LABORATORY SAFETY MANUAL

AUBURN

UNIVERSITY

RISK MANAGEMENT AND SAFETY

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Section 1. Auburn University Chemical Safety Plan

1.1 Introduction

As part of continuing efforts to provide a safe and healthful work place for students, visitors and employees, Auburn University has implemented the use of a Lab Safety Manual (LSM). A LSM is defined as a written program that specifies procedures, laboratory equipment, personal protective equipment, and work practices that assist in protecting employees from the health hazards associated with the use of chemicals in the workplace. The LSM is to be used in every lab that uses chemicals on the Auburn University campus and any associated labs. A LSM is not a substitute for individual laboratories 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 understand the LSM and any SOP associated with the duties within their laboratories.

The primary goal of this program is to ensure the safety and wellbeing of faculty, laboratory instructors, staff, students, and the visiting public will not be compromised in any university laboratory. To accomplish this, Auburn University is committed to achieving the following goals:

- Maintain a safe environment for all faculty, staff, students, and the visiting public;
- Provide the necessary facilities, staff, and equipment for safety;
- Minimize all chemical exposures;
- Avoid underestimation of risk;
- Provide adequate ventilation;
- Institute a Lab Safety Manual;
- Observe Threshold Limit Values (TLVs) for chemicals;
- Protect the environment from hazardous chemicals and wastes;
- Conduct laboratory inspections to ensure these goals are being met.

While the LSM is an important part of laboratory safety, not all issues involve chemicals. Therefore, it is important to establish additional safety policies and SOP regarding biological, physical, electrical, radiological, and life safety considerations and incorporate them into the overall laboratory safety program.

1.2 Chemical Safety Responsibilities

Responsibility for chemical health and safety rests at all levels including the:

President of the University, who has ultimate responsibility for chemical safety within the institution and must, along with other officers and administrators, provide continuing support for institutional chemical safety.

Department Chairman/Head or Director of an administrative unit, who is responsible for chemical safety in the department/unit.

Principal Investigator (PI)/Supervisor, is an employee of Auburn University who has the primary responsibility for chemical safety in the laboratory. He/she is responsible for:

- Following all applicable federal, state and local laws;
- Acquiring the knowledge and information needed to recognize and control chemical hazards in the laboratory;
- Conducting workplace hazard assessments;
- Selecting and employing laboratory practices and engineering controls that reduce the potential for exposure to hazardous chemicals to the appropriate level;
- Providing laboratory workers with appropriate personnel protective equipment and enforcing its use within the laboratory;
- Informing laboratory personnel working in the laboratory of the potential hazards associated with the use of chemicals in the laboratory and instructing them in the safe lab practices, adequate controls, and procedures for dealing with accidents involving hazardous chemicals;
- Informing personnel on contents of the manual and where to access all pertinent safety information;
- Supervising the performance of laboratory workers to ensure the required chemical safety rules are adhered to in the laboratory;
- Ensuring that all laboratory workers attend required safety training;
- Ensuring appropriate controls (engineering and personal protective equipment) are used and are in good working order;
- Developing an understanding of the current legal requirements regulating hazardous substances used in the laboratory;
- Ensuring that chemical waste is collected, labeled, and stored properly;
- 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 rules/precautions;
- Informing visitors who enter the lab of the potential hazards and safety rules/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/injuryProgram.aspx.

Laboratory worker (personnel), is an employee, AU student, visiting student, volunteer in the Principal Investigator's/Supervisor's laboratory who is responsible for:

- Following all applicable federal, state, and local laws;
- Being aware of the hazards of the materials she/he is around or working with, and handling those chemicals in a safe manner;

- Planning and conducting each operation in accordance with Auburn University's policies and procedures;
- Following PI's instructions and SOPs for conducting laboratory experiments;
- Using and maintaining required personal protective equipment (i.e. lab coats, safety glasses, goggles, face shields, respiratory protection, and gloves.);
- Developing good chemical hygiene habits (chemical safety practice and procedures);
- Reporting unsafe conditions to the PI, immediate laboratory supervisor, or Risk Management and Safety (RMS);
- Attending all required safety training;
- Collecting, labeling, and storing chemicals and chemical waste properly;
- Informing visitors who enter the lab of the potential hazards and safety rules/precautions;
- Reporting injuries to the Auburn University Department of Risk Management and Safety on the job injury program https://cws.auburn.edu/rms/injuryProgram.aspx.

Lab Safety Program Manager, is a representative from Auburn University Risk Management and Safety who is responsible for:

- Updating the Lab Safety Manual;
- 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 Lab Safety Manual, 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;
- Knowing the current legal requirements concerning regulated substances;
- Investigating or overseeing the investigation of all reported accidents which result in the exposure of personnel or the environment to hazardous chemicals.

1.3 Definitions

1.3.1 Laboratory Definition

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 OSHA standard.

1.3.2 Hazardous Chemical Definition

The OSHA Laboratory Health 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, an explosive, an 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 Toxins
- Mutagens
- Sensitizers
- Hepatotoxins
- Agents that act on the hematopoietic system
- Hematopoietic toxins
- Irritants
- Carcinogens
- Corrosives
- Asphyxiates
- Neurotoxins
- Nephrotoxins
- Agents that damage the lungs, skin, eyes or mucus membranes

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 **Material Safety Data Sheet** (MSDS) 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 Training and Information

1.5.1 Chemical Safety Training

All employees must receive information regarding this manual and lab safety training prior to working with hazardous chemicals. Principal Investigators shall direct employees to the AU Risk Management and Safety website https://cws.auburn.edu/rms/ to obtain access to manuals/policies and other safety information. Training sessions arranged by RMS are held regularly, and are announced in the AU Daily and on the RMS website. Most training is also available on the web at cws.auburn.edu/OHS. It is important that an employee, who receives hazardous materials including chemicals, must take Hazardous Materials Receiver training at the link: https://cws.auburn.edu/RMS/ConMan/ConMan_FileDownload.aspx?FileName=course-reg_hazmat.pdf. If employees have a need to ship or transport Hazardous Materials, they should contact Environmental Programs Hazardous Materials staff with questions by calling 334-844-4870.

Additional lab specific safety training should be provided by the supervisor.

All employees working in the lab must receive this training prior to beginning work with hazardous chemicals. When an employee is to perform a non-routine task presenting hazards for which he or she has not already been trained, the supervisor is responsible for discussing with the employee the hazards of the task and any special measures that should be used to protect the employee. RMS is available to consult with the supervisor or employee, as necessary.

Every laboratory worker should know the location and proper use of available personnel protective clothing and equipment, and emergency equipment/procedures. Information on protective clothing is contained in Section 2.3 of this manual.

1.5.2 Chemical Safety Information Sources

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

- The labels found on the containers of hazardous chemicals;
- The substance's Material Safety Data Sheet (MSDS);
- 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…);
- Reference literature available from RMS.

In addition, your supervisor and RMS are available to provide safety information.

1.5.2.1 Container Labeling

All chemical containers must be labeled clearly identifying their contents. Labels on purchased chemicals must not be removed or defaced except when empty. If you use secondary working containers that will take more than one work shift to empty, or there is a chance that someone else will handle the container before you finish it, you must label it. This is part of your responsibility to help protect co-workers. The label and information must be in English and clearly and fully identify the contents.

Many labels may provide you with additional safety information to help you protect yourself while working with this substance. This includes information on toxicity, flammability, instability (reactivity), and physical warnings. Protective measures may also be included on the container such as handling of the material, clothing that should be worn, first aid instructions, storage information, and procedures to follow in the event of a fire, leak or spill.

Read the 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 insure that it is labeled with the information outlined above. RMS should be notified if containers do not have proper labels.

1.5.2.3 Material Safety Data Sheets

A Material Safety Data Sheet (MSDS) 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 Material Safety Data Sheet aids in the selection of safe products, helps employers and employees 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 Material 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.

Material Safety Data Sheets for most chemicals are readily available on-line. Links to these MSDS web sites can be found on the RMS web site at https://cws.auburn.edu/rms/msds.aspx.

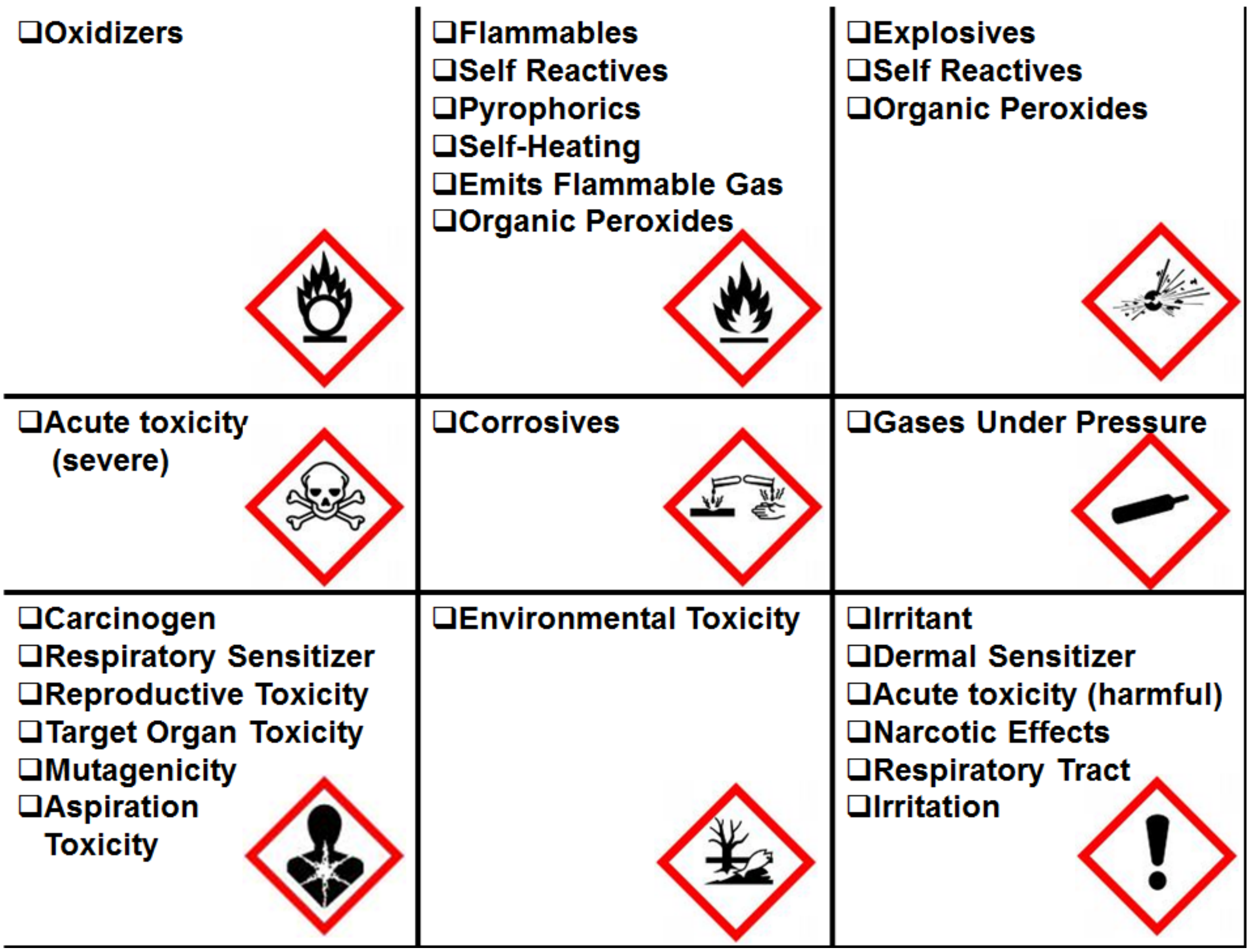
If you do not have web access and want to review a hard copy form of an MSDS, RMS can provide you with one upon request free-of-charge. Your laboratory supervisor may also have MSDSs available for the materials commonly used in your laboratory. You can also contact the chemical manufacturer and receive MSDSs directly from the supplier.

The format of a Material Safety Data Sheet may vary, but there is specific information that must be included in each sheet. All MSDSs must contain the following information:

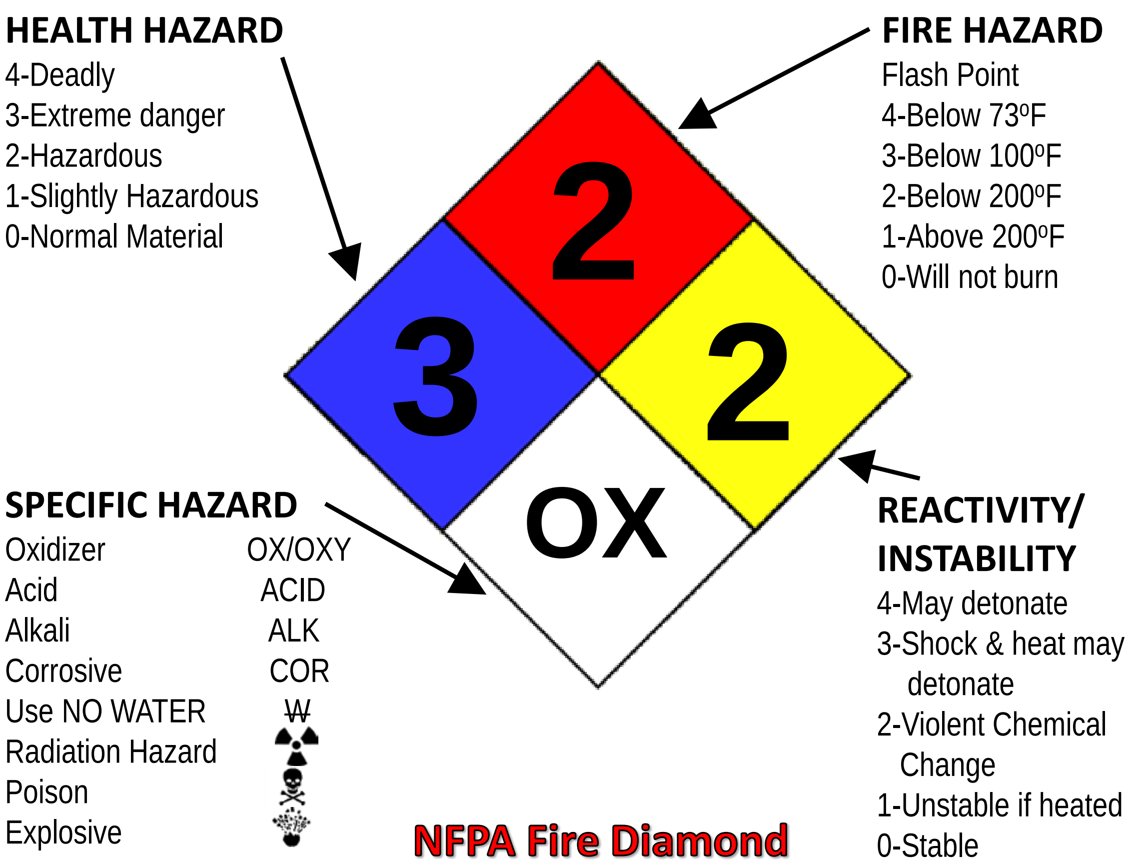
- Identity of the product, using the name used on the original label;
- The chemical and common names of the hazardous ingredients, if in >0.1% concentration;
- Physical and chemical characteristics of the product;
- Physical and health hazards of the product, specifying carcinogens at >0.1% concentration;
- 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 MSDS revision;
- Name and contact information of the chemical manufacturer, importer, or other responsible party preparing or distributing the MSDS.

Many manufactures are using the United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS) as tool to assist with communicating health, physical, and environmental hazards of chemicals. The figure below shows the pictograms that manufacturers may use on their MSDS and chemical containers. For more information on the GHS system visit the United States Occupational Safety and Health Administration (OSHA) website at www.osha.gov.



On most Material Safety Data Sheets (MSDS) and on some chemical containers you will find the National Fire Protection Agency (NFPA) 704 rating system. This system uses numbers from zero (0) to four (4) to represent the severity of hazard with zero (0) indicating minimal hazard and four (4) indicating a severe hazard. The numbers are used to indicate severity for the following hazard classes: health, flammability, and reactivity/instability. When these numbers are used in conjunction with NFPA fire diamond (listed below), placed in a particular order. Health hazard will be indicated in the left most diamond. Fire hazard will be indicated in the top diamond. Reactive/Instability will be indicated in the right diamond. The bottom diamond is used for special hazard such as: oxidizers, acids, alkalis, corrosives, water reactive, radiation, and other hazards. If color is used with the diamond, health hazard will be blue, fire hazard will be read and reactive/instability will be yellow. If no colors are present, the diamond is all white with just numbers and abbreviations.



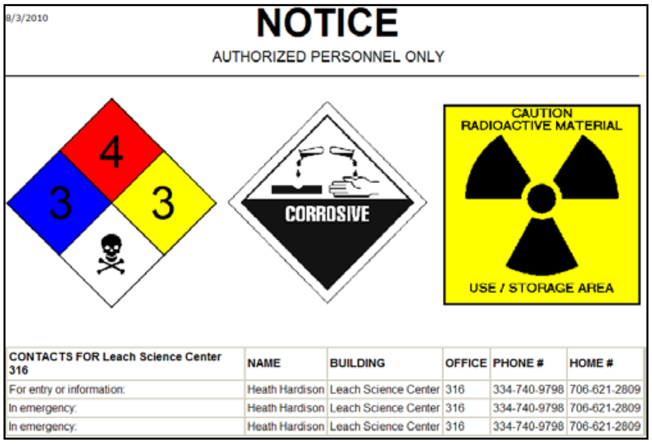
It should be noted that the NFPA 704 rating system should not be confused with systems such as GHS, HMIS, DOT, and other hazard rating systems.

If you would like additional information concerning the content or use of MSDS, contact your supervisor or RMS.

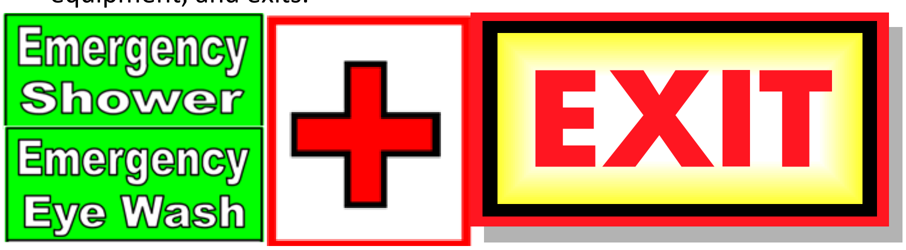
1.5.2.4 Signs

Prominent signs of the following types should be posted in each laboratory or areas that the laboratory uses:

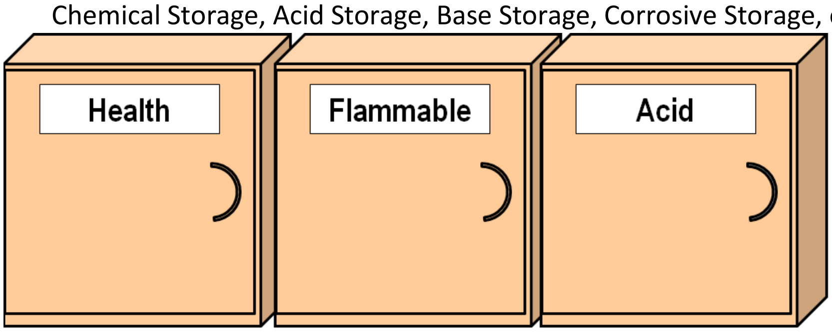
- Door Signs (https://cws.auburn.edu/rmsDoorSign/Login.aspx) must be placed outside each exit door of a laboratory listing the names and telephone numbers of the PI and other responsible personnel. These signs provide a general idea of some of the hazards present within laboratory. Door signs must be kept updated as they are used by emergency responders in the event of an off-hours emergency in the lab.



- Signs identifying locations for safety showers, eyewash stations, other safety and first aid equipment, and exits.

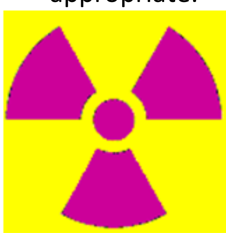


- Signs on the outside of chemical storage cabinets stating: Toxic Chemical Storage, Flammable Chemical Storage, Acid Storage, Base Storage, Corrosive Storage, etc…



- Emergency contact numbers prominently located on or near the exit and/or lab phone.

- Radiation safety or biological safety signs at lab doors, sinks, benches, hoods, etc., as appropriate.

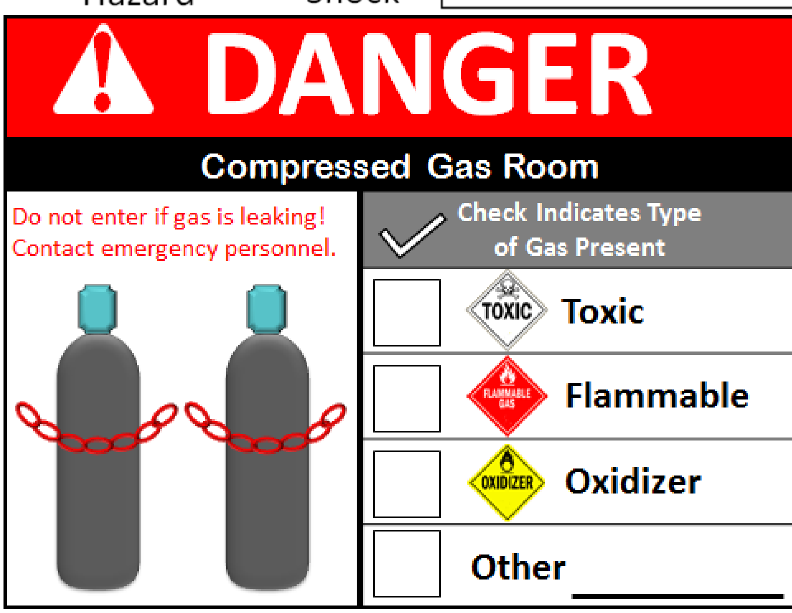

Radiation


Biological Hazard

- Warnings at areas or equipment where special or unusual hazards exist.


Magnetic Field Hazard


Electrical Shock



- No Food or Drink signs must be placed on refrigerators, microwaves, incubators, etc…

- Research Use Only signs must be placed on ice machines, dishwashers for research use, etc…

1.6 Medical Consultation and Examination

The University will provide employees who work with hazardous chemicals an opportunity to receive medical attention through the employee health program, including any follow-up examinations which the examining physician determines to be necessary, whenever an employee:

- Develops signs or symptoms associated with excessive exposure to a hazardous chemical used in their laboratory;
- Is exposed routinely above the action level (or in the absence of an action level, the applicable OSHA work place exposure limit) for an OSHA regulated substance;
- May have been exposed to a hazardous chemical during a chemical incident such as a spill, leak, explosion, or fire;
- Is referred for medical follow up by RMS.

Individuals with serious or life-threatening emergencies should proceed immediately to the East Alabama Medical Center emergency room. An ambulance can be obtained by dialing 911 from any Auburn University phone.

1.7 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) employee training; and (6) compliance with Federal/State regulation and University policies. More frequent inspections may be established for laboratories working with higher risk materials. Department chairs, business managers, safety representatives and/or committees, as directed by the department chairperson, may receive inspection summary reports for their department. Note that laboratories that use radioactive materials are inspected on a more frequent basis by the AU Radiation Safety Program.

1.8 Respiratory Protection Program

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 personal respiratory protective equipment may be necessary. A sound and effective program is essential to assure that the personnel using such equipment are adequately protected.

The University has a written plan governing the use of respirators on campus. This plan outlines organizational responsibilities for the following respirator program components: exposure assessment; respirator selection; medical approval and surveillance; fit testing; user training; inspection/repair; cleaning/disinfection; and storage. Each of these program components is required by OSHA's respiratory protection standard (29 CFR 1910.134) in all situations where respirators are used. The Auburn University Respiratory Protection Program is available for review in the Office of Environmental Health and Safety or on its website at www.auburn.edu/rms. If you are using a respirator and are not included in the University's respiratory protection program, or have questions concerning the use of respirators or any of the program components, contact your supervisor or RMS.

Section 2. Standard Operating Procedures for Working with Hazardous Chemicals

2.1 Chemical Handling Work Practices and Procedures

2.1.1 General Guidelines

Carefully read the label before using a chemical. The manufacturer's or supplier's Material Safety Data Sheet 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, transport and disposal of chemicals within the facility.

- Try not to work alone in the laboratory. If you must work alone or 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 the appropriate exposure controls (such as a chemical fume hood) and administrative programs/procedures (training, restricted access, etc.). Always use adequate ventilation with chemicals. Operations using 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. **It is of the upmost importance to understand what you are working with and to follow the manufacturer's instructions when handling any hazardous material.**
- Inspect equipment or apparatus for damage before adding a hazardous chemical. Do not use damaged equipment.
- Inspect personal protective apparel and equipment for integrity or proper functioning before use.
- Malfunctioning laboratory equipment (such as a chemical fume hood) should be identified as "out of service" so that others will not inadvertently use it before repairs are made.
- Do not dispense more of a hazardous chemical than is needed for immediate use.

2.1.2 Personal Hygiene

- Remove contaminated clothing and gloves before leaving 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 thoroughly with soap and water after handling any chemical.
- 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.

2.1.3 Housekeeping

- Keep floors clean and dry. Keep all aisles, hallways, and stairs clear of all chemicals. 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.
- Access to emergency equipment, utility controls, showers, eyewashes and exits should never be blocked.
- Wastes should be kept in the appropriate containers and labeled properly.
- Any unlabeled containers are considered wastes at the end of each working day.

2.1.4 Glassware Safety

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 service 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. Work with pressurized glass/plastic vessels or evacuated vessels requires use of the following PPE: face shield, safety goggles or glasses depending on the substance in the vessel, long-sleeved lab coat, and closed toe shoes.

2.2 When Not To Proceed Without Reviewing Safety Procedures

Sometimes laboratory workers should not proceed with what seems to be a familiar task. Hazards may exist that are not fully recognized. Certain indicators should cause the employee to stop and review the safety aspects of their procedure. 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); usually one should review safety practices if the volume of chemicals used increases by 200%.
- A failure of any of the equipment used in the process, especially safeguards such as chemical fume hoods.
- Unexpected experimental results (such as a pressure increase, increased reaction rates, unanticipated byproducts). When an experimental result is different from the predicted, a review of how the new result may affect safety practices should be made.
- 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 researcher to pause, evaluate the safety implications of these changes or results, make changes as necessary and proceed cautiously. If needed, call RMS for assistance.

2.3 Protective Clothing and Laboratory Safety Equipment

2.3.1 General Consideration - Personal Protective Clothing/Equipment

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 employee's work practices and training to be effective. The engineering and administrative controls that should always be considered first when reducing or eliminating exposures to hazardous chemicals include:

- Substitution of a less hazardous substance or less hazardous equipment or process;
- Scaling down size of experiment;
- Isolation of the operator or the process;
- Local and general ventilation (e.g., use of fume hoods).

A laboratory coat, gloves, protective eyewear, and closed toe shoes are required to be worn in Auburn laboratories whenever handling hazardous chemicals. Additional personal protective equipment, such as face shield, utility gloves, aprons, and respirators, may be necessary depending on an assessment of the hazard and operation. Your supervisor and RMS can assist you in determining the personal protective devices required for each task. Departments must provide appropriate personal protective equipment to employees.

2.3.2 Protection of Skin and Body

Skin and body protection involves 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).

2.3.2.1 Standard Laboratory Clothing

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. Employees shall not wear shorts, short skirts or sandals in a laboratory. A laboratory coat with cuffs at the sleeves should be worn over street clothes and be laundered regularly. Laboratory coats are intended to prevent contact with dirt, chemical dusts and minor chemical splashes or spills. If it becomes contaminated it should be removed immediately and the affected skin surface washed thoroughly. When working with chemicals that may ignite on contact with air, RMS recommends the use of a flame-resistant lab coat. Closed-toe shoes should be worn in the laboratory at all times.

2.3.2.2 Protective Clothing

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. Rubberized aprons, plastic coated coveralls, shoe covers, and arm sleeves offer much greater resistance to permeation by chemicals than laboratory coats and, therefore, provide additional time to react (remove the garment and wash affected area) if contaminated.

If you are working with substances of high acute or chronic toxicity and wearing washable garments (such as a laboratory coat), evaluate the potential for exposing non-laboratory personnel when laundering. Wear disposable garments if others may be placed 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.

2.3.2.3 Gloves

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 important 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 lab personnel to develop a sensitization to the latex. Nitrile exam style gloves are generally more chemically resistant than vinyl or latex, but due to the thinness of these gloves thicker utility style reusable gloves should be worn if there is a probability of contact with hazardous chemicals. The following table offers a general guide to glove selection:

Glove Material	Intended Use	Advantages	Disadvantages
Latex exam style	Incidental Contact	• Good for biological and water-based materials • User acceptability	• Poor for organic solvents • Hard to detect puncture holes • Latex allergy issues
Nitrile exam style	Incidental Contact	• Good for solvents, oils, greases, some acids and bases • Clear indication of tears and breaks • User acceptability	• Slightly more expensive than latex
Utility style Nitrile – Solvex	Extended Contact	• Good for solvents, oils, greases, some acids and bases • Can be washed and reused	• Not effective for halogenated and aromatic hydrocarbons
Neoprene – utility style	Extended contact	• Good for acids, bases alcohols, fuels, peroxides, hydrocarbons, and phenols	• Poor for halogenated and aromatic hydrocarbons
Butyl rubber utility gloves	Extended contact	• Good for ketones and esters	

Contact RMS for personal protection equipment selection assistance or information. A glove chart is also available here.

2.3.3 Eye Protection

Eye protection is required for all personnel, students, and any visitors present in locations where chemicals are handled and a chemical splash hazard exists. American National Standard Institute (ANSI) safety glasses, goggles and goggles with face shield should be worn in the laboratory based upon the physical state, the operation or the level of toxicity of the chemical used. Safety glasses with side shields effectively protect the eye from solid materials (dusts and flying objects) but are less effective at protecting the eyes from chemical splash to the face. Safety glasses are the minimum eye protection that must be worn in the laboratory. ANSI approve chemical splash goggles shall be worn in situations where bulk quantities of chemicals are handled and chemical splashes to the eyes are possible. Goggles form a liquid proof seal around the eyes, protecting them from a splash. When handling highly reactive substances, chemicals under pressure, or larger quantities of corrosives, poisons, and hot chemicals, goggles with face shield should be worn.

2.3.4 Protection of the Respiratory System

Inhalation hazards can be controlled using ventilation or respiratory protection. Check the label and MSDS for information on a substance's inhalation hazard and special ventilation requirements. When a potential inhalation hazard exists a substance's label or MSDS contains warnings such as:

- Use with adequate ventilation,
- Avoid inhalation of vapors,
- Use in a fume hood,
- Provide local ventilation.

Take appropriate precautions before using these substances. Controlling inhalation exposures via engineering controls (ventilation) is always the preferred method. As with other personal protective equipment, respiratory protection relies heavily on employee work practices and training to be effective.

<u>Use of Respirators</u>

Respirators are designed to protect against specific types of substances in limited concentration ranges. Respirators must be selected based on the specific type of hazard (toxic chemical, oxygen deficiency, etc.), the contaminant's anticipated airborne concentration, and required protection factors.

Types of respiratory protective equipment include:

- Disposable NPR95 or HEPA filter masks (particle-removing respirators)
- Air purifying respirators (vapor, gas and/or particle removing – ½ mask, full face, or powered air purifying (PAPR))
- Atmosphere supplying respirators (air line or SCBA)

Respirators are not to be used except in conjunction with a complete respiratory protection program as required by OSHA. If your work requires the use of a respirator, contact RMS and your supervisor. Do not use respiratory protective equipment until you have met all elements of the written Auburn University Respiratory Protection Program. Users of respirators must be fitted to the proper size respirator, and thoroughly trained in proper use, maintenance, storage and limitations of this equipment, the nature of the respiratory hazard, and the signals of respirator failure. Medical surveillance to determine your ability to physically wear a respirator must also be conducted. This entails the completion of a medical surveillance questionnaire that is evaluated by the Occupational Health Physician. The physician will determine whether a physical examination is needed before providing medical clearance to wear the respirator. No one is allowed to wear a respirator on campus without medical clearance and without approval and training from RMS.

2.3.5 Laboratory Safety Equipment

2.3.5.1 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 the 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 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 employees. 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. 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 air-flow to pass underneath the equipment.
- Follow the instructions on the "Safe Use of Laboratory Fume Hoods" sticker posted on all hoods. For constant volume hoods, set the appropriate sash opening by lining up the red arrows placed on the sash door and hood frame. This sash opening will ensure the appropriate air velocity through the face of the hood. For variable air volume hoods, keep the hood sash lowered when not manipulating chemicals or adjusting apparatus within the hood.

Follow the chemical manufacturers or supplier's specific instructions for controlling inhalation exposures with ventilation when using their products. These instructions are located on the MSDS and/or label. It is recommended that all work involving volatile or higher hazard chemicals be conducted inside a chemical fume hood whenever feasible. Contact RMS with any questions or concerns regarding engineering controls for specific operations. RMS performs an annual air flow test on chemical fume hoods. Fume hoods will be tagged Approved (image 1), Limited Used (image 2), or Do Not Use (3). Fume hoods that have been approved will also have the sash height indicated with an arrow. Do not use a chemical fume that has not been tested and approved for use or limited use. Follow the instructions listed on the tags for limited use fume hoods.

image 1

image 2

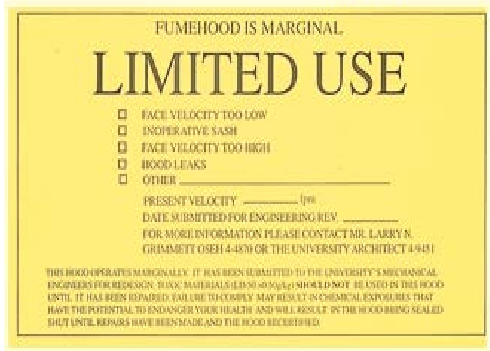
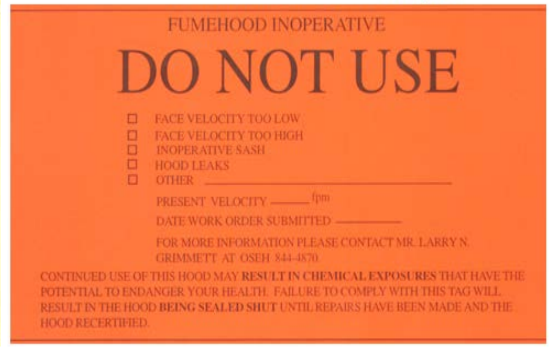


image 3



2.3.5.2 Comment on the Use of Ductless Chemical Fume Hoods

Ductless chemical fume hoods (hoods which recycle air to the laboratory after passing it through a filter) are offered by a variety of manufacturers. Manufacturers claim that these devices are safe and extremely energy efficient because no air is exhausted from the laboratory. These systems typically have a particulate filter and/or a charcoal filter for the removal of organic vapors. These systems must be used with extreme caution. Contact RMS before purchasing or using one of these ductless hood systems to control chemical exposures. These hoods cannot be purchased without approval from RMS.

The primary safety concern with these devices is their filtering mechanism. Charcoal filters are not 100% efficient at removing organic vapors and some organic vapor will always be returned to the laboratory atmosphere. Charcoal filters have a limited ability to adsorb organic vapors and often become saturated in a matter of months. Most hoods do not have a method for detecting when the filters are saturated and breakthrough of organic vapors begins. Those that have monitors depend on non-specific chemical sensors that will respond at different concentrations for different substances. Some substances will not be detected. Charcoal filter replacements are extremely expensive (approximately 20-25% of the hoods initial cost) and studies have shown that (when operated over several years) ductless hoods may actual be more expensive (as well as less protective) to operate than ducted hoods.

Applications where ductless chemical fume hoods might be appropriate include the control of particulate and nuisance odors. Ductless hoods should not be used to protect laboratory workers from toxicologically significant concentrations of hazardous chemicals. Where ductless hoods are installed their use must be monitored to ensure that flow rates and capture effectiveness do not change over time and include procedures using hazardous chemicals as outlined above.

2.3.5.3 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 even 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.
- 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.

2.4 Chemical Storage

2.4.1 Chemical Storage in the Laboratory

Carefully read the label before storing a hazardous chemical. The manufacturer's MSDS 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.*

Chemical must be separated by hazard class and compatibility. The main hazard classes for hazardous classes for hazardous chemicals are health, flammable, reactive, and general storage. Even within a particular hazard class such as flammables, physical separation may be required. It is important to follow the chemical manufacturer's instructions for storage. Separate hazardous chemicals in storage as follows:

Solids:

- Oxidizers
- Flammable solids (phosphorus, magnesium, lithium)
- Water reactives
- Others

Liquids:

- Flammable/combustible
- Inorganic acids
- Organic acids
- Caustics
- Oxidizers
- Others

Gases:

- Toxic
- Oxidizers
- Flammable

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. 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 all be kept separate from oxidizing acids such as nitric acid and perchloric acid. Separation of nitric and perchloric acid from other acids may be accomplished by placing in a plastic pan or tray.

Hazardous chemicals should not be stored on bench tops, on the floor, or in hoods. Chemicals should also not be stored under sinks, if possible. If separate cabinets are not feasible, chemicals of different chemical classes can be segregated by placing them in trays. Corrosive or hazardous liquids should not be stored above eye level.

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.

Update chemical inventory information in the Chematix inventory system. Conduct periodic inventories of chemicals stored in the laboratory and dispose of old or unwanted chemicals promptly in accordance with RMS's chemical waste program. When a new chemical is received in the laboratory, make sure that it is added to the inventory to the laboratory in the Chematix inventory system. Assure all containers are properly labeled with the identity of the contents and any appropriate hazard warnings.

2.4.2 Chemical Storage - Chemical Stability

Stability refers to the susceptibility of a chemical to dangerous decomposition. The label and MSDS will indicate if a chemical is unstable.

Special note: peroxide formers - Ethers, liquid paraffins, and olefins form peroxides on exposure to air and light. Peroxides are extremely sensitive to shock, sparks, or other forms of accidental ignition and can be even more sensitive than primary explosives such as TNT. 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 and discarded by the expiration date on the container. If the container does not have an expiration date but the chemical is a peroxide- former, the container should be discarded after one (1) year of receipt, even if unopened. Please see the Standard Operating Guideline for Peroxide-forming Materials (Potentially Explosive Chemicals) found online at:
https://cws.auburn.edu/rms/ConMan/ConMan_FileDownload.aspx?FileName=PEC Guidelines.pdf.

Store peroxide-forming chemicals in a dark, cool, and dry place.

For additional information on chemical stability, contact your supervisor or RMS.

2.4.3 Chemical Storage - Incompatible Chemicals

Certain hazardous chemicals should not be mixed or stored with other chemicals because a severe reaction can take place or an extremely toxic reaction product can result. The label and MSDS will contain information on incompatibilities and should always be consulted. The following table contains examples of incompatible chemicals, but is not a complete list:

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	Acids, organic or inorganic
Cyanides	Acids
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
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, alkalies, 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

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

2.5 Chemical Spills and Accidents

2.5.1 General Information

Try to anticipate the types of chemical spills that can occur in your laboratory and obtain the necessary equipment (spill kits and personal protective equipment) to respond to a minor spill. Learn how to safely clean up minor spills of the chemicals you use regularly. An MSDS 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, requires you to put on respiratory protection, is a threat to personnel, students or the public, or involves a highly toxic or reactive chemical, call for assistance immediately:

- Simple Chemical Spills – RMS – 844-4870
- Complex Chemical Spills – 911

2.5.2 Cleaning Up Chemical Spills

If you are cleaning up a small 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 chemical fume hood. Contact RMS for disposal instructions and pickup.

2.5.3 Simple Chemical Spill

- 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 neutralize and absorb inorganic acids and bases. Collect residue, place in container, and dispose as hazardous chemical waste. Call RMS for disposal information, if necessary.
- For other chemicals, use appropriate kit or absorb spill with vermiculite, dry sand, diatomaceous earth, spill pads, or paper towels. Collect residue, place in container, and dispose as chemical waste.
- Store material in a chemical fume hood temporarily while awaiting chemical waste pickup.
- Clean spill area with water.

2.5.4 Complex Chemical Spill

- Attend to injured or contaminated persons and remove them from exposure.
- 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.

2.5.5 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.

2.6 Personal Contamination and Injury

2.6.1 General Information

- Know the locations of the nearest safety shower and eye wash fountain.
- 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 MSDS may contain special first aid information.
- Do not move an injured person unless they are in further danger (from inhalation or skin exposure).
- A blanket should be used immediately to protect the victim from shock and exposure.
- Get medical attention promptly by dialing 911.

2.6.2 Chemicals Spills on the Body

- Quickly remove all contaminated clothing and footwear.
- Get to a 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 (eg. 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.

2.6.2.1 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 is 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 5 minutes, if calcium gluconate is available. 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.

- Gently rub calcium gluconate ointment onto the affected area. Continue applying until emergency medical responders arrive.
- Inform responders and all others that the exposure involved hydrogen fluoride/hydrofluoric acid.

2.6.3 Chemical Splash in the Eye

- Use 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.

2.6.4 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 MSDS with the victim.

2.6.5 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.

2.7 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 assist oneself to evacuate, assist another to evacuate, or 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.

2.8 Chemical Waste Disposal Program

Laboratory chemical waste must be handled according to the University's policy and management guidelines outlined in AU's Hazardous Waste Management Guide. The University's waste management practices are designed to ensure maintenance of a safe and healthful environment for laboratory employees 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 compliance with local, state, and federal regulations. The manual provides laboratory personnel with specific guidance on how to identify, handle, collect, segregate, store, tag and dispose of chemical waste appropriately. For additional information on Auburn's chemical waste management program ask your supervisor or contact RMS.

3.1 Flammable Liquids

3.1.1 General Information

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 concentrated vapors of flammable liquids are usually heavier than air and can travel away from a source for a considerable distance (across laboratories, into hallways, down elevator shafts or stairways). If the vapors reach a source of ignition a flame can result that may flash back to the source of the vapor.

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.

3.1.2 Special Handling Procedures

While working with flammable liquids you should wear gloves, protective glasses or goggles, long sleeved lab coats and closed toe shoes. Wear goggles if dispensing solvents or performing an operation 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.

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 autoignition temperature of the solvent is above the oven temperature or its internal elements.

3.2 Highly Reactive Chemicals and High Energy Oxidizers

3.2.1 General Information

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. Reaction rates almost always increase dramatically as the temperature increases. Therefore, if heat evolved from a reaction is not dissipated, the reaction can accelerate out of control and possibly result in injuries or costly accidents. 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. Hydrogen and chlorine react explosively in the presence of light. Alkali metals, such as sodium, potassium and lithium, react violently with water liberating hydrogen gas. 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.

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.

Peroxide formers can form peroxides during storage and especially after exposure to the 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 vinylidine compounds.

3.2.2 Special Handling Procedures

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. Standard Operating Procedures (SOPs) should be developed for highly reactive material. 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. Unused peroxides should be discarded as hazardous waste and not be returned to the original container.

Do not work alone. All operations where highly reactive and explosive chemicals are used should be performed during the normal work day or when other employees are available either in the same laboratory or in the immediate area. Work with highly reactive and explosive chemicals must not be conducted: when inadequate facilities are not present, by untrained personnel or by sleep deprived personnel. Work with these materials requires the utmost of attention.

Perform all manipulations of highly reactive or high energy oxidizers in a chemical fume hood. 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 will volatilize and potentially condense 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 hood. SOPs must be established for using perchloric acid fume hoods.

When working with highly reactive compounds and high energy oxidizers always wear the following personal protection equipment: long sleeved lab coats, gloves, closed toe shoes and protective glasses/goggles. During the reaction, a face shield long enough to give throat protection should be worn.

A face shield or body shield should be worn in addition to protective eyewear based on the scale of the reaction.

Store highly reactive chemicals and high-energy oxidizers in closed cabinets segregated from the materials with which they react, inside secondary containment. You can also store them in the cabinet under a hood. Do not store these substances above eye level or on open shelves.

Store peroxides and peroxide forming compounds at the lowest possible temperature. If you use a refrigerator make sure it is appropriately designed for the storage of flammable substances. Store light-sensitive compounds in the light-tight containers. Store water-sensitive compounds 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.

3.2.3 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 hexanitrate	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	Trinitroanisole
Fulminating silver	Nitroglycol	Trinitrobenzene
Gelatinized nitrocellulose	Nitroguanidine	Trinitrobenzoic acid
Germane	Nitroparaffins	Trinitrocresol
Guanyl nitrosamino guanyl-tetrazene	Nitronium perchlorate	Trinitronaphtalene
Guanyl nitrosaminoguanylidene hydrazine	Nitrourea	Urea nitrate

3.2.4 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

3.2.5 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:

Table A: Forms without concentration	Table B: Forms on concentration	Table C: May autopolymerize
Isopropyl ether	Acetal	Acrylic acid
Butadiene	Cumene	Butadiene
Chlorobutadiene (chloroprene)	Cyclohexene	Chlorotrifuoroethylene
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	
	Cylcopentene	
	Methyl acetylene	
	Methyl cylopentane	
	Methyl-isobutyl ketone	
	Tetrahydrofuran	
	Vinyl ethers	

Note: This table is not all inclusive.

Please see the document for Peroxide-forming Materials on the Risk Management and Safety website.

3.3 Compressed Gases

3.3.1 General Information

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 it important to read the manufacturers' material safety data sheet (M.S.D.S.). 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 potential other hazards (i.e. equipment, chemical leakage, etc…) in this area that could damage a gas cylinder. Confined spaces increase the possibility of exposure and asphyxiation from leaking gas systems.

3.3.2 Special Handling Procedures

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 are not being used 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 MSDS 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 pyrophoric gases should be purchased in the smallest quantity possible. Compressed gases that toxic and pyrophoric must be stored/used in a ventilated gas cylinder storage cabinet, fume hood or under local exhaust ventilation. Please see section 3.3.4 "Special Precautions for Toxic Gases." 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.

Wear safety goggles, gloves, long sleeved lab coat and closed toe shoes when handling compressed gases.

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 be 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.

3.3.3 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 (LEL 4%, 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.

3.3.4 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:

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

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

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

3.4 Corrosive Chemicals

3.4.1 General Information

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 includes 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. It should be handled only after thorough familiarization with recommended operating procedures (see Section 3.2).

3.4.2 Special Handling Procedures

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 whenever moving corrosive chemicals from one laboratory to another or from a stockroom.

3.5 Chemicals of High Acute and Chronic Toxicity

3.5.1 General Information

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 (3.5.2) 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. Oral LD50 data for the rat or mouse may be listed in the substance's MSDS. On the MSDS, those chemicals with an oral LD50 <50 mg/kg is identified as “Highly Toxic”, and those with an oral LD50 >50 mg/kg but <500 mg/kg is identified as “Toxic”. The

LD50 toxicity test is usually the first toxicological test performed and is a good indicator of a substances acute toxicity.

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 or sensitizers. The definition of each of these categories of toxic substances, and examples of substances that fall into each of these different categories, can be found in Section 4 of this manual.

Specific acute and chronic toxicity information on the substances used in your laboratory can be found on these substances' MSDSs or from RMS and on the web. RMS can assist you with any information on chemical hazards and toxicity that you may need.

3.5.2 Special Handling Procedures

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 (See guidelines for chemical fume hood use in Section 2.3.5.1). Chemical fume hoods should be evaluated to confirm that they are performing adequately (a face velocity of at least 100 linear feet per minute (±20%)) with the sash at the operating height.

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 with wet paper towels after completing procedures. Place the towels in plastic bags and secure. Dispose of them in the normal trash.

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.

3.6 Reproductive Toxins and Auburn University Fetal Risk Policy

3.6.1 General Information

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 mean 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. The Argonne National Laboratory has a list on their website http://www.anl.gov/ of reproductive toxins. This list may not include all known or suspected reproductive toxins.

Auburn University has a Fetal Risk Policy that can be accessed at https://cws.auburn.edu/rms/.

Section 4. Chemical Toxicology

4.1 Chemical Toxicology Overview

4.1.1 Definitions

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.

4.1.2 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.

4.1.3 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 (ACGHI) and Permissible Exposure Limits (PELs) by the Occupational Safety and Health Administration (OSHA), are based on the inhalation route of exposure. These limits are normally expressed in terms of either parts per million (ppm) or milligrams per cubic meter (mg/m^3) concentration in air. If a significant route of exposure for a substance is through skin contact, the MSDS, 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 on chemical MSDS sheets.

4.1.4 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.

A 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.

Substances in combination: When two or more hazardous materials are present at the same time, the resulting effect can be greater than the effect predicted based on the additive effect of the individual substances. This is called a synergistic or potentiating effect. Example: exposure to alcohol and chlorinated solvents; or smoking and asbestos.

4.1.5 Other Factors Affecting Toxicity

- Rate of entry and route of exposure; that is, how fast is the toxic dose delivered and by what means.
- Age can affect the capacity to repair tissue damage.
- Previous exposure can lead to tolerance, increased sensitivity or make no difference.
- State of health, physical condition and life style can affect the toxic response.
- Pre-existing disease can result in increased sensitivity.
- Environmental factors such as temperature and pressure.
- Host factors including genetic predisposition and the sex of the exposed individual.

4.1.6 Physical Classifications

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

A 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.

4.1.7 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. Example: dilute hydrogen chloride.

A secondary irritant's effect on mucous membranes is overshadowed by a systemic effect resulting from absorption. Examples: Hydrogen sulfide, Aromatic hydrocarbons.

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 (a few ppm). 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 include:

- Trialkyl tin compounds
- Tetraethyl lead
- Methyl mercury
- Carbon disulfide
- Organic phosphorus insecticides
- Thallium
- Manganese

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
- 4-nitrobiphenyl
- Alpha-napthylamine
- Methyl chloromethyl ether
- 3,3'-Dichlorobenzidine
- Bis-chloromethyl ether
- Vinyl chloride
- Inorganic arsenic
- Ethylene oxide
- 1,2-Dibromo-3-chloropropane (DBCP)
- N-nitrosodimethylamine
- 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.

4.2 Some Target Organ Effects

The following is a categorization of target organ effects which may occur from chemical exposure. Signs and symptoms of these effects and examples of chemicals which have been found to cause such effects are listed.

Toxins	Target organ effect	Signs and symptoms	Example chemicals
Hepatotoxins	Cause liver damage	Jaudice; liver enlargement	Nitrosamines, chloroform, toluene, perchloro-ethylene, cresol, dimethylsulfate
Nephrotoxins	Cause kidney damage	Edema; proteinuria	Halogenated hydrocarbons, uranium, chloroform, mercury, dimethylsulfate
Neurotoxins	Affect the nervous system	Narcosis; behavior changes; decreased muscle coordination	Mercury, carbon disulfide, benzene, carbon tetrachloride, lead, mercury, nitrobenzene
Hematopoietic toxins	Decrease blood function	Cyanosis; loss of consciousness	Carbon monoxide, cyanides, nitro-benzene, aniline, arsenic, benzene, toluene
Pulmonary toxins	Irritate or damage the lungs	Cough; tightness in chest, shortness of breath	Silica, asbestos, ozone, hydrogen sulfide, chromium, nickel, alcohols
Reproductive toxins	Affect the reproductive system	Birth defects; sterility	Lead, 2-ethoxyethanol, dibromodichloropropan
Skin hazards	Affect the dermal layer of the body	Defatting of skin; rashes; irritation	Ketones, chlorinated compounds, alcohols, nickel, phenol, trichloroethylene
Eye hazards	Affect the eye or vision	Conjunctivitis, corneal damage	Organic solvents, acids, cresol, quinone, hydroquinone, benzol, chloride, butyl alcohol, methanol, bases

4.3 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 or air (mg/M3). 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 work day. 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 work day. Some substances have Ceiling (C) limits. Ceiling limits are concentrations that should never be exceeded.

Section 5. Other Safety Concerns

5.1 Sharps and Needles

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. Please see the link Medical Waste Management for information of proper disposal of medical waste.

5.2 First Aid

It is important for a laboratory to first aid supplies on hand. Laboratories will need to make decisions of first aid supplies (i.e. bandages, calcium gluconate paste, etc…) that should readily available in cases of emergency. Principal Investigators and Laboratory Supervisors should make decisions on first aid training that is needed for laboratory personnel.

5.3 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 safe guards are in place to protect employees and visitors to Auburn University campus.

Section 6.0 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 (run with private funding) that develops consensus standards nationally for a wide variety of devices and procedures.

ASPHYXIANT - 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.

cc - Cubic centimeter, a volumetric measurement which is also equal to one milliliter (ml).

^{o}C - Degrees, Celsius; a temperature scale.

CHEMICAL - As broadly applied to the chemical industry, an element or a compound produced by chemical reactions on a large scale for either direct industrial and consumer use or for reaction with other chemicals.

CHEMICAL REACTION - A change in the arrangement of atoms or molecules to yield substances of different composition and properties. (see REACTIVITY)

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".

CONCENTRATION - The relative amount of a material in combination with another material - for example, 5 parts of (acetone) per million (parts of air) = 5 ppm acetone.
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.

DECOMPOSITION - The breakdown of a chemical or substance into different parts or simpler compounds. Decomposition can occur due to heat, chemical reaction, decay, etc.

DERMAL - Pertaining to or affecting the skin.

DERMATITIS - An inflammation of the skin.

DILUTION VENTILATION - See GENERAL VENTILATION.

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.

EPA NUMBER - The number assigned to chemicals regulated by the Environmental Protection Agency (EPA).

EPIDEMIOLOGY - The study of disease in human populations.

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.

°F - Degrees, Fahrenheit; a temperature scale.

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. Two tests are used to determine the flash point: open cup and closed cup. The test method is indicated on the MSDS after the flash point.

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. (See LOCAL EXHAUST VENTILATION).

GRAM (g) - A metric unit of weight. One ounce equals 28.4 grams.

GRAMS PER KILOGRAM (g/Kg) - This indicates the dose of a substance given to test animals in toxicity studies. For example, a dose may be 2 grams (of substance) per kilogram of body weight (of the experimental animal).

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 140oF. 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.

KILOGRAM (Kg) - A unit of weight in the metric system equal to 2.2 pounds.

LEL - See LOWER EXPLOSIVE LIMIT.

LETHAL CONCENTRATION 50 (LC_{50}) - 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 (LD_{50}) - 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.

LITER (L) - A measure of capacity. One quart equals 0.9 liters.

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.

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 changes to a liquid. A melting range may be given for mixtures.

MILLIGRAM (mg) - A unit of weight in the metric system. One thousand milligrams equal one gram.

MILLIGRAMS PER CUBIC METER (mg/m^3) - Units used to measure air concentrations of dusts, gases, mists, and fumes.

MILLIGRAMS PER KILOGRAM (mg/kg) - This indicates the dose of a substance given to test animals in toxicity studies. For example, a dose may be 2 milligrams (of substance) per kilogram of body weight (of the experimental animal).

MILLILITER (ml) - A metric unit used to measure capacity. One milliliter equals one cubic centimeter. One thousand milliliters equal one liter.

MSHA - The Mine Safety and Health Administration; a federal agency that regulates the mining industry in the safety and health area.

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 responsibilities 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.

OXIDATION - The process of combining oxygen with some other substance to a chemical change in which an atom loses electrons.

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.
ppm - Parts (of vapor or gas) per million (parts of air) by volume.

Pyrophoric Gas – The National Fire Protection Agency define a pyrophoric gas as a "A gas with an autoignition temperature in air at or below 704^{o} (1300^{o}).

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 a MSDS.

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.

SUBSTANCE - Any chemical entity.

SYNONYM - Another name by which the same chemical may be known.

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

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 work day), 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 (LC_{50}) 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.

TRADE NAME - The commercial name or trademark by which a chemical is known. One chemical may have a variety of trade names depending on the manufacturers or distributors involved.

UNSTABLE LIQUID - A liquid that, in its pure state or as commercially produced, will react vigorously in some hazardous way under shock conditions (i.e., dropping), certain temperatures, or pressures.

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 1 – Laboratory Safety References

29CFR1910 Code of Federal Regulations, United States Department of Labor, OSHA.

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*Content and design based on Yale University's Laboratory Chemical Hygiene Plan. www.yale.edu/oehs