Research
Research Laboratory & Safety Services

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The University of Arizona
Chemical Hygiene Plan

THE UNIVERSITY OF ARIZONA

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Responsible Officer/Title: RLSS/Chemical Hygiene Officer
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1. Introduction to Laboratory Safety

1.1 Purpose

This document, the University Chemical Hygiene Plan (UCHP), outlines the procedures, equipment, work practices, and personal protective equipment needed to keep employees and students safe in research labs across the University of Arizona. While this document aims to provide safety information, it also ensures the University meets the regulatory requirements as established in the Occupational Safety and Health Administration's (OSHA) standard for chemical use in laboratories (29 CFR 1910.1450). This standard is commonly referred to as the Lab Standard, and it supersedes most of the requirements of all other OSHA health standards in 29 CFR 1910, subpart Z in laboratory settings. In particular, the Lab Standard supersedes most of the requirements of the use of chemicals in a production setting following the Hazard Communication standard (29 CFR 1910.1200). All research spaces engaged in laboratory-scale work involving hazardous chemicals are covered under this document, irrespective of home department or location within the University. The UCHP is just one component to the overall Chemical Safety Program at the University of Arizona.

At the University of Arizona, the Chemical Safety Program is overseen and managed by the Chemical Hygiene Officer, who is appointed to the position by the Vice President of Operations within the Office of Research Innovation & Impact (RII). The Chemical Hygiene Officer is responsible for creating, modifying, and implementing the UCHP and all other components of the Chemical Safety Program. The Chemical Hygiene Officer for the University of Arizona is Russell Noon.

Russell Noon

Chemical Hygiene Officer

Research Laboratory and Safety Services

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1.2 Pre-Planning in the Laboratory

It is necessary that all workers in a research setting are properly trained and understand the expectation that **everyone is responsible for contributing to their personal safety**. The UCHP is designed to provide practical information and solutions to prevent and minimize hazardous situations and unsafe work environments. However, everyone is expected to receive an initial in-person training in their research spaces from experienced members of the lab, which typically will be the faculty responsible for the research or knowledgeable senior staff. Everyone is also

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expected to go through an annual review/refresher training that is specific to the work they are doing.

All laboratory work should be done in accordance with the RAMP method of safety (Lab Safety for chemistry students, 2010. Pg. xiv):

1. **R**ecognize hazards;
2. **A**ssess the risks of those hazards;
3. **M**inimize, manage, and/or control those hazards; and
4. **P**repare to respond to emergencies.

Every work situation can be assessed by everyone by using the ***RAMP*** method, and in doing so, workers will be empowered to ensure their own personal safety and the safety of those around them, ultimately creating a safe work environment. This behavior is already practiced by everyone in their normal day-to-day lives. For example, the choice to wear a seat belt in a vehicle, eat healthier, or not smoke are all risk-avoidance behaviors that many people engage in because they have ***Recognized*** the risks, ***Assessed*** the hazards, and taken action to ***Minimize*** the hazards. In a research setting, we can take this risk-avoidance behavior a step further by planning and ***Preparing*** for emergencies to further aid in creating a culture of safety in the workplace.

1.3 Laboratory Safety Management

Research Laboratory & Safety Services (RLSS) uses a database program to manage laboratory safety and compliance. This is known internally as CHESTER, and all users have access to the features and information on this platform through the CHESTER User Dashboard: https://rlss.arizona.edu/services/. All research is assigned an Approval Number (simply referred to as an Approval) based upon the work being done (Biological, Chemical, Radiation, and/or Laser). Within each Approval, there are three designations of lab personnel:

- First, there is the **Approval Holder (AH)**, who is typically the Principal Investigator (PI) or faculty member responsible for the research. However, in the case of research core or support labs, the AH can be a senior staff member.
- Next, there is the **Approval Safety Coordinator (ASC)**. This designation is not required, but is strongly encouraged, since it allows for a better delegation of duties and responsibilities within the research workspace. More than one ASC is permitted to be designated for each Approval, and doing so helps to ensure that all workers (staff, post-docs, graduate students, undergraduate students, and volunteers) are properly trained in lab safety.
- Lastly, everyone else in the Approval is assigned the position of a **Worker**. Workers are also expected to be involved in building a culture of safety and a work environment free of recognized hazards.

Through the CHESTER User Dashboard, lab personnel can find lots of information and resources. When an individual is added to an approval, they are automatically assigned trainings based on the hazards present, and these trainings are completed through EDGE Learning (https://edge.arizona.edu/). Additionally, CHESTER acts as a central location for documents such as this UCHP and the Laboratory-Safety, Training, & Emergency Procedures (Lab-STEP).

CHESTER also gives research groups/approvals the ability to use the chemical inventory management system, which allows lab personnel electronic access to Safety Data Sheets (SDS) for the over 34,000 chemicals in existence across the University campus and the ability to generate labels for any chemical containers that may need them. Lastly, the CHESTER User Dashboard also has quick links for chemical waste pickup, injury reporting, and much more.

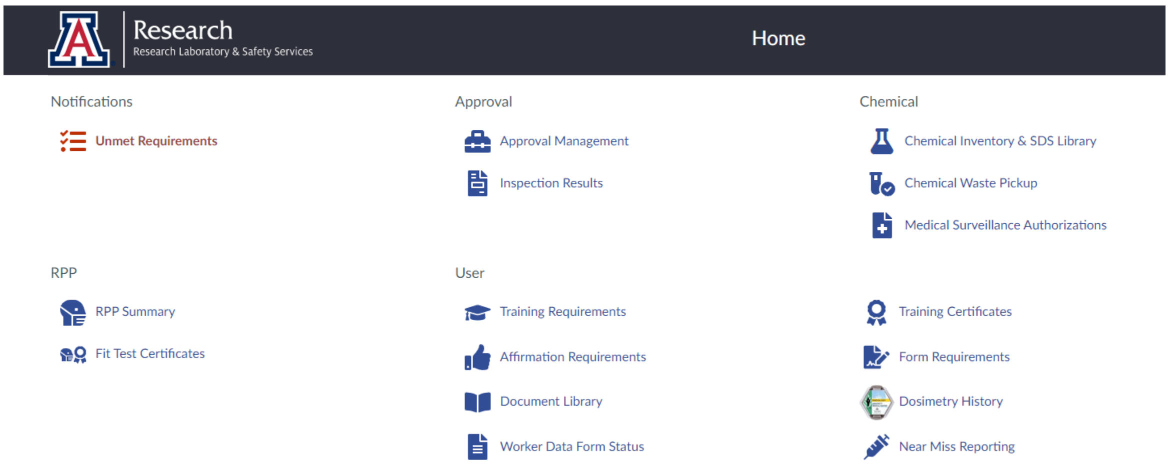

Figure 1. Home page of the CHESTER User Dashboard

1.4 Training

It is the responsibility of the Approval Holder to ensure all personnel in the lab space are properly trained and made aware of the hazards present in the space ***before*** any personnel begin working in the lab. General and hazard-specific training for the lab are provided by RLSS. However, it is ultimately the responsibility of the Approval Holder (AH) and/or Approval Safety Coordinator (ASC) to ensure that unique hazards are clearly identified, communicated, and that all affected workers are trained. This training should be documented in a physical and easily retrievable manner, with details such as the date of the training, those involved, as well as signatures of those who were trained.

RLSS encourages the practice of AHs and ASCs signing and dating lab notebooks and work plans. The use of electronic lab notebooks (e.g., LabGuru, Benchling, EXEMPLAR) is also strongly encouraged. In general, any way that training and oversight of lab operations can be demonstrated will ensure safety of lab members and the production of quality research.

In the event of an accident or injury, if an Approval Holder has failed to properly train and document training of their employees, they may be subject to fines, as well as civil and/or criminal charges. In the case of the death of Sheri Sangji in 2009 at UCLA, her immediate supervisor, Dr. Patrick Harran, was criminally charged with her death: (https://newsroom.ucla.edu/file?fid=53a47254bd26f5374b000373) charges against The Regents and Defendant Harran alleging three felony violations of California Labor Code section 6425(a), specifically the willful violation of an Occupational Safety & Health standard causing the death of an employee. The charges alleged that the defendants willfully: (1) failed to train, supervise, or instruct Ms. Sangji in the proper handling and operating procedures for working with chemicals in her work area; (2) failed to implement and maintain an effective Injury and Illness Prevention Program that included methods and/or work procedures; and (3) failed to require appropriate clothing be worn for the work being done. (California Code

Figure 2. Legal filings against Dr. Harran

Lab personnel should be trained by the AH, ASC, or other knowledgeable personnel on relevant information related to processes and chemicals they will be working with. This training is required to be provided and documented **prior** to any work beginning in the lab space and should include the following information:

- The chemical hazards in the space, regardless of whether the worker is working with those chemicals.
- Signs and symptoms of exposure to the hazardous chemicals present in the space.
- Information related to how to access this UCHP and the SDS for the chemicals in the lab space through the CHESTER User Dashboard.

An annual refresher training and/or review of work processes should also occur in the laboratory to check and verify that everyone is continuing to follow all safety procedures and performing research in a safe and proper manner.

Work in the laboratory should follow the Hierarchy of Controls while using the RAMP method of safety assessment. Worker training should emphasize following the Hierarchy of Controls in all processes, since the Hierarchy of Controls provides the best means and methods to minimize worker injury and health exposure.

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1.5 Risk Mitigation

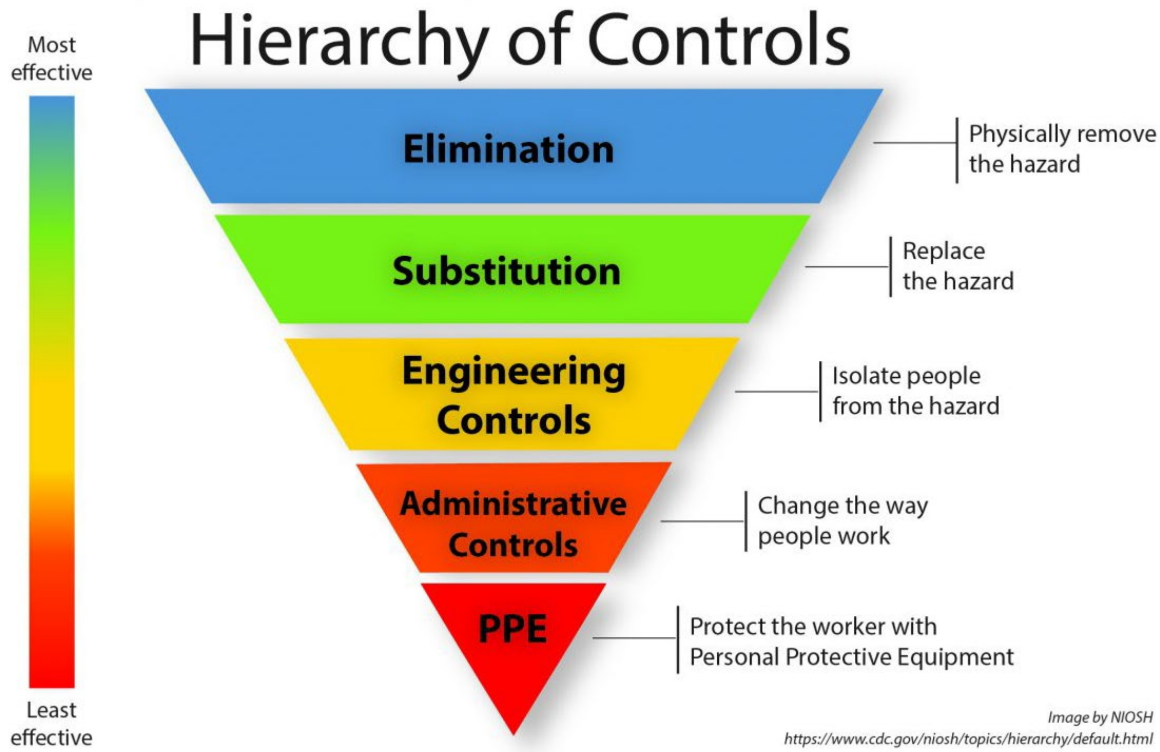

Figure 3. Hierarchy of Controls, courtesy of NIOSH

Examples of these different controls are listed below. These lists are not exhaustive and are instead designed to demonstrate general approaches that can be taken to promote safety.

Elimination: Leaking and old chemical containers that are stored but never used can off-gas and expose workers. Eliminate these chemicals by scheduling a waste pickup with Risk Management Services (RMS) at rms-hazmat@arizona.edu.

Substitution: Instead of using mercury thermometers, manometers, and bubblers, exchange them out for alcohol/electric and oil (respectively) options to prevent potential mercury spills and exposures.

Engineering Controls: Conduct chemical work in fume hoods, store hazardous gases in gas cabinets, and install and use RLSS-approved local ventilation (snorkels, elephant trunks, etc.) to remove airborne contaminants from work areas.

Administrative Controls: Pipette chemicals from bottles instead of pouring; use the "buddy system" when performing chemical work; use particularly hazardous chemicals in a single designated area to facilitate cleaning and minimize worker exposure.

Personal Protective Equipment (PPE): Always consult and read the chemical SDS before using any chemical and use at least the minimum PPE as is listed on the chemical SDS. Nitrile

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exam gloves rarely provide adequate protection against hazardous chemicals. If utilizing multiple chemicals in a process, each with differing glove material requirements, it may be permissible to use barrier laminate gloves under disposable nitrile glove. Only handle bulk (greater than 2 liter) flammable materials when wearing a flame-resistant lab coat. If chemical handling and use results in the possibility, however unlikely, that droplets can be formed, then a splash hazard exists and as such, these chemicals should only be handled with chemical resistant goggles and/or with a splash shield. Since PPE is the least effective type of control to protect workers, it should only be relied upon after all other controls have been considered and/or implemented.

To summarize, training should include what components of the Hierarchy of Controls are followed when working with the chemicals in the lab space, including, but not limited to:

1. Minimizing the scale of reactions and processes to minimize waste and exposure;
2. Using different, less hazardous chemicals to achieve the same results;
3. Conducting hazardous chemical work in fume hoods, under local ventilation exhausts, in glove boxes, or anywhere else that offers better and/or more dedicated ventilation;
4. Not conducting chemical work alone, unsupervised, or without prior permission and review from the AH and/or ASC; and
5. Using the proper appropriate PPE for the chemicals being used and the way they are being used.

1.6 Process Safety Management and Management of Change

The Approval Holder responsible for the space and/or work is required to review all work in the laboratory. Depending on the scope of the work to occur in the lab, it may be necessary for RLSS to review the work as well. Processes and practices are regularly established in the laboratory to address the expected work to occur. However, the concept of Process Safety Management requires that when these established processes and practices are drastically changed, for example by scaling a reaction up in size, the safety of the entire process is reanalyzed, and gaps in safety are addressed prior to work recommencing.

By regularly reviewing and reanalyzing the safety in the lab and the safety associated with processes and practices in the lab, workers and supervisors alike can ensure that everyone stays safe in the workplace. **Some of the most common injuries and accidents occur from a failure to reassess the hazards associated with a change in work practices.** More than 50% of the laboratory incidents that have occurred in the last 3 years, happened to workers with more than 5 years of experience in their lab. This statistic clearly demonstrates that those that are comfortable in their work environment can easily become complacent and injured by their complacency.

If a lab intends to significantly change, alter, or add to their chemical work processes, RLSS must be notified at rlss-help@arizona.edu beforehand so that a comprehensive review of safety in the laboratory can be adequately assessed.

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2. Understanding & Communicating Chemical Hazards

All purchased chemicals which are handled and used across the University are labeled with a standardized labeling system from the manufacturer. There are several labeling systems used for chemicals, depending on which regulatory agency those chemicals fall under.

2.1 OSHA/GHS

Reagent grade chemicals will commonly display the Global Harmonized System (GHS) pictograms on their label to communicate the hazard associated with the chemical. The GHS pictograms have been adopted by OSHA as the standard for labeling chemicals.

 • Explosives • Self-Reactives • Organic Peroxides	 • Flammables • Pyrophorics • Self-Heating • Emits Flammable Gas • Self-Reactives • Organic Peroxides	 • Oxidizers
 • Compressed Gases • Cryogenics • Aerosols	 • Corrosives • Skin Burns/Corrosion • Eye Damage • Corrosive to metals	 • Fatal Acute Toxicity • Toxic
 • Skin and Eye Irritants • Skin Sensitizer • Non-Fatal Acute Toxicity • Respiratory Tract Irritant	 • Carcinogen • Mutagenicity • Reproductive Toxin • Target Organ Toxicity	 • Aquatic Environment Toxicity • Ozone Degradation Hazard

Figure 4. Abbreviated categorization of GHS hazards

For chemical containers that were received from a manufacturer (primary containers) with a manufacturer's label, the label, including GHS pictograms must always remain intact until disposal. If the original label is damaged and/or defaced, the chemical must either be transferred into a new, labeled bottle, or a new OSHA GHS-compliant label must be generated through the CHESTER User Dashboard and placed on the original bottle. If a chemical is transferred to a new bottle, the bottle material should be appropriate and compatible with the chemical.

Large containers (greater than 2 liters or 5 lbs) that are not primary containers, shall bear an OSHA GHS-compliant label, since the use of larger containers can begin to mimic production processes (which is governed by different regulations with different requirements). Examples of large containers can include transfer kegs and acid/base baths.

For non-primary containers, such as beakers, flasks, wash bottles, and sample bottles, which are often referred to as secondary containers, labelling with tape and sharpie is permissible, provided the following criteria are met:

- All writing must be in English, legible, and easily read.
- If the writing on the label is no longer legible, it must be immediately replaced. This is common on alcohol wash bottles, as the alcohol tends to dissolve the ink used.
- Common name or IUPAC name of the chemical used. Labeling using only chemical structures is prohibited.
- The abbreviations in the following table are an example of accepted abbreviations, but for a complete list, contact RLSS. These abbreviations are only permitted to be used on bottles and containers that are 2 liters or 5 lbs in size or smaller. The lab specific list must be kept updated and a copy must be posted in a conspicuous location in the lab. Multiple copies may be necessary for large spaces and/or multiple locations.

2.1.1 Approved Abbreviations

Organic Acids		**Organic Bases**	
Acetic acid	AcOH	Tetraethylammonium	TEA
Ethylenediaminetetraacetic acid	EDTA	Phenol, isopropylated phosphate	PIP
Trichloroacetic acid	TCA	N,N-Diisopropylethylamine	DIEA
Trifluoroacetic acid	TFA	N-methylimidazole	NMI
		Triethylamine	Et_3N
Inorganic acids/bases			
Hydrofluoric acid	HF		
Hydrochloric acid	HCl	**Organic Solvents/Compounds**	
Hydrobromic acid	HBr	Methanol	MeOH
Nitric acid	HNO_3	Ethanol	EtOH
Sulfuric acid	H_2SO_4	Isopropanol	IPA
Phosphoric acid	H_3PO_4	Ethyl acetate	EtOAc
Sodium hydroxide	NaOH	Dichloromethane	DCM
Potassium hydroxide	KOH	Dimethyl formamide	DMF
		Dimethyl sulfoxide	DMSO
Buffers		Tetrahydrafuran	THF
Phosphate-buffered saline	PBS	Sodium dodecyl sulfate	SDS

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Tris-acetate-EDTA	TAE	Paraformaldehyde	PFA
Tris(hydroxymethyl)aminomethane	TRIS	Ethidium Bromide	EtBr
(4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid	HEPES	Acetonitrile	ACN
(piperazine-N,N'-bis(2-ethansulfonicacid))	PIPES	N-methylpyrollidine	NMP
(3-(N-morpholino)propanesulfonic acid	MOPS	Dichloroethane	DCE
		N,N'-Diisopropylcarbodiimide	DIC
		Tetra-n-butylammonium fluoride	TBAF
		Hexafluorophosphate Benzotriazole Tetramethyl Uronium	HBTU
		Trimethylsilyl chloride	TMSCl
		Triethanolamine	TEOA

This list of U of A approved chemical abbreviations is not all inclusive and as such, there may be other abbreviations that are commonly used, but are not listed. If there is a chemical abbreviation that should be added to this list, please email RLSS at help-rlss@arizona.edu.

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2.2 IFC

The State of Arizona follows the International Fire Code (IFC), version 2018 (IFC 2018), for fire code related safety. Within the fire code, there is an additional type of labeling that is not used as commonly on chemical containers but is still used on buildings. This is known as the National Fire Protection Agency (NFPA) 704 Hazard Diamond, and helps to communicate to first responders, particularly fire fighters, what hazards exist in the building or room, before they enter the space.

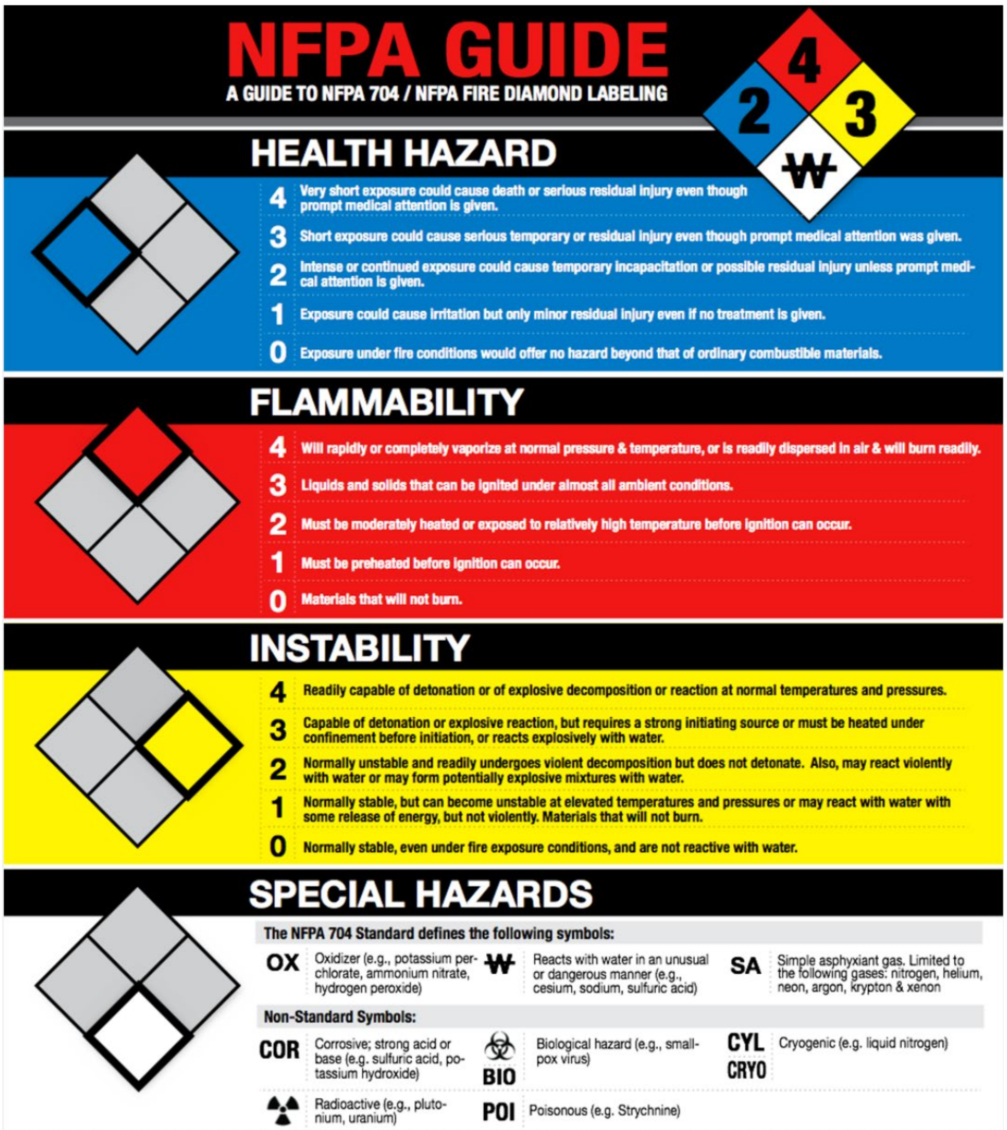

Figure 5. NFPA 704 Fire Diamond explained

2.3 DOT/IATA

Commonly, when hazardous chemicals are received, the exterior packaging will contain another form of labeling which is required by the United Stated Department of Transportation (DOT) and/or the International Air Transport Association (IATA) for shipment. These signs and symbols are internationally accepted and used and are required anytime regulated quantities of chemicals considered *Dangerous Goods* are shipped **<u>out</u>** from the University.

If a lab wishes to ship chemicals out from the University, they must contact Risk Management Services (RMS) at rms-contact@arizona.edu, to ensure that they have adequately prepared and labeled their package for shipment.

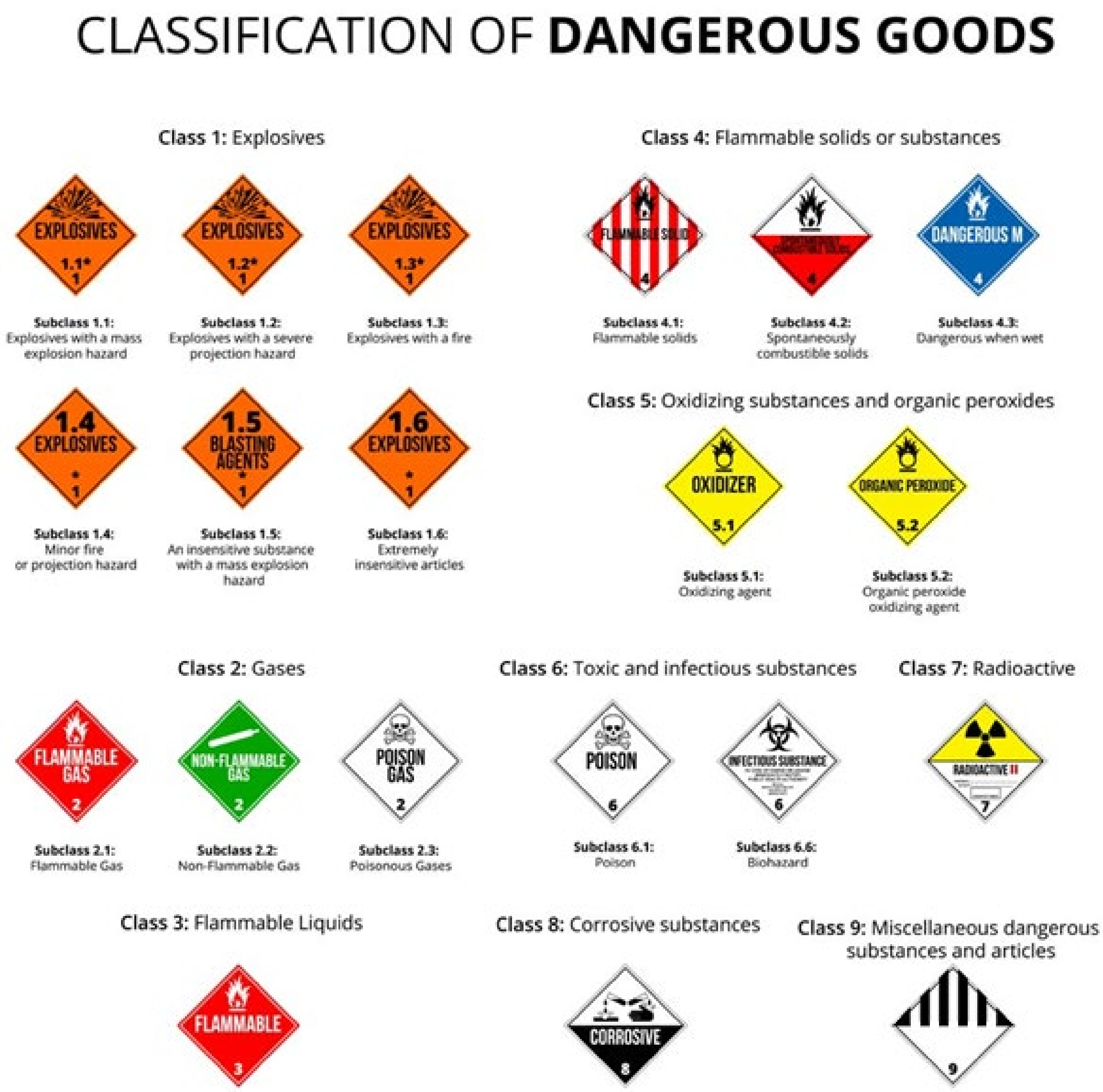

Figure 6. DOT shipping labels explained

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2.4 FDA

Some products used in research spaces are what are colloquially referred to as consumer products, wherein their labeling requirements are governed by the United States Food and Drug Administration (FDA). The FDA has requirements for the labeling of food, medical devices, cosmetics, and drugs, among other consumer products. Of these, drugs and medical devices are the most common consumer products categories that will be encountered across the University. Common examples include veterinary drugs for animal work and cleaning products.

It is always recommended that labs include their consumer/retail products in their inventory, if a hazard exists for the product. In the case that no hazard exists, then adding these chemicals to the lab inventory is not strictly required but is still encouraged as a best practice.

Figure 7. Example of a product with an FDA-approved label

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3. Emergency Preparedness

3.1 Medical Incidents & Emergencies

First aid kits must be present in the lab, but are only intended to treat immediate, minor injuries. Common injuries that may be treated with a first aid kit include papercuts, blood blisters from pinching, minor burns from hot plates, and cuts/lacerations from razors and needles (needlesticks). Though these injuries can be common, all lab personnel should do everything possible to minimize their injuries in the workplace. Any injury that is not a minor injury should be treated at an Urgent Care or Emergency Room and reported to the Risk Management Services insurance group through either UAccess or at the following website: https://risk.arizona.edu/insurance/incident-reporting.

What is stocked in a first aid kit should be based upon a **RAMP** analysis of the work done in the lab. The following are just a few examples of the more specific types of first aid equipment that are relevant and applicable and should be present in the various following lab situations:

- A lab working with mosquitoes or ants should have insect bite cream in their first aid kit.
- A lab working with Bunsen burners and hot plates should have burn cream and/or a cold compress in their first aid kit.
- A lab working with saws, lathes, and other power tools should have amputation bags and tourniquets in their first aid kit (https://www.dhs.gov/sites/default/files/publications/STB_Applying_Tourniquet_08-06-2018_0.pdf).
- A lab working with hydrofluoric acid should have calcium gluconate (Calgonate) cream both in their first aid kit and immediately available at the work area.

In all cases, it is critical that lab workers know how to properly use the various first aid equipment. They should therefore be properly trained in the use of the various first aid equipment that is stocked in the lab. Some resources for first aid training are below:

- (Free) National Safety Council first aid video library (https://www.nsc.org/pages/safety-training-pages/first-aid-video-library)
- (Free) Centers for Disease Control first aid kit checklist, skills, and resources (https://blogs.cdc.gov/publichealthmatters/2021/05/first-aid-kits/)
- (Paid) American Red Cross first aid training classes (https://www.redcross.org/take-a-class/first-aid/first-aid-training)

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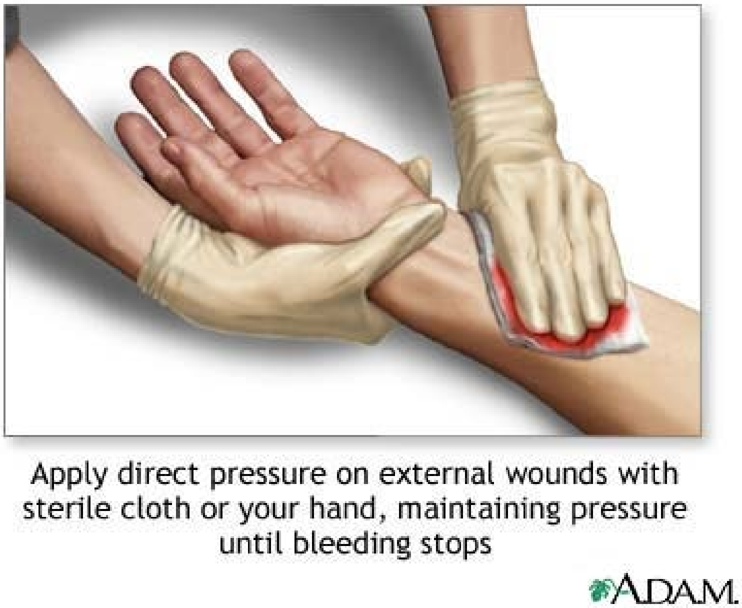

Figure 8a. All bleeding wounds should have pressure applied until the bleeding stops.

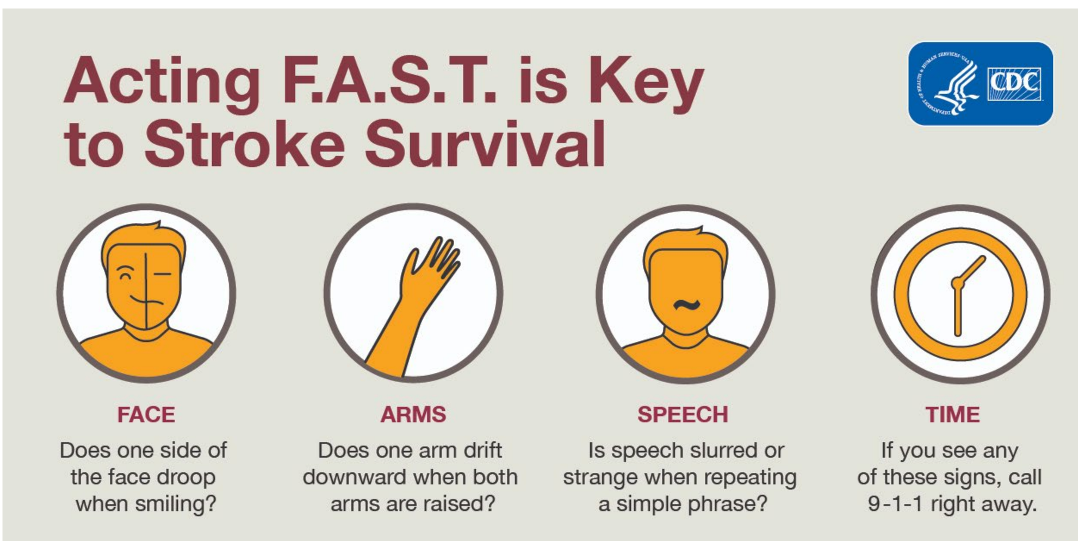

Figure 8b. Know the warning signs of a stroke to be able to rapidly assist.

If an injury results in the release of blood or other bodily fluids, bag up all contaminated gauze, bandages, and wipes for disposal by RMS as biohazardous waste. In these situations, use the "Universal Precautions" to safely clean blood or bodily fluids; more can be learned by completing the online Bloodborne Pathogens course via EDGE Learning. Do not dispose of biohazardous waste in the regular trash.

3.2 Chemical Exposures

If chemicals or biological agents are splashed in the eye or spilled on the skin, use the nearest emergency eyewash (eye exposure), sink (hand/wrist exposure), or emergency shower (body exposure) to wash the affected area for a full 15 minutes.

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Labs are expected to have a sink with clean running water, soap, and paper towels available for lab personnel to wash their hands before exiting the lab. The sink must be in good operating condition and must be free of glassware and other clutter.

Eyewashes and safety showers are required to be nearby when labs are working with corrosives but may be recommended when other chemical hazards as present. Where eyewashes are present, there must be a clear path to them, and they must be free of clutter within 6-inches in all directions. Safety showers must also have a clear path to them, but they need 16 inches of clearance in all directions. Both eyewashes and safety showers are tested by Facilities Management every 3 months. It is strongly recommended that labs check the flow and clarity of the water of sink mounted eye washes on a weekly basis.

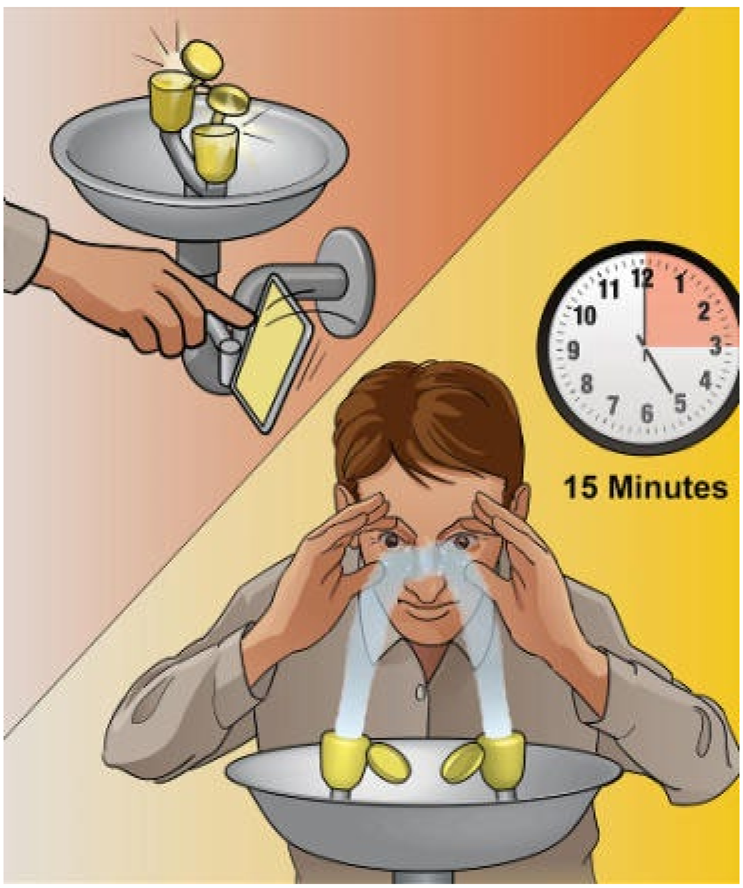

Figure 9. Always rinse eyes for at least 15 minutes when using an emergency eyewash station.

All lab members shall also have access to the following information, provided to them by their Approval Holder:

- The location of a nearby UrgentCare
- Arizona Poison Control 24/7 Contact Number: 1-800-222-1222
- For non-emergency medical incidents contact CORVEL: 1-800-685-2877 for triage instructions from a qualified healthcare professional.

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3.3 Spill/Leak Response

In the case of emergency, dial 911
M-F, 8AM – 4PM contact RLSS: (520)-626-6850
After-hours, evenings, weekends, and holidays contact UAPD: (520)-626-8273 or 911

MERCURY SPILLS: All mercury spills ***must*** be immediately reported to RLSS for cleanup. If a spill occurs during the evening, on weekends, or on holidays, contact UAPD. Lab workers should evacuate to safe areas to avoid breathing any vapors, mist, or gas. Do not attempt to amalgamate mercury with zinc or sulfur, as this is not the safest approach to cleaning up a mercury spill. RLSS has a vacuum specifically designed to recover mercury and capture vapors, and the vacuum is cleanroom certified to ensure no contamination occurs to research projects and equipment.

COMPRESSED GAS LEAKS: Immediately evacuate the area. All compressed gas leaks ***must*** be immediately reported to RLSS. If a gas leak occurs during the evening, on weekends, or on holidays, contact UAPD. Do not attempt to patch, repair, or stop a gas leak. Special equipment is necessary to determine the health and physical hazards in the event of a gas leak. After making an assessment, RLSS will coordinate with RMS to contract an external HazMat company to address the leak, if it is determined that a hazardous environment exists from the leaking gas.

NATURAL GAS LEAKS: Immediately evacuate the building, activate the fire alarm, and call 911. If possible, turn off heat generating equipment and extinguish open flames while evacuating the building.

SOLID OR LIQUID SPILLS: If workers do not feel safe or adequately prepared to address a spill, regardless of its size, contact RLSS immediately. Referencing safety data sheets (SDS) will always be the best source of information for absorbing, neutralizing, and addressing a chemical spill.

In the event of a large spill (greater than 10 ml or 0.25 lbs of a particularly hazardous chemical or greater than 1 liter or 2.5 lbs of any other chemical) RLSS **must** be contacted immediately for cleanup. If a spill occurs during the evening, on weekends, or on holidays, contact UAPD. RLSS will respond to conduct the cleanup of the lab, or if the spill is too large, RLSS will coordinate with RMS to contract an external HazMat company to perform the cleanup.

Small spills (less than 10 ml or 0.25 lbs or a particularly hazardous chemical or less than 1 liter or 2.5 lbs of any other chemical) may be cleaned up by properly trained lab workers using appropriate neutralizers and absorbents. Workers **must** consult the safety data sheets (SDS) to determine the necessary and appropriate personal protective equipment (PPE) before attempting to clean up the spill. If the chemical requires respiratory protection, RLSS **must** be contacted to perform the cleanup.

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In general, the following spill response will be appropriate for most spill situations:

1. Stop all work operations in the area and evacuate other workers from the area.
2. Communicate to at least one other person that there is a spill. Communicate what has been spilled, and what your intended response is. Reference the SDS for information.
3. Isolate the spill from spreading further. In the case of a liquid spill, this can often be accomplished by forming a raised retaining ring/border around the puddle with a compatible absorbent or neutralizer. Common broad-spectrum absorbents include vermiculite, bentonite clay (kitty litter), and Chemizorb®. **Alternatively, spill pads (commonly pink in color) are available from various vendors online.**
4. Once the spill is contained, it may be appropriate to begin absorbing and/or neutralizing the spilled chemical, if the lab has sufficient absorbing/neutralizing material, is properly trained, and has the appropriate PPE.
5. Place all dry waste from a chemical spill into a clear plastic bag and secure with a knot or tie. Place this bag into a second bag, knot/tie the second bag, and label it as spill waste material with an RMS Waste Tag.
6. Never dispose of any waste down the drain.

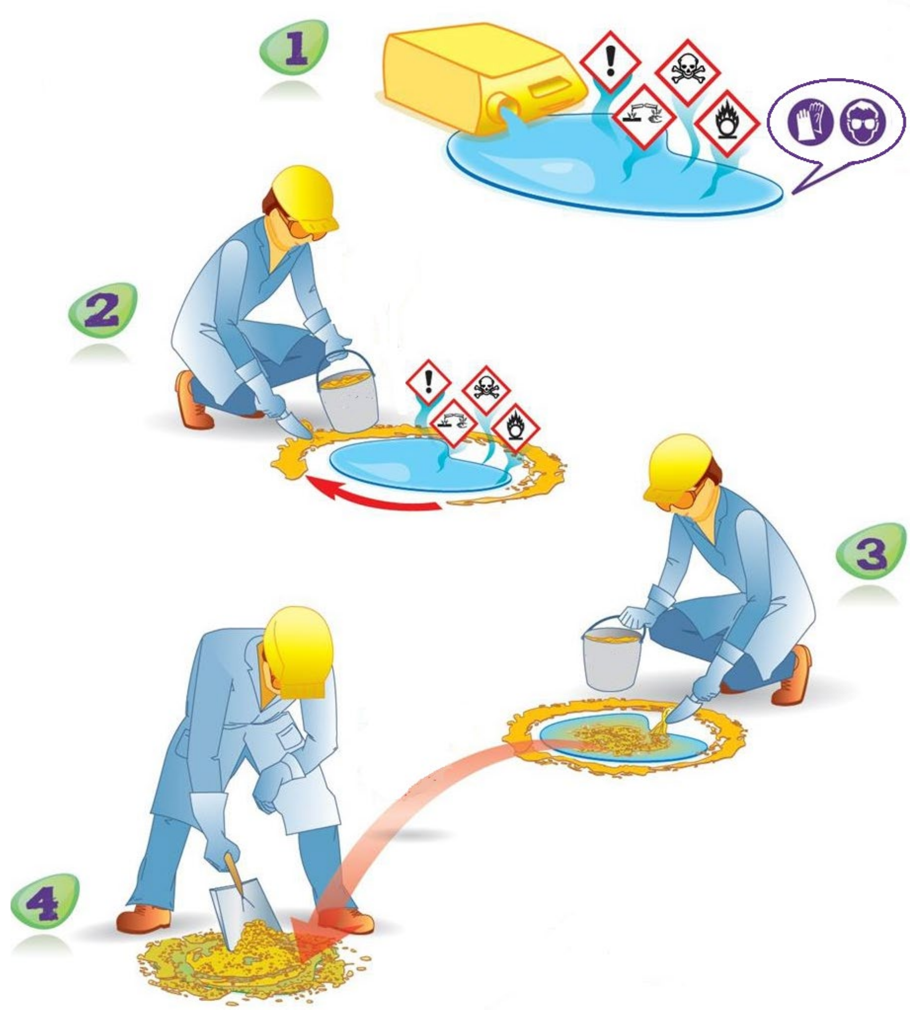

Figure 10. Always contain a spill before beginning to neutralize or absorb the spilled material.

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BULGING/DAMAGED RECHARGEABLE BATTERIES & BATTERY PACKS: The bulging associated with rechargeable batteries is due to the beginning of a process known as thermal runaway. **Immediately** place the batteries into a thermal runaway bag if available. Alternatively, a supersaturated solution of salt water can be prepared and the batteries placed into this solution to rapidly discharge them. This does not automatically make them safe to handle, but it does lower the risk of explosion and fire. In all cases, contact RMS to have your bulging/damaged rechargeable batteries picked up for disposal. In the event of a fire, immediately activate the fire alarm as you evacuate the building and call 911. Do not attempt to extinguish the fire with a normal ABC (red) fire extinguisher, as the chemical reactions will result in the fire being fueled as opposed to being extinguished.

ELEMENTAL METAL & RECHARGEABLE BATTERY FIRES: If the fire is small, it may be possible to contain it with either a Class D (yellow) fire extinguisher, Met-L-X graphite powder, masonry sand, or granulated sodium chloride (table salt). These options work to smother a fire and prevent oxygen from reacting with the reactive metal. It can be very hazardous to apply these extinguishing agents to an active metal fire so only attempt if the fire is small and easily accessible. Whether an attempt is made to extinguish the metal fire or not, the building must still be evacuated. **Immediately** activate the fire alarm as you evacuate the building and call 911. Do not attempt to extinguish the fire with a normal ABC (red) fire extinguisher, as the chemical reactions will result in the fire being fueled as opposed to being extinguished.

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4. Safety in the Laboratory

4.1 Chemical Hoods and Other Ventilated Devices

It is infeasible to test the exposure levels of workers to every chemical in use in every quantity and process in every lab for every reaction, extraction, and synthesis. It is therefore infeasible, and often unproductive, to quantify what danger lab personnel may be exposed to on a day-to-day basis. However, in general, it is known that breathing the dust, vapor, mist, fumes and/or other airborne forms of chemicals is not safe (though the safety varies based on the relative hazards of the chemical). Therefore, lab personnel should make all efforts to minimize their exposure to airborne (and other) exposures to chemicals. This is best achieved by having adequate ventilation, such as engineering controls, in the workspace which was previously mentioned as part of the Hierarchy of Controls. One of the most effective means of minimizing worker exposure to chemicals in the lab, is to perform your work inside a chemical hood.

Working in a chemical hood allows for dust, vapors, mists, and fumes and airborne chemicals to be captured, directed away from the user, and directly vented to the outside of the building above the roofline. However, the chemical hood exhaust system is very carefully tuned and adjusted to prevent unnecessary airflow at too quick of a speed to be drawn through the ductwork. During normal operation, a fume hood ideally has a face velocity (air speed at the sash) of 100 ft/min; however, an acceptable range is anywhere between 80-120 ft/min. Face velocities outside of this range can result in users being inadequately protected from the work they are conducting inside the hood. High air speeds can create turbulence inside the hood, resulting in eddy currents and dead air pockets in areas of the hood. The lower air speeds are instead beneficial since they can generate suction in what is known as a venturi effect, which helps to draw air into the hood and aids in the capture and removal of contaminants present in the hood.

For this finely tuned airflow to work effectively, the sash of the chemical hood must never be raised or opened beyond the permissible limit. For older fume hoods, the maximum height of the vertical sash is represented by a red arrow sticker. For newer fume hoods, they have horizontal sliding glass doors which help prevent the opening from ever being too large. Facilities Management certifies all the ventilated devices on campus annually. The testing for certification is performed with the hood in its normal operating condition, which may include there being equipment present. Although it is not advised to operate a hood with large quantities of chemicals and large pieces of equipment present, the reality is that some situations, such as using a rotovap or running a reflux reaction, necessitate this type of setup inside the hood. Setting up a process inside the hood may require opening the sash above the certified level—this is the only acceptable time for the sash to be open above the certified level. The moment any chemicals are brought into the hood, the sash should never be opened beyond the limit marked by the red arrow.

There are numerous other types of ventilated devices that provide varying degrees of protection to workers, such as snorkels, slotted benches, gas cabinets, ductless chemical hoods, downdraft tables, and canopy hoods. Additionally, some ventilated devices, such as laminar flow hoods, are designed to protect the process, with minimal or protection provided for the user, by blowing air out of the hood. Laminar flow hoods are commonly used in semiconductor and electrical

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fabrication to prevent dust and other particulates from accumulating on the fabricated parts; laminar hoods do NOT protect the worker, only the sample. Ventilated devices other than fume hoods must be reviewed by RLSS to ensure the type and configuration are adequate to protect workers for the specific processes it is intended for—contact RLSS-help@arizona.edu to request an assessment.

4.2 OSHA Monitored Chemicals

In the normal course of laboratory operations, workers may encounter a group of chemicals designated by OSHA to pose a significant health concern when made airborne. These are commonly referred to as OSHA Monitored Chemicals. Specifically, if airborne concentrations of these chemicals exceed established occupational exposure levels, workers must be enrolled in a medical surveillance program to monitor them for the health effects associated with these chemicals. RLSS helps to identify, assess, and monitor these chemicals for lab workers and can assist upon request (rlss-help@arizona.edu).

Chemicals or compounds that contain any of the following OSHA Monitored Chemicals, if present in the lab, can pose a significant health hazard to workers in the lab, particularly due to airborne exposure, and as such can require medical surveillance:

- Asbestos
- Select carcinogens: 4-nitrobiphenyl; alpha-naphthylamine; methyl chloromethyl ether; 3,3'-dichlorobenzidine; bis-chloromethyl ether; beta-naphthylamine; benzidine; 4-aminodiphenyl; ethyleneimine; beta-propiolactone; 2-acetylaminofluorene; 4-dimethylaminoazobenzene; N-nitrosodimethylamine
- Vinyl chloride
- Inorganic arsenic
- Beryllium
- Lead
- Chromium (VI); also knows as hexavalent chromium
- Cadmium
- Benzene
- 1,2-dibromo-3-chloropropane
- Acrylonitrile
- Ethylene oxide
- Formaldehyde
- Methylenedianiline
- 1,3-butadiene
- Methylene chloride; also known as dichloromethane
- Respirable crystalline silica

While the list of chemicals is relatively short, it is important to note that any solution, mixture, or in the case of arsenic, beryllium, lead, hexavalent chromium, and cadmium, any ionic compound/salt containing these particular chemicals is also included. From this list of 29

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chemicals, there exist over 250 different chemicals across the University campus which can qualify as a monitored chemical.

Workers working with any of these OSHA Monitored Chemicals should ***Recognize*** the health hazards and risks associated with exposure to these chemicals, ***Assess*** the potential for being exposed to any of these chemicals during their normal lab work, and make efforts to ***Minimize*** their exposure, which in turn will also ***Prepare*** them to respond to emergencies and spills associated with the release of any of these chemicals. In addition to always using appropriate PPE, any chemicals or compounds that possess any of these above listed chemicals should always be used as follows:

1. In the smallest quantity possible
2. For the minimum amount of time necessary
3. As infrequently as possible
4. In a fume hood or other ventilated device

Adhering to the above measures will minimize worker exposure to these chemicals, precluding them from having to be enrolled in a medical surveillance program.

In addition to the Monitored Chemicals, there is also another list of chemicals that are also mandated to have airborne exposure levels kept below established levels. These chemicals are listed in 29 CFR 1910.1000 TABLE Z-1. Airborne exposure levels can be kept below established thresholds by utilizing the same measures as detailed for the handling of the OSHA Monitored Chemicals. Across the University, there are over 2,500 chemicals that fall under the TABLE Z-1 category. RLSS can assist upon request (rlss-help@arizona.edu) to help identify, assess, and monitor these chemicals for lab workers.

By using the ***RAMP*** method of lab safety, lab workers are able to evaluate their work practices and behavior when using chemicals that are listed in TABLE Z-1 as well as those chemicals that are included in the OSHA Monitored Chemicals list.

4.3 Designated Areas

A designated area is a location in the lab, usually a fume hood or other ventilated device, where a specific group of chemicals, referred to as Particularly Hazardous Chemicals (PHCs), are used. These chemicals are categorized as PHCs in the CHESTER User Dashboard, and are comprised of select carcinogens, reproductive toxins, and/or chemicals with a high degree of acute toxicity. In some cases, the presence and usage of PHCs in the lab may be so great and diverse, that the entire lab itself is assigned as the designated area. It is important that all lab workers ***Recognize*** the risks associated with working with PHCs. The best way to prevent exposure is to work with these chemicals inside a chemical hood or other appropriate ventilated device. However, you should also ***Assess*** the potential for exposure regardless of the method of working with the chemicals. Using a fume hood and minimizing the usage of these chemicals are great ways to ***Minimize*** the hazards and potential exposures. Working with small quantities and inside a chemical hood also allows for workers to ***Prepare*** a more effective response in the event of an emergency or spill.

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Research Laboratory & Safety Services

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The purpose of establishing a designated area is twofold:

1. To ensure that the processes involved with the use are properly contained and minimize worker exposure to prevent detrimental health consequences;
2. To establish appropriate and specific procedures for the safe removal of contaminated waste and the proper decontamination of contaminated surfaces and equipment.

RLSS works with the AH, ASC, and lab workers to determine the best classification of select areas within the lab that will be the designated areas. Where applicable, entire labs will be classified as designated areas. However, doing so can result in an elevated burden on the lab to properly clean and decontaminate equipment, so it is strongly recommended that labs choose specific areas, preferably a chemical hood, to be their designated areas.

To emphasize, the major component associated with working with PHCs is the decontamination of equipment and surfaces. In a research lab setting, especially when there are rotating students, as opposed to process work, each workstation may have the presence of a PHC. Therefore, it should be assumed that all surfaces in the lab may be contaminated with a PHC. To that end, decontaminating all surfaces after working with PHCs must be part of the standard lab operating procedures.

4.4 Respiratory Protection Program (RPP)

The use of respirators (including any disposable mask with a NIOSH approval, such as N95s) in a work setting must only be done in accordance with the applicable regulation (29 CFR 1910.134) and U of A policies. Specifically, workers must be medically cleared to wear the respirator, properly trained, and have undergone a fit test to ensure the exact respirator that the worker will use seals properly and has been demonstrated with a fit test. It is important to note that with the exception of loose-facepiece Powered Air Purifying Respirators (PAPRs), all other respirators require a skin seal, which means no facial hair is permitted along the seal. Contact rlss-help@arizona.edu with questions or concerns regarding respiratory protection.

Figure 11. Various types of disposable filtering facepiece respirators exist, and not everyone fits into the same make, model, or size.

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The only type of respirator that is permitted to be worn on a voluntary basis (without medical clearance and fit testing) at the University of Arizona are disposable filtering facepiece respirators (e.g. N95, P100). However, voluntary use of respirators must be assessed and approved by RLSS. If RLSS has determined the chemical exposure approaches or meets the selected occupational exposure limits, then the use of respirators would be required, and voluntary usage is not an option. Therefore, always use engineering controls which are more protective, so that the reliance on PPE, which is less protective, is less demanding.

4.5 Street Clothes

The clothes that we wear every day to work and school (pants, shirts, shoes, etc.) are not and should never be considered PPE. These are instead considered "street clothes" and while the University does not have a "street clothes" dress code for work in a laboratory setting, in general, the following are established acceptable lab attire:

- Loose, long pants and dresses/skirts that cover the legs.
  - Pants, scrubs, and dresses/skirts that do not fully cover the legs and leave a portion of the lower leg/ankle exposed should be paired with long socks to keep all exposed skin surfaces covered. However, if the work poses a reasonable risk of splashing the ankles/lower legs, PPE would be necessary as opposed to relying on street clothes.
- Closed-toe shoes made of non-absorbent material.
  - Shoes with a heel greater than 1 inch are not recommended.
  - Crocs with vent holes are not permitted. However, Croc "On-The-Clock Slip-On" and Croc "Clog" type shoes are acceptable for lab work. Shoes that do not cover the back of the heel are permissible, provided that the work being done will not result in foot splashes. If foot splashes are likely, then shoe covers, which are a form of PPE, are required.
  - Tennis shoes, sneakers, and converse style shoes are only recommended when the chance of a spill hazard is non-existent.
- Loose hair, including long beards, must be tied up and jewelry, including watches, should be removed. Religious headwear is permitted as well but should be fashioned in such a way that it does not pose a hazard to the worker. For information and accommodations related to religious headwear, contact the U of A Disability Resource Center at workplaceaccess@arizona.edu.

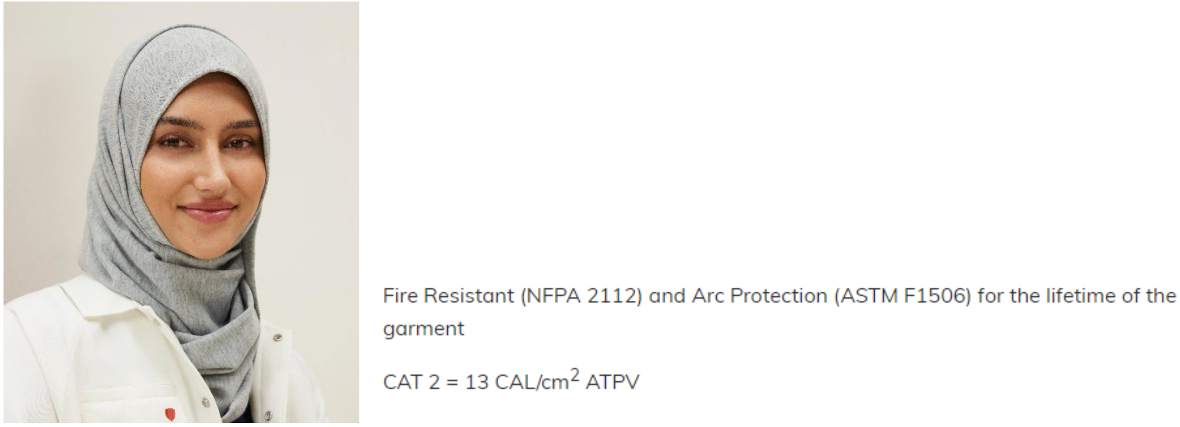

Figure 12. Flame resistant hijab, acceptable for lab work, available through AmorSui.

In all cases, lab members should ***Recognize*** the risks they will be exposed to during their lab work. Street clothes are not intended to protect against injury, and instead, after ***Assessing*** the hazards you will be exposed to, your attire should be selected to ***Minimize*** the hazard in ***Preparation*** for an emergency or spill.

4.6 Personal Protective Equipment

Due to the broad range of chemicals and procedures used across all laboratories and experiments, no one-size-fits-all approach to PPE can be created. Therefore, lab members must adequately assess the hazards of their projects to use the appropriate PPE accordingly. At a minimum, skin and eye protection should be used. Skin protection includes gloves and a lab coat, while eye protection can include safety glasses, safety goggles, and face splash visors. The PPE used must be appropriate for the greatest hazard present when work is being done.

An experiment may use a diverse range of chemicals that may require differing glove thickness and materials. Changing gloves frequently throughout an experiment can create other safety issues, so it may instead be necessary to use a pair of barrier laminate gloves beneath nitrile or neoprene gloves to provide adequate protection.

Ultimately, the best way to protect lab workers from hazards is to use the PPE as stated on a product SDS. However, it is essential to remember that PPE does not provide nearly the health and safety protection that elimination, substitution, engineering, and administrative controls, do.

PPE, regardless of how recently it was put on, should never be worn outside of the lab area. This is especially the case with gloves. Never wear gloves outside of the lab or when travelling through doors, on the elevators, or on the stairs. The only exception to this is if you are transporting chemicals. The chemicals should be in appropriate containment and never moved through office spaces, kitchenettes, or non-lab spaces.

Lab coats should be laundered on a regular basis, and lab coat laundering services are available for U of A labs through Shaffer Dry Cleaning. The cleaning costs are the responsibility of the lab, and lab coats can be scheduled for pickup and cleaning by calling (520)-881-1216.

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4.7 Chemical Storage

When working with a multitude of chemicals in a laboratory, it is critical that all chemicals are properly stored and segregated. One of the most important components of chemical storage safety is the quantity of chemical that is stored; both on a per container basis and cumulatively. Perhaps the single most applicable regulation for laboratory chemical storage is from the International Fire Code (IFC 2018 5003.9.8), which states:

> "Chemicals that are in storage and are incompatible with other chemicals either in storage or in use, must be properly segregated when the individual container sizes exceed 5-pounds (2 kg), 0.5 gallons (2 liters), or if any amount of incompatible compressed gas is present."

Considering the restrictive container size, it becomes evident that following this regulation allows for complying with the scope of the OSHA Lab Standard, wherein *laboratory-scale* work is occurring in U of A Laboratories.

Small chemical containers: When individual chemical containers remain below the 5-pounds (2 kgs) or 0.5 gallons (2 liters) threshold, many containers of potentially incompatible materials can be relatively safely comingled. By ***Recognizing*** the hazard that larger chemical containers pose, it is possible to ***Minimize*** these hazards by minimizing the physical presence of the chemicals by minimizing the chemical container size. These actions then naturally help a lab to ***Prepare*** for an emergency that may arise from an accident or unintentional mixing of the incompatible materials, since the container size and subsequent potential for reaction has already been minimized.

Large chemical containers: However, when individual chemical containers cannot be kept below the 5-pounds (2 kg) or 0.5 gallon (2 liter) level, or if an incompatible compressed gas is present, the following actions are required to properly segregate the incompatible chemicals:

1. Segregating *incompatible materials* in storage by a distance of at least 20 feet (610 cm).
2. Separating *incompatible materials* in storage by a noncombustible partition extending at least 18 inches (46 cm) above and to the sides of the stored material.
3. Storing liquid and solid materials in approved hazardous material storage cabinets.
4. Storing *compressed gases* in approved gas cabinets or exhausted enclosures in accordance with the relevant sections of the Fire Code.

Materials that are incompatible shall not be stored within the same cabinet or exhausted enclosure.

It is critical to recognize that by following these requirements, labs are ***Minimizing*** the potential for an accident, injury, fire or spill that arises from the improper storage of chemicals in a laboratory. It is therefore recommended that lab personnel ***Assess*** what chemicals are present in the lab, whether it is necessary to have as large of quantities as are present, and whether a downsizing can occur, which can potentially remove many of the restrictive requirements that come with storing larger containers of chemicals.

Some examples of potentially challenging chemical storage situations are below:

In the case of Acetic Acid, it is both a corrosive and a flammable:

2.2 GHS Label elements, including precautionary statements

Pictogram 

Signal Word Danger

Per the SDS, acetic acid is supposed to be stored in a flammable cabinet. However, the Technical Rules for Hazardous Substances (TRGS 510) storage system, which is followed by manufacturers, is designed for production situations, wherein bulk chemicals are being worked with and stored.

7.2 Conditions for safe storage, including any incompatibilities

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

Moisture sensitive.

Storage class
Storage class (TRGS 510): 3: Flammable liquids

Across laboratories on campus, acetic acid is almost exclusively stored in corrosive cabinets, which is not an incorrect decision to make. However, irrespective of whether the acetic acid is stored in a flammable cabinet or a corrosive cabinet, if the total container size is less than 0.5 gallons (2 liters), then the storage issue becomes less critical.

Another example of chemical storage challenges exists in Sulfuric Acid, which per the SDS appears to just be a corrosive:

2.2 GHS Label elements, including precautionary statements

Pictogram 

Per the SDS, a standard corrosive cabinet would be an acceptable storage location.

7.2 Conditions for safe storage, including any incompatibilities

Storage conditions
No metal containers.
Tightly closed.

Storage class
Storage class (TRGS 510): 8B: Non-combustible, corrosive hazardous materials

However, per Fire Code, sulfuric acid is also a Class 2 water reactive chemical, which has the potential to cause severely restricted storage requirements as well as limiting how much sulfuric acid can be stored in a lab.

> Class 2: calcium carbide, calcium metal, cyanogen bromide, lithium hydride, methyldichlorosilane, potassium metal, potassium peroxide, sodium metal, sodium peroxide, sulfuric acid and trichlorosilane.

When excess sulfuric acid is stored in a lab, it can then further restrict how much flammable liquids can be present, due to their violent reactivity and their incompatibility. Therefore, to prevent these issues from arising, sulfuric acid, like all chemicals, should be in containers not exceeding 0.5 gallons (2 liters), and only the minimum amount necessary should be purchased and stored in the lab.

Figure 13. Corrosive resistant cabinets, which would be considered "Approved Hazardous Storage Cabinets". These may be necessary for the storage of corrosive chemicals, if possession is excessive and/or incompatible chemicals cannot be adequately segregated.

The following sections provide more details that are specific to each hazard class of chemicals when it comes to storing, handling, and working with each respective hazard class of chemical.

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4.8 Hazardous Waste Disposal

Proper management of chemical waste, as it is generated, is the responsibility of the lab. Once the waste is removed from the lab, U of A RMS is responsible for the management and disposal of the waste. This is an important responsibility for RMS because of the complexity of regulations, and the potential for significant monetary penalties for non-compliance. Through a cooperative team effort between labs and RMS, U of A can achieve and maintain the highest level of environmental compliance. In addition to waste management, RMS also manages the U of A Pollution Prevention (P2) Program, as mandated by the Arizona Department of Environmental Quality (ADEQ). The purpose of the P2 Program is to reduce the presence of toxic substances, the generation of hazardous waste, and the release of pollutants into the environment.

Some of the ways that labs can meet the objectives of the P2 Program, include:

- Limit the inventory of chemicals in the lab to just those essential and in the minimum quantity necessary to perform work;
- Substitute chemicals or processes for less toxic alternatives;
- Increase the collaboration between labs to facilitate the sharing of chemicals, thereby minimizing the inventory on campus overall;
- Reduce the scale at which processes are conducted to minimize the amount of waste generated;
- Distill and reuse chemical solvents, thereby decreasing the ordering and usage of chemicals as well as minimizing waste generated;
- Use computational/instrumental methods instead of wet bench (chemicals) techniques, as this minimizes and eliminates the need for large chemical inventories in the lab.

Glass, plastic, and metal primary containers shall be emptied completely of their contents before disposal. Any liquid used to rinse the containers must be collected as hazardous chemical waste. If the containers possessed flammable solvents, allow the residue to evaporate overnight in a fume hood, until dry. If the container possessed a corrosive, then the residue shall be neutralized, triple rinsed, and allowed to dry in a fume hood. All other chemical containers shall be rinsed with a compatible solvent and allowed to dry in a fume hood. All rinsate shall be collected and submitted to RMS as hazardous waste.

Once the empty container is dry, the label must be removed or defaced. Glass containers should be placed in a glass-specific waste container. Plastic and metal containers can go in the regular trash. Alternatively, coordinate with your building manager to have custodial services pick up the cleaned and dried containers for disposal.

Broken glass shall be disposed of in a glass-specific waste container for custodial services to remove and dispose properly. A glass-specific waste container can be purchased through any of the numerous U of A-approved vendors, or labs can create their own by lining a carboard box with a thick plastic bag.

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Figure 14. Glass waste containers are available through Fisher Scientific or can be "assembled" by the lab. Both broken glass and empty glass bottles can go into the glass waste container, though these containers can fill up very quickly if used for empty glass containers; coordinate with your building manager on the best way to dispose of empty glass containers.

Batteries, such as lead-acid batteries, lithium batteries (LiPo), and nickel-cadmium (NiCd) can be disposed of through RMS by submitting a waste pickup request. Alkaline batteries (such as non-rechargeable Duracell/Energizer AA, AAA, C, D, 9V, etc.) can be disposed of in the regular trash.

Fluorescent & High Intensity Discharge (HID) Lamps should not be disposed of in regular trash, as they often contain mercury. To dispose of these bulbs/lamps, contact Facilities Management at 520-621-3000 to arrange a pickup. If you have mercury containing short arc bulbs, contact RMS to facilitate the disposal of these bulbs specifically.

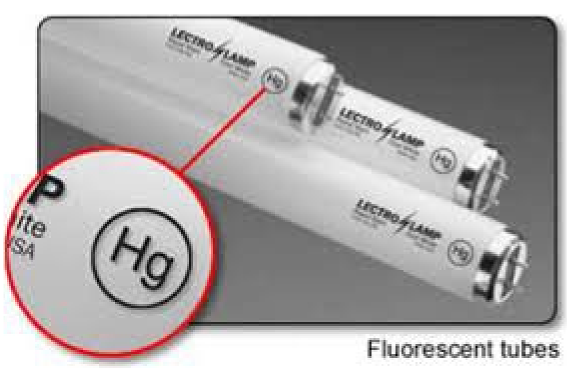

Figure 15. Most, but not necessarily all, fluorescent and HID bulbs will contain the atomic symbol for mercury, "Hg", in a circle printed somewhere on the bulb. If in doubt, treat all bulbs as possibly containing mercury and coordinate with Facilities Management for disposal.

Sharps shall be disposed of in an approved sharps container. Sharps containers shall be puncture-resistant, leakproof on the sides and bottom, closeable, and kept upright. The following shall be disposed of in sharps containers, which can be picked up by RMS:

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- Needles
- Razors
- Metal shards

Sharp-like objects can be disposed of in a carboard box with a plastic bag lining. The purpose of the plastic bag is to prevent any liquid residue from leaking, and the cardboard box is intended to prevent the sharp-like objects from puncturing through. When being disposed of by your building custodial staff, both the box and bag must be disposed of as a single article.

- Plastic pipette tips
- Fiber optic cables

While not required, it is recommended that when disposing of pipette tips less than 1 ml, they be placed in a plastic container such as empty media bottles or repurposed empty drink bottles, as these will further prevent the accidental injury of custodial staff when disposing of the sharp-like object waste containers.

Gas cylinders, whether empty or partially filled, shall be returned to U of A Cryogenics & Compressed Gas Facility. They can be reached by phone at 520-621-2374.

Gas lecture bottles, whether empty or partially filled, cannot be returned to U of A Cryogenics, and must be scheduled for pickup by RMS for disposal. RLSS must also be notified when a lecture bottle is being scheduled for pickup and disposal with RMS, to ensure that lab procedures and training are adequately revised if necessary.

Figure 16. Gas lecture bottles are small and easily held in the hand. This cylinder of cyanogen gas bottled in October 1995 was submitted as hazardous waste in June 2023 – almost 28 years after it had been initially filled!

Dry ice should never be disposed of in a sink. The safest way to dispose of dry ice is to allow for it to sublimate (melt and evaporate) in a tub inside of a fume hood. This ensures that no one in the lab is exposed to the increased carbon dioxide levels that can occur as the dry ice sublimates.

Chemical waste shall be segregated and labeled according to RMS guidance, available on their website, or by contacting rms-hazmat@arizona.edu.

RMS provides 3.5-gallon plastic buckets, labeled with the required HazMat labels, at no cost to labs upon request. The inlet hole on the buckets must be aligned so that it is 90° from the handle, and the lid should be completely affixed on the bucket with a mallet. These waste buckets are emptied, cleaned, and returned to the labs by RMS. In order to have the same bucket returned after being picked-up, you must write your building name, room number, and name on the bucket. It is recommended that labs keep a two-month supply of waste buckets to ensure the lab has waste containers while RMS empties the full containers removed from the lab.
Containers smaller than the 3.5-gallon buckets are acceptable if a lab generates minimal amounts of waste. Acceptable small containers are made of thick wall plastic (not a soda bottle or milk jug). These containers are considered single use only and will not be returned.

Proper waste identification is as critical as using the proper containers. Federal and state regulations require the contents of the container to be identified as soon as the first drop of waste is added to the bucket. The U of A Hazardous Waste Identification Tag is designed to list waste constituents. It is therefore expected that labs begin filling out the waste tag as soon as they begin filling the buckets.

Required information on the tag includes:

1. Name of the person most familiar with the waste
2. Phone number
3. Building name and lab number
4. Full chemical name of waste(s)
5. Percentage of the total volume

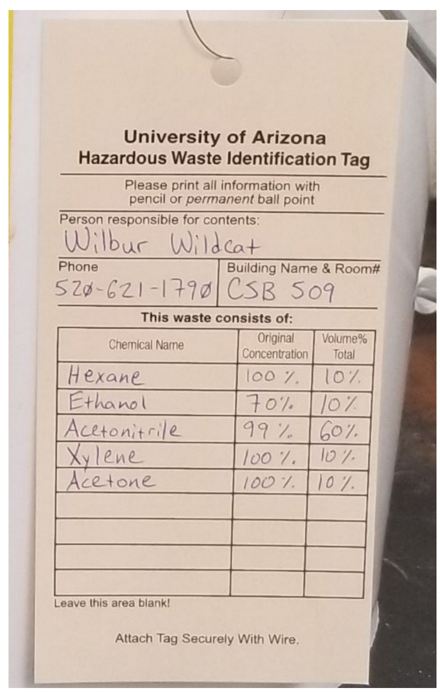

Figure 17. The yellow tag on the left must be present on all waste containers and properly marked, to provide a quick visual of the general hazards of the waste. The tan waste card on the right will have a more specific chemical characterization written out and must also be present at all times on all waste containers.

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Liquid waste should be segregated into the following compatibility groups:

- Non-halogenated organics (this includes organic acids)
- Halogenated organics
- Inorganic acids and heavy metal solutions
- Inorganic bases
- Cyanides
- Photo fixer

As waste is added to the container, the complete chemical name must be written on the tag. Solids and liquids must be segregated, since solids in the liquid waste containers hinder the consolidation process and may damage the waste disposal facility's pump system.

Waste containers must be kept closed at all times, except when actively adding waste. This can be achieved by either manually capping the waste containers, or by using spring-loaded ECO Funnels. Additionally, all waste containers shall be placed in some sort of secondary containment, both as lab best practice, and to help achieve our P2 Program goals. For buckets, and other smaller containers holding less than 25 lbs. worth of liquid waste, trays and tubs are acceptable forms of secondary containment. For larger waste barrels that are 30-50 gallons in volume, labs are expected to use spill containment decks/platforms. As the generator of the waste, the lab is expected to purchase their own secondary containment.

Figure 18. A spill containment deck/platform is a great means of providing secondary containment for barrels and large collections of buckets.

Waste pickup requests should be submitted when chemical waste containers are ¾ full; once they are full, waste buckets should no longer be used for waste accumulation. Requests can be made in four ways.

- Phone: 520-621-5861
- Fax: 520-626-4925
- Email: **rms-hazmat@arizona.edu**
- On-line (**preferred**): **http://risk.arizona.edu/chemicalwastepickupform**

A request by the lab must be made to initiate a waste pick-up; waste will not be removed unless the request has been submitted. For labs in the Chemistry Department, requests must be received

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by Thursday night. For most other labs, who are on the **Quadrant schedule** (PDF format), requests must be received by the Wednesday before the scheduled pick-up day.

Make sure the containers are properly tagged and closed and fully prepared for pick-up the day before the scheduled pick-up day. These must be left in a clearly marked area that can be found readily by the pick-up team. Improperly or untagged waste, or waste that has been collected and presented in a manner that is hazardous to the disposal team, will not be removed and another request must be submitted.

When labs are closing out, or wish to perform a cleanout, the following steps are required to be followed to have your waste picked up:

- Put all solid chemicals with original labels that contain the original chemicals into boxes. Make sure the boxes are no larger than 12”x12”x12”;
- Liquid chemicals in their original containers should be consolidated into one area within the lab and not boxed;
- Chemical mixtures need to be tagged with a chemical waste tag, and the contents of the mixture should be stated on each tag. Unknown chemicals will be tagged with a chemical waste tag and “unknown” should be stated under contents;
- Any unknown chemicals will need to be identified by RMS using a hazardous and laborious process to determine the chemicals characteristics. This is a time-consuming process. If your lab has chemicals that are reactive, (e.g. air reactive, water reactive), or general unstable chemicals, please let contact RMS;
- **All chemicals in original containers with original chemicals do not need to be tagged with a RMS waste tag.**

Lab cleanouts are scheduled events. A pickup for a lab cleanout can take anywhere from two days to two months depending on the volume at the hazardous waste facility and the size of the cleanout.

P-Listed Waste are chemicals that are acutely hazardous and can never be disposed of down the sink/drain. Common examples are acrolein, 2,4-dinitrophenol, and sodium azide. All P-Listed contaminated materials, including empty bottles and PPE must be disposed of as hazardous waste to RMS. For more information on handling this P-Listed waste, contact RMS. Some other chemicals that follow the P-Listed Waste disposal requirements, but are not P-Listed include ethidium bromide.

Sink Drain Disposal of chemicals is almost never an acceptable means of chemical waste disposal. In addition to the wastewater treatment facility possibly being unable to adequately clean the water, chemicals poured down the drain can also cause damage to plumbing, dangerous reactions, explosions in the sewer system, and result in non-compliance for U of A. Only the following chemicals may be disposed of down the drain provided the volume discharged is flushed with at least ten times the volume of clean water as what is disposed of:

- Chlorine bleach solutions;
- Ethanol, in amounts of 500 ml or less, per lab, per week (with 10 times the volume of water to flush);
- Inorganic buffer solutions, not containing any heavy metals or other prohibited contaminants;

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- Inorganic acid or base solutions, neutralized to a pH between 5.0 and 11.0, not containing heavy metals or other prohibited contaminants;
- Black and white photo developer with a pH between 5.0 and 11.0 that is not contaminated with even the smallest amount of photographic fixer.

Unlicensed Radioactive Materials are radioactive materials that labs are permitted to purchase and use without being registered in the U of A Radiation Safety Program. Examples of these types of materials include:

- Uranyl acetate
- Uranyl nitrate
- Uranium ICP standards
- Thorium acetate
- Thorium nitrate
- Thorium ICP standards

If the lab is using these materials, then all waste must be segregated separately from any other waste streams, since radioactive waste disposal is managed by RLSS. For a waste pickup, contact RLSS at rlss-help@arizona.edu. Alternatively, if the lab is no longer in need of their available for other labs that may wish to work with the material.

DEA Controlled Substances have a separate regulatory component to their destruction and disposal. RLSS facilitates the destruction of the DEA Controlled Substances in the lab. To receive assistance in the destruction of DEA Controlled Substances, contact RLSS at rlss-help@arizona.edu.

Waste Charcoal Canisters pose a risk in the disposal process of catching fire due to the spontaneous combustible nature of the charcoal contained within them. As a result, these canisters must be disposed of like chemical waste, and not placed in red bags with biological waste. The canisters themselves can be placed in a cardboard box and submitted to RMS for a waste pickup.

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5. Chemical Hazards Quick Reference Guides

The following pages are the quick reference guides and can easily be printed out for lab workers to become familiar with the various chemical hazards that they may be exposed to in their workplace. They are not designed to be all-inclusive, nor are they intended to be the sole means of information and training that a worker receives with regards to working with the various chemical hazards. AHs and ASCs are expected to properly train all workers in the lab on hazards and processes in the lab and how to safely mitigate risk.

Workers are also expected to be responsible for their own safety. If a worker finds themselves in an unsafe situation or working with chemicals or processes without adequate training or PPE, they are also expected to speak up for themselves and exercise their rights as an employee to work in a place of employment free of recognized hazards that are causing or are likely to cause death or serious physical harm.

Always remember to consult the chemical SDS ***before*** working with a chemical, so that in the event of an emergency, you are already familiar with the first aid measures needed to address and exposure.

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5.1 Explosives

DEFINITION: An explosive chemical is either a solid or liquid chemical which by itself, is capable via a chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. Pyrotechnic chemicals/compounds are included even when they do not evolve gases.

EXAMPLES: Common explosive chemicals found at U of A are azides and nitro derivatives of phenols or other similar ring compounds such as phenylhydrazine. In each of these cases, the high abundance of nitrate groups lends to the rapid oxidation of the carbon compounds, thereby generating heat and gaseous expansion that can be over 1,000 times greater than the initial volume of the nitrated explosive compound. Proper handling of these chemicals when they are in storage is by far the best preventative measure to ensure safety in the lab.

Many explosive chemicals are sold as “desensitized explosives” or “wetted explosives”, which means they are sold in a solution of water. By being immersed in water, it reduces the sensitivity of the explosive chemicals to shock and friction. Many of the nitro derivatives of phenol and phenylhydrazine are sold wetted. In the case of picric acid (2,4,6-trinitrophenol), it may be sold as a wetted with 25% water. In this case, it is wetted to be 25% by weight of the picric acid. This means that a 100-gram bottle of picric acid would be dissolved in 400 grams (mls) of water, such that it then is a 25% by weight solution. Wetted explosives that are allowed to dry out, that is if the solid particles are not kept submerged, can become very unstable and in the case of picric acid, have the explosive power equivalent to TNT.

DISPOSAL: If an explosive chemical is found to have dried out, it is safest to dispose of it immediately. To properly dispose of explosives, leave them where they have been found, alert others who have access to the area on proper behavior, and contact RMS Hazardous Waste Group at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab.

STORAGE: Explosives should be labeled with the date they were received and the date they are opened. Additionally, there should be a periodic inspection (monthly) of the bottles to ensure that if they are supposed to be wetted, they are remaining properly wetted. If they are showing signs of drying out, it is much easier to top the bottle off with DI water, than to allow the entire bottle to dry out and become an explosive hazard. Explosive chemicals should also never come into contact with incompatible materials, which is oftentimes metals, as this can cause the formation of extremely sensitive and reactive explosive salts.

HANDLING: In general, explosive chemicals should not be handled with metal tools or equipment, due to the potential for reaction. Some processes that use explosive materials should be done so while utilizing blast shields. These are commonly plexiglass shields that go around the reaction setup and can help protect workers in the event of an explosion. In 2010, two students at Texas Tech University were working with a Nickel (II) Hydrazine Perchlorate derivative where they scaled up their work in excess of what was prudent, resulting in 10 grams of energetic material being present as opposed to the common 50-300 milligrams. As a result of

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failing to wear proper eyewear, not performing work behind blast shields, and not performing a ***RAMP*** analysis beforehand, one of the students lost three fingers, injured an eye, and suffered burns on their hands and face.

PPE: When working with explosives, appropriate PPE should always be used, since relying on engineering and administrative controls may not be sufficient. Common PPE that is stated across many products' SDS is:

- Impact and splash resistant safety glasses/goggles as well as face shields
- Flame-Resistant (FR) lab coats, in addition to anti-static clothing, such as cotton.
- Appropriate gloves as stated in the SDS): many of the wetted explosives are also toxic, so ensuring the proper glove material and thickness is selected is critical

FIRST AID: In the event of an explosion, immediately call 911. If an injured person is easily accessible, begin administering first aid to them. Be careful to minimize moving them if they are unconscious as this can exacerbate some injuries. If there is a fire present, activate the building fire alarm system. If the fire is small enough, use the nearest fire extinguisher and use it to extinguish the flames.

FUN FACT: 2,4-Dinitrophenol (DNP) causes mitochondrial uncoupling, which leads to a rapid loss of ATP and subsequent hyperthermia. DNP was therefore used as one of the first weight loss drugs but has since been banned due to the high level of toxicity and potential for overdose and accidental death.

Figure 19. A 125-gram bottle of dried picric acid found in a laboratory in 2022, with a purchase/open date of June 2002. The risk of explosion from desensitized explosives increases significantly if the material is allowed to dry out.

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5.2 Flammables

DEFINITION: A flammable chemical is either a liquid, solid, or gas that will ignite and burn when raised to a particular temperature in the presence of oxygen, resulting in exothermic decomposition. Flammables also include self-reactive chemicals, which are thermally unstable liquid or solid chemicals that can undergo exothermic decomposition, even if oxygen is not present.

EXAMPLES: Common flammable liquid chemicals found at U of A are primary and secondary alcohols, aldehydes, and mono- and poly-cyclic aromatic ring solvents. Common flammable solid chemicals found at U of A are powdered metals, as well as alkali metals that are kept submerged in mineral oil or another inert liquid. Common flammable gas chemicals found at U of A are methane, hydrogen, and butane.

DISPOSAL: All flammable chemicals (except for returnable cylinders of flammable compressed gas) can be picked up by the RMS. To schedule a pickup, email them at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab. If you have returnable flammable compressed gas cylinders, contact U of A Cryogenics & Compressed Gas Facility. They can be reached by phone at 520-621-2374.

STORAGE: Many flammable chemicals are used in the lab in large quantities and end up inadvertently stored improperly. For example, on the ground floor of a building with automatic sprinklers installed, a maximum of 60 gallons of flammables in their original containers may be stored outside of approved flammable cabinets. This number also includes any flammable waste, so when looking at a building with 10 separate lab rooms across the ground floor, it quickly becomes evident that anything in excess of 6 gallons per room would be in violation with Fire Code storage requirements. Therefore, flammables should be stored in approved flammable cabinets and/or approved flammable safety cans as much as possible, in addition to minimizing the amount that exists in the lab. This is especially true as you increase in height in a building. Labs that are on the 4^{th}, 5^{th}, and 6^{th} floors above ground level are limited to 12.5% of the limits that exist on the ground floor. This means on the 4th floor above ground level, there can be no more than 7.5 gallons outside of approved flammable cabinets or approved flammable safety cans, *for the entire floor*!

HANDLING: By utilizing proper engineering controls, lab workers can ***Minimize*** the risks associated with working with flammables. When dispensing flammable liquids, the containers should be bonded, and the receiving containers should be grounded to an earth-contact ground. An earth-contact ground is one where a direct, conductive path exists to the actual ground/soil of the earth. All buildings already have these built into their electrical systems, so the addition of a grounding bar in a laboratory is a simple addition that can be requested through Facilities Management. When a dispensing and receiving container are bonded, they are connected together with a conductive pathway, which allows for the flow of current between containers without arcing anywhere in between. By grounding the receiving container, it ensures that any accumulated charge is conducted safely away from the containers and dissipated to an earth-contact ground. The bonding and grounding of flammable liquid containers is important when dispensing flammables, since the electrostatic charge of the flowing flammable liquid can generate static electricity, which if not properly grounded and bonded, can arc between surfaces, thereby generating a spark and causing a fire.

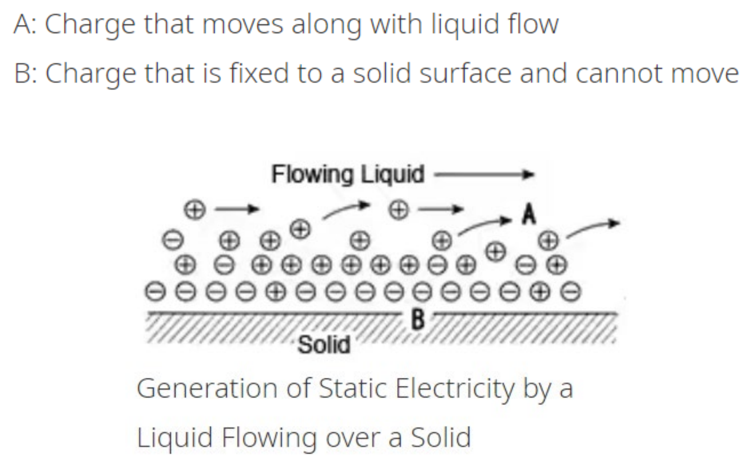

Figure 20. Generation of static electricity caused from the flowing of a liquid

Static electricity is also more likely to accumulate in dry climates that lack high levels of humidity, due to the lack of water vapor that can help to dissipate electrical charge. U of A's main campus and satellite locations are located in very arid climates, and therefore, the possibility for static electricity generation is relatively high.

PPE: If flammables are being used in bulk quantities, then appropriate flame-resistant PPE should be used. However, remember that PPE is the last line of defense for protecting yourself. Some flammable solvents are not compatible with traditional PPE. Nitrile exam gloves for example are particularly susceptible to acetone. Therefore, if working with acetone (SDS below) or any other solvent, it is best to make sure that you follow what the manufacturer states:

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Personal protective equipment

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

Skin protection
This recommendation applies only to the product stated in the safety data sheet, supplied by us and for the designated use. When dissolving in or mixing with other substances and under conditions deviating from those stated in EN374 please contact the supplier of CE-approved gloves (e.g. KCL GmbH, D-36124 Eichenzell, Internet: www.kcl.de).
Full contact
Material: butyl-rubber
Minimum layer thickness: 0.7 mm
Break through time: 480 min
Material tested:Butoject® (KCL 898)

This recommendation applies only to the product stated in the safety data sheet, supplied by us and for the designated use. When dissolving in or mixing with other substances and under conditions deviating from those stated in EN374 please contact the supplier of CE-approved gloves (e.g. KCL GmbH, D-36124 Eichenzell, Internet: www.kcl.de).
Splash contact
Material: Latex gloves
Minimum layer thickness: 0.6 mm
Break through time: 10 min
Material tested:Lapren® (KCL 706 / Aldrich Z677558, Size M)

Body Protection
Flame retardant antistatic protective clothing.

Figure 21. Example PPE requirements found in a product SDS.

FIRST AID: When working with flammables, there are a myriad of injuries that can occur. In the case of methanol, high levels of dermal absorption or ingestion can lead to blindness and/or death. If concentrated acetic acid is spilled on the skin or in the eyes, it can cause irreversible damage. However, the most common injuries observed on campus that occur from working with flammables is either splashing in the eyes or burns as a result of a fire. In the case of splashing in the eyes, immediately consult the SDS, wherein the majority of the time a lab worker should rinse their eye(s) for 15 minutes, removing their contact lenses if they are wearing them before rinsing, and be seen by an ophthalmologist.

In the event of a burn, make sure to extinguish the fire if it is burning your clothes. The best way to do this is to remember Stop, Drop, and Roll:

- Stop what you are doing immediately
- Drop to the floor and lay with your legs out straight, and cover your eyes, mouth, and nose with your hands if possible
- Roll back and forth until the fire is out

Many clothes are comprised of synthetic fibers and therefore can be more likely to burn *and melt to the skin*! This further exacerbates the recovery process, which can lead to medical complications and possibly death. Remember, Sheri Sanji died from severe burns across her body 18 days after her acrylic sweater caught fire after not wearing appropriate PPE during her lab accident at UCLA. In the case of Sheri, a post-doc in the lab tried to smother the fire on her by using his non-fire-resistant lab coat, which in turn burned as well, thereby worsening her injuries.

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Once a fire has been extinguished, immediately wash the area with cool water, apply burn cream, and seek medical attention. Burns can very easily become infected if not properly taken care of by medical professionals.

FUN FACT: Many carbon-based solids, such as sugar, can burn and if conditions are just right, cause explosions as well. In 2008, a sugar refinery for the Imperial Sugar Company exploded in Georgia, USA, killing 14 people, injuring 38, and leveling a large portion of the factory.

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5.3 Oxidizers

DEFINITION: An oxidizing chemical is either a liquid, solid, or gas that by itself does not burn, but can cause and/or contribute to, the burning of other material. This is usually accomplished by the oxidizer yielding oxygen to the fire, but may not always be the case, as is the case with chlorine gas.

EXAMPLES: Common oxidizing liquid chemicals found at U of A are hydrogen peroxide and inorganic acids such as sulfuric, nitric, and perchloric. Common oxidizing solid chemicals found at U of A are nitrate, chromate, and permanganate salts. Common oxidizing gas chemicals found at U of A are oxygen and nitrous oxide.

DISPOSAL: All oxidizing chemicals (except for returnable cylinders of oxidizing compressed gas) can be picked up by RMS. To schedule a pickup, email them at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab. If you have returnable oxidizing compressed gas cylinders, contact U of A Cryogenics & Compressed Gas Facility. They can be reached by phone at 520-621-2374.

STORAGE: When oxidizing liquids and solids are present in containers greater than the 5 pound (2 kg) or 0.5 gallon (2 liter) threshold, they must be stored away from incompatible materials. The challenge with oxidizing chemicals, is that in addition to flammables, many other chemical classes are also incompatible, which means that oxidizers would therefore need to be stored completely separate from all other chemicals in an approved hazardous material storage cabinet. It is therefore strongly recommended that labs purchase the smallest sized container of oxidizers possible to mitigate storage problems in the lab.

HANDLING: Oxidizers, in the sense of chemical safety, contribute to the combustion of materials. This can differ from oxidizing agents in a chemistry setting, which are compounds that *accept or gain* electrons in a reaction. Potassium chromate, for example, is an oxidizing agent in a reduction-oxidation reaction but is not classified as an oxidizer with respect to chemical safety. In general, oxidizing chemicals should not be handled with metal tools or equipment, due to the potential for reaction. Since oxidizing chemicals commonly yield oxygen to combustion reactions, they can also potentially cause injuries that can cause irreversible damage to the skin and/or eyes.

PPE: When working with oxidizers, appropriate PPE should always be used, since relying on engineering and administrative controls may not be sufficient. Common PPE that is stated across many oxidizing chemical SDS is:

- Impact and splash resistant safety glasses/goggles as well as face shields
- Appropriate gloves
- Be aware that some oxidizers, like sulfuric and nitric acid react more readily with some natural fibers like cotton than they do with some synthetic fibers like polyester. However, this also depends on the temperature, concentration, and residence time that the oxidizers sit on the fabric.

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FIRST AID: Always consult the product SDS if you have splashed, spilled, or ingested an oxidizing chemical. In some cases, oxidizers are also corrosive, so it may be necessary to use a safety shower and/or emergency eye wash.

FUN FACT: Despite possessing four oxygens and being incapable of acting as a reducing agent, phosphoric acid is not considered to be an oxidizer from a chemical safety standpoint. This is due to the fact that phosphoric acid is a weak acid and therefore does not disassociate as easily as other oxidizing strong acids like sulfuric and nitric. As a result of the lack of disassociation, the oxygens are bound strongly to both the phosphorus atom and the hydrogen atoms, preventing them from being available in a combustion reaction. Phosphoric acid therefore would pose little to no hazard being stored with flammable liquids, and in fact, per the manufacturer SDS, this is often permitted.

Figure 22. Fuming nitric acid, a very powerful oxidizer, can react with nitrile gloves to result in a combustion reaction.

5.4 Compressed Gases

DEFINITION: A compressed gas is a gas that is held in a pressurized vessel at a minimum pressure of 29 psi (200 kPa). This classification includes gases that are liquefied or liquified *and* refrigerated. Important to also note, is that aerosols are also considered to be compressed gases. Aerosols, specifically, are non-refillable pressurized vessels that contain a compressed, liquefied, or dissolved under pressure gas. Aerosol containers are also equipped with a release device that allows for the contents to be ejected as particles in suspension in a gas, or as a foam, paste, powder, liquid, or gas. Compressed gases are unique, in that any type of chemical hazard can exist as the physical hazard of a compressed gas.

EXAMPLES: Common compressed gases found at U of A are liquid nitrogen, carbon dioxide, helium, argon, methane, and butane, as well as any combination of these various gases.

DISPOSAL: Almost all compressed gases at U of A are purchased in refillable cylinders from the U of A Cryogenics & Compressed Gas Facility. Some gases may be purchased in non-refillable cylinders, commonly referred to as lecture bottles. Refillable containers must be returned to U of A Cryogenics within five years of receipt, to ensure that their hydrostatic test remains valid and they can continue to be used across the university. To order any compressed gas and/or to schedule a pickup of a refillable cylinder, contact U of A Cryogenics & Compressed Gas Facility. They can be reached by phone at 520-621-2374. To schedule the pickup of a non-refillable gas cylinder, such as a lecture bottle, reach out to RMS. They can be emailed at rms-hazmat@arizona.edu.

STORAGE: Compressed gas cylinders must always be kept adequately segregated from incompatible chemicals, regardless of the amount and quantity of gas or other chemical present. There are three ways that segregation can be achieved. The first is by physical space, specifically, 20 feet of separation between the compressed gas and the incompatible chemical. The second means of segregation is by ensuring that the compressed gas is stored behind a barrier that has at least a 30 minute fire resistance. The third means of segregation is by storing either the compressed gas or the incompatible chemical in an approved hazardous material storage cabinet. For gases, this would be an RLSS-approved gas cabinet. For flammable liquids and solids, this would be an approved flammable cabinet. For corrosives, this would be an approved corrosive cabinet. All compressed gas cylinders with an internal water volume greater than 1.3 gallons must be securely anchored upright to the wall or other *solid structure* with either a tight-fitting chain or strap about 1/2-2/3 of the height of the cylinder from the floor. Alternatively, compressed gas cylinders can also be stored in stationary cylinder stands. Compressed gas cylinders with an internal water volume less than 1.3 gallons are permitted to be stored on their side as long as they are prevented from rolling and dropping.

HANDLING: Aside from the other intrinsic health and physical hazards that may exist depending on the molecule(s) that make up the compressed gas, the most important hazard that exists in handling compressed gases is the fact that the cylinders is their weight and pressurization. It is therefore discouraged that labs move gas cylinders themselves. If a cylinder

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must be moved, always use a gas cylinder hand truck. If a gas cylinder or any cryogenic gas must be transported up and down floors, the following steps must be followed:

1. Use the freight elevator when possible. However, regardless of the elevator used, place signs on each floor that will be passed, warning people to not enter the elevator if a gas cylinder or cryogenic dewar is present. If possible, station a person on each floor to ensure that no one enters the elevator being used.
2. Place the gas cylinder hand truck with the gas cylinder still securely strapped to it or the cryogenics dewar on the elevator and send it directly to the floor it will be used/stored, but never ride with the cylinder/dewar. Remember, the elevator should never be occupied with anyone when there is a gas cylinder or cryogenics dewar present.
3. Once the gas cylinder has arrived at the floor where it will be used/stored, there must be a person present to receive it and immediately move it out of the elevator. At this point, remove all posted signage and personnel on the floors guarding the elevator doors.

Compressed gases must always be used with a regulator to properly regulate the pressure of the gas being discharged. It is also required that compressed gas systems have a manual or automatic shut-off valve both at the source (on the cylinder) and at the point of use. Since gas cylinders have hand valves on them, that satisfies the shut-off valve at the source, so always be sure the end of the piping or hose you are using also has an appropriate means of shut-off. This can include the electronic controls on the incubator, the valves on the torch, or any other means flow control at the point of use.

PPE: When working with compressed gases, be aware that the high pressure of the gases can send small particles flying. Therefore, always wear safety glasses, goggles, or a face shield. If your compressed gas is a flammable gas, you may likely need to wear flame resistant PPE.

When working with cryogenic liquids, it is imperative to wear cryogenic gloves, since they are adequately insulated to protect against frostbite and cold burns.

FIRST AID: Always consult the product SDS if you have been adversely exposed to a compressed gas. Typically, the health hazard will be associated with the intrinsic properties of the gas molecules. In the case of a cryogenic burn, treat the injury as you would treat frostbite. Start by slowly warming to affected area with warm, but not hot, water. It is always critical to seek professional medical attention after you have been adversely exposed to cryogenics.

If a gas cylinder has fallen on your foot, hand or elsewhere on your body, you may end up with one or more broken bones. Immediately go to the Emergency Room or UrgentCare or call 911 to be transported.

FUN FACT: Although compressed gas cylinders are designed to spin around in a circle if the valve fails or breaks off, the amount of energy stored in the compressed gas molecules can actually cause the cylinder to shoot off like a missile. The energy that these cylinders have upon rupture can be enough that they can easily penetrate brick and block walls and cause considerable damage to concrete walls. Workers standing in the way of a flying gas cylinder can easily lose struck limbs and be killed upon impact.

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5.5 Corrosives

DEFINITION: A corrosive chemical is either a liquid, solid, or gas that causes *irreversible* damage to the eyes, skin, or both. In the case of skin, this means that there is visible necrosis through the epidermis and into the dermis. In the case of eyes, this means that there is serious physical decay of vision. Many corrosive chemicals are also corrosive to metals, which means they will materially damage, or even destroy, metals via chemical action.

EXAMPLES: Common corrosive liquid chemicals found at U of A are formaldehyde, hydrogen peroxide, bleach, hydrochloric acid, and ammonium hydroxide. Common corrosive solid chemicals found at U of A are sodium hydroxide and phenol. Common corrosive gas chemicals found at U of A are nitrogen dioxide and ammonia.

DISPOSAL: All corrosive chemicals (except for returnable cylinders of corrosive compressed gas) can be picked up by RMS. To schedule a pickup, email them at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab. If you have returnable corrosive compressed gas cylinders, contact U of A Cryogenics & Compressed Gas Facility. They can be reached by phone at 520-621-2374.

STORAGE: When corrosive liquids and solids are present in containers greater than the 5 pound (2 kg), 0.5 gallon (2 liter) threshold, they must be stored away from incompatible materials. The challenge with corrosive chemicals is that they can be reactive with many storage cabinets. Across the university, many storage cabinets tend to be either wood or enamel coated metal. While pouring liquid corrosives out of the bottle during normal work, there tends to be a bead of liquid that dribbles down the side of the bottle. This results in the telltale rings of chemical that accumulate at the base of the bottle, in contact with the storage shelf. When the storage shelf is wood, this chemical absorbs into the wood, thereby damaging it, and in the case of metal, this chemical residue can cause rusting and deterioration of the shelf. For this reason, secondary containment should always be used to prevent the accumulation of leaking and dribbling chemicals in storage. Further, it is strongly recommended that labs purchase the smallest sized container of corrosives they can, to help to mitigate storage problems in the lab.

HANDLING: Corrosives should always be handled with care, particularly since they can cause *irreversible* damage to the skin and eyes. To ***Prepare*** for working with corrosives, always be aware of the closest eyewash and safety shower in the lab, and make sure they are operational, including having been tested within the last 3 months. When transporting larger bottles of corrosives, use rubber bottle carriers. Fume hoods are always the best location to work with corrosives, as they keep the vapors aways from workers. When transferring corrosives to smaller containers, including beakers and flasks, always label what is in the container and the concentration; can you tell the difference between a beaker of 1M (1N) hydrochloric acid and a beaker of water?

PPE: When working with corrosives, appropriate PPE should always be used, since relying on engineering and administrative controls may not be sufficient. Common PPE that is stated across many corrosive chemical SDS is:

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- Impact and splash resistant safety glasses/goggles as well as face shields
- Appropriate gloves
- Loose-fitting clothes give more time to disrobe and get to an emergency shower, thereby preventing irreversible damage to the skin. Tight fitting clothes, however, will hold spilled corrosives against the skin more tightly and for a longer period of time than loose fitting clothes will. Think twice before wearing leggings or compression pants in the lab!

FIRST AID: Always consult the product SDS if you have splashed, spilled, or ingested a corrosive chemical. **Never attempt to neutralize a corrosive on the skin; this can lead to an exothermic reaction and further complicate the injury.** In almost all cases, time is of the essence to rinse the corrosive out of your eyes and/or off your skin. Therefore, immediately use the nearest eyewash, safety shower, or sink to remove spilled corrosives from your body. Some corrosives can be lethal from a single exposure; in the case of hydrofluoric acid, this can occur if you spill approximately enough acid to cover the palm of your hand. Lethality occurs from the fluoride ions absorbing and binding to the calcium in your blood, leading to a condition known as hypocalcemia. As a result, labs working with hydrofluoric acid must have calcium gluconate (Calgonate™) present in their first aid kit. Other corrosives, like phenol, when spilled on the skin, can actually be mitigated by washing immediately with low molecular weight polyethylene glycol (PEG-300 or PEG-400) or isopropyl alcohol. Washing with either polyethylene glycol or isopropyl does require using copious amounts and wiping away with a rag or sponge to help absorb the phenol on the skin.

FUN FACT: Strong bases can impart a bitter taste if accidentally ingested and typically have a slippery feeling when contact is made with the oils on the skin. Strong acids, however, typically taste sour if accidentally ingested and will create a burning sensation on the skin. Bases ($pH>7$) require more rinsing and washing than acids ($pH<7$) from the skin and eyes. This is due to the fact that acids denature proteins in the skin, resulting in coagulation necrosis, which limits tissue penetration. Bases on the other hand denature the proteins and saponify the fats in the skin, leading to liquefaction necrosis, which does not limit tissue penetration.

5.6 Acute Toxins

DEFINITION: An acutely toxic chemical is a liquid, solid, or gas that causes adverse effects following oral or dermal administration of any of the following:

- A single dose of the chemical
- Multiple doses are given within 24 hours

Additionally, if the chemical produces adverse effects after being inhaled for a maximum of four hours, then it is also considered to be acutely toxic. Essentially, exposure to these chemicals in small quantities can cause major health problems in the short-term, including death.

EXAMPLES: Common acutely toxic liquid chemicals found at U of A are methanol, formaldehyde, chloroform, and hydrofluoric acid. Common acutely toxic solid chemicals found at U of A are phenol, ethidium bromide, and potassium dichromate. Common acutely toxic gas chemicals found at U of A are carbon monoxide and ammonia.

DISPOSAL: All acutely toxic chemicals (except for returnable cylinders of acutely toxic compressed gas) can be picked up by RMS. To schedule a pickup, email them at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab. If you have returnable acutely toxic compressed gas cylinders, contact U of A Cryogenics & Compressed Gas Facility. They can be reached by phone at 520-621-2374.

STORAGE: Acutely toxic chemicals represent a health hazard to workers in the lab. The chemicals may possess physical hazards, such as being flammable or reactive, but with regard to properly storing acutely toxic chemicals, contamination is the biggest concern. Since acutely toxic chemicals are represented by a skull and crossbones pictogram, these chemicals are considered as having "a high degree of acute toxicity" within the scope of the Particularly Hazardous Chemicals. As a result, the storage of acutely toxic chemicals shall be in such a way that it does not cause contamination of the storage area.

Since acutely toxic chemicals can have a very low lethal dose (LD50), it is important to minimize the accumulation of acutely toxic chemicals to just what is absolutely necessary for the chemical work occurring in the lab.

HANDLING: Since acutely toxic chemicals fall under the classification of Particularly Hazardous Chemicals (PHCs), they must always be handled in a Designated Area. A designated area can be a chemical hood, or in some cases, it can be the entire lab. It is important to remember though, that following the use of any acutely toxic chemical, an assessment must be made as to the degree of contamination in the designated area. If the designated area is contaminated, then lab members must decontaminate the designated area.

When working with acutely toxic chemicals, it is imperative that human exposure is eliminated as much as possible. Always try to use acutely toxic chemicals inside a fume hood or other ventilated device. Additionally, always use the smallest amount necessary for the shortest period of time, as infrequently as possible.

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PPE: Although engineering controls are critical in preventing exposure and injury to acutely toxic chemicals, it is still important to always wear the proper PPE. Different materials protect against different chemicals. When Dr. Karen Wetterhahn was working with dimethylmercury at Dartmouth in 1996, she accidentally spilled several drops of dimethylmercury on her latex-gloved hand. Unbeknownst to her, dimethylmercury permeates latex within 15 seconds. Blood tests 5 months later showed that her blood mercury levels were 20 times higher than the toxic thresholds. Less than 10 months after her initial exposure, Dr. Wetterhahn died from acute mercury poisoning.

Examples like these show the criticality of selecting the right PPE when working with acutely toxic chemicals. Since the routes of exposure can be oral, dermal, ocular, or inhalation, then workers must always consult the SDS prior to working with acutely toxic chemicals to know how to best protect themselves from toxic exposures. Contact RLSS (RLSS-help@arizona.edu) for assistance in PPE selection if you are unsure.

If PPE becomes contaminated with an acutely toxic chemical, then it should be either properly cleaned, or submitted as hazardous waste to RMS.

FIRST AID: Always consult the product SDS if you have splashed, spilled, ingested, or inhaled an acutely toxic chemical. Some acutely toxic chemicals have special first aid instructions. For example, if phenol is spilled on the skin, rinsing and washing the exposed area with polyethylene glycol is actually better to help prevent absorption of phenol into the skin than water. However, this only applies in the first few minutes of exposure; if more than a few minutes have elapsed, rinse with soap and water.

Due to the high degree of toxicity associated with acutely toxic chemicals, any exposure should be checked by a medical professional.

FUN FACT: Osmium tetroxide historically has been used as a stain for electron microscopy due to the contrast that it provides in images. Particularly, osmium tetroxide is a very effective stain for lipids. If osmium tetroxide is improperly handled while working with it, it can cause irreversible staining of the cornea, leading to permanent blindness. To properly decontaminate surfaces of osmium tetroxide, corn oil is used, since as a lipid, it will turn black as it absorbs osmium tetroxide, thereby providing a visual indicator of residual contamination levels.

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5.7 Irritants

DEFINITION: An irritant chemical is either a liquid, solid, or gas that causes tissue sensitization or an allergic reaction following oral, dermal, or inhalation exposure. In the case of irritant gases, narcosis (e.g. drowsiness and unconsciousness) can also occur. The effects of irritant chemical exposures are often local and will typically disappear within days or weeks of exposure.

EXAMPLES: Common irritant liquid chemicals found at U of A include many of the enzymes like proteases and cellulases as well as common consumer glues like Loctite Super Glue and Gorilla Glue. Common irritant solid chemicals found at U of A include many of the antibiotics like ampicillin, penicillin, and streptomycin. Common salts are also included here, such as sodium carbonate, ammonium acetate, and calcium chloride. There are not many gases that are commonly irritants, but smokes and fumes from combustion, soldering, and welding can all produce respiratory irritation in addition to vapors that can come off liquid chemicals.

DISPOSAL: All irritant chemicals can be picked up by RMS. To schedule a pickup, email them at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab.

STORAGE: Irritant chemicals do not pose nearly the health risks to workers as other classes of chemicals do. However, workers may continually be exposed to irritant chemicals, which can result in the development of sensitizations and allergies. As a result, irritant chemical containers should always be kept closed when not being used, and care should be taken to minimize unnecessary exposure.

HANDLING: Irritant chemicals can cause the development of certain sensitizations and allergies. People who wear jewelry or watches containing nickel can develop allergic contact dermatitis, thereby necessitating the usage of stainless steel instead. In a laboratory setting, the regular usage of latex gloves can lead to the development of a latex allergy.

When working with animals in the laboratory, particularly mice and rats, constant and regular exposure to rodent dander can lead to the development of a dermal sensitization or even an allergy to rodents.

PPE: As with all other chemicals, proper PPE is essential when working with irritant chemicals. But in the case of latex gloves, even the PPE can contribute to the development of an allergy or sensitization.

If PPE becomes heavily contaminated with an irritant chemical, then it should be either properly cleaned, or submitted as hazardous waste to RMS.

FIRST AID: Always consult the product SDS if you have splashed, spilled, ingested, or inhaled an irritant chemical. Some irritant chemicals have special first aid instructions. In the case of allergens, a worker can go into anaphylactic shock upon exposure to the irritant chemical.

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Regardless of the degree of exposure to irritant chemicals, any exposure should be checked by a medical professional.

FUN FACT: Because sensitizers and allergens are specific to the immune system, what causes an allergy in one person may not cause an allergy in another person. When a chemical irritant binds with a human protein, the body's immune system can perceive it as a threat and begin producing antibodies to recognize and target these modified proteins leading to the development of a sensitization and/or allergy. Future exposure to the irritant chemical can then cause a cascading immune response leading to symptoms ranging from watery eyes, runny nose, and itchy skin to full anaphylactic shock.

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5.8 Carcinogens, Reproductive Toxins, and other Mutagens

DEFINITION: A carcinogenic, reproductive toxin, or other mutagen chemical is a liquid, solid, or gas that causes a mutation to the genetic material in a cell. Sometimes these can be mutations that target the cells of specific organs, and in other cases, it can cause cellular mutation at the point of exposure.

EXAMPLES: Common mutagenic liquid chemicals found at U of A include benzene, chloroform, dichloromethane, and formaldehyde. Common mutagenic solid chemicals found at U of A include silica for column chromatography as well as many of the common salts containing heavy metals such as lead oxides, and hexavalent chromium. The only common mutagenic gas chemical found at U of A is ethylene oxide, however, the smokes and fumes from combustion, soldering, and welding can all produce mutagenicity in addition to vapors that can come off liquid chemicals.

DISPOSAL: All mutagenic chemicals can be picked up by RMS. To schedule a pickup, email them at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab.

STORAGE: Mutagenic chemicals represent a chronic health hazard to workers in the lab. The chemicals may possess physical hazards, such as being flammable or corrosive, but with regard to properly storing mutagenic chemicals, contamination is the biggest concern. Continuous, repeated usage of mutagenic chemicals poses the biggest hazard, as chronic exposure is associated with increased mutagenic effects. However, short and intense exposures can also result in mutagenic effects. Mutagenic chemicals may be identified by the disintegrating torso pictogram. Additionally, mutagenic chemicals also fall within the scope of the Particularly Hazardous Chemicals (PHCs), which means that they shall be stored in a way that does not cause contamination of the storage area.

HANDLING: Since mutagenic chemicals fall under the classification of Particularly Hazardous Chemicals, they must always be handled in a Designated Area. A Designated Area can be a chemical hood, or in some cases, it can be the entire lab. It is important to remember though, that following the use of any acutely toxic chemical, an assessment must be made as to the degree of contamination in the Designated Area. If the Designated Area is contaminated, then lab members must decontaminate the Designated Area.

When working with mutagenic chemicals, it is imperative that exposure is eliminated as much as possible. Always try to use mutagenic chemicals inside a fume hood or other ventilated device. Additionally, always use the smallest amount necessary for the shortest period of time, as infrequently as possible.

PPE: Although engineering controls can help to prevent exposure and injury to mutagenic chemicals, it is still important to always wear the proper PPE. One of the main routes of entry for mutagenic chemicals is via inhalation. In the event that engineering controls are insufficient at protecting against exposure to mutagenic chemicals, respiratory protection may be necessary.

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However, use of respirators in the workplace requires medical clearance, training, and fit testing. Therefore, minimizing exposure through engineering controls will always be the best approach. Since the health hazards associated with mutagenic chemicals may not be immediately noticed, reusable PPE must always be kept clean and properly decontaminated. If PPE becomes contaminated with a mutagenic chemical and cannot be properly cleaned, it must be submitted as hazardous waste to RMS.

FIRST AID: Always consult the product SDS and/or Poison Control if you have splashed, spilled, ingested, or inhaled a mutagenic chemical. Some mutagenic chemicals have special first aid instructions. Due to the potential for cellular mutation as a result of exposure to a mutagenic chemical, any exposure should be checked by a medical professional.

FUN FACT: Streptozotocin (STZ) is an antibiotic that is used to treat pancreatic cancer. However, exposure in healthy individuals can result in the death of insulin-producing cells of the pancreas, leading to the development of diabetes. This type of chemical behavior is very common for the class of drugs that are known as antineoplastic chemicals. Antineoplastic chemicals are also known as chemotherapy chemicals. Although they can be useful in combatting cancer, healthy people are at a higher risk of developing cellular mutation upon exposure to antineoplastic chemicals.

5.9 Environmental Hazards

DEFINITION: A chemical that poses an environmental hazard can be either a liquid, solid, or gas that causes toxicity to aquatic species and/or has the potential to damage the ozone layer in the upper atmosphere. It is important to note that chemicals that do not have an environmental hazard warning may still be hazardous to the environment. All chemicals that have the potential to contaminate the environment are designated as such through the Environmental Protection Agency, but only some of these chemicals are designated as being environmental hazards through the Global Harmonized System (GHS) as adopted by OSHA.

EXAMPLES: Common GHS environmental hazard liquid chemicals found at U of A are guanidine thiocyanate containing kits, liquid phenol, chloroform, and formaldehyde. Common GHS environmental hazard solid chemicals found at U of A are potassium dichromate, as well as lead and silver containing salts. Common GHS environmental hazard gas chemicals found at U of A are ammonia and chlorofluorocarbon (CFC) refrigerants like Freon 11 and Freon 31.

DISPOSAL: All GHS environmental hazard chemicals can be picked up by RMS. To schedule a pickup, email them at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab. If you have returnable environmental hazard chemical compressed gas cylinders, contact U of A Cryogenics & Compressed Gas Facility. They can be reached by phone at 520-621-2374.

STORAGE: GHS environmental hazard chemicals can pose a risk to human health, as well as pose a physical hazard. However, one of the main factors that should be considered when storing these chemicals, is that no release into the environment occurs. This means that these chemicals are not intentionally nor accidentally poured down the sink or any other drain, nor are they allowed to vent into the atmosphere. The release of CFCs (Freon) into the atmosphere contributes to the degradation of the ozone layer and an increase in harmful ultraviolet light that makes its way to the Earth's surface.

HANDLING: Just as there is a concern of environmental discharge during storage of GHS environmental hazard chemicals, there is also the same hazard while working with, and using these chemicals. Rarely does a chemical have only a single hazard associated with it, therefore, it is imperative that all hazards associated with a chemical are ***Recognized***, and plans are made to ***Minimize*** these hazards while working with these chemicals in the laboratory.

PPE: Since GHS environmental hazard chemicals pose a hazard to the environment, care should be taken to prevent the over-contamination of PPE with these chemicals. Single-use nitrile gloves that are disposed of in the regular trash can pose a hazard when they are heavily contaminated with chemical residue, even when disposed of in a sealed landfill.

If PPE becomes heavily contaminated with a GHS environmental hazard chemical, then it should be either properly cleaned, or submitted as hazardous waste to the RMS Hazardous Waste Group.

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FIRST AID: Always consult the product SDS if you have splashed, spilled, ingested, or inhaled a GHS environmental hazard chemical. The first aid response for the chemical will be directly related to the health hazard associated with that chemical.

FUN FACT: Carbon tetrachloride was historically used to manufacture refrigerants like Freon 11, and it itself was used as a refrigerant prior to the development of Freons. Due to its nonreactive nature, and the fact that it is not flammable, carbon tetrachloride was used in a type of fire extinguisher in the early 1900's. The fire extinguisher would essentially be a large glass bulb filled with carbon tetrachloride mounted on a wall, that when the bracket was heated by fire, would cause the bulb to drop and break, thereby creating a carbon tetrachloride gas cloud that would suffocate the fire of oxygen. The suffocation effect was so effective that it could also result in the suffocation and death of any occupants in the room.

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5.10 Hazards Not Otherwise Classified (HNOCs)

DEFINITION: A chemical that possesses a physical or health hazard but doesn't fit into any of the other GHS hazard classifications.

EXAMPLES: Chemicals that can form combustible dusts are considered to be a HNOC. This is also the case for chemicals that are considered to be simple asphyxiants. Common combustible dust forming chemicals are powdered zinc and iron. Examples of simple asphyxiants would be nitrogen and argon gas. In the case of powdered iron, in lab scale work, the likelihood of a combustible dust atmosphere occurring is very low but it is important that workers are aware of the potential hazard. In the case of the simple asphyxiants like nitrogen, an unattended dewar of liquid nitrogen can evaporate and quickly displace the oxygen in a work environment, leading to asphyxiation and death.

DISPOSAL: All chemicals, regardless of whether they have a classified hazard or if they have a HNOC, can be picked up by RMS. To schedule a pickup, email them at rms-hazmat@arizona.edu. They will then coordinate the pickup and disposal of the chemicals with the lab. If you have returnable compressed gas cylinders, contact U of A Cryogenics & Compressed Gas Facility. They can be reached by phone at 520-621-2374.

STORAGE: Chemicals with HNOCs should be evaluated for the potential for physical and health hazards. By consulting the product SDS and referring to Section 2.3, it is possible to see if and what HNOCs apply to a chemical. In the case of a simple asphyxiant, care should be taken to ensure the laboratory has adequate ventilation to prevent the accumulation of oxygen displacing gas that can lead to worker fatalities.

HANDLING: When working with chemicals with HNOCs, care should be taken to not expose workers to the chemicals, as well as keep the chemicals physically secure, and all work surfaces clean. In the case of chemicals that can produce combustible dust atmospheres, work surfaces should be regularly wiped down to prevent the accumulation of dust particles that when made airborne can detonate and cause accidents and injuries. Care should be taken to not use a vacuum on combustible dust generating chemicals, as the carbon brushes on electric motors can act as an ignition source and cause a fire and subsequent detonation.

PPE: As with all other chemicals, proper PPE is essential when working with chemicals that have a HNOC. However, in the case of simple asphyxiants, the only PPE that is adequately protective is a Self-Contained Breathing Apparatus. Therefore, when working with chemicals with HNOCs, the best approach is to always minimize exposure and not solely rely upon PPE to keep workers safe.

FIRST AID: Always consult the product SDS if you have splashed, spilled, ingested, or inhaled a chemical with a HNOC. Simple asphyxiants can cause asphyxiation, so CPR may be necessary. However, always consult the product SDS and if unsure, call 911 before beginning to perform any emergency aid to an injured worker.

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FUN FACT: When liquid nitrogen evaporates and becomes a gas, it increases in volume by approximately 700%. That means that 1 liter of liquid nitrogen evaporates and displaces 700 liters of air space or24 cubic feet. While this may not seem like a lot, consider a liquid nitrogen dewar that holds 15 liters. If the lid was left off and all the liquid nitrogen evaporated that would mean there would be 10,500 liters of nitrogen gas, which is equal to 370 cubic feet. This means that a single dewar stored in a closet measuring 7 feet by 7 feet would be entirely occupied by nitrogen gas. Any worker who entered that workspace would immediately die of asphyxiation. In 2021, 6 workers were killed by asphyxiation after entering a freezer room at a Georgia, USA poultry plant where the liquid nitrogen coolant system had leaked.

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