

# LABORATORY SAFETY MANUAL



AUBURN UNIVERSITY

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RISK MANAGEMENT & SAFETY

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# 1 AUBURN UNIVERSITY CHEMICAL SAFETY PLAN

## 1.1 Introduction

As part of continuing efforts to provide a safe and healthful workplace for students, visitors and employees, Auburn University has implemented this Lab Safety Manual (LSM). The LSM is a written program that defines procedures and control measures that should be observed by all individuals in laboratories to ensure safe work practices and protect employees from health hazards associated with the use of chemicals in the workplace. The LSM is a uniform reference for administrative procedures, engineering controls, and safe work practices that protect laboratory personnel from hazards associated with laboratory chemicals.

The LSM does not substitute the need for individual laboratories to have written standard operating procedures (SOP) pertinent to the work conducted. Principle Investigators (PI) have a duty to ensure that employees, students, and volunteers within their work areas are aware of the LSM, and that they understand and follow all provisions of the LSM that apply to their work, and all laboratory-specific SOPs.

The primary objectives of the LSM are:

- Maintain a safe environment for all faculty, staff, students, and the visiting public.
- Provide the necessary facilities, staff, and equipment for safety.
- Protect the environment from hazardous chemicals and wastes.
- Institute a Lab Safety Manual.
- Comply with all regulatory requirements that would impact laboratory functions.
- Conduct laboratory inspections to ensure safety goals are being met.

## 1.2 Chemical Safety Responsibilities

Responsibility for chemical health and safety rests at all levels; Auburn University has designated the following responsibilities for the development and implementation of the LSM.

### 1.2.1 Risk Management and Safety

Risk Management and Safety (RMS) unit has the responsibility for developing and implementing University safety programs. The Lab Safety Program Manager; a representative from RMS is responsible for:

- Updating the LSM
- Working with the laboratory community, administrators, and other employees to develop and implement appropriate chemical hygiene policies and practices;
- Providing technical assistance for complying with the LSM and answering chemical safety questions for employees;
- Overseeing the University-wide chemical safety inspection and training;
- Assisting PIs in the selection of appropriate laboratory safety practices and engineering controls for new and existing projects and procedures;
- Provide investigation of incidents which result to exposure of personnel or the environment to hazardous chemicals.



### **1.2.2 Department Chairman/Head or Director of an Administrative Unit**

Department Chair/ Head / Director is responsible for chemical safety in the department/unit. The chair ensures that faculty members understand and promote implementation of the LSM in the department's laboratories; the chair may choose to appoint a safety liaison who works closely with RMS to coordinate and monitor implementation of the LSM within the department.

### **1.2.3 Faculty/Principal Investigator (PI)/Supervisor**

Faculty / PI/ Supervisors are employees of Auburn University who have the primary responsibility for chemical safety in the laboratory. Each PI, supervisor, or other responsible person designated by the PI is responsible for the safety of individuals working under their direction in their assigned laboratory. PIs must work closely with RMS to implement safety provisions outlined in the LSM.

They should also ensure that:

- Each individual working in their lab is provided with appropriate safety training
- Each individual working in their lab follows all applicable federal, state and local regulatory requirements
- Safety equipment is used to reduce potential exposure to hazardous chemicals
- Appropriate Personal Protective Equipment (PPE) is provided, maintained and used.
- Specific safety considerations or specific safety procedures (SOP) are developed and observed
- Prompt action is taken to correct observed or reported unsafe conditions and actions
- Ensuring that chemical waste is managed properly (collection, labelling, storage and disposal)
- Informing Auburn University personnel (i.e. AU Facilities, AU Maintenance, etc..) and contractors who service and maintain the laboratory of the potential hazards and safety precautions that should be observed
- Informing visitors who enter the lab of the potential hazards and safety precautions.
- Restricting access to non-authorized personnel and ensuring securing hazardous materials kept within a laboratory.
- Ensuring accuracy of chemical inventories of their laboratories.
- Reporting injuries of laboratory personnel or visitors to the Auburn University Department of Risk Management and Safety on the job injury program: <https://cws.auburn.edu/rms/pm/injuryprogram>.

### **1.2.4 Laboratory Personnel**

Laboratory Personnel are employees, AU students, visiting students, volunteers in the Principal Investigator's/Supervisor's laboratory that are responsible for implementing all the requirements of the LSM.

These include:

- Participating in all required safety training.
- Using appropriate safety equipment and PPE.
- Understanding and observing all safety considerations or standard operating procedures.
- Informing the PI/supervisor or RMS of any near-misses, accidents or unsafe acts and conditions.
- Following all applicable federal, state, and local regulatory requirements.
- Informing visitors who enter the lab of the potential hazards and safety precautions.
- Reporting injuries to the Auburn University Department of Risk Management and Safety on the job injury program <https://cws.auburn.edu/rms/pm/injuryprogram>.

## 1.3 Definitions

### 1.3.1 Laboratory

For the purposes of this LSM, a laboratory is defined as a facility in which hazardous chemicals are handled or manipulated in reactions, transfers, etc. in small quantities on a non-production basis. This definition is taken from the Occupational Safety and Health Administration (OSHA) standard.

### 1.3.2 Hazardous Chemical

The OSHA Laboratory Safety Standard defines a hazardous chemical as any element, chemical compound, or mixture of elements and/or compounds which is a physical hazard or a health hazard. Auburn University applies this definition to all hazardous chemicals regardless of the quantity.

A chemical is a physical hazard if there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, organic peroxide, an oxidizer, or is pyrophoric, flammable, or reactive.

A chemical is a health hazard if there is statistically significant evidence, based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed people.

Health hazards include:

- Toxic Agents
- Highly Toxic Agents
- Reproductive Hazards
- Mutagens
- Sensitizers
- Hepatotoxins
- Hematopoietic toxins
- Irritants
- Carcinogens
- Corrosives
- Asphyxiates
- Neurotoxins
- Nephrotoxins

In most cases, the chemical container's original label will indicate if the chemical is hazardous. Look for key words like **caution, hazardous, toxic, dangerous, corrosive, irritant, carcinogen**, etc. Note that containers of hazardous chemicals acquired or manufactured before 1986 may not contain appropriate hazard warnings.

If you are not sure a chemical you are using is hazardous, review the **Safety Data Sheet (SDS)** for the substance or contact your supervisor, PI, or Risk Management and Safety.



## 1.4 Hazard Identification

Some laboratories will synthesize or develop new chemical substances during the course of their research. If the composition of the substance is known and will be used exclusively in the laboratory, the researcher must label the substance and determine, to the best of his/her ability, the hazardous properties (e.g. corrosive, flammable, reactive, toxic, etc.) of the substance. This can sometimes be done by comparing the structure of the new substance with the structure of similar materials with known hazardous properties. If the chemical produced is of unknown composition, it must be assumed to be hazardous, and appropriate precautions should be taken. If a chemical substance is produced for another user outside of the University, the laboratory producing the substance is required to provide as much information as possible regarding the identity and known hazardous properties of the substance to the receiver of the material. Contact RMS if you have questions or would like assistance in meeting this obligation.

## 1.5 Medical Consultation and Examination

Employees who work with chemicals should seek medical consultation/examination whenever:

- They develop signs or symptoms associated with excessive exposure to a hazardous chemical to which they may have been exposed to in their laboratory.
- There is a likelihood of chemical exposures resulting from spills, leaks, explosions or other events occurring in the laboratory

Exposure monitoring (for substances that are monitored) reveals an exposure level routinely above the action level (or in the absence of an action level, the applicable workplace permissible exposure limit, PEL)

Medical services are available to Auburn University students, faculty and staff at:

Auburn University Medical Clinic  
400 Lem Morrison Dr, Auburn, Alabama  
Phone: 334 844 4416

East Alabama Medical Center (EAMC)  
2000 Pepperell Pkwy, Opelika, Alabama  
Phone: 334-749-3411



## 1.6 Laboratory Inspection Program

RMS conducts annual inspections of all University laboratories handling or storing hazardous materials, including chemical and biological materials.

These inspections evaluate

1. The Status of Critical Control Equipment (Hoods)
2. Microbiological Practices and The Handling and Storage of Chemicals
3. Use of Personal Protective Equipment
4. Waste Disposal
5. Laboratory Personnel Training
6. Compliance with Federal/State Regulations and University Policies

More frequent inspections may be established for laboratories working with higher risk materials. Department chairs, designated safety representatives and/or committees (as directed by the department chairperson) may receive inspection summary reports for their department. Lab inspections are managed in [BioRAFT Research Management Platform](#). Note that laboratories that use radioactive materials are inspected on a more frequent basis by the AU Radiation Safety Program.



## 2 HAZARD CONTROL MEASURES

Laboratory personnel are required to implement appropriate control measures to ensure that exposure to hazardous chemicals is minimized and maintained below the allowed exposure limits and as low as reasonably achievable. Chemical exposure control can be achieved through administrative controls, engineering controls, procedural controls and use of appropriate personal protective equipment (PPE).

### 2.1 Administrative Controls

Administrative controls include established procedures and guidelines usually at an administrative level e.g. by the PI, department chair, lab manager, departmental safety committee or RMS to promote safety in the laboratory.

Examples of administrative controls are:

- Posting appropriate signs for identification of hazards within an area
- Prior approval/ additional control measures for certain hazardous operations
- Restricting access to areas where particularly hazardous chemicals are used
- Ensuring that all laboratory personnel have been trained before being allowed to handle chemicals and/or conduct experimental procedures

#### ***2.1.1 Prior Approval of Hazardous Operations and Procedural Controls***

Sometimes hazards may exist that are not recognized or have not been fully evaluated. Certain indicators should cause the laboratory personnel to stop and conduct additional safety review.

These indicators include:

- New procedure, process or test even if it is very similar to older practices.
- A change or substitution of any of the ingredient chemicals in a procedure.
- A substantial change in the amount of chemicals used (scale up of experimental procedures) or experimental conditions.
- Failure of any of the equipment used in the process including chemical fume hoods.
- Unexpected experimental results (such as pressure increase, increased reaction rates, unanticipated products and byproducts).

Chemical odors, illness in the laboratory staff that may be related to chemical exposures or other indicators of a failure in engineered safeguards.

The occurrence of any of these conditions should cause the laboratory personnel to evaluate the safety implications of the observed changes or results with lab PI/supervisor, make changes as necessary and proceed cautiously. If needed, call RMS for assistance.

### 2.1.2 Laboratory Signage

Prominent signs of the following types should be posted in each laboratory or areas that the laboratory uses. Door signs are created in BioRAFT and must be placed outside each exit door of a laboratory listing the names and telephone numbers of the PI and other responsible personnel. These signs provide a general idea of some of the hazards present within the laboratory and they are used by emergency responders in the event of an off-hour emergency in the lab.

Signage is also used for:

- Identifying locations for safety showers, eyewash stations, other safety and first aid equipment
- Chemical storage (Flammable, acids, bases, toxic chemicals, biohazards, radioactive materials etc.)
- Warnings at areas or equipment where special or unusual hazards exist (magnetic fields, electrical shock, inhalation hazards)
- No food or drink signs on research refrigerators, ice machines, dishwashers, microwaves, ovens and incubators
- Emergency contact numbers prominently located near the exit or lab phone

Use this link to access more lab signs and labels: <https://cws.auburn.edu/rms/pm/chemguidestools>

## 2.2 Engineering Controls

Engineering controls are primary barriers used to reduce or eliminate a hazard at its source therefore they should be fully considered and utilized whenever possible as the *first* step in chemical hazard control within the laboratory. Examples of engineering controls are fume hoods, biosafety cabinets, glove boxes, ventilated gas cabinets and other ventilation systems for used for containment of airborne chemicals or enclosing potentially explosive reactions.

## 2.3 Personal Protective Equipment (PPE)

Personal protective clothing and equipment should be selected carefully and used after all feasible engineering and administrative controls have been put in place or while such controls are being established. These devices are viewed as less protective than other controls because they rely heavily on each lab personnel's work practices and training to be effective. Engineering and administrative controls should always be considered first when reducing or eliminating exposures to hazardous chemicals.

A laboratory coat, gloves, protective eyewear, and closed shoes that cover the foot (front, back and top) are required to be worn in Auburn University laboratories whenever handling hazardous chemicals. Additional or enhanced personal protective equipment, such as face shield, utility gloves, aprons, and respirators, may be necessary depending on risk assessment. Lab supervisors and RMS can assist in determining the appropriate PPE, Departments must provide appropriate personal protective equipment to employees.



### **2.3.1 Eye Protection**

Eye protection is required for all laboratory personnel, including any visitors present in locations where chemicals are handled, and a chemical splash hazard exists. American National Standard Institute (ANSI) approved safety glasses, goggles and goggles with face shield should be worn in the laboratory based on the hazards that are present.

### **2.3.2 Skin and Body Protection**

Skin and body protection involve wearing protective clothing over all parts of the body that could potentially become contaminated with hazardous chemicals. Personal protective equipment (PPE) should be selected on a task basis and checked to ensure it is in good condition prior to use (e.g. no pinholes in gloves).

Where there is no immediate danger to the skin from contact with a hazardous chemical it is still prudent to select clothing to minimize exposed skin surfaces in the laboratory. Laboratory personnel shall not wear shorts, short skirts or sandals in a laboratory. Closed shoes that cover the foot (front, back and top) should be worn in the laboratory at all times. A lab coat with cuffs at the sleeves should be worn over street clothes and be laundered regularly. RMS recommends the use of a flame-resistant lab coats when handling pyrophoric chemicals (may ignite on contact with air).

Additional protective clothing may be required for some types of procedures or with specific substances or operations; such as when carcinogens or large quantities of corrosives, oxidizing agents or organic solvents are handled. This clothing may include chemically resistant aprons and gloves as well as face shields, shoe covers, and arm sleeves. These should never be worn outside the laboratory. The choice of garment depends on the degree of protection required and the areas of the body that may become contaminated.

Disposable lab coats are recommended when working with substances of high acute or chronic toxicity. Evaluate the potential for exposing non-laboratory personnel when laundering non disposable lab coats, this will help in minimizing placing others at risk during the laundering process.

For work where contamination with highly hazardous chemicals is possible, special attention must be given to sealing all openings in the clothing. Tape can be utilized for this purpose. In these instances, caps should also be worn to protect hair and scalp from contamination.

### **2.3.3 Hand Protection**

Chemical resistant gloves should be worn whenever handling hazardous chemicals or whenever there is a possibility of contact with hazardous materials. Gloves should be selected on the basis of the materials being handled, the particular hazard involved, and their suitability for the operation being conducted. It is important to follow the glove manufacturers' and chemical manufacturers' information on personal protective equipment selection. Before each use, gloves should be checked for integrity. Thin exam-style gloves are most commonly used for laboratory work and are disposed of in the regular trash after each use. In general, nitrile exam-style gloves offer better chemical protection than either latex or vinyl and all laboratories that use chemicals are strongly encouraged to stock and use nitrile gloves. Nitrile gloves do not provide adequate protection from all chemicals. It is important to follow the glove manufacturers' and chemical manufacturers' recommendations for glove selection. Latex gloves are discouraged not only because they do not hold up well to many chemicals, but also because of the potential for the user or other laboratory personnel to develop a sensitization to the latex.

A glove chart is available [here](#).

### **2.3.4 Respiratory Protection**

The University attempts to minimize employee respiratory exposure to potentially hazardous chemical substances through engineering methods (such as local exhaust ventilation) or administrative controls. It is recognized, however, that for certain situations or operations, the use of these controls may not be feasible or practical. Under these circumstances, while such controls are being instituted, or in emergency situations, the use of respirators may be necessary. A sound and effective respiratory protection program is essential to assure that laboratory personnel using such equipment are adequately protected.

The University has a [Respiratory Protection Program](#) (RPP) covering the use of respirators on campus. Contact RMS if you are using a respirator and are not included in the University's Respiratory Protection Program, or for questions concerning the use of respirators or any of the program components.



### 3 SAFE WORK PRACTICES AND GUIDELINES

Carefully read the chemical label before using a chemical. The manufacturer's or supplier's Safety Data Sheets (SDS) may also provide special handling information. Be aware of potential hazards existing in the laboratory and the appropriate safety precautions. Know the location and proper use of emergency equipment, the procedures for responding to emergencies, and the proper methods for storage, transportation and disposal of chemicals within the facility.

#### 3.1 General Work and Laboratory Hygiene Practices

- Laboratory personnel are responsible for regular cleaning and disinfection of laboratory surfaces to maintain good laboratory hygiene. Solid waste (regular trash cans) should be placed outside the lab at the end of each business day for custodial staff to pick for disposal. Custodial staff will have access to labs only for services requested through AU Facilities work management by [submitting a work order](#). Examples of these services include deep cleaning and floor waxing.
- Lab personnel are responsible for transporting autoclaved waste to the trash dumpster located outside of the building. Custodians shall not remove any waste from autoclave rooms.
- Do not work alone in the laboratory during after work hours. If you must work alone in the evening, let someone else know and have them periodically check on you.
- Label all secondary chemical containers with appropriate identification and hazard information.
- Use only those chemicals for which you have appropriate exposure controls (such as a chemical fume hood) and administrative procedures (training, restricted access, etc.). Always use adequate ventilation with chemicals. Operations utilizing volatile or toxic substances should be performed in a chemical fume hood.
- Use hazardous chemicals and all laboratory equipment only as directed for their intended purpose.
- Inspect equipment or apparatus for damage before use, do not use malfunctioning equipment.
- Inspect PPE for integrity or proper functioning before use.
- Do not dispense more of a hazardous chemical than is needed for immediate use.
- Remove contaminated clothing and gloves before leaving the laboratory.
- Avoid direct contact with any chemical. Keep chemicals off your hands, face and clothing, including shoes.
- Never smell, inhale or taste a hazardous chemical. Wash hands thoroughly with soap and water after handling chemicals and removing gloves.
- Smoking, drinking, eating and the application of cosmetics is forbidden in laboratories where hazardous chemicals are used.
- Never pipet by mouth. Use a pipet bulb or other mechanical pipet filling device.
- Keep floors clean and dry. Keep all aisles, hallways, and stairs clear of all chemicals and equipment. Stairways and hallways should not be used as storage areas.
- Keep all work areas, and especially work benches, clear of clutter and obstructions.
- All working surfaces should be cleaned regularly by lab personnel, regular trash should be placed outside the lab at the end of each business day for custodial staff to pick for disposal.
- Access to emergency equipment, utility controls, showers, eyewashes and exits should never be blocked.
- Hazardous waste should be stored in appropriate containers and labeled properly.

## 3.2 Procedures for Proper Labeling, Storage and Management of Chemicals

### 3.2.1 Chemical Storage

Carefully read the chemical label before storing a hazardous chemical, chemicals must be stored according to hazard class and compatibility. The manufacturer's SDS will provide any special storage information as well as information on incompatibilities. *Do not store unsegregated liquid chemicals in alphabetical order. Do not store incompatible chemicals in close proximity to each other. See Appendix C-1 for examples of incompatible chemicals; this list is not a complete list:*

Common chemical hazard groups are:

Flammable /combustible liquids	Toxic / Poisons
Unstable (shock sensitive/explosive chemicals)	Caustics (bases)
Flammable solids	Toxic gases
Water Reactives	Oxidizers
Flammable Gases	Reproductive Toxins
Air Reactives	Oxidizing acids
Inorganic acids	Carcinogens
Corrosive gases	Caustics (bases)
Organic acids	Oxidizing gases

Once separated into the above hazard classes, chemicals may be stored alphabetically. Use approved storage containers and safety cans for flammable liquids. Store flammable chemicals in flammable storage cabinets, no greater than 10 gallons of flammable liquids may be kept outside of rated flammable storage cabinets in any laboratory. *Flammable chemicals requiring refrigeration should be stored only in the refrigerators and freezers specifically designed for flammable storage.*

Acids must be separated from bases and from active metals such as sodium, magnesium and potassium. Acids must be kept separate from chemicals that can emit toxic gases on contact, such as sodium cyanide and iron sulfide. Corrosive or hazardous liquids should not be stored above eye level. Acids and bases shall be stored below shoulder height of the shortest person within the laboratory. Organic acids, organic material, flammable and combustible materials must be separated from oxidizing acids such as nitric acid and perchloric acid. Separation of nitric and perchloric acid from other acids may be accomplished by utilizing a plastic pan or tray.

Hazardous chemicals should not be stored on bench tops, on the floor, or in hoods for extended periods of time. Chemicals should not be stored under sinks. If separate cabinets are not feasible, different hazard classes can be segregated by utilizing a plastic pan or tray. Use secondary containers for highly corrosive or toxic chemicals. Avoid exposure of chemicals while in storage to heat sources (especially open flames) and direct sunlight.



### 3.2.2 Chemical Management

Update chemical inventory information using [Chematix Chemical](#) Inventory System. Conduct periodic inventories of chemicals stored in the laboratory and dispose of old or unwanted chemicals promptly in accordance with RMS's [Hazardous waste program](#). Ensure that all secondary containers are properly labeled with the identity of the contents and any appropriate hazard warnings.

**Note:** Peroxide formers form peroxides on exposure to air and light. The two most serious hazards associated with peroxides are fires and explosions when exposed to heat, shock, or friction. Some common oxidizable functional groups are: Ethers, conjugated dienes, enynes and diynes, hydrocarbons with exposed tertiary hydrogens etc.

Since many of these chemicals are packaged in an air atmosphere, peroxides can form even though the containers have not been opened. All containers of ether or other peroxide formers should be dated upon receipt, when opened, and tested for peroxide formation after storage for 12 months. These chemicals should be discarded when peroxides greater than 100 ppm are present. Peroxide formers are grouped into three categories depending on their tendency to form peroxides and associated hazards. Group A, Group B and Group C (see appendix C-2 for a partial list of chemicals under each of these categories) Group A peroxide formers can form peroxide amounts that may cause an explosion without concentration. They should be tested for peroxides before use and discarded when peroxides are present. It is best practice to discard them after three months of opening and unopened containers should be discarded after 12 months of storage.

See the Standard Operating Guideline for Peroxide-forming Materials (Potentially Explosive Chemicals) document found online at: <https://cws.auburn.edu/shared/files?id=227&filename=PEC%20Guidelines%20Updated.pdf>.

### 3.2.3 Chemical Labelling

All chemical containers must be labeled clearly identifying their contents. Labels on purchased chemicals must not be removed or defaced except when empty. All secondary containers must be clearly labelled with full chemical name to identify contents. The label and information must be in English and clearly written to identify the contents.

Many labels may provide you with additional safety information to help you protect yourself while working with the substance. This includes information on toxicity, flammability, instability (reactivity), and physical hazards. Protective measures may also be included on the container such as handling of the material, first aid instructions and storage information.

Read the manufacturer's label each time you use a newly purchased chemical. It is possible the manufacturer may have added new hazard information or reformulated the product since your last purchase, and thus altered the potential hazards you face while working with the product. All employees involved in unpacking chemicals are responsible for inspecting each incoming container to ensure that it is in good condition and labeled properly.



### 3.2.4 Chemical Waste Disposal Program

Laboratory chemical waste must be handled according to the University's procedures outlined in Auburn University [Chemical Waste Management Guide](#). The University's waste management practices are designed to ensure maintenance of a safe and healthful environment for laboratory personnel and the surrounding community without adversely affecting the environment. This is accomplished through regular removal of chemical waste from University facilities and disposal of these wastes in accordance with local, state, and federal regulations. For additional information on Auburn's chemical waste management program ask your supervisor or contact RMS. Chemical waste pickup must be requested through [Chematix](#) chemical management system. All chemical containers utilized in experimental procedures or otherwise treated as waste should be updated (removed) from inventory in Chematix as "used up in experiment" or "treated as waste".

## 3.3 Chemical Spills and Accidents Procedure

Be prepared for chemical spills that may occur in your laboratory (based on the types of chemicals used in your lab) by obtaining the necessary equipment (spill kits and personal protective equipment) to respond to minor spills. Learn how to safely clean up minor spills of the chemicals you use regularly. An SDS contains special spill clean-up information and should also be consulted. Chemical spills should only be cleaned up by trained, knowledgeable **and experienced personnel**.

If the spill is too large for you to handle, is a threat to laboratory personnel or the public, or involves a highly toxic or reactive chemical, call 911 for immediate assistance.

- Simple (small) chemical spills – Call RMS (844-4870)
- Complex (large) chemical spills – Call 911

### 3.3.1 Cleaning Up Chemical Spills

If you are cleaning up a small chemical spill yourself, make sure that you are aware of the hazards associated with the materials spilled, have adequate ventilation (open windows, chemical fume hood on) and proper personal protective equipment (minimum - gloves, goggles, and lab coat). Consider all residual chemical and cleanup materials (adsorbent, gloves, etc.) as hazardous waste. Place these materials in sealed containers (plastic bags), label, and store in a satellite accumulation area (SAA), Contact RMS for disposal instructions and pickup.

### 3.3.2 Simple Chemical Spills

- Alert people in immediate area of spill.
- Increase ventilation in area of spill (open windows, turn on hoods).
- Wear protective equipment, including safety goggles, gloves, long-sleeve lab coat and closed toe shoes.
- Avoid breathing vapors from spill.
- Use appropriate kit to adsorb/contain spill Collect residue, place in container and dispose as hazardous chemical waste. Call RMS for disposal information and waste pick up if necessary.



### **3.3.3 Complex Chemical Spill**

- Attend to injured or contaminated persons and remove them from exposure if safe to do so
- Alert people in the laboratory to evacuate.
- If spilled material is flammable, turn off ignition and heat sources. Place spill cleanup material over spill to keep substance from volatilizing.
- Call 911.
- Close doors to affected area.
- Have a person with knowledge of the incident and laboratory available to answer questions from responding emergency personnel.

### **3.3.4 Mercury Spills**

- Do not use a domestic or commercial vacuum cleaner.
- Use a disposable pipette to pick up mercury droplets.
- Cover small droplets in inaccessible areas with powdered sulfur or zinc.
- Place residue in a labeled container and call RMS for disposal information. For larger spills, call RMS to clean up the mercury.
- Contact RMS if you have a mercury spill that exceeds the quantity found in a normal laboratory thermometer.

### **3.3.5 Personal Contamination and Injury**

- Know the locations of the nearest emergency safety shower and emergency eye wash.
- Report all incidents and injuries to your supervisor.
- If an individual is contaminated or exposed to a hazardous material in your laboratory do what is necessary to protect their life and health as well as your own.
- Determine what the individual was exposed to. The SDS may contain special first aid information.
- Do not move an injured person unless they are in further danger (from inhalation or skin exposure).
- Get medical attention promptly by dialing 911.
- Report exposure incidents or injuries to RMS or to [on the job injury program](#)

### **3.3.6 Chemicals Spills on the Body**

- Quickly remove all contaminated clothing and footwear
- Get to an emergency safety shower and immediately flood the affected body area for at least 15 minutes.
- Remove jewelry to facilitate removal of any residual material.
- Yell for assistance as soon as incident occurs.
- Get medical attention promptly by dialing 911. Be sure to indicate specifically what chemical was involved.

It should be noted that some chemicals (e.g. phenol, aniline) are rapidly adsorbed through the skin. If a large enough area of skin is contaminated an adverse health effect (systemic toxicological reaction) may occur immediately to several hours after initial exposure depending on the chemical. In general, if more than 9 square inches of skin area has been exposed to a hazardous chemical, seek medical attention after washing the material off the skin.

### **3.3.7 Chemicals Spills on the Body – Hydrofluoric Acid (HF)**

Calcium gluconate paste is an effective treatment for hydrofluoric acid exposure. Every laboratory and location where HF are used or stored should have a tube of calcium gluconate paste readily available. In the event of an HF spill to the body:

- Immediately flood the affected body area with cool water for a minimum of 15 minutes, gently rub calcium gluconate ointment onto the affected area. Continue applying until emergency medical responders arrive.
- If no calcium gluconate is immediately available, continue rinsing the affected area with copious amounts of water until emergency medical responders arrive. Remove contaminated clothing and footwear while rinsing.
- Call or have a co-worker call 911. Be sure to indicate that you were exposed to hydrofluoric acid.
- Inform responders and/or others that the exposure involved hydrogen fluoride/hydrofluoric acid.

### **3.3.8 Chemical Splash in the Eye**

- Use emergency eyewash to irrigate the eyeball and inner surface of eyelid with plenty of water for at least 15 minutes. Forcibly hold eyelids open to ensure effective wash.
- Check for and remove contact lenses.
- Get medical attention promptly and inform medical attendants of the specific type of chemical you were exposed to.

### **3.3.9 Ingestion of Hazardous Chemicals**

- Identify the chemical ingested.
- Call 911.
- Cover the injured person to prevent shock.
- Provide the ambulance crew and physician with the chemical name and any other relevant information. If possible, send the SDS with the victim.

### **3.3.10 Inhalation of Smoke, Vapors, and Fumes**

Anyone overcome with smoke or chemical vapors or fumes should be removed to uncontaminated air and treated for shock.

- Do not enter the area if you expect that a life-threatening condition still exists -oxygen depletion, explosive vapors or highly toxic gases (cyanide gas, hydrogen sulfide, nitrogen oxides, carbon monoxide).
- If CPR certified, follow standard CPR protocols.
- Get medical attention promptly.

### **3.3.11 Fire and Fire Related Emergencies**



If you discover a fire or fire-related emergency such as abnormal heating of material, a flammable gas leak, a flammable liquid spill, smoke, or odor of burning, immediately follow these procedures:

- Call 911.
- Activate the building alarm (fire pull station). If not available or operational, verbally notify people in the building.
- Isolate the area by closing windows and doors and evacuate the building.
- Shut down equipment in the immediate area, if possible.
- If trained to do so, use a portable fire extinguisher to control a small fire.
- Provide the fire/police teams with the details of the problem upon their arrival. Special hazard information you might know is essential for the safety of the emergency responders.

If the fire alarms are ringing in your building:

- You must evacuate the building and stay out until notified to return.
- Move upwind from the building and stay clear of streets, driveways, sidewalks and other access ways to the building.
- If you are a supervisor, try to account for your employees, keep them together and report any missing persons to the emergency personnel at the scene.

### 3.4 Flammable and Combustible Liquids

Flammable liquids are among the most common of the hazardous materials found in laboratories. They are usually highly volatile (have high vapor pressures at room temperature) and their vapors, mixed with air at the appropriate ratio, can ignite and burn. By definition, the lowest temperature at which they can form an ignitable vapor/air mixture (the flash point) is less than 37.8°C (100°F) and for many common laboratory solvents (ether, acetone, toluene, acetaldehyde) the flash point is well below room temperature. As with all solvents, their vapor pressure increases with temperature and, therefore, as temperatures increase, they become more hazardous.

For a fire to occur, three distinct conditions must exist simultaneously: (1) the concentration of the vapor must be between the upper and lower flammable limits of the substance (the right fuel/air mix); (2) an oxidizing atmosphere, usually air, must be available; and (3) a source of ignition must be present. Removal of any of these three conditions will prevent the start of a fire. Flammable liquids may form flammable mixtures in either open or closed containers or spaces (such as refrigerators), when leaks or spills occur in the laboratory, and when heated.

Strategies for preventing ignition of flammable vapors include removing all sources of ignition or maintaining the concentration of flammable vapors below the lower flammability limit by using local exhaust ventilation such as a hood. The former strategy is more difficult because of the numerous ignition sources in laboratories. Ignition sources include open flames, hot surfaces, operation of electrical equipment, and static electricity.

The danger of fire and explosion presented by flammable liquids can usually be eliminated or minimized by strict observance of safe handling, dispensing, and storing procedures. These include:

- Wearing PPE such as protective glasses or goggles, long sleeved lab coats and closed toe shoes. Wear goggles if dispensing solvents or performing operations that could result in a splash to the eyes.

- Large quantities of flammable liquids should be handled in a chemical fume hood or under some other type of local exhaust ventilation. Five-gallon containers must be dispensed to smaller containers in a hood or under local exhaust ventilation. When dispensing flammable solvents into small storage containers, use metal or plastic containers or safety cans (avoid glass containers). If splash risk is high wear a face shield in addition to goggles.
- Make sure that metal surfaces or containers through which flammable substances are flowing are properly grounded, discharging static electricity. Free flowing liquids generate static electricity that can produce a spark and ignite the solvent.
- Large quantities (five gallons) of flammable liquids must be handled in areas free of ignition sources (including spark emitting motors and equipment) using non-sparking tools. Remember that vapors are heavier than air and can travel to a distant source of ignition. Heavier than air vapors can flow downhill and gather/ aggregate at the bottom of an enclosure or along the floor of a room and could form explosive mixtures waiting for a spark.
- Never heat flammable substances by using an open flame. Instead use any of the following heat sources: steam baths, water baths, oil baths, heating mantles or hot air baths. Do not distill flammable substances under reduced pressure.
- Store flammable substances away from ignition sources. Flammable liquids should be stored inside rated flammable storage cabinets. If no flammable storage cabinet is available store these substances in a cabinet under the hood or bench. Five-gallon containers should only be stored in a storage cabinet that is rated for flammables. You can store flammable liquids inside the hood for short periods of time. However, storage inside chemical fume hoods is not preferred because it reduces hood performance by obstructing air flow.
- The volume of flammable liquids kept outside of rated flammable cabinets must not exceed 10 gallons at any one time in the laboratory. Never store containers of flammable liquids or other hazardous chemicals on the floor.
- Oxidizing and corrosive materials should not be stored in close proximity to flammable liquids. Flammable liquids should not be stored or chilled in domestic (general purpose) refrigerators and freezers but in units specifically designed for this purpose. It is acceptable to store or chill flammables in ultra-low temperature units.
- If flammable liquids will be placed in ovens make sure they are appropriately designed for flammable liquids (no internal ignition sources and/or vented mechanically). Make sure the auto ignition temperature of the solvent is above the oven temperature or its internal elements.

### 3.5 Highly Reactive Chemicals and High Energy Oxidizers

Highly reactive chemicals include those which are inherently unstable and susceptible to rapid decomposition as well as chemicals which, under specific conditions, can react alone or with other substances in a violent uncontrolled manner, liberating heat, toxic gases, or leading to an explosion. Air, light, heat, mechanical shock (when struck, vibrated or otherwise agitated), water, and certain catalysts can cause decomposition of some highly reactive chemicals, and initiate an explosive reaction. Examples of shock sensitive materials include acetylides, azides, organic nitrates, nitro compounds, and many peroxides. It is important to keep these chemicals stored in dark, cool, and dry places away from incompatible materials.

#### 3.5.1 Organic peroxides

Organic Peroxides are a special class of compounds that have unusual stability problems, making them among the most hazardous substances normally handled in the laboratories. As a class, organic peroxides are low powered explosives. Organic peroxides are extremely sensitive to light, heat, shock, sparks, and other forms of accidental ignition; as well as to strong oxidizing and reducing materials. All organic peroxides are highly flammable.



### 3.5.2 Peroxide formers

Peroxide formers can form peroxides during storage and especially after exposure to air (once opened). Peroxide forming substances include aldehydes, ethers (especially cyclic ether), compounds containing benzylic hydrogen atoms, compounds containing the allylic structure (including most alkenes), vinyl and vinylidene compounds.

- Before working with a highly reactive material or high energy oxidizer, review available reference literature to obtain specific safety information. The proposed reactions must be discussed with the principal investigator or your supervisor. Safety considerations must be incorporated in procedures using highly reactive materials. Always minimize the amount of material involved in the experiment; the smallest amount sufficient to achieve the desired result should be used. Scale-ups should be handled with great care, giving consideration to the reaction vessel size and cooling, heating, stirring and equilibration rates.
- Excessive amounts of highly reactive compounds should not be purchased, synthesized, or stored in the laboratories. The key to safely handling reactive chemicals is to keep them isolated from the substances that initiate their violent reactions. Do not work alone when manipulating highly reactive and/or explosive chemicals. Work with these chemicals must not be conducted when adequate facilities are not present, by untrained or sleep deprived laboratory personnel.
- Perform all manipulations of highly reactive or high energy oxidizers in appropriate safety equipment such as chemical fume hoods. Some factors to be considered in judging the adequacy of the hood include its size in relation to the reaction and required equipment, the ability to fully close the sash, and the composition of the sash.
- Make sure that the reaction equipment is properly secured. Reaction vessels should be supported from beneath with tripods or lab jacks. Use shields or guards which are clamped or secured.
- If possible, use remote controls for controlling the reaction (including cooling, heating and stirring controls). These should be located either outside the hood or at least outside the shield.
- Handle shock sensitive substances gently; avoid friction, grinding, and all forms of impact. Glass containers that have screw-cap lids or glass stoppers should not be used. Polyethylene bottles that have screw-cap lids may be used. Make sure containers and equipment are compatible with chemicals used.
- Handle water-sensitive compounds away from water sources. It should also be understood that the water vapor in the air can present problems when handling water-sensitive compounds. Light-sensitive chemicals should be used in light-tight containers. Handle highly reactive chemicals away from the direct light, open flames, and other sources of heat. Oxidizing agents should only be heated with fiberglass heating mantles or sand baths.
- High energy oxidizers, such as perchloric acid, should only be handled in a wash down hood if the oxidizer is used in reactions that may result to volatilization and potential condensation in the ventilation system. Inorganic oxidizers such as perchloric acid can react violently with most organic materials. Work with large volumes of perchloric acid can only be done in a specially designed perchloric acid wash down hoods. SOPs must be established for using perchloric acid fume hoods.
- Store highly reactive chemicals and high-energy oxidizers in closed cabinets segregated from incompatible materials, inside secondary containment. These materials can also be stored in the cabinets under a hood. Do not store these substances above eye level or on open shelves.
- Peroxides and peroxide forming compounds should be stored at the lowest possible temperature. Flammables refrigerators should be used for storage if refrigeration is needed. Light-sensitive compounds should be stored away from light and water-reactive compounds should be stored away from water sources.
- Shock sensitive materials should be discarded after one year if in a sealed container and within six months of opening unless an inhibitor was added by the manufacturer. A list of shock sensitive chemicals is provided in Appendix C-4.



## 3.6 Compressed Gases

Compressed gases present both a physical and a potential chemical hazard, depending on the particular gas. Gases contained in cylinders may be from any of the hazard classes described in this section (flammable, reactive, corrosive, or toxic). Prior to working with any compressed gases, it is important to read the manufacturers' safety data sheet (SDS). Because of their physical state (gaseous), concentrations in the laboratory can increase instantaneously if leaks develop at the regulator or piping systems, creating the potential for a toxic chemical exposure or a fire/explosion hazard. Even inert gases such as nitrogen or argon can displace room oxygen if accidentally released. Often there is little or no indication that leaks have occurred or are occurring. Finally, the large amount of potential energy resulting from compression of the gas makes a compressed gas cylinder a potential rocket or fragmentation bomb if the tank or valve is physically broken.

- When storing compressed gases in your work area it is important to think about the following concerns; is the area a confined space and are there other potential hazards that could damage a gas cylinder. Confined spaces increase the possibility of exposure and asphyxiation from leaking gas systems.
- The contents of any compressed gas cylinder should be clearly identified. No cylinder should be accepted for use that does not legibly identify its contents by name. Color coding is not a reliable means of identification and labels on caps have no value as caps are interchangeable.
- All gas cylinders should be clearly marked with appropriate tags indicating whether they are in use, full, or empty. Empty and full cylinders should not be stored in the same place. Cylinders are considered empty if their pressure is less than 25 psig.
- All gas cylinders must be secured (anchored) to a permanent structure in an upright position. Do not anchor more than two gas cylinders per strap or chain. It is important to use appropriate regulators and piping systems with gas cylinders. Do not use equipment that is incompatible with the gas being used. Gas cylinders that are not in use must have a valve protection cap screwed in place. These caps must also be on cylinders that are being transported or are empty. Keep gas cylinders away from heat sources. Store as few cylinders as possible in your laboratory.
- Carefully read the label before using or storing compressed gas. The SDS will provide any special hazard information.
- Transport gas cylinders on gas cylinders carts one or two at a time only while they are secured and capped. Do not move gas cylinders by rolling them.
- It is important to make sure gas line materials are compatible with the gas being used. Never interchange regulators and gas lines among different types of gases. All gas lines leading from a remote compressed gas supply should be clearly labeled identifying the gas and the laboratory served. Gas lines should be properly tested for leaks using an appropriate testing method for the gas being used.
- Place gas cylinders in such a way that the cylinder valve is accessible at all times. Always turn off gas cylinders from the main stem valve (not the regulator) as soon as the gas flow is no longer needed. Do not store gas cylinders with pressure on the regulator or piping. Use the wrenches or other tools provided by the cylinder supplier to open a valve if necessary. Pliers should not be used to open a cylinder valve or attach a regulator or pigtail.
- Use a leak check solution to detect leaks. Leak test the regulator, pigtail connections, and any piping system after performing maintenance or modifications which could affect the integrity of the system. Always use a leak check solution that is approved for oxygen whenever leak checking oxygen or nitrous oxide cylinders.
- Oil or grease on the high-pressure side of an oxygen cylinder can cause an explosion. Do not lubricate an oxygen regulator. Personnel should use caution to make sure their hands do not have oil or grease on them. Many products (i.e. soaps, lotions, etc.) can create the same complications as oil and grease and should be avoided prior to working with compressed oxygen.
- Compressed gases that are toxic, reactive and/or pyrophoric should be purchased in the smallest quantity possible. Compressed gases that are toxic and pyrophoric must be stored/used in a ventilated gas cylinder storage cabinet, fume hood or under local exhaust ventilation. Use the smallest returnable sized cylinder.

- If possible, avoid the purchase of lecture bottles. These cylinders are not returnable, and it is extremely difficult and costly to dispose of them. Small refillable cylinders may be an available alternative. Consult with RMS and cylinder vendor for options.
- Keep regulators safe from damage when not in use. Do not use any regulator that appears damaged, dirty, or in otherwise questionable condition. Regulators greater than 10 years old in storage should not be used unless they have been tested and certified.
- Use only Compressed Gas Association standard combinations of valves and fittings for compressed gas installations. Never use a regulator adaptor. The CGA number should be visible on all regulators. Do not use any regulator that does not have a CGA number marking. Use regulators that are appropriate for the gas being used.

### **3.6.1 Special Precautions for Hydrogen**

Hydrogen gas has several unique properties that make it a potential danger with which to work. It has an extremely wide flammability range (Lower Explosive Limit (LEL) 4%, Upper Explosive Limit (UEL) 74.5%) making it easier to ignite than most other flammable gases. Unlike most other gases, hydrogen's temperature increases during expansion. If a cylinder valve is opened too quickly the static charge generated by the escaping gas may cause it to ignite. Hydrogen burns with an invisible flame. Caution should therefore be exercised when approaching a suspected hydrogen flame. A piece of paper can be used to tell if the hydrogen is burning. Hydrogen embrittlement can weaken carbon steel, therefore cast-iron pipes and fittings must not be used. Seamless tubes should be used. Those precautions associated with other flammable substances identified above also apply to hydrogen.

### **3.6.2 Special Precautions for Toxic Gases and Pyrophoric Gases**

Lecture bottle-sized cylinders of the following gases must be kept in a continuously mechanically ventilated chemical fume hood or other continuously ventilated enclosure approved by RMS:

- All gases that have National Fire Protection Agency (NFPA) Health Hazard Ratings of 3 or 4.
- All gases that have a Health Hazard Ratings of 2 without physiological warning properties (i.e. Carbon Monoxide).
- Pyrophoric gases.

Cylinders of all gases that are greater than lecture bottle size must be kept under one of the following conditions in a continuously mechanically ventilated gas cabinet:

- All gases that have National Fire Protection Agency (NFPA) Health Hazard Ratings of 3 or 4.
- All gases that have a Health Hazard Ratings of 2 without physiological warning properties (i.e. Carbon Monoxide).
- Pyrophoric gases.

Cylinders of pyrophoric gases that are larger than lecture bottle size must be kept in continuously mechanically ventilated, sprinkled gas cabinets. Pyrophoric gas cylinders require additional controls and must comply with requirements listed in NFPA 45, NFPA 55, and Compressed Gas Association CGA P-1- 2008 Safe Handling of Compressed Gases in Containers eleventh edition.



### 3.7 Corrosive Chemicals

The major classes of corrosive chemicals are strong acids and bases, dehydrating agents, and oxidizing agents. These chemicals can erode the skin and the respiratory epithelium and are particularly damaging to the eyes. Inhalation of vapors or mists of these substances can cause severe bronchial irritation. If your skin is exposed to a corrosive chemical, flush the exposed area with water for at least fifteen minutes. Then seek medical treatment.

**Strong acids** - All concentrated acids can damage the skin and eyes and their burns are very painful. Nitric, chromic, and hydrofluoric acids are especially damaging because of the types of burns they inflict. Seek immediate medical treatment if you have been contaminated with these materials.

**Strong alkalis** - The common strong bases used in the labs are potassium hydroxide, sodium hydroxide, and ammonia. Burns from these materials are often less painful than acids. However, damage may be more severe than acid burns because the injured person, feeling little pain, may not take immediate action and allow the material to penetrate into the tissue. Ammonia is a severe bronchial irritant and should always be used in a chemical fume hood.

**Dehydrating agents** - This group of chemicals include concentrated sulfuric acid, sodium hydroxide, phosphorus pentoxide, and calcium oxide. Because much heat is evolved on mixing these substances with water, mixing should always be done by adding the agent to water, and not the reverse, to avoid violent reaction and spattering. Because of their affinity for water, these substances cause severe burns on contact with skin. Affected areas should be washed promptly with large volumes of water.

**Oxidizing agents** - In addition to their corrosive properties, powerful oxidizing agents such as concentrated hydrogen peroxide (>30%), perchloric and chromic acids (sometimes used as cleaning solutions), present fire and explosion hazards on contact with organic compounds and other oxidizable substances. The hazards associated with the use of perchloric acid are especially severe.

- Corrosive chemicals should be used in the chemical fume hood or over plastic trays when handled in bulk quantities (> 1 liter) and when dispensing.
- When working with corrosive chemicals wear gloves, goggles, long sleeved lab coat and closed toe shoes. Handling of bulk quantities of these chemicals requires use of rubber aprons and the combined use of face shields and goggles.
- An eyewash and safety shower should be close by in areas where corrosive chemicals are handled. Spill materials - absorbent pillows, neutral absorbent materials or neutralizing materials should be available in the laboratory.
- Store corrosive chemicals in corrosive cabinets. If these cabinets are not available, store them under fume hoods or on low shelves in impervious trays to separate them physically from other groups of chemicals. Keep containers not in use in storage areas and off bench tops.
- Use a chemical carrier (secondary containers) whenever moving corrosive chemicals from one laboratory to another or from a stockroom.



### 3.8 Chemicals of High Acute and Chronic Toxicity

Substances that possess the characteristic of high acute toxicity can cause damage after a single or short-term exposure. The immediate toxic effects to human health range from irritation to illness and death. Hydrogen cyanide, phosgene, and nitrogen dioxide are examples of substances with high acute toxicity. The lethal oral dose for an average human adult for highly toxic substances ranges from one ounce to a few drops. The following procedures should be used when the oral LD50 of a substance in the rat or mouse is less than 50 milligrams per kilogram body weight for solid materials or non-volatile liquids and 500 mg/kg body weight for volatile liquids or gases.

- Substances that possess the characteristic of high chronic toxicity cause damage after repeated exposure or exposure over long periods of time. Health effects often do not become evident until after a latency period up to twenty or thirty years. Substances that are of high chronic toxicity may be toxic to specific organ systems - hepatotoxins, nephrotoxins, neurotoxins, toxic agents to the hematopoietic system and pulmonary tissue or carcinogens, reproductive toxins, mutagens, teratogens.
- Avoid or minimize contact with these chemicals by any route of exposure. Protect yourself by wearing gloves, closed toe shoes and long-sleeved laboratory coat. Protect your eyes with safety goggles or glasses. If the procedure involving use of these chemicals has a potential for splashing, consider putting on an impermeable apron or coveralls, and a face shield in addition to goggles.
- Use these chemicals in a chemical fume hood or other appropriate containment device if the material is volatile or the procedure may generate aerosols.
- Store chemicals of high acute or chronic toxicity in a designated storage cabinet in unbreakable primary or secondary containers or placed in chemically resistant trays to contain spills. Do not store toxic chemicals on open shelves or counters. Decontaminate working surfaces after completing procedures.
- All chemicals should be transported between laboratories in durable outer containers or chemical carriers.
- Vacuum pumps used in procedures should be protected from contamination by installing two collection flasks in series along with in-line HEPA-like filter.

### 3.9 Reproductive Toxins, Mutagens, Teratogens and Embryotoxins

*OSHA Laboratory Standard Definitions:* Reproductive toxins are defined as substances which affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis).

**Reproductive toxins** are chemicals that affect the reproductive capabilities including adverse effects on sexual function and fertility in adult males and females, as well as adverse effects on the development of the offspring.

**Embryo toxins** are substances that cause harmful effects on a developing fetus. Auburn University has [Reproductive Health Policy and Procedures](#) that can be accessed for more information.

### 3.10 Electrical Safety

All electrical equipment must be double insulated or grounded. Laboratories should take steps to ensure the safety of Personnel from electrocution. Procedures and Equipment (including personal protective equipment) should be evaluated to ensure appropriate safeguards are in place to protect laboratory personnel and visitors on Auburn University Campus.

### 3.11 Glassware, Sharps and Needles

Handle and store laboratory glassware with care. Do not use damaged glassware. Borosilicate glassware is recommended for all laboratory glassware except for special experiments that use UV or other light sources. Any glass equipment to be evacuated, such as suction flasks, should be specially designed with heavy walls. Glass equipment in pressure or vacuum should be provided with shielding to protect users and other laboratory occupants. Glass vessels at reduced pressure are capable of collapsing violently, either spontaneously (if cracked or weakened) or from an accidental blow. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them with safety netting to contain chemicals or fragments should implosion occur. Use appropriate PPE when working with pressurized glass/plastic vessels or evacuated vessels after evaluating potential hazards. Lab personnel are responsible for [broken glass disposal](#).

All sharps and needles must be treated as medical waste regardless of the type of use. Sharps and needles must be placed in a puncture resistant sharps container. When a sharps container is in need of pickup, a disposal request can be submitted to RMS. These containers must not be overfilled past the full line on the container.

### 3.12 Lab Close-Out Procedures

Proper transfer or disposal of hazardous materials is required whenever a PI vacates their assigned lab. PIs are responsible for ensuring that graduate students, post-doctoral researchers and visiting researchers leave labs in safe conditions upon graduation or separation from Auburn University.

- Notify RMS (334-844-4870) at least one month (or as soon as possible) prior to closing labs
- Plan the transfer or disposal of hazardous materials carefully; use the laboratory close-out checklist (Appendix B) for guidance. Refer to Laboratory Close-Out Guidelines located on the RMS website for more information.



## 4 INFORMATION AND TRAINING

All laboratory personnel must receive information regarding this manual and lab safety training prior to working with hazardous chemicals. Principal Investigators shall direct laboratory personnel to the AU Risk Management and Safety website <https://cws.auburn.edu/rms/> to access manuals, policies, procedures and other safety information.

### 4.1 Laboratory Safety Training

Training sessions arranged by RMS are held regularly and are announced in the AU Daily and/or on the RMS website. Most training is also available on the web at [cws.auburn.edu/OHS](https://cws.auburn.edu/OHS).

Contact RMS Environmental Programs at 334-844-4870 for information on [Hazardous Materials Shipping and Receiving](#).

Additional lab specific safety training should be provided by the supervisor. All laboratory personnel must receive this training prior to beginning work with hazardous chemicals or for non-routine tasks presenting new /unique hazards for which an individual has not been trained in.

### 4.2 Chemical Safety Information Resources

There are numerous sources of chemical safety information. These sources include:

- The labels found on the containers of hazardous chemicals
- The substance's Safety Data Sheets (SDS)
- Special health and safety reference literature available at the library or on the web (i.e. Prudent Practices in the Laboratory, Merck Index, Laboratory Health and Safety Handbook, NIOSH Pocket Guide, Lab Safety Institute, etc.)
- Other reference literature recommended by RMS
- [PubChem](#) database maintained by the National Center for Biotechnology Information (NCBI), a component of the National Library Medicine, which is part of the National Institutes of Health (NIH).
- In addition, your supervisor and RMS are available to provide safety information.

### 4.3 Safety Data Sheets

A Safety Data Sheet (SDS) is a detailed informational document prepared by the manufacturer or importer of a hazardous chemical which describes the physical and chemical properties of the product. Information included in a Safety Data Sheet aids in the selection of safety products, helps individuals understand the potential health and physical hazards of the chemical, and describes how to respond effectively to exposure situations. It should be noted that the health and safety guidance in the Safety Data Sheet is often very generic and addresses worst case situations. It is not always helpful in selecting appropriate safeguards in the laboratory. If you have safety questions regarding a particular chemical contact RMS or your supervisor.

Safety Data Sheets for most chemicals are readily available on-line. If you do not have web access and want to review a hard copy form of an SDS, RMS can provide you with one upon request free-of-charge. Your laboratory supervisor may also have SDSs available for the materials commonly used in your laboratory. You can also contact the chemical manufacturer and receive SDSs directly from the supplier.

The format of a Safety Data Sheet may vary, but there is specific information that must be included in each sheet.

All SDSs must contain the following information:

- Identity of the product, using the name used on the original label
- The chemical and common names of the hazardous ingredients, if in >0.1% concentration
- Physical and chemical characteristics of the product
- Physical and health hazards of the product, specifying carcinogens at >0.1% concentration
- Primary routes of entry
- Exposure limits, if any
- Safe handling and use information
- Engineering and personal protective equipment control recommendations
- Emergency and first aid procedures
- Date of the SDS revision
- Name and contact information of the chemical manufacturer, importer, or other responsible party preparing or distributing the SDS

Many manufacturers are using the United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS) as a tool to assist with communicating health, physical, and environmental hazards of chemicals.

## 4.4 Chemical Toxicology

### 4.4.1 Chemical Toxicology Overview

**Toxicology** is the study of the nature and action of poisons.

**Toxicity** is the ability of a chemical substance or compound to produce injury once it reaches a susceptible site in, or on, the body.

A material's **hazard potential** is the probability that injury will occur after consideration of the conditions under which the substance is used.

### 4.4.2 Dose-Response Relationships

The potential toxicity (harmful action) inherent in a substance is exhibited only when that substance comes in contact with a living biological system. The potential toxic effect increases as the exposure increases. All chemicals will exhibit a toxic effect given a large enough dose. The toxic potency of a chemical is thus ultimately defined by the dose (the amount) of the chemical that will produce a specific response in a specific biological system.



### 4.4.3 Routes of Entry into the Body

There are three main routes by which hazardous chemicals enter the body:

- Absorption through the respiratory tract via inhalation.
- Absorption through the skin via dermal contact.
- Absorption through the digestive tract via ingestion. (Ingestion can occur through eating or smoking with contaminated hands or in contaminated work areas.)

Most exposure standards. Such as the Threshold Limit Values (TLVs) by the American Conference of Government and Industrial Hygienists (ACGIH) and Permissible Exposure Limits (PELs) by the Occupational Safety and Health Administration (OSHA), are based on the inhalation route of exposure. The limits are expressed in terms of parts per million (ppm) or milligrams per cubic meter (mg/m<sup>3</sup>) in concentration in air. If a significant route of exposure for a substance is through skin contact, the SDS, PEL, and/or TLV will have a “skin” notation. Examples of substances where skin absorption may be a significant factor include pesticides, carbon disulfide, carbon tetrachloride, dioxane, mercury, thallium compounds, xylene, and hydrogen cyanide. It is important to not exceed PEL and TLV limits. These limits are often found in chemical SDS sheets.

### 4.4.4 Types of Effects

**Acute poisoning** is characterized by sudden and severe exposure and rapid absorption of the substance. Normally, a single large exposure is involved. Adverse health effects are often reversible. Examples: carbon monoxide or cyanide poisoning.

**Chronic poisoning** is characterized by prolonged or repeated exposures of a duration measured in days, months or years. Symptoms may not be immediately apparent. Health effects are often irreversible. Examples: lead or mercury poisoning.

**Local Effect** refers to an adverse health effect that takes place at the point or area of contact. The site may be skin, mucous membranes, the respiratory tract, gastrointestinal system, eyes, etc. Absorption does not necessarily occur. Examples: strong acids or alkalis.

**Systemic effect** refers to an adverse health effect that takes place at a location distant from the body's initial point of contact and presupposes absorption has taken place. Examples: arsenic affects the blood, nervous system, liver, kidneys and skin; benzene affects bone marrow.

**Cumulative poisons** are characterized by materials that tend to build up in the body as a result of numerous chronic exposures. The effects are not seen until a critical body burden is reached. Example: heavy metals. Physical Classifications

**Gas** applies to a substance which is in the gaseous state at room temperature and pressure.

**Vapor** is the gaseous phase of a material which is ordinarily a solid or a liquid at room temperature and pressure.

When considering the toxicity of gases and vapors, the solubility of the substance is a key factor. Highly soluble materials, like ammonia, irritate the upper respiratory tract. On the other hand, relatively insoluble materials, like nitrogen dioxide, penetrate deep into the lung. Fat soluble materials, like pesticides, tend to have longer residence times in the body and be cumulative poisons.

An aerosol is composed of solid or liquid particles of microscopic size dispersed in a gaseous medium. The toxic potential of an aerosol is only partially described by its airborne concentration. For a proper assessment of the toxic hazard, the size of the aerosol's particles must be determined. A particle's size will determine if a particle will be deposited within the respiratory system and the location of deposition. Particles above 10 micrometers tend to deposit in the nose and other areas of the upper respiratory tract. Below 10 micrometers particles enter and are deposited in the lung. Very small particles (<0.2 micrometers) are generally not deposited but exhaled.

#### 4.4.5 *Physiological Classifications*

Irritants are materials that cause inflammation of mucous membranes with which they come in contact. Inflammation of tissue results from exposure to concentrations far below those needed to cause corrosion. Irritants can also cause changes in the mechanics of respiration and lung function. Long term exposure to irritants can result in increased mucous secretions and chronic bronchitis.

A primary irritant exerts no systemic toxic action either because the products formed on the tissue of the respiratory tract are non-toxic or because the irritant action is far in excess of any systemic toxic action. A secondary irritant's effect on mucous membranes is overshadowed by a systemic effect resulting from absorption.

**Asphyxiants** have the ability to deprive tissue of oxygen.

**Simple asphyxiants** are inert gases that displace oxygen. Examples: Nitrogen, Helium, Carbon dioxide.

**Chemical asphyxiants** reduce the body's ability to absorb, transport, or utilize inhaled oxygen. They are often active at very low concentrations. Examples: Carbon monoxide, Cyanides.

**Primary anesthetics** have a depressant effect upon the central nervous system, particularly the brain. Examples: Halogenated hydrocarbons, Alcohols.

**Hepatotoxic agents** cause damage to the liver. Examples: Carbon tetrachloride, Tetrachloroethane, Nitrosamines.

**Nephrotoxic agents** damage the kidneys. Examples: Halogenated hydrocarbons, Uranium compounds.

**Neurotoxic agents** damage the nervous system. The nervous system is especially sensitive to organometallic compounds and certain sulfide compounds. Examples: Tetraethyl lead and carbon disulfide

Some toxic agents act on the blood or hematopoietic system. The blood cells can be affected directly or the bone marrow (which produces the blood cells) can be damaged. Examples: Nitrites, Aniline, Toluidine, Nitrobenzene, Benzene.

There are toxic agents that produce damage of the pulmonary tissue (lungs) but not by immediate irritant action. Fibrotic changes can be caused by free silica and asbestos. Other dusts can cause a restrictive disease called pneumoconiosis. Examples: Coal dust, Cotton dust, Wood dust.



A **carcinogen** is an agent that can initiate or increase the proliferation of malignant neoplastic cells or the development of malignant or potentially malignant tumors.

A chemical is considered a carcinogen or potential carcinogen if it is listed in any of the following publications:

- National Toxicology Program, Annual Report on Carcinogens (latest edition)
  - Listed under the category of “known to be carcinogens”
- International Agency for Research on Cancer, Monographs (latest edition)
  - listed as Group 1, Group 2A or Group 2B
- Regulated by OSHA as a carcinogen under 29 CFR 1910 Subpart Z, Toxic and Hazardous Substances

Known human carcinogens include:

Asbestos	Vinyl chloride
4-nitrobiphenyl	Inorganic arsenic
Alpha-naphthylamine	Ethylene oxide
Methyl chloromethyl ether	1,2-Dibromo-3-chloropropane (DBCP)
3,3'-Dichlorobenzidine	N-nitrosodimethylamine
Bis-chloromethyl ether	Coal tar pitch volatiles

A **mutagen** causes heritable changes (mutations) in the genetic material (DNA) of exposed cells. If germ cells are involved, the effect may be inherited and become part of the genetic pool passed onto future generations.

A **teratogen** (embryotoxic or fetotoxic agent) is an agent which interferes with normal embryonic development without causing a lethal effect to the fetus or damage to the mother. Effects are not inherited. Examples: Lead, Thalidomide.

A **sensitizer** is a chemical which can cause an allergic reaction in normal tissue after repeated exposure to the chemical. The reaction may be as mild as a rash (allergic dermatitis) or as serious as anaphylactic shock. Examples: Epoxy compounds, Toluene diisocyanate, Nickel compounds, Chromium compounds, Poison ivy, Formaldehyde, d-Limonene.



#### 4.4.6 Occupational Health Standards

**TLV:** The threshold limit value is a recommended occupational exposure guideline published by the American Conference of Governmental Industrial Hygienists. TLVs are expressed as parts of vapor or gas per million parts of air by volume (ppm) or as approximate milligrams of particulate per cubic meter of air (mg/M<sup>3</sup>). The TLV is the average concentration of a chemical that most people can be exposed to for a working lifetime with no ill effects. The TLV is an advisory guideline. If applicable, a ceiling concentration (C) that should not be exceeded, or a skin absorption notation (S) will be indicated with the TLV.

**PEL:** The permissible exposure limit is a legal standard issued by OSHA. Unless specified, the PEL is a time weighted average (TWA).

**TWA:** Most exposure standards are based on time weighted averages. The TWA is the average exposure over an eight (8) hour workday. Some substances have short term exposure limits (STELs). These levels are time weighted over a 15-minute period, and exposures should not exceed the STEL in any 15-minute period over the course of an 8-hour workday.

Some substances have Ceiling (C) limits. Ceiling limits are concentrations that should never be exceeded.



## 5 LABORATORY SAFETY EQUIPMENT

### 5.1 Chemical Fume Hoods

In the laboratory the chemical fume hood is the primary means of controlling inhalation exposures. It is the responsibility of the Principal Investigator and/or laboratory supervisor to ensure that personnel receive proper training on the use of fume hood(s) available in their laboratory prior to beginning work with any hazardous materials. It should be noted that not all chemical fume hoods function the same. Personnel must be trained on the specific chemical fume hoods that they will be using in order to best protect themselves. Hoods are designed to retain vapors and gases released within them, protecting the laboratory worker's breathing zone from the contaminant. Chemical fume hoods can also be used to isolate apparatus or chemicals that may present physical hazards to laboratory personnel. The closed sash on a hood serves as an effective barrier to fires, flying objects, chemical splashes or spattering and small implosions and explosions. Auburn University standards require that there be a face velocity of 100 fpm (+/- 20) at the sash opening to adequately control vapors and gases within. All fume hoods are tested by RMS on an annual basis to verify that this face velocity is maintained. Fume hoods will be tagged Approved (image I), Limited Used (image II), or Do Not Use (III). Fume hoods that have been approved will also have the sash height indicated with an arrow.

Do not use a chemical fume hood that has not been tested and approved for use or limited use.



Image I

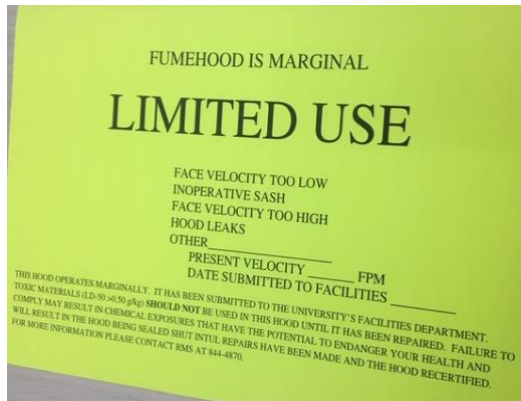


Image II

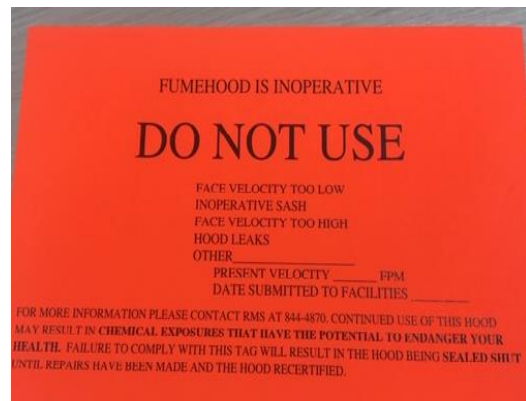


Image III

In general, chemical fume hood sash heights shall maintain at 18 inches or less unless otherwise specified by the chemical fume hood manufacturer.

When using a chemical fume hood keep the following principles of safe operation in mind:

- Keep all chemicals and apparatus at least six inches inside the hood behind the sash.
- Hoods are not intended for storage of chemicals and materials stored in them should be kept to a minimum. Stored chemicals should not block vents or alter airflow patterns.
- Fume hood should remain unobstructed.
- Large equipment should be raised up with breaks on each end to allow airflow to pass underneath the equipment.
- When **not in use**, the **sash** should be kept **closed**
- Report any hood not functioning properly to RMS or AU Facilities work management by [submitting a work order](#).

## 5.2 Use of Ductless Chemical Fume Hoods

Ductless fume hoods are not connected to an exhaust system and rely on a fan to draw air into a chamber where filters trap vapors and fumes before the air is recirculated back into the lab. The filters are usually made of specially treated or activated charcoal media that treat or adsorb chemical fumes including certain organic solvents, ammonia, acids and formaldehyde.

A concern with these devices is their filtering mechanism. Users must select the appropriate filter for the chemicals in use. Filters are not 100% efficient at removing organic vapors and some organic vapor will always be returned to the laboratory atmosphere. Filters have a limited ability to adsorb organic vapors and can quickly become saturated. Most hoods do not have a method of detecting when the filters are saturated, and breakthrough of organic vapors begins. Some substances will not be detected. Once the breakthrough of vapor begins, lab personnel are exposed to the vapors due to the recirculating nature of ductless fume hoods. Regular monitoring of the hood as well as frequent replacement and rotation of the filters is essential to provide maximum protection and help ensure safe operation. Since these enclosures recirculate filtered air back into labs, ductless fume hoods are strongly discouraged.

Applications where ductless chemical fume hoods might be appropriate include the control of nuisance particulates and odors. Ductless hoods should not be used to protect laboratory workers from toxicologically significant concentrations of hazardous chemicals. These hoods are mainly used for applications involving small quantities of chemicals.

Ductless fume hoods should only be considered for temporary projects and under the following circumstances:

- A ducted fume hood system is not feasible in the lab space
- The project cannot be moved to a laboratory with an externally exhausted fume hood
- The project is limited to a consistent process that involves only small quantities of a fixed group of known (not synthesized) chemicals. These chemicals should NOT be reactive, pyrophoric, highly toxic, carcinogenic, corrosive, or flammable.
- A preventative maintenance program must be implemented, including filter changes and an inspection of the system that follows the manufacturer's guidelines and recommendations.
- A written SOP should be submitted to RMS for all processes to be completed in the ductless fume hood prior to use.

Where ductless hoods are installed, their use must be monitored to ensure that flow rates, capture effectiveness, and procedures using hazardous chemicals do not change over time. Please consult with RMS before purchasing or beginning a project in a ductless fume hood.

These recommendations follow Prudent Practices in the Laboratory, American National Standards Institute (ANSI), and National Fire Protection Association (NFPA) standards. According to the NFPA Appendix A (A6.4.1-2000) "Ductless laboratory hoods that pass air from the hood interior through an absorption filter and then discharge the air into the laboratory are only applicable for use with nuisance vapors and dusts that do not present a fire or toxicity hazard." ANSI standard (Z.9.5-2003) specifies that ductless fume hoods must have prominently displayed signage that informs lab personnel of the allowable chemicals in the hood, the limitations of the filters, the maintenance schedule, and a warning that the hood recirculates air back into the laboratory.



### 5.3 Other Ventilation Systems

Work with hazardous materials must be conducted using appropriate ventilation equipment to minimize exposures to laboratory personnel. Examples of potentially hazardous materials encountered in laboratories are chemicals, radioactive materials and infectious biological agents. Work with hazardous biological agents must be done in approved biological safety cabinets. Other examples of ventilation equipment include gas cabinets, gloveboxes, canopy hoods, laminar benches, snorkels and downdraft tables. Each of this equipment has their own purpose and should be used for work suited for their intended purpose. Contact RMS for more information on other ventilation systems.

### 5.4 Eyewashes and Safety Showers

Whenever chemicals have the possibility of damaging the skin or eyes, an emergency supply of water must be available. All laboratories in which hazardous chemicals are handled and could contact the eyes or skin resulting in injury should have ready access to plumbed eyewash stations and safety showers.

To ensure easy access and safe use of eyewashes and safety showers:

- Keep all passageways to eyewashes and safety showers clear of any obstacle. This includes temporary storage of supplies, carts, etc.
- Ensure that you and all laboratory personnel know the location of the nearest eyewashes and safety showers, and how to operate them.
- Eyewashes should be checked routinely by laboratory personnel to be certain that water flows through it. Allow them to run for several minutes once per week to clear out the supply lines. Record testing on tags provided by RMS.
- Showers should be checked routinely by laboratory personnel to assure that access is not restricted and that the start chain or lever is within reach.
- The safety showers are tested annually by RMS to ensure proper operation and sufficient flow rates. Eyewash stations that are not equipped with drain are tested by RMS to verify functionality.

## 5.5 Fire Extinguishers

Fires are one of the most common types of laboratory accidents. Laboratory personnel should know the location, type of fire extinguishers present in the lab and type of extinguisher appropriate for the emergency. RMS provides hands on training on how to use fire extinguishers upon request. You can contact RMS at 844-4870 for more information on fire safety training. Laboratory personnel should be trained on how to use all fire extinguishers present in their labs; this includes knowledge of the type of fires for which a particular extinguisher is appropriate for and how to properly operate them. Extinguishers are classified according to a particular fire type. Type A are used on combustible (wood, paper, rubber, plastic) fires, Type B are used on flammable liquid fires, Type C are used on energized electrical equipment fires, and Type D are used on combustible metal (lithium, sodium, magnesium, potassium) fires. Multipurpose (Type ABC and Type BC) extinguishers are also available. Fire extinguishers should be easily accessible, mounted properly on a wall, and unobstructed.

## 5.6 Chemical Spill kits and First Aid Kits

It is important for a laboratory to have first aid supplies and spill kits on hand. Laboratories will need to make decisions of first aid supplies (i.e. bandages, calcium gluconate paste, etc.) that should be readily available in case of emergency. Principal Investigators and Laboratory Supervisors should make decisions on first aid training that is needed for laboratory personnel. Chemical spill kits must also be present, lab personnel should be trained on how to respond to chemical spills. Spill kits should be appropriate for the expected spill.



## APPENDIX A: GLOSSARY OF TERMS

### Glossary of Terms

**ACGIH** - The American Conference of Governmental Industrial Hygienists - a voluntary membership organization of professional industrial hygiene personnel. The ACGIH develops and publishes recommended occupational exposure limits each year called Threshold Limit Values (TLV's) for hundreds of chemicals, physical agents, and biological exposure indices.

**ACUTE** - Short duration, rapidly changing conditions.

**ACUTE EXPOSURE** - An intense exposure over a relatively short period of time.

**ANSI** - The American National Standards Institute - a voluntary membership organization that develops consensus standards nationally for a wide variety of devices and procedures.

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

**BOILING POINT** - The temperature at which the vapor pressure of a liquid equals atmospheric pressure or at which the liquid changes to a vapor. The boiling point is usually expressed in degrees Fahrenheit. If a flammable material has a low boiling point, it indicates a special fire hazard.

**"C" OR CEILING** - A description usually seen in connection with ACGIH exposure limits. It refers to the concentration that should not be exceeded, even for an instant. It may be written as TLV-C or Threshold Limit Value-Ceiling. (See also THRESHOLD LIMIT VALUE).

**CARCINOGEN** - A substance or physical agent that may cause cancer in animals or humans.

**CAS NUMBER** - Identifies a particular chemical by the Chemical Abstracts Service, a service of the American Chemical Society that indexes and compiles abstracts of worldwide chemical literature called Chemical Abstracts.

**CHRONIC** - Persistent, prolonged or repeated conditions.

**CHRONIC EXPOSURE** - A prolonged exposure occurring over a period of days, weeks, or years. **COMBUSTIBLE** - According to OSHA and NFPA, combustible liquids are those having a flash point between 100-200°F. They do not ignite as easily as flammable liquids at room temperature. However, combustible liquids can be ignited under certain circumstances, and must be handled with caution.

Substances such as wood, paper, etc., are termed "Ordinary Combustibles".

**CORROSIVE** - A substance that, according to the DOT, is highly corrosive to steel. In addition, OSHA states that corrosive substances will cause visible destruction or permanent changes in human skin tissue at the site of contact.

**CUTANEOUS** - Pertaining to or affecting the skin.

**DERMAL** - Pertaining to or affecting the skin.

**DERMATITIS** - An inflammation of the skin.

**DOT** - The United States Department of Transportation - the federal agency that regulates the labeling and transportation of hazardous materials.

**DYSPNEA** - Shortness of breath; difficult or labored breathing.

**EPA** - The Environmental Protection Agency - the governmental agency responsible for administration of laws to control and/or reduce pollution of air, water, and land systems.

**ERYTHEMA** - A reddening of the skin.

**EVAPORATION RATE** - The rate at which a material is converted to vapor (evaporates) at a given temperature and pressure. Health and fire hazard evaluations of materials involve consideration of evaporation rates as one aspect of the evaluation.

**FLASH POINT** - The lowest temperature at which a liquid gives off enough vapor to form an ignitable mixture with air and burn when a source of ignition is present.

**FLAMMABLE LIQUID** - According to the OSHA and NFPA, a flammable liquid is one that has a flash point below 100°F. (See FLASH POINT). DOT defines flammable liquids as those that have a flash point below 140°F.

Flammable Solvent Class	Boiling Point	Flash Point
Class 1A	< 100°F	< 73°F
Class 1B	≥ 100°F	< 73°F
Class 1C	≥ 100°F	Between 73 and 100°F

**GENERAL VENTILATION** - Also known as general exhaust ventilation, this is a system of ventilation consisting of either natural or mechanically induced fresh air movements to mix with and dilute contaminants in the workroom air. This is not the recommended type of ventilation to control hazardous contaminants.

**LOCAL EXHAUST VENTILATION** - A ventilation system that captures and removes contaminants at the point where they are being produced before they escape into the workroom air. The system consists of hoods, ducts, a fan and possibly an air cleaning device. Advantages of local exhaust ventilation over general ventilation include removes the contaminant rather than dilutes it; requires less air flow and thus is more economical over the long term; and the system can be used to conserve or reclaim valuable materials. However, the system must be properly designed with the correctly shaped and placed hoods, and correctly sized fans and duct work.

**HAZARDOUS MATERIAL** - Any substance or compound that has the capability of producing adverse effects on the health and safety of humans.

**IGNITABLE** - A solid, liquid or compressed gas that has a flash point of less than 140°F. Ignitable materials are regulated by the EPA as a hazardous waste.





**INCOMPATIBLE** - The term applied to two substances to indicate that one material cannot be mixed with the other without the possibility of a dangerous reaction.

**INGESTION** - Taking a substance into the body through the mouth, such as food, drink, medicine, or unknowingly as in contaminated hands or cigarettes, etc.

**INHALATION** - Breathing in of an airborne substance that may be in the form of gases, fumes, mists, vapors, dusts, or aerosols.

**INHIBITOR** - A substance that is added to another to prevent or slow down an unwanted reaction or change.

**IRRITANT** - A substance that produces an irritating effect when it contacts skin, eyes, nose, or respiratory system.

**LETHAL CONCENTRATION 50 (LC50)** - The concentration of an air contaminant that will kill 50 percent of the test animals in a group during a single exposure. This test is used to determine toxicity of a substance.

**LETHAL DOSE 50 (LD50)** - The dose of a substance or chemical that will kill 50 percent of the test animals in a group within the first 30 days following exposure. This test is used to determine toxicity of a substance.

**LOWER EXPLOSIVE LIMIT (LEL)** - (Also known as Lower Flammable Limit). The lowest concentration of a substance that will produce a fire or flash when an ignition source (flame, spark, etc.) is present. It is expressed in percent of vapor or gas in the air by volume. Below the LEL or LFL, the air/contaminant mixture is theoretically too "lean" to burn. (See also UEL).

**MELTING POINT** - The temperature at which a solid change to a liquid. A melting range may be given for mixtures.

**MUTAGEN** - Anything that can cause an inherited change (or mutation) in the genetic material of a living cell.

**NARCOSIS** - Stupor or unconsciousness caused by exposure to a chemical.

**NFPA** - The National Fire Protection Association is a voluntary membership organization whose aims are to promote and improve fire protection and prevention. NFPA has published 16 volumes of codes known as the National Fire Codes. Within these codes is Standard No. 704, Identification of the Fire Hazards of Materials. This is a system that rates the hazard of a material during a fire. These hazards are divided into health, flammability, and reactivity hazards and appear in a well-known diamond system using from zero through four to indicate severity of the hazard. Zero indicates no special hazard and four indicates severe hazard.

**NIOSH** - The National Institute of Occupational Safety and Health is a federal agency that among its various responsibility's trains occupational health and safety professionals, conducts research on health and safety concerns, and tests and certifies respirators for workplace use.

**ODOR THRESHOLD** - The minimum concentration of a substance at which a majority of test subjects can detect and identify the substance's characteristic odor.

**OSHA** - The Occupational Safety and Health Administration - a federal agency under the Department of Labor that publishes and enforces safety and health regulations for most businesses and industries in the United States.

**OXIDIZER** - A substance that gives up oxygen easily to stimulate combustion of organic material.



**OXYGEN DEFICIENCY** - An atmosphere having less than the normal percentage of oxygen found in normal air. Normal air contains 20.9% oxygen at sea level.

**PERMISSIBLE EXPOSURE LIMIT (PEL)** - An exposure limit that is published and enforced by OSHA as a legal standard. PEL may either be a time-weighted-average (TWA) exposure limit (8 hour), a 15-minute short term exposure limit (STEL), or a ceiling (C). PEL's are found in Tables Z-1, Z-2, or Z-3 of OSHA regulations 1910.1000, and in the chemical-specific standards under Subpart Z.

**PERSONAL PROTECTIVE EQUIPMENT** - Any devices or clothing worn by the worker to protect against hazards in the environment. Examples are respirators, gloves, and chemical splash goggles.

**POLYMERIZATION** - A chemical reaction in which two or more small molecules combine to form larger molecules that contain repeating structural units of the original molecules. A hazardous polymerization is the above reaction with an uncontrolled release of energy.

**PYROPHORIC MATERIAL**- A material with the ability to spontaneously ignite, without the influence of heat or fire, in air at temperatures of 130° F (54° C) or below, they can be in the solid, liquid or gas phase. Pyrophoric gases, pyrophoric liquids and pyrophoric solids all share the property of spontaneous ignition.

**REACTIVITY** - A substance's susceptibility to undergoing a chemical reaction or change that may result in dangerous side effects, such as explosions, burning, and corrosive or toxic emissions. The conditions that cause the reaction, such as heat, other chemicals, and shaking or dropping, will usually be specified as "Conditions to Avoid" when a chemical's reactivity is discussed on an SDS.

**RESPIRATOR** - A device which is designed to protect the wearer from inhaling harmful contaminants.

**RESPIRATORY HAZARD** - A particular concentration of an airborne contaminant that, when it enters the body by way of the respiratory system or by being breathed into the lungs, results in some bodily function impairment.

**SENSITIZER** - A substance that may cause no reaction in a person during initial exposures, but afterwards, further exposures will cause an allergic response to the substance.

**SHORT TERM EXPOSURE LIMIT (STEL)** - Represented as STEL or TLV-STEL, this is the maximum concentration to which workers can be exposed for a short period of time (15 minutes) for only four times throughout the day with at least one hour between exposures. Also, the daily TLV-TWA must not be exceeded.

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

**TERATOGEN** - An agent or substance that may cause physical defects in the developing embryo or fetus when a pregnant female is exposed to that substance.

**THRESHOLD LIMIT VALUE (TLV)** - Airborne concentrations of substances devised by the ACGIH that represent conditions under which it is believed that nearly all workers may be exposed day after day with no adverse effect. TLV's are advisory exposure guidelines that are based on evidence from industrial experience, animal studies, or human studies when they exist. There are three different types of TLV's: Time Weighted Average (TLV-TWA), Short Term Exposure Limit (TLV-STEL) and Ceiling (TLV-C). (See also PEL.)



**TIME WEIGHTED AVERAGE** - The average time, over a given work period (e.g. 8-hour workday), of a person's exposure to a chemical or an agent. The average is determined by sampling for the contaminant throughout the time period. Represented as TLV-TWA.

**TOXIC GAS** – The National Fire Protection Agency (NFPA) defines a toxic gas “a gas with a median lethal concentration (LC50) in air of more than 200 ppm, but not more than 2000 ppm by volume of gas or vapor, or more than 2 mg/L, but not more than 20 mg/L of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 g and 300 g (0.44 lb and .66 lb) each.

**TOXICITY** - The potential for a substance to exert a harmful effect on humans or animals and a description of the effect and the conditions or concentrations under which the effect takes place.

**UPPER EXPLOSIVE LIMIT (UEL)** - Also known as Upper Flammable Limit. Is the highest concentration (expressed in percent of vapor or gas in the air by volume) of a substance that will burn or explode when an ignition source is present. Theoretically above this limit the mixture is said to be too "rich" to support combustion. The difference between the LEL and the UEL constitutes the flammable range or explosive range of a substance. That is, if the LEL is 1ppm and the UEL is 5ppm, then the explosive range of the chemical is 1ppm to 5ppm. (see also LEL).

**VAPOR** - The gaseous form of substances which are normally in the liquid or solid state (at normal room temperature and pressure). Vapors evaporate into the air from liquids such as solvents. Solvents with low boiling points will evaporate

## APPENDIX B: STANDARD FORMS

### Laboratory Closeout Checklist

The following items are to be completed by the PI (or designated departmental staff if researcher is unavailable) prior to vacating a lab.

#### Research Materials

Item	Initial Survey			Final Survey		
	YES	NO	N/A	YES	NO	N/A
Inventory biological materials and samples (including animal/human tissues). Properly dispose of unwanted samples or transfer to other researchers. Autoclave or make safe by other approved methods before disposal. Contact the Biosafety Officer (BSO) (334-750 8040; <a href="mailto:dzs0023@auburn.edu">dzs0023@auburn.edu</a> ) if you have questions.						
Properly remove /dispose of all chemicals: Remove chemicals and samples from refrigerators, freezers, cold rooms, storage rooms, and shared labs. Check beneath hoods for chemicals or other materials that might easily be left behind. Discard empty chemical containers after defacing the label and rinsing thrice with appropriate solvent						
Follow proper disposal or transfer procedures for radioactive materials. The labs should be surveyed to rule out presence of radioactive materials or contamination. Contact Radiation Safety Office (334-844 6238; <a href="mailto:kucukse@auburn.edu">kucukse@auburn.edu</a> ) for assistance.						
Usable chemicals transferred to other PIs should be updated using Chematix Chemical Inventory Management System. The receiving party will be responsible for proper inventory, storage, and disposal. Contact <a href="mailto:cheminv@auburn.edu">cheminv@auburn.edu</a> for assistance.						
Controlled substances: DEA licensee should keep up with all DEA guidelines and/ or regulations. Notify RMS <a href="mailto:cns0013@auburn.edu">cns0013@auburn.edu</a> (334) 740 9711 if legacy-controlled substances are found during this process.						
Registered select agent labs should contact the BSO for proper close-out procedures. Other labs should notify the BSO immediately if legacy select agents are found during this process						
Contact Tom Hodges ( <a href="mailto:hodgetf@auburn.edu">hodgetf@auburn.edu</a> /334-703-7511 for guidelines on off campus shipment of hazardous materials and /or Facilities Campus Relocation Coordinator <a href="mailto:jbl0007@auburn.edu">jbl0007@auburn.edu</a> (334) 703 0214 for assistance with lab equipment moving.						
Follow proper hazardous waste disposal procedures. Contact Environmental Program (334-703-7511; <a href="mailto:hodgetf@auburn.edu">hodgetf@auburn.edu</a> ) if you have questions.						



**Laboratory Space and Equipment**

Item	Initial Survey			Final Survey		
	YES	NO	N/A	YES	NO	N/A
Drawers and cabinets emptied and clean. Decontaminate all laboratory surfaces as required.						
Survey all shared spaces and labs to locate and appropriately dispose of all hazardous materials.						
All compressed gas cylinders removed, check with your compressed gas provider. Contact Environmental Program (334-703-7511); <a href="mailto:hodgetf@auburn.edu">hodgetf@auburn.edu</a> if you have questions.						
Biosafety cabinet decontamination: The BSO will provide guidance on decontamination and recertification needs. Contact the BSO (334 750 8040; <a href="mailto:dzs0023@auburn.edu">dzs0023@auburn.edu</a> ) for assistance. Arrangements for recertification should be made in advance to allow contractors to meet your schedule.						
Decontaminate lab equipment (including freezers, refrigerators, incubator, ovens etc.) that may be contaminated with chemical, biological or radioactive materials. Remove or deface warning stickers.						
Check with RMS for proper disposal of mercury containing equipment (Thermometers, flow meters, pressure gauges etc.)						
Equipment that may be contaminated with radioactive materials should be decontaminated and surveyed per Radiation Safety guidelines. Contact Radiation Safety Office at (334-844 6238) for assistance.						
Fume hood(s) tested for perchlorate residues by RMS (if applicable)						
Fume Hoods decontaminated and clean						
Properly dispose of broken and unwanted glassware.						
Properly dispose of sharps (needles, razor blades, scalpels, etc.)						
General cleanliness & hygiene acceptable						
Other unique situations:						



## Laboratory Equipment Decontamination Form

This form is to be filled by a laboratory researcher/employee knowledgeable of the hazardous materials used in the equipment. The form only clears the lab equipment (fume hood, cabinets, refrigerator, freezer, etc.) for transportation or repair by facilities / contractors. After decontamination, attach the decontamination tag (see lab equipment decontamination tag) on the equipment and follow normal channels for surplus, work order submission, or equipment moving. Instructions for completing the form are provided on page 2 for instructions. This form must be forwarded to:

For equipment surplus: William (Bill) Capps (334-844-4984) Email: [cappswb@auburn.edu](mailto:cappswb@auburn.edu)

For equipment moving /relocation: Josh Lane (334-703-0214) Email: [jbl0007@auburn.edu](mailto:jbl0007@auburn.edu)

For equipment repair:

After submitting a work order, email this form to [workmgt@auburn.edu](mailto:workmgt@auburn.edu) (Facilities help desk Tel: 334-844-4357)

### Equipment Owner Information

Building:\_\_\_Room: \_\_\_\_\_

Contact Person:\_\_\_Phone/Email \_\_\_

Department:\_\_\_\_\_Principal Investigator:\_\_\_

Equipment Description and Use:

Equipment Description: \_\_\_

This equipment has been used with the following materials (check applicable contaminant)

Hazardous Materials

Biological agents

Radioactive materials

Describe actions taken to decontaminate:

---

Equipment Owner:

I certify that the above referenced equipment has been thoroughly cleaned and decontaminated of all chemical, biological and radioactive contaminants according to recommended guidelines.

Print Name: \_\_\_\_\_ Phone number: \_\_\_\_\_

Signature: \_\_\_\_\_ Date: \_\_\_\_\_



## Instructions for filling out Laboratory Equipment Decontamination Form

Type of equipment should be identified e.g. (refrigerator, fume hood, storage cabinets) and the appropriate box checked for type of contaminant or hazardous material (chemical hazard, biological or radiation materials). All requested information on the form must be filled by the individual doing the decontamination.

Lab equipment and fixtures used for chemical storage or research activities (storage cabinets, fume hoods, refrigerators, centrifuges, countertops, incubators, ovens etc.): Remove all chemicals from equipment to be moved or repaired and thoroughly clean with warm soapy water. Facilities will not move equipment containing spilled chemicals or do repairs during active manipulation of hazardous materials. Remove or deface safety related hazard warning stickers from equipment if the equipment is being transported from the lab to surplus. Laboratory equipment not used with chemicals, biological or radioactive materials should also be cleaned with a detergent solution before being sent to surplus. Contact RMS at (334) 844-2546 (Heath Hardison) or (334) 740-9711 (Catherine Situma) if you have questions on chemical hazards decontamination.

Contact RMS Lab Safety at (334) 844-4870 if fume hoods are to be removed from labs.

Contact RMS at (334) 844-4805 (Tom Hodges or Michael Freeman) if the equipment contains hazardous or regulated components such as coolants, mercury or oil from vacuum pumps etc.

Equipment used for storage and processing of biological materials should be decontaminated with appropriate disinfectant while allowing adequate contact time. Following decontamination with 10% bleach solution, metal surfaces should be rinsed with water and 70% ethanol. Contact AU Biosafety Officer at 334-750-8040 (Deepika Suresh) for decontamination of Biosafety Cabinets.

Equipment used with radioactive materials must be decontaminated with appropriate cleaning solution. Contact AU Radiation Safety at 334-703-0164 (Sevgi Kucuktas) for initial survey, recommended cleaner suggestions and after decontamination process surveys. The equipment must be cleaned until radiation surveys show that any contamination has been removed and meet acceptable levels. Any radioactive waste materials must be disposed in the appropriate radioactive waste bin and AU Radiation Safety must be notified for waste pick-up. To render the decontamination process complete, the final radiological survey must be performed by AU Radiation Safety staff.

## APPENDIX C: Chemical Lists

### Partial List of Incompatible Chemicals

(Adapted from Manufacturing Chemists' Association, Guide for Safety in the Chemical Laboratory, pp. 215-217)

CHEMICAL	KEEP OUT OF CONTACT WITH
Acetic Acid	Chromic acid, nitric acid hydroxyl compounds, ethylene, glycol, perchloric acid, peroxides, permanganates
Acetone	Concentrated nitric and sulfuric acid mixtures
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali Metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, the halogens
Ammonia, anhydrous	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium Nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent
Azides	Acids
Bromine	Same as chlorine
Calcium Oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents.
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organic or combustible materials
Chromic Acid	Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids in general
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Chlorine Dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cumene Hydroperoxide Cyanides	Acids, organic or inorganic
Flammable Liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic Acid	Nitric acid, alkali
Hydrofluoric Acid	Ammonia, aqueous or anhydrous
Hydrogen Peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidizing gases
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases, acetylene, ammonia (aqueous or anhydrous), hydrogen
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen



CHEMICAL	KEEP OUT OF CONTACT WITH
Mercury	Acetylene, fulminic acid, ammonia
Nitrates	Sulfuric acid
Nitric Acid	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide,
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic Acid	Silver, mercury
Oxygen	Oils, grease, hydrogen; flammable liquids, solids, or gases
Perchloric Acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorus (white)	Air, oxygen, alkalis, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium Chlorate	Sulfuric and other acids
Potassium Permanganate	Glycerin, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium Peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride,
Sulfides	Acids
Sulfuric Acid	Potassium chlorate, potassium perchlorate, potassium permanganate (or
Tellurides	Reducing agents





## Chemical List of Peroxide Formers

The following are examples of the materials commonly used in laboratories that may form explosive peroxides. Note that Class III peroxide formers must be used within 3 months of receipt: Note: This table is not all inclusive. Please see the document for Peroxide-forming Materials on the Risk Management and Safety website.

**Group A: Forms without concentration**

**Group B: Forms on concentration**

**Group C: May autopolymerize**

Isopropyl ether	Acetal	Acrylic acid
Butadiene	Cumene	Butadiene
Chlorobutadiene (chloroprene)	Cyclohexene	Chlorotrifluoroethylene
Potassium amide	Cyclooctene	Ethyl acrylate
Potassium metal	Diacetylene	Methyl methacrylate
Sodium amide (sodamide)	Dicyclopentadiene	Styrene
Tetrafluoroethylene	Diethylene glycol dimethyl ether	Vinyl acetate
Divinyl acetylene	Diethyl ether	Vinyl chloride
Vinylidene chloride	Tetrahydronaphthalene	Vinyl pyridine
	Dioxane	
	Ethylene glycol dimethyl ether	
	Furan	
	Cyclopentene	
	Methyl acetylene	
	Methyl cyclopentane	
	Methyl-isobutyl ketone	
	Tetrahydrofuran	
	Vinyl ethers	



## Chemical List of High Energy Oxidizers

The following are examples of materials which are powerful oxidizing reagents:

Ammonium perchlorate	Dibenzoyl peroxide	Potassium chlorate
Ammonium permanganate	Fluorine	Potassium perchlorate
Barium peroxide	Hydrogen peroxide	Potassium peroxide
Bromine	Magnesium perchlorate	Propyl nitrate
Calcium chlorate	Nitric acid	Sodium chlorate
Calcium hypochlorite	Nitrogen peroxide	Sodium chlorite
Chlorine trifluoride	Perchloric acid	Sodium perchlorate
Chromium anhydride (chromic acid)	Potassium bromate	Sodium peroxide

## List of Shock Sensitive Chemicals:

Shock sensitive refers to the susceptibility of the chemical to decompose rapidly or explode when struck, vibrated or otherwise agitated. The following are examples of materials that can be shock sensitive:

Acetylides of heavy metals	Heavy metal azides	Organic amine nitrates
Aluminum ophrite explosive	Hexanite	Organic nitramines
Amatol Ammonal	Hexanitrodiphenylamine	Organic peroxides
Ammonium nitrate	Hexanitrostilbene	Picramic acid
Ammonium perchlorate	Hexogen	Picramide
Ammonium picrate	Hydrazinium nitrate	Picratol
Ammonium salt lattice	Hyrazoic acid	Picric acid
Butyl tetryl	Lead azide	Picryl chloride
Calcium nitrate	Lead mannite	Picryl fluoride
Copper acetylide	Lead mononitroresorcinate	Polynitroaliphatic compounds
Cyanuric triazide	Lead picrate	Potassium nitroaminotetrazole
Cyclotrimethylenetrinitramine	Lead salts	Silver acetylide
Dinitroethyleneurea	Lead styphnate	Silver azide
Dinitroglycerine	Trimethylolethane	Silver styphnate
Dinitrophenol	Magnesium ophorite	Silver tetrazene
Dinitrophenolates	Mannitol hexanitate	Sodatol
Dinitrophenyl hydrazine	Mercury oxalate	Sodium amatol
Dinitrotoluene	Mercury tartrate	Sodium dinitro-orthocresolate
Dipicryl sulfone	Mononitrotoluene	Sodium nitrate-potassium
Dipicrylamine	Nitrated carbohydrate	Sodium picramate
Erythritol tetranitrate	Nitrated glucoside	Styphnic acid
Fulminate of mercury	Nitrated polyhydric alcohol	Tetrazene
Fulminate of silver	Nitrogen trichloride	Tetranitrocarbazole
Fulminating gold	Nitrogen tri-iodide	Tetrytol
Fulminating mercury	Nitroglycerin	Trimonite
Fulminating platinum	Nitroglycide	Trinitroanisoie
Fulminating silver	Nitroglycol	Trinitrobenzene
Gelatinized nitrocellulose	Nitroguanidine	Trinitrobenzoic acid
Germane	Nitroparaffins	Trinitrocresol
Guanyl nitrosamino guanyl-	Nitronium perchlorate	Trinitronaphtalene
Guanyl nitrosaminoguanylidene	Nitrourea	Urea nitrate



## APPENDIX D: References

- (i) 29CFR1910 Code of Federal Regulations, United States Department of Labor, OSHA.
- (ii) American Conference of Governmental Industrial Hygienists. Guidelines for the Selection of Chemical Protective Clothing.
- (iii) American Conference of Governmental Industrial Hygienists. ACGIH Threshold Limit Values for Chemical Substances and Physical Agents, and Biological Exposure Indices. Updated Annually.
- (iv) Bretherick, L. (ed.). Handbook of Reactive Chemical Hazard, 6th edition. Butterworth Heinemann. 1999.
- (v) Budavari (ed). The Merck Index: An Encyclopedia of Chemical Drugs and Biologicals. Merck Research Laboratories, New Jersey. 1996.
- (vi) Clayton, G.D. and Clayton, F.L. (ed.). Patty's Industrial Hygiene and Toxicology. General Principles, Vol. I through III. Wiley Interscience, New York. 1982.
- (vii) Furr, A. K. (ed.). CRC Handbook of Laboratory Safety, 5th ed. CRC Press, Boca Raton, Florida. 2000.
- (viii) Greenberg, M. Occupational, Industrial, and Environmental Toxicology, 2nd edition. Mosby, Inc., Pennsylvania. 2003.
- (ix) Klaassen, CD (ed.). Casarett & Doull's Toxicology: The Basic Science of Poisons, 5th ed. McGraw-Hill Co., 1996.
- (x) Manufacturing Chemists Association. Guide for Safety in the Chemical Laboratory, 2nd ed. Van Nostrand Reinhold Co., 1972.
- (xi) National Research Council. Prudent Practices in the Laboratory. Handling and Disposal of Chemicals. National Academy Press, Washington, DC. 1995.
- (xii) Sax, N.J. and Lewis, R.J. (ed.). Rapid Guide to Hazardous Chemical in the Workplace. Van Nostrand Reinhold Company, New York. 1986.
- (xiii) U.S. Department of Health and Human Services. NIOSH Pocket Guide to Chemical Hazards.

\*Content and design based on Yale University's Laboratory Chemical Hygiene Plan. [www.yale.edu/oehs](http://www.yale.edu/oehs)