ASU Arizona State University

ASU Environmental Health and EHS

Chemical Hygiene Plan, CHP

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Frequently Asked Questions

Why does ASU need a Chemical Hygiene Plan (CHP) and a Laboratory Safety Program?

Many government regulations require a lab safety program and OSHA requires a CHP for ensuring that work in the lab is conducted safely - 29 CFR 1910.1450(e). OSHA requires that we identify hazards considered both physical and health related, and identify how we use hazardous materials safely. We must also identify how we approve new uses of hazardous materials in our laboratories and develop detailed procedures for how we handle what OSHA considers particularly hazardous substances.

What training is required?

At ASU, all employees and volunteers working in laboratories must attend, at a minimum, Laboratory Safety Training and an annual refresher. Please remember that all ASU employees must attend Fire Prevention and Safety training – ASU EHSEHS 108 Environmental Health and Safety Training. Any employee or volunteer who physically places waste into hazardous waste containers must participate in Hazardous Waste Management training. Those who also work with specific classes of hazards must also participate in applicable training programs as described below:

- **Compressed gases**
- Hydrofluoric acid safety
- Dry ice shipping
- Hazardous waste management
- Liquid nitrogen safety
- ASU Pyrophorics safety training
- Anesthetic gas safety

Additional training classes that may be required are listed below:

- **Biohazards** - Biosafety training, bloodborne pathogens
- **Class 3B** and **4 Lasers** – Laser Safety
- **Radiation hazards** – Radiation Safety
- **Shop tools** such as lathes, drill presses and saws – Machine Shop Safety
- **Incident investigation and report preparation**

Many labs also have their own lab safety-training plan. For any SOPs, your lab has developed for Particularly Hazardous Substances (PHS) please check with your lab manager and/or Principal Investigators (PI) and be sure to complete that training.

What PPE is required?

The PPE listed below are the minimum required items.

- Appropriate gloves.

- Closed-toe shoes that protect the entire foot.
- Suitable clothes that cover the skin. This includes long pants.
- Lab coats and safety glasses are always required when working with hazardous materials.

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

How and why do I register my laboratory?

Laboratories must be registered to:

- Provide emergency responders with lab-specific hazard and contact information
- Maintain current chemical inventories
- Allow EHS to conduct laboratory inspections and assessments

Please see the Laboratory Registration section for more information about the registration process.

What are labeling requirements?

All lab staff must ensure that all hazardous materials are labeled. Staff should keep the manufacturer's original container label in place – 29 CFR 1910.1201. If the manufacturer's label becomes illegible or is removed, the container must be labeled with the chemical name and the primary hazards identified.

If you transfer a hazardous material (chemical) from an original manufacturer's container into a secondary container, the secondary container must be labeled. Very small containers may be labeled with the name or an abbreviation as long as a list of the abbreviations with the chemical name is posted nearby.

Hazardous waste containers have specific labeling requirements and only those employees who have completed ASU EHS Hazardous Waste Management training are to place waste into hazardous waste container.

Please see the Container Labeling section for more information.

What documents must I keep?

You must keep consultation reports, corrective actions, training activities, safety meetings, or one-on-one job safety training sessions.

What are Particularly Hazardous Substances (PHS)?

This is a term used for substances including: "select carcinogens," reproductive toxins and substances which have a high degree of acute toxicity. Use of a PHS requires Standard Operating Procedures (SOP). Please see Appendix C for more information, a list of PHSs and SOP templates.

What if I need to use a new chemical?

Government regulations require ASU to specify prior approval process. Prior approval is required for use of PHS (see Appendix C) and materials that are highly dangerous while recommended for all new uses of chemicals and hazardous processes. Please see the Prior Approval section for more information.

Introduction and purpose
Arizona State University (ASU) continually strives to provide a learning, teaching, and research environment free from recognized hazards. The Occupational Safety and Health Administration (OSHA), 29 CFR 1910.1450(e) and 29 CFR 1910.132, requires the University to establish this Chemical Hygiene Plan (CHP) to protect employees and students from potential health hazards associated with handling, use, and storage of hazardous chemicals in laboratories and to certify Personal Protective Equipment (PPE) requirements. This CHP includes methods designed to protect employees from the health hazards presented by hazardous chemicals and other materials used in laboratories.

Scope and application
The purpose of the ASU CHP is to provide lab employees basic safety information regarding the use of chemicals. It also meets the requirements of ASU EHSEHS 104: Laboratory Use of Hazardous Chemicals. The safe storage, use and disposal of chemicals in the lab require policies for the protection of students, employees, and the environment. ASU has academic, research, and clinical laboratories using hazardous chemicals and other materials. ASU is dedicated to provide an effective program to prevent, reduce, and control hazards in the work area.
In addition, the ASU Hazard Communication Program addresses university employees using hazardous chemicals engaged in non-lab workplaces. The ASU Exposure Control Plan for Blood borne Pathogens is designed to protect the health of employees determined to have potential exposure to human blood and other potentially infectious materials as mandated by OSHA. These programs are available through the ASU EHS Department website.

Permissible Exposure Limits
The ASU CHP outlines processes to ensure that lab use of OSHA regulated substances do not exceed the Permissible Exposure Limits (PEL) specified in 29 CFR § 1910, Subpart Z. PEL refers to the eight-hour time-weighted average for airborne concentrations of hazardous chemicals. An action level is a concentration below the PEL for a specific regulated substance that requires certain actions to prevent exposures above the PEL. If employee exposure to the OSHA regulated substances exceeds the action level (or the PEL in the absence of an action level), then the employer must comply with the substance-specific health standards specified in 29 CFR 1910, subpart Z.

In addition, ASU EHS staff will review and apply consensus standards and recommendations related to evaluating and controlling potential exposures to hazardous materials. Resources such as the National Institute of Occupational Safety and Health (NIOSH) Recommended Exposure Limits (RELs) and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) will be applied as applicable.

Responsibilities

Academic Unit Leadership
Academic Unit Leadership, which may include Deans, Directors and Chairs, are responsible for establishing and implementing department information and training programs for their respective areas, as outlined in the Employee Information and Training section of this plan. Academic Unit Leadership may delegate this responsibility to the Principal Investigator (PI), Lab Manager, or Compliance Officer and/or safety committee is acceptable.

Academic Unit Leadership are also responsible for assuring that laboratories are properly registered according to ASU EHS policy. Additionally, they must ensure that deficiencies found during consultations are addressed within the required 30-day turnaround time. Delegation of this responsibility to the PI, Lab Manager, graduate or post-doctoral student, Compliance Officer and/or safety committee is acceptable.
Academic Unit Leadership are also responsible for assuring that each PI who sets-up, moves, remodels or vacates a lab contacted ASU EHS to ensure the proper transportation and disposition of hazardous materials. Delegation of this responsibility to the PI, Lab Manager, graduate and post-doctoral students, Compliance Officer, and/or safety committee is acceptable.

Principal Investigators
PIs ensure compliance to this plan including: lab registration or re-registration, chemical inventory, employee training plan, PPE hazard assessments, hazardous waste, lab operating procedures, lab specific Standard Operating Procedure (SOP), lab specific training on SOPs and lab operations, compliance to ASU EHSEHS requirements including federal and state requirements, responsible for corrective action for findings noted after lab consultations including chemical, bio-safety, fire safety and radiation safety reviews. PIs also ensure contractors and vendors comply with requirements while working in lab. PIs ensure all assigned laboratories and hazardous materials within are kept secure by locking doors while the lab is unattended.
PIs are responsible for understanding the provisions of this plan and ensuring employees are aware of dangers involved in the handling and use of hazardous chemicals or materials. The PI is required to notify ASU EHS if there is reason to believe an employee is showing signs or symptoms of an over exposure to a hazardous chemical. They must also ensure that Safety Data Sheets (SDS) are available for every chemical in the workplace and employees are trained in their use. PIs using outside vendors or contractors are responsible for obtaining SDSs from the contractor. PIs are also responsible for informing any visitor, contractor or vendor of the hazards of the chemicals used in their lab they are working in or visiting.

Employees
Employees are any paid personnel, including graduate students on stipends. Employees are responsible for understanding the hazards involved with the chemicals they use. They must be familiar with the location and contents of the Safety Data Sheet (SDS) file in their work area. They must consult their PI or Lab Manager if they are unsure of the safe handling, use, and/or storage of the hazardous chemicals. All applicable safety training must take place before the employee begins working in the lab or anywhere hazardous materials are in use. Employees must follow standard operating procedures and wear PPE designated for the task.

Environmental Health and Safety
ASU EHS is responsible for ensuring regulatory compliance with the OSHA Laboratory Standard for ASU. ASU EHS will serve as the custodian of documents required by the standard, i.e., the ASU CHP, Title 29 Code of Federal Regulations, OSHA Permissible Exposure Limit (PEL), and American Conference for Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV).

Chemical Hygiene Officer
As mandated by the OSHA Lab Standard, the Chemical Hygiene Officer (CHO) is appointed by the university. The CHO provides technical guidance in the development and implementation of the provisions of the CHP.
The CHO will serve as a liaison between the university and regulatory agencies relative to OSHA Laboratory Standard compliance issues. EHS

Compliance Officers
ASU EHS 005: Management Policy requires the University to be a model of quality in environmental health and safety. COs are the principal liaison between the departments, colleges and schools with ASU EHS. College or departmental COs, by virtue of their special training and relationship to the ASU EHS, serve as the major source of coordination for activities that support ASU EHS 005 Management Policy and the activities of the Policy and Operations Committees.
Compliance Officers serve as the major source of coordination for those activities which support the ASU EHS Management Policy and the activities of the Policy and Operations Committees. The CO has authority delegated from the Provost, Dean, Director, or Chair for managing environmental health and safety activities in the Campus/Institute or Department, including the authority to establish processes, investigate complaints and/or incidents and audit the performance of ASU employees performing their duties. The CO has the responsibility to report questionable activities and unresolved compliance issues to the delegating authority as well as to the Director of ASU EHS.

Safety Committees
The ASU EHS Operations Committee provides oversight for all ASU EHS programs at ASU. See ASU EHSEHS 005: Management Policy for more information regarding the ASU EHS Operations Committee.
Individual departments who establish safety committees, the 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 in accordance with regulatory and ASU EHS mandates. Each department's safety committee should consist of faculty and/or other department representatives (i.e. CO), as appointed by the Dean, Director, Chair.
Each department’s safety committees may implement lab safety practices specific to their department while maintaining the ASU CHP requirements and all applicable ASU EHS policies. Established safety committees should consult the CHO on any matter involving interpretation and application of ASU EHS policies to laboratories.

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

Laboratory Registration
Lab registration is the process the university uses to maintain lab emergency contacts and information, develop and maintain lab chemical inventories, as an operating permit to use hazardous materials in the location, and ensuring regulatory compliance.

The lab registration process requires the PI or her/his designee (Lab Manager/supervisor, coordinator, manager, etc.) to annually verify a current Chemical Inventory and Responsible Party Information (RPI) sheet to ASU EHS. When physical, personnel, process, or lab location (including lab transfers) changes occur in the registered space, the PI is responsible to update the registration or email to ASU EHS. Please see the registration website for more information.

General guidelines on registering shared lab space:

Shared lab is considered a lab room shared by multiple research groups.

- Each PI(s) or designee must submit a separate RPI for their group.
- PI(s) or designee can collaborate and submit a cumulative chemical inventory for the open lab (preferred method). Alternatively, each researcher can submit their own separate chemical inventory.

Laboratory start-up and closeout procedure

ASU EHS must be notified when a lab is to move, relocate, or vacate for any reason. Each department is responsible for making certain that hazards are removed from the lab prior to any PI departure from the lab. Prior to the move, ASU EHS will conduct a Lab Close-out Assessment and will offer guidance and assistance to ensure that all hazardous material regulations are addressed and satisfied.

ASU EHS must also be notified when a lab is to be newly occupied. ASU EHS will conduct a Lab Start-up Consultation and provide guidance and assistance to ensure regulatory compliance and ASU EHS policies are met. Lab Start-up Consultation will not be routinely conducted on existing lab renewals or lab transfers. For more information ASU EHS 405: Laboratory Start-up/Close-Out and Equipment Relocation

ASU EHS Lab Registration Reminders

ASU EHS sends reminder notices related to updating the laboratories registration annually; however, the annual update is the responsibility of the PI or their designee. The lab's annual registration review and update provides each lab the opportunity to perform a self-assessment of their lab. In order to update the registration please respond to the reminder notice with confirmed or updated information. If no registration changes are made the lab will continue to use the existing posted placard. If there have been changes ASU EHS will create a new placard for the lab.

Responsible Party Information Sheet (RPI)

The RPI sheet identifies emergency contacts, locations of emergency equipment, and any hazards or special concerns specific to each lab. ASU EHS will maintain this information in a database and has developed a registration sign for posting outside each lab to be used by emergency response personnel. The RPI sheet contains instructions for completing the sheet and submitting for annual registration. Please see the registration website for more information.

Chemical inventory

The chemical inventory must include a complete account of the chemicals used or stored in the work area or lab, including compressed gases, paints, oils, insecticides, herbicides, fertilizers, aquarium products, cleaning products, etc.

During an initial lab registration each PI or designee will generate their inventory using the provided chemical inventory template and submit to ASU EHS. ASU Policy ASU EHS 408 requires chemicals be purchased through the ASU designated chemical purchasing system (i.e. Workday). A chemical inventory shall be maintained and available to employees in the lab. To access your current inventory log on to the EHSA Portal. Please see the registration website for more information.

Maximum Allowable Quantities of hazardous materials
A control area is defined as a space within a building which 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 be in accordance with the maximum allowable quantities per control area as defined by Table 5003.1.1(1) of the International Fire Code, 2018 revision. A condensed version of the table is provided in Appendix I.

Chemical Hygiene Plan requirements
Provisions of the ASU CHP are outlined in the following sections. Individual departments or colleges may develop their own version of a CHP provided at a minimum it meets the requirements of the ASU CHP. The OSHA standard requires the CHP be available for all employees. The CHP is accessible at the ASU EHS web site.

Standard Operating Procedures
Standard operating procedures, or SOPs that are relevant to safety and health considerations must be developed and followed when lab work involves the use of hazardous chemicals, equipment, and conditions (examples listed in Appendix C), especially for particularly hazardous substances (PHSs). SOPs are written instructions that detail the steps that will be performed during a given experimental procedure and include information about potential hazards and how these hazards will be mitigated.

SOPs shall be written by lab personnel who are most knowledgeable and involved with the experimental process. SOP templates are available on the ASU EHS website. 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 approval 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
ASU EHS or designated Safety Officers will conduct laboratory safety consultations determining individual lab compliance with the CHP as identified in Appendix B. Consultations may be performed in conjunction with the PI, Lab Manager, Compliance Officer, or safety committee members. Any immediate safety concerns will be addressed during the consultation. A report identifying deficiencies and areas for improvement will be directed to the lab's PI may include the Lab Manager, Compliance Officer, or safety committee members. Follow-up consultations may also be conducted based on severity of findings. For more specific information on the lab safety consultations process please refer to Appendix B.

Program evaluation
CHP and lab 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 systems audit and based upon the effectiveness of the CHP. The ASU EHS Operations Committee may direct the CHO to propose modifications to CHP, ASU EHS policy, or initiate new policies.

Record keeping
Required documentation and records are kept in compliance with applicable lab standards. These records may include reports, questionnaires, and permits for various federal, state, and local agencies. Records and the associated information collected through consultations and submittals by laboratories are kept on file by ASU EHS.
Departments or PIs must maintain records required by this plan which may include consultation reports, corrective actions, documentation that corrective actions have been completed, training records, safety meetings, or one-on-one job safety training sessions. Safety committees should maintain records of their activities and meeting minutes.
ASU EHS maintains records detailing employee exposure monitoring. These records provide an accurate account of measurements taken to monitor potential employee exposures to any chemical contaminant above the action level. These records must be kept for 30 years past the date the employee ceases working at ASU. These records are available from ASU EHS.
ASU Health Services maintains records detailing employee medical consultations, including an accurate report of examinations, tests, and written opinions by the attending physician. These records must be kept for 30 years past the date the employee ceases work at ASU. Records must be available to employees or their representatives only. The physician's written opinion concerning occupational exposure is available to ASU.

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 assist in ensuring effective communication of ASU EHS issues and programs. ASU EHS will publish information related to lab safety for CO's to communicate with their respective groups.

Shared Lab Spaces
Shared Laboratory Space has become a very 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 lab space may lead to problems when users leave shared resources unclean, fail to label containers, or leave the space in a generally unsafe condition. To address these potential problems, please reference Shared Lab Space Guidance on the ASU EHS website.

Minors in Laboratories
Minors in Laboratories policy EHS116: Minors in Laboratories, prohibits anyone under the age of 18 from entering an ASU laboratory. Exceptions include minors who are participating in an organized educational program that has been approved by the head of the academic

unit where the program will take place. Additional exceptions must be approved by ASU EHS. For more information reference Minors in Laboratories

The purpose of the policy is to ensure that persons under the age of 18 have approval to be in a lab, are under proper supervision, and receive appropriate training. A Request for minor access to ASU Laboratories form available through ASU EHS is required for minors actually working in a lab.

Employee exposure determination

If there is a reason to believe employees are being overexposed to hazardous materials please contact ASU EHS to determine if monitoring is required to determine employee exposure. The decision to conduct monitoring is based on a review of procedures conducted in individual laboratories, equipment setup, ventilation or information obtained during the lab 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 is required for OSHA regulated chemicals such as arsenic, benzene, chromium, cadmium, ethylene oxide, formaldehyde, and methylene chloride. Any lab use of a chemical for which there is a specific OSHA health standard, ASU EHS may monitor for potential exposures if:

- A request for monitoring is made by the lab 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 permissible exposure limit.
- 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 permissible exposure limit.

For more information contact ASU EHS or 480-965-1823.

Process Hazard Analysis

A hazard analysis is a step-by-step review of the procedures used by a lab and functions to predict hazards and risks to personnel, property, or the environment. PIs and Lab Managers should conduct Process Hazard Analysis on any new hazardous material, process, or procedure. This analysis assists in defining control methods to prevent exposures to hazards.

The analysis should include the following:

- Chemical Use Evaluation.
- Evaluation for the need of a Prior Approval Form.
- Laboratory Use Evaluation.
- PPE Evaluation.
- Pollution Prevention Analysis.

Prior approval

The prior approval process is recommended for all new uses of chemicals and required for processes involving particularly hazardous substances (see Appendix C) and materials that are highly dangerous. Prior approval is accomplished by completing an ASU Prior Approval Form and submitting it to ASU EHS.

Select Agent Toxins
Select Agent Toxins are certain toxins of biological origin, which are to subject to stringent regulatory requirements under 42 CFR 73 for their potential to pose a severe threat to public, animal, or plant health, or to animal or plant products. These toxins, along with specified biological agents (viruses, bacteria, fungi), fall under the oversight of the National Select Agents Registry (NSAR) Program, which requires registration for possession, use, and transfer of the listed Select Agents. Possession of small amounts of Select Agent Toxins as described in ASU's Biological Safety Manual is exempt from registration with the NSAR Program. An SOP is required for use of exempt amounts and meet the Federal Select Agent Program Due Diligence requirements.

Personal Protective Equipment (PPE)
PPE is required to be used at all times while in the lab. Prior to each use, verify the PPE is in good working condition. The PPE listed below are the minimum required items.

- Appropriate gloves.
- Closed-toe shoes that protect the entire foot.
- Suitable clothes that cover the skin.
- Lab coats and safety glasses are always required when working with hazardous materials.

Due to specific hazards in the lab, additional PPE may be required. This additional PPE is based on the lab's PPE hazard assessment. Additional PPE may include equipment such as flame resistant lab coats, face shields, acid aprons, hearing protections, respirators, or other specialty PPE. The PI, with the assistance of the CO or ASU EHS should perform a PPE hazard assessment to determine specific PPE requirements for each lab task. PPE requirements are reviewed during lab safety training and must be followed by all employees and visitors to the lab. Items to consider when performing PPE hazard assessments include:

- Additional information can be obtained by reviewing the OSHA Personal Protective Equipment Standard, 29 CFR § 1910.132.
- Approved respirators in the absence of adequate ventilation, e.g., glove boxes or fume hoods.
- Hearing protection devices may be required if noise hazards are present in the lab.
- Specific PPE for handling potentially hazardous chemicals (i.e. reproductive toxins, carcinogens, and sensitizers).
- Standard operating procedures should include required PPE.

PPE criteria
OSHA requires PPE to meet the following:

- Eye and Face Protection: 29 CFR § 1910.133
- Head Protection: 29 CFR § 1910.135
- Foot Protection: 29 CFR § 1910.136

Lab coats
PI's are responsible for ensuring their staff and students wear lab coats when required. The PPE hazard assessment specifies the required PPE, which includes lab coats. ASU EHS recommends lab coats be worn at all times in laboratories where potentially hazardous materials are present.

Lab coats must not be taken out of the lab into any meeting room, break area or dining facility.

Proper lab coat use and storage guidelines:
- Do not access pant pockets via side slits.
- Hang lab coats on hooks or hangars in designated areas.
- If you need to transport your lab coat to another location, verify it is not contaminated and carry it to the next location in a bag or backpack.
- Lab coats should fit properly and be completely buttoned.
- Remove lab coat before leaving the lab.
- Sleeves must extend beyond the wrist.
- Store clean lab coats separately from used ones.

Lab coats used for flammable materials should be made of 100 percent cotton or FR rated materials. ASU EHS recommends the use of flame retardant lab coats for any use or potential exposure to pyrophoric liquids or gases. Many lab coats are made from cotton/polyester fabric blends. These materials should not be used with open flames or pyrophoric materials.

If a hazardous material is splashed on a lab coat, the wearer is to remove it to prevent the splash from coming into contact with wearer's street clothes or skin. If a splash occurs, remove the lab coat immediately and determine if street clothes or skin have been contaminated. If street clothes are contaminated with corrosives, or materials toxic by skin absorption, remove the street clothes and immediately wash the affected area(s) in an emergency safety shower, report the incident to your supervisor, and follow your lab's emergency procedures.

Laundry of Lab Coats
Lab coats must not be taken home or to public laundries to be cleaned. ASU provides a laboratory coat laundering service.

Before sending to laundry:
- Check and have lab coats cleaned and washed at regular intervals or when they are dirty, whichever is earlier.
- If the lab coat cannot be safely decontaminated or satisfactorily made safe to be handled by the laundry, it should be disposed of accordingly.
- If the lab coat is heavily stained with chemical or biological splash, it should be discarded immediately via the appropriate waste route.
- Replace torn or old lab coats.
- The lab coat should be either free from obvious contamination or autoclaved before sending to the laundry.

If the lab coat is contaminated, guidelines for pre-laundry treatment:

- Do not send radioactive isotope-contaminated lab coats to the laundry. Contact Radiation Safety for guidance.
- If a solvent is spilled on the lab coat, it should be completely evaporated in the fume hood first.
- If it is a biological contaminant (e.g. blood, urine, sputum, etc.) or microorganisms, the lab coat should be autoclaved first. Do not autoclave lab coats that are contaminated with chemicals.

- If the chemical spilled on the lab coat is safe to be disposed to the sewage (e.g. most acids and alkalis), rinse the lab coat with plenty of water.
- Place lab coats for laundering in special plastic bags for collection by contract laundry.
- The lab coat may have to be disposed of via chemical waste if the contaminant is a particularly hazardous chemical. Consult ASU EHS for guidance.

Use of respirators
Respirator use may be necessary in order to maintain exposure levels below permissible limits or short-term exposure limits. ASU EHS can help you determine the necessity for respirator use by evaluating your individual circumstances. Employees may request an evaluation by contacting ASU EHS or your department's safety committee.

Respiratory protection users must comply with the ASU Respiratory Protection Plan and includes compliance related to all types of respirators and dust masks. Respirator equipment will be provided at no cost to employees by the specific department.

Use of hearing protection devices
Hearing protection devices, such as earmuffs or earplugs may be necessary to maintain employee exposure to noise below OSHA's permissible exposure limits. Departments may request a noise evaluation by contacting ASU EHS. Any employee using hearing protection devices must comply with the ASU Hearing Conservation Program.

Laboratory safety equipment
Lab work is prohibited where general room ventilation is inadequate. All lab fume hoods, glove boxes, special ventilation areas, and biological safety cabinets must meet required performance criteria. General lab ventilation and special ventilation device (i.e. snorkel exhaust, glove box, biological safety cabinet) guidelines are located within the ASU Capital Programs Management Group Design Guidelines and ANSI\AIHA Z9.5 American National Standard Laboratory Ventilation guideline.

Fume Hoods
Refer to the ASU EHS Chemical Fume Hood User Guide for proper use of chemical fume hoods. Fume hoods should be performance tested by qualified personnel at least annually. Daily fume hood monitoring must be conducted by lab personnel and is accomplished by consultation of the hood prior to use to ensure hood is working correctly. Proper use of hoods equipped with an on/off switch must be addressed in lab specific training or in other standard operating procedures. Problems with fume hoods must be immediately reported to ASU Facilities Management.

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 or designee or department in possession of a fume hood not equipped with a flow-measuring device should contact ASU EHS for a risk assessment of the fume hood.

ASU EHS prohibits the use of ductless fume hoods without prior review and approval by ASU EHS.

Walk-in hoods

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

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 approved by the PI that minimize the potential risks of injury until a suitable emergency eyewash and safety shower can be accessed. General guidelines are located within the ASU Capital Programs Management Group Design Guidelines. American National Standards Institute (ANSI Z358.1 2009) and National Research Council Prudent Practices in the Lab provide detailed information regarding the installation, operation, and testing of emergency eyewash and shower equipment. Refer to the ASU EHS Emergency eyewash and safety showers for more information.

General Information

- Employees who may be exposed to hazardous materials shall be instructed in the location and proper use of emergency shower and eyewash units.
- 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 labelled as such. Lab specific training programs and SOPs should identify the nearest suitable emergency eyewash and safety shower if not located within the lab.
- Where the hazard is not a corrosive, one intervening door can be present so long as 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.

Eyewash

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

Shower

- Plumbed and self-contained shower equipment shall be capable of delivering flushing fluid at a minimum of 75.7 liters per minute (20 gpm) for a minimum of 15 minutes.
- Showers should be checked routinely to assure access is not restricted and the pull down bar to start water flow is within users reach.

Eyewash and shower

- Emergency eyewash and shower equipment should be available for immediate use, but in no instance should it take an individual longer than 10 seconds (approximately 50 feet) to reach the nearest facility. A door is considered to be an obstruction.
- The emergency shower and eyewash 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.
- The water flow valve shall remain open without the use of the operator's hands until intentionally closed. The valve shall be simple to operate and shall go from "off" to "on" in 1 second or less.

Routine testing

- Plumbed shower and eyewash equipment should be inspected and tested. Eyewashes may be activated weekly or monthly for a period long, enough to verify operation and ensure that flushing fluid is available. Guidance for routine testing is available from ASU EHS. Please contact ASU EHS or your departments ASU EHS Compliance Officer if there are questions about testing frequency, or if guidance is needed for setting up routine testing by lab personnel.

Eyewash/Safety Shower Alarms

In some situations it may be appropriate to install a local alarm to notify lab 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.

1) The alarm must be capable of being silenced or disabled for routine testing and by anyone assisting the injured party using the unit.
2) Noise levels should not exceed 85 dB(A) to ensure use of the unit is not deterred.
3) Local alarms must not be tied into building automation systems or fire alarm systems.

Privacy concerns should also be considered. If an employee is splashed with a hazardous substance, he or she must quickly disrobe in order for a drench shower to completely flush all chemicals or contaminants from the skin. Particularly in mixed-gender environments, there may be hesitation about disrobing in order to flush all chemicals or contaminants from the skin. Installing privacy curtains around drench showers or combination shower/eyewash units can address privacy issues and is encouraged. Additionally, enclosures for safety showers also offer privacy in a larger space and include a shower basin and drain to collect the water. The enclosure also provides added protection from dust, debris or accidental damage of the safety fixture.

Fire safety equipment

Fire safety equipment must be easily accessible to the lab staff including an available fire extinguisher (type ABC). Fire extinguishers are routinely inspected. Fire blanket or automatic extinguishing systems may be available to the lab. Lab personnel shall maintain fire sprinkler clearance requirements as outlined in the Fire Safety and Prevention training.

Employee information and training

Lab employees must annually complete at a minimum the following classes Laboratory Safety, Fire Prevention, and Hazardous Waste Management. Additional training courses may be required depending on the hazards present in the lab. Employees must complete all required training as identified in the ASU EHS Training Determination Tool. ASU policy ASU EHS 108: ASU EHS Training outlines employee safety training requirements. Please visit the ASU EHS Training Page for more information regarding safety training for employees, volunteers, and minors.

The PI must ensure safety training of all lab employees is completed annually. Training must be provided for new employees prior to working in the lab or when a new hazardous chemical or procedure is introduced into the work area. PIs or Lab Managers must provide additional lab-specific safety training to employees and non-employees (e.g. students and volunteers) relative to the specific hazards associated in their lab (e.g. chemicals and equipment). A Laboratory-Specific Training checklist is available for use in Appendix D.

ASU EHS recommends new PIs or Lab Managers attend the Laboratory Safety Management Workshop. The workshop reviews the Lab Safety Manual and provides credit for Lab Safety, Fire Prevention, and Hazardous Waste Management Training.

Employees with special needs will be provided training when necessary. Special needs training can be performed by a department as part of their emergency preparedness plan. Call the ASU Fire Marshal Office or ASU EHS for guidance.

Container labeling

Hazardous chemical containers in the lab must be properly labeled. PIs or Lab Managers must ensure all chemical containers have labels with legible writing indicating:

- If the material is a peroxide former, include date container was opened or the date of the most recent peroxide test. See Appendix G for more details.
- Name of contents (the label must be written in English using acceptable International Union of Pure and Applied Chemistry (IUPAC) chemical names).
- Primary health and physical hazards (National fire Protection Association (NFPA) or Globally Harmonized System (GHS) hazard warnings, e.g. corrosive, oxidizer, acid, alkali, radiation, etc.).

Chemical containers received from the manufacturer must also include these items as well name and address of the chemical manufacturer or distributor.

When a chemical container is repurposed for a new material, a new label must be affixed meeting the above requirements.

Abbreviations are acceptable on labels only if the lab maintains an abbreviation document clearly visible and in the vicinity of the container that indicates the chemical name represented by the abbreviations.

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

Use the following procedure for chemical substances developed by the lab and for which there is no known written hazard information:

- If the chemical developed by the lab is produced exclusively for the lab's use (new compounds and drugs), the lab must determine if the substance is hazardous;

- If the substance is hazardous, the lab must label the containers as such, and indicate those hazards on the label;
- If the lab is unable to determine the hazards, it must label the chemical as if it were hazardous; and
- If another company produces the chemical developed by the lab for use, the lab must develop an SDS for that chemical substance.

Safety Data Sheets

SDS's must be readily available to lab employees for each hazardous chemical used in the work area. The SDS must contain the following information:

- Chemical and common name.
- Emergency and first aid procedures.
- Handling procedures including hygienic practices and recommended protective measures during release clean-up.
- Health hazards, including signs and symptoms of exposure and medical conditions recognized as being aggravated by exposure.
- If a mixture:
  - Chemical and common name of ingredients that are health hazards.
  - Chemical and common name of ingredients that are physical hazards.
- Indication if the chemical is a carcinogen or potential carcinogen.
- Name, address, and telephone number of the SDS preparer.
- OSHA Permissible Exposure Limit (PEL), the Threshold Limit Value (TLV), and any other exposure limit used or recommended by the manufacturer.
- Physical and chemical characteristics (vapor, pressure, flash point and color).
- PPE, engineering controls, and work practices.
- Physical hazards, including potential for fire, explosion, and reactivity.
- Primary routes of entry into the body.
- SDS preparation date.

The responsible party for the lab or their designee must maintain an updated collection of SDS, meeting the above criteria, for all chemicals in the lab and ensure that they are readily accessible. If additional information concerning a chemical becomes available, it must be added to the SDS within three (3) months. The collection can either be maintained as an electronic or paper copy. SDSs must be arranged alphabetically or in any other manner suitable to readily locating an SDS. Electronic collections must not be password protected and also readily available to anyone in the lab.

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, be prepared to provide your location. If there is a major incident, contact the ASU PD by calling 911 from a cell phone or blue call box.
- Before transporting autoclaved materials, please review the following materials: Autoclave Safety Manual.
- Bring PPE (safety glasses, lab coats, appropriate gloves) in case of a spill (and a spill kit).
- Contact ASU EHS if additional guidance is needed.
- Do not transport hazardous materials on the Malls during class change times.

- If transporting more than a single 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 not transported in personal vehicles. The material's SDS will assist you in determining if the material is hazardous. Contact ASU EHS if you need assistance in this determination. Hazardous material transportation must be done only by ASU EHS or employees authorized to transport hazardous materials. Contact ASU EHS if a chemical must be transported onto or off campus. Avoid transporting non-hazardous materials in a passenger vehicle, but if you must, do not place the materials in the passenger compartment. Place the containers in the trunk or cargo bed and ensure that they are properly 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 first contacting ASU EHS (e.g. outdated peroxide formers such as THF, dry Picric Acid, >20 gal containers of flammable or corrosive liquids).
- See 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 be in attendance to prevent tipping cart as it is moved over uneven terrain and changes in elevation.
- 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 or uneven terrain, two people must be in attendance 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. If not possible, use an approved chemical carrier and ensure that it is properly labeled.

When transporting chemicals on campus between lab rooms within the building (i.e. 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. Transport of any corrosive or heated materials requires secondary containment unless exempted by ASU EHS.
- Before transporting autoclaved materials, please review the following materials: asu.edu/ehs/documents/asu-autoclave-safety-manual.pdf.
- Carry or wear appropriate PPE. Minimum PPE includes safety glasses, lab coat or other appropriate lab attire, and closed toe shoes. Hazardous chemicals must be attended at all times while being transported.

- Individuals transporting chemicals must ensure containers are properly 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 first contacting ASU EHS (e.g., outdated peroxide formers such as THF, dry Picric acid, >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 be in attendance 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.
- Transporting cryogenic materials refer to Appendix K.
- Use freight elevators for moving chemicals between floors. If freight elevators are not available, use unoccupied passenger elevators. Stairs should be used only if elevators are not available.

Eating, drinking, smoking, chewing and use of cosmetics

Many respected institutions including the National Research Council, the 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 laboratories.

Each Department Dean, Director, Chair or their designee may designate areas within lab facilities where these activities are permitted. Prohibitions related to the use hazardous materials in these locations must be communicated to all lab 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 with the terms **"no food, beverage, or ice for human consumption"** or equivalent. Similar appliances in designated locations within laboratories intended for use with food or beverage to be used 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.

Physical hazards

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

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

All equipment manufacturer's signage related to physical hazards must be left intact and employees are informed to adhere to all manufacturer's warning labels. In situations where the manufacturer's label has become 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. Signs are available on the ASU EHS website.
Please be sure to verify the following types of equipment are provided with warning labels associated with physical hazards.

- Robots, pneumatic lifts, and material handling devices that are not equipped with physical barriers or interlocks engineered to prevent exposure to physical hazards.
- The presence of bare electrical conductors greater than 50 volts as defined in EHS118: Electrical Safe Work Practices.

Equipment generating excessive noise levels need to be surveyed by ASU EHS per the ASU Hearing Conservation Program and appropriate signage used to identify where hearing protection may be required or recommended.

Radiation producing equipment and materials, radio frequency generating equipment and lasers must be labeled. If the equipment manufacturer did not provide labels, contact the Radiation Safety Office for assistance at radiationsafety@asu.edu.

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 provide guidance, which applies to 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 policy ASU EHS: 122 Compressed Gases.

Safe Handling of Pressurized Glass Containers
Please ensure all users of compressed gases have completed compressed gas safety training and following the Standard Operating Procedure and the lab specific training plan. Every ASU employee is encouraged to use the ASU EHS Training Determination Tool to identify all safety related training that may be required.

Do not use glass containers for experiments and processes that may become pressurized without conducting a hazard assessment. Pressure levels must be understood, containers rated for the application, or other engineering safeguards (i.e. a pressure relief device) must be used. ASU EHS is available to assist with hazard assessments.

Ensure proper PPE is identified for each process or protocol used in the lab. This should be identified in your lab specific training. ASU EHS provides a PPE hazard assessment tool and is available to assist with assessments.

Verify personnel in your lab understand emergency procedures and what to do in the event of an incident.

ASU EHS is available for consultation of pressurized systems.

Hydrogen Generators

To reduce the amount of flammable compressed hydrogen gas within a laboratory or space a hydrogen generator may be installed. Hydrogen generators are particularly useful 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/disapproved by the EHS/ASU Fire Marshal's Office (FMO) prior to installation. Typical hydrogen generator installations may not require additional local exhaust ventilation, enclosures such as gas cabinets, and gas detection. Use of hydrogen generators will not impact the maximum allowable quantities of flammable gases in a control area it is installed within when approved by EHS/ASU Fire Marshal's Office.
These requirements shall be followed for installation;

1. The distance between the generator and the tool/equipment using the gas shall be as short as possible and no more than 20ft.
2. 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.
3. Piping shall not penetrate walls, run above ceilings, or below floors.
   Question for Chris Esperti – is a hydrogen sensor and alarm needed for hydrogen generator? If so, should it be local

Ozone generators?

Shop equipment

OSHA requires that machine guarding and other safeguards be provided and maintained to protect employees who may operate machines typically considered shop equipment and other persons present in machine areas from potential hazards – 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. Risk of injury 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 labs and under shop supervisors for designated machine shops. To assist with fulfilling these responsibilities ASU EHS offers web based training. ASU EHS also conducts consultations of machines 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 source of energy such as electricity, or who needs to remove guards or panels exposing moving parts must be trained in ASU Lockout/Tag Out program.

In order to prevent potential hazards from exposure to toxic metals such as Beryllium, machining of any metal alloy that is not stocked in shop supplies must be approved through the use of a Prior Approval Form.

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

Working alone procedures

Hazard assessments are to be conducted whenever employees and volunteers are working alone as required in ASU EHS 123 Working Alone with Hazardous Materials, Processes or Equipment. Working alone with hazardous materials, hazardous equipment, or hazardous processes is prohibited unless authorized by the PI, or his or her designee, in accordance with this policy or as otherwise approved by ASU EHS.

ASU EHS is responsible for providing Procedures for Working Alone with Hazardous Materials, Processes, or Equipment and a Working-Alone Checklist, for use in conjunction with this policy. The Working-Alone Checklist should be used to easily assess tasks that fall under this policy. ASU EHS will also provide guidance and consultation in connection with situations or circumstances where working alone may take place.

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, hazardous equipment, or hazardous 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/or establish procedures and training that eliminate or minimize the risks of one working alone. Each PI, or designee, is responsible for ensuring that any alternative working procedures are at least as effective as the Working Alone Procedures.

Lab Safety Manual (LSM)

The LSM is compiled of important information from a variety of regulatory areas into a single source repository of lab specific compliance topics that PIs are required to keep with respect to the operation of their lab. The LSM helps PIs to organize and develop certain Lab Specific information required for their research lab and reduce the amount of administrative time needed for future lab consultations, incident investigations, or answering questions related to regulatory compliance.

ASU EHS provides the initial LSM and updates through communication with the manual holders. The LSM should be located in an easy to find location during possible regulatory inspections, lab specific training, or anyone who may need to reference the information. It is the PIs responsibility to ensure that the appropriate information is added and included in each Section of the LSM.

Shipping and receiving hazardous materials/dangerous goods (HM/DG)

No person may receive a HM/DG without function-specific training. Training must be documented and must be included in the employee's ASU EHS training records. No person may ship or offer for shipment HM/DG unless that person has received certified 16-hour US DOT training for hazardous materials.

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

International shipments may require export permits and the recipient may require import permits, please plan accordingly. For international shipments only please email the ASU Office of Research Integrity.

Anyone shipping using dry ice must take ASU EHS dry ice training before shipping.

For more information see ASU EHS 406 Shipping and Receiving Hazardous Materials.

Pollution prevention analysis

Pollution prevention analysis is the systematic review of lab procedures, which use hazardous chemicals in order to reduce volume and toxicity of waste and to prevent the release of substances 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 of any kind are allowed in the trash or down the drain**. All laboratories must be accountable for all hazardous chemicals and materials to make sure they are not released into the air, sewer, or ground. The safest and most efficient way to dispose of hazardous chemicals is to have wastes picked up by on-campus by hazardous waste management services.

Pollution prevention analysis requires the researcher to review all processes and to identify those chemicals that can be substituted by less hazardous chemicals. Researchers must be able to justify to ASU EHS and the Arizona Department of Environmental Quality, or ADEQ, the use and volumes of hazardous chemicals used in their laboratories.

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 is harmful to researchers. Open bench surgeries involving gaseous anesthetics should employ waste gas scavenging systems that are connected to non-recirculating exhaust systems.

- Refer to 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 ASU EHS prior to installation of scavenger systems to existing building ventilation.

Medical consultations and medical 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:

- Whenever an employee develops signs or symptoms associated with a hazardous chemical exposure which may have occurred in the lab,
- 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, and/or any TLV or REL for which there are prescribed exposure monitoring and medical surveillance requirements,
- Whenever there is a spill, leak or other release resulting in a potential hazardous chemical exposure of an employee above the PEL or action level, or
- Examinations must be conducted under the direct supervision of a licensed physician and provided at no cost or loss of pay to the employee.

ASU will provide the physician with the following:

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

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

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

Hazardous waste management
Lab operations that produce waste chemicals are considered as producing hazardous waste. Hazardous waste is regulated by The Arizona Department of Environmental Quality, or ADEQ. All lab personnel who produce hazardous waste are required to manage their waste 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 lab employees who physically place hazardous waste into designated hazardous waste containers are required to complete Hazardous Waste Management training either in classroom or using the web-based training available through ASU EHS.

Broken glass
The following is the procedure recommended for handling broken glass. If the broken glass involves blood, microorganisms or bioresearch materials, please review the following link: asu.edu/ehs-biowaste-compliance-guideline.

If a potentially hazardous chemical is involved, please review this link: emergency.asu.edu/ep_emergency_guide.

If broken glass is the only issue, then the glass should be carefully picked up using forceps or broom and dust pan 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 that need to handle it. Broken glass that is not contaminated may be recycled as indicated at cfo.asu.edu/lab-glass.

Emergency procedures

Lab 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 use of special ventilation areas.
- Shut down and lock-out during evacuations.

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

Accident and near miss reporting

PIs or Lab Managers must submit accident/near miss reports to ASU 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 be of help to safety committees as they strive to improve future lab safety.

To report an incident related to an employee, visitor, or student in regards to an injury, illness or near miss refer to the ASU EHS website and fill out the Accident/Near Miss/Quality Improvement Report. ASU EHS 115: Incident Reporting and Investigation policy

Hazardous Materials Incident

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

RELATED WEB DOCUMENTS

Biological Hazardous Waste Compliance Guidelines
Hazardous Waste Management Compliance Guidelines
Respiratory Protection Program
Compressed Gas Safety Program

Appendix A

Definitions

ACGIH - American Conference of Governmental Industrial Hygienists is 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 (see "TLV") for hundreds of chemical substances and physical agents.

Action Level - A concentration designated in 29 CFR § 1910 for a specific substance, calculated as an eight (8)-hour time-weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance.

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

Acute Exposure – Acute exposure is a single, brief exposure to toxic substances. Adverse effects on the human body, if applicable, are evident soon after the exposure and come quickly to a crisis.

Alloys - A mixture of metals (such as brass), in some cases a metal and a non-metal.

Ambient Temperature - Temperature of the immediate surroundings.

Appearance/Odor - The color, physical state at room temperature, size of particles and characteristics of the material. Odor is described in comparison to common 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 a fluid into the lungs, causing an inflammatory response to occur.

Assistant Secretary - The Assistant Secretary of Labor for Occupational Safety and Health, US Department of Labor, or designee.

Auto ignition Temperature - Lowest temperature at which a flammable gas or vapor-air mixture will ignite from its own heat source or other contacted heat source.

Boiling Point - Temperature at which vapor pressure of a liquid equals atmospheric pressure.

C.A.S. 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, which changes the speed of a chemical reaction but undergoes no permanent change itself. An example of a catalyst is the platinum used in automotive catalytic converters on the exhaust system.

Chemical Hygiene Officer - An employee who is designated by the employer, and who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions of the CHP. This definition is not intended to place limitations on the position description or job classification that 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:

> (i) Are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace, and

(ii) 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 of time or recur frequently.

Combustible - A substance capable of fueling a fire. Also, a term used to classify certain liquids on the basis of their flashpoints. Also, see "flammable".

Combustible Liquid - Any liquid having a flashpoint at or above 100^0F (37.8^0C), but below 200^0F (93.3^0C), except any mixture having components with flashpoints of 200^0F (93.3^0C), or higher, the total volume of which make up 99 percent or more of the total volume of the mixture.

Compressed Gas -

(i) A gas or mixture of gases in a container, having an absolute pressure exceeding 40 psi at 70^0F (21.1^0C) or

(ii) A gas or mixture of gases in a container, having an absolute pressure exceeding 104 psi at 130^0F (54.4^0C) regardless of the pressure at 70^0F (21.1^0C) or

(iii) A liquid having a vapor pressure exceeding 40 psi at 100^0F (37.8^0C) as determined by ASTM D-323-72.

Corrosive or Corrosive Material - As defined by the Department of Transportation (DOT), a corrosive material is 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, a liquid that has a severe corrosion rate on steel. For the purposes of locating emergency eyewash and safety shower units, liquids with pH ranging from <1 to > 12 shall be considered corrosive.

Cutaneous - Pertaining to or affecting the skin.

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

Dermal - Pertaining to or affecting the skin.

Designated area - An area, which may be used for work with "select carcinogens", reproductive toxins, or substances, which have a high degree of acute toxicity. A designated area may be the entire lab, an area or a device such as a lab hood.

Dyspnea - Shortness of breath, difficult 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 work place.

Emergency Eye-Wash/Safety Shower – equipment provided in the lab for emergency use in treating splashes of corrosive materials meeting the requirement of ANSI Z358.1 2009).

Employee - An individual employed in a lab work place who may be exposed to hazardous chemicals in the course of his or her 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 - Limit set to minimize occupational exposure to a hazardous substance. Recommended occupational exposure limits used are American Council of Governmental

Industrial Hygienists' Threshold Limit Values (TLV’s), Occupational Safety, and Health Administration Permissible Exposure Limits (PEL's).

Extinguishing Agents - Agent(s) suitable for controlling or putting out a fire, when properly applied.

Flammable Limits - The range of a vapor/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:

(i) Aerosol, flammable means an aerosol that, when tested by the method described in 18 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

(ii) Gas, flammable:

(A) A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less or

(B) A gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12 percent by volume, regardless of the lower limit.

(iii) Liquid, flammable: Any liquid having a flashpoint below 100 F (37.7^{0}C), except any mixture having components with flashpoints of 100 F (37.7^{0}C) or higher, the total of which make up 99 percent or more of the total volume of the mixture.

(iv) 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 serious hazard. A chemical must be considered to be 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 when tested as follows:

(i) Tagliabue Closed Tester (See American National Standard Method of Test for Flash Point by Tag Closed Tester, Z11.24-1979 (ASTM D 56-79)-for liquids with a viscosity of less than 45 Saybolt Universal Seconds (SUS) at 100^{0}F (37.8^{0}C), that do not contain suspended solids and do not have a tendency to form a surface film under test or

(ii) Pensky-Martens Closed Tester (see American National Standard Method of Test for Flash Point by Pensky-Martens Closed Tester, Z11.7-1979 (ASTM D 93-79))-for liquids with a viscosity equal to or greater than 45 SUS at 100^{0}F (37.8^{0}C), or that contain suspended solids, or that have a tendency to form a surface film under test or

(iii) Setaflash Closed Tester (see American National Standard Method for Test for Flash Point by Setaflash Closed Tester (ASTM D 3278-78)).

Organic peroxides, which undergo auto accelerating thermal decomposition, are excluded from any of the flashpoint determination methods specified above.

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

Generic Substance - A substance identified by its general chemical name and/or 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. It also specifies details pertaining to chemical labels, chemical storage, SDS, 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 in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals, which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, and neurotoxins, agents which act on the hematopoietic systems and agents which 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 there is at least one scientific study that shows it may cause acute or chronic health symptoms. This includes chemicals, which are carcinogens, toxic or highly toxic, irritants, corrosives, sensitizers, or chemicals that effect target organs including the lungs, kidneys, nervous system, pulmonary system, reproductive system, skin and eyes.

Highly Toxic - A chemical, which has been found through testing of lab animals to cause death when exposed at certain levels.

(i) A chemical is highly toxic to ingest if it has a median lethal dose (LD50) of less than 50 mg/kg. This means that 50 percent of the test animals (rats) died when given an oral dosage of 50 milligrams for each kilogram of body weight.

(ii) A chemical is highly toxic to touch if it has a (LD50) rating of less than 200 mg/kg, meaning that 50 percent of the lab animals (rabbits) die after having continuous skin contact at that dosage for 24 hours or less.

(iii) A chemical is highly toxic to breathe if it has a (LC50) rating of less than 200 PPM for gas or vapor and a 2 mg/m^3 for dust, fume, or mist when exposed for an hour or less.

Ignition Source - Anything that provides heat, sparks, or flame sufficient to cause combustion/explosion.

Incompatible - Materials which could cause dangerous reactions from direct contact with one another are described as incompatible.

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

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

Laboratory (Lab) – A laboratory is defined as a facility or room where the use of potentially hazardous chemicals, biological agents or sources of energy (i.e. lasers, high voltage, radiation, etc.) used for scientific experimentation, research, or education.

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

Laboratory Startup and Closeout – Process to ensure laboratory operations adhere to 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 of the following conditions are met:

(i) Chemical manipulations are carried out on a "laboratory scale"

(ii) Multiple chemical procedures or chemicals are used

(iii) The procedures involved are not part of a production process, nor in any way simulate a production process and

(iv) "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

LC50 - Lethal Concentration 50 the concentration in 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 a single dose of material which on the basis of 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) LEL is the lowest concentration of a gas or vapor in the air that can produce ignition or explosion.

Local Exhaust – A local exhaust system is used for capturing and exhausting contaminants from the air to point where the contaminants (gases, particulates) are released. Not to be confused with "general exhaust".

Medical consultation - A consultation which takes place between an employee and a licensed physician for the purpose of determining what medical examinations or procedures, if any, are appropriate in cases where a significant exposure to a hazardous chemical may have taken place.

MSDS – (Material Safety Data Sheet) See definition for Safety Data Sheet.

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.

Narcosis - Stupor or unconsciousness caused by exposure to a chemical.

Neutralize - To render chemically neutral or harmless, e.g., 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, pertaining to, or affecting the mouth

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

OSHA – (Occupational Safety and Health Administration of the U.S. Department of Labor)

OSHA is a federal agency with safety and health enforcement authority for most of U.S. industry and business.

Oxidizer - Department of Transportation defines oxidizer or oxidizing material as a substance that yields oxygen readily to stimulate the combustion (oxidation) of organic matter. Chlorate (CLO_3), permanganate (MnO_4) and nitrate (NO_3) compounds are examples of oxidizers.

Particularly Hazardous Substance – include select carcinogens, reproductive toxins and substances, which have a high degree of acute toxicity.

PEL - Permissible Exposure Limit an exposure limit established by OSHA's regulatory authority. PELS may be expressed as either a time weighted average (TWA) limit or a 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 a large number of relatively simple molecules combine to form a large chainlike molecule. A hazardous polymerization is a reaction, which takes place at a rate, which 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 pyrophoric is a chemical, which ignites spontaneously with air at 130^0F 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 users' respiratory system from exposure to airborne contaminants by inhalation.

Reproductive toxins - Chemicals which 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:

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

Sensitizer - A substance, which on first exposure, causes little or no reaction in man or test animals, but which on subsequent exposure(s) may cause a marked response not necessarily limited to the contact site. Skin sensitization is the most common form of the problem in the industrial setting, although respiratory sensitization to a few chemicals has been known to occur.

Solubility in Water - The percentage of a material (by weight) that will dissolve in water at a specific temperature.

NEGLIGIBLE LESS THAN 0.1%

SLIGHT 0.1 TO 1.0%

MODERATE 1 TO 10%

APPRECIABLE MORE THAN 10%

COMPLETE SOLUBLE IN ALL PROPORTIONS

Solvents - A substance, which 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 specific gravity is the ratio of the weight of a volume of material to the weight of an equal volume of water usually at 60^0F.

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

TLV - Threshold Limit Value (exposure limit for a specific substance as per ACGIH). TLV is a measure of exposure to inhalation only.

TLV "Skin" - This designation sometimes appears alongside a TLV or PEL. It refers to the possibility of absorption of the particular chemical through the skin and eyes. Thus, the protection of 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 could be the liver, kidney, central nervous system or skin.

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

UEL - Upper Explosive Limit - The highest concentration of a gas or vapor in air that can produce ignition or explosion.

Unstable (Reactive) – An unstable or reactive chemical can go through vigorous polymerization, decomposition or condensation. This process occurs when the chemical undergoes shock or changes in pressure or temperature.

Vapor Density - The ratio of the density of a substances vapor to the density of another substances vapor, usually air. A vapor density of greater than one means that 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

ASU EHS Laboratory Consultation Process

The following lab consultation process was approved by the ASU EHS Operations Committee and University Laboratory Safety Committee.

1. **Purpose** – To define the roles, responsibilities, and process for the ASU EHS general lab safety consultation at ASU campuses.

2. **References and Regulations**
   - Prudent Practices in the Laboratory Handling and Management of Chemical Hazards, National Research Council of the National Academies
   - ASU EHS 104 Laboratory Use of Hazardous Chemicals
   - OSHA 29 CFR Part 1910.1450

3. **Equipment – Materials**
   - ASU EHS Laboratory Safety Consultation Checklist
   - ASU EHS Laboratory Safety Consultation Database
   - Personal Protective Equipment

4. **Responsibility**
   - ASU EHS Laboratory Consultation Program
     - Coordinate consultations of ASU Laboratories
     - Report metrics of consultations
     - Designate laboratories to be visited
     - Oversee communication of consultation results to lab managers (Principal Investigator (PI), Department Heads, etc.)
     - Track completed consultations
     - Maintain ASU EHS consultation database
     - Consult with laboratories and provide results as directed by ASU EHS
     - Provide support to Lab Managers where applicable
   - Lab Managers
     - Correct and respond to consultation findings as determined by ASU EHS consultation reports under the guidance of the lab PI
   - Compliance Officers
     - Assist with correcting administrative deficiencies as determined by ASU EHS consultation reports and follow-up

5. **Procedures**
   - Laboratories to be consulted are designated by ASU EHS.
   - Lab consultations for high risk labs will be performed annually at a minimum, while startup and follow up consultations will be conducted within 60 and 30 days respectively.
   - ASU EHS consultant examines an area by physically walking through the location with ASU EHS Laboratory Safety Consultation Checklist.
   - Any consultation finding of imminent danger defined by OSHA (conditions or practices in a place of employment which are such that a danger exists which could reasonably be expected to cause death or serious physical harm) must be corrected immediately. This item will be documented in the report.
   - ASU EHS Consultation Team or individual ASU EHS employee note deficiencies in work areas. The Laboratory Safety Consultation Checklist is to be used for guidance, but additional identified safety, health, and environmental deficient issues may be noted as deficiencies.
   - The consultant (or designee) enters information into the ASU EHS Laboratory Consultation Database and sends reports to the PI or their designee.

- PI or their designee is responsible for correcting deficiencies and notifying ASU EHS when actions are complete.
- PI or their designee may contact ASU EHS for support, when applicable.
- ASU EHS will contact the PI or designee for follow-up of non-completed identified. deficiencies.
- ASU EHS CHO tracks metrics and reports as necessary.

6. Consultation ranking guidelines

ASU EHS ranks lab safety consultation findings based on the risk and severity of the finding. 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 findings from consultations.

Consultation Findings Ranked number 1

Consultation findings ranked number one consist of administrative findings, which can be resolved by email communication with the lab staff or PI. These findings can be closed without a follow up consultation.

Consultation Findings Ranked number 2

Consultation findings ranked number two consist of more hazardous and riskier types of infractions. These consultation findings can be closed by conducting a physical follow up consultation. Compliance officers, lab managers, or ASU EHS lab consultants can conduct the follow up consultation.

Consultation Findings Ranked number 3

Consultation findings ranked number three consist of serious hazards and high-risk regulatory infractions. These infractions consist of noncompliance of regulatory policies and procedures. Examples can include imminent threats, exposure compliance, hazardous waste procedures, compressed gas processes and overall OSHA regulations. These findings can only be resolved via a physical follow up consultation by the initial lab consultant or their supervisors.

Follow up Consultations

ASU EHS performs a follow up lab safety consultation and issues a report 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 ASU EHS may, as a courtesy, contact the PI of the lab with a reminder. Additional parties such as safety committee, compliance officer, or department designee may also be notified.

If no response is received and/or findings remain open after a total of 60 days from receipt of the initial follow up consultation report, the information will be forwarded to the CHO for review and to determine if any additional follow up may be required.

Repeat Findings
Repeat consultation findings ranked number 3 may be communicated with Academic Unit Leadership and placed on a quarterly consultation schedule. A quarterly consultation schedule is intended to assist the lab in resolving these repeat findings. The Chemical Hygiene Officer and ASU EHS Director will determine when these repeat findings have been resolved and when to resume the regular consultation schedule.

Self-Assessments
PIs are encouraged to perform annual lab self-assessments as part of the annual registration process. ASU EHS provides a lab self-assessment checklist on the ASU EHS website and mobile application for the PI or their designee to use.

Consultation Finding Trends and Recordkeeping
ASU EHS generates routine reports to identify consultation finding trends and determine corrective actions. All consultation records are maintained in an ASU EHS database.

ASU EHS Risk Categories

Risk Categories	Areas Defined (Examples only not all inclusive)
1 (Low)	Areas with general hazardous chemicals that do not have special risks. Examples: 1. Biosafety Level One (BSL1) laboratories 2. Labs with small useable amounts of chemicals 3. Classroom teaching labs(Academic teaching) 4. Lasers (Class 1, 2, 3A)
2 (Moderate)	Areas considered special risk laboratories. This defines the majority of laboratories. These labs use and store Particularly Hazardous Substances as defined in the ASU Chemical Hygiene Plan (select carcinogens, reproductive toxins, and toxic chemicals.) Examples: 1. All radioisotopes (use and storage) 2. Radiation producing equipment (X-rays, accelerators) 3. Biosafety Level Two (BSL2) containment laboratories with Non-Select Agents 4. Lasers (Class 3B, 4) 5. Large volumes of chemicals in storage (flammable cabinets etc.) 6. High voltage electrical equipment (>600 volts) 7. DEA Controlled Substances 8. Lab performing research with vertebrate animals
3 (High)	Areas with extremely hazardous activities and chemical or material use including highly sensitive areas where highest risk conditions exist. Examples:

<table>
<tr><td></td><td>1. Select Agent laboratories and Biosafety Level Three (BSL3) facilities
2. Laboratories with security related equipment requiring passwords or security related entries (Select Agent, other highly sensitive or regulated areas)</td><td>3. Highly toxic gases or pyrophoric materials or gases (any quantity)
4. Areas whose grant applications require environmental and safety certification</td></tr>
<tr><td>Training/ SOPs</td><td colspan="2">Risk Category Training and Procedure Requirements
Category 1 All applicable ASU EHS required training and PI provided lab-specific safety training
Category 2 and 3 All applicable ASU EHS required training and PI provided lab-specific safety training and Standard Operating Procedures, or SOPs, for Particularly Hazardous Substances</td></tr>
</table>

Carcinogens are chemicals, which cause cancer. For the purpose of the CHP, chemicals which are known carcinogens include those which: are regulated by OSHA as carcinogens (29 CFR 1910); are listed under the category, "known to be human carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program, or are listed under group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer Monographs.

Reproductive toxins are chemicals, which affect the reproductive capabilities including chromosomal damage (mutagens) and effects on the fetuses (teratogens). Examples of signs and symptoms include birth defects and sterility. Examples of chemicals, which are reproductive toxins, include lead and DBCP (dibromochloropropane).

Highly toxic are chemicals, which have an average lethal dose of:

Ingestion: LD_{50} of less than 50 mg/kg body weight when administered orally to albino rats;

Skin Contact: LD_{50} of less than 200 mg/kg body weight when administered by continuous dermal contact over a 24 hour period to albino rabbits, or

Inhalation: LC_{50} of less than 200 parts per million of gas or vapor or 2 mg/l of mist, fume, or dust, when administered continuously by inhalation for one hour to albino rats.

Extremely Hazardous Activities – a short list of chemicals/activities that are difficult to control and have lethal potential, or could trigger a life-shortening disease, in one low, level exposure, or could cause a lethal event (e.g., 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.

Appendix C

List of Particularly Hazardous Substances (Dangerous Chemicals)

Particularly Hazardous Substances

Particularly hazardous substances fall into the following three categories: acute toxins, reproductive toxins and carcinogens. All materials referred to in this section require the development and use of lab-specific Standard Operating Procedures (SOPs); more information can be found in Appendix E.

Acute Toxins

Substances that have a high degree of acute toxicity are substances that may be fatal or cause damage to target organs as the result of a single exposure or exposures of short durations. For a more complete definition, see "Highly Toxic" materials in Appendix A for more information. A few examples are listed below, a more complete list of acutely toxic compounds is maintained online at
ASU EHS list of PHS.

Acutely Toxic Chemicals (examples, more complete list go to ASU EHS list of PHS)

Arsenic (inorganic)	7440-38-2	Formaldehyde	50-00-0
Benzene	71-43-2	Hydrazine	302-01-2
Bromine	7726-95-6	Hydrofluoric acid	7664-39-3
Dimethyl mercury	593-74-8	Perchloric acid	7601-90-3

Acutely Toxic Gases (examples, more complete list go to ASU EHS list of PHS)

Ammonia	7664-41-7	Hydrogen fluoride	7664-39-3
Arsine	7784-42-1	Hydrogen sulfide	2148-87-8
Carbon monoxide	630-08-0	Methyl mercaptan	74-93-1
Diborane	19287-45-7	Phosphine	7803-51-2

Reproductive Toxins

Reproductive toxins include any chemical that may affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis). A list of reproductive toxins is maintained online at ASU EHS list of PHS.

Carcinogens

Carcinogens are 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 more complete definition of "Select Carcinogen" in Appendix A. The following 13 "Listed Carcinogens" are regulated by OSHA and have specific use and handling requirements per 29 CFR 1910.1003.

Listed Carcinogens

2-Acetylaminofluorene
4-Aminodiphenyl
Benzidine (and its salts)
3,3'-Dichlorobenzidine (and its salts)
4-Dimethylaminoazobenzene
alpha-Naphthylamine
beta-Naphthylamine
4-Nitrobiphenyl
N-Nitrosodimethylamine
beta-Propiolactone
bis-Chloromethyl ether
Methyl chloromethyl ether
Ethyleneimine

Air-Reactive Chemicals

Air reactive chemicals can spontaneously and violently react with air, and most are pyrophoric, meaning that they spontaneously ignite with air. These chemicals should be stored tightly in an inert atmosphere or in an inert liquid. A few examples are listed below. A more complete list of air reactive chemicals is maintained online at ASU EHS list of PHS.

Aluminum alkyls
Barium hydride
Boranes
Cesium
Grignard reagents
Magnesium
Organolithium compounds
White and Red Phosphorus
Gases: Silane, Phosphine, Arsine

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 come in contact with liquid water or water vapor. A few examples are listed below. A more complete list of water-reactive chemicals is maintained online at ASU EHS list of PHS.

Acetic anhydride
Acetyl chloride
Aluminum phosphide
Aluminum tribromide
Calcium carbide
Chlorosulfonic Acid
Diborane
Lithium
Metallic Peroxides
Metallic phosphides
Sodium
Sodium hydride
Sodium oxide

Shock-Sensitive Compounds

Common classes of shock sensitive lab chemicals are listed below which have potential for producing a violent explosion when subjected to shock or friction.

- Acetylenic compounds, especially polyacetylenes, haloacetylenes, 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 oxosalts: metal compounds with coordinated ammonia, hydrazine or similar nitrogenous donors and ionic perchlorate, nitrate, permanganate, or other 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-nitromethylamine, 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 undergo violent reaction 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 metal, such as nickel, lead, mercury, copper and zinc.
- Polynitroalkyl compounds such as tetranitromethane and dinitroacetonitrile.
- Polynitroaromatic compounds, especially polynitro hydrocarbons, phenols and amines (e.g., dinitrotoluene, trinitrotoluene and picric acid).

Sensitizers and Allergens

Sensitizers and/or allergenic chemicals include a wide variety of substances that can produce skin and lung hypersensitivity. Once a person is sensitized, repeated exposures to even the smallest levels of sensitizers can result in life-threatening allergic reactions.

A sensitizer causes a substantial portion of people to develop an allergic reaction in normal tissue after repeated exposure to it. The reaction may be as mild as a rash (contact dermatitis) or as serious as anaphylactic shock. A few examples are listed below:

Epoxides	Nickel compounds
Poison ivy	Toluene diisocyanate
Chlorinated hydrocarbons	Chromium compounds
Formaldehyde	Amines

Appendix D

Laboratory-Specific Training Plan

Laboratory-Specific Training

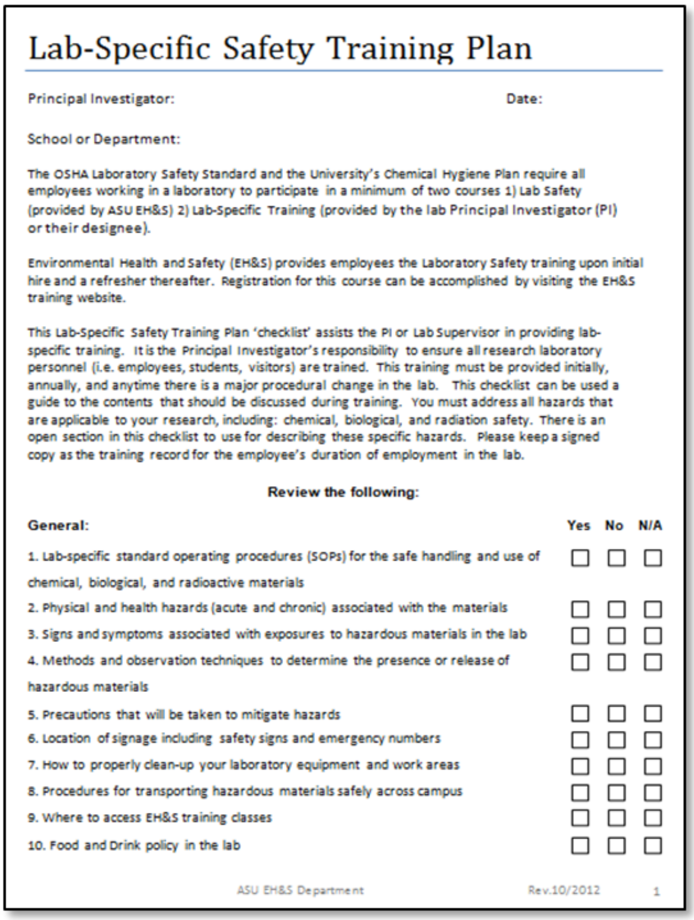
The OSHA Laboratory Safety Standard and the University's Chemical Hygiene Plan require all employees working in a lab to participate in a minimum of two courses

1) Lab Safety (provided by ASU EHS), and
2) Lab-Specific Training (provided by the Principal Investigator (PI) or their designee).

Environmental Health and Safety provides employees the Lab Safety training course upon initial hire and an annual refresher thereafter. Registration for this course can be accomplished by visiting the ASU EHS training website.

ASU EHS provides a Lab-Specific Training Plan template (checklist) designed to assist the PI or Lab Supervisor in the development of lab-specific training. It is the responsibility of the PI to ensure all research lab personnel (i.e. employees, students, and visitors) are trained. This training must be provided initially, annually, and anytime there is a major procedural change in the lab. The checklist can be used as a framework for material to be discussed during training. You must address all hazards that are applicable to your research, including chemical, biological, and radiological safety. There is an open section in the checklist that can be used in describing these specific hazards. Please keep a signed copy as the training record for the employee's duration of employment in the lab.

Lab-Specific Safety Training Plan is available at asu.edu/ehs/forms/lab-specific-training-plan.docx



Lab-Specific Safety Training Plan

Principal Investigator: Date:

School or Department:

The OSHA Laboratory Safety Standard and the University's Chemical Hygiene Plan require all employees working in a laboratory to participate in a minimum of two courses 1) Lab Safety (provided by ASU EH&S) 2) Lab-Specific Training (provided by the lab Principal Investigator (PI) or their designee).

Environmental Health and Safety (EH&S) provides employees the Laboratory Safety training upon initial hire and a refresher thereafter. Registration for this course can be accomplished by visiting the EH&S training website.

This Lab-Specific Safety Training Plan 'checklist' assists the PI or Lab Supervisor in providing lab-specific training. It is the Principal Investigator's responsibility to ensure all research laboratory personnel (i.e. employees, students, visitors) are trained. This training must be provided initially, annually, and anytime there is a major procedural change in the lab. This checklist can be used a guide to the contents that should be discussed during training. You must address all hazards that are applicable to your research, including: chemical, biological, and radiation safety. There is an open section in this checklist to use for describing these specific hazards. Please keep a signed copy as the training record for the employee's duration of employment in the lab.

Review the following:

General:	**Yes**	**No**	**N/A**
1. Lab-specific standard operating procedures (SOPs) for the safe handling and use of chemical, biological, and radioactive materials	☐	☐	☐
2. Physical and health hazards (acute and chronic) associated with the materials	☐	☐	☐
3. Signs and symptoms associated with exposures to hazardous materials in the lab	☐	☐	☐
4. Methods and observation techniques to determine the presence or release of hazardous materials	☐	☐	☐
5. Precautions that will be taken to mitigate hazards	☐	☐	☐
6. Location of signage including safety signs and emergency numbers	☐	☐	☐
7. How to properly clean-up your laboratory equipment and work areas	☐	☐	☐
8. Procedures for transporting hazardous materials safely across campus	☐	☐	☐
9. Where to access EH&S training classes	☐	☐	☐
10. Food and Drink policy in the lab	☐	☐	☐

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Appendix E

Standard Operating Procedure

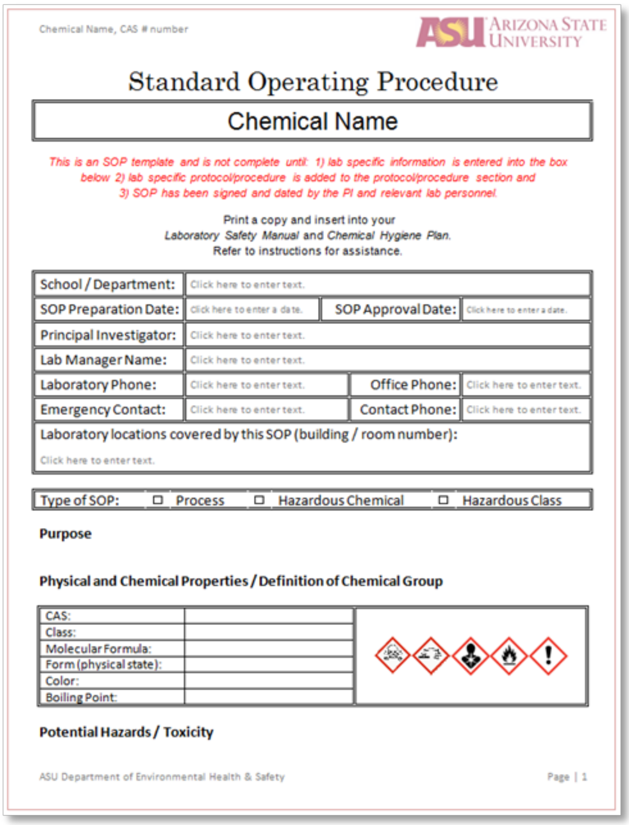
SOP Instructions and Template

Instructions for Completing Standard Operating Procedures

If your lab research involves the use of particularly hazardous substances or physically reactive materials such as the ones defined in Appendix C, you must develop lab-specific SOPs to supplement the information found in the Chemical Hygiene Plan and the material's Safety Data Sheet. ASU EHS maintains a library of SOP templates to further aid in the development of lab-specific research procedures. Below are instructions for completing the SOP using the corresponding template. Please contact ASU EHS with any questions or comments you may have while completing your SOPs. Completed SOPs shall be reviewed by the PI and each lab employee prior to working with the material or procedure. The PI must approve changes to the procedure and all lab employees prior to work shall again review the newly revised SOP. A sample template, like the one shown on this page, is available through the ASU EHS website, click here for template.

1. **Type of SOP**

   - **Process**: the SOP will be for a process such as distillation, synthesis, etc.
   - **Hazardous Chemical**: the SOP will be for an individual chemical such as arsenic, formaldehyde, nitric acid, etc.
   - **Hazard Class**: the SOP will be for a hazard class of chemicals such as oxidizer, flammable, corrosive, etc.


Chemical Name, CAS # number

ARIZONA STATE UNIVERSITY

Standard Operating Procedure

Chemical Name

This is an SOP template and is not complete until: 1) lab specific information is entered into the box below 2) lab specific protocol/procedure is added to the protocol/procedure section and 3) SOP has been signed and dated by the PI and relevant lab personnel.

Print a copy and insert into your *Laboratory Safety Manual* and *Chemical Hygiene Plan*.
Refer to instructions for assistance.

School / Department:	Click here to enter text.		
SOP Preparation Date:	Click here to enter a date.	SOP Approval Date:	Click here to enter a date.
Principal Investigator:	Click here to enter text.		
Lab Manager Name:	Click here to enter text.		
Laboratory Phone:	Click here to enter text.	Office Phone:	Click here to enter text.
Emergency Contact:	Click here to enter text.	Contact Phone:	Click here to enter text.
Laboratory locations covered by this SOP (building / room number): Click here to enter text.			

Type of SOP: ☐ Process ☐ Hazardous Chemical ☐ Hazardous Class

Purpose

Physical and Chemical Properties / Definition of Chemical Group

CAS:	
Class:	
Molecular Formula:	
Form (physical state):	
Color:	
Boiling Point:	

Potential Hazards / Toxicity

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2. **Purpose**

   Brief description of how the chemical is used in the lab along with any information, which describes why an SOP is important for the chemical, or interest.

3. **Physical and Chemical Properties / Definition of Chemical Group**

   Provide basic information on the chemical of interest including the CAS#.

4. **Potential Hazards / Toxicity**

   Describe all the potential hazards for each process, hazardous chemical, or hazard class. Describe the potential for both physical and health hazards. Health hazards include carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes. State the potential for chronic and/or acute health hazard effects of the chemical(s).

   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 chemical.

5. **Personal Protective Equipment (PPE)**

   Identify the required PPE for the process, hazardous chemical, or hazard class. PPE includes, but is not limited to: gloves, aprons, lab coats, safety glasses, goggles, masks, respirators, or face shields.

6. **Engineering Controls**

   Describe or list engineering controls that will be used to prevent or reduce employee exposure to hazards. Examples of engineering controls are fume hoods, glove boxes, interlocks on equipment, and shielding of various kinds.

7. **First Aid Procedures**

   Describe any emergency first aid procedures that should be followed in case of a chemical exposure. Provide specific detail on responses under specific circumstances of exposure (e.g. inhalation, ingestion, skin contact, etc.).

8. **Special Handling and Storage Requirements**

   Describe the storage requirements for hazardous substances, including special containment devices, special temperature requirements, special 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 lab. Describe any special procedures, such as dating peroxide forming chemicals on receipt, opening and disposal, or testing after an appropriate amount of time has passed. Describe safe methods of transport, such as in a secondary container using a low, stable cart, or using two hands to carry the chemical container.

9. **Spill and Accident Procedures**

   Describe special procedures for spills, releases or exposures (e.g., neutralizing agents, use of fluorescence to detect materials, etc.). Indicate how spills, accidental releases and exposures will be handled. List location of the following emergency equipment: chemical spill clean-up kit, first-aid kit, emergency shower, eyewash, and fire extinguisher.

   Indicate the designated area established for experiments using particularly hazardous substances (PHS). A portion of a lab bench, a piece of equipment, the fume hood, or the entire lab may be considered as a designated area for experiments using PHS.

10. **Decontamination procedures and waste disposal procedures**

    Describe specific decontamination procedures for equipment, glassware or work areas. Describe the anticipated waste products as well, as how waste will be collected and disposed.

11. **Safety Data Sheet location**

State where the SDSs are kept for the chemicals, or hazardous substances, used in the lab. Indicate the location of other pertinent safety information (e.g., references, equipment manuals, etc.).

12. Protocols

Insert a copy of your specific lab procedures for the process, hazardous chemical or chemical hazard class.

13. Documentation of training

A list of personnel who have reviewed the SOP. A signature and date of training are needed to complete the table.

Appendix F

Personal Protective Equipment Hazard Assessment

Certificate of Hazard Assessment | Personal Protective Equipment, or PPE

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

Instructions: Identify the workplace location. Conduct a walkthrough survey of the workplace and list the task or job functions that require PPE. Ensure PPE has an acceptable ANSI rating based on the chart provided on the back of this sheet. Conduct interviews with employees while performing field observations when necessary and complete this form. Sign and date this certificate. The completed certificate should remain on file in your area as well as additional areas required by your department.

Please 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.

Location______________________________ **Department** ______________________

Task	Potential hazard	PPE required

Observation		
Are employees wearing PPE appropriate to tasks? □ Yes ⍰ No	Is PPE worn and adjusted properly? □ Yes ⍰ No	Is PPE maintained in good condition? □ Yes ⍰ No

If no, describe corrective action taken:

I,______________________________certify that the above location has been evaluated for potential hazards, the appropriate PPE and that training has been performed.

Signature of Assessor__________________________Date_______________________

PPE criteria

*ANSI criteria for protective equipment is as follows:

Protective equipment	Purchased after July 5, 1994			Purchased before July 5, 1994		
Eye and face protection	ANSI	Z87.1	1989	ANSI	Z87.1	1968
Head protection	ANSI	Z89.1	1986	ANSI	Z89.1	1969
Foot protection	ANSI	Z41	1991	ANSI	Z41.1	1967

*This form was taken from Arizona State Risk Management training handout for OSHA 1910.132 - Personal Protective Equipment

Appendix G

Hazardous Material Storage Guide

Arizona State University
Hazardous Material Storage Guide
General Rules and Principles

Stock containers of chemicals in ASU labs must be organized and stored in accordance with 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 lab. Specifically, it is designed to 1) protect flammables from ignition; 2) minimize the potential of exposure to poisons; and 3) segregate incompatible materials to prevent their accidental mixing.

A Designated storage place for each compound

Stock chemical containers should have a designated storage place and returned to that location after each use. Storage locations can be marked on containers.

Do not store excess supplies of chemicals on lab bench tops where they are unprotected from ignition sources or potentially damaged. Only chemicals in use or of low hazard (e.g., salts and buffers) are permitted on bench tops.

Do not store in 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 actually filling the container. In some instances, potential pressure build-up inside of containers poses a significant hazard; written SOPs should warn users about such a hazard and provide alternative guidance.

Alphabetical only within storage groups

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

Away from sun and heat

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

Storage under the sink

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.

Label chemicals and hazardous waste properly

All containers within the lab must be labeled according to the instructions in the ASU Chemical Hygiene Plan. 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 storage of solids and are subject to numerous and varied storage requirements.

Safeguard against theft

This plan does not require security measures (e.g., locked cabinets) to prevent theft, but lab workers should make sure that lab doors are locked when unattended.

Chemical 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 storage of liquids because of the variety of hazards posed by these chemicals. Specific instructions must be followed for metal hydrides (Group 8) and certain individual compounds, but otherwise, all dry solids are in Group 9.

How to determine correct storage group

Determine the correct storage group by the hazard information on the chemical container label, chemical Safety Data Sheet, or contact ASU EHS.

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 is the group representing the greatest 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°F Examples: all alcohols, acetone, acetaldehyde, acetonitrile, amyl acetate, benzene, cyclohexane, dimethyldichlorosilane, dioxane, ether, ethyl acetate, histoclad, hexane, hydrazine, methyl butane, picolene, piperidine, propanol, pyridine, some scintillation liquids, all silanes, tetrahydrofuran, toluene, triethylamine, and xylene

Primary Storage Concern: To protect from ignition.

Acceptable Storage Facilities/Methods:

- Flammable cabinet
- Explosion-proof refrigerator/freezer
- 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.

Group 2: Volatile Poisons

Includes poisons, toxics, and "select" and suspected carcinogens with strong odor or an evaporation rate greater than 1 (butyl acetate = 1). Examples: carbon tetrachloride, chloroform, dimethylformamide, dimethyl sulfate, formamide, formaldehyde, halothane, mercaptoethanol, methylene chloride, phenol.

Primary Storage Concern: To prevent inhalation exposures.

Acceptable Storage Facilities/Methods:

- Flammable cabinet
- Refrigerator for containers less than 1 liter

Compatible Storage Groups: Volatile poisons may be stored with flammables if bases are not present.

Group 3: Oxidizing Acids

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

Primary Storage Concern: Preventing contact and reaction with each other and other substances and corrosive action on surfaces.

Acceptable Storage Facilities/Methods:

- Safety cabinet
- Each oxidizing acid must be double-contained (i.e., the primary container must be kept inside a canister, tray or tub)

Compatible Storage Groups: Oxidizing acids must be double contained and should be segregated in their own compartment in a safety cabinet. When quantities are small (e.g., 1 or 2 small bottles) they do not warrant a separate compartment. Small quantities may be double contained and stored with Group 4 Organic and Mineral Acids. Store oxidizing acids on the bottom shelf see section below Group 4.

Group 4: Organic and Mineral Acids

Organic and mineral acids. Examples: acetic, butyric, formic, glacial acetic, hydrochloric, isobutyric, mercaptoproprionic, proprionic, trifluoroacetic acids.

Primary Storage Concern: To prevent contact and reaction with bases and oxidizing acids and corrosive action on surfaces.

Acceptable Storage Facilities/Methods:

- Safety cabinet

Compatible Storage Groups: Small amounts of double-contained oxidizing acids can be stored in the same compartment with 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.

Group 5: Liquid Bases

Liquid bases. Examples: sodium hydroxide, ammonium hydroxide, calcium hydroxide, glutaraldehyde

Primary Storage Concern: Preventing contact and reaction with acids.

Acceptable Storage Facilities/Methods:

- Safety cabinet
- In tubs or trays in a standard 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.

Group 6: Liquid Oxidizers

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

Primary Storage Concern: To isolate from other materials.

Acceptable Storage Facilities/Methods:

- Total quantities exceeding 3 liters must be kept in a cabinet housing no other chemicals

- Smaller quantities must be double-contained when stored near other chemicals (e.g., in a refrigerator)

Compatible Storage Groups: None

Group 7: Non-Volatile Liquid Poisons

Includes highly toxic (LD_{50} oral rat < 50 mg/kg) and toxic chemicals (LD_{50} oral rat < 500 mg/kg), "select carcinogens", suspected carcinogens, and mutagens. Examples: acrylamide solutions; Coomassie blue stain; diethylpyrocarbonate; diisopropyl fluorophosphate; uncured epoxy resins; ethidium bromide; triethanolamine

Primary Storage Concern: To prevent contact and reaction with other substances.

Acceptable Storage Facilities/Methods:

- Cabinet or refrigerator (i.e., must be enclosed)
- Do not store on open shelves in the lab or cold room
- Liquid poisons in containers larger than 1 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 (e.g., buffer solutions).

Exceptions: Anhydrides (e.g., acetic and trichloroacetic) are organic acids, however it is better to store them with this group since they are highly reactive with other acids.

Group 8: Metal Hydrides

Most metal hydrides react violently with water; some ignite spontaneously in air (pyrophoric). Examples: sodium borohydride, calcium hydride, lithium aluminum hydride

Primary Storage Concern: To prevent contact and reaction with liquids and, in some cases, air.

Acceptable Storage Facilities/Methods:

- Secure, waterproof double-containment according to label instructions
- Isolation from other storage groups

Compatible Storage Groups: If securely double contained to prevent contact with water and/or air, metal hydrides may be stored in the same area as Group 9 Dry Solids.

Group 9: Dry Solids

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

Primary Storage Concern: To prevent contact and potential reaction with liquids.

Acceptable Storage Facilities/Methods:

- Cabinets are recommended, but if not available, open shelves are acceptable
- Store above liquids
- Warning labels on highly toxic powders should be inspected and highlighted or amended to stand out against less toxic substances in this group
- It is recommended that the most hazardous substances in this group be segregated
- It is particularly important 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

Compatible Storage Groups: Metal hydrides, if properly double contained may be stored in the same area.

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.

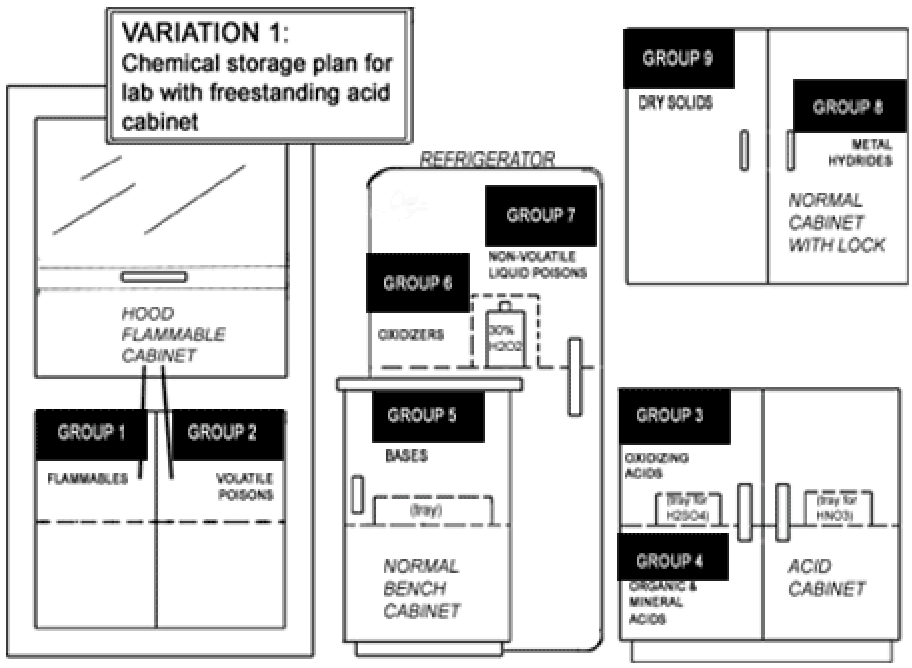
Storage Plan Variations for Different Lab Facilities

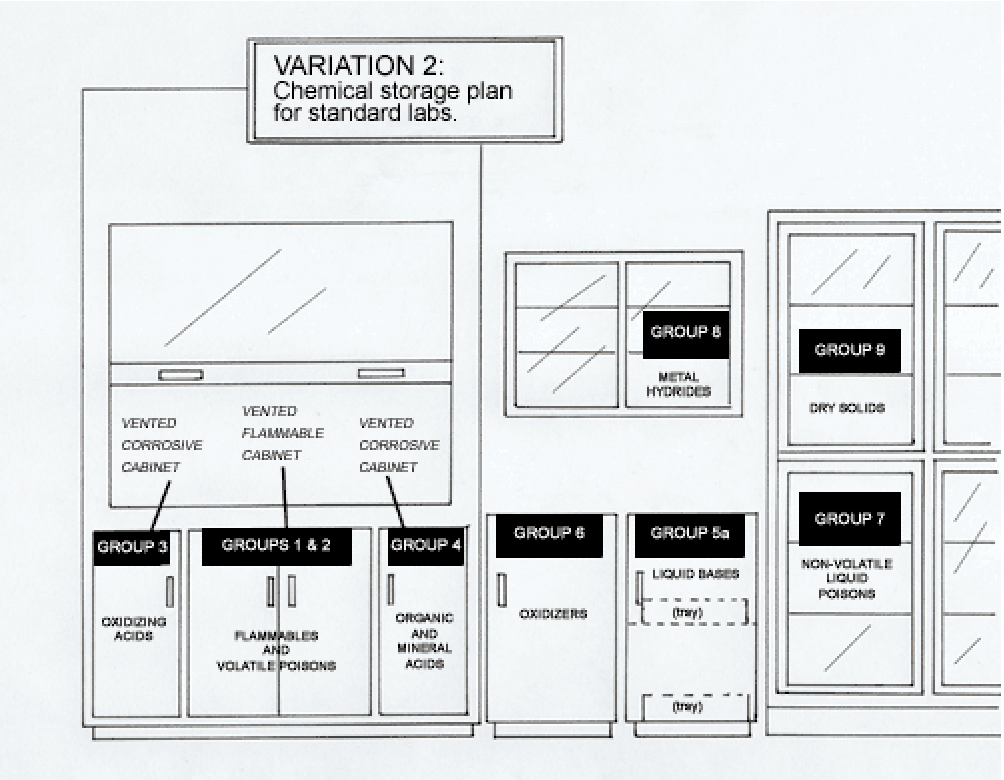
On the following pages are illustrations of possible (non-mandatory) chemical storage arrangements for two types of lab facilities. They are provided merely as examples of arrangements that satisfy the requirements of the chemical storage plan. They are not intended to restrict storage to the particular arrangements and facilities depicted. Refer to Storage Group Definitions for segregation and facility requirements.

The illustrations are titled as follows:

Variation 1: Chemical storage plan for lab with freestanding acid cabinet.

Variation 2: Chemical storage plan for standard labs.





Examples of incompatible chemicals

The following is not a complete listing of incompatible materials. It contains some of the more common incompatible materials. Always utilize research materials such as Safety Data Sheets you work with in order to work safely in the lab.

Chemicals listed in Column A should not be stored with or used near those in Column B.

Column A	Column B
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetic anhydride	Hydroxyl-containing compounds such as ethylene glycol, perchloric acid
Acetone	Concentrated nitric and sulfuric acid mixtures, hydrogen peroxide
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali and alkaline earth metals such as powdered magnesium, sodium, potassium	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, halogens
Ammonia (anhydrous)	Mercury, halogens, calcium hypochlorite, hydrofluoric acid
Column A	**Column B**

Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent
Azides	Acids, heavy metals and their salts, oxidizing agents
Calcium oxide	Water
Carbon, activated	All oxidizing agents, calcium hypochlorite
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organic or combustible material
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Chromic acid and chromium trioxide	Acetic acid, alcohol, camphor, glycerol, naphthalene, flammable liquids in general
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids (organic or inorganic)
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens, other oxidizing agents
Fluorine	All other chemicals
Hydrides	Water
Hydrocarbons (e.g., butane, propane, benzene)	Fluorine, chlorine, bromine, chromic acid, peroxides
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, any flammable liquid (i.e., alcohols, acetone), combustible materials, aniline, nitromethane
Column A	**Column B**
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen

Mercury	Acetylene, fulminic acid, ammonia
Metal hydrides	Acids, water
Nitrates	Acids
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, copper, brass, any heavy metals
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Mercury and silver and their salts
Oxygen	Oils, grease, hydrogen; flammable liquids, solids, or gases
Perchloric acid	Acetic anhydride, alcohol, bismuth, paper, wood, grease, oils
Permanganates	Concentrated sulfuric acid, glycerol, ethylene glycol, benzaldehyde
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorus, white	Air, oxygen, alkalis, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate	Sulfuric and other acids, ammonium salts, metal powders, sulfur, finely divided organics, combustibles
Potassium perchlorate (see also chlorates)	Sulfuric and other acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Silver and silver salts	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
Column A	**Column B**
Sodium	Carbon tetrachloride, carbon dioxide, other chlorinated hydrocarbons, 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, furfural
Sulfides	Acids
Sulfuric acid	Chlorates, perchlorates, permanganates

Adapted from *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals*, National Research Council, 1995

Basic Chemical Segregation

Hazard Class of Chemical	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.	Methane Hydrogen Acetylene Propane	Oxidizing and toxic compressed gases, oxidizing solids.
Compressed gases - Oxidizing	Store in a cool, dry area, away from flammable gases and liquids. Securely strap or chain cylinders to a wall or bench.	Oxygen Chlorine Bromine	Flammable gases
Compressed gases - Poisonous	Store in a cool, dry area, away from flammable gases and liquids. Securely strap or chain cylinders to a wall or bench.	Carbon monoxide Hydrogen sulfide Nitrogen dioxide	Flammable and/or oxidizing gases.
Hazard Class of Chemical	**Recommended Storage Method**	**Examples**	**Incompatibilities**
Corrosives - Acids	Store separately in acid storage cabinet. Segregate oxidizing acids (i.e., Chromic, nitric, sulfuric, and perchloric acids) from organic acids	Acetic acid Phenol Sulfuric acid Chromerge Nitric acid Perchloric acid Chromic acid Hydrochloric acid	Flammable liquids, flammable solids, bases, oxidizers
Corrosives - Bases	Store in separate corrosive storage cabinet. Store solutions of inorganic hydroxides in labeled polyethylene containers.	Ammonium hydroxide Sodium hydroxide Calcium hydroxide	Flammable liquids, oxidizers, poisons, and acids

Flammable Liquids	Store in flammable storage cabinet and away from sources of ignition. Store highly volatile flammable liquids in an explosion-proof refrigerator.	Acetone Benzene Diethyl ether Methanol Ethanol Toluene Glacial acetic acid	Acids, bases, oxidizers, and poisons
Flammable Solids	Store in a separate dry, cool area away from oxidizers, corrosives, flammable liquids	Phosphorus, yellow Calcium carbide Picric acid Benzoyl peroxide	Acids, bases, oxidizers, and poisons
General Chemicals - Non-reactive	Store on general lab benches or shelving preferably behind glass doors and below eye level.	Agar Sodium chloride Sodium bicarbonate Most non-reactive salts	See specific SDS.
Water-Reactive Chemicals	Store in dry, cool location, protect from water fire sprinkler.	Sodium metal Potassium metal Lithium metal Lithium aluminum hydride	Separate from all aqueous solutions and oxidizers.
Hazard Class of Chemical	**Recommended Storage Method**	**Examples**	**Incompatibilities**
Oxidizers	Store in a spill tray inside a chemical storage cabinet. Separate from flammable and combustible materials.	Ammonium persulfate Ferric chloride Iodine Sodium hypochlorite Benzoyl peroxide Potassium permanganate Potassium dichromate The following are generally considered oxidizing substances: Peroxides, perchlorates, chlorates, nitrates, bromates, and superoxides.	Separate from reducing agents, flammables, and combustibles.
Poisons/Toxic Compounds	Store separately in vented, cool, dry area, in unbreakable chemically	Aniline Carbon tetrachloride	Flammable liquids, acids, bases, and oxidizers.

	resistant secondary containers and in accordance with the hazardous nature of the chemical.	Chloroform Cyanides Heavy metals compounds, i.e., cadmium, mercury, osmium Oxalic acid Phenol Formic acid	See specific SDS.
Carcinogens	Label all containers as "Cancer Suspect Agents". Store according to the hazardous nature of the chemical, using appropriate security when necessary.	Benzidine Beta-naphthylamine Benzene Methylene chloride Beta-propiolactone	See specific SDS.
Hazard Class of Chemical	**Recommended Storage Method**	**Examples**	**Incompatibilities**
Teratogens	Label all containers as "Suspect Reproductive Hazard". Store according to the hazardous nature of the chemical, using appropriate security when necessary.	Lead and mercury compounds Benzene Aniline	See specific SDS.
Peroxide-Forming Chemicals	Store in airtight containers in a dark, cool, dry area. See Table 3 for recommended storage time limits.	Diethyl ether Acetaldehyde Acrylonitrile	See specific SDS.
Strong Reducing Agents	Store in cool, dry, well-ventilated location. Water reactive. Segregate from all other chemicals.	Acetyl chloride Thionyl chloride Maleic anhydride Ferrous sulfide	See specific SDS.

Suggested storage time limits for common peroxide crystal forming compounds

Peroxide formation occurs when certain lab chemicals react with air at ordinary temperatures to form peroxy compounds, which are violently reactive or explosive. Organic peroxides are classified as low-power explosives that are hazardous because of the sensitivity 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 rate of decomposition under a given set of conditions. Due to unusual stability problems, bulk quantities of peroxides should be approached with caution because they may generate enough heat to auto accelerate up to ignition. Peroxides/Peroxide forming chemicals include, but are not limited to the following lists.

MOST DANGEROUS: Discard after 3 months. Peroxide formation hazard during storage.	
Diisopropyl ether Divinyl acetylene Isopropyl ether	Potassium metal Sodium amide Vinylidene chloride

DANGEROUS: Discard after one year. Peroxide formation hazard during storage and on concentration (i.e., distillation) of compound.		
Acetal Acetaldehyde Cumene Cyclohexene Diacetylene	Dicyclopentadiene Diethyl ether 1,4-Dioxane Ethylene glycol dimethyl ether Methyl acetylene	Methyl cyclopentane Methyl isobutyl ketone Tetrahydrofuran Tetrahydronaphthalene Vinyl ethers

DANGEROUS: Discard after one year. Peroxide formation causes initiation of hazardous polymerization.		
Acrylic acid Acrylonitrile 1,3-Butadiene 2-Butanol	Chloroprene Chlorotrifluoroethylene Methyl methacrylate 2-Propanol Styrene	Tetrafluoroethylene Vinyl acetate Vinyl acetylene Vinyl chloride Vinyl pyridine

Appendix H

Guidelines for Nanotechnologies Related Research

Nanotechnology is an emerging industry and area of research that involves the engineering of items on a molecular level. For years now, experts have been heralding the 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. Reason for concern related to potential ASU EHS risks associated with nanotechnologies and in particular, carbon nanotubes, have recently surfaced. For this reason, ASU EHS's department is recommending an approach referred to as control banding to address the potential risks associated with research in areas concerned with nanotechnologies.

Control banding, or CB is a strategy for qualitative risk assessment and management of hazards in the workplace. The strategy involves a process to group workplace risks into control bands based on combinations of hazard and exposure information. CB strategies are not intended to be predictive exposure models. The table below provides general guidelines for specific nanotechnologies already in use in many areas of research. It is recommended that this table be used a guideline for develops 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 – NSL 1 **Nanomaterials consist of Little to no harm - known to be inert**	
Scenario Description	**Name or Description of Nanomaterial**
Gold nanoparticles used to test carbon nanotube filter	Gold nanoparticles
Mixed polystyrene spheres with buffer, etching nanostructures onto semiconductors.	Polystyrene spheres, nanostructures
Deposition of liquid-suspended nanoparticles onto surfaces using low voltage electric fields	Polymer latex, gold, platinum, palladium nanoparticles
Preparation of examples. Activities include cutting, slicing, grinding, lapping, polishing, chemical etching, electrochemical polishing and ion etching	Carbon black, Aluminum (Al) oxide, Mg oxide, polycrystalline diamond suspension, colloidal silica, Palladium (Pd) power, carbon nanotubes
Sample preparation and characterization	Gold, silver nanoparticle, Iron oxide, silicon dioxide, aluminum oxide, carbon, ceramic aerogels and nanopowders
Synthesis of aerogel	Silica, iron, chromium, copper, zinc nanoparticles, titanium nanoparticles
Required: Engineering Controls	**General Ventilation**
	General HVAC
Required: Personal Protective Equipment	**Lab coat, safety glasses/goggles single nitrile gloves**

Yellow – NSL 2 Nanomaterials consist of Potential Hazards(s)	
SCENARIO DESCRIPTION	**NAME OR DESCRIPTION OF NANOMATERIAL**
Synthesis of metal oxide nanowires on substrates within a tube furnace	Zinc oxide (ZnO), Tin Oxide (SnO2), Titanium Oxide (TiO2), Lead zirconium titanium oxide (PBZrTiO3), Barium Titanium oxide (BaTiO3) and Strontium Titanium oxide (SiTiO3) nanowires
Synthesis of silver and copper oxide nanoparticles	Silver (Ag) oxide nanoparticles, Copper (Cu) oxide nanoparticles
Addition of quantum dots onto porous glass	Cadmium selenide, lead sulfide
Growth of palladium nanocatalyst	Palladium nanocatalyst
Water is poured into container with liquid-suspended carbon nanotubes	Carbon nanotubes
Analysis of nanomaterial waste samples in to lab	Various
Purification and functionalization of carbon nanotubes	Carbon nanotubes
Synthesis and optical characterization of nanoparticles	Cadmium Selenium (CdSe) quantum dots, germanium quantum dots, iron oxide, gold, lead sulfide nanoparticles
Sample preparation and characterization of CdSe Nano dots	Cadmium Selenium (CdSe) quantum dots
Sample preparation and characterization of carbon diamonoids	Carbon diamonoids
Sample preparation and characterization using laser microscopy	Gold, silver nanoparticles
SCENARIO DESCRIPTION	**NAME OR DESCRIPTION OF NANOMATERIAL**
Preparation of nanofoams sample for microscopy	Gold, copper, aluminum, nickel nanoparticles
Preparation of carbon nanotubes sample for microscopy	Carbon nanotubes
Machining (e.g., turning, milling) of aerogels and nanofoams for target assembly	Silica aerogels, tantulum aerogels, metal nanofoams (copper, gold), carbon nanofoams
Site wide waste sampling activities	Various
Waste accumulation area activities, including waste management, waste packaging, etc.	Various
Radioactive and Hazardous Waste Management field tech activities,	Various

including waste management, waste packaging, waste sampling, etc.	
Required: Engineering Controls	**Fume hood or BSL**
	
Required: Personal Protective Equipment	**Lab coat, safety glasses/goggles, single nitrile gloves**
	

Orange – NSL 3 Nanomaterials – limited information is known	
SCENARIO DESCRIPTION	**NAME OF DESCRIPTION OF NANOMATERIAL**
Activities related to operating and maintaining a vertical tube quench furnace and horizontal tube furnace	Gold, (Ag) Copper (Cu) Nickel (Ni) brass, Silver (Au) and Platinum (PT) nanoparticles
Required: Engineering Controls	**Glove box, fume hood with HEPA or hard ducted BSC**
	
Required: Personal Protective Equipment	**Lab coat, safety glasses/goggles, double nitrile gloves**
	

RED – NSL 4 Nanomaterials information is unknown Inhalation hazard	
SCENARIO DESCRIPTION	**NAME OF DESCRIPTION OF NANOMATERIAL**
Nanomaterial is attached to a chemical that is carcinogenic, etc.	
Required: Engineering Controls	**Glove box, fume hood with HEPA or hard ducted BSC**
	

Required: Personal Protective Equipment	Lab coat, safety glasses/goggles double nitrile gloves and N95/N100 respirator
	

Appendix I

Maximum Allowable Storage Quantities
International Fire Code, 2018 Revision, Table 5003.1.1(1)

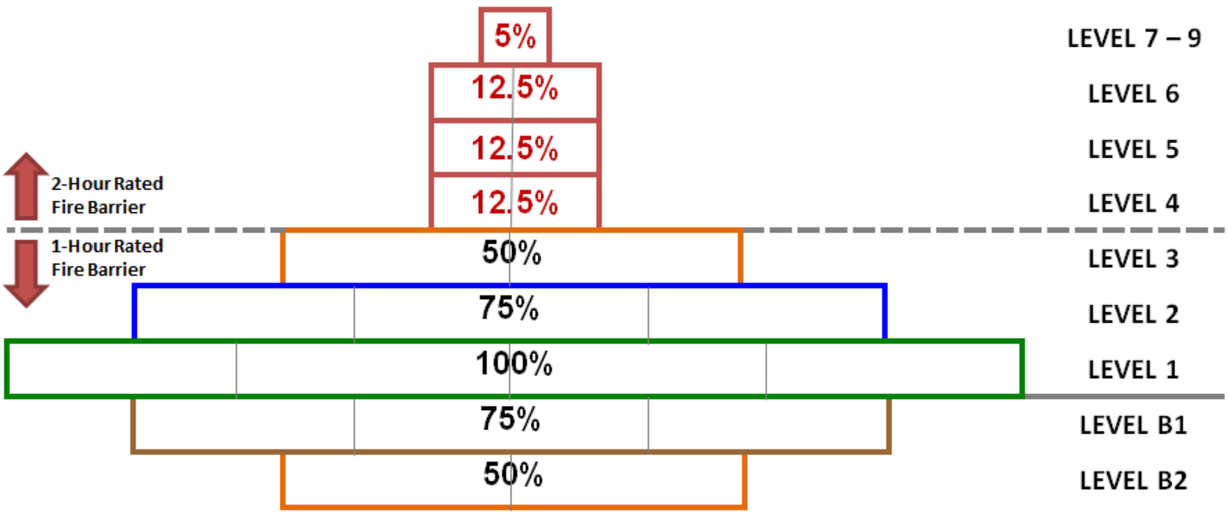
TABLE 5003.1.1(1)

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 Baled[o]	H-3	(100) (1,000)	NA	NA	(100) (1,000)	NA	NA	(20) (200)	NA
Combustible liquid[c, i]	II IIIA IIIB	H-2 or H-3 H-2 or H-3 NA	NA	120[d, e] 330[d, e] 13,200[e, f]	NA	NA	120[d] 330[d] 13,200[f]	NA	NA	30[d] 80[d] 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 Liquefied	H-2	NA	NA (150)[d, e]	1,000[d, e] NA	NA	NA (150)[d, e]	1,000[d, e] NA	NA	NA
Flammable liquid[c]	IA IB and IC	H-2 or H-3	NA	30[d, e] 120[d, e]	NA	NA	30[d] 120[d]	NA	NA	10d 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 Liquefied	NA NA	NA NA	NA NA	NL NL	NA NA	NA NA	NL NL	NA NA	NA NA
Organic peroxide	UD I II III IV V	H-1 H-2 H-3 H-3 NA NA	1[e, g] 5[d, e] 50[d, e] 125[d, e] NL NL	(1)[e, g] (5)[d, e] (50)[d, e] (125)[d, e] NL NL	NA	0.25[g] 1[d] 50[d] 125[d] NL NL	(0.25)[g] (1)[d] (50)[d] (125)[d] NL NL	NA	0.25[g] 1[d] 10[d] 25[d] NL NL	(0.25)[g] (1)[d] (10)[d] (25)[d] NL NL
Oxidizer	4 3[k] 2 1	H-1 H-2 or H-3 H-3 NA	1[g] 10[d, e] 250[d, e] 4,000[e, f]	(1)[e, g] (10)[d, e] (250)[d, e] (4,000)[e, f]	NA	0.25[g] 2[d] 250[d] 4,000[f]	(0.25)[g] (2)[d] (250)[d] (4,000)[f]	NA	0.25[g] 2[d] 50[d] 1,000[f]	(0.25)[g] (2)[d] (50)[d] (1,000)
Oxidizing gas	Gaseous Liquefied	H-3	NA	NA (150)[d, e]	1,500[d, e] NA	NA	NA (150)[d, e]	1,500[d, e] NA	NA	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 3 2 1	H-1 H-1 or H-2 H-3 NA	1[e, g] 5[d, e] 50[d, e] NL	(1)[e, g] (5)[d, e] (50)[d, e] NL	10[e, g] 50[d, e] 750[d, e] NL	0.25[g] 1[d] 50[d] NL	(0.25)[g] (1)[d] (50)[d] NL	2[e, g] 10[d, e] 750[d, e] NL	0.25[g] 1[d] 10[d] NL	(0.25)[g] (1)[d] (10)[d] NL
	3	H-2	5[d, e]	(5)[d, e]		5[d]	(5)[d]		1[d]	(1)[d]

MAXIMUM ALLOWABLE QUANTITY PER BUILDING LEVEL OF HAZARDOUS MATERIALS POSING A PHYSICAL HAZARD
TABLE 5003.8.3.2, INTERNATIONAL FIRE CODE, 2018, TABLE APPEARANCE MODIFIED FOR ASU CHP



Appendix J

Vacuum Pump and Vacuum System Safety Guidance

GENERAL SAFETY PRACTICES FOR UTILIZING VACUUM PUMPS AND HOUSE VACUUM SYSTEMS WITH CHEMICAL SOLUTIONS

Vacuum Pumps

1) Inspect all lab vacuum pumps used with chemicals and verify that they do not vent into general room air. If the system vents into general room air and cannot be vented into the lab hood or local exhaust system, contact ASU EHS 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 in such a manner as 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 vacuum equipment safely and understand that cold traps must be monitored to ensure they do not go dry.

House Vacuum Pumps

House vacuum systems are evaluated by ASU EHS and CPMG during installation and are designed to vent potentially hazardous materials in a controlled manner to prevent potential exposure to lab personnel. However, this does not eliminate user responsibilities 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 significant amount of potentially hazardous material from contaminating the house vacuum system. Contamination of the house vacuum system may lead to vacuum system down time and impact all labs in the building.

Procedure for working on contaminated lab vacuum pumps and systems

The following information is provided as guidance to minimize potential chemical exposure while performing maintenance or repair on lab vacuum pumps. This is a brief overview only. More information is available from ASU EHS. Please forward an e-mail message to SafetyPartners@asu.edu or contact us at 480-965-1823 if more information is needed.

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, facilities personnel could potentially be exposed to small amounts of a variety of hazardous materials, during removal, maintenance or reconfiguration of vacuum systems.**

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

- For **small vacuum systems using portable pumps**, attempt to identify specific hazardous chemicals entering the system by conferring with lab personnel regarding the uses of vacuum systems and the extent that traps or other control devices have been used. If the history of usage indicates that, a dangerous material has been used in the system and may have potentially left residue or hazardous byproducts, disconnect the pump and conduct all service operations within a lab fume hood. If this is not possible, contact ASU EHS at 480-965-1823.
- For **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.
- 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.
- Close appropriate valves to isolate effected parts of the system.
- **Where possible, purge the system with clean air before beginning work.**
- **Ensure there is proper ventilation to the work area, particularly when working in small areas. Use of portable ventilation systems or closed systems designed to route displaced air to a safe location are recommended.**
- 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.
- If cutting or other work generates dusts, safety glasses with side shields are indicated. If work generates mists or the possibility of liquid splash, goggles are indicated.
- If applicable, remove sealing liquid carefully. Avoid splashing or excessive pouring. Place in a sealed container. Liquid should be containerized and disposed of as a hazardous waste. Smaller vacuum pumps or systems can be drained in lab hoods to avoid exposure.
- Sealing liquid that is removed during the course of service must be disposed of as a hazardous waste. If you have any questions regarding hazardous waste contact ASU EHS Hazardous Waste at 480-965-8554.
- Reusable gloves, drop cloths and coveralls may be rinsed or laundered and reused. Disposable or damaged personal protective equipment can be disposed of as regular trash.

- Always wash hands after service activities.

IMPORTANT! Reactions involving highly reactive compounds such acetylene, butadiene, dioxane, ethylene oxide, oxygen and all strong oxidizing agents, must be handled with caution.

What is a Pressure Vessel?
Based on the ASME Code Section VIII, pressure vessels are containers for the containment of pressure, either internal or external. This pressure may be obtained from an external source or by the application of heat from a direct or indirect source, or any combination thereof. Generally, a pressure vessel is a storage tank or vessel that has been designed to operate at pressures above 15 p.s.i.g.
Examples include glassware, autoclaves, compressed gas cylinders, compressors (including refrigeration), vacuum chambers, and custom designed lab vessels.

What are the Hazards associated with Pressure Vessels?
The pressure differential (whether created from chemical reaction, compressed gas, heating, chilling or vacuum), cracked/damaged vessels or leakage from vessels are all potential hazards.

Two consequences result from a complete rupture:

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

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

- Suffocation or poisoning, depending on the nature of the contained fluid, if the leakage occurs into a closed space.

- Fire and explosion (physical hazards for a flammable fluid).
- Chemical and thermal burns from contact with process liquids.

How to Use and Handle Pressure Vessels Safely

1. Select a reactor or pressure vessel, which has the capacity, pressure rating, corrosion resistance, and design features that are 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) take the following steps to prevent personal injury:

   - Use a metal or shatter proof glass or plastic screen to protect personnel from physical injury;

   - 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;

   - Make sure the regulator is appropriate or designed for the system;

   - Periodically inspect the set up for physical damage or stress. If not sure what to look for contact ASU EHS.

   - Use a lower pressure or a different system (e.g., a pump) if it will not adversely affect the research;

   - Consider all conditions that may affect the pressure vessel (gas versus liquid, heated/cooled, corrosion, etc.);

3. Install and operate the equipment within suitable barricade, if required, using appropriate safety accessories.

4. Establish training procedures to ensure that any person handling the equipment knows how to use it properly.

5. Maintain the equipment in good condition and establish procedures for periodic testing to be sure that the vessel remains structurally sound.

Ventilation
The room in which a pressure vessel will be operated must be well ventilated. This is particularly important when working with flammable or toxic material. Labs are considered well-ventilated rooms. The reactors should be located close to a lab hood or exhaust fan so that any released gases can be discharged safely. There should be no open flames 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 most subtle and 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 is not sufficient to accommodate the expanding the 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 °C. If the free space in the vessel is not sufficient to accommodate this expansion, destructive pressures will develop very suddenly and unexpectedly.

Maintenance and training
The user must realize that it is his/her responsibility to keep the vessel in good condition and to use it only within the prescribed temperature and pressure limits. User must be constantly aware of the serious consequences that can result from 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 be sure that all safety rules are being observed.

For more information
Contact ASU EHS at SafetyPartners@asu.edu or 480-965-1823 if you have questions or need assistance.

Additional information is available through the Arizona Division of Occupational Safety

and Health
Section R20-5-404. Standards for Boilers, Lined Hot Water Heaters and Pressure Vessel
azica.gov/divisions/adosh/boiler-section

Appendix K

Safe Handling Procedures for Cryogenic Materials

General precautions for all use of liquid nitrogen and other cryogenic materials:

Liquid nitrogen and all other cryogenic materials can cause significant burns. Hand protection and goggles (not safety glasses) are to be worn at all times when handling liquid nitrogen. When handling large quantities, a full-length apron will minimize the chance of a spill going into your shoes, where it 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/pants or a full-length apron, and footwear that cover the entire foot.

1. **Properties**

Liquid nitrogen is a colorless, odorless liquid with a boiling point of -196^0 C. At low temperatures the gas/ vapor is heavier than air. Small amounts of liquid vaporize rapidly to produce large volumes of gas (1 liter of liquid nitrogen will produce 0.7m^3 of gas). Nitrogen gas is invisible - the cloudy vapor which appears when liquid nitrogen is exposed to air is condensed moisture, not the gas itself.

2. **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 nitrogen gas which is inert and non-toxic but there is a risk of asphyxiation in situations where high concentrations may accumulate and subsequently displace air from the room. Short exposures to cold gas vapor leads to discomfort in breathing whilst prolonged inhalation can produce serious effects on the lungs and could also result in death.
Cryogenic burns: Liquid nitrogen can cause cryogenic burns if the substance itself, or surfaces which are or have been in contact with the substance (e.g. metal transfer hoses), come into contact with 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.
Frostbite: Continued exposure of unprotected flesh to cold atmospheres can result in frostbite. There is usually sufficient warning by local pain whilst the freezing action is taking place.
Hypothermia: Low air temperatures arising from the proximity of liquefied gases can cause hypothermia. Susceptibility is dependent upon temperature, exposure time and the individual concerned (older people are more likely to succumb).
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. Adequate pressure relief must be provided to all parts of a system to permit this routine out gassing and prevent explosion.
Explosions – Chemical: Cryogenic fluids with a boiling point below that of liquid oxygen are able to condense oxygen from the atmosphere. Repeated replenishment of the system can thereby 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, e.g. rapid combustions or explosion, may occur if the materials which make contact with the oxygen are combustible.

3. **Personal Protective Equipment (PPE)**

Always wear proper PPEs when handling liquid nitrogen.

- Hands - non-absorbent insulated gloves must always be worn when handling anything that is or has been in recent contact with liquid nitrogen. Cryogenic gloves are designed to be used in the vapor phase only and should not be immersed into liquid nitrogen under any circumstances. They should be a loose fit to facilitate easy removal. Gauntlet style gloves are not recommended for some liquid handling uses as liquid can drip into them and become trapped against the skin - sleeves should cover the ends of gloves or alternatively, a ribbed cuff style may be used.

- Face - a full face visor should be used to protect the eyes and face where splashing or spraying may occur
- Body - a laboratory coat or overalls should be worn at all times. Non-absorbent cryogenic aprons are also commercially available. Open pockets and turn-ups where liquid could collect should be avoided.
- Trouser bottoms should overlap boots or shoes for the same reason
- Feet - sturdy shoes with a re-enforced toecap are recommended for handling liquid nitrogen vessels. Open toed shoes should not be worn under any circumstances.
- Guard against pressure build-up by using a pressure relief vessel or a venting lid. Remove metallic jewelry/watches on hand and wrists

When not in use, all PPE should be stored in an appropriate manner (e.g. visors on wall mounted hooks) to ensure that it does not become damaged or contaminated.

4. **Training**

All liquid nitrogen users must be made aware of the properties and hazards and be fully trained in the local departmental procedures for usage, storage and transportation before they engage in handling the substance.

5. **First Aid**
    - 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 whilst medical attention is obtained. If breathing has stopped then resuscitation should be commenced by a trained first aider.
    - 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 (40ºC) for at least 15 minutes and a sterile burn dressing applied to protect the injury until the person can be taken to receive hospital treatment.

Do NOT:

- use a direct source of heat such as a radiator
- permit smoking or alcohol consumption
- give analgesics (e.g. Paracetamol, aspirin)

For major injuries apply first aid as far as is practicable and arrange for the victim to receive medical attention.

6. **Storage & Use**

Ventilation is a key issue. Large scale vacuum insulated tanks are normally 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:

- store below 50°C in well ventilated place
- ensure appropriate hazard warning signs are displayed (yellow triangle with exclamation symbol and text: ‘Liquid nitrogen’)
- use only properly specified equipment for storing liquid nitrogen

With regard to general use:

- do not leave vessels unattended when filling
- use only proper transfer equipment
- do not overfill vessels
- with non-pressurized containers, do not plug the entrance with any device that would interfere with the venting of gas. Use only the loose-fitting neck tube core or an approved accessory
- do not use brittle plastics which may shatter on contact with the cold liquid
- do not use hollow dipsticks - use solid metal or wood
- 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 when inserting objects into these liquids.
- never tamper or modify safety devices such as cylinder valve or regulator of the tank

Departments have a responsibility to monitor all procedures to ensure that lab rules are being complied with.
When working with liquid nitrogen in Cold Rooms, following points should be considered:

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

7. Maintenance

All static and transportable pressurized vessels must be maintained and tested in accordance with the Pressure Systems Safety Regulations. Completion of a written standard operating procedure and the periodic examination itself is usually carried out by trained personnel. Any obvious 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 until.
Forced ventilation systems and oxygen deficiency alarms should be maintained in good working order.

8. Rules for decanting liquid nitrogen storage tank

- All users must be trained and authorized to dispense liquid nitrogen from storage vessel
- Liquid nitrogen may only be dispensed into containers designed for liquid nitrogen use
- Liquid nitrogen and other cryogenic materials are to be dispensed only into smaller dewars which either have carrying handles or are on wheels, and which have pressure relief valves or pressure venting lids. A wide-base Dewar which is stable on a wheeled cart qualifies as on wheels.
- Wear proper PPE (gloves and eye/face protection) at all times during the dispensing process. Persons filling dewars should wear full-length trousers/pants or full-length apron, and footwear that covers the entire foot, along with goggles, face shield, hearing protection and cryo-gloves. Persons filling must be in constant awareness of the filling operation. To prevent splashing, place the filling hose at or below the mouth of the receiving vessel.
- If raining ensure people are warned of possible slippery surface
- If liquid is leaking from delivery hose or joints, stop filling and report the problem.

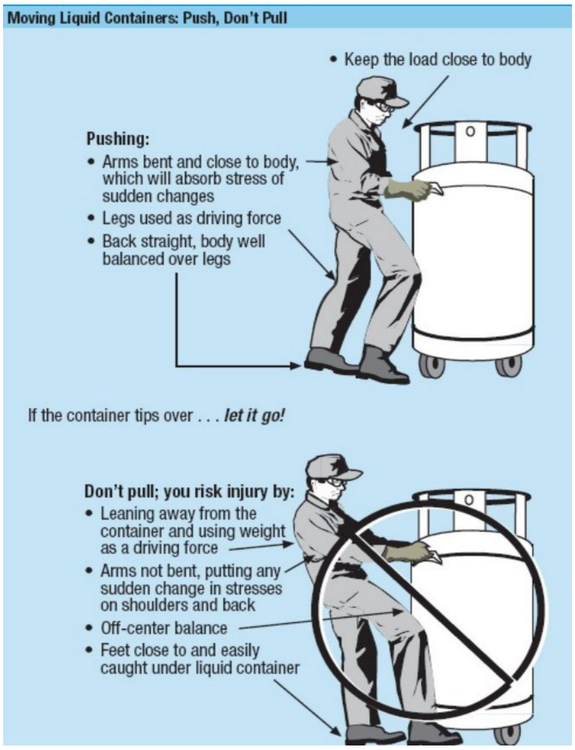
- If liquid nitrogen from the pressurized storage dewar is handled out of office hours (8am -5pm), it must be carried out by two trained members of staff working together to allow for the alarm to be raised if there is an incident/accident.

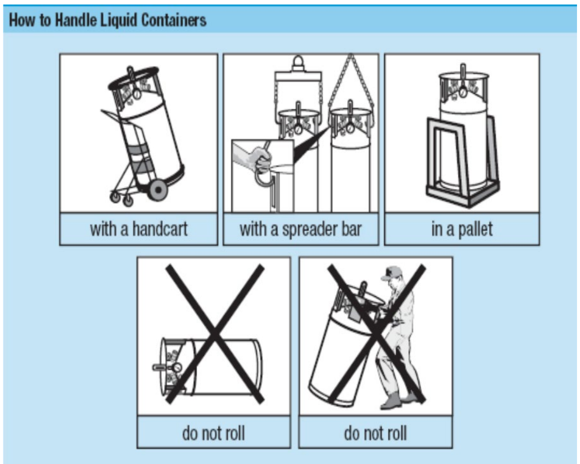
9. Transportation of Vessels within the Department

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 persons particularly 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 a building or between buildings should be equipped with a braking mechanism. Do not use feet to “brake” wheels. Take care to 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:

- rest stops
- movement through populated work areas
- possible obstructions and clutter
- lifts
- floor surfaces (are they sound and even?)
- curbs
- stairs (hazardous due to potential for 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 arranges 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 Environmental Health and Safety. Small quantities of chemicals (i.e., one box may be transported in their original shipping container on a pushcart. When crossing public streets two people should be involved, one observing for traffic and the other moving the cart with hazardous materials. Inside buildings the best transport from room to room is by using a Dewar that is equipped with carrying handles or is on wheels, and which have pressure relief valves or pressure venting lids. Note: A wide-base Dewar that is 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 which have no handles, as long as:

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

Transport of nitrogen and other cryogenic materials on an elevator Care must be exercised when transporting pressurized liquid cryogenic material containers on an elevator. Due to the confined nature of an elevator, a nitrogen gas or other cryogenic material leak from a pressurized container could produce an oxygen deficient atmosphere in a very small amount of time through the displacement of oxygen.

- When a pressurized container has been placed on an elevator, the elevator must travel between floors unoccupied.
- All elevator doors should be manned to prevent entry or signage placed on the dewar to prevent riders from entering elevator.
- 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.
- Do not transport a pressurized container of liquid nitrogen or cryogenic material at any time in an elevator with any other person/s in the elevator car.
- If the elevator cannot be operated to prevent unauthorized entry, then a sign must be posted on the dewar itself to warn anyone observing the dewar in the elevator not to enter. See example below.

10. Emergency Procedures

In the event of a large spillage or accidental release, the following procedures should be followed:

- Call 911
- Evacuate the area. Alert the others in the area. Deploy warning signs as necessary.
- Ventilate the area. Open doors and windows or activate forced ventilation to allow any spilt liquid to evaporate and the resultant gas to disperse.
- Try to stop the release if at all possible e.g. turn off valves, but only if it is safe to do so - always wear protective clothing.
- Do not re-enter area unless it is proved safe to do so. The presence of oxygen deficiency monitors will indicate the oxygen levels in the vicinity.
- Prevent liquid nitrogen from entering drains, basements, pits or any confined space where accumulation may be dangerous.

Appendix L

INTERDISCIPLINARY RESEARCH

Interdisciplinary research is encouraged at ASU. In conducting this type of research, it is common to have researchers trained primarily in a single discipline such as biology or physics conducting researcher-requiring expertise from several disciplines. In those cases, it is recommended that PI leading that research involve a PI from each discipline involved in that research in the review and design of safety protocols. The standard approach to lab chemical safety addressed in the OSHA Laboratory Standards Appendix A includes general principles on minimizing risks. Several of those principles are highlighted here and recommended for use in evaluating potential hazards of interdisciplinary research.

The risk of lab injuries can be reduced through adequate training, improved engineering, good housekeeping, safe work practice and personal behavior.

Lab personnel should conduct their work under conditions that minimize the risks from both known and unknown hazardous substances. Before beginning any lab work, the hazards and risks associated with an experiment or activity should be determined and the necessary safety precautions implemented. Every lab should develop facility-specific policies and procedures for the highest-risk materials and procedures used in their lab. To identify these, consideration should be given to past accidents, process conditions, chemicals used in large volumes, and
particularly hazardous chemicals.

Perform Risk Assessments for Hazardous Chemicals and Procedures
Prior to lab work:

(a) Identify chemicals to be used, amounts required, and circumstances of use in the experiment. Consider any special employee or lab conditions that could create or increase a hazard. Consult sources of safety and health information and experienced scientists to ensure that those conducting the risk assessment have sufficient expertise.

(b) Evaluate the hazards posed by the chemicals and the experimental conditions. The evaluation should cover toxic, physical, reactive, flammable, explosive, radiation, and biological hazards, as well as any other potential hazards posed by the chemicals.

(c) For a variety of physical and chemical reasons, reaction scale-ups pose special risks, which merit additional prior review and precautions.

(d) Select appropriate controls to minimize risk, including use of engineering controls, administrative controls, and personal protective equipment to protect workers from hazards. The controls must ensure that OSHA's Permissible Exposure Limits (PELs) are not exceeded. Prepare for contingencies and be aware of the institutional procedures in the event of emergencies and accidents.

One sample approach to risk assessment is to answer these five questions:

(a) What are the hazards?
(b) What is the worst thing that could happen?
(c) What can be done to prevent this from happening?
(d) What can be done to protect from these hazards?
(e) What should be done if something goes wrong?

2. Avoid underestimation of risk

Even for substances of no known significant hazard, exposure should be minimized; when working with substances that present special hazards, special precautions should be taken. Reference should be made to the safety data sheet, or SDS, that is provided for each chemical. Unless otherwise known, one should assume that any mixture will be more toxic than its most toxic component and that all substances of unknown toxicity are toxic.

Determine the physical and health hazards associated with chemicals before working with them. This determination may involve consulting literature references, lab chemical safety summaries (LCSSs), SDSs, or other reference materials. Consider how the chemicals will be processed and determine whether the changing states or forms will change the nature of the hazard. Review your plan, operating limits, chemical evaluations and detailed risk assessment with other chemists, especially those with experience with similar materials and protocols.

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 that the risks and hazards associated with exposure to engineered nanomaterials are not well known. 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 sources of ignition, accelerants, and fuel that could result in fire or explosion. Easily dispersed dry nanomaterials may pose the greatest 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.

Consideration should be given to all possible routes of exposure to nanomaterials including 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, whether suspended in liquids or in a dry particle form, in closed (tightly sealed) containers. Unless cutting or grinding occurs, nanomaterials that are 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 only consider the final material in the risk assessment, but consider the hazardous properties of the precursor materials as well.

To minimize lab personnel exposure, conduct any work that could generate engineered nanoparticles in an enclosure that operates at a negative pressure differential compared to the lab personnel-breathing zone. Limited data exist regarding the efficacy of PPE and ventilation systems against exposure to nanoparticles. 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 level of hazard according to the requirements set forth in OSHA's Personal Protective Equipment Standard.

Appendix M

Glove box safety tips

A glove box is a sealed container used to manipulate materials where a separate atmosphere is desired. They are commonly used to protect workers from hazardous materials or to protect 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 are used to protect workers and are used for hazardous materials such as toxic gases or pathogens.

Daily inspections

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

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

Other considerations:

- If it is a shared glove box, assign 1 or 2 senior people in the lab to ensure that all maintenance on the box and components are up-to-date.
- Maintain service contracts with the manufacturer and have them perform routine maintenance on the system.
- Avoid abruptly extending gloves into the box, this can severely stress the system and cause an over pressurization.
- Use nitrile gloves on the glove box gloves. This extends the life of the glove box gloves and helps to avoid cross contamination and makes cleanup easier
- Train all individuals working in the box. Document this training in a lab specific training file.
- Maintain a log of user and require each user to record date and time of use, and any pertinent parameters that ensure proper glove box operation.
- Ensure proper backup measures are in place for a loss of power or loss of the source of the inert atmosphere.

Appendix N

Chair/Stool Guidelines

Chair/Stool Guideline

Guidance for laboratory furniture is to have smooth, non-porous surfaces that resist the absorption of liquids and the harsh effects of disinfectants. Chairs and other furniture used in the laboratory must be covered with a non-fabric material that can be easily decontaminated. Laboratory seating may be upholstered with vinyl or be constructed of solid materials such as plastic or wood that has been sealed to render it non-porous. Finishes must be as resistant as possible to the corrosive chemical activity of disinfectants and other chemicals used in the laboratory. It is recommended to have heavy-duty chair wheels made from industrial-grade steel, precision ball bearings, and durable polyurethane. Replace the wheel casters if they are worn or broken. This specification applies to all laboratories on campus. Project Managers, Principal Investigators or Laboratory Managers should consult with EHRS before submitting final purchase requests.

Appendix O

Guideline for Bunsen burner safety

Guide for Bunsen Burner Use

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 °C. 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 end. These holes adjust the amount of air entering the barrel (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 designed specifically for lighting them. Use a Bunsen burner when there's **at least 12 inches of overhead clearance**. In other words, don't use it under a shelf, light fixture or other equipment unless there's at least 12 inches of space. The heat from the flame could ignite nearby objects, especially if those objects are within 12 inches from the Bunsen burner. Before using a flame, tie back loose hair and remove or confine scarves. If you do not know how to adjust the burner ask your supervisor for instructions.
Please Note: Heat sources such as Bunsen burners are strictly prohibited inside the BSCs as they significantly disrupt the laminar flow of air. Additionally, the flame and heat can damage the HEPA filter inside the cabinet.

Description of Work:	Using a Bunsen/Meker Burner
	**Potential Hazards:** Fire hazard with the potential to cause harm through exposure to heat, explosions, sparks, fumes and flame.

Personal Protective Equipment (PPE) Required *(Check the box for required PPE)*:

 Gloves	 Face Masks	 Eye Protection	 Welding Mask	 Appropriate Footwear	 Hearing Protection	 Protective Clothing
☒	☐	☒	☐	☒	☐	☒

Safe Work Procedure Checklist:

1. PRE-Operation/Task:

- Task (e.g. Drawings, instructions, specifications etc.) is clearly understood.
- Ensure the work area is clean and clear of grease, oil, papers, notebooks, excess chemicals, and any other flammable materials.
- Use a Bunsen burner when there's at least 12 inches of overhead clearance. In other words, don't use it under a shelf, light fixture or other equipment unless there's at least 12 inches of space. The heat from the flame could ignite nearby objects, especially if those objects are within 12 inches from the Bunsen burner
- Place the Bunsen burner away from any overhead shelving, equipment, or light fixtures.
- Inspect hose for cracks, holes, pinched points, or any other defect and ensure that the hose fits securely on the gas valve and the Bunsen burner.
- Replace all hoses found to have a defect before using.
- Ensure all fittings are tight and the gas hose is in good condition.
- Ensure appropriate PPE is worn.
- Tie-Back any long hair, dangling jewelry, or loose clothing.
- Use the fume cupboard if undertaking experiments which produce fumes.
- Notify others in the laboratory that burner will be in use.
- Do not use a Bunsen burner in biological safety cabinet.
- Immediately report any gas leaks to your supervisor and EHS.

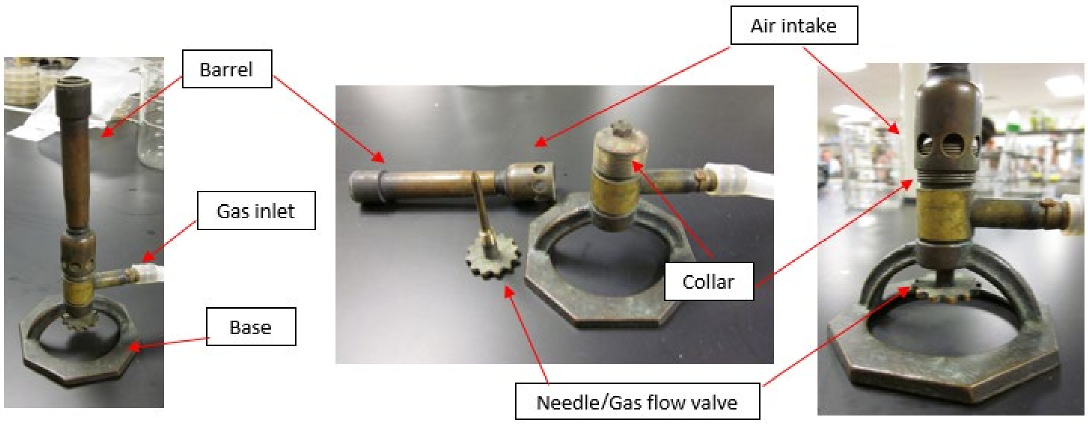
2. Operation/Task:

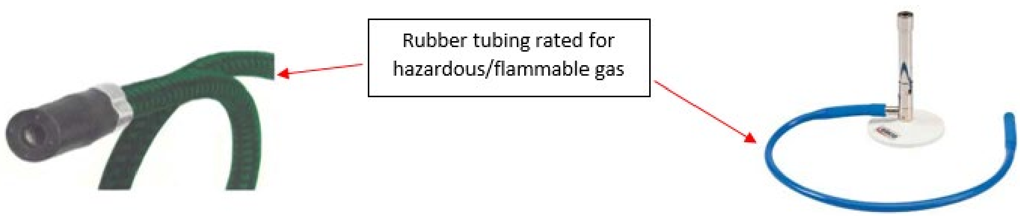
- Utilize a sparker/lighter with extended nozzle to ignite the Bunsen burner. Never use a match to ignite burner.
- Have the sparker/lighter available before turning on gas.
- Adjust the flame by turning the collar to regulate air flow and produce an appropriate flame for the experiment (typically a medium blue flame).
- Turn adjustable opening so the flame turns to blue when in use.
- Turn adjustable opening so the flame turns to orange when not in use.
- ***Never*** leave the Bunsen/Meker burner running unattended.
- Wait for instruments and burner to cool prior to handling.

3. POST-Operation/Task:

- Shut-Off gas when its use is complete.
- Allow the burner to cool before handling.
- Ensure that the main gas valve is off before leaving the laboratory.
- Clean and return all materials to storage area.
- Report any breakages or incidents immediately.

Components of a Bunsen Burner:





Bunsen Burner Safe Operating Procedure:

1. To use a Bunsen burner, first make sure the collar, barrel, and needle are correctly attached to the base and that the collar is closed.
2. To ensure that you have the hottest, cleanest flame possible, make sure your rubber tubing is securely connected to the gas jet and to the gas inlet valve. Inspect the tubing for cracks, holes, or other signs of wear.
3. A heatproof mat can be placed under the Bunsen burner as an extra safety precaution to prevent damage to your bench top and to catch stray sparks.
4. Before lighting, place the Bunsen burner at least 12 inches in front of any overhead shelving or equipment. Always keep safety equipment, like fire extinguishers and safety blankets, close at hand. If present, know the location of the emergency gas shutoff switch.
5. Then fully open the gas jet. Use a spark lighter to light the flame. Never use a match or lighter.
6. With the collar fully closed, the "safety flame" - a brighter, dirty, less intense flame – will appear. This flame is cooler and is generally used to indicate that the burner is "on". The safety flame doesn't burn as hot, because with the collar closed, there is minimal airflow through the burner tube, resulting in an incomplete combustion reaction.
7. Now begin turning the collar counterclockwise. As the collar opens, two distinctive flames appear. The blue outer flame is hotter than the safety flame and makes no noise. This flame can be difficult to see, so be careful when the burner is in this state.

8. The blue inner flame burns the hottest, particularly at the tip. In addition to being the hottest flame, it is also the cleanest and loudest flame, making a kind of “roaring” sound.
9. Once you have adjusted the collar to get the flame at the desired temperature, open or close the needle valve to increase the size of the flame or close it to make it smaller. Never leave a lit burner unattended.
10. When your work is done, remember to turn off the gas.
11. Allow burner to cool before handling or put into storage.

Appendix P

Guideline for mineral oil baths

Guideline for mineral oil bath

- When using an oil bath, take the following precautions:
- Always make sure the bath is on a flat and stable surface.
- Always make sure you know the location and usage of the nearest safety shower and eyewash in case you may need it. Ensure that they have been tested annually.
- Always wear proper personal protective equipment, or PPE, including a fireproof lab 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 not in use and return to their proper storage locations.
- Avoid leaving the bath unattended whenever possible. Set temperature well below the oil's flash point if you must leave the bath unattended.
- Before using an oil bath, ensure that you have an appropriate spill kit readily accessible to safely contain spills. 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 contamination of bath.
- Dispose used oil as hazardous waste. Do not dispose down the drains.
  Do not overfill the bath.
- Hot oil can cause serious burns. Allow the oil to cool to near room temperature before handling or disassembly of the apparatus.
- Follow your lab specific training and any standard operating procedures established related to work with oil bath.
- Have the safety data sheet for the oil in the lab and make sure you know the contents of the same.
- Inspect 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 be using and set the bath temperature below the flash point of the oil. Use a thermometer or thermistor 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.
- Prior to first time use of oil bath, a dry run or test experiment must be conducted with your principal investigator or supervisor.
- Store the oil in a place away from all heat sources. Make sure to label your oil container with the safe working temperature range as soon as you get the oil in the lab.

Appendix Q

Hydrogen Gas Safety Guidelines

Hydrogen Gas Safety Guideline

Hydrogen is a colorless, odorless, tasteless, flammable nontoxic gas which is flammable over a wide range of concentrations. Some of the unique hydrogen properties that contribute to potential hazards (flammability and explosivity) are:

- Hydrogen is combustible over a wide range of concentrations. At atmospheric pressure, hydrogen is combustible at concentrations from 4% to 74.2% by volume.
- Hydrogen has very low ignition energy.
- Hydrogen burns with a nonluminous flame which can be invisible under bright light.
- Due to its small molecular size, hydrogen can easily pass through porous materials and has the ability to be absorbed by some containment materials. This can eventually result in loss of ductility or embrittlement (this reduces performance of some containment and piping materials such as carbon steel). Loss of ductility/embrittlement is accelerated at elevated temperatures.

General Precautions when handling Hydrogen Gas:

- 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 to self-ignition.
- Hydrogen gas cylinders must be secured in an upright position to avoid being knocked over
- There should be no open flames or smoking in areas where hydrogen is used. Remove all combustible material from in and around the hood.
- Work in an area with plenty of ventilation. If possible, work in a fume hood or use a canopy hood as fugitive vapors, if not captured, may collect near the ceiling.
- Ground all equipment and piping used with hydrogen, and make sure that 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.
- Wear appropriate lab safety gear for the work being performed: safety glasses/ goggles, lab coat, gloves and preferably a face shield.
- Remove electrical equipment or electronic devices from the vicinity of hydrogen gas unless the device is certified "intrinsically safe". Even invisible small 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 electrically bonding and grounding the cylinder, metal piping and apparatus being used.
- Where feasible, discontinue use of Hydrogen tanks and switch to Hydrogen generators that have automatic shut off when a leak is detected.

- Clean up any spills that occur 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.
- All electrical connections should be located outside of hood.
- Hydrogen cylinders must be stored with valve's protective cap in place. If the cap has been removed, the cylinder must be stored upright and secured with noncombustible straps or chains.
- Hydrogen cylinders must be stored more than 20 feet away from cylinders of oxygen or other oxidizers, e.g., bromine, chlorine, fluorine or be separated by a noncombustible wall extending not less than 18" above and to the sides of the stored material.
- Never open the cylinder valve before making sure all your connections are secure as the static discharge from flowing gas may cause hydrogen to be ignited.
- NEVER USE ADAPTERS.
- Be aware of leaks! Hydrogen has a low viscosity which makes it to have a high leakage rate. Check that the pressurized system does not leak hydrogen with leak detection solution or pressure sensing.
- Due to hydrogen's low molecular weight, this gas will diffuse rapidly in a room and will collect near the ceiling. It is important to only use hydrogen in well ventilated locations. Hoods must have free air flow and cannot be overly crowded with reactors and/ or equipment.
- All electronic equipment used near hydrogen gas must be grounded.
- Close the cylinder valve when not in use. Do not leave the piping pressurized if not is use.

Hydrogen is incompatible with many materials and situations (check SDS for complete list of incompatibles):

- It ignites easily with oxygen, could explode when heated.
- It reacts violently or explosively or forms heat- and/or-shock sensitive explosive mixtures with oxidizers, halogens, halogen compounds, acetylene, bromine pentafluoride, chlorine oxides, fluorine perchloride, oxides of nitrogen (check SDS for list of incompatibles).
- Mixtures with chlorine may explode on exposure to light.
- Mixtures with oxygen may explode in presence of platinum catalyst.
- 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 tetrafluorohydrazine, xenon hexafluoride.
- It forms hydrides when heated with alkalis, alkaline earth, and some other elements.

If you are using hydrogen in a research laboratory, you should prepare a standard operating procedure (SOP). The safety information in this fact sheet may assist you in drafting the SOP.

Appendix R

Guideline for Dry Ice Handling

Guideline for Dry Ice Handling

- Allowing dry ice to sublimate at room temperature is an effective way to dispose of it, but it's important to take precautions to help prevent hazards.
- Make sure to allow dry ice to sublimate only in well-ventilated areas to avoid a harmful buildup of CO_2.
- Do not leave dry ice unattended in public places.
- Never dispose of dry ice in a toilet, sink or garbage disposal. The extreme cold can damage plumbing.
- Never dispose of dry ice in a trash can.
- Avoid putting dry ice directly on tile or laminated countertops. The cold can weaken adhesives and cause cracking.
- Vehicles? Recommend not putting dry ice in a vehicle other than one designed to carry dry ice.