyrophoric materials.

- Call 911 for emergency assistance and notify EHS.
- Do not use combustible materials like paper towels to clean up a spill, which may increase the risk of igniting the reactive compound.
- Keep spill material within arm's length to absorb spills. Powdered lime, dry sand, celite or clay-based kitty litter should be used to smother and cover any spill that occurs entirely.
- The recommended fire extinguisher is a standard dry powder — ABC — type. Class D extinguishers are recommended for combustible solid metal fires, such as sodium, but not for organolithium reagents.

Small spills

Exert extreme caution due to potential spontaneous combustion and potential ignition of flammable solvents or other materials in the area. Clean up the spill only if it is safe to do so, you are comfortable with it, and you understand the hazards of the chemical. If not, then call EHS for spill clean-up.

1. Call 911 for emergency assistance, if necessary.
2. Call EHS.
3. Activate the buddy system.
4. Carefully remove nearby flammable materials.
5. Carefully drench by slowly adding isopropanol.
6. After slowly adding isopropanol, double bag spill residues for hazardous waste pickup.

Large spills

Exert extreme caution due to potential spontaneous combustion and potential ignition of flammable solvents or other materials in the area. Clean up the spill only if it is safe to do so, you are comfortable with it, and you understand the hazards of the chemical. If not, then call EHS for spill clean-up.

If anyone is contaminated, wash with copious water at the nearest emergency shower. If clothing ignites, stop, drop, and roll, call for help, smother the flames and then decontaminate with copious amounts of water under an emergency shower.

1. Evacuate the spill area.
2. Call 911 for emergency assistance.
3. Call EHS.
4. Post someone or mark off the hazardous area with tape and warning signs to keep people from entering.
5. Provide emergency personnel with technical advice on the chemicals involved.

Pyrophoric material examples		
Pyrophoric alkyl metals and derivatives (a)	**Pyrophoric carbonyl metals (b)**	**Pyrophoric alkyl non-metals (c)**
Groups		
Dialkytzincs	Carbonyllithium	Bis-(dibutylborino) acetylene
Diplumbanes	Carbonylpotassium	Bis-dimethylsilyl oxide
Trialkylaluminiums	Carboylsodium	Bis-dimethylsilyl sulfide
Trialkylbismuths	Dodecacarbonyldivanadium	Bis-trimethylsilyl oxide
	Dodecacarbonyltetracobalt	Dibutyl-3-methyl-3-buten-1-Yniborane
	Dodecacarbonyltriiron	Diethoxydimethylsilane
	Hexacarbonylchromium	Diethylmethylphosphine
Compounds		
Bis-dimethylstibinyl oxide	Hexacarbonylmolybdenum	Ethyldimthylphosphine
Bis(dimethyl thallium) acetylide	Hexacarbonyltungsten	Tetraethyldiarsine
Butyllithium	Nonacarbonyldiiron	Tetramethylsilane
Diethylberyllium	Diethylcadmium	Tribenzylarsine
Diethylcadmium	Diethylmagnesium	Tribenzylarsine
Diethylmagnesium	Pentacarbonyliron	mixo-Tributylborane
Diethylzinc	Tetracarbonylnickel	Tributylphosphine
Diisopropylberyllium	**Pyrophoric metals (finely divided state) (d)**	Triethylarsine
Dimethylberyllium	Caesium Rubidium	Triethylborane
Dimethylbismuth chloride	Calcium Sodium	Triethylphosphine
Dimethyl cadmium	Cerium Tantalum	Triisopropylphosphine
Dimethylmagnesium	Chromium Thorium	Trimethylarsine
Dimethylmercury	Cobalt Titanium	Trimethylborane
Dimethyl-phenyl ethynyl thallium	Hafnium Uranium	Trimethylphosphine
Dimethyl-1-propynylthallium	Iridium Zirconium	**Pyrophoric alkyl non-metal halides (e)**
Dimethylzinc	Iron	Butyldichloroborane
Ethoxydiethylaluminium	Lead Alloys	Dichlorodiethylsilane
Methylbismuth oxide	Lithium Aluminium-Mercury	Dichlorodimethylsilane
Methylcopper	Manganese Bismuth-Plutonium	Dichloro(ethyl)silane
Methyllithium	Nickel Copper-Zirconium	Dichloro(methyl)silane
Methylpotassium	Palladium Nickel-Titanium	Iododimethylarsine
Methylsilver	Platinum	Trichloro(ethyl)silane
Methylsodium	Plutonium	Trichloro(methyl)silane
Poly (methylenemagnesium)	Potassium	Trichloro(vinyl)silane
Propylcopper	**Pyrophoric metal sulfides (f)**	**Pyrophoric alkyl non-metal hydrides (g)**
Tetramethyldistibine	(Ammonium sulfide)	Diethyl-arsine
Tetramethyl lead	Barium sulfide	Diethylphosphine
Triethyl antimony	Calcium sulfide	Dimethyl-arsine
Triethyl bismuth	Chromium (II) sulfide	1,1-Dimethyldiborane
Triethylgallium	Copper (II) sulfide	1,2-Dimethyldiborane
Trimethylation	Diantimony trisulfide	Dimethylphosphine
Trimethylgallium	Dibismuth trisulfide	Ethylphosphine
Trimethylthallium	Dicaesium selenide	Methylphosphine
Trivinylbismuth	Dicerium trisulfide	Methylsilane
Triethylgallium	Digold trisulfide	
trimethylation	Europium (II) sulfide	

Trimethylgallium	Germanium (II) sulfide	
Trimethylthallium	Iron disulfide	
Trivinylbismuth	Iron (II) sulfide	
Vinyllithium	Manganese (II) sulfide	
	Mercury (II) sulfide	
	Molybdenum (IV) sulfide	
	Potassium sulfide	
	Rhenium (VII) sulfide	
	Silver sulfide	
	Sodium disulfide	
	Sodium polysulfide	
	Sodium sulfide	
	Tin (II) sulfide	
	Tin (IV) sulfide	
	Titanium (IV) sulfide	
	Uranium (IV) sulfide	
	Germanium (II) sulfide	
	Iron disulfide	
	Iron (II) sulfide	
	Manganese (II) sulfide	
	Mercury (II) sulfide	
	Molybdenum (IV) sulfide	
	Potassium sulfide	
	Rhenium (VII) sulfide	
	Silver sulfide	
	Sodium disulfide	
	Sodium polysulfide	
	Sodium sulfide	
	Tin (II) sulfide	
	Tin (IV) sulfide	
	Titanium (IV) sulfide	
	Uranium (IV) sulfide	

Appendix S

Guidelines for grounding and bonding flammable liquids

Static hazards associated with flammable liquid dispensing

Static electricity can be generated when dispensing flammable liquids with a flash point <100° Fahrenheit or ignitable liquids >100° Fahrenheit when heated above their flashpoint from one container to another. An accumulation of static electricity can discharge enough energy to lead to a spark, igniting the flammable vapors likely to be present during dispensing operations.

To prevent sparking when dispensing flammable liquids, all dispensing components, such as containers, piping, funnels and pumps, must be electrically connected to a static grounding system using bond wires, conductive materials, ground cables and attachments.

Flammable liquids must be bonded and grounded when transferring them, according to the Code of Federal Regulations, 29 CFR 1910.106(e)(6)(ii): Grounding.

Definitions

- Bonding: The process of connecting two or more conductive objects using a conductor to have the same electrical potential, but not necessarily at the same potential as the earth per NFPA 77: 3.1.2.
- Grounding: The process of bonding one or more conductive objects to the ground so that all objects have zero electrical potential; it is also referred to as earthing per NFPA 77: 3.1.10.
- Grounding plate: A metal plate that provides a bond for the receiving container.
- Grounding rod: An easily cleaned, nonreactive metal rod designed to provide a bonding point for containers that are too small or have no metal attachment point.
- Static electric discharge: A release of static electricity in the form of a spark, corona discharge, brush discharge, or propagating brush discharge that might be capable of causing ignition under appropriate circumstances per NFPA 77 3.1.16.

Quality of ground source

Grounding is accomplished by attaching a ground cable to a ground rod or grounding system designed to provide a continuous ground path to less than 5 Ohms — NFPA 77 states 10 Ohms. To ensure a good connection, the ground attachment must be metal-to-metal, not painted, clean and free of debris or dirt. It is recommended that an electrician check the grounding system annually to verify the ground resistance.

Dispensing into plastic or glass containers

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

Select a proper location for dispensing

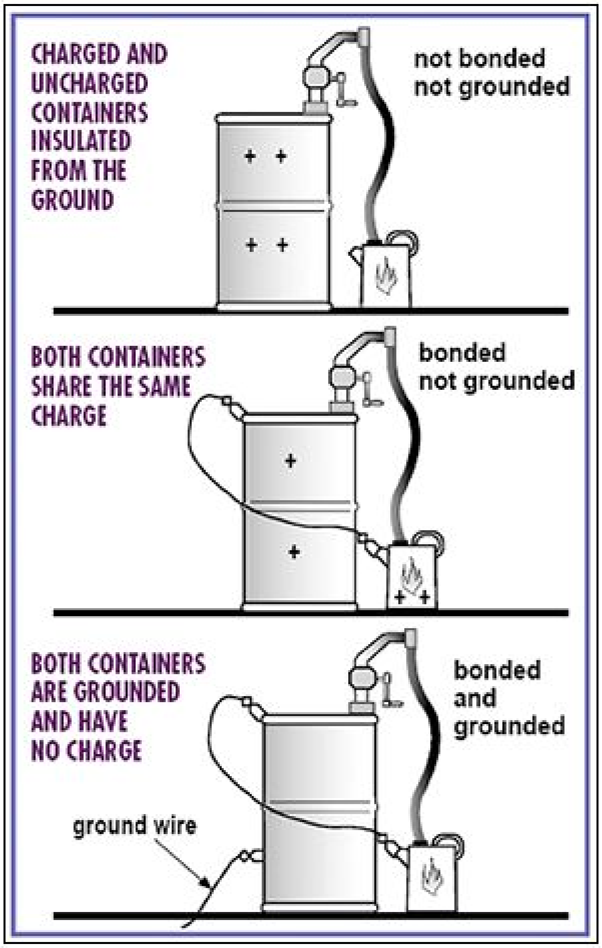
- Carefully assess and identify a safe location for flammable liquids transfer.
- Dispense flammable liquids — < 20 liters — inside a chemical fume hood or in a well-ventilated place.
- Ensure all ignition sources, like flames, electrical outlets, etc., are located at least three feet from dispensing operations.
- Ensure the dispensing location's exit door and egress pathways are apparent.

- Flammable liquids in quantities > 20 liters must be dispensed inside a room or area specifically designed to dispense flammable liquids with explosion-proof electrical wiring, equipment and special ventilation systems.

Call EHS with questions.

Safety cans

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



Source: Bonding and Grounding configuration for transferring flammable liquid.

How to bond and ground

1. Carefully assess and identify a safe location, avoiding:
    a. Poorly ventilated spaces.
    b. Open flames or heat sources, such as hot plates, Bunsen burners, etc.
    c. Electrically charged equipment.
2. Transfer flammable liquids within a chemical fume hood when possible and in a proper dispensing location, such as a high-hazard or flammable room or well-ventilated laboratory room.

3. Use proper bonding and grounding cables:
    a. Plastic-coated 10-inch coiled grounding cable with clamps on both ends works well. Some locations may have permanent cables available.
    b. A 3-inch bonding cable with alligator clips on both ends works well.
4. Find an earth ground — copper water lines work well — and label it for future reference. **Do not use fire sprinkler lines**.
5. Remove dirt, debris, paint, etc., to ensure a good metal-to-metal connection.
6. Connect the dispensing vessel to the earth ground.
7. Place the receiving vessel in a secondary container or on a bonding metallic floorplate.
8. Connect the bonding cable metal to metal from the receiving vessel to the dispensing vessel or floorplate.

Note: If the receiving container is too small, has no metal connection, or has no metal floorplate, provide a grounding rod. Ensure that it does not tip over.

- Clean all equipment and adequately transport the material to the laboratory.
- Leave the bonding and grounding equipment readily available for the next person to use.
- Once correctly connected, proceed with your transfer.
- When complete, disconnect all bonding and grounding cables and remove the grounding rod if applicable.

Appendix T

Picric acid use

Trinitrophenol, picronitric acid, is a pale yellow, odorless crystal slightly soluble in water. Outside of laboratories, picric acid has primarily been used for explosives and fireworks. Within the laboratory, picric acid is used in many common fixatives for histology applications, such as the staining of microscopic specimens and pharmaceutical applications.

Picric acid use and storage shall follow the approved Maximum Allowable Quantities per Control Area per the International Fire Code 2018 Edition and Chapter 50 Hazardous Materials — General Provisions. Table 5003.1.1(2).

Picric acid can be safely used when diluted or hydrated with water or moisture, but it poses a potential explosion hazard when it dries. It should always be stored underwater to protect against explosions. Picric acid is primarily reactive with metals or metallic salts. Dry picric acid — less than 30% solution — is friction and heat-sensitive, considered a highly shock-sensitive chemical.

Metal caps and lids are especially susceptible to highly sensitive picrate salts forming. Picrate salts are often more explosive and shock-sensitive than picric acid. If dry crystals are present inside the container or cap threads, the friction from removing the cap may be sufficient to detonate the container.

Storage of picric acid

- Avoid heat, flame, ignition sources, shock, dryness and the many incompatible materials that may cause an explosion.
- Dispose of picric acid stocks that are more than two years old. Also, dispose of all old picric acid bottles with metal caps. Use extreme caution with such containers that still contain picric acid.
- Do not store excess amounts of picric acid. Purchase only the amount needed.
- It will also react with alkaline materials, including plaster and concrete, to form explosive materials. The rapid decomposition generates nitrogen, carbon dioxide, water, and other substances that may be toxic.
- Keep the container tightly closed and in a cool, dry, well-ventilated area.
- Keep quantities to a minimum. A minimum amount of picric acid should be acquired in laboratories for manipulation. Purchase picric acid in solution — not as a dry solid — when possible. Label all picric acid with the date received.
- Picric acid forms sensitive salts; therefore, it is incompatible with alkalis, transition metal oxides, alkaline salts, and heavy metal oxides. Iron, nickel, copper, zinc, lead and mercury compounds are mentioned in various reports, but manganese, cobalt, palladium, silver and cadmium compounds should also be suspected.
- Storage of unused liquid inventories should be put in polyethylene secondary containers that are large enough to contain all the contents of the original container that should rupture and stored with all other inorganic acids. Be sure to label all containers that contain picric acid, including the date received.

Potentially, old picric acid is an item of particular concern. If old or previously unaccounted-for bottles of picric acid are discovered, the following steps should be taken:

- Dry picric acid or picrate salts should not be touched or moved under any circumstances. This is a serious potential hazard. If your laboratory may have old picric acid in your chemical inventory, call EHS for pick-up, but do not handle it yourself.
- Immediately secure the area and restrict access.
- Inspect the container for product identification and check for an expiration date.
- Most importantly, do not touch the container. Depending on how long the bottle has been left and the state of the product inside, even a minor disturbance could be dangerous. Crystals may have

formed between the lid and the container. Attempting to open the container could result in an explosion large enough to damage personnel and equipment severely.
- Visually inspect the bottle's contents to determine water content and check for signs of crystallization around the lid. If there is no evidence of crystal formation and the water content is relatively high, there is probably little cause for concern. The situation is more severe if there is even the slightest indication of crystallization or low water levels in the bottle. Contact EHS immediately for guidance.

Working with picric acid

- Always make sure picric acid is always disposed of in excess water.
- Before starting work with picric acid, researchers should do the following:
    - Read the safety data sheet for picric acid. Have the SDS present in the laboratory.
    - Read and understand the ASU guidelines for picric acid.
    - Review or create an SOP for how picric acid is used. The SOP must be present in the laboratory.
    - Conduct a dry run before the actual experiment.
- Check for evidence of dried crystals before starting work with this chemical.
- Clean bottleneck, cap and threads with a wet cloth before re-sealing.
- Contact EHS at 480-965-1823 to schedule a pick-up of unwanted chemicals.
- Do not pour picric acid down the drain due to its reactivity with metal.
- Do not store large amounts of picric acid.
- Do not touch, move, or open a container of dry picric acid. Contact EHS **immediately** upon discovery of dry picric acid.
- Don’t allow picric acid to come in long-term contact with metal surfaces.
- Keep picric acid away from heat.
- Maintain a log for regular inspection of containers, usage, and the dates of receipt and opening.
- Make sure any stored picric acid is always wet.
- Never work alone while using picric acid. Always use the buddy system when working.
- Provide a carbon dioxide dry powder extinguisher within 30 feet of storage.
- Rehydrate contents every six months with DI water as needed. Document it on the bottle.
- Store in a fireproof cabinet.
- Store in original containers in an approved flame-proof area.
- The PI must approve all picric acid work.
- Use extreme caution with containers that contain picric acid.
- Use picric acid in a fume hood to reduce exposure.

When using picric acid, you must wear at least the following protective clothing:

- Closed-toe shoes.
- Gloves — nitrile, neoprene or other picric acid gloves.
- Laboratory coat with fully extended sleeves.
- Long pants or clothing that cover the ankle.
- Safety glasses.

Picric acid spills

If a significant picric acid spill occurs, follow the emergency chemical spill procedures:

1. Cease all activities and immediately evacuate the affected area. Make sure that all personnel are aware of the spill and evacuate.
2. If chemical exposure has occurred to the skin or eyes, contact 911, and the affected personnel should be taken to the nearest safety shower and eye wash station.

3. Initiate an emergency chemical spill response and clean up. If the situation is or could become an emergency, like if a chemical exposure has occurred, a fire or an explosion has happened, call 911.
4. In case of a minor spill restricted inside a chemical fume hood, laboratory staff can clean the spill, assuming that the correct equipment is present and that the staff understands the hazards associated with picric acid.
5. Do not allow spilled material to dry — dampen spilled solids with water or a 2% v/v aqueous acetone solution without stirring to keep picric acid wet.
6. Never attempt to sweep up dry material; always keep picric acid wet to reduce explosion hazards.
7. Use a spill response pad or pillow damp with water to absorb spilled material.
8. Place the pads and pillows in a compatible, waterproof container with water added.
9. Thoroughly wash the spill site after material pickup is complete.
10. Collect all waste containing picric acid in plastic or glass bottles for disposal.
11. Identify the waste container with **picric acid waste** written on it.
12. Contact EHS at 480-965-1823 to request a hazardous waste pick-up of the containers of spilled products and contaminated absorbent material.

Follow these guidelines when handling picric acid:

- Clean bottleneck, cap and threads with a wet cloth before re-sealing.
- Do not use a new bottle until the old picric acid is used completely.
- Do not use metal spatulas when manipulating picric acid. Wooden and plastic spatulas are safe to use.
- Don’t allow picric acid to come in long-term contact with metal surfaces. Remember, many metal picrates are more sensitive to potential explosion than picric acid.
- If there is any formation of solid deposits of picric acid around the plastic cap, immerse the container and lid in cold water and allow water to seep into the seal. Cold water can create negative pressure inside the reagent bottle.
- Keep inventories of picric acid low and contact EHS at 480-965-1823 for pick-up of unwanted chemicals.
- Label the containers to show the date when they are first opened.
- Make sure any stored picric acid is kept wet.
- Never put picric acid in a metal container or use metal, unlined lids.
- When possible, purchase picric acid in solution. If you must purchase it as a solid, ensure it is sold moistened, not as a dry solid.

Disposal

Picric acid must be appropriately disposed of as the chemical is hydrated, and no crystal formation is evident.

If the picric acid is dry or crystal formation is evident, **call EHS immediately** for stabilization and disposal. **Do not touch, move or open the container**. When in doubt, contact EHS for a determination.

Appendix U

Reproductive toxin guidelines

A reproductive toxin is a substance or agent that can cause adverse effects on the reproductive system. The toxic effects may include alterations to the reproductive organs and the endocrine system, including the thyroid and adrenal glands. These effects can occur in both men and women. Make sure you are aware of the reproductive toxins that are present or used in your laboratory. Several reproductive toxins are chronic toxins that cause damage after repeated or long-duration exposures and can have long latency periods.

Persons of childbearing potential and those planning families should be cautious when handling reproductive toxins. Pregnant women and persons intending to start families should seek the advice of their physician before working with known or suspected reproductive toxins. Toxic and highly toxic use and storage shall follow the approved Maximum Allowable Quantities per Control Area per the International Fire Code 2018 Edition and Chapter 50 Hazardous Materials — General Provisions. Table 5003.1.1(2).

Reproductive toxins are chemical agents that have the potential to affect human reproductive capabilities, including chromosomal damage — mutagens — sterility, miscarriages, and effects on the fetus — teratogens. There are numerous references on reproductive toxicology, but, unfortunately, no scientific or government agency has established a definitive method for classifying potential human chemical reproductive toxins as they have done for carcinogens. It is, therefore, impossible to give an exhaustive list of all chemicals that should be considered reproductive toxins. The particularly hazardous substance list below provides examples of chemicals known or suspected to be human reproductive toxins, such as:

- Arsenic and arsenic compounds.
- Benzene.
- Cadmium and cadmium compounds.
- Ethidium bromide.
- Lead compounds — inorganic.
- Mercury compounds.

Safety data sheets should be consulted to determine whether chemical agents or products containing those agents are human reproductive toxins. Agents or products containing agents classified as categories 1A or 1B based on the Globally Harmonized System of classification and labeling of chemicals should be treated as reproductive toxins.

PI and departments are responsible for the following:

- Completing an SOP for PHSs.
- Completing Laboratory Safety and Hazardous Waste training before initial use.
- Complying with the procedures outlined in the CHP.
- Contact EHS at 480-965-1823 if assistance is needed.
- Contact EHS before obtaining chemicals that can potentially be reproductive toxins and assist in the hazard assessment.
- Creating and maintaining the standard operating procedure for each reproductive toxin.
- Ensuring that a current SDS for the reproductive toxin is obtained, available and reviewed.
- Identifying alternate job duties or temporary reassignment within the department if indicated by the user's licensed healthcare professional.
- Informing the supervisor of concerns relating to reproductive health.
- Maintaining a clean and hygienic work area in rooms where reproductive toxins are housed.
- Purchasing reproductive toxins per the EHS Hazardous Materials Purchasing Guidelines.
- Understand and comply with the requirements of the CHP.

User responsibility

The following precautions should be taken when working with potentially toxic materials:

- All procedures should occur in a controlled area clearly labeled with a warning and restrictive access sign.
- All work surfaces should be easily cleanable and covered in a waterproof or disposable material.
- All work with reproductive toxins that can create exposure via inhalation must be done in a designated laboratory area inside a properly functioning chemical fume hood. A functioning glove box may sometimes be required when working with reproductive toxins. If these are not feasible, proper respiratory protection must be worn.
- Always wear the appropriate PPE, including, gloves selected based on chemical properties and use, safety glasses, a buttoned lab coat and long pants or clothes that cover the ankle and closed-toe shoes in the laboratory.
- Consult SDSs for hazard and exposure information for all reproductive toxins.
- Containers destined for storage should not be unpacked until they can be transferred to the appropriate storage area.
- Containers of reproductive toxins must be stored in a leak-proof secondary container.
- Designated use and storage areas must be selected for reproductive toxins.
- Do not eat, drink, chew gum or apply cosmetics in the area where toxic chemicals are being used.
- Each reproductive toxin container's label must include an appropriate pictogram.
- Ensure that containers of contaminated waste are transferred from a controlled area in a secondary container to avoid further contamination.
- Have a plan, proper equipment, and materials to minimize exposure if an accident occurs.
- Keep accurate records of the amounts of these substances used.
- Keep containers securely sealed when not in use.
- Materials should be unpacked for use, transferred to a dry box or a chemical hood, and used as instructed.
- Newly received packages of reproductive toxins should be transported through buildings in the same packaging designed for interstate transport.
- Obtain SDS and procedure information for medical providers if they have any questions.
- Procedure should be done with the minimum material needed to complete the task.
- Protective apparel worn while working with toxic materials should not be worn outside the laboratory.
- Read and understand the SDS before working with the chemical.
- Reproductive toxins may not be handled or stored in a room with recirculating exhaust; the room should have a minimum of six air changes per hour.
- The secondary container's label to store reproductive toxins must include an appropriate pictogram and identify the material as a reproductive toxin.
- Thoroughly clean the immediate and adjacent work areas after using reproductive toxins.
- Wash hands, wrists and arms thoroughly when done with the procedure.
- When weighing dry powder reproductive toxins, open balances should be moved to the fume hood when practical and feasible. If not, an additional risk assessment is required to determine respiratory protection needs.

Emergency procedures

- **Eye contamination**: Flush with eyewash for 15 minutes. Call 911 and notify EHS.
- **Localized skin contamination**: Wash the impacted area with soap and water. Call 911 and notify EHS.
- **Widespread contamination**: Remove contaminated clothing and shoes and flush the body with an emergency safety shower. Call 911 and notify EHS.

For small chemical spills, complete the following steps:

- Alert people in the immediate area of the spill.
- Avoid breathing vapors from the spill.
- Collect the residue, place it in a labeled container and submit a hazardous waste pickup request or contact EHS for assistance.
- Use the chemical spill kit to confine the area and clean the spill.
- Wear protective clothing and gloves when addressing spills.

For large chemical spills, complete the following steps:

- Alert people in the immediate area of the spill. Stop work, turn off equipment and close doors as you exit. Evacuate to a safe location.
- Assist injured or contaminated people.
- Call 911 and notify EHS. Post do not enter sign.
- Control the spread of contamination if it is safe to do so.

Disposal

Reproductive toxins and items contaminated with reproductive toxins must be appropriately disposed of through the University's chemical waste program. Visit the ASU EHS waste management and shipping webpage for more information.

Appendix V

Perchloric acid safety

Perchloric acid use and storage shall follow the approved Maximum Allowable Quantities per Control Area per the International Fire Code 2018 Edition and Chapter 50 Hazardous Materials — General Provisions. Table 5003.1.1(2). Perchloric acid is one of the strongest acids known. At room temperature, aqueous solutions up to 72% do not have significant oxidizing power, and the corrosive properties are very similar to other mineral acids — however, the oxidizing power increases with concentration and temperature.

Concentrated perchloric acid at 72% heated above 150° Celsius is a strong oxidizer and reacts violently with organic material, which has resulted in devastating explosions in the past. The monohydrate of perchloric acid at 85% is a good oxidizer at room temperature.

Anhydrous perchloric acid is volatile, explodes upon contact with organic material, and explodes spontaneously at room temperature after storage for a few days. Its preparation should be avoided. Perchloric acid forms an azeotrope with water at 72.5% perchloric acid. Therefore, aqueous solutions do not form anhydrous perchloric acid by evaporation. However, dangerous anhydrous perchloric acid can form when an aqueous solution is subjected to dehydrating solid conditions, such as exposure to concentrated sulfuric acid, acetic anhydride, or phosphorous pentoxide.

At elevated temperatures, vapors from perchloric acid can condense on surfaces in the ductwork of the hood, where they form perchlorate salts that are often highly shock-sensitive and pose a severe explosion hazard. Perchloric acid reacts with alcohols and other organic compounds to form volatile and explosive perchlorate esters.

Purchasing of perchloric acid

Before ordering this chemical, prior approval from EHS is required. Visit the CEMS portal to access the chemical approval form.

Safe handling

- A current safety data sheet of the exact chemical present in the laboratory should be kept in the laboratory.
- A preventive maintenance program must be in effect for perchloric acid hoods and other hoods where hazardous materials are used.
- Always create and follow the approved standard operating procedure for the laboratory.
- Appropriate PPE - such as a laboratory coat, safety glasses, acid-resistant gloves and close-toed shoes must be worn when handling perchloric acid.
- Clean up spills immediately. Do not allow materials to dry. Contact EHS immediately for pickup of materials or if you need assistance with clean-up.
- Dilute by adding perchloric acid to water, not water to acid.
- Do not heat perchloric acid in an oil bath. Use a sand bath, a heating mantle, or a hot plate.
- Do not mix concentrated perchloric acid — >72% — with organic chemicals if temperatures could rise above ambient levels.
- Do not subject perchloric acid to dehydrating solid conditions.
- Contact EHS before attempting to perform perchloric acid experiments that require heating. Heating should only be done in a wash-down hood designed for perchloric acid use.
- If solutions containing perchloric acid are filtered through a paper filter, the filter — and precipitate — should be washed thoroughly with water to remove all perchlorate before being allowed to dry.
- If you suspect equipment has been contaminated with perchloric acid, contact EHS.
- Isolate perchloric acid from organic materials.

- Keep the sizes and quantities of containers in your work area as small as possible.
- Laboratory personnel working with perchloric acid should read the SDS before commencing work.
- Line work surfaces with removable plastic-backed absorbent paper.
- Perchloric acid digestions and other uses at elevated temperatures require that the procedures be conducted in a specially designed fume hood with a water wash-down system. This system is necessary to prevent the buildup of explosive perchlorates in the ductwork.
- Perchloric acid work must be pre-approved by EHS before purchasing the chemical.
- Perform a dry run of your process to identify potential pitfalls.
- Restrict access to the work area.
- Use less dangerous, more stable products when you can.

Note: If perchloric acid is inappropriately heated in a standard fume hood, accumulation of perchlorates in the fume hood or the associated ductwork can make servicing the hood dangerous.

The following actions will be required before the fume hood can be serviced or placed in operation:

- Have the hood tested for perchlorates by a qualified outside vendor.
- If test results are positive for perchlorate contamination, a qualified vendor must perform remediation of the fume hood and associated duct work before the room and fume hood can be cleared.
- The PI or the department responsible for the equipment is responsible for testing and remediation.

Storage and waste disposal

- Anhydrous perchloric acid shall not be used or stored at ASU. Anhydrous perchloric acid reacts violently with many organic materials, posing a severe explosion hazard.
- Opened bottles should not be stored longer than one year from the date opened or expiration date, whichever comes first. Unopened containers may be stored for a maximum of two years from the date received. If an old bottle of perchloric acid is discovered in the laboratory, do not open or move the bottle. Immediately contact EHS for pickup.
- Perchloric acid should be inspected before use and disposed of immediately if discolored.
- Perchloric acid should be stored in its original container with the label intact and placed in a ceramic or plastic secondary container large enough to contain all the contents. It should never be stored in a wooden cabinet or shelves lined with paper.
- Perchloric acid should be stored separately from many other compounds, including acetic acid, acetic anhydride, alcohols, aniline, bismuth and bismuth alloys, combustible materials, dehydrating agents, ethyl benzene, hydriodic acid, hydrochloric acid, grease, iodides, ketones, other organic materials, oxidizers and pyridine.
- If possible, wastes should be collected in the original container and not mixed.

Appendix W

Lead and soldering safety

Lead is a naturally occurring metal with beneficial physical properties in various art, medical, industrial and research applications. Before 1975–1978, lead-containing materials like gasoline, paint, etc., were significantly more common, but they are still used in everyday items like car batteries. Although lead has favorable properties as a material, it is very toxic and can cause various health issues.

Elemental and inorganic lead can enter the body through inhalation and direct contact with the mouth, eyes and nose — mucous membranes — and through skin breaks, like cuts and abrasions. Organic lead compounds have the added hazard of potential absorption through the skin and are considered even more toxic than elemental or inorganic lead materials. Although the usage of lead in consumer products has decreased over the years, it is still imperative to follow proper safety principles to reduce lead toxicity hazards.

Working with welding, cutting and soldering of lead-containing materials

Heating, cutting, and abrading lead-containing materials generate minute particles of lead dust, which can be inhaled. Improperly handled waste from these processes poses a potential hazard to human health and the environment.

If lead is present, engineering controls and respiratory protection may be required.

PPE

Use the following PPE when working with solder, lead or lead-containing materials:

- Fire-protective clothing if working with heat sources.
- Gloves, long pants or clothes that reach the ankle, head and foot protection.
- Respiratory protection, if necessary.
- Safety glasses and, if necessary, a face shield.

Working with lead

Lead may be used in various processes in art studios, classrooms, and research laboratories. Individuals with potential exposure must be aware of the hazards associated with each process and the steps to protect themselves from exposure to lead.

Safety principles for working with lead-based materials include the following:

- Always wash your hands and exposed surfaces after working with leaded materials.
- Consult EHS for questions or concerns about working with leaded materials.
- Never eat, drink, smoke or apply cosmetics while using leaded materials or handling your PPE.

Solder and lead waste management

Consider all leaded waste as hazardous waste, which must be labeled appropriately and disposed of per ASU CHP and hazardous waste management compliance guidelines.

In the case of soldering waste, ensure it has sufficiently cooled and carefully transferred to a sealable container, such as a releasable bag, with a clear label identifying it as **Hazardous Waste: Solder Waste**.