UTIA Lab Safety Program Document

University of Tennessee Institute of Agriculture

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1 Introduction

The protection of the safety and health of employees, students and the environment is a high priority at the University of Tennessee Institute of Agriculture (UTIA). The Occupational Safety and Health Administration (OSHA) put forth a regulation in 1990 designed to protect laboratory workers from the hazards of the chemicals they use. The regulation is 29 CFR 1910.1450, “Occupational exposures to hazardous chemicals in laboratories.” For a definition of which campus workplaces are considered laboratories under this standard see Section 3 of this document.

OSHA regulation requires that all employers covered by the standard develop a Chemical Hygiene Plan (CHP). A CHP is a written program which sets forth work practices, equipment use and maintenance procedures, and personal protective equipment requirements that protect employees from the hazards presented by chemicals used in the lab. The plan must be readily available to employees and inspectors.

The CHP must include Standard Operating Procedures (SOPs), criteria for the implementation of chemical control measures, measures to ensure proper operation of engineering controls, provisions for the training of workers, provisions for medical consultation in the case of exposure, designation of responsible people in the lab, and identification of procedures for the use of particularly hazardous substances or processes. This binder, provided by the UTIA Safety Office, includes this document, lab- specific SOPs, and other related documents that together comprise a lab-specific CHP.

Each laboratory CHP must include information and training about the proper use of the particular chemicals in that laboratory. Specifically, each lab must give special consideration to particularly hazardous chemicals, including:

- Carcinogens
- Reproductive toxins
- Acutely toxic compounds
- Highly flammable or explosive compounds
- Students or visitors in the laboratory – people who do not routinely work in a laboratory and can inadvertently create a safety hazard for themselves or others if they do not have appropriate guidance.

Any time a laboratory uses “particularly hazardous chemicals,” the SOPs must include a detailed description of all authorized activities and safety procedures in regard to the particularly hazardous chemicals. Existing SOPs and lab documentation provide much of the lab-specific information. In many cases, Principal Investigators (PI) or lab managers may use documents they have already developed to create the lab-specific portions of the CHP. The method of building a lab-specific CHP is flexible, so long as it meets the intent of identifying and giving special consideration to usage of particularly hazardous chemicals (see chapter 9).

Laboratory-specific training must be documented and may be in the form of written procedures, literature libraries, video presentations, and/or group or individual training. The PI or laboratory manager is responsible for the interpretation and enforcement of policies described in his lab-specific CHP.

The UTIA Safety Office is available to provide technical assistance with this effort. Contact us at 974-1153 or susan@utk.edu for more information.

2 Definitions and Abbreviations

Definitions:

Carcinogen (***see select carcinogen***).

Chemical Hygiene Officer: an employee, designated by the employer, who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan. This definition is not intended to place limitations on the position description or job classification that the designated individual shall hold within the employer's organizational structure.

Chemical Hygiene Plan: a formal document developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment and work practices that (i) are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and (ii) meets the requirements set forth by OSHA.

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

Compressed gas:

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

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

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

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

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

Employee: an individual employed in a laboratory workplace that may be exposed to hazardous chemicals in the course of his or her assignments.

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

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

(i) ***Aerosol, flammable***: an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame protection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening;

(ii) ***Gas, flammable***:

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

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

(iii) ***Liquid, flammable***: any liquid having a flashpoint below 100 deg F (37.8 deg. C), except any mixture having components with flashpoints of 100 deg. C or higher, the total of which make up 99 percent or more of the total volume of the mixture.

(iv) ***Solid, flammable***: a solid, other than a blasting agent or explosive as defined in 29 CFR 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered to be a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.

Flashpoint: the minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite when tested as follows:

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

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

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

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

Hazardous chemical: a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems and agents which damage the lungs, skin, eyes, or mucous membranes.

Appendices A and B of the Hazard Communication Standard (29 CFR 1910.1200) provide further guidance in defining the scope of health hazards and determining whether or not a chemical is to be considered hazardous for purposes of this standard.

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

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

Laboratory-type hood: a device located in a laboratory, enclosure on five sides with a movable sash or fixed partial enclosed on the remaining side; constructed and maintained to draw air from the laboratory and to prevent or minimize the escape of air contaminants into the laboratory; and allows chemical manipulations to be conducted in the enclosure without insertion of any portion of the employee's body other than hands and arms.

Walk-in hoods with adjustable sashes meet the above definition provided that the sashes are adjusted during use so that the airflow and the exhaust of air contaminants are not compromised and employees do not work inside the enclosure during the release of airborne hazardous chemicals.

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

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

(ii) Multiple chemical procedures or chemicals are used;

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

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

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

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

Oxidizer: a chemical other than a blasting agent or explosive as defined in (OSHA) 29 CFR 1910.109(a), that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases.

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

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

Reproductive toxins: chemicals which affect the reproductive health of women or men or the ability of couples to have healthy children. These effects can include chromosomal damage (mutations) and effects on fetuses (teratogenesis).

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

(i) It is regulated by OSHA as a carcinogen; or

(ii) It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP)(latest edition); or

(iii) It is listed under Group 1 ("carcinogenic to humans") by the International Agency for research on Cancer Monographs (IARC)(latest editions); or

(iv) It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:

(A) After inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m^3;

(B) After repeated skin application of less than 300 (mg/kg of body weight) per week; or

(C) After oral dosages of less than 50 mg/kg of body weight per day.

Unstable (reactive): a chemical which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shocks, pressure or temperature.

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

Abbreviations:

CHO – Chemical Hygiene Officer
CHP – Chemical Hygiene Plan
MSDS – Material Safety Data Sheet
NIOSH – National Institute for Occupational Safety and Health
OSHA – Occupational Safety and Health Administration
PPE – Personal Protective Equipment
SOP – Standard Operating Procedure

3 Chemical Hygiene Responsibilities

3.1 Scope and Application of this Plan

This standard applies where **"laboratory use"** of hazardous chemicals occurs. Laboratory use of hazardous chemicals means handling or use of such chemicals in which all of the following conditions are met:

- The handling or use of chemicals occurs on a "laboratory scale"; that is, the work involves containers which can easily and safely be **manipulated by one person,**
- **Multiple chemical procedures** or chemical substances are used, and
- Protective **laboratory practices and equipment** are available and in common use to minimize the potential for employee exposures to hazardous chemicals.

At a minimum, this definition covers **employees (including student employees, technicians, supervisors, lead researchers and physicians)** who use chemicals in teaching, research and clinical laboratories at the University of Tennessee Institute of Agriculture. Also, it is the policy of the University that **laboratory students**, while not legally covered under this standard, will be given training commensurate with the level of hazard associated with their laboratory work.

Where the use of hazardous chemicals provides no potential for employee exposure, such as in procedures using chemically impregnated test media and commercially prepared test kits, a CHP is not required.

3.2 Chemical Hygiene Responsibilities

Health and safety responsibilities for laboratory chemical hygiene are described in this section.

Laboratory Supervisor:

The laboratory supervisor (typically the Principal Investigator, except in clinical labs) has the ultimate responsibility for chemical hygiene throughout the laboratory. Specifically, the lab supervisor shall:

- Develop and implement appropriate written chemical hygiene policies and practices specific to the operations of the lab(s) he is responsible for. This will comprise the lab's SOP.
- Perform regular, formal chemical hygiene inspections, including inspections of emergency equipment. Weekly housekeeping inspections and monthly equipment inspections are suggested. The self audit checklist in Appendix 1 outlines the major areas to review during these audits.
- Develop SOPs specific to lab operations. Any work with particularly hazardous substances requires the development of written SOPs that describe the special hazards and appropriate safety precautions. Tab 1 provides a template for this required information.
- Determine the proper level and type of personal protective equipment for lab operations.
- Ensure that appropriate training has been provided to employees and keep documentation on file.
- Maintain a current knowledge concerning the legal requirements of regulated substances in the laboratory, e.g. DEA regulated materials or materials with special disposal requirements.
- Review and update the Chemical Hygiene Plan on an annual basis. This annual review must be documented. See Appendix 1.
- Maintain an updated copy of your lab's chemical inventory at all times. Likewise, ensure the inventory is accessible to all lab workers, as well as Health and Safety representatives. See the Chemical Inventory tab for more information.

Chemical Hygiene Officer:

The principal investigator or lab supervisor may name a Chemical Hygiene Officer (CHO) with appropriate training and experience to assist with the activities described above. If no person is named CHO, the laboratory supervisor will retain responsibility for all chemical hygiene practices.

Laboratory Workers:

The laboratory workers are individually responsible for planning and conducting each laboratory operation in accordance with the Chemical Hygiene Plan and developing good personal chemical hygiene habits. Specifically, lab workers are responsible to:

- Use equipment only for its designed purpose.
- Be familiar with emergency procedures, including knowledge of the location and use of emergency equipment for the laboratory, as well as how to obtain additional help in an emergency.

- Know the types of protective equipment available and use the proper type for each procedure.
- Be alert to unsafe conditions and actions and call attention to them so corrections can be made as soon as possible
- Properly store and dispose of any hazardous materials introduced into the work environment. All employees leaving employment with the University must contact the UTIA Safety Office for an exit review and sign-off on their "Release of Final Paycheck" form.

UTIA Safety Office:

The UTIA Safety Office offers a range of chemical health and safety services. These services are designed to provide general assistance in meeting regulatory compliance and safety concerns. They need to be supplemented by laboratory-specific safety programs in order to achieve full regulatory compliance. The UTIA Safety Office shall:

- Inspect laboratories annually for general safety conditions
- Evaluate the effectiveness of the chemical hygiene programs
- Conduct annual testing of the chemical fume hoods
- Provide chemical hazard assessments on request or as needed
- Provide consultation on selection of appropriate personal protective equipment
- Coordinate emergency response for spills and chemical exposures
- Investigate accidents and make recommendations to prevent recurrent events
- Investigate complaints relative to laboratory safety concerns
- Consult with Facilities on laboratory design and renovation activities
- Provide training on laboratory safety issues
- Coordinate quarterly hazardous waste pick-up
- Perform exit surveys for personnel who work with chemicals or generate hazardous waste, to ensure safe chemical management during personnel turnover

3.3 Coordination with Other Regulations and Procedures

Although this standard deals only with use of hazardous chemicals, employees may also encounter potential physical, biological or radioactive hazards in the laboratory. In addition, other campus policies and procedures affect the use of hazardous chemicals. For example, the procedures for Hazardous Waste Management, which can also be found at http://safety.ag.utk.edu/safetyplan/23hazwaste/23hazwaste.htm, describe the proper process for the disposal of laboratory chemicals. In the event that there is a conflict between provisions of various policies, contact the UTIA Safety Office at 4-1153 for assistance in resolving the discrepancy.

4 Employee Information and Training

4.1 Required Information

It is essential that laboratory employees have access to information on the hazards of chemicals and on proper procedures for working safely. Supervisors must ensure that laboratory employees are informed about and have access to the following information sources (NOTE – access to the OSHA regulations can be in the form of on-line browsing, provided that the employee has computer access and an opportunity to view the information during work hours):

- The contents of the OSHA lab standard, **Occupational Exposure to Hazardous Chemicals in Laboratories**, and its appendices (29 CFR 1910.1450 – available on-line at www.osha.gov under the Laws and Regulations link).
- The University of Tennessee Institute of Agriculture Program Safety Document (this document) and local laboratory standard operating procedures (SOPs), which together constitute the lab-specific **Chemical Hygiene Plan.**
- The **Permissible Exposure Limits** (PEL) for OSHA regulated substances (29 CFR 1910.1000 – available on-line at www.osha.gov under the Laws and Regulations link)
- **Material safety data sheets** (MSDS) for laboratory chemicals. The MSDS provides information on hazards, safe handling practices, and symptoms of exposure for commercially sold products. MSDSs are available from collections on the UTIA Safety website (MSDS information section), in individual laboratory collections and from the manufacturer. Departments or laboratories that receive MSDSs directly with chemical shipments will keep them on file and make them available to the employees using the chemicals.

4.2 Training

Each laboratory supervisor is responsible for ensuring that laboratory employees are provided with training about the hazards of chemicals present in their laboratory work area, and methods to control exposure to such chemicals. Each employee shall receive training at the time of initial assignment to the laboratory and prior to assignments involving new exposure situations. Refresher training shall be conducted at least annually. Training must be **documented**, for example with a training sign-in sheet that includes an outline of the material covered, or the UT Human Resources Request for Additional Training Credit form, which can be found athttp://hr.utk.edu/forms.shtml . Employee training must be recorded and kept in the laboratory or department file for five years. See the Lab Safety Agreement tab for a checklist for new employee orientation.

Training materials may include any of the following:

- **Literature** describing proper lab practices (such as using this document or MSDS reviews)
- **Video** libraries
- **Group and individual** training conducted by lab personnel or UTIA/UTK safety staff
- **On-Line** laboratory safety modules

Employee training programs must include, at a minimum, the following subjects:

- Methods of **detecting the presence** of hazardous chemicals (observation, signage and labeling, odor, real-time monitoring, air sampling, etc.)
- **Symptoms** associated with exposures, and the physical and health hazards of the chemicals in the work area
- Good **laboratory practice**, including general techniques designed to reduce personal exposure and to control physical hazards, as well as specific protective mechanisms and warning systems used in individual laboratories
- **Emergency response** actions appropriate to individual laboratories
- Applicable details of the Chemical Hygiene Plan, including general and laboratory-specific **Standard Operating Procedures**
- Proper procedures for **handling, labeling, and storing chemical waste,** generated by laboratory operations

4.3 Laboratory Door Signs

Door hazard warning signs provide an overview of the hazards in the laboratory, and also serve as a quick reference for the names and phone numbers of both laboratory management and emergency contact personnel. **Each laboratory must have up-to-date door signage that includes names and phone numbers for personnel managing that laboratory who are familiar with the content and workings of the lab.** Note: 911 is NOT a legitimate emergency contact number. The door sign must also include phone numbers for UT Police, the Safety, Radiation and Biosafety Offices, and a summary of the key hazards in the laboratory. The contact phone numbers on the door are critical in the event of an emergency involving the laboratory. Keep this information current and accurate. To create or update door signage, use the UTIA Safety Office Door Sign Utility program at http://safety.ag.utk.edu/hazRooms/. Door signage must be reviewed annually and whenever there are personnel changes. For help printing or laminating door signs, contact the UTIA Safety Office at 4-1153.

5 Annual Chemical Hygiene Plan Review

The laboratory supervisor and Chemical Hygiene Officer (CHO) will review the laboratory's Chemical Hygiene Plan annually. The review must be documented, such as with the date and initials of the reviewer on the front of the CHP. The CHO is responsible for assigning responsibility for taking corrective action for any deficiency noted.

During the annual CHP review, the laboratory door sign will also be reviewed to ensure the contact names and phone numbers are still accurate, and that the hazard signage is still appropriate for the chemicals and activities in the laboratory.

6 Chemical Hazards

6.1 Hazards Overview

Understanding the specific hazards associated with certain chemicals is imperative to creating a safe laboratory environment. Chemicals are hazardous by virtue of many different properties, such as fire hazard, health hazard, or reactive/explosive hazard. Additionally, the health hazard is dependent on the amount of exposure, and the route of exposure.

***NOTE*:** Being able to smell a chemical (the odor threshold) is not a reliable indicator of safe working conditions. Some chemicals are toxic at levels well below a person's ability to smell them (e.g. create a hazard without any warning smell), and conversely other chemicals are detectable at levels that do not present a health hazard.

6.2 Corrosives

Chemicals are classified as corrosive if they:

- Are capable of rapidly eroding building materials or metals, or
- Burn, irritate or destructively attack organic tissues such as skin, eyes, lungs and stomach.

Examples of corrosives include concentrated acids and bases, acetic anhydride, bromine, fluorine, chlorine, hydroxides, phenol, and many dehydrating and oxidizing agents.

Safe Handling Guidelines for Corrosives

To ensure safe handling of corrosives, the following special handling procedures should be used:

- Always store corrosives properly. Handle these chemicals with care and clean any spills, leaks, or dribbles immediately. Refer to the MSDS and the Chemical Storage section for more information.
- Always wear gloves, face, and eye protection when working with corrosives. Wear other personal protective equipment as appropriate.
- To dilute acids, **always add acid to water**.
- Use a chemical fume hood when handling fuming acids or volatile irritants (e.g., hydrochloric acid or ammonium hydroxide.)
- A continuous flow eye wash station must be in every work area where corrosives are present. An emergency shower should also be within 100 feet of the area.

6.3 Flammables

A flammable chemical is any solid, liquid, vapor, or gas that ignites easily and burns rapidly in air. NFPA classifies flammable chemicals on a scale of 0 – 4, as follows:

- 4 = Extremely flammable. Any liquid or gas with a flash point below 73°F and a boiling point below 100°F.
- 3 = Ignites at normal temperatures. Flash point below 100°F.
- 2 = Ignites when moderately heated. Flash point below 200°F.
- 1 = Must be preheated to burn. Flash point above 200°F.
- 0 = Will not burn.

Flashpoint (FP) is the lowest temperature at which a flammable liquid gives off sufficient vapor to ignite. Class 3 and 4 flammable materials require special handling and storage consideration because of the fire hazard. Flammable vapors can travel a considerable distance to an ignition source and "flash back." The following table lists examples of some common highly flammable chemicals and their flash points:

Chemical	Flashpoint	NFPA rating	Comments
Acetaldehyde	-36°F	4	
Acetic acid	103°F	2	Heating can release ignitable vapors.
Acetone	0°F	3	
Acetonitrile	42°F	3	
Acetylene	NA - gas	4	
Benzene	12°F	3	
Ethanol	55°F	3	
Ethyl ether (diethyl ether)	-49°F	4	Extremely low ignition temp. Vapor may be ignited by hot surfaces such as hot plates and static discharges. Can form shock and heat sensitive peroxides, which may explode on concentration by distillation or evaporation.
Formaldehyde (37%	185°F	2	

sol'n in methanol)			
Formaldehyde gas	NA - gas	4	Formaldehyde gas is extremely flammable.
Hexane	-7°F	3	
Isopropyl alcohol	53°F	3	
Methanol	52°F	3	
Petroleum ether (VM&P naptha)	20°-55°F	4	
Phenol	175°F	2	
Propane	NA – gas	4	
Tetrahydrofuran	6°F	3	Can form shock and heat sensitive peroxides, which may explode on concentration by distillation or evaporation.
Toluene	40°F	3	
Xylene	81°-90°F	3	

Safe Handling Guidelines for Flammable Materials:

- Flammable chemicals should be handled in areas free from ignition sources. For illustration, follow the link to the Lessons Learned (http://www.nmsu.edu/~safety/news/news-items/tt-chem-lab-fire2.htm) page regarding flammable liquids and improper storage. This was a fire at Texas Tech University's Chemistry Building. Below is a picture from that event:

- Never heat flammable chemicals with an open flame. Use a water bath, oil bath, heating mantle, hot air bath, etc.
- Use grounding straps when transferring flammable chemicals between metal containers to avoid generating static sparks.
- Use a fume hood when there is a possibility of dangerous vapors. (Ventilation will help reduce dangerous vapor concentrations.)
- Restrict the amount of stored flammable materials, and minimize the amount present in a work area.
- Remove from storage only the amount of chemical needed for a particular experiment or task.

Flammability hazards in microbiology procedures

Working with flammable liquids, such as alcohol, and a sterilizing flame together has an inherent fire risk; and yet it is a common practice in microbiology procedures. However, given enough opportunities, circumstances will conspire to allow the alcohol to catch on fire, sometimes with a disastrous outcome.

Both latex and nitrile gloves are readily combustible. A glove with alcohol on it readily catches on fire. The flaming glove turns into a sticky gel that is an excellent conductor of heat. The molten glove will cause much more serious burns than the alcohol alone would.

The three-part combination of open flame, ethanol, and gloves creates a significant safety hazard. UTIA labs are strongly recommended to find methods to conduct research such that they do not use all three components (wearing gloves plus using ethanol plus flame sterilizing) in combination.

6.4 Reactive and Explosive Compounds

Reactive chemicals are sensitive to either friction or shock, or they react in the presence of air, water, light, or heat. Explosive chemicals decompose or burn very rapidly when subjected to shock or ignition. Reactive and explosive chemicals produce large amounts of heat and gas; they are extremely dangerous. Some common laboratory chemicals which can become reactive or explosive if they are not handled properly are listed below:

- Ethyl ether and tetrahydrofuran (THF) – when exposed to air can form explosive peroxides over time. Must be tested with peroxide test strips every 12 months.
- 1,4-Dioxane (p-Dioxane) – can form peroxides on concentration. Must be tested with peroxide test strips every 12 months.
- Concentrated perchloric acid – vapors from perchloric acid digestions can react with metals in the ductwork to form explosive perchlorates. Any heated digestions with perchloric acid must be in a perchloric acid fume hood with a special wash down capacity.
- Concentrated picric acid becomes unstable and shock sensitive if it dries out. Keep a liquid layer in the bottle.

The above items should be initialed and dated upon receipt, and the ethers tested annually. The peroxide test strips can be obtained from the UTIA Safety Office.

6.5 Toxicity and Routes of Entry

The degree of risk from a chemical exposure depends primarily on the following factors:

- Toxicity of the chemical. Each chemical causes different biological effects, with some being much more hazardous than others
- Dose **(the amount of a substance to which one is exposed).**
- Duration of exposure **(how often, and for how long the exposure occurs).**
- Route **of exposure (inhalation, ingestion, or skin absorption).**
- Other factors **such as gender, reproductive status, age, general health and nutrition, lifestyle factors, previous sensitization, genetic disposition, and exposure to other chemicals.**

Exposure to higher doses and longer or more repeated durations of exposure generally lead to more severe health effects. Understanding the route of exposure is important to know what precautions to take to prevent exposure. Chemicals can get into the body in three main ways:

- **Inhalation:** breathing airborne vapors and particles. Chemicals that enter the lungs and are absorbed or cause lung injury are an inhalation hazard. Precautions to prevent breathing inhalation hazards include using a chemical fume hood and using procedures that minimize possible airborne contamination. For a spill of an inhalation hazard, key response actions are to prevent the spread of airborne contaminants into other areas (such as to close the fume hood sash, or the door to a room), and to vacate the area until the concentration is diluted.
- **Ingestion:** eating, drinking, or inadvertently swallowing chemicals, which are then absorbed in the gut. Precautions to prevent ingestion include labeling container contents so they aren't inadvertently assumed to be something nontoxic, and avoiding eating, drinking, smoking, dipping, applying cosmetics, putting fingers in or around them mouth, or putting pens or other contaminated surfaces in the mouth (and of course, no mouth pipetting). Wash hands after handling chemicals.
- **Skin Absorption:** when chemicals are absorbed through direct skin contact or from vapors that are readily absorbed through the skin. For chemicals with a skin route of exposure, the toxicity is not limited to the contact site. The chemical is absorbed and will cause systemic toxicity at target organs that may be very remote from the contact site. For example, the chemical burn from an acid is not skin absorption, whereas the central nervous system and bone marrow toxicity from benzene contact is. Many chemicals which are absorbed via skin have both a local and a systemic toxic effect. To prevent exposure it is critical to wear appropriate chemical resistant gloves, and to avoid spilling it on your person.

Once in the body, chemicals can have **acute** or **chronic** health effects (or both). The **acute toxicity** of a chemical is its ability to cause damage from short-term exposure to a relatively high dose of the chemical. In most cases, the exposure is sudden and results in an emergency situation. **Do not work alone when handling acute hazards.** Examples of acute hazards include chlorine gas, hydrogen cyanide, and concentrated acids. **Chronic toxicity** is a chemical's ability to cause damage or illness as a result of repeated exposures, over a prolonged time period, at relatively low concentrations. A chemical that causes cancer is an example of a chronic hazard, as are many solvents which cause liver damage, and toxic metals which have long term health effects. The material safety data sheets (MSDS) will cover these topics. See UTIA MSDS links website: http://safety.ag.utk.edu/msdslinks.htm

6.6 Toxic – Carcinogen

Carcinogens are materials that can cause cancer in humans or animals. Several agencies including OSHA, NIOSH, and IARC (International Agency for Research on Cancer) are responsible for identifying carcinogens. There are relatively few chemicals known to cause cancer in humans, but there are many suspected carcinogens and many substances with properties similar to known carcinogens.

Examples of select human carcinogens include the following:

- Acrylamide
- Asbestos
- Benzene
- Formaldehyde
- Tobacco smoke
- Chromium, hexavalent
- Aflatoxins

Examples of suspect carcinogens include the following:

- Chloroform
- Para-Dichlorobenzene
- Propylene oxide
- Pyridine
- Silica dust
- Sulfuric acid
- Tetrahydrofuran

Zero exposure should be the goal when working with known or suspected carcinogens. Workers who are routinely exposed to carcinogens should undergo periodic medical examinations.

6.7 Toxic – Reproductive Toxin

Reproductive toxins are chemicals that can produce adverse effects in parents and developing embryos. Chemicals including heavy metals, some aromatic solvents (benzene, toluene, xylene, etc.) and some therapeutic drugs are capable of causing these effects. In addition, the adverse reproductive potential of ionizing radiation and certain lifestyle factors, including excessive alcohol consumption, cigarette smoking, and the use of illicit drugs, are recognized. While some factors are known to affect human reproduction, knowledge in this field (especially related to the male) is not as broadly developed as other areas of toxicology. In addition, the developing embryo is most vulnerable during the time before the mother knows she is pregnant. **Therefore, it is prudent for all persons with reproductive potential to minimize chemical exposure**.

6.8 Toxic – Sensitizer

A sensitizer may cause little or no reaction upon first exposure. Repeated exposures and high level exposures may result in severe allergic reactions, which can even be life threatening such as anaphylactic shock. A sensitized individual may react to extremely low levels (parts per billion) that do not cause symptoms for most of the population. Becoming sensitized can cause quality of life impairment because many of the sensitizing compounds are found at low levels in many commercial and residential environments. Examples of sensitizers include the following:

- Isocyanates
- Latex
- Nickel salts
- Beryllium compounds
- Formaldehyde
- Diazomethane

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7 Protective Equipment and Control Measures to Reduce Exposure

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7.1 General Criteria

It is prudent to minimize all chemical exposures. Because few laboratory chemicals are without hazards, general precautions for handling all laboratory chemicals should be adopted. **Skin contact with chemicals should be avoided as a cardinal rule**. Avoid underestimating the risks involved. Take special precautions for work with substances which present special hazards. **Assume that any mixture will be more toxic than its most toxic component and that all substances of unknown toxicity are toxic.** Provide adequate ventilation. The best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by use of hoods and other ventilation devices.

Guidance: *Pay particular attention to the following paragraph.* ***If you, as a lab supervisor or Chemical Hygiene Officer, suspect exposure concentrations exceed allowable levels,*** *please contact the UTIA Safety Office for technical assistance.*

An employee's workplace exposure to any regulated substance must be monitored if there is reason to believe that the exposure will exceed an OSHA exposure limit. If exposures to any regulated substance routinely exceed an exposure limit, **control measures must be implemented.** Air sampling to evaluate exposure to chemical substances shall be conducted on an as-needed basis**.** Air sampling will be conducted according to established industrial hygiene practices. Copies of air sampling results must be forwarded to the UTIA Safety Office for records maintenance.

The lab supervisor can use **professional judgment** to assess the nature of chemical exposure resulting from a lab procedure and prescribe engineering controls and personal protective equipment to be used during the procedure. This judgment will be documented through the use of chemical-specific Standard Operating Procedures (SOPs).

The **engineering controls** installed in the laboratory are intended to **minimize employee exposure** to chemical and physical hazards in the workplace. These controls must be maintained in proper working order for this goal to be realized. **No modification** of engineering controls will occur unless testing of the modification indicates that worker protection will continue to be adequate. Improper function of engineering controls must be reported to the lab supervisor immediately. The system shall be taken **out of service** until proper repairs have been executed.

Engineering controls, personal protective equipment, hygiene practices, and administrative controls each play a role in a comprehensive laboratory safety program. **Implementation of specific measures must be carried out on a case-by-case basis, using the following criteria for guidance in making decisions.**

7.2 Chemical Fume Hoods

The laboratory fume hood is the major protective device available to laboratory workers. It is designed to capture chemicals that escape from their containers or apparatus and to remove them from the laboratory environment before they can be inhaled. Fume hoods also provide physical protection against fire, spills, and explosion. Characteristics to be considered in requiring fume hood use are **physical state, volatility, toxicity, flammability, eye and skin irritation, odor, and the potential for producing aerosols**. A fume hood should be used if a chemical procedure exhibits any one of these characteristics:

- Airborne concentrations might approach an OSHA exposure limit,
- Flammable vapors might approach one tenth of the lower explosion limit,
- Materials of unknown toxicity are used or generated, or
- Odor produced is irritating to laboratory occupants or adjacent units.

Procedures that can generally be carried out safely outside the fume hood (depending on the capacity of the general ventilation system to remove any airborne contaminants) include those involving:

- **Water-based solutions** of salts, dilute acids, bases, or other reagents,
- **Very low volatility** liquids or solids (provided they are low toxicity),

- **Closed systems** that do not allow significant escape to the laboratory environment,
- **Extremely small quantities** of otherwise problematic chemicals.

It is sometimes difficult to tell if the fume hood fan motor is operational. Without the fan, the fume hood system will not provide adequate protection. If the hood is not equipped with an airflow monitor, a piece of “Kim Wipe” taped at the bottom of the sash will give an indication of air movement into the hood. Notify the UTIA Safety Office immediately if you suspect the fume hood is not operational.

Fume hoods are tested annually by the UTIA Safety Office. The test includes an inspection of the hood system, airflow measurements and an assessment of the use of the fume hood. Additionally fume hoods are tested after a repair, after a fume hood is moved, and when an employee requests an inspection.

Guidelines for effective fume hood use:

- Keep the hood clear and uncluttered. Numerous bottles and pieces of equipment in a hood interfere with proper airflow, and in an accident they increase the hazard and complicate cleanup.
- All work should be performed at least 6 inches inside the hood.
- When large equipment is used inside the hood, elevate the equipment at least two inches on risers or racks to allow air flow under the equipment. This will minimize the turbulent spot in front of the piece of equipment which can allow contaminants to escape out of the hood.
- Always lower the sash to the lowest possible level, and use the sash as a shield
- Never place your head inside the hood.
- Avoid rapid movement in front of the hood. Avoid drafts created by turbulence from external air currents such as pedestrian traffic or operating a fan in the laboratory.
- Always recap bottles of chemicals and chemical waste immediately.
- Ensure that hazardous chemicals are used in the proper type or class of hood. For example, use perchloric acid only in hoods specifically designed with a washdown system for perchloric acid, and use radioisotopes only in a hood designated for work with radioactive materials.
- Maintain all components of the hood in good operating condition.

Ductless fume hoods circulate air through a filter and exhaust it back into the room. They can not be used for volatile toxic materials, and should be posted as "**Not for use with toxic materials**." This type of hood is not well suited for academic laboratories because the filters must be appropriate for the chemicals in use, so any change in chemical utilization requires a new evaluation to ensure the filter is appropriate and adequate. Additionally, these hoods are expensive to operate because they require a written inspection schedule and documented replacement of the filters at the manufacturer’s recommended replacement schedule. Consult the UTIA Safety Office before purchasing or using these hoods to control chemical vapors.

7.3 Local Exhaust Ventilation and Ventilated Chemical Storage Cabinets

Local exhaust ventilation may be required for equipment that exhausts toxic or irritating materials to the laboratory environment. The following procedures shall apply to the use of local exhaust ventilation:

- Openings of local exhaust will be as **close as possible** to the source of the contaminants.
- Local exhaust fans shall be turned on when exhaust hoods are being used.
- After using local exhaust, operate the fan for an additional period of time sufficient to clear residual contaminants from the ductwork.
- If there are changes in the operation of the ventilation system notify the UTIA Safety Office immediately.
- Prior to a change in chemicals or procedures, the adequacy of the available ventilation systems shall be determined by the lab supervisor.

Ventilated chemical storage cabinets or rooms should be used when the chemicals in storage may generate toxic, flammable or irritating levels of airborne contamination.

Chemical storage cabinets for flammable and hazardous chemicals will be **ventilated** as needed. They will be provided with a **spill containment** system appropriate to the chemicals stored in them. Use secondary containment trays for corrosive, toxic, and reactive liquids to prevent unwanted reactions and equipment damage if a bottle leaks or breaks.

7.4 Cold Rooms and Warm Rooms

Temperature control rooms generally do not have fresh air ventilation. **Do not** use volatile chemicals in temperature controlled rooms! Also note that liquid nitrogen stored in these rooms has the potential to displace oxygen and can cause oxygen deficient conditions.

7.5 Eye Washes, Safety Showers and Fire Extinguishers

Any laboratory working with toxic or corrosive chemicals must have an easily accessible eye wash. Eye washes must be **flushed regularly** by the user to ensure that they are working, and that the water is clean, should emergency use become necessary. Ideally these eye wash checks should be performed weekly, and no less frequently than monthly, and must be documented (date and initials). Report malfunctions in the eyewash to your facility coordinator. The facility coordinator at the College of Veterinary Medicine (CVM) is the Hospital Operations office, at non-CVM laboratories on the Ag Campus it is the UTIA Director of Services, Mike Keel's, office, and at other facilities it is the local facility contact. Safety showers are tested annually by Facilities Services. For Knoxville area locations the fire extinguishers are checked monthly (and in some cases quarterly) by the UTK Office of Environmental Health and Safety.

7.6 Safety Shields

Safety shields, such as the sliding sash of a fume hood, are appropriate when working with highly concentrated acids, bases, oxidizers or reducing agents, all of which have the potential for causing sudden spattering or even explosive release of material. Reactions carried out at non-ambient pressures (vacuum or high pressure) also require safety shields, as do reactions that are carried out for the first time or are significantly scaled up from normal conditions.

Other containment devices, such as **glove boxes**, may be required when it is necessary to provide an inert atmosphere for the chemical procedure taking place, when capture of any chemical emission is desirable, or when the standard laboratory fume hood does not provide adequate assurance that overexposure to a hazardous chemical will not occur. The presence of biological or radioactive materials may also mandate certain special containment devices.

7.7 Personal Protective Equipment (PPE) Overview

Laboratory supervisors or CHOs shall designate areas, activities, and tasks which require specific types of personal protective equipment. Protective equipment shall not be worn in public areas, in order to prevent the spread of chemical or biological contamination from laboratory areas.

7.8 PPE -- Eye Protection (Safety Glasses and Goggles)

Eye protection is required for all personnel and any visitors whose eyes may be exposed to chemical or physical hazards. Ordinary prescription glasses are not considered effective eye protection since they do not provide side shielding. Side shields on safety glasses provide some protection against splashed chemicals or flying particles, but goggles or face shields are necessary when there is a greater than average danger of eye contact. A higher than average risk exists when working with highly reactive chemicals, concentrated corrosives, or with vacuum or pressurized glassware systems. **For contact lens wearers**, it is especially important to wear appropriate eye protection because the contacts may increase injury from chemical splashes or vapors. There is controversial guidance on wearing contact lenses in a chemical use environment. Consult with an optometrist prior to wearing contact lens in the laboratory.

7.9 PPE -- Protective Clothing

Lab coats or other similar clothing protectors are strongly encouraged for all laboratory personnel. **Lab coats are required when working with select carcinogens, reproductive toxins, substances which have a high degree of acute toxicity, strong acids and bases,** and any substance for which the OSHA exposure limit has a "skin" notation.

Bare feet are not permitted in any laboratory. Sandals and open-toed shoes are strongly discouraged in all laboratories and **are not permitted in any situation where lab coats or gloves are required.** Similarly, clothing should cover one's arms and legs.

7.10 PPE -- Gloves

Gloves made of appropriate material are required to protect the hands and arms from thermal burns, cuts, or chemical exposure that may result in absorption through the skin or reaction on the surface of the skin. Gloves are also required when working with particularly hazardous substances where possible transfer from hand to mouth must be avoided.

Select the right kind of glove to provide protection from the specific chemicals in use, especially for work with highly toxic substances. Each type of glove material (nitrile, latex, neoprene, etc.) has a different breakthrough time for different chemicals. General selection guides are available; however, glove resistance to chemicals varies with the manufacturer, model and thickness. Therefore, review a glove-resistance chart from the manufacturer before purchasing gloves, or contact the UTIA Safety Office for help identifying appropriate gloves for handling different chemicals. Change gloves whenever they get contaminated or show signs of deterioration. Remove or change gloves before touching common use items such as the phone, door, writing utensils, etc.

7.11 PPE -- Respiratory Protective Equipment

Respiratory protection is generally **not necessary** in the laboratory setting and must not be used as a substitute for adequate engineering controls. Availability of respiratory protection for emergency situations may be required when working with chemicals that are highly toxic and highly volatile or gaseous. If an experimental protocol requires exposure above the action level that cannot be reduced, respiratory protection will be required. All use of respiratory protective equipment is covered under the University of Tennessee Institute of Agriculture Respiratory Protection Program (http://safety.ag.utk.edu/safetyplan/19RPP/19RPP.htm).

8 Standard Procedures for Working in the Laboratory

The following are **generally accepted practices** for use of chemicals in particular situations. They can be overridden in specific instances when appropriate. It is advisable to document the reasons for such modifications. For hazards associated with activities not covered here, the lab supervisor and CHO shall develop an SOP.

8.1 Controlling Chemical Exposure

Each laboratory employee shall **minimize personal and coworker exposure** to the chemicals in the laboratory. General precautions which shall be followed to achieve this goal during the handling and use of all chemicals are as follows:

- A chemical mixture shall be assumed to be **as toxic as its most toxic component**. Possibilities for substitution will be investigated.

- Laboratory employees shall be familiar with the **symptoms of exposure** for the chemicals with which they work and the precautions necessary to prevent exposure.
- **Label all chemicals** to identify the container contents and appropriate hazard warnings.
- Recap bottles tightly (but do not over-tighten or the cap may break), and clean any residue off the outside of the bottle. **Loose caps and drips** on the outside of the bottle create unexpected **chemical exposures**.
- **Eating, drinking, and smoking is prohibited** in areas where laboratory chemicals are present. Thoroughly wash hands after handling chemicals. Storage, handling and consumption of food or beverages shall not occur in chemical storage areas, nor with glassware or utensils also used for laboratory operations.
- Refrigerators used to store reagents and samples cannot be used to store food and drinks for human consumption. Ensure that they are clearly labeled to indicate their function such as with signage that says either “No food or drink” or “For Food Only.”
- Ice from a laboratory ice machine is not to be used for human consumption.
- Each employee shall keep the **work area clean and uncluttered** (clutter “…shall not interfere with safe work operations” per Tennessee OSHA). At the completion of each work day or operation, the work area shall be cleaned.
- Hallways, corridors, and exit ways must be kept clear. Do not allow equipment to block the exit pathway (even temporarily). If equipment is located outside of the lab space – it must be **labeled with emergency contact information**.
- Mouth suction for pipetting or starting a siphon is prohibited.
- **Skin contact** with all chemicals shall be **avoided**. Employees shall wash exposed skin prior to leaving the laboratory.
- Additional specific precautions based on the toxicological characteristics of individual chemicals shall be implemented as deemed necessary by the lab supervisor.

8.2 Children in the Laboratory

UTIA is committed to promoting equity for all students, faculty, and staff, and to ensure that individuals are not disadvantaged in their academic and career aspirations by actual or perceived family responsibilities. However, UTIA is a place of work and study, and the ability to concentrate for extended periods of time is a prerequisite within a healthy academic environment. Therefore, the following guidelines have been established, and will be enforced by the UTIA Safety Office to ensure that an appropriate academic environment is maintained for the safety of all.

- For this policy, the terms “child” and “children” refer to minor(s) under the age of 18.
- Children visiting UTIA buildings must be directly supervised at all times by an adult responsible for the child or children, except when participating in programs and/or special events sponsored by the university.
- Do not allow children in UTIA laboratories. (It is a violation of state law for a child to be unattended in a place that presents a risk of harm.)

8.3 Safe Handling Guidelines

Treat chemicals with caution and respect by following these guidelines:

- Use only the amount of chemical needed for the immediate task at hand.
- Properly seal, label, and store chemicals in appropriate containers. Keep the containers clearly marked and in a well-ventilated area.
- Learn how to dispose of chemicals safely and legally. Follow UTIA waste disposal requirements (http://safety.ag.utk.edu/safetyplan/23hazwaste/23hazwaste.htm).
- Clean up spills and leaks immediately.
- Know what to do in an emergency.
- Do not transport unprotected chemicals between the work area and other areas. Use a tray, rack, cart, or rubber carrier. Always use a secondary container when transporting hazardous or highly odorous chemicals on an elevator.

8.4 Chemical Purchasing and Storage

Purchasing guidelines:

- Buy the smallest quantity needed for use in the near future. Large quantities increase the spill and hazard potential, take up valuable space in chemical storage areas, and require on-going effort to properly store and inventory. Additionally, excess chemicals that become unusable due to deterioration and age cost additional expense for disposal as hazardous waste.
- Less concentrated chemicals generally are less hazardous, so purchasing the least concentrated form necessary reduces the hazard potential.
- Some chemicals are available as a concentrated powder or in a dilute liquid form. The powder form is a greater hazard both as an inhalation risk and for contamination of the work area. For example, ethidium bromide in a powder form presents a much greater hazard potential than the liquid suspension. Whenever possible avoid purchasing concentrated powders to minimize exposure potential during weighing and from spills.
- Initial and date the label on all new chemicals. This lets other people in the lab know who is responsible for the item, and provides valuable information for long term chemical management.
- Whenever possible, substitute less hazardous chemicals into a procedure.

Storage guidelines:

- Proper chemical storage is as important to safety as proper chemical handling. Often, seemingly logical storage ideas, such as placing chemicals in alphabetical order, may cause incompatible chemicals to be stored together.
- Read chemical labels and MSDSs for specific storage instructions.
- Store chemicals in a well-ventilated area; however, do **not** routinely store chemicals in a fume hood (they block airflow, and impair proper usage of the hood).
- Return chemical containers to their proper storage location after use.
- Check stored chemical supplies for deteriorated chemicals and broken containers.
- Do not store chemicals near heat or in direct sunlight.
- Do not store flammable materials near electrical sources.
- Store corrosive and reactive chemicals in secondary containment trays.
- Store glass chemical containers so that they are unlikely to be broken.
- Whenever possible store hazardous chemicals below eye level.

- Never store hazardous chemicals in a public area or corridor.

Segregating Hazardous Chemicals

The following information provides one chemical storage grouping that minimizes the risk of fire, explosive reactions, or the formation of highly toxic substances. The necessity of following storage compatibility guidelines can be made obvious by reading descriptions of laboratories following the California earthquakes in recent decades. This is **not** a complete and comprehensive list; refer to manufacturer's instructions and MSDS information if there are special storage considerations. This information is based in part from "Prudent Practices in the Laboratory" by the National Research Council and from "Safety in Academic Chemistry Laboratories" by the American Chemical Society.

Overview of Chemical Storage Groups

There are many ways to segregate chemicals into compatible storage groups. This plan provides one method that has wide applicability to research chemical inventories. It is based on nine storage groups. These groups are:

1. Flammable Liquids
2. Volatile Poisons
3. Oxidizing Acids
4. Organic and Mineral Acids
5. Liquid Bases
6. Liquid Oxidizers
7. Non-Volatile Poisons
8. Reactives
9. Solids

Seven of the groups cover storage of liquids due to the wide variety of hazards they pose. Each group is described in terms of its hazards, storage, examples, and compatibilities below.

Group 1 – Flammable Liquids

Primary hazard	Fires. Flammable liquids have flashpoints < 100^{o} F. Avoid ignition sources and reactions that may cause fires.
Recommended storage	Flammable storage cabinets.
Examples	All common low molecular weight alcohols (Methanol, Ethanol, etc.), Acetone, Acetaldehyde, Acetonitrile, Amyl acetate, Benzene, Ethyl ether, Ethyl acetate, Hexane, Hydrazine, Tetrahydrofuran, Toluene, Xylenes.
Storage compatibilities	Flammable liquids and volatile poisons may be stored in the same vented compartment provided bases are not present.

Group 2 – Volatile Poisons

Primary hazard	Poisoning. Prevent inhalation and contact exposures.
Recommended storage	In vented storage cabinets, or a refrigerator for small containers that can be enclosed in a sealed secondary container. Put signs on storage location indicating the special hazard.
Examples	Includes poisons, toxics and known and suspected carcinogens with strong odor or evaporation rate greater than 1 (butyl acetate = 1). Carbon tetrachloride, Chloroform, Dimethylformamide, Dimethyl sulfate, Formamide, Formaldehyde, Halothane, Mercaptoethanol, Methylene chloride, Osmium tetroxide, Phenol.
Storage compatibilities	Volatile poisons may be stored in the same vented compartment as flammable liquids provided bases are not present.

Group 3 – Acids-Oxidizing

Primary hazard	Corrosion of skin and metals, some inhalation hazards, reactions with organic compounds and other acids and bases. Prevent skin contact and inhalation exposures, contact with other substances, and corrosive action on surfaces.
Recommended storage	Safety Cabinet. Each oxidizing acid must be double-contained, i.e., the primary container must be kept inside canister, tray or tub. Segregate from bases, active metals (e.g. sodium, potassium, magnesium, etc.), organic chemicals and chemicals that could liberate toxic gases upon contact (e.g. sodium cyanide, iron sulfide, etc.). Use bottle carriers or other secondary containment when transporting acid bottles. Store large bottles of acid on shelves waist height or lower. Place containers for acid and acid wastes in non-reactive spill trays to contain leaks or spills. Oxidizing acids must be double-contained and should be segregated in their own compartment in a safety cabinet. When quantities are small (e.g., 1 or 2 bottles) they do not warrant a separate compartment. Small quantities may be double-contained and stored with Group 4 Organic and Mineral Acids. Store oxidizing acids on bottom shelf below Group 4.
Examples	Chromic acid, Chromerge (Chromic/sulfuric acid concentrate), Perchloric acid, Nitric acid, Sulfuric acid.
Storage compatibilities	None.

Group 4: Organic and Mineral Acids

Primary hazard	These acids are generally noxious, corrosive to skin and steel, and some are flammable. Prevent contact and reaction with bases and oxidizing acids and corrosive action on surfaces.
Recommended storage	Safety cabinet. Segregate acids from bases, from active metals (e.g. sodium, potassium, magnesium, etc.) and from chemicals that could liberate toxic gases upon contact (e.g. sodium cyanide, iron sulfide, etc.). Use bottle carriers or other secondary containment when transporting acid bottles. Store large bottles of acid on shelves waist height or lower. Place containers for acid and acid wastes in spill trays to contain leaks or spills. Plastic trays or Pyrex baking pans are effective and inexpensive.
Examples	Phosphoric acid, Acetic acid, Hydrochloric acid, Formic acid, Butyric acid.
Storage compatibilities	Small amount of double-contained oxidizing acids can be stored in the same compartment with organic acids if the oxidizing acids are stored on the bottom shelf. Exceptions: Acetic anhydride and Trichloroacetic anhydride are corrosive. These organic acids are very reactive with oxidizing and mineral acids and should not be stored in this group. It is better to store these with organic compounds as in Group 7 Non-volatile Liquid Poisons.

Group 5: Liquid Bases

Primary hazard	Liquid bases are corrosive to skin and steel. Prevent contact with skin and reaction with acids.
Recommended storage	Safety cabinet or in tubs or trays in normal cabinet.
Examples	Sodium hydroxide, Ammonium hydroxide, Potassium hydroxide, Calcium hydroxide, and Glutaraldehyde
Storage compatibilities	Liquid bases may be stored with flammables in the flammable cabinet if volatile poisons are not also stored there.

Group 6: Oxidizing Liquids

Primary hazard	Oxidizing liquids are reactive with organic compounds. Prevent contact with skin and isolate from other materials. Oxidizing liquids react with a wide variety of compounds, potentially causing fires, explosions or corrosion of surfaces.
Recommended storage	Total quantities exceeding 3 liters should be kept in a cabinet housing no other chemicals. Smaller quantities must be double-contained if kept near other chemicals, e.g., in a refrigerator.

Examples	Methyl ethyl ketone peroxide, Ammonium persulfate solutions, and hydrogen peroxide (if greater than or equal to 30%)
Storage compatibilities	None.

Group 7: Non-Volatile Liquid Poisons

Primary hazard	Prevent contact with skin and reactive substances.
Recommended storage	Cabinet or refrigerator (i.e., must be enclosed). Do not store on open shelves in the lab or cold room. Liquid poisons in containers larger than 1 liter must be stored below bench level on shelves closest to the floor. Smaller container of liquid poison can be stored above bench level only if behind sliding (non-swinging) doors.
Examples	Includes highly toxic (LD50 oral rat < 50 mg/kg) and toxic chemicals (LD50 oral rat < 500 mg/kg), known carcinogens, suspected carcinogens and mutagens. Acrylamide solutions; Diethylpyrocarbonate; Diisopropyl fluorophosphate; uncured Epoxy resins; Ethidium bromide; Triethanolamine.
Storage compatibilities	Non-hazardous liquids (e.g., buffer solutions). Exceptions: Anhydrides, e.g., Acetic and Trichloroacetic, are organic acids, however it is better to store with this group than with Group 4 Organic Acids, since they are highly reactive with other organic, oxidizing or mineral acids.

Group 8: Reactive Metal Hydrides, Pyrophorics, and Water Reactives

Primary hazard	Most metal hydrides react violently with water, some ignite spontaneously in air (pyrophoric). Water-reactives react with water, usually generating heat, corrosive liquid and flammable gases.
Recommended storage	Secure water-proof double-containment according to label instructions. Isolation from other storage groups. The primary storage concern is to prevent contact and reaction with liquids and, in some cases, air.
Examples	Some metal hydrides are Sodium borohydride, Calcium hydride, Lithium aluminum hydride. Some pyrophorics are Boron, Diborane, Dichloroborane, 2-Furaldehyde, Diethyl aluminum chloride, Lithium, white or yellow Phosphorus and Trimethyl aluminum. Water reactives include Aluminum chloride-anhydrous, Calcium carbide, Acetyl chloride, Chlorosulfonic acid, Sodium metal, Potassium metal, Phosphorous pentachloride, Calcium metal, Aluminum tribromide, Calcium oxide, and acid anhydrides.

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

Group 9: Dry Solids

Primary hazard	Includes all salts, powders, and granules. These may be hazardous and non-hazardous.
Recommended storage	The primary storage concern is to prevent contact and potential reaction with liquids. Cabinets are recommended, but if not available, open shelves are acceptable. Store above liquids. Warning labels on highly toxic powders should be inspected and highlighted or amended if they do not cause the containers to stand out against less toxic substances in this group. It is recommended that the most hazardous substances in this group be segregated. It is particularly important to keep liquid poisons below cyanide-or sulfide-containing poisons (solids). A spill of aqueous liquid onto cyanide - or sulfide - containing poisons would cause a reaction that would release poisonous gas. Metal hydrides, if properly double-contained, may be stored in the same area.
Examples	Benzidine, Cyanogen bromide, Ethyl maleimide, Oxalic acid, Potassium cyanide, Sodium cyanide, Iron sulfide, Urea, Sodium thiosulfate.
Storage compatibilities	All other solids. Exceptions: solid Picric acid or Picrylsulfonic acid can be stored with this group, but should be checked regularly for dryness. When completely dry, picric acid is explosive and may detonate upon shock or friction. Picric acid in contact with some metals may form explosive metal-picrate salts. Use non-metal caps.

Chemical Compatibility

The following table briefly provides examples of incompatible chemicals:

CHEMICAL	INCOMPATIBLE WITH . . .
Acetic acid	Chromic acid, nitric acid, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Acetone	Concentrated nitric and sulfuric acid mixtures, hydrogen peroxide
Alkali metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, halogens

Ammonia	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Chlorates	Ammonium salts, acids, powdered metals, sulfur, finely divided organic or combustible materials
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals, turpentine
Cyanide	Acids
Fluorine	Most other chemicals
Hydrofluoric acid	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, flammable liquids, combustibles, aniline, nitromethane
Nitrates	Sulfuric acid
Nitric acid (concentrated)	Organic substances (including acetone, acetonitrile, many alcohols and amines, and benzene), many bases, alkali metals, copper, phosphorous, and ammonia
Oxygen	Oils, grease, hydrogen, flammable liquids, solids, or gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils,
Sodium	Carbon tetrachloride, carbon dioxide, water
Sulfides	Acids

Additional Resources for Chemical Segregation and Storage

- How to separate bases for storage: http://safety.ag.utk.edu/safetyplan/10chemweb/sepbases.htm
- How to separate flammable liquids for storage: http://www.safety.vanderbilt.edu/resources/hazard_lab_activate.htm#segregate
- How to separate oxidizers for storage: http://safety.ag.utk.edu/safetyplan/10chemweb/sepox.htm
- How to separate flammable solids for storage: http://safety.ag.utk.edu/safetyplan/10chemweb/sepflams.htm
- How to separate reactive and extremely toxic chemicals for storage: http://safety.ag.utk.edu/safetyplan/10chemweb/#
- How to separate pyrophoric substances for storage: http://safety.ag.utk.edu/safetyplan/10chemweb/seppyro.htm
- How to store light-sensitive substances: http://safety.ag.utk.edu/safetyplan/10chemweb/seplight.htm
- How to separate peroxide-forming chemicals for storage (see below list of peroxide forming compounds): http://safety.ag.utk.edu/safetyplan/10chemweb/sepperox.htm
- How to store compressed gases: http://safety.ag.utk.edu/safetyplan/10chemweb/sepcgas.htm

Common Compounds That Form Peroxides During Storage

The following table provides examples of peroxide-forming chemicals. These compounds must be tested every twelve months for the presence of peroxides. If peroxide levels reach 20 ppm, the material must be disposed of as hazardous waste.

- Acetal
- Butadiene
- t-Butyl alcohol
- Chlorobutadiene (Chloroprene)
- Chlorotrifluorethylene
- Cumene
- Cyclohexene
- Diacetylene
- Dibenzocyclopentadiene
- Dicyclopentadiene
- 9,10 Dihydroanthracene
- Dioxane
- Divinyl acetylene
- Ethyl ether
- Ethylene glycol dimethyl ether (glyme)
- Indene
- Isopropyl ether
- Methyl acetylene
- Methyl i-butyl ketone
- Methylcyclopentane
- Potassium metal
- Sodium amide
- Styrene
- Tetrafluoroethylene
- Tetrahydrofuran
- Tetrahydronaphthalene
- Vinyl pyridine
- Vinyl acetate
- Vinyl chloride
- Vinyl ethers
- Vinylidene chloride

These materials should be carefully segregated as above.

Shipping/Receiving of Chemicals

The U.S. Department of Transportation regulates the shipment of hazardous materials. Anyone who packages, receives, unpacks, signs for, or transports hazardous chemicals must be trained and certified in Hazardous Materials Transportation. The Institute of Agriculture will receive, but **does not ship** hazardous materials unless in small “excepted quantities.” Contact the Safety Office for more information.

8.5 Off-Hours Work Procedures

Laboratory personnel are not permitted to work after hours in the lab, except with specific authorization by the lab supervisor. This authorization can be as broad or specific as needed to ensure personnel in the laboratory know what work hours are allowed for each employee. Having this authorization written and included in the (lab-specific) CHP is the best method to ensure that employees are clearly informed of any constraints.

8.6 Working Alone

Work with acutely hazardous chemicals or procedures (circumstances when an accident or chemical release will create immediately dangerous conditions) will not be performed in the laboratory when the only person in the room is the laboratory person performing the work. If feasible, work with chemicals will not be conducted alone.

8.7 Unattended Operations

When laboratory operations are performed which will be unattended by laboratory personnel (continuous operations, overnight reactions, etc.) and may present special hazards to other lab workers, custodial staff, or visitors, **warning signage** will be posted at all entrances to the laboratory identifying the process and the appropriate special hazards or precautions. It is essential that the laboratory door signs which list the names and phone numbers of laboratory contact personnel be kept up-to-date, so that in the event of an emergency someone knowledgeable about the specific conditions in the laboratory can be contacted.

8.8 Laboratory Equipment Overview

The following rules shall apply to the use of laboratory equipment:

- All laboratory equipment shall be used properly and only for its **intended purpose**.
- All laboratory equipment shall be **inspected** on a periodic basis and receive maintenance, repair or replacement as necessary.
- Do not defeat, remove, or override equipment safety devices.

IMPORTANT: Disconnect any equipment that is unsafe or does not work properly and remove it from service. Notify other users of the problem.

8.9 Laboratory Equipment – Aerosol Production

The term “aerosol” refers to liquid or solid particles suspended in air. These can pose a serious risk because small aerosols readily penetrate and remain deep in the respiratory tract, they can remain suspended in the air for long period of time, and they easily contaminate equipment and ventilation systems. The following equipment may produce aerosols:

- Centrifuge
- Blender
- Shaker

- Magnetic stirrer
- Sonicator
- Pipet
- Vortex mixer
- Syringe and needle
- Grinder, mortar and pestle
- Separatory funnel

Follow these guidelines to eliminate or reduce the hazards associated with aerosols:

- Conduct procedures that may produce aerosols in a biological safety cabinet or a chemical fume hood, as appropriate.
- Keep tubes stoppered when vortexing or centrifuging.
- Allow aerosols to settle for one to five minutes before opening a centrifuge, blender or tube.
- When combining liquids, discharge the secondary material down the side of the container or as close to the surface so the primary liquid as possible.
- Use a mechanical pipetting device.

8.10 Laboratory Equipment – Centrifuges

Centrifuging presents the possibility of two serious hazards: mechanical failure and aerosols. The most common hazard associated with centrifuging is a broken tube. To ensure safety when operating a centrifuge, take precautions to ensure the following:

- Proper loading (accurate balancing)
- Safe operating speeds (do not exceed manufacturing recommendations)
- Safe stopping
- Complete removal of materials
- Proper cleanup

Follow these guidelines when working with a centrifuge:

- When loading the rotor, examine the tubes for signs of stress and discard any tubes that are damaged.
- Inspect the inside of each tube cavity or bucket. Remove any glass or other debris from the rubber cushion.
- Ensure that the centrifuge has adequate shielding to guard against accidental 'fly-aways'.
- Use a centrifuge only if it has a disconnect switch that deactivates the rotor when the lid is open.
- Always keep the lid closed during operations and shut down. Do not open the lid until the rotor is completely stopped.
- Do not break the head rotation by hand.
- Do not use aluminum foil to cap a centrifuge tube. Foil may rupture or detach.

- When balancing the rotors, consider the tubes, buckets, adapters, inserts and any added solution.
- Stop the rotor and discontinue operation if you notice anything abnormal such as a noise or vibration.
- Rotor heads, buckets, adapters, tubes and plastic inserts must match.

High-speed centrifuges pose additional hazards due to the higher stress and force applied to their rotors and tubes. In addition to the safety guidelines outlined above, follow these guidelines for high-speed centrifuges:

- Filter the air exhausted from the vacuum lines.
- Keep a record of rotor usage in order to avoid the hazard of metal fatigue.
- Frequently inspect, clean and dry rotors to prevent corrosion or other damage.
- Follow the manufacturers operating instructions exactly.

8.11 Laboratory Equipment – Compressed Gases

IMPORTANT: Cylinders that are knocked over or dropped can be very dangerous and can cause serious injuries. If a valve is knocked off a compressed gas cylinder, the cylinder can become a lethal projectile. *Damaged cylinders can travel through walls much like a torpedo travels through water. They can cause structural damage, severe injury and death.*

Follow these guidelines to ensure safe storage of gas cylinders:

- Secure all cylinders in racks, holders, or clamping devices in a well-ventilated area.
- Do not rely on color to identify container contents. Check the label.
- Close valves, and release pressure on the regulators when cylinders are not in use.
- Minimize the number of hazardous gas cylinders in a laboratory.
- Keep heat, sparks, flames and electrical circuits away from gas cylinders.
- Store cylinders of oxygen and other oxidizing agents at least 20 feet from flammable gas cylinders, or separate these items with a fire wall at least five-feet high, having a fire-resistance rating of at least 0.5 hour.
- Do not store gas cylinders in exit or egress routes, hallways or public areas.

When working with compressed gas cylinders, remember the following:

- Never move a gas cylinder unless the cylinder cap is in place and the cylinder is chained or otherwise secured to a cart.
- Wear sturdy shoes (no open-toed, sandals, etc.) when moving or transporting cylinders.
- Do not move a cylinder by rolling it on its base.
- Only use regulators approved for the type of gas in the cylinder.
- Do not use adapters to interchange regulators.
- When opening a cylinder valve, follow these guidelines:
  a. direct the cylinder opening and the valve faceplate away from people
  b. open the valve slowly.
- If an inert gas cylinder leaks, carefully move the cylinder to an open space outdoors (if it is safe to move the cylinder). Have the supplier pick up the cylinder.

- If a flammable or oxidizing gas cylinder leaks, move the cylinder to the hood, shut off all ignition sources, pull the fire alarm, and evacuate the area. When firefighters arrive, meet them and tell them the situation. Once the situation is stabilized, call the supplier to replace the cylinder (if it is rented).
- If a poison gas leaks, move the cylinder to a hood (if it is not already there), pull the fire alarm, and evacuate the area. When firefighters arrive, meet them and tell them the situation. Once the situation is stabilized, call the supplier to replace the cylinder (if it is rented).
- Do not use oil or other lubricant on valves and fittings.
- Do not use oxygen as a substitute for compressed air.
- Do not lift cylinders by the cap.
- Do not tamper with the safety devices on a cylinder. Have the manufacturer or supplier handle cylinder repairs.
- Do not change a cylinder's label or color. Do not refill cylinders yourself.
- Do not heat cylinders to raise internal pressure.
- Do not use compressed gas to clean your skin or clothing.
- Do not completely empty cylinders. Maintain at least 30 psi.
- Do not use copper (or use <65% copper alloy) connectors or tubing with acetylene. Acetylene can form explosive compounds with silver, copper and mercury.
- Always wear impact resistant glasses or goggles when working with compressed gases.

8.12 Laboratory Equipment – Cryogenic Fluids

Cryogenic fluids, such as liquid air, liquid nitrogen or liquid oxygen are used to obtain extremely cold temperatures. Most cryogenic liquids are odorless, colorless and tasteless when vaporized. When cryogenic liquids are exposed to the atmosphere, however, they create a highly visible and dense fog. All cryogens other than oxygen can displace breathable air and can cause asphyxiation. Cryogens can also cause frostbite on exposed skin and eye tissue.

Cryogens pose numerous hazards. For example, cryogenic vapors from liquid oxygen or liquid hydrogen may cause a fire or explosion if ignited. Materials that are normally noncombustible (e.g., carbon steel) may ignite if coated with an oxygen-rich condensate. Liquefied inert gases, such as liquid nitrogen or liquid helium, are capable of condensing atmospheric oxygen and causing oxygen entrapment or enrichment in unsuspected areas. Extremely cold metal surfaces are also capable of entrapping atmospheric oxygen. Because the low temperatures of cryogenic liquids may affect material properties, take care to select equipment materials accordingly.

Follow these guidelines when working with cryogenic liquids:

1. Before working with cryogenic liquids, acquire a thorough knowledge of cryogenic procedures, equipment operation, safety devices, material properties, protective equipment usage.
2. Keep equipment and systems extremely clean.
3. Avoid skin and eye contact with cryogenic liquids. Do not inhale cryogenic vapors. Never touch a dispensing nozzle *barehanded* after dispensing has begun.
4. Pre-cool receiving vessels to avoid thermal shock and splashing.
5. Use tongs to place and remove items in cryogenic liquid.

6. When discharging cryogenic liquids, purge the line slowly. Only use transfer lines specifically designed for cryogenic liquids. Liquid nitrogen boils and spews out of containers (such as Thermo-Flasks or mortars) when room temperature objects are inserted. Avoid flying droplets!
7. Rubber and plastic may become very brittle in extreme cold. Handle these items carefully when removing them from cryogenic liquid.
8. Store cryogenic liquids in double-walled, insulated containers (e.g., Dewar flasks.)
9. To protect yourself from broken glass if the container breaks or implodes, tape the exposed glass on cryogenic containers.
10. Do not seal a container until it comes to ambient temperature. Sealed containers containing cryogenic samples may implode as the air space rapidly cools, or explode as the sample comes to room temperature.
11. DO NOT pour excess cryogenic liquid down the drain! The plumbing will freeze and break.
12. Do not store cylinders of cryogenic liquids in hallways or other public areas.

IMPORTANT: Be aware of the tremendous expansion and displacement of oxygen when a cryogenic liquid vaporizes at room temperature.

8.13 Laboratory Equipment – Electrophoresis

Electrophoresis equipment may be a major source of electrical hazard in the laboratory. The presence of high voltage and conductive fluid in this apparatus presents a potentially lethal combination. Many people are unaware of the hazards associated with this apparatus; even a standard electrophoresis operating at 100 volts can deliver a lethal shock at 25 milliamps. In addition, even a slight leak in the device tank can result in a serious shock. Protect yourself from the hazards of electrophoresis and electrical shock by taking these precautions:

- Use physical barriers to prevent inadvertent contact with the apparatus.
- Use electrical interlocks.
- Frequently check the physical integrity of the electrophoresis equipment.
- Use warning signs to alert others of the potential electrical hazard.
- Use only insulated lead connectors.
- Turn the power off before connecting the electrical leads.
- Connect one lead at a time using one hand only.
- Ensure that your hands are dry when connecting the leads.
- Keep the apparatus away from water and water sources.
- Turn the power off before opening the lid or reaching into the chamber.
- Do not disable safety devices.
- Follow the equipment operating instructions.

8.14 Laboratory Equipment – UV Light Tables

UV or ultraviolet lamps are used in biological safety cabinets, light boxes, and cross linkers in many university laboratories. One of the problems in working with UV radiation is that the symptoms of overexposure are not immediately felt so that persons exposed do not realize the hazard until after the damage is done.

UV radiation is that radiation just outside the visible range, or under 400 nanometers (nm). There are three ranges of UV light (see table below).

Region	Also known as	*Range in nm	Hazard Potential	Damage Mechanism (High Exposures)
UV-A	near UV	320-400	lowest	cataracts
UV-B	mid UV	290-320	mid to high	**skin or eye burns
UV-C	far UV	190-290	highest	skin or eye burns

*Early "black lights" emitted in the range of 360-390 nm.
** Increased risk of some types of skin cancer.

A University lab employee received skin and eye burns while using an acrylic plastic shield for protection against UV. The lab did not realize that the shield had not been manufactured for this use and was not rated for protection against UV light. Please check your safety equipment to ensure that it is rated for the wavelength in use.

The health effects of exposure to UV light are familiar to anyone who has had sunburn. However, the UV light levels around some UV equipment greatly exceed the levels found in nature. Acute (short-term) effects include redness or ulceration of the skin. At high levels of exposure, these burns can be serious. For chronic exposures, there is also a cumulative risk of harm. This risk depends upon the amount of exposure during your lifetime. The long-term risk for large cumulative exposure includes premature aging of the skin and even skin cancer.

UV exposure is not immediately felt . . . the user may not realize a hazard until after the damage is done.

The eyes are also susceptible to UV damage. Like the skin, the covering of the eye or the cornea, is epithelial tissue, too. The danger to the eye is enhanced by the fact that light can enter from all angles around the eye and not only the direction you are looking in. The lens can also be damaged, but since the cornea acts as a filter, the chances are reduced. This should not lessen the concern over lens damage however, because cataracts are the direct result of lens damage.

Burns to the eyes are usually more painful and serious than a burn to the skin. Make sure your eye protection is appropriate for this work. There are specially-made safety glasses for the different UV ranges. NORMAL EYEGLASSES OR CONTACTS OFFER VERY LIMITED PROTECTION!!

Do not forget to protect the rest of the face. Severe skin burns can happen in a very short time, especially under your chin (where most people forget to cover). Full-face shields are really the only appropriate protection when working with UV light boxes for more than a few seconds.

Be sure to protect your arms and hands by wearing a long-sleeve lab coat and gloves.

8.15 Laboratory Equipment – Glassware

Accidents involving glassware are the leading cause of laboratory injuries. To reduce the chance of cuts or punctures, use common sense when working with glassware. In addition, follow special safety precautions for tasks that involve unusual risks. Follow these practices for using laboratory glassware safely:

- Prevent damage to glassware during handling and storage.
- Inspect glassware before and after each use. Discard or repair any cracked, broken or damaged glassware in a sturdy container.
- Thoroughly clean and decontaminate glassware after each use.
- When inserting glass tubing into rubber stoppers or corks, follow these guidelines:
  a. use adequate hand protection
  b. lubricate the tubing
  c. hold hands close together to minimize movement if the glass breaks
- When possible, substitute plastic or metal connectors for glass connectors.
- Large glass containers are highly susceptible to thermal shock. Heat and cool large glass containers slowly.
- Use Pyrex or heat-treated glass for heating operations.
- Leave at least 10 percent air space in containers with positive closure.
- Never use laboratory glassware for vacuum operation.
- Use round-bottomed glassware for vacuum operations. Flat-bottomed glassware is not as strong as round-bottomed glassware.

NOTE: If not absolutely necessary, do not use chromic acid to clean glassware. Use a standard laboratory detergent. Chromic acid is extremely corrosive and expensive to dispose of. Spent (green) Chromic acid solutions must always be collected for disposal as hazardous waste.

Follow these safety guidelines for handling glassware.

- When handling cool flasks, grasp the neck with one hand and support the bottom with the other hand.
- Lift cool beakers by grasping the sides just below the rim. For large beakers, use two hands: one on the side and one supporting the bottom.
- Never carry bottles by their necks.
- Use a cart to transport large bottles of dense liquid (e.g. a 4 liter bottle of Chloroform).

Follow these guidelines for handling and disposing of broken glass:

- Do not pick up broken glass with bare or unprotected hands. Use a brush and dust pan to clean up broken glass. Remove broken glass in sinks by using tongs for large pieces and cotton held by tongs for small pieces and slivers.
- Glass contaminated with biological, chemical, or radioactive materials must be decontaminated before disposal or be disposed of as hazardous waste.
- Before disposing of broken glass in a trash can, place the glass in a rigid container such as cardboard and mark it "Broken Glass." To prevent accidental cuts and punctures to the housekeeping staff during trash disposal (as easily happens if the cardboard gets wet), the best option is to take collections of broken glass directly to the dumpster.

8.16 Laboratory Equipment – Heating Systems

Common hazards associated with laboratory heating devices include electrical hazards, fire hazards and hot surfaces. Some laboratory heating procedures involve an open flame. Devices that supply heat for reactions or separations include the following:

- Open flame burners
- Hot plates
- Heating mantles
- Oil and air baths
- Hot air guns
- Ovens
- Furnaces
- Ashing systems

IMPORTANT: Never leave an open flame unattended.

Follow these guidelines when using heating devices:

- Ensure that heating units have an automatic shutoff to protect against overheating.
- Ensure that heating devices and all connecting components are in good working condition.
- Heating baths should be equipped with timers to ensure that they turn on and off at appropriate times.
- Use a chemical fume hood when heating flammable or combustible solvents. Arrange the equipment so that escaping vapors do not contact heated or sparking surfaces.
- Use non-asbestos thermal-heat resistant gloves to handle heated materials and equipment.
- Perchloric acid digestions must be conducted in a perchloric fume hood.

- Minimize the use of open flames.

Heated chemicals can cause more damage and more quickly than would the same chemicals at a lower temperature. RULE OF THUMB: Reaction rates double for each 10°C increase in temperature.

8.17 Laboratory Equipment – Pressurized Systems

Do not conduct a reaction in, or apply heat to, a closed system apparatus unless the equipment is designed and tested to withstand pressure. Pressurized systems should have an appropriate relief valve. Pressurized systems must be fully shielded and should not be conducted in an occupied space until safe operation has been assured. Until safe operation is assured, remote operation is mandatory.

Safety Points to Remember:

- Minimize risk and exposure
- Identify and assess all hazards and consequences
- Use remote manipulations whenever possible
- Minimize pressure, volume and temperature
- Use material with a predictably safe failure mode
- Ensure that the components of the pressurized system will maintain structural integrity at the maximum allowable working pressure; avoid material that may become brittle.
- Operate within the original design parameters
- Provide backup protection (e.g., pressure relief valves, fail-safe devices)
- Use quality hardware
- Use protective shield or enclosures
- Use tie-downs to secure tubing and other equipment
- Do not leave a pressurized system unattended

IMPORTANT: Normally pressurized systems should not include glass components unless they are specially designed and intended for that purpose.

8.18 Laboratory Equipment – Vacuum Systems

Vacuum systems pose severe implosion hazards. **IMPORTANT:** Conduct all vacuum operations behind a table shield or in a fume hood with the sash down. Follow these guidelines and requirements to ensure system safety:

- Ensure that pumps have belt guards in place during operation.
- Ensure that service cords and switches are free from defects.
- Always use a trap on vacuum lines to prevent liquids from being drawn into the pump, house vacuum line or water drain.
- Replace and properly dispose of vacuum pump oil that is contaminated with condensate. Used pump oil must be disposed as hazardous waste.
- Place a pan under pumps near containers of flammable chemicals.

- Do not place pumps in an enclosed, unventilated cabinet.

CAUTION: Do not underestimate the pressure differential across the walls of glassware that can be created by a water aspirator.

The glassware used with vacuum operations must meet the following requirements:

- Only heavy-walled round-bottomed glassware should be used for vacuum operations. The only exception to this rule is glassware specifically designed for vacuum operations, such as an Erlenmeyer filtration flask.
- Wrap exposed glass with tape to prevent flying glass if an implosion occurs.
- Carefully inspect vacuum glassware before and after each use. Discard any glass that is chipped, scratched, broken or otherwise stressed.

Glass desiccators often have a slight vacuum due to contents cooling. When using desiccators, follow these guidelines:

- When possible, use molded plastic desiccators with high tensile strength.
- For glass desiccators, use a perforated metal desiccator guard.

8.19 Laboratory Equipment – Refrigerators/Freezers

Household refrigerators must not be used to store flammable liquids, unless the flammable liquid container can be secondarily enclosed in a sealed container. Many flammable solvents are still volatile at refrigerator temperatures. The storage compartment of a household refrigerator contains ignition sources such as the thermostat and light. Additionally, the compressor and electrical circuits located at the bottom of the unit where chemical vapors are likely to accumulate are not sealed. This combination of flammable vapor and ignition source has created explosions in many university laboratories.

Laboratory-safe or explosion-proof refrigerators are required if large containers or volumes of flammable liquids must be refrigerated. In laboratory-safe refrigerators the sparking components are located on the exterior of the refrigerator. Explosion-proof refrigerators are required in areas that may contain high levels of flammable vapors (e.g., chemical storage rooms with large quantities of flammable chemicals).

8.20 Laboratory Equipment – Cold Traps

A cold trap is a condensing device used to prevent moisture contamination in a vacuum line. Guidelines for using a cold trap include:

1. Locate the cold trap between the system and vacuum pump.
2. Ensure that the cold trap is of sufficient size and cold enough to condense vapors present in the system.
3. Check frequently for blockages in the cold trap.

4. Use isopropanol/dry ice or ethanol/dry ice instead of acetone/dry ice to create a cold trap. Isopropanol and ethanol are cheaper, less toxic and less prone to foam.
5. Do not use dry ice or liquefied gas refrigerant bath in a closed system. These can create uncontrolled and dangerously high pressures.

8.21 Laboratory Equipment – Mercury Containing Devices and Thermometers

Mercury thermometers and mercury-containing devices are a major source of contamination from spills, leaks and breaks. Contamination is easily spread and often expensive to clean up. This is in addition to the usual high cost of disposal. It is therefore the policy of UTIA that the use of mercury containing devices must be phased out as much as practicable. Here are a few ways to better manage mercury containing devices:

- Collect and take to hazardous waste collection any unwanted mercury thermometers.
- Dispose of any mercury spill cleanup debris as hazardous waste. Call the UTIA Safety Office at 974-1153 if you have any questions.
- Replace mercury thermometers with alcohol thermometers (blue and red types are alcohol thermometers) whenever possible.
- Dispose of mercury containing items through the quarterly hazardous waste collection day (these include manometers, some blood pressure cuffs, mercury switches, and thermometers). Always double-bag mercury containing items.
- Do not take mercury containing devices to salvage unless the mercury has first been removed. If this is not practical, please call the UTIA Safety Office at 974-1153.
- Do not accumulate more mercury thermometers than you need.
- If precision work is being done that necessitates a mercury thermometer, buy a Teflon coated thermometer. The added cost is easily offset compared against the inconvenience and money spent cleaning up broken thermometers.

9 Chemical Waste

Reference the chapter in the UTIA safety manual on hazardous waste:
http://safety.ag.utk.edu/safetyplan/23hazwaste/23hazwaste.htm

- Please keep all waste containers closed and labeled,
- Safely transport items on waste collection day: waste generators should double contain bottles to prevent spills, and wear proper equipment to protect hands, eyes and feet,
- Any waste materials in a given lab are the responsibility of that lab-regardless of who created the wastes or when. Old or “legacy” wastes should be disposed of as soon as possible.
- Hazardous waste pickup is quarterly.

10 Emergency Situations, Spills and Releases

10.1 Emergency Response

Telephone numbers of emergency personnel, supervisors (and other workers as appropriate) are posted on the **lab entrance**. A few emergency contact numbers are also listed in the Lab Emergencies tab. Contact the UTIA Safety Office to update the door sign if there are changes.

10.2 Disruptions during Procedures with Highly Hazardous Chemicals

In the event that there is a significant disruption while an experiment with highly hazardous chemicals is in-process (for example: the fume hood stops working, there is a medical emergency or a fire):

- If possible to do so safely, **close down the experiment**. Alternately, take what steps are readily available to contain or **minimize the spread of the chemical hazard**.
- **Notify other people** in the area of the special hazard, and any special precautions that are needed.
- Immediately **notify the UTIA Safety Office**, so that any special actions related to emergency response efforts or building evacuation are addressed.

10.3 In Case of Fire

The first reaction to a fire is to **evacuate the occupants** of the building. Fire extinguishers are available in labs, and may be used by trained personnel to fight small fires. Fire extinguisher training is available both on-line and hands-on through the UTIA Safety Office.

10.4 In Case of Spills

Personnel should be trained and equipped to handle most small spills in their work areas. **The size of the spill and its hazards will guide the appropriate response.** If there is any doubt about a lab worker's ability to safely clean up the spill, call the UTIA Safety Office. Note that proper emergency response depends on understanding the hazards present in the lab. Do not attempt to clean a spill unless you are familiar with the hazards and safe handling of a chemical. To prepare for a potential spill, follow these guidelines:

- Have a chemical spill kit available, properly stocked, and make sure everyone in the lab knows the location
- Train all laboratory employees on how to use the spill kit

- Know how to turn off equipment, heat sources, electrical panels, etc.
- Know the routes of exposure and the hazards of the chemicals you work with, as well as the location of the MSDS

Clean contaminated equipment and spills immediately. Mercury from broken thermometers or other devices can create major contamination of equipment and environmental surfaces; clean mercury spills immediately.

Spill Response Kit:
Work areas that contain hazardous chemicals must have a chemical spill response kit. This kit should include the following items:

- Disposable gloves (two different types, such as latex and vinyl)
- Safety goggles
- Absorbent (e.g. spill pillows, vermiculite, kitty litter, etc.)
- Plastic scoop
- Plastic trash bags
- Mercury spill kit (if mercury is present in thermometers or equipment in the lab).

Responding to Chemical Spills
The following sequence provides a brief overview of proper chemical spill response procedures:

1. Notify others in the immediate area that a spill has occurred. Evacuate the area if necessary.
2. Attend to injured and exposed people.
3. Identify the spilled chemical and read the MSDS to determine the proper procedure for cleaning up the spill. If it is necessary for lab personnel to receive medical attention due to the chemical spill, share the MSDS information with first responders or emergency room medical staff.
4. If the spilled material is flammable, turn off all ignition and heat sources.
5. Based on the hazards and the personal protective equipment needed (e.g., respiratory protection), determine if you can safely clean the spill or if assistance is necessary. (Most spills can be cleaned safely by the people who were using the chemical.)

If you determine that you can safely clean the spill without emergency assistance, follow these guidelines:

1. Wear appropriate protective clothing and equipment.
2. Have another person stand by during the cleanup.
3. Clean up the spill and collect all wastes for proper disposal.
4. Ventilate the area, as necessary, before it is re-occupied.
5. Decontaminate reusable cleanup supplies such as scoops, rubber boots, etc.
6. Restock the chemical spill kit and return it to the normal storage location ***before using any more chemicals.***

Do not take unnecessary risks with chemical spills. Call the Safety Officer whenever a spill involves the following:

- Large volume of spilled material
- Very hazardous material
- Very hazardous conditions (e.g., fire, explosion, toxicity, etc.)
- Strong odor
- Personnel injury or exposure

11Chemical Exposures and Medical Care

All employees shall be instructed in the **location and proper usage of emergency showers and eyewashes**. The general rule is to flush any chemical exposure to skin or eyes for 15 minutes, and to decontaminate as appropriate for the chemical. Remove contaminated clothing immediately. Do not reuse the clothing again until it has been properly decontaminated.

All employees who work with hazardous chemicals will have an opportunity to receive medical attention, including any follow-up examinations which the examining physician determines to be necessary, under the following circumstances:

- Whenever an employee develops **symptoms** associated with a hazardous chemical to which the employee may have been exposed in the laboratory.
- Where exposure monitoring reveals an **exposure level routinely above the action level or PEL** for an OSHA regulated substance for which there are exposure monitoring and medical surveillance requirements.
- Whenever an event takes place in the work area such as a **spill, leak, explosion** or other occurrence resulting in the likelihood of a hazardous exposure.

The UTIA Safety Office will be contacted whenever the need for medical consultation or examination occurs, or when there is uncertainty as to whether any of the above criteria have been met.

Arranging for Exams:
All medical examinations and consultations will be performed by or under the direct supervision of a licensed physician and will be provided through the UT Workers' Compensation Program, without loss of pay and at a reasonable time and place. In the event of a life-threatening illness or injury, dial 911 and request an ambulance. For non-life-threatening injuries, the recommended transportation for medical follow-up is either via UT Police dispatch, or in a UT vehicle. It is not recommended to transport injured persons in a personally owned vehicle.

Provide the examining physician with the following information:

- The **identity** of the hazardous chemical(s) to which the employee may have been exposed.

- A description of the **conditions** under which the exposure occurred including quantitative exposure data, if available.
- A description of the **symptoms** of exposure that the employee is experiencing, if any.

The above information will be collected and transmitted **by the lab supervisor** and will be sent to **both** the **UTIA Safety Office** and to the **examining physician**.

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12 References and Other Information Sources

National Research Council, **Prudent Practices for Handling and Disposing Hazardous Chemicals in Laboratories**, National Academy Press, Washington, D.C., 1995.

Code of Federal Regulations, 29 CFR part 1910 subpart Z section 1910.1450, **Occupational Exposure to Hazardous Chemicals in Laboratories**, 1990.

American Chemical Society, **Safety in Academy Chemistry Laboratories**, 5th ed., Washington, D.C., 1991.

Internet Resources:

- **University of Tennessee Institute of Agriculture UTIA Safety Office**
  http://safety.ag.utk.edu
- **University of Tennessee Biosafety Program**
  http://biosafety.tennessee.edu/
- **Laboratory Chemical Safety Summaries**
  http://www.hhmi.org/about/labsafe/lcss/lcss.html
- **Material Safety Data Sheets**
  http://safety.ag.utk.edu/msdslinks.htm
- **OSHA Regulations and Technical Information**
  http://www.osha.gov

Appendix 1: Laboratory Self-Audit Checklist

Building, Room Number & PI: ____

Inspector & Date:

	YES	NO	If **NO**, corrective action to be taken:
Up-to-date emergency phone numbers are posted on the laboratory doors?			
All personnel have received Chemical Hygiene training and have reviewed the CHP annually?			
All personnel know how to obtain MSDS's?			
All personnel have received Lab Specific Training?			
Chemical spill kits are available?			
No leaking containers are present?			
No 'legacy'chemicals (from discontinued processes) are deteriorating in the lab?			
No 'legacy'chemicals (from previous lab users) are abandoned in the lab?			
Chemicals are stored according to compatibility (i.e. chemicals that should not mix such as acids, bases, and flammables have separate, designated storage areas)?			
Special storage areas and/or secondary containment is established for chemicals requiring special segregation such as fluorine and perchloric acid?			
Peroxide forming reagents (ex: p-Dioxane, Ethyl ether) are dated when opened, and disposed of or tested after one year?			
Flammable storage area(s) is labeled?			
Flammables are kept away from sources of heat, ignition, flames, etc.?			
Flammable liquids in excess of 10 gallons are stored in flammable storage cabinets?			
Flammable liquids are not stored in regular (non-explosion proof) refrigerators?			
Fire extinguisher is mounted on the wall and access is not blocked by equipment or supplies?			
Utility panels (circuit breakers) are accessible and access is not blocked by equipment or supplies?			

	YES	NO	If **NO**, corrective action to be taken:
Corrosive materials are stored low to the ground?			
Work and storage areas for high hazard chemicals (carcinogens, reproductive toxins, highly toxic and reactive materials) have hazard warning signage?			
Chemicals in the open are kept to a minimum?			
Hazardous waste storage area is labeled with yellow *Hazardous Waste Storage Area* sign?			
Hazardous waste containers have yellow and red UT *Hazardous Waste* labels? Labels are properly filled out with contents identified by chemical names (abbreviations or product names do not meet waste shipping requirements)?			
Hazardous waste containers are closed except when they are actively being filled?			
Hazardous waste is not stored beyond 90 days?			
An emergency eyewash is accessible and regularly testing (at least monthly) by lab personnel? Testing is documented on eyewash card or sheet?			
An emergency shower is accessible, and tested at least annually by Facilities personnel?			
Hand washing facilities are available in the lab, including soap and paper towels?			
Required protective equipment (such as gloves, safety glasses, goggles) is available and in functional condition?			
Food and beverages are not stored or used in lab?			
Aisles are uncluttered and are without tripping hazards?			
All exit ways are clear and unobstructed?			
Sharps are in labeled, puncture-proof containers?			
Fume hoods have current inspection sticker?			
Gas cylinders are properly secured, i.e. chained & upright?			
All proper guards are in place and functioning?			
Electrical equipment is UL approved and in good condition? Cords are not damaged? Equipment with 3-prong plugs is plugged into grounded outlets?			

Appendix 2: Examples of “Particularly Hazardous Chemicals”

The chemicals listed below are extremely hazardous due to their toxic or carcinogenic effects. This is not an exclusive list, and may be expanded, based on the professional judgment of the laboratory supervisor. Workers must have knowledge of the dangers of these chemicals prior to use, and documentation of training in safe working procedures.

Some Common Select Carcinogens in Research Laboratories

2-Acetylaminofluorene	4-Diethylaminoazobenzene
Acrylamide	Dimethyl sulfate
Acrylonitrile	Ethylene dibromide
Aflatoxins	Ethylene oxide
4-Aminobiphenyl	Ethyleneimine
Arsenic and certain As compounds	Formaldehyde
Asbestos	Hexamethylphosphoramide
Azathioprine	Hydrazine
Barium chromate	Melphalan
Benzene	4,4’-Methylene-bis[2-chloroaniline]
Benzidine	Mustard gas (bis(2-Chloroethyl)sulfide)
Bis(chloromethyl)ether	α-Naphthylamine
Myleran	β-Naphthylamine
Chlorambucil	Nickel carbonyl
Chlornaphazine	4-Nitrobiphenyl
Chloromethyl methyl ether	N-Nitrosodimethylamine
Chromium and certain Cr compounds	β-Propiolactone
Cyclophosphamide	Thorium dioxide
1,2-Dibromo-3-chloropropane	Treosulfan
3,3’-Dichlorobenzidine (and its salts)	Vinyl chloride
Diethylstilbesterol	

Some Common Reproductive and Developmental Toxins in Research Laboratories

Arsenic and certain As compounds	Ethylene oxide
Benzene	Lead compounds
Cadmium and certain Cd compounds	Mercury compounds
Carbon disulfide	Toluene
Ethylene glycol monomethyl ether	Vinyl chloride
Ethylene glycol monoethyl ether	Xylenes

Some Common Acute Toxins in Research Laboratories

Acrolein	Nickel carbonyl
Arsine	Nitrogen dioxide
Chlorine	Osmium tetroxide
Diazomethane	Ozone
Diborane (gas)	Phosgene
Hydrogen cyanide	Sodium azide
Hydrogen fluoride	Sodium cyanide (and other cyanide salts)
Methyl fluorosulfonate	Sodium sulfide (and other sulfide salts)

Please see http://oregonstate.edu/ehs/carcingn/appendx4.html for a more exhaustive list of chemical carcinogens.