Laboratory Chemical Hygiene Plan

Western Colorado University

1.1 INTRODUCTION

The Occupational Safety and Health Administration's (OSHA) laboratory health standard (Occupational Exposures to Hazardous Chemicals in Laboratories (CFR 1910.1450)) requires employers of laboratory employees to implement exposure control programs and convey chemical health and safety information to laboratory employees working with hazardous materials. Specific provisions of the standard require:

1. chemical fume hood evaluations;
2. establishment of standard operating procedures for routine and “high hazard” laboratory operations;
3. research protocol safety reviews;
4. employee exposure assessments;
5. medical consultations/exams;
6. employee training;
7. labeling of chemical containers;
8. the management of chemical safety information sheets (Material Safety Data Sheets) and other safety reference materials.

The standard's intent is to ensure that laboratory employees are apprised of the hazards of chemicals in their work area, and that appropriate work practices and procedures are in place to protect laboratory employees from chemical health and safety hazards.

The standard operating procedures (laboratory practices and engineering controls) recommended in this manual identify the safeguards that should be taken when working with hazardous materials. These safeguards will protect laboratory workers from unsafe conditions in the vast majority of situations. There are instances, however, when the physical and chemical properties, the proposed use, the quantity used for a particular purpose or the toxicity of a substance will be such that either additional, or fewer, controls might be appropriate to protect the laboratory worker. Professional judgment is essential in the interpretation of these standard operating procedures, and individual laboratories may modify these procedures to meet their specific uses and operational needs.

This document outlines how Western Colorado University is complying with each of the elements in OSHA's Laboratory Standard. An official copy of the Chemical Hygiene Plan is located in the main office of Hurst Hall, Hurst 128.

1.1.1 Important phone numbers for emergencies, chemical spills, or information.

Emergency	Phone
Gunnison Fire/police/ Department Non emergency Dispatch	9-911 641-8000
Facilities emergency response (Flood, broken pipe, etc)	970-901-2449
Jarral Ryter, Chemical Hygiene	943-2875
Campus security	943-3084 209-1020 cel
Lori Clement, Natural and Environmental Sciences Office Admin.	943-2015
Poison Information (Rocky Mountain Poison & Drug Ctr www.rmpdc.org	1-800-222-1222
Robin Bingham, NES Chair, starting 7/1/2019	943-3355

1.2 CHEMICAL HYGIENE RESPONSIBILITIES

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

- President of the University, who has ultimate responsibility for chemical hygiene within the University and must, along with other officials, provide continuing support for chemical safety.
- The Department Chairperson is responsible for chemical hygiene in the department/unit.

Western Colorado University Departments that are required to implement the Chemical Hygiene Plan are as follows:

- Art
- Natural and Environmental Sciences
- Physics
- Psychology

Each of these departments conduct laboratory work as defined in the OSHA Laboratory Standard.

"Laboratory, means 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".

Any department at Western Colorado University not listed above will also be required to implement the Chemical Hygiene Plan if laboratory work is conducted.

The Department Chemical Hygiene Officer/Laboratory Supervisor has the responsibility, as defined in the OSHA Laboratory Standard and the Western University Chemical Hygiene Plan, to implement the Chemical Hygiene Plan, thus ensuring compliance with the regulatory requirements and maintaining a safe work environment. The Department Chemical Hygiene Officer/Laboratory Supervisor has the following duties:

- Ensure that all work is conducted in accordance with the department Chemical Hygiene Plan.
- Work with principal investigators to define the location of work areas where toxic substances and/or potential carcinogens will be used, and ensure that the inventory of these substances is properly maintained.
- Ensure that program and support staff receive instructions and training in safe work practices, use of personal protective equipment (PPE), and in procedures for dealing with accidents involving toxic substances.
- Ensure that employees understand the training received.
- Monitor the safety performance of the staff to ensure that the required safety practices and techniques are being employed.
- Investigate report accidents and recommended procedures that will minimize the repetition of that type of accident.
- Report incidents that cause (1) personnel to be seriously exposed to hazardous chemicals or materials, such as through the inoculation of a chemical through cutaneous penetration,

ingestion of a chemical, or probable inhalation of a chemical, or that (2) constitute a danger of environmental contamination.

- Make copies of the approved Chemical Hygiene Plan available to the research program and support staff as needed.

The Department of Natural and Environmental Sciences Chemical Hygiene Officer can be reached by calling.

Department of Natural and Environmental Sciences Chemical Hygiene Officer: Jarral Ryter (Lab Supervisor) tel: 970-943-2875; email jryter@western.edu

The Laboratory Supervisor has the primary responsibility for chemical hygiene in the laboratory. He/she is responsible for:

- Acquiring the knowledge and information needed to recognize and control chemical hazards in the laboratory.
- Selecting and employing laboratory practices and engineering controls that reduce the potential for exposure to hazardous chemicals to the appropriate level.
- Informing employees working in their laboratory of the potential hazards associated with the use of chemicals in the laboratory and instructing them in safe laboratory practices, adequate controls, and procedures for dealing with accidents involving hazardous chemicals.
- Ensuring that all personnel obtain training, medical examinations and protective equipment and clothing necessary for the safe performance of their jobs.
- Ensuring that action is taken to correct work practices and conditions that may result in the release of toxic chemicals.
- Defining hazardous operations, designating safe practices and selecting protective equipment.
- Ensuring that appropriate controls (engineering and personal protective equipment) are used and are in good working order.
- Developing an understanding of the current requirements regulating hazardous substances used in his/her laboratory.
- Conducting formal laboratory inspections routinely to ensure compliance with existing laboratory SOP's.
- Preparing procedures for dealing with accidents that may result in the unexpected exposure of personnel, or the environment, to toxic substances.
- Properly disposing of unwanted and/or hazardous chemicals and materials.
- Documenting and maintaining compliance with all applicable local, state, and federal requirements.
- Ensuring that, in case of job transfer or termination, workers shall properly dispose of or transfer all chemicals to another responsible party before leaving.

Laboratory worker, who is responsible for:

- Being aware of the hazards of the materials she/he is around or working with, and handling those chemicals in a safe manner.
- Planning and conducting each operation in accordance with established chemical hygiene procedures.

- Developing good chemical hygiene habits (chemical safety practices and procedures).
- Reporting unsafe conditions to his/her supervisor, or the department chemical hygiene officer.

The principal investigator and laboratory workers share responsibility for collecting, labeling and storing chemical hazardous waste properly, as well as informing visitors entering their laboratory of the potential hazards and safety rules/precautions.

Student is responsible for:

- Attending required training sessions and following all standard operating procedures of working in a laboratory.
- Wearing personal protective equipment as directed by the principal investigator.
- At a minimum, wearing safety glasses at all times when in the laboratory.
- Reporting to the teaching assistant, faculty member, or department chemical hygiene officer/laboratory supervisor any accidents that result in the exposure to toxic chemicals, and/or any action or condition that may exist which could result in an accident.

1.3 DEFINITIONS

1.3.1 Laboratory Definition

For the purposes of this OSHA standard a laboratory is defined as a facility in which hazardous chemicals (defined below) are handled or manipulated in reactions, transfers, etc. in small quantities (containers that are easily manipulated by one person) on a non-production basis. Typically, multiple chemical procedures are used.

1.3.2 Hazardous Chemical Definition

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

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

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

* carcinogens

* reproductive toxins

* sensitizers

* hepatotoxins (liver)

* irritants

* corrosives

* neurotoxins (nerve)

* nephrotoxins (kidney)

* agents that act on the hematopoietic system (blood)

* agents that damage the lungs, skin, eyes, or mucus membranes

A chemical is considered a carcinogen or potential carcinogen if it is listed in any of the following publications (OSHA uses the term "select" carcinogen):

- National Toxicology Program, Annual Report on Carcinogens (latest edition)
- International Agency for Research on Cancer, Monographs (latest edition)
- OSHA, 29 CFR 1910.1001 to 1910.1101, Toxic and Hazardous Substances

A chemical is considered hazardous, according to the OSHA standard, if it is listed in any of the following:

- OSHA, 29 CFR 1910.1000 Table Z-1 through Z-3
- Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment, ACGIH (latest edition)
- The Registry of Toxic Effects of Chemical Substances, NIOSH (latest edition)

Over 600,000 chemicals are considered hazardous by the OSHA definition.

In most cases, the chemical container's original label will indicate if the chemical is hazardous. Look for key words like caution, hazardous, toxic, dangerous, corrosive, irritant, carcinogen, etc. Containers of hazardous chemicals acquired or manufactured before 1985 may not contain appropriate hazard warnings.

If you are not sure a chemical you are using is hazardous, review the Material Safety Data Sheet for the substance or contact your supervisor.

1.4 HAZARD IDENTIFICATION

Some laboratories may synthesize or develop new chemical substances on occasion. If the composition of the substance is known and will be used exclusively in the laboratory, the laboratory worker must label the substance and determine, to the best of his/her abilities, the hazardous properties (e.g., corrosive, flammable, reactive, toxic, etc.) of the substance. This can often be done by comparing the structure of the new substance with the structure of similar materials with known hazardous properties. If the chemical produced is of unknown composition, it must be assumed to be hazardous and appropriate precautions taken.

If a chemical substance is produced for another user outside this facility, the laboratory producing the substance is required to provide as much information as possible regarding the identity and known hazardous properties of the substance to the receiver of the material.

1.5 TRAINING & INFORMATION

1.5.1 Chemical Safety Training

All faculty, staff, and students who work in any laboratory where hazardous chemicals are stored or used must read and understand the Chemical Hygiene Plan and pertinent Material Safety Data Sheets, MSDS. Other safety awareness may include Hazardous Waste, Radiation Safety, and Biological Safety. The principal investigator of the laboratory is responsible to ensure that all laboratory personnel complete the required training. In addition, principal investigators must ensure that undergraduate students, high school students, and visitors are sufficiently informed and aware of potential hazards in the lab and receive appropriate safety awareness training.

When an employee is to perform a non-routine task presenting hazards for which he or she has not already been trained, the employee's supervisor will be responsible for discussing with the employee the hazards of the task and any special measures (e.g., personal protective equipment or engineering controls) that should be used to protect the employee.

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

1.5.2 Underage Personnel

Any person under the age of 16 will generally not be allowed to work in a laboratory where hazardous chemicals are stored or used. The Chemical Hygiene Officer must approve any exceptions to this requirement. For laboratories that utilize radioactive materials, no one under the age of 18 is allowed to work in the laboratory. Underage personnel, including high school students or visitors, must be directly supervised by faculty, staff or graduate students at all times.

1.5.3 Chemical Safety Information Sources

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

1. special health and safety reference literature available in the Chemical stockroom;
2. the labels found on containers of hazardous chemicals;
3. the substance's Material Safety Data Sheet; and
4. laboratory signs.

In addition, your supervisor is available to provide safety information. Each of these sources is now discussed in greater detail.

1.5.3.1 Safety Reference Literature

The Chemical Stockroom maintains a library of reference materials addressing chemical health and safety issues. One of the references contains all applicable chemical workplace exposure standards and recommended exposure levels. Another reference contains a copy of OSHA's laboratory safety standard and its appendices. Material Safety Data Sheets received from suppliers are available online and in the main office of Hurst Hall.

1.5.3.2 Container Labeling

All containers of hazardous chemicals that could pose a physical or health hazard to an exposed employee must have a label attached. Labels on purchased hazardous chemicals must include:

1. the common name of the chemical;
2. the name, address and emergency phone number of the company responsible for the product; and
3. an appropriate hazard warning.

The warning may be a single word – “danger”, “warning” and “caution” - or may identify the primary hazard, both physical (i.e., water reactive, flammable or explosive) and health (i.e., carcinogen, corrosive, or irritant).

Most labels will provide you with additional safety information to help you protect yourself while working with this substance. This includes protective measures to be used when handling the material, clothing that should be worn, first aid instructions, storage information and procedures to follow in the event of a fire, leak or spill.

If you find a container with no label, report it to your supervisor. You should also report labels that are torn or illegible so that the label can be replaced immediately. Existing labels on new containers of hazardous chemicals should never be removed or defaced, *except when empty!* If you use secondary working containers that will take more than one work shift to empty, or if there is a chance that someone else will handle the container before you finish it, you must label it. This is part of your responsibility to help protect co-workers. If you need labels for these types of containers, Cornell University (http://beta.ehs.cornell.edu/labels/cgi-bin/label_selection.pl) has an excellent site for printing up your own chemical labels.

Read the label each time you use a newly purchased chemical. It is possible the manufacturer may have added new hazard information or reformulated the product since your last purchase, and thus altered the potential hazards you face while working with the product.

All employees involved in unpacking chemicals are responsible for inspecting each incoming container to insure that it is labeled with the information outlined above. The principal investigators or department chemical hygiene officer/laboratory supervisors should be notified if containers do not have proper labels (See Laboratory Chemical Labeling Requirements).

1.5.3.3 Material Safety Data Sheets

A Material Safety Data Sheet, often referred to by its acronym MSDS, is a detailed informational document prepared by the manufacturer or importer of a hazardous chemical that describes the physical and chemical properties of the product. Information included in a Material Safety Data Sheet aids in the selection of safe products, helps employers and employees understand the potential health and physical hazards of a chemical and describes how to respond effectively to exposure situations. Material Safety Data Sheets can be accessed through the main office in Hurst Hall, or you can look up your chemical on the internet (http://www.western.edu/chemistry/hygiene/msds.htm). All laboratory personnel within a research group must be able to access this site or they will be required to keep hard copies of MSDS's for each chemical they use or store in the laboratory.

The format of a Material Safety Data Sheet may vary but there is specific information that must be included in each sheet. It is useful to review this information to increase your ability to use a Material Safety Data Sheet.

<u>All Material Safety Data Sheets should include the following information:</u>

Section I of the MSDS lists information identifying the manufacturer and the product.

- Manufacturer's name, address and telephone number
- Number to call in case of emergency involving product
- Chemical name and synonyms
- Trade name and synonyms
- Chemical family and formula
- CAS number (Chemical Abstract Service) for pure materials

Section II describes the various hazardous ingredients contained in the product, the percentages, and exposure limits when appropriate. All hazardous chemicals that comprise 1% or greater of the mixture will be identified. Carcinogens will be listed if their concentrations are 0.1% or greater. If a component is not listed, it has been judged to be non-hazardous or is considered proprietary information by the manufacturer. The types of components that might be listed include:

- Pigments, catalysts, vehicles, solvents, additives, others
- Base metals, alloys, metallic coatings, fillers, hazardous mixtures of other liquids, solids or gases

Section III describes the physical properties of the material.

- Boiling point	- Specific gravity
- Vapor pressure	- Percent volatile
- Vapor density	- Evaporation rate
- Solubility in water	- Appearance and odor

Section IV describes the fire and explosion hazard data for the material. Based on the flash point and other fire and explosion data, the appropriate extinguishing agent for fires involving the material will be listed. Special procedures may also be listed.

- Flash point
- Lower and upper explosive limits (LEL/UEL)
- Extinguishing agent - water, dry chemical, foam, halon, etc.
- Unusual fire and explosion hazards, toxic fumes

Section V describes the known health hazards associated with the material, applicable exposure limits and symptoms/health effects associated with overexposure. This information will help the user and medical personnel recognize if an overexposure has occurred.

- Threshold Limit Value
- Effects of overexposure: headache, nausea, narcosis, irritation, weakness, etc.
- Primary routes of exposure: inhalation, skin, ingestion
- Cancer or other special health hazards
- Emergency and first aid procedures for ingestion, inhalation and skin or eye contact

Section VI describes reactivity data; that is, the material's ability to react and release energy or heat under certain conditions or when it comes in contact with certain substances.

- Stability: stable, unstable, conditions to avoid
- Incompatibility: materials to avoid
- Hazardous decomposition products
- Hazardous polymerizations: conditions to avoid

Section VII gives instructions for the steps to be taken in case of an accidental release or spill. The steps normally include information on containment, evacuation procedures and waste disposal as appropriate. The statements on the Material Safety Data Sheet are very general; more specific information is available from your supervisor or the Department Chemical Hygiene Officer/Laboratory Supervisor.

- Steps to be taken in case material is released or spilled
- Waste disposal methods

Section VIII describes the protective equipment for the individual who might have to work with the substance. This section normally describes worst case conditions; therefore, the extent to which personal protective equipment is required is task dependent. Contact your supervisor or department Chemical Hygiene Officer/Laboratory Supervisor for specific instructions if you are unsure.

- Respiratory equipment: dust mask, chemical cartridge respirator, self-contained breathing apparatus
- Ventilation: local, general, special
- Protective gloves: type, fabrication material
- Eye protection: goggles, face shield
- Other protective equipment

Section IX describes handling and storage procedures to be taken with the material. Information may include statements, such as: keep container closed; store in a cool, dry, well ventilated area, keep refrigerated (caution: flammable solvents require a "flammable storage refrigerator"), avoid exposure to sunlight, etc.

Section X describes any special precautions or miscellaneous information regarding the material.

Manufacturers may withhold certain information as proprietary (such as hazardous ingredients) on a Material Safety Data Sheet if the information is considered a trade secret. The Chemical Hygiene Officer has a legal right to obtain this information from the manufacturer to evaluate the potential health risk if potential overexposure or adverse health effects are suspected.

1.5.3.4 Laboratory Signs

Prominent signs of the following types should be posted in each laboratory:

- NFPA hazardous warning information and telephone numbers of emergency personnel/facilities, supervisors, and laboratory workers;
- Signs identifying locations of safety showers, eyewash stations, other safety and first aid equipment, and exits;
- Warnings at areas or equipment where special or unusual hazards exist.

1.6 CHEMICAL EXPOSURE ASSESSMENT

Regular environmental or employee exposure monitoring of airborne concentrations is not usually warranted or practical in laboratories because chemicals are typically used for relatively short time periods and in small quantities. However, sampling may be appropriate when a highly toxic substance is either used regularly (3 or more separate handling sessions per week), used for an extended period of time (greater than 3 to 4 hours at a time), or used in especially large quantities. Notify the Chemical Hygiene Officer if you are using a highly toxic substance in this manner.

The exposures to laboratory employees who suspect and report that they have been overexposed to a toxic chemical in the laboratory, or are displaying symptoms of overexposure to toxic chemicals, will also be assessed. The assessment will initially be qualitative and, based upon the professional judgment of the Chemical Hygiene Officer, may be followed up by specific quantitative monitoring. A memo, or report, documenting the assessment will be sent to the employees involved and their supervisors within fifteen days of receipt of the results. A copy will be stored in a central exposure records file maintained by the Office of Environmental Health and Safety.

Individual concerns about excessive exposures occurring in the laboratory should be brought to the attention of your supervisor or the Chemical Hygiene Officer immediately.

1.7 MEDICAL CONSULTATION & EXAMINATION

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

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

Individuals with life threatening emergencies should dial 9-911 for emergency transport to the hospital. All accidents resulting in injuries, which require medical treatment (including first aid) should be reported immediately to your supervisor and the Chemical Hygiene Officer or the Hazardous Materials Response (Henry Case, 209-8836). Medical examination/consultation visits (non-life threatening) will be handled by the Health Center. Appointments can be arranged by contacting the health center. Medical exams and consultations shall be done by or under direct supervision of a licensed physician at no cost to the employee.

Where medical consultations or examinations are provided, the examining physician shall be provided with the following information:

1. the identity of the hazardous chemical(s) to which the employee may have been exposed;
2. the exposure conditions; and
3. the signs and symptoms of exposure the laboratory employee is experiencing, if any.

1.8 CHEMICAL (FUME) HOOD EVALUATION

Every laboratory ventilation hood used for the control of air contaminants shall be tested once per year to assure that adequate airflow is being maintained to provide continued protection against employee over-exposure. Laboratory hood airflow shall be considered adequate when the average face velocity equals a minimum of a 100 feet/minute with the hood sash at a working height (14 to 20 inches). Other local exhaust ventilation, such as instrument vents, will also be tested. Results of laboratory ventilation tests shall be recorded and maintained by the Chemical Hygiene Officer.

1.9 RESPIRATORY PROTECTION PROGRAM

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

Respirator use depends on the following components: exposure assessment; respirator selection; medical approval and surveillance; fit testing; user training; inspection/repair; cleaning/disinfection; and storage. Each of these components is required by OSHA's respiratory protection standard (29 CFR 1910.134) in all situations where respirators are used. If you have questions concerning the use of respirators or any of the components, contact your supervisor or the Chemical Hygiene Officer.

1.10 RECORDKEEPING

All exposure assessments and occupational medical consultation/examination reports will be maintained in a secure area in accordance with OSHA's medical records rule (29 CFR 1910.20).

SECTION 2

STANDARD OPERATING PROCEDURES FOR WORKING WITH CHEMICALS

2.1 GOOD WORK PRACTICES/PROCEDURES FOR HANDLING LABORATORY CHEMICALS

2.1.1 General Guidelines

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

- Do not work alone in the laboratory. If you must work alone or in the evening, let someone else know and have them periodically check on you.
- Anyone considering running an experiment unattended should consider the possible hazards that could occur as a result of failures, malfunctions, operational methods, environments encountered, maintenance error and operator.
- Label all secondary chemical containers with appropriate identification and hazard information (see Section I, Container Labeling).
- Use only those chemicals for which you have the appropriate exposure controls (such as a chemical fume hood) and administrative programs/procedures (training, restricted access, etc.). Always use adequate ventilation with chemicals. Operations using large quantities (500 milliliters) of volatile substances with workplace standards at or below 50 ppm should be performed in a chemical fume hood.

- Use hazardous chemicals and all laboratory equipment only as directed or for their intended purpose.
- Inspect equipment or apparatus for damage before adding a hazardous chemical. Do not use damaged equipment.
- Inspect personal protective apparel and equipment for integrity or proper functioning before use.
- Malfunctioning laboratory equipment (hood) should be labeled or tagged "out of service" so that others will not inadvertently use it before repairs are made.
- Handle and store laboratory glassware with care. Do not use damaged glassware. Use extra care with Dewar flasks and other evacuated glass apparatus; shield or wrap them to contain chemicals or fragments should implosion occur.
- Do not purchase or dispense more of a hazardous chemical than is needed for immediate use.

2.1.2 Supervision

1. To ensure that liability risk is properly managed, qualified supervisors must fulfill their inherit responsibilities to ensure that all activities with hazardous materials and/or in potentially hazardous work environments are done in compliance with environmental/occupational health regulations.
2. Qualified supervisors need to be Western Colorado University employees who actively participate in the applicable safety programs by attending safety training/awareness sessions. They are assigned responsibility and authority from their department to conduct routine safety audits of work areas, provide oversight of all activities in assigned work areas, and take necessary action to abate unsafe activities or conditions. Qualified supervisors can include faculty, staff, and graduate students.
3. Visitors, high school and undergraduate students, and any other 'non-employee' must be properly supervised at all times when working in laboratories and work shops.
4. Everyone who is allowed access to a laboratory or workshop must be provided with the applicable safety awareness information by the area/project supervisor or must attend a scheduled training session provided by the department or the office of Environmental Health & Safety.
5. Departments must ensure that proper supervision is provided during Western Colorado University affiliated activities conducted off campus. Do not work alone in the laboratory. If you must work alone or in the evening let someone else know and have them periodically check on you.

2.1.3 Personal Hygiene

- Remove contaminated clothing and gloves before leaving laboratory.
- Avoid direct contact with any chemical. Keep chemicals off your hands, face and clothing, including shoes. Never smell, inhale or taste a hazardous chemical. Wash thoroughly with soap and water after handling any chemical.

- Smoking, drinking, eating and the application of cosmetics is forbidden in laboratories where hazardous chemicals are used.
- Never pipet by mouth. Use a pipet bulb or other mechanical pipet filling device.

2.1.4 Housekeeping

- Keep floors clean and dry.
- Keep all aisles, hallways, and stairs clear of all chemicals. Stairways and hallways should not be used as storage areas.
- Keep all work areas, and especially work benches, clear of clutter and obstructions.
- All working surfaces should be cleaned regularly.
- Access to emergency equipment, utility controls, showers, eyewashes and exits should never be blocked.
- Wastes and broken glassware should be kept in the appropriate containers and labeled properly.
- Any unlabeled containers must be labeled if it is not under your supervision or at the end of each working day.

2.2 WHEN NOT TO PROCEED WITHOUT REVIEWING SAFETY PROCEDURES

Sometimes laboratory workers should not proceed with what seems to be a familiar task. Hazards may exist that are not fully recognized. Certain indicators (procedural changes) should cause the employee to stop and review the safety aspects of their procedure. These indicators include:

- A new procedure, process or test, even if it is very similar to older practices.
- A change or substitution of any of the ingredient chemicals in a procedure.
- A substantial change in the amount of chemicals used (scale up of experimental procedures); usually, one should review safety practices if the volume of chemicals used increases by 200%.
- A failure of any of the equipment used in the process, especially safeguards such as chemical hoods.
- Unexpected experimental results (such as a pressure increase, increased reaction rates, unanticipated byproducts). When an experimental result is different from the predicted, a review of how the new result impacts safety practices should be made.
- Chemical odors, illness in the laboratory staff that may be related to chemical exposure or other indicators of a failure in engineered safeguards.

The occurrence of any of these conditions should cause the laboratory employee to pause, evaluate the safety implications of these changes or results, make changes as necessary and proceed cautiously.

2.3 PROTECTIVE CLOTHING AND LABORATORY SAFETY EQUIPMENT

2.3.1 General Consideration - Personal Protective Clothing/Equipment

Personal protective clothing and equipment should be selected carefully and used in situations where engineering and administrative controls cannot be used or while such controls are being established. These devices are viewed as less protective than other controls because they rely heavily on each employee's workpractices and training to be effective. The engineering and administrative controls which should always be considered first when reducing or eliminating exposures to hazardous chemicals include:

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

The Material Safety Data Sheet (MSDS) will list the personal protective equipment (PPE) recommended for use with the chemical. The MSDS addresses worst case conditions. Therefore, all the equipment shown may not be necessary for a specific laboratory scale task.

Your supervisor, other sections of this manual or the Chemical Hygiene Officer can assist you in determining which personal protective devices are required for each task. Remember, there is no harm in being overprotected. Appropriate personal protective equipment will be provided to employees.

2.3.2 Protection of Skin and Body

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

2.3.2.1 Normal clothing worn in the laboratory

Where there is no immediate danger to the skin from contact with a hazardous chemical it is still prudent to select clothing to minimize exposed skin surfaces. Employees should wear long sleeved/long legged clothing and avoid short sleeved shirts, short trousers or skirts. A laboratory coat should be worn over street clothes and be laundered regularly. A laboratory coat is intended to prevent contact with dirt, chemical dusts and minor chemical splashes or spills. If it becomes contaminated, it should be removed immediately and the affected skin surface washed thoroughly. Shoes should be worn in the laboratory at all times. Sandals and perforated shoes are not appropriate. In addition, long hair and loose clothing should be confined.

2.3.2.2 Protective clothing

Additional protective clothing may be required for some types of procedures or with specific substances (such as when carcinogens, cryogens or large quantities of corrosives, oxidizing agents or organic solvents are handled). This clothing may include impermeable aprons, face shield and gloves as well as plastic coated coveralls, shoe covers, and arm sleeves. Protective sleeves should always be considered when wearing an apron. These garments can either be washable or disposable in nature. They should never be worn outside the laboratory. The choice of garment depends on the degree of protection required and the areas of the body, which may become contaminated. Rubberized aprons, plastic coated coveralls, shoe covers, and arm sleeves offer much greater resistance to permeation by chemicals than laboratory coats and, therefore, provide additional time to react (remove the garment and wash affected area) if contaminated.

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

Chemical resistant and special gloves should be worn whenever the potential for contact with corrosive, cryogen or toxic substances and substances of unknown toxicity exists. Gloves should be selected on the basis of the materials being handled, the particular hazard involved, and their suitability for the operation being conducted. Before each use, gloves should be checked for integrity. Gloves should be washed prior to removal whenever possible to prevent skin contamination. Non-disposable gloves should be replaced periodically, depending on frequency of use and their resistance to the substances handled.

Protective garments are not equally effective for every hazardous chemical. Some chemicals will "break through" the garment in a very short time. Therefore, garment and glove selection is based on the specific chemical utilized. General selection criteria are as follows:

GLOVE TYPE SELECTION GUIDE

S - Superior E - Excellent G - Good F - Fair NR - Not Recommended

CHEMICAL FAMILY	BUTYL RUBBER	NEOPRENE	PVC (VINYL)	NITRILE	NATURAL LATEX
Acetates	G	NR	NR	NR	NR
Acids, inorganic	G	E	E	E	E
Acids, organic	E	E	E	E	E
Acetonitrile, Acrylonitrile	G	E	G	S	E
Alcohols	E	E	NR	E	E
Aldehydes	E	G	NR	S*	NR
Amines	S	NR	NR	F	NR
Bases, inorganic	E	E	E	E	E
Ethers	G	F	NR	E	NR
Halogens (liquids)	G	NR	F	E	NR
Inks	G	E	E	S	F
Ketones	E	G	NR	NR	G

Nitro compounds (Nitrobenzene, Nitromethane)	G	NR	NR	NR	NR
Oleic Acid	E	E	F	E	NR
Phenols	E	E	NR	NR	G
Quinones	NR	E	G	E	E
Solvents, Aliphatic	NR	NR	F	G	NR
Solvents, Aromatic	NR	NR	F	F	NR

**Not recommended for Acetaldehyde, use Butyl Rubber*

Contact the Chemical Hygiene Officer for personal protection equipment selection assistance or information.

2.3.3 Protection of the Eyes

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

Contact lenses can increase the risk of eye injury if worn in the laboratory - particularly if they are of the gas permeable variety. Gases and vapors can be concentrated under such lenses and cause permanent eye damage. Chemical splashes to the eye can get behind all types of lenses. Once behind a lens the chemical is difficult to remove with a typical eye wash. For these reasons it is recommended that contact lenses not be worn in laboratories.

Eye and face injuries are prevented by the use of the following:

COMPARISON CHART -- EYE PROTECTION DEVICES

Type of Hazard	Goggles	Glasses (no shields)	Glasses (shields)	Face shield (various sizes)
Front Splash	Excellent	Good	Good	Excellent
Side Splash	Excellent	Poor	Good	Excellent
Front flying impact	Excellent	Excellent	Good	Excellent (if adequate thickness)
Side impact	Excellent	Poor	Fair	Good to excellent

Neck/Face	Poor	Poor	Poor	Depend on length
Comfort to Wearer	Fair	Good to excellent	Good	Fair
User Acceptance	Poor	Very Good	Good	Good for Short Periods
Use Lifetime	Fair	Very Good	Good	Fair
Cost	Moderate	Moderate	Moderate	Moderate

SOURCE: ANSI Z87.1(1989) Occupational and Educational Eye and Face Protection, available from American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018

2.3.4 Protection of the Respiratory System

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

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

Take appropriate precautions before using these substances. Controlling inhalation exposures via engineering controls (ventilation) is always the preferred method (See Section 2.3.5.1). As with other personal protective equipment, respiratory protection relies heavily on employee work practices and training to be effective.

Use of Respirators

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

Types of respiratory protective equipment include:

- Particle-removing air purifying respirators
- Gas and vapor-removing air purifying respirators
- Atmosphere supplying respirators

Respirators are not to be used except in conjunction with a complete respiratory protection program as required by OSHA. If your work requires the use of a respirator, contact your supervisor or the Chemical Hygiene Officer. See Section 1.9 for additional information.

2.3.5 Laboratory Safety Equipment

2.3.5.1 Chemical (Fume) Hoods

In the laboratory, the chemical hood is the primary means of controlling inhalation exposures. Hoods are designed to retain vapors and gases released within them, protecting the laboratory employee's breathing zone from the contaminant. This protection is accomplished by having a curtain of air (approximately 100 linear feet per minute) move constantly through the face (open sash) of the hood. Chemical hoods can also be used to isolate apparatus or chemicals that may present physical hazards to employees. The closed sash on a hood serves as an effective barrier to fires, flying objects, chemical splashes or spattering and small implosions and explosions. Hoods can also effectively contain spills which might occur during dispensing procedures particularly if trays are placed in the bottom of the hoods.

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

- Keep all chemicals and apparatus at least six inches inside the hood (behind sash).
- Hoods are not intended for storage of chemicals. Materials stored in them should be kept to a minimum. Stored chemicals should not block vents or alter air flow patterns.
- Keep the hood sash at a minimum height (4 to 6 inches) when not manipulating chemicals or adjusting apparatus within the hood.
- When working in front of a fume hood, make sure the sash opening is appropriate. This can be achieved by lining up to arrows placed on the sash door and hood frame. This sash opening will ensure an adequate air velocity through the face of the hood.
- Do not allow objects such as paper to enter the exhaust ducts. This can clog ducts and adversely affect their operation.

Follow the chemical manufacturer's or supplier's specific instructions for controlling inhalation exposures with ventilation (chemical fume hood) when using their products. These instructions are located on the products MSDS and/or label. However, it should be noted that these ventilation recommendations are often intended for non-laboratory work environments and must be adapted to suit the laboratory environment as well as the specific procedure or process.

If specific guidance is not available from the chemical manufacturer or supplier, or if the guidance is inappropriate for the laboratory environment, contact the Chemical Hygiene Officer and/or review the hood use guidelines in the table below. These guidelines are based on information readily available on a chemical's MSDS:

1. applicable workplace exposure standards [Threshold Limit Values (TLV) or Permissible Exposure Limits (PEL)];
2. acute and chronic toxicity data (LD_{50} and specific organ toxicity); and
3. potential for generating airborne concentrations (vapor pressure).

These terms are defined in the glossary at the back of this manual. The guidelines outlined in the table below should not be considered as necessary or appropriate in every case, but as reasonable "rules of thumb".

Guidelines For Chemical (Fume) Hood Use

It may be appropriate to use a hood when handling the type of substance listed in column 1 if the exposure standard or toxicological criteria in column 2 applies.	
Column 1	**Column 2**
Type Substance & Handling Procedure	**Exposure Standard or Toxicity of Substance**
Substance handled is solid, liquid or gaseous **and** when other effective controls are not being used.	TLV or PEL < 5 ppm (vapor) or < 0.2 mg/M^3 (particulate) **or** oral LD_{50} < 10 mg/Kg (rat or mouse) (see note 1 below) **or** chemicals handled are respiratory sensitizers.
Substance handled is liquid or gaseous **and** it is handled in large quantities (greater than 500 milliliters) or the procedure used could release the substance to the laboratory atmosphere (heating) **and** you may be exposed to the substance (handling it in open containers) for an extended period of time (greater than 2 hrs. per day).	TLV or PEL >5 but < 50 ppm **or** substances handled are toxic to specific organ systems, carcinogens or reproductive toxins with a vapor pressure exceeding 25 mm Hg at 25°C. **or** oral LD_{50} >10 but < 500 mg/Kg (rat or mouse)(see note 1 below)
Substance handled is a solid **and** the particle size of the material is small (respirable) or consistency of the material is "light and fluffy" and the procedure used may generate airborne particulates.	TLV or PEL >0.2 but < 2 mg/M^3 **or** oral LD_{50} >10 but < 50 mg/Kg (rat or mouse)(see note 1 below)

Note 1: The oral LD_{50} hood use criteria has been included because it is often the only toxicological data available on a Material Safety Data Sheet. The species of animals most often used in these acute toxicity tests are the rat and/or the mouse. The LD_{50} criterion outlined in the table is a reasonable "rule of thumb" for materials that require control due to their acute toxicity characteristics. LD_{50} data should only be used if other criteria are unavailable.

2.3.5.2 Eyewashes and Safety Showers

Whenever chemicals have the possibility of damaging the skin or eyes, an emergency supply of water must be available. All laboratories in which bulk quantities of hazardous chemicals are handled and could contact the eyes or skin resulting in injury should have access to eyewash stations and safety showers. As with any safety equipment, these can only be useful if they are accessible, therefore:

- Keep all passageways to the eyewash and shower clear of any obstacle (even a temporarily parked chemical cart).
- The eyewash should be checked routinely to be certain that water flows through it.
- Showers should be checked routinely to assure that access is not restricted and that the pull chain/bar is within reach.
- The flow through the safety showers should be tested periodically to ensure sufficient flow (approximately 30 gallons per minute).

Eyewashes and showers should be checked twice yearly.

2.3.5.3 Fire Safety Equipment

Fire safety equipment easily accessible in the laboratory must include a fire extinguisher (type ABC) and may include fire hoses, fire blankets, and automatic extinguishing systems.

2.4 CHEMICAL PROCUREMENT, DISTRIBUTION AND STORAGE

2.4.1 Procurement

Before a new substance that is known or suspected to be hazardous is received, information on proper handling, storage, and disposal should be known to those who will handle it. It is the responsibility of the supervisor to ensure that the laboratory facilities in which the substance will be handled are adequate and that those who will handle the substance have received the proper training. The necessary information on proper handling of hazardous substances can be obtained from the Material Safety Data Sheets that are provided by the vendor. Because storage in laboratories is restricted to small containers, order small-container lots to avoid hazards associated with repackaging. No container should be accepted without an adequate identifying label as outlined in Section 1.5.3.2 of this manual.

2.4.2 Distribution

When hand-carrying open containers of hazardous chemicals or unopened containers with corrosive or highly acutely or chronically toxic chemicals, place the container in a secondary container or a bucket. Rubberized buckets are commercially available and provide both secondary containment as well as “bump” protection (these are available in the stockroom). If several bottles must be moved at once, the bottles should be transported on a small cart with a substantial rim to prevent slippage from the cart. Wherever available, a freight elevator should be used to transport chemicals from one floor to another.

2.4.3 Chemical Storage in the Laboratory

Carefully read the label before storing a hazardous chemical. The MSDS will provide any special storage information as well as information on incompatibilities. *Do not store unsegregated chemicals in alphabetical order. Do not store incompatible chemicals in close proximity to each other.*

Separate hazardous chemicals in storage as follows:

Solids:

- oxidizers
- flammable solids (red phosphorus, magnesium, lithium)

- water reactive
- others

Liquids:

- acids
- oxidizers
- flammable/combustible
- caustics
- perchloric acid

Gases:

- toxic
- oxidizers and inert
- flammable

Once separated into the above hazard classes, chemicals may be stored alphabetically.

Use approved storage containers and safety cans for flammable liquids. It is preferable to store flammable chemicals in flammable storage cabinets. *Flammable chemicals requiring refrigeration should be stored only in the refrigerators and freezers specifically designed for flammable storage.*

A good place to store hazardous chemicals is a vented cabinet under the hood. Chemicals of different chemical classes can be segregated by placing them in trays. Do not store chemicals on bench tops or in hoods. Liquids (particularly corrosives or solvents) should not be stored above eye level.

Use secondary containers (one inside the other) for especially hazardous chemicals (carcinogens, etc.). Use spill trays under containers of strong reagents.

Avoid exposure of chemicals while in storage to heat sources (especially open flames) and direct sunlight.

Conduct annual inventories of chemicals stored in the laboratory and dispose of old or unwanted chemicals promptly in accordance with the facility's hazardous chemical waste program.

Ensure that all containers are properly labeled.

2.4.3.1 Chemical Storage - Chemical Stability

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

Special note: peroxide formers- Ethers, liquid paraffin and olefins form peroxides on exposure to air and light. Peroxides are extremely sensitive to shock, sparks, or other forms of accidental ignition (even more sensitive than primary explosives such as TNT). Since these chemicals are packaged in an air atmosphere, peroxides can form even though the containers have not been opened. Unless an inhibitor was added by the manufacturer, sealed containers of ethers should be discarded after one (1) year. Opened containers of ethers should also be discarded within one (1) year of opening. All such containers should be dated upon receipt and upon opening (see Peroxidizable Compounds Fact Sheet and Appendix D).

See Section 3.2, Highly Reactive Chemicals and High energy Oxidizers for additional information and examples of materials that may form explosive peroxides.

For additional information on chemical stability, contact your supervisor or the Chemical Hygiene Officer.

2.4.3.2 Chemical Storage - Incompatible Chemicals

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

CHEMICAL	KEEP OUT OF CONTACT WITH
Acetic Acid	Chromic acid, nitric acid hydroxyl compounds, ethylene, glycol, perchloric acid, peroxides, permanganates
Acetone	Concentrated nitric and sulfuric acid mixtures
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali Metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, the halogens
Ammonia, anhydrous	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium Nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Arsenical materials	Any reducing agent
Azides	Acids
Bromine	Same as chlorine
Calcium Oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents.
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organic or combustible materials
Chromic Acid	Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids in general
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Chlorine Dioxide	Ammonia, methane, phosphine, hydrogen sulfide

CHEMICAL	KEEP OUT OF CONTACT WITH
Copper	Acetylene, hydrogen peroxide
Cumene Hydroperoxide	Acids, organic or inorganic
Cyanides	Acids
Flammable Liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic Acid	Nitric acid, alkali
Hydrofluoric Acid	Ammonia, aqueous or anhydrous
Hydrogen Peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidizing gases
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases, acetylene, ammonia (aqueous or anhydrous), hydrogen
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitrates	Sulfuric acid
Nitric Acid (concentrated)	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases
Nitrites	Acids
Nitroparaffins	Inorganic bases, amines
Oxalic Acid	Silver, mercury
Oxygen	Oils, grease, hydrogen; flammable liquids, solids, or gases
Perchloric Acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorus (white)	Air, oxygen, alkalies, reducing agents
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium Chlorate	Sulfuric and other acids
Potassium Permanganate	Glycerin, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds

CHEMICAL	KEEP OUT OF CONTACT WITH
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium Peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric Acid	Potassium chlorate, potassium perchlorate, potassium permanganate (or compounds with similar light metals, such as sodium, lithium, etc.)
Tellurides	Reducing agents

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

2.5 CHEMICAL SPILLS & ACCIDENTS

2.5.1 General Information

Try to anticipate the types of chemical spills that can occur in your laboratory and obtain the necessary equipment (spill kits and personal protective equipment) to respond to a minor spill. Learn how to clean up minor spills of the chemicals you use regularly safely. A MSDS contains special spill clean-up information and should also be consulted. *Chemical spills should only be cleaned up by knowledgeable and experienced personnel.*

If the spill is too large for you to handle, is a threat to health safety or the environment, or involves a highly toxic or reactive chemical, call for assistance immediately:

Henry Case, Hazardous Materials (tel: 209-8836; 943- 7039)

Or 9-911

2.5.2 Cleaning Up Chemical Spills

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

2.5.3 Minor Chemical Spill

If a spill is minor and not a significant hazard:

- Alert people in immediate area of spill.
- Increase ventilation in area of spill (open windows, turn on hoods).
- Wear personal protective equipment, including safety goggles, gloves and long-sleeve lab coat.
- Avoid breathing vapors from spill.

- Use appropriate kit to neutralize and absorb inorganic acids and bases. Collect residue, place in container, and dispose as hazardous chemical waste.
- For other chemicals, use appropriate kit or absorb spill with vermiculite, dry sand, diatomaceous earth or paper towels. Collect residue, place in container, and dispose as chemical waste.
- Clean spill area with water.

2.5.4 Major Chemical Spill

- Attend to injured or contaminated persons and remove them from exposure.
- Alert people in the laboratory to evacuate.
- If spilled material is flammable, turn off ignition and heat sources. Place other device (plastic bag) over spilled material to keep substance from volatilizing.
- Call Henry Case , Hazardous Materials (tel: 209-8836; 943- 7039) r 9-911
- Close doors to affected area.
- Have a person with knowledge of the incident and laboratory available to answer questions from responding emergency personnel.

2.5.5 Mercury Spills

Use a vacuum line with an in-line dry trap attached to a tapered glass tube similar to a medicine dropper to pick up mercury droplets. The Chemistry Stockroom has a mercury vacuum and other mercury spill clean-up supplies available for laboratory personnel to use to handle mercury spills. *Do not use a domestic or commercial vacuum cleaner.*

Cover small droplets in inaccessible areas with one of the following:

- Powdered sulfur
- Powdered zinc

Place residue in a labeled container and dispose of as hazardous chemical waste.

2.5.6 Alkali Metal Spills

Smother with powdered graphite, sodium carbonate, calcium carbonate or “Met-L-X”. Call the Chemical Hygiene Officer for assistance.

2.5.7 White Phosphorus

Smother with wet sand or wet “noncombustible” absorbent. Call the Chemical Hygiene Officer for assistance.

2.6 PERSONAL CONTAMINATION AND INJURY

2.6.1 General Information

Know the locations of the nearest safety shower and eye wash fountain.

Report all incidents and injuries to your supervisor.

If an individual is contaminated or exposed to a hazardous material in your laboratory, do what is necessary to protect their life and health as well as your own. Determine what the individual was exposed to. The MSDS will contain special first aid information.

Do not move an injured person unless they are in further danger (from inhalation or skin exposure).

A blanket should be used immediately to protect the victim from shock and exposure.

Get medical attention promptly by dialing 9-911.

2.6.2 Chemicals Spills on the Body

- Quickly remove all contaminated clothing and footwear.
- Immediately flood the affected body area with cold water for at least 15 minutes. Remove jewelry to facilitate removal of any residual material.
- Wash off chemical with water only. ***Do not use*** *neutralizing chemicals, unguents, creams, lotions or salves.*
- Get medical attention promptly by dialing 9-911.

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

2.6.3 Chemical Splash in the Eye

- Irrigate the eyeball and inner surface of eyelid with plenty of cool water for at least 15 minutes. Use eyewash or other water source. Forcibly hold eyelids open to ensure effective wash.
- Check for and remove contact lenses.
- Get medical attention promptly.

2.6.4 Ingestion of Hazardous Chemicals

- Identify the chemical ingested.
- Call for an ambulance by dialing 9-911.
- Call the Poison Information Center by dialing 1-800-222-1222 (Rocky Mountain Poison & Drug Ctr www.rmpdc.org).
- Cover the injured person to prevent shock.
- Provide the ambulance crew and physician with the chemical name and any other relevant information. If possible, send the container, MSDS or the label with the victim.

2.6.5 Inhalation of Smoke, Vapors and Fumes

- Anyone overcome with smoke or chemical vapors or fumes should be removed to uncontaminated air and treated for shock.
- Do not enter the area if you expect that a life threatening condition still exists - oxygen depletion, explosive vapors or highly toxic gases (cyanide gas, hydrogen sulfide, nitrogen oxides, carbon monoxide)
- If CPR certified, follow standard CPR protocols.
- Get medical attention promptly.

2.6.6 Burning Chemicals on Clothing

- Extinguish burning clothing by using the drop-and-roll technique, by dousing with cold water, using a fire blanket, or use an emergency shower if it is immediately available.
- Remove contaminated clothing; however, avoid further damage to the burned area. If possible, send the clothing with the victim.
- Remove heat with cool water or ice packs until tissue around burn feels normal to the touch.
- Cover injured person to prevent shock.
- Get medical attention promptly.

2.6.7 Actions to be Avoided During Emergencies

There are some actions which must not be taken when handling emergencies. These include:

- Do not force any liquids into the mouth of an unconscious person.
- Do not handle emergencies alone, especially without notifying someone that the accident has occurred.
- Do not linger at the accident scene if you are not one of the emergency responders.

2.7 FIRE AND FIRE RELATED EMERGENCIES

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

- Notify the Fire Department by dialing 9-911.
- Activate the building alarm (fire pull station). If not available or operational, verbally notify people in the building.
- Isolate the area by closing windows and doors and evacuate the building.
- Shut down equipment in the immediate area, if possible.
- Use a portable fire extinguisher to:
    - assist oneself to evacuate;
    - assist another to evacuate; and
    - control a small fire, if possible.
- Provide the fire/police teams with the details of the problem upon their arrival. Special hazard information you might know is essential for the safety of the emergency responders.

If the fire alarms are ringing in your building:

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

2.8 HAZARDOUS WASTE DISPOSAL PROGRAM

Laboratory hazardous "chemical" waste must be disposed of in accordance with local, state, federal and Western Colorado University requirements. These waste management practices are designed to ensure maintenance of a safe and healthy environment for laboratory employees and the surrounding community without adversely affecting the environment. This is accomplished through regular removal of hazardous waste and disposal of these wastes in compliance with all regulations and policies. Specific guidance on how to identify, handle, collect, segregate, store and dispose of chemical waste is available from Henry Case (943-7039) or Jarral Ryter (943-2875, jryter@western.edu).

Remember:

- Hazardous waste must be disposed of in a timely manner.
- Hazardous waste containers must be closed at all times during storage, except when waste is being added or removed.
- All hazardous waste must be properly labeled at the time the waste is first placed in the container.
- Hazardous waste should be accumulated in a designated storage area consistent with applicable regulations.
- Hazardous waste regulations require separate training of personnel who generate or handle hazardous waste.
- Do not use sinks or rubbish bins for hazardous waste disposal.
- Generators of hazardous waste are required to incorporate waste minimization into any process that generates hazardous waste.

SECTION 3

HEALTH AND SAFETY INFORMATION FOR WORK WITH CHEMICALS OF SPECIFIC HAZARD CLASS

3.1 FLAMMABLE LIQUIDS

3.1.1 General Information

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

For a fire to occur, three distinct conditions must exist simultaneously:

1. the concentration of the vapor must be between the upper and lower flammable limits of the substance (the right fuel/air mix);
2. an oxidizing atmosphere, usually air, must be available; and
3. a source of ignition must be present.

Removal of any of these three conditions will prevent the start of a fire. Flammable liquids may form flammable mixtures in either open or closed containers or spaces (such as refrigerators), when leaks or spills occur in the laboratory, and when heated.

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

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

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

3.1.2 Special Handling Procedures

While working with flammable liquids you should wear gloves, protective glasses, and a long sleeved lab coat. Wear goggles if dispensing solvents or performing an operation that could result in a splash to the face.

Large quantities of flammable liquids should be handled in a chemical fume hood or under some other type of local exhaust ventilation. Five gallon containers <u>must be</u> dispensed to smaller containers in a hood or under local exhaust ventilation. When dispensing flammable solvents into small storage containers, use metal or plastic containers or safety cans (avoid glass containers).

Make sure that metal surfaces or containers through which flammable substances are flowing are properly grounded, discharging static electricity. Free flowing liquids generate static electricity which can produce a spark and ignite the solvent.

Large quantities of flammable liquids must be handled in areas free of ignition sources (including spark emitting motors and equipment) using non-sparking tools. Remember that vapors are denser than air and can travel to a distant source of ignition.

Never heat flammable substances by using an open flame. Instead, use any of the following heat sources: steam baths, water baths, oil baths, heating mantles or hot air baths.

Do not distill flammable substances under reduced pressure.

Store flammable substances away from ignition sources. The preferred storage location is in flammable storage cabinets. If no flammable storage cabinet is available, store these substances in a cabinet under the hood or bench. Five gallon containers should only be stored in a flammable storage cabinet or under a hood. You can also keep the flammable liquids inside the hood for a short period of time. Storage in chemical fume hood is not preferred because it reduces hood performance by obstructing air flow.

Oxidizing and corrosive materials should not be stored in close proximity to flammable liquids.

Flammable liquids should not be stored or chilled in domestic refrigerators and freezers but in units specifically designed for this purpose. It is acceptable to store or chill flammable in ultra-low temperature units.

If flammable liquids will be placed in ovens, make sure they are appropriately designed for flammable liquids (no internal ignition sources and/or vented mechanically).

3.2 HIGHLY REACTIVE CHEMICALS & HIGH ENERGY OXIDIZERS

3.2.1 General Information

Highly reactive chemicals include those, which are inherently unstable and susceptible to rapid decomposition as well as chemicals that under specific conditions can react alone, or with other substances in a violent, uncontrolled manner, liberating heat, toxic gases, or leading to an explosion. Reaction rates almost always increase dramatically as the temperature increases. Therefore, if heat evolved from a reaction is not dissipated, the reaction can accelerate out of control and possibly result in injuries or costly accidents.

Air, light, heat, mechanical shock (when struck, vibrated or otherwise agitated), water and certain catalysts can cause decomposition of some highly reactive chemicals, and initiate an explosive reaction. Hydrogen and chlorine react explosively in the presence of light. Alkali metals, such as sodium, potassium and lithium, react violently with water, liberating hydrogen gas. Examples of shock sensitive materials include acetylides, azides, organic nitrates, nitro compounds, and many peroxides.

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

Peroxide formers can form peroxides during storage and especially after exposure to the air (once opened). Peroxide forming substances include aldehydes, ethers (especially cyclic ethers), compounds containing benzylic hydrogen atoms, compounds containing the allylic structure (including most alkenes), vinyl and vinylidene compounds. Only buy the amount of these chemicals that are needed. Test the chemical for the presence of peroxides as listed in the appendix or on the web site every 3 or 6 months.

Examples of shock sensitive chemicals, a high energy oxidizers and substances which can form explosive peroxides are listed at the end of this section.

3.2.2 Special Handling Procedures

Before working with a highly reactive material or a high energy oxidizer, review available reference literature to obtain specific safety information. The proposed reactions should be discussed with your supervisor. Always minimize the amount of material involved in the experiment; the smallest amount sufficient to achieve the desired result should be used. Scale-ups should be handled with great care, giving consideration to the reaction vessel size and cooling, heating, stirring and equilibration rates.

Excessive amounts of highly reactive compounds should not be purchased, synthesized, or stored in the laboratories. The key to safely handling reactive chemicals is to keep them isolated from the substances that initiate their violent reactions. Unused peroxides should not be returned to the original container.

Do not work alone. All operations where highly reactive and explosive chemicals are used should be performed during the normal work day or when other employees are available either in the same laboratory or in the immediate area.

Perform all manipulations of highly reactive or high energy oxidizers in a chemical fume hood. (Some factors to be considered in judging the adequacy of the hood include its size in relation to the reaction and required equipment, the ability to fully close the sash, and the composition of the sash.)

Make sure that the reaction equipment is properly secured. Reaction vessels should be supported from beneath with tripods or lab jacks. Use shields or guards, which are clamped or secured.

If possible, use remote controls for controlling the reaction (including cooling, heating and stirring controls). These should be located either outside the hood or at least outside the shield.

Handle shock sensitive substances gently. Avoid friction, grinding and all forms of impact. Glass containers that have screw-cap lids or glass stoppers should not be used. Polyethylene bottles that have screw-cap lids may be used. Handle water-sensitive compounds away from water sources. Light-sensitive chemicals should be used in light-tight containers. Handle highly reactive chemicals away from the direct light, open flames and other sources of heat. Oxidizing agents should only be heated with fiberglass heating mantles or sand baths.

High energy oxidizers, such as perchloric acid, should only be handled in a wash down hood if the oxidizer will volatilize and potentially condense in the ventilation system. Inorganic oxidizers such as perchloric acid can react violently with most organic materials.

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

Labels on peroxide forming substances should contain the date the container was received, first opened and the initials of the person who first opened the container. They should be checked for the presence of peroxides before using, and quarterly while in storage (peroxide test strips are available at EHS Office). If peroxides are found, the materials should be decontaminated, if possible, or disposed of. The results of any testing should be placed on the container label. Never distill substances contaminated with peroxides. Peroxide forming substances that have been opened for more than one year should be discarded. *Never use a metal spatula with peroxides. Contamination by metals can lead to explosive decompositions.*

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

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

Shock sensitive materials should be discarded after one year if in a sealed container and within six months of opening unless an inhibitor was added by the manufacturer.

3.2.3 List of Shock Sensitive Chemicals

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

Acetylides of heavy metals	Heavy metal azides	Picramic acid
Aluminum ophrite explosive	Hexanite	Picramide
Amatol	Hexanitrodiphenylamine	Picratol
Ammonal	Hexanitrostilbene	Picric acid
Ammonium nitrate	Hexogen	Picryl chloride
Ammonium perchlorate	Hydrazinium nitrate	Picryl fluoride
Ammonium picrate	Hydrazoic acid	Polynitro aliphatic compounds
Ammonium salt lattice	Lead azide	Potassium nitroaminotetrazole
Butyl tetryl	Lead mannite	Silver acetylide
Calcium nitrate	Lead mononitroresorcinate	Silver azide
Copper acetylide	Lead picrate	Silver styphnate
Cyanuric triazide	Lead salts	Silver tetrazene
Cyclotrimethylenetrinitramine	Lead styphnate	Sodatol
Cyclotetramethylenetranitramine	Trimethylolethane	Sodium amatol
Dinitroethyleneurea	Magnesium ophorite	Sodium dinitro-orthocresolate
Dinitroglycerine	Mannitol hexanitrate	Sodium nitrate-potassium
Dinitrophenol	Mercury oxalate	Sodium picramate
Dinitrophenolates	Mercury tartrate	Styphnic acid
Dinitrophenyl hydrazine	Mononitrotoluene	Tetrazene
Dinitrotoluene	Nitrated carbohydrates	Tetranitrocarbazole
Dipicryl sulfone	Nitrated glucoside	Tetrytol
Dipicrylamine	Nitrated polyhydric alcohol	Trimonite
Erythritol tetranitrate	Nitrogen trichloride	Trinitroanisole
Fulminate of mercury	Nitrogen triiodide	Trinitrobenzene
Fulminate of silver	Nitroglycerin	Trinitrobenzoic acid
Fulminating gold	Nitroglycide	Trinitrocresol
Fulminating mercury	Nitroglycol	Trinitro-*meta*-cresol
Fulminating platinum	Nitroguanidine	Trinitronaphthalene
Fulminating silver	Nitroparaffins	Trinitrophenetol

Gelatinized nitrocellulose	Nitronium perchlorate	Trinitrophloroglucinol
Germane	Nitrourea	Trinitroresorcinol
Guanyl nitrosamino	Organic amine nitrates	Tritonal
Guanyltetrazene	Organic nitramines	Urea nitrate
Guanyl nitrosaminoguanylidene-hydrazine	Organic peroxides	

3.2.4 List of High Energy Oxidizers

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

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

3.2.5 List of Peroxide Formers

The following are examples of the materials commonly used in laboratories which may form explosive peroxides:

Acetal	Dimethyl ether	Sodium amide
Cyclohexene	Dioxane	Tetrahydrofuran
Decahydronaphthalene	Divinyl acetylene	Tetrahydronaphthalene
Diacetylene	Ether (glyme)	Vinyl ethers
Dicyclopentadiene	Ethyleneglycol dimethyl ether	Vinylidene chloride
Diethyl ether	Isopropyl ether	
Diethylene glycol	Methyl acetylene	

3.3 COMPRESSED GASES

3.3.1 General Information

Compressed gases are unique in that they represent both a physical and a potential chemical hazard (depending on the particular gas). Gases contained in cylinders may be from any of the hazard classes described in this section (flammable, reactive, corrosive, or toxic). Because of their physical state (gaseous), concentrations in the laboratory can increase instantaneously if leaks develop at the regulator or piping systems, creating the potential for a toxic chemical exposure or a fire/explosion hazard. Often there is little or no indication that leaks have or are occurring. Finally, the large amount of potential energy resulting from compression of the gas makes a compressed gas cylinder a potential rocket or fragmentation bomb if the tank or valve is physically broken.

3.3.2 Special Handling Procedures

The contents of any compressed gas cylinder should be clearly identified. No cylinder should be accepted for use that does not legibly identify its contents by name. Color coding is not a reliable means of identification and labels on caps have no value as caps are interchangeable.

Carefully read the label before using or storing a compressed gas. The MSDS will provide any special hazard information.

Transport gas cylinders in carts one or two at a time only while they are secured and capped. All gas cylinders should be capped and secured when stored. Use suitable racks, straps, chains or stands to support cylinders. All cylinders, full or empty, must be restrained and kept away from heat sources. Store as few cylinders as possible in your laboratory.

Use only Compressed Gas Association standard combinations of valves and fittings for compressed gas installations. Always use the correct pressure regulator. Do not use a regulator adaptor.

All gas lines leading from a compressed gas supply should be clearly labeled identifying the gas and the laboratory served.

Place gas cylinders in such a way that the cylinder valve is accessible at all times. The main cylinder valve should be closed as soon as the gas flow is no longer needed. Do not store gas cylinders with pressure on the regulator. Use the wrenches or other tools provided by the cylinder supplier to open a valve if available. In no case should pliers be used to open a cylinder valve.

Use soapy water to detect leaks. Leak test the regulator, piping system and other couplings after performing maintenance or modifications, which could affect the integrity of the system.

Oil or grease on the high pressure side of an oxygen cylinder can cause an explosion. Do not lubricate an oxygen regulator or use a fuel/gas regulator on an oxygen cylinder.

Never bleed a cylinder completely empty. Leave a slight pressure to keep contaminants out (172 kPa or 25 psi). Empty cylinders should not be refilled in laboratories unless they are equipped to prevent overfilling.

All gas cylinders should be clearly marked with appropriate tags indicating whether they are in use, full, or empty. Empty and full cylinders should not be stored in the same place.

Cylinders of toxic, flammable or reactive gases should be purchased in the smallest quantity possible and stored/used in a fume hood or under local exhaust ventilation. If at all possible, avoid the purchase of lecture bottles. These cylinders are not returnable and it is extremely difficult and costly to dispose of them. Use the smallest returnable sized cylinder.

Wear safety goggles when handling compressed gases that are irritants, corrosive or toxic.

Try to purchase compressed gas cylinder that can be returned to the manufacturer.

3.3.3 Special Precautions for Hydrogen

Hydrogen gas has several unique properties which make it potentially dangerous to work with. It has an extremely wide flammability range (LEL 4%, UEL 74.5%) making it easier to ignite than most other flammable gases. Unlike most other gases, hydrogen's temperature increases during expansion. If a cylinder valve is opened too quickly, the static charge generated by the escaping gas may cause it to ignite. Hydrogen burns with an invisible flame. Caution should therefore be exercised when approaching a suspected hydrogen flame. A piece of paper can be used to tell if the hydrogen is burning. Hydrogen embrittlement can weaken carbon steel, therefore cast iron pipes and fittings must not be used. Those precautions associated with other flammable substances also apply to Hydrogen (see Section 3.1).

3.3.4 Special Precautions for Cryogens

If not handled properly, cryogenic liquids can be hazardous to personnel. Never stopper or allow a Dewar to not vent pressure built up by the evaporation of liquid nitrogen or other cryogenic liquids. The liquids are very cold and can easily cause frostbite.

3.4 CORROSIVE CHEMICALS

3.4.1 General Information

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

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

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

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

Oxidizing agents. In addition to their corrosive properties, powerful oxidizing agents such as perchloric and chromic acids (sometimes used as cleaning solutions) present fire and explosion hazards on contact with organic compounds and other oxidizable substances. The hazards associated with the use of perchloric acid are especially severe. It should be handled only after thorough familiarization with recommended operating procedures (see the section 3.2.2 on reactive & high energy oxidizers).

3.4.2 Special Handling Procedures

Corrosive chemicals should be used in the chemical fume hood and over plastic trays especially when handled in bulk quantities (> 1 liter) and when dispensing.

When working with bulk quantities of corrosives, wear gloves, face shields, laboratory coats and rubber aprons.

If you are handling bulk quantities on a regular basis, an eyewash should be immediately available and a shower close by. Spill materials - absorbent pillows, neutral absorbent materials or neutralizing materials (all commercially available) should be available in the laboratory.

Store corrosives in cabinets, under the hood or on low shelves, preferably in impervious trays to separate them physically from other groups of chemicals. Keep containers not in use in storage areas and off bench tops.

If it is necessary to move bulk quantities from one laboratory to another or from the stockroom, use a safety carrier (rubber bucket for secondary containment and protection of the container).

3.5 CHEMICALS OF HIGH ACUTE & CHRONIC TOXICITY

3.5.1 General Information

Substances that possess the characteristic of high acute toxicity can cause injury after a single or short term exposure. The immediate toxic effects to human health range from irritation to illness and death. Hydrogen cyanide, phosgene and nitrogen dioxide are examples of substances with high acute toxicity. The lethal oral doses for an average human adult of highly toxic substances range from one ounce to a few drops. The following procedures should be used when the oral LD_{50} of a substance in the rat or mouse is less then 50 milligrams per kilogram body weight for solid materials or non-volatile liquids and 500 mg/kg body weight for volatile liquids or gases. Oral LD_{50} data for the rat or mouse is listed in the substance's MSDS. The LD_{50} toxicity test is usually the first toxicological test performed and is a good indicator of a substance's acute toxicity.

Substances that possess the characteristic of high chronic toxicity cause damage after repeated exposure or exposure over long periods of time. Health effects often do not become evident until after a long latency period - twenty to thirty years. Substances that are of high chronic toxicity may be toxic to specific organ systems - hepatotoxins, nephrotoxins, neurotoxins, toxic agents to the hematopoietic system and pulmonary tissue or carcinogens, reproductive toxins, mutagens, teratogens or sensitizers. The definition of each of these categories of toxic substances, and examples of substances, which fall into each of these different categories, can be found in Section 4 of this manual.

Specific acute and chronic toxicity information on the substances used in your laboratory can be found on these substances' MSDS. See Section 1.5.3.1 for information on how to obtain/locate MSDSs. If you have additional questions, contact the Chemical Hygiene Officer.

3.5.2 Special Handling Procedures

Avoid or minimize contact with these chemicals by any route of exposure. Protect the hands and forearms by wearing gloves and a laboratory coat. Rinse gloves with water prior to removing them.

Use these chemicals in a chemical fume hood or other appropriate containment device if the material is volatile or the procedure may generate aerosols (See guidelines for chemical fume hood use in Section 2.3.5.1). If a chemical fume hood is used, it should be evaluated to confirm that it is performing adequately (a face velocity of at least 100 linear feet per minute (±20%)) with the sash at the operating height.

Store volatile chemicals of high acute or chronic toxicity in the cabinet under the hood or other vented area. Volatile chemicals should be stored in unbreakable primary or secondary containers or placed in chemically resistant trays (to contain spills). Nonvolatile chemicals should be stored in cabinets or in drawers. *Do not store these chemicals on open shelves or counters.*

Decontaminate working surfaces with wet paper towels after completing procedures. Place the towels in plastic bags and secure. Confirm disposal requirements with the Chemical Hygiene Officer.

Volatile chemicals should be transported between laboratories in durable outer containers.

Vacuum pumps used in procedures should be protected from contamination with scrubbers or filters.

Lab personnel of childbearing age should be informed of any known male and female reproductive toxins used in the laboratory. An employee who is pregnant, or planning to become pregnant, and who is working with potential reproductive toxins that might affect the fetus, should contact the Chemical Hygiene Officer to evaluate her exposure and inform her personal physician. The Chemical Hygiene Officer can assess potential exposures and work with the employee and laboratory supervisor, if necessary, to adjust work practices to minimize the potential risk.

3.6 REGULATED CHEMICALS AND PARTICULARLY HAZARDOUS CHEMICALS

3.6.1 General Information

This section establishes supplemental work procedures to control the handling of substances that are known to exhibit unusual acute or long-term chronic health hazards (carcinogens, reproductive toxins and highly acutely toxic substances). This set of procedures applies (as indicated in Appendix A) to chemical carcinogens listed and regulated by the Department of Labor, Occupational Safety and Health Administration (OSHA), and of human carcinogens listed by the International Agency for Research on Cancer (IARC) and the National Toxicology Program (NTP).

Appendix A identifies under what conditions and for what substances the special handling procedures listed below should be used. Please note that a key component in controlling the most hazardous substances is the controlled distribution and use of these substances. In some instances special authorization is required before purchasing and using these substances.

Appendix A lists the substances and/or procedures that require prior approval of the research protocol before beginning work. See Section 1.11 for the chemical safety protocol review process.

3.6.2 Special Handling Procedures

Use these chemicals only in a chemical fume hood or other appropriate containment device (glove box). If a chemical fume hood is used, it should be evaluated to confirm that it is performing adequately (a face velocity of at least 100 linear feet per minute with the sash at the operating height).

Volatile chemicals should be stored in a vented storage area in an unbreakable, primary or secondary container or placed in a chemically resistant tray (to contain spills). Nonvolatile chemicals should be stored in cabinets or in drawers. *Do not store these chemicals on open shelves or counters.* Access to all of these chemicals should be restricted.

Volatile chemicals should be transported between laboratories in durable outer containers.

All procedures with these chemicals should be performed in designated areas. Other employees working in the area should be informed of the particular hazards associated with these substances and the appropriate precautions that are necessary for preventing exposures. All designated areas should be posted with a sign which reads:

WARNING
DESIGNATED AREA FOR HANDLING THE FOLLOWING
SUBSTANCES WITH HIGH ACUTE OR CHRONIC TOXICITY:
[list of substances - identify acute or chronic hazard]
[Example: Benzene - carcinogen]
AUTHORIZED PERSONNEL ONLY

Vacuum pumps used in procedures should be protected from contamination with scrubbers or filters.

Analytical instruments or other laboratory equipment generating vapors and/or aerosols during their operation, should be locally exhausted or vented in a chemical fume hood.

Skin surfaces that might be exposed to these substances during routine operations or foreseeable accidents should be covered with appropriate protective clothing. Gloves should be worn whenever transferring or handling these substances. Consider using full body protection (disposable coveralls) if the potential for extensive personal contamination exists.

All protective equipment should be removed when leaving the designated area and decontaminated (washed) or, if disposable, placed in a plastic bag and secured. Call the Chemical Hygiene Officer for disposal instructions. Skin surfaces - hands, forearms, face and neck - should be washed immediately.

Work surfaces on which these substances will be handled should be covered with an easily decontaminated surface (such as stainless steel) or protected from contamination with plastic trays or plastic backed paper. Call the Chemical Hygiene Officer for decontamination and disposal procedures; these will be substance specific. Materials that will be disposed of should be placed in plastic bags and secured.

Chemical wastes from procedures using these substances should be placed in containers and disposed of as hazardous chemical waste. The wastes should be stored in the designated area (defined above) until picked up. If it is possible to safely chemically decontaminate all toxic substances to nontoxic materials during or at the end of the procedure, this should be done.

Normal laboratory work should not be conducted in a designated area until it has been decontaminated or determined to be acceptable by the principal investigator or Chemical Hygiene Officer.

SECTION 4 CHEMICAL TOXICOLOGY

4.1 CHEMICAL TOXICOLOGY OVERVIEW

4.1.1 Definitions

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

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

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

4.1.2 Dose-Response Relationships

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

4.1.3 Routes of Entry into the Body

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

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

Most exposure standards, such as the Threshold Limit Values (TLV's) and Permissible Exposure Limits (PEL's), are based on the inhalation route of exposure. These limits are normally expressed in terms of either parts per million (ppm) or milligrams per cubic meter (mg/m3) concentration in air. If a significant route of exposure to a substance is through skin contact, the MSDS, PEL and/or TLV will have a “skin” notation. Examples of substances where skin absorption may be a significant factor include: pesticides, carbon disulfide, carbon tetrachloride, dioxane, mercury, thallium compounds, xylene and hydrogen cyanide.

4.1.4 Types of Effects

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

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

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

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

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

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

4.1.5 Other Factors Affecting Toxicity

Rate of entry and route of exposure; that is, how fast is the toxic dose delivered and by what means.

Age can affect the capacity to repair tissue damage.

Previous exposure can lead to tolerance, increased sensitivity or make no difference.

State of health, physical condition and life style can affect the toxic response. *Pre-existing disease* can result in increased sensitivity.

Environmental factors such as temperature and pressure.

Host factors including *genetic predisposition* and the *sex* of the exposed individual.

4.1.6 Physical Classifications

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

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

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

An aerosol is composed of solid or liquid particles of microscopic size dispersed in a gaseous medium.

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

4.1.7 Physiological Classifications

Irritants are materials that cause inflammation of mucous membranes with which they come in contact. Inflammation of tissue results from exposure to concentrations far below those needed to cause corrosion. Examples include:

Ammonia	Nitrogen dioxide	Ozone
Hydrogen chloride	Arsenic trichloride	Diethyl/dimethyl sulfate
Halogens	Alkaline dusts and mists	Phosphorus chlorides
Phosgene	Hydrogen fluoride	

Irritants can also cause changes in the mechanics of respiration and lung function. Examples include:

Sulfur dioxide	Acetic acid
Formaldehyde	Formic acid
Sulfuric acid	Acrolein
Iodine	

Long term exposure to irritants can result in increased mucous secretions and chronic bronchitis.

A primary irritant exerts no systemic toxic action either because the products formed on the tissue of the respiratory tract are non-toxic or because the irritant action is far in excess of any systemic toxic action. Example: hydrogen chloride.

A secondary irritant's effect on mucous membranes is overshadowed by a systemic effect resulting from absorption. Examples include:

Hydrogen sulfide	Aromatic hydrocarbons

Asphyxiants have the ability to deprive tissue of oxygen. Simple asphyxiants are inert gases that displace oxygen. Examples include:

Nitrogen	Nitrous oxide
Carbon dioxide	Hydrogen
Helium	

Chemical asphyxiants reduce the body's ability to absorb, transport, or utilize inhaled oxygen. They are often active at very low concentrations (a few ppm). Examples include:

Carbon monoxide	Cyanides

Primary anesthetics have a depressant effect upon the central nervous system, particularly the brain. Examples include:

Halogenated hydrocarbons	Alcohols

Hepatotoxic agents cause damage to the liver. Examples include:

Carbon tetrachloride	Tetrachloroethane	Nitrosamines

Nephrotoxic agents damage the kidneys. Examples include:

Halogenated hydrocarbons	Uranium compounds

Neurotoxic agents damage the nervous system. The nervous system is especially sensitive to organometallic compounds and certain sulfide compounds. Examples include:

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

Some toxic agents act on the blood or hematopoietic system. The blood cells can be affected directly or the bone marrow (which produces the blood cells) can be damaged. Examples include:

Nitrites	Aniline	Toluidine
Nitrobenzene	Benzene	

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

Coal dust	Cotton dust	Wood dust

A carcinogen is an agent that can initiate or increase the proliferation of malignant neoplastic cells or the development of malignant or potentially malignant tumors. Known human carcinogens include:

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

A mutagen interferes with the proper replication of genetic material (chromosome strands) in exposed cells. If germ cells are involved, the effect may be inherited and become part of the genetic pool passed onto future generations.

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

Lead	Thalidomide

A sensitizer is a chemical, which can cause an allergic reaction in normal tissue after repeated exposure to the chemical. The reaction may be as mild as a rash (allergic dermatitis) or as serious as anaphylactic shock. Examples include:

Epoxies	Toluene diisocyanate
Nickel compounds	Chromium compounds
Poison ivy	Chlorinated hydrocarbons

4.2 SOME TARGET ORGAN EFFECTS

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

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

4.3 OCCUPATIONAL HEALTH STANDARDS

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

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

TWA: Most exposure standards are based on time weighted averages. The TWA is the average exposure over an eight (8) hour work day. Some substances have Ceiling (C) limits. Ceiling limits are concentrations that should never be exceeded.

The MSDS will list the occupational health standard(s) for the hazardous chemical or each component of a mixture.

SECTION 5 GLOSSARY OF TERMS

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

ACUTE - Short duration, rapidly changing conditions.

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

ANSI - The American National Standards Institute is a voluntary membership organization (run with private funding) that develops consensus standards nationally for a wide variety of devices and procedures.

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

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

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

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

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

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

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

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

CHRONIC - Persistent, prolonged or repeated conditions.

CHRONIC EXPOSURE - A prolonged exposure occurring over a period of days, weeks, or years.

COMBUSTIBLE - According to the DOT and NFPA, combustible liquids are those having a flash point at or above 100ºF (37.8ºC), or liquids that will burn. They do not ignite as easily as flammable liquids. However, combustible liquids can be ignited under certain circumstances, and must be handled with caution. Substances such as wood, paper, etc., are termed “Ordinary Combustibles”.

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

CORROSIVE - A substance that, according to the DOT, causes visible destruction or permanent changes in human skin tissue at the site of contact or is highly corrosive to steel.

CUBIC METER (m^3) - A measure of volume in the metric system.

CUTANEOUS - Pertaining to or affecting the skin.

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

DERMAL - Pertaining to or affecting the skin.

DERMATITIS - An inflammation of the skin.

DILUTION VENTILATION - See GENERAL VENTILATION.

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

DYSPNEA -Shortness of breath; difficult or labored breathing.

EHS - Environmental Health and Safety Office.

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

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

EPIDEMIOLOGY - The study of disease in human populations.

ERYTHEMA - A reddening of the skin.

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

ºF - Degrees, Fahrenheit; a temperature scale.

FLAMMABLE LIQUID - According to the DOT and NFPA, a flammable liquid is one that has a flash point below 100ºF. (See FLASH POINT)

Classes Of Flammable Liquids		
Flammable Solvent Class	Boiling Point	Flash Point
Class 1A	< 100ºF	< 73ºF
Class 1B	>= 100ºF	< 73ºF
Class 1C	>= 100ºF	Between 73 and 100ºF

FLASH POINT - The lowest temperature at which a liquid or a solid emits vapor sufficient to form an ignitable mixture with air near the surface of the liquid or the solid, and burn when a source of ignition (sparks, open flames, cigarettes, etc.) is present. Two tests are used to determine the flash point: open cup and closed cup. The test method is indicated on the MSDS after the flash point.

g - See GRAM.

GENERAL VENTILATION - Also known as general exhaust ventilation, this is a system of ventilation consisting of either natural or mechanically induced fresh air movements to mix with and dilute contaminants in the workroom air. This is not the recommended type of ventilation to control contaminants that are highly toxic, when there may be corrosion problems from the contaminant, when the worker is close to where the contaminant is being generated, and where fire or explosion hazards are generated close to sources of ignition (See LOCAL EXHAUST VENTILATION).

g/Kg - See GRAMS PER KILOGRAM.

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

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

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

IGNITABLE - A solid, liquid or compressed gas that has a flash point of less than 140ºF. Ignitable material may be regulated by the EPA as a hazardous waste, as well.

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

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

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

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

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

Kg - See KILOGRAM.

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

L - See LITER.

LC_{50}- See LETHAL CONCENTRATION$_{50}$.

LD_{50}- See LETHAL DOSE$_{50}$.

LEL - See LOWER EXPLOSIVE LIMIT.

LETHAL CONCENTRATION$_{50}$ - The concentration of an air contaminant (LC_{50}) that will kill 50 percent of the test animals in a group during a single exposure.

LETHAL DOSE$_{50}$ - The dose of a substance or chemical that will (LD_{50}) kill 50 percent of the test animals in a group within the first 30 days following exposure.

LFL - See LOWER EXPLOSIVE LIMIT.

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

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

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

m^3 - See CUBIC METER.

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

mg - See MILLIGRAM.

mg/Kg - See MILLIGRAMS PER KILOGRAM.

mg/m^3 - See MILLIGRAMS PER CUBIC METER.

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

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

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

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

mL - See MILLILITER.

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

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

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

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

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

WCU - Western Colorado University

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

ORAL - Having to do with the mouth.

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

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

OXIDIZER - Is a substance that gives up oxygen easily to stimulate combustion of organic material.

OXYGEN DEFICIENCY - An atmosphere having less than the normal percentage of oxygen found in normal air. Normal air contains 21% v/v oxygen at sea level.

PEL - See PERMISSIBLE EXPOSURE LIMIT.

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

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

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

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

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

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

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

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

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

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

STEL - Short Term Exposure Limit.

SUBSTANCE - Any chemical entity.

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

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

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

THRESHOLD LIMIT VALUE - Airborne concentrations of substances devised by the ACGIH that represent conditions under which it is believed that nearly all workers may be exposed day after day with no adverse effect. TLV's are advisory exposure guidelines, not legal standards, that are based on evidence from industrial experience, animal studies, or human studies when they exist. There are three different types of TLV's: Time Weighted Average (TLV-TWA), Short Term Exposure Limit (TLV-STEL) and Ceiling (TLV-C). (See also PEL.)

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

TLV - See THRESHOLD LIMIT VALUE.

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

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

TWA - See TIME WEIGHTED AVERAGE.

UEL - See UPPER EXPLOSIVE LIMIT.

UFL - See UPPER EXPLOSIVE LIMIT.

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

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

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

APPENDIX A. Poisonous Gases

The gases on this list are either on the Department of Transportation's Category 1 list, or the Linde Specialty Gases company's Group 6 - Very Poisonous list. These chemicals are highly toxic gases at ambient temperature and pressure. They have an extremely high potential for causing significant harm if not adequately controlled.

Arsine	Boron trichloride	Chlorine pentafluoride
Chlorine trifluoride	Cyanogen	Cyanogen chloride
Diborane	Dinitrogen tetroxide	Fluorine
Germane	Hydrogen selenide	Nitric oxide
Nitrogen dioxide	Nitrogen trioxide	Nitrosyl chloride
Oxygen difluoride	Phosgene	Phosphine

Phosphorus pentafluoride	Selenium hexafluoride	Stibine
Sulfur tetrafluoride	Tellurium Hexafluoride	Tetraethyldithiopyrophosphate
Tetraethylpyrophosphate		

Guidance: Other chemicals may be add to this list: for example, sulfur-containing compounds such as mercaptans can cause significant odor problems when used in the laboratory. Pre-approval of the conditions under which they can be used may prevent odor complaints.

APPENDIX B. Shock Sensitive Chemicals

The classes of chemicals listed below may explode when subjected to shock or friction. Therefore users must have appropriate laboratory equipment, information, knowledge and training to use these compounds safely.

Acetylenic compounds, especially polyacetylenes, haloacetylenes, and heavy metal salts of acetylenes (copper, silver, and mercury salts are particularly sensitive)
Acyl nitrates
Alkyl nitrates, particularly polyol nitrates such as nitrocellulose and nitroglycerine
Alkyl and acyl nitrites
Alkyl perchlorates
Amminemetal oxosalts: metal compounds with coordinated ammonia, hydrazine, or similar nitrogenous donors and ionic perchlorate, nitrate, permanganate, or other oxidizing group
Azides, including metal, nonmetal, and organic azides
Chlorite salts of metals, such as $AgClO_2$ and $Hg(ClO_2)_2$
Diazo compounds such as CH_2N_2
Diazonium salts, when dry
Fulminates such as mercury fulminate ($Hg(CNO)_2$)
Hydrogen peroxide (which becomes increasingly treacherous as the concentration rises above 0%, forming explosive mixtures with organic materials and decomposing violently in the presence of traces of transition metals
N-Halogen compounds such as difluoroamino compounds and halogen azides
N-Nitro compounds such as N-nitromethylamine, nitrourea, nitroguanidine, and nitric amide
Oxo salts of nitrogenous bases: perchlorates, dichromates, nitrates, iodates, chlorites, chlorates, and permanganates of ammonia, amines, hydroxylamine, guanidine, etc.
Perchlorate salts (which can form when perchloric acid mists dry in fume hoods or associated duct work. Most metal, nonmetal, and amine perchlorates can be detonated and may undergo violent reaction in contact with combustible materials)
Peroxides and hydroperoxides, organic
Peroxides (solid) that crystallize from or are left from evaporation of peroxidizable solvents (see the following Section 3)
Peroxides, transition-metal salts
Picrates, especially salts of transition and heavy metals, such as Ni, Pb, Hg, Cu, and Zn
Polynitroalkyl compounds such as tetranitromethane and dinitroacetonitrile
Polynitroaromatic compounds especially polynitrohydrocarbons, phenols, and amines (e.g., dinitrotoluene, trinitrotoluene, and picric acid)
Note: Perchloric acid must be used only in specially-designed perchloric acid fume hoods that have built-in wash down systems to remove shock-sensitive deposits. Before purchasing this acid, laboratory supervisors must arrange for use of an approved perchloric acid hood.

APPENDIX C. Pyrophoric Chemicals

The classes of chemicals listed below will readily oxidize and ignite spontaneously in air. Therefore, users must demonstrate to the department that they have the appropriate laboratory equipment, information, knowledge and training to use these compounds safely.

Grignard reagents, RMgX
Metal alkyls and aryls, such as RLi, RNa, R_3Al, R2Zn
Metal carbonyls such as $Ni(CO)_4$, $Fe(CO)_5$, $Co_2(CO)_8$
Alkali metals such as Na, K
Metal powders, such as Al, Co, Fe, Mg, Mn, Pd, Pt, Ti, Sn, Zn, Zr
Metal hydrides such as NaH, $LiAlH_4$
Nonmetal hydrides, such as B_2H_6 and other boranes, PH_3, AsH_3
Nonmetal alkyls, such as R_3B, R_3P, R_3As
Phosphorus (white)

APPENDIX D. Peroxide-Forming Chemicals

The chemicals listed below can form explosive peroxide crystals on exposure to air, and therefore require special handling procedures after the container is opened. Some of the chemicals form peroxides that are violently explosive in concentrated solution or as solids, and therefore should never be evaporated to dryness. Others are polymerizable unsaturated compounds and can initiate a runaway, explosive polymerization reaction. All peroxidizable compounds should be stored away from heat and light. They should be protected from physical damage and ignition sources. A warning label should be affixed to all peroxidizable materials to indicate the date of receipt and the date the container was first opened. Due to these special handling requirements, users must have the appropriate laboratory equipment, information, knowledge and training to use these compounds safely.

A. Severe Peroxide Hazard with Exposure to Air (discard within 3 months from opening)
diisopropyl ether (isopropyl ether)
divinylacetylene (DVA)
vinylidene chloride (1,1-dichloroethylene)
potassium metal
sodium amide (sodamide)
potassium amide

B. Peroxide Hazard on Concentration
Do not distill or evaporate without first testing for the presence of peroxides (discard or test for peroxides after 6 months)
acetaldehyde diethyl acetal (acetal)
cumene (isopropylbenzene)
cyclohexene
cyclopentene
decalin (decahydronaphthalene)
diacetylene (butadiene)
dicyclopentadiene
diethyl ether (ether)
diethylene glycol dimethyl ether (diglyme)

dioxane
ethylene glycol dimethyl ether (glyme)
ethylene glycol ether acetates
ethylene glycol monoethers (cellosolves)
furan
methylacetylene
methylcyclopentane
methyl isobutyl ketone
tetrahydrofuran (THF)
tetralin (tetrahydronaphthalene)
vinyl ethers
C. Hazard of Rapid Polymerization Initiated by Internally-Formed Peroxides
Liquids (discard or test for peroxides after 6 months)
chloroprene (2-chloro-1,3-butadiene)
vinyl acetate
styrene
vinylpyridine
Gases (discard after 12 months)
butadiene
vinylacetylene (MVA)
tetrafluoroethylene (TFE)
vinyl chloride

APPENDIX E. Carcinogens, Reproductive Toxins or Highly Toxic Chemicals

The chemicals listed below are extremely hazardous. Workers must have knowledge of the dangers of these chemicals prior to use, and documentation of training in safe working procedures.
Biologically active compounds
protease inhibitors (e.g. PMSF, Aprotin, Pepstatin A, Leopeptin);
protein synthesis inhibitors (e.g. cycloheximide, Puromycin);
transcriptional inhibitors (e.g. a-amanitin and actinomycin D);
DNA synthesis inhibitors (e.g. hydroxyurea, nucleotide analogs (i.e. dideoxy nucleotides), actinomycin D, acidicolin);
phosphatase inhibitors (e.g. okadaic acid);
respiratory chain inhibitors (e.g. sodium azide);
kinase inhibitors (e.g. NaF);
mitogenic inhibitors (e.g. colcemid); and
mitogenic compounds (e.g. concanavalin A).
Castor bean (Ricinus communis) lectin: Ricin A, Ricin B, RCA toxins
Diisopropyl fluorophosphate: highly toxic cholinesterase inhibitor; the antidote, atropine sulfate and 2-PAM (2-pyridinealdoxime methiodide) must be readily available
Jaquirity bean lectin (Abrus precatorius)
N-methyl-N'-nitro-N-nitrosoguanidine: carcinogen (this chemical forms explosive compounds upon degradation)
Phalloidin from Amanita Phalloides: used for staining actin filaments
Retinoids: potential human teratogens

Streptozotocin: potential human carcinogen
Urethane (ethyl carbamate): an anesthetic agent, potent carcinogen and strong teratogen, volatile at room temperature

APPENDIX F. Incompatible Chemicals

Certain chemicals should not be stored (and cannot be easily/safely mixed) with certain other chemicals due to severe exothermicity of reaction or uncontrolled production of a toxic product. In the event of earth tremor or other unexpected breakage, especially during fire, the consequences of proximal storage of incompatible materials can be fatal to staff, fire fighters, and other emergency responders.
The following list contains examples of incompatibilities. The list should not be considered complete. For complete information about a specific chemical, always consult at least one current Material Safety Data Sheet.

Chemical	Incompatible chemicals
Acetic acid	aldehydes, bases, carbonates, hydroxides, metals, oxidizers, peroxides, phosphates, xylene, chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetone	Concentrated nitric and sulfuric acid mixtures, acids, amines, oxidizers, plastics
Acetylene	halogens, mercury, potassium, oxidizers, silver, copper
Alkali/alkaline earth metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, halogens, aldehydes, ketones, sulfur, plastics, acids
Ammonia (anhydrous)	mercury, calcium hypochlorite, hydrofluoric acid, acids, aldehydes, amides, halogens, heavy metals, oxidizers, plastics, sulfur
Ammonium nitrate	acids, alkalis, chloride salts, flammable & combustible materials, metals, organic materials, phosphorous, reducing agents, urea, chlorates, sulfur
Aniline	acids, aluminum, dibenzoyl peroxide, oxidizers, plastics,
Arsenical materials	Any reducing agent
Azides	acids, heavy metals, oxidizers
Bromine	acetaldehyde, alcohols, alkalis, ammonia, amines, petroleum gases, combustible materials, ethylene, fluorine, hydrogen, ketones (acetone, carbonyls, etc.), metals, sodium carbide, sulfur
Calcium oxide	water, acids, ethanol, fluorine, organic materials
Carbon (activated)	alkali metals, calcium hypochlorite, halogens, oxidizers
Carbon tetrachloride	Sodium
Chlorates	finely divided organic or combustible materials ammonium salts, acids, powdered metals, sulfur
Chlorine	acetylene, alcohols, ammonia, benzene, butadiene, butane, combustible materials, ethylene, flammable compounds (hydrazine), hydrocarbons (acetylene, hydrogen, hydrogen

Chemical	Incompatible chemicals
	peroxide, iodine, metals, methane, nitrogen, oxygen, propane (or other petroleum gases), sodium carbide, sodium hydroxide
Chlorine dioxide	hydrogen, mercury, organic materials, phosphorus, potassium hydroxide, sulfur, methane, phosphine, ammonia, methane, phosphine, hydrogen sulfide
Chromic acid, chromic oxide	acetone, alcohols, alkalis, ammonia, bases, acetic acid, naphthalene, camphor, glycerin, flammable liquids in general, naphthalene, camphor, glycerol, benzene, hydrocarbons, metals, organic materials, phosphorus, plastics
Copper	calcium, hydrocarbons, oxidizers, acetylene, hydrogen peroxide
Cumene	hydroperoxide acids (organic or inorganic)
Cyanides	acids, alkaloids, aluminum, iodine, oxidizers, strong bases
Flammable liquids	ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens, oxygen, oxidizers in general
Fluorine	All other chemicals
Hydrocarbons (liq and gas)	see flammable liquids
Hydrocyanic acid	nitric acid, alkali
Hydrofluoric acid	metals, organic materials, plastics, silica (glass, including fiberglass), sodium, ammonia
Hydrogen peroxide	all organics, nitric acid, phosphorous, sulfuric acid, sodium, most metals or their salts
Hydrogen sulfide	acetylaldehyde, metals, oxidizers, sodium, fuming nitric acid
Hydroperoxide	reducing agents
Hypochlorites	acids, activated carbon
Iodine	acetylaldehyde, acetylene, ammonia, metals, sodium, hydrogen
Mercury	acetylene, aluminum, amines, ammonia, calcium, fulminic acid, lithium, oxidizers, sodium
Nitric acid	acids, nitrites, metals, sulfur, sulfuric acid , most organics, plastics, sodium
Nitrites	acids
Nitroparaffins	inorganic bases, amines
Oxalic acid	oxidizers, silver, mercury, sodium chlorite
Oxygen	all flammable & combustible materials, oil, grease, ammonia, carbon monoxide, metals, phosphorous, polymers
Perchloric acid	all organics, wood, paper, oil, grease, dehydrating agents, hydrogen halides, iodides, bismuth and alloys
Peroxides,	organic Acids (organic or mineral), avoid friction, store cold
Phosphorus (white)	oxygen, air, alkalis, reducing agents
Potassium chlorate	acids, ammonia, combustible materials, fluorine, hydrocarbons, metals, organic materials, sugars, reducing agents

Chemical	Incompatible chemicals
Potassium perchlorate	alcohols, combustible materials, fluorine, hydrazine, metals, organic matter, reducing agents, sulfuric acid
Potassium permanganate	benzaldehyde, ethylene glycol, glycerol, sulfuric acid
Selenides	Reducing agents
Silver Acetylene, oxalic acid, tartartic acid, ammonium compounds, fulminic acid, ozonides, peroxyformic acid	
Sodium	Carbon tetrachloride, carbon dioxide, water, acids, hydrazine, metals, oxidizers
Sodium nitrate	acetic anhydride, acids, metals, organic matter, peroxyformic acid, reducing agents
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural, benzene, hydrogen sulfide metals, oxidizers, peroxyformic acid, phosphorous, reducing agents, sugars, water
Sulfides	acids
Sulfuric acid	alcohols, bases, chlorates, perchlorates, permanganates of potassium, lithium, sodium, magnesium, calcium
Tellurides	Reducing agents

Reference: Guide for Safety in the Chemical Laboratory, 2nd ed., Manufacturing Chemists' Association, Van Nostrand Reinhold: New York, 1972, pp. 215-217, Safety in Academic Chemistry Laboratories, ACS 6th ed. 1995, and various MSDSs and chemical container labels.