CSN Procedure	**Facilities Management**
Category: Environmental Health and Safety	**Effective Date: 03/15/2022**
Laboratory Safety Manual	

College of Southern Nevada

Investing in Our Future. Students First.

CSN
LABORATORY
SAFETY MANUAL

TABLE OF CONTENTS

APPENDICIES

1.0 PURPOSE AND APPLICABILITY

The purpose of the Laboratory Safety Manual (LSM) is to provide guidance to employees, supervisors, and managers with the goal of preventing human injury and environmental damage from hazardous chemicals, equipment, procedures, and testing methods; and preventing human disease from biological agents used in College of Southern Nevada (CSN) Laboratories.

This manual includes guidelines to promote workplace safety developed by the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention (CDC). Both the Occupational Safety and Health Administration (OSHA) and the National Institute of Occupational Safety and Health (NIOSH) are referenced.

2.0 ROLES AND RESPONSIBILITIES

2.1 Laboratory Administrative Staff:

- Review the LMS and send updates to Environmental Health and Safety the to ensure its compliance with applicable regulations and procedures.
- Administer the LSM and all applicable policies and procedures.
- Perform a hazardous assessment in accordance with Section 5.1. A Job Safety Analysis (JSA) Checklist shall be completed for each assessment.
    - A job safety analysis should evaluate both chemical and biological agent hazards and laboratory procedure hazards.
    - In addition, consider the capability of the laboratory staff to control hazards. Workers are the first line of defense for protecting themselves and others in the laboratory, so a JSA should identify any potential deficiencies in the practices of laboratory workers. The laboratory should also reference standard operating procedures (SOPs), which outline specific hazards and personal protective equipment (PPE) associated with the method.
    - Consideration of facility safeguards is an integral part of the JSA and SOPs. The laboratory and Environmental Health & Safety (EHS) staff should assess the facility's capability to provide appropriate protection for the planned work as well as provisions in the event of spills or exposures.
    - Refer to sections 5.0 (Health Hazards of Chemicals) and 6.0 (Health Hazards of Biological Agents) for more assessment guidelines.
- Conduct periodic laboratory safety inspections as required by the CSN Laboratory Safety Procedure (see Appendix C).

2.2 Environmental Health and Safety (EHS should be first 2.1 and Lab/Admin Staff should be 2.2)

- Establish and implement a hazard communication program with all laboratory workers. Communication includes, but is not limited to, posting safety-related bulletins, providing access to Safety Data Sheets (SDS), and reviewing accident/illness reports.
- Conduct annual laboratory safety inspections as required by the CSN Laboratory Safety Procedure (see Appendix C).
- Establish and implement a chemical hygiene plan as required by 29 CFR 1910.1450.
- Individual responsibilities to procedures and practices are detailed within specific sections of this manual.

3.0. EMERGENCY PROCEDURES

3.1 Emergency Contacts

Emergency services can be accessed from any laboratory location by calling x7-911 (from a campus phone) or 702-895-3669 (from a cellphone). Addresses for the various locations are as follows:

North Las Vegas Campus
3200 E. Cheyenne Avenue
North Las Vegas, NV 89030

West Charleston Campus
6375 W. Charleston Boulevard
Las Vegas, NV 89146

Henderson Campus
700 College Drive
Henderson, NV 89015

Be prepared to provide the dispatcher with the following information:

- Your name and telephone number
- Nature of the emergency
- Location of the emergency on campus (building, floor, and room number)
- Number of people involved: Is victim(s) conscious, breathing, bleeding?
- Remain on the line until the dispatcher has asked you all the questions and follow their instructions

3.2 Reporting Accidents and Injuries

All accidents, injuries, or near-misses must be reported by the employee's supervisor or department to the CSN Department of Environmental Health & Safety (EH&S) at 702-651-7445, and UNLV Risk Management and Safety at 702-895-5404. Incidents involving employee hospitalization or fatality must be reported immediately so the appropriate actions can be taken. If University Police Services records an employee injury report, a copy of that report should be forwarded to EH&S.

For any occupational injury or illness, including a concern about an over-exposure to a chemical substance, the employee must fill out the *C-1 Notice of Injury Form*. For additional information on injury reporting refer to the *Incident Reporting and Investigation Procedure*. The most current manual is located on the intranet "AtCSN" at
https://at.csn.edu/sites/default/files/documents/incident_reporting_and_investigation_aug-20.pdf

3.3 Immediate Response to Contamination

- In the event of a chemical or biological spill, leak, or other emergencies; immediately alert others in the area and your supervisor, and evacuate the area, if necessary.
- If there is a fire or medical attention is needed, call University Police Services at 702-895-3669 or x7-911 from a campus phone for emergency assistance. Do NOT use a cellular phone near the presence of combustible vapors. Report the incident to EH&S at x7445.
- If a volatile, flammable material is spilled, immediately warn everyone, control sources of ignition, and ventilate the area.
- If a biohazard contamination occurs, isolate the pathogen either within the biosafety hood or immediately vacate and seal off the laboratory if the spilled is uncontrolled.
- Wear appropriate personal protective equipment before controlling the source of the contamination.
- Don’t become a victim. Refer to the Safety Data Sheets (SDSs) or other references [e.g., American Type Culture Collection (ATCC) certified reference materials] for information as needed.
- Wear appropriate PPE before attending to people who may be contaminated.
- Follow decontamination procedures in accordance with the type of material and the extent of exposure. Refer to section 9.0 for additional information.

3.4 Investigate and Remediate

- Laboratory supervisors and EHS shall investigate the source and cause of chemical or other hazardous exposure, leak, or spill to determine what actions are required to avoid future incidents.
- Work affected by the contamination can only resume when formally directed to do so by the EH&S.

4.0. CHEMICAL AND BIOLOGICAL HAZARD IDENTIFICATION

4.1 General

Chemical manufacturers are required to perform an assessment to classify the physical, health, and environmental hazards of the chemicals they produce. This information must be made available in two places: the chemical label and the SDS. Thus, the information found on the original container label and the SDS may provide a great deal of information about the identity of the chemical constituents and their health and physical hazards.

No hazardous chemical may be purchased or stored at a College of Southern Nevada facility unless accompanied by an appropriate SDS and properly labeled**.** The department requesting the purchase of a chemical or hazardous product is responsible for obtaining an SDS from the supplier or vendor and submitting the proper paperwork to the EH&S Department for product approval. An SDS must be received with the shipment of chemicals.

A list of hazardous materials and related documents shall be kept in a central area that is accessible by all employees. The list shall include the product name, any product code numbers, and manufacturer name as it appears on the SDS. The SDS will be maintained for any chemical product received before June 1, 2015. An SDS must accompany the shipment.

4.2 Training

All laboratory workers, including faculty, staff, and student workers must be trained on the information contained in the LSM. Documentation for completing the training must be maintained by the Manager or Supervisor (See Appendix A).

All laboratory workers, including faculty, staff must attend Laboratory Safety Training given by Environmental Health and Safety (EH&S) staff or an online system. This training gives an overview of general laboratory safety principles; references and resources for more specific safety information; and details about several support programs, such as the hazardous waste disposal program. The training supplements instruction given by supervisors regarding safe work practices for specific chemicals and equipment.

EH&S provides training, resources, and consultation for a variety of laboratory safety issues, including chemical safety, biological safety, radiation safety, electrical safety, and other topics.

4.3 Chemical Labeling

- The manufacturer’s label should be kept intact and legible.
- At a minimum, chemical container labels shall include the chemical name, manufacturer, and physical and/or health hazards associated with the chemical. Compressed gas cylinders shall be marked with the vendor’s original label containing the proper shipping name, identification number, and hazard class warning.
- Manufacturers, importers, and distributors must include the appropriate pictograms, signal word, hazard statements, and precautionary statements to address health, physical and environmental hazards on container labels.
- Hazard warning labels, tags, or markings on containers may not be removed or defaced unless a new label or marking with the appropriate information is immediately replaced or attached.
- When a chemical is transferred from the original container into a secondary container for use or storage, the new container shall be labeled with the name of the product, the chemical constituents, and the primary hazard warnings.
- All buildings storing hazardous chemicals and, where appropriate, bulk tanks or containers must be labeled using the NFPA 704 M Hazard Identification Labeling Systems. Shipping containers such as boxes, carboys, tanks, or drums will be labeled using the DOT hazardous materials labeling system according to 49 CFR Part 173.
- Refer to National Fire Protection Association (NFPA) 704M, Hazard Identification Labeling System, for additional information to understand labels.
- Damaged labels or labels lacking appropriate information should be immediately reported to the department director, supervisor, or EH&S representative and new labels procured.

4.4 Safety Data Sheets (SDS)

- All laboratory workers, including faculty, staff, and student workers shall familiarize themselves with the contents of the appropriate SDS prior to using any chemical.
- The manufacturer or distributor is required to provide an SDS with the initial shipment of their products. If an SDS does not accompany the product, the department requesting the purchase of a chemical or hazardous product is responsible for obtaining an SDS from the supplier or vendor.

- Any SDS's received by a laboratory shall be maintained in a central location in the laboratory or the department.
- SDS's can be accessed online through the CSN EH&S Website at: https://www.csn.edu/environmental-health-safety
- It is the policy of CSN to discontinue purchasing hazardous chemicals from any supplier, company, or vendor that does not provide an appropriate SDS when requested and/or at the time the product is delivered on-site. Furthermore, the vendor shall send any updated SDSs to CSN for replacement.

4.5 Potentially Infectious Materials

- All work areas storing potentially infectious materials shall be posted with biohazard signs. Included with this sign will be the name of the infectious agent, any special requirements for entering the area, and name and the telephone number of the department director or other responsible person.
- Warning labels on potentially infectious materials shall be affixed to containers of those materials, refrigerators, and freezers, and other containers used to store or transport potentially infectious materials. Labels shall also bear the Biohazard Communication of Hazards symbol.
- Labels shall either be an integral part of the container or shall be attached in other method that prevents their loss or unintentional removal.
- Red biohazard bags or red containers may be substituted for labels on containers of infectious waste.

4.6 Safety Data Sheets for Potentially Infectious Material

While there is no formal program mandating Safety Data Sheets for potentially infectious materials, some manufacturers provide SDS's for their products. However, the ATCC does provide certified reference materials for many biological materials. In accordance with International Organization for Standardization (ISO) Guide 30 (1992), each product is accompanied by a certificate stating property values, expiration date, and proper use.

4.7 Individual Laboratory Safety Plans

Each laboratory must develop an individual Laboratory Safety Plan (LSP) to provide laboratory specific safety roles and responsibilities, safety information, safe laboratory practices, and emergency procedures unique to an individual lab, course, or research project (see Appendix B). A LSP can act as an easy reference for laboratory personnel and students that augments the CSN Laboratory Safety Manual, Chemical Hygiene Plan, and other laboratory-specific Standard Operating Procedures. The content of this LSP must be approved by the Laboratory Supervisor, Instructor, or other designee and should be reviewed and updated annually.

5.0 HEALTH HAZARDS OF CHEMICALS

5.1 Hazard Assessment

- It is the responsibility of all lab managers and supervisors to examine all chemicals and the way they are intended to be used in the laboratory to identify potential hazards prior to acquiring those chemicals or conducting a procedure.
- To assess the hazards of a particular chemical, both the physical and health hazards of the chemical must be considered. Review the applicable SDS.

- Once those hazards have been identified, the analysis should be included in the individual Laboratory Safety Plan (See Appendix B). Any risk assessment should include preventative measures that can be implemented to provide a reasonable means of controlling the hazards to a negligible risk level and responding to any emergencies which may arise.
- Chemicals that are classified with the following hazardous effects pose a health hazard: Acute toxicity (any route of exposure); skin corrosion or irritation; serious eye damage or eye irritation; respiratory or skin sensitization; germ cell mutagenicity; carcinogenicity; reproductive toxicity; specific target organ toxicity (single or repeated exposure); or aspiration hazard.

5.2 Basic Toxicology

The health effects of hazardous chemicals are often less clear than the physical hazards. The health effects of chemical exposure must consider the chemical's toxicity, its hazard, and the actual exposure.

- **Toxicity** is the ability of a chemical substance to cause an undesirable effect in a biological system.
- **Hazard** is the likelihood that a material will exert its toxic effects under the conditions of use.
- **Exposure:** No matter how toxic the material may be, there is little risk involved unless it enters the body. An assessment of the toxicity of the chemicals and the possible routes of entry will help determine what protective measures should be taken.

RISK = TOXICITY x EXPOSURE

- Thus, with proper handling, highly toxic chemicals can be used safely. Conversely, less toxic chemicals can be extremely hazardous if handled improperly.
- How a chemical exposure affects a person depends on many factors.
- **Dose:** The dose is the amount of a chemical that enters the body. The actual dose that a person receives depends on the concentration of the chemical and the frequency and duration of the exposure. The sum of all routes of exposure must be considered when determining the dose.
- In addition to the dose, the outcome of exposure is determined by (1) the way the chemical enters the body, (2) the physical properties of the chemical, and (3) the susceptibility of the individual receiving the dose.

Toxic effects of a chemical

- Chemical routes of transmission include absorption, injection, ingestion, and inhalation (see Routes of Entry below).
- An injury may be localized when injuries involve the area of the body in contact with the chemical and are typically caused by reactive or corrosive chemicals, such as strong acids, bases, or oxidizing agents.
- Systemic injuries involve tissues or organs unrelated to or removed from the contact site when toxins have been transported through the bloodstream.
    - For example, methanol that has been ingested may cause blindness, while a significant skin exposure to nitrobenzene may affect the central nervous system.
- Certain chemicals may affect a target organ.
    - For example, lead primarily affects the central nervous system, kidneys, and red blood cells; isocyanates may induce an allergic reaction (immune system); and chloroform may cause tumors in the liver and kidneys.

- It is important to distinguish between acute and chronic exposure and toxicity. Acute and chronic effects are distinguished in the SDS, usually with more information about acute exposures than chronic.
- **Acute:** toxicity results from a single, short exposure. Effects usually appear quickly and are often reversible.
- **Chronic** toxicity results from repeated exposure over a long period of time. Effects are usually delayed and gradual and may be irreversible.
    - For example, the acute effect of alcohol exposure (ingestion) is intoxication, while the chronic effect is cirrhosis of the liver.
- Relatively few chemicals have been evaluated for chronic effects, given the complexity of that type of study. Chronic exposure may have very different effects than acute exposure. Usually, studies of chronic exposure evaluate its cancer-causing potential or other long-term health problems.

Evaluating Toxicity Data

Most estimates of human toxicity are based on animal studies, which may or may not relate to human toxicity. In most animal studies, the effect measured is usually death. This measure of toxicity is often expressed as an LD_{50} (lethal dose 50) – the dose required to kill 50% of the test population. The LD_{50} is usually measured in milligrams of the material per kilogram of body weight of the test animal. The concentration in air that kills half of the population is the LC_{50}.

To estimate a lethal dose for a human-based on animal tests, the LD_{50} must be multiplied by the weight of an average person. Using this method, it is evident that just a few drops of a highly toxic substance, such as dioxin, may be lethal; while much larger quantities of a slightly toxic substance, such as acetone, would be necessary for the same effect.

Susceptibility of Individuals

Factors that influence the susceptibility of an individual to the effects of toxic substances include nutritional habits, physical condition, obesity, medical conditions, drinking and smoking, and pregnancy. Due to individual variation and uncertainties in estimating human health hazards, it is difficult to determine a dose of a chemical that is totally risk-free.

Regular exposure to some substances can lead to the development of an allergic rash, breathing difficulty, or other reactions. This phenomenon is referred to as sensitization. Over time, these effects may occur with exposure to smaller and smaller amounts of the chemical but will disappear soon after the exposure stops. For reasons not fully understood, not everyone exposed to a sensitizer will experience this reaction. Examples of sensitizers include epoxy resins, nickel salts, isocyanates, and formaldehyde.

Employees who are pregnant, planning a pregnancy, or nursing can work safely in laboratories by using prudent work practices outlined in this manual. Consult with your personal physician about your work conditions and activities to plan a safe course of action pre-conception, during pregnancy, and post-partum. Any restrictions placed by the physician should be brought to the attention of supervisor or manager immediately.

Particularly Hazardous Substances

The OSHA Laboratory Standard requires special handling procedures for certain chemicals identified as particularly hazardous substances. OSHA defines a particularly hazardous substance as "select carcinogens", reproductive toxins, and substances that have a high degree of acute toxicity. Refer to section 8.10 for additional information on working with particularly hazardous substances.

Where to Find Toxicity Information

Toxicity information may be found in the SDS, on product labels, in the Registry of Toxic Effects of Chemical Substances (RTECS), or in many other sources listed on the SDS page. Toxicity data is found in Section 2, *Hazard Identification,* and Section 11, *Toxicological Information* on the SDS.

5.3 Routes of Entry

Skin Contact: The simplest way for chemicals to enter the body is through direct contact with the skin or eyes. Skin contact with a chemical may result in a local reaction, such as a burn or rash, or absorption into the bloodstream. Absorption into the bloodstream may then allow the chemical to cause toxic effects on other parts of the body. The SDS usually includes information regarding whether skin absorption is a significant route of exposure.

The absorption of a chemical through intact skin is influenced by the health of the skin and the properties of the chemical. Skin that is dry or cracked or has lacerations offers less resistance. Fat-soluble substances, such as many organic solvents, can easily penetrate the skin and, in some instances, can alter the skin’s ability to resist absorption of other substances.

To minimize skin exposure, wear gloves and other personal protective equipment. Avoid the use of solvents for washing skin. They remove the natural protective oil from the skin and can cause irritation and inflammation. In some cases, washing with a solvent may facilitate the absorption of a toxic chemical. Symptoms of skin exposure include dry, whitened skin, redness and swelling, rashes or blisters, and itching.

Eye Contact: Chemical contact with eyes can be particularly dangerous, resulting in painful injury or loss of sight. Wear appropriate safety eyewear (i.e., safety goggles, chemical safety goggles, or a face shield) to reduce the risk of eye contact.

Inhalation: The respiratory tract is the most common route of entry for gases, vapors, particles, and aerosols (smoke, mists, and fumes). These materials may be transported into the lungs and exert localized effects or be absorbed into the bloodstream.

Factors that influence the absorption of these materials may include the vapor pressure of the material, solubility, particle size, its concentration in the inhaled air, and the chemical properties of the material.

Vapor pressure is an indicator of how quickly a substance evaporates into the air and how high the concentration in air can become – higher concentrations in air cause greater exposure in the lungs and greater absorption in the bloodstream.

Most chemicals have an odor that is perceptible at a certain concentration, referred to as the odor threshold; however, there is no relationship between odor and toxicity. There is considerable individual variability in the perception of odor. Olfactory fatigue may occur when exposed to high concentrations or after prolonged exposure to some substances. This may cause the odor to seem to diminish or disappear, while the danger of overexposure remains.

Symptoms of overexposure may include headaches; increased mucus production; and eye, nose, and throat irritation. Narcotic effects, including confusion, dizziness, drowsiness, or collapse, may result from exposure to some substances, particularly many solvents. In the event of exposure, close containers or otherwise increase ventilation and move to fresh air. If symptoms persist, seek medical attention.

Volatile hazardous materials should be used in a well-ventilated area, or in a fume hood, to reduce the potential of exposure.

Ingestion: Although direct ingestion of a laboratory chemical into the gastrointestinal tract is unlikely, exposure may occur because of ingesting contaminated food or beverages, touching the mouth with contaminated fingers, or swallowing inhaled particles that have been cleared from the respiratory system.

The possibility of exposure by this route may be reduced by not eating, drinking, smoking, or storing food in the laboratory, and by washing hands thoroughly after working with chemicals, even when gloves were worn. Direct ingestion may occur because of the outdated and dangerous practice of mouth pipetting**.**

Injection: Injection effectively bypasses the protection provided by intact skin and provides direct access to the bloodstream, and thus, to internal organ systems. Injection may occur through mishaps with syringe needles, or through accidents with pipettes, broken glassware, or other sharp objects that have been contaminated with toxic substances.

If an accidental injection has occurred, wash the area with soap and water and seek immediate medical attention, if necessary. Cautious use of any sharp object is always important. Substituting cannulas for syringe needles, where possible, and wearing gloves may also reduce the possibility of injection.

5.4 Chemical Exposure Determination

OSHA establishes exposure limits for several hundred substances. Laboratory staff must not be exposed to substances more than the Permissible Exposure Limits (PEL) specified in OSHA Subpart Z, *Toxic and Hazardous Substances* (reference 11.4). PELs refer to airborne concentrations of substances averaged over an eight-hour day.

Some substances also have "action levels" below the PEL requiring certain actions such as medical surveillance or routine air sampling. The SDS for a particular substance indicates whether any of the chemicals are regulated through OSHA and, if so, the permissible exposure limit(s) for the regulated chemical(s). This information is also available in the OSHA Table Z list of regulated chemicals.

Exposure Monitoring

Exposure monitoring must be conducted if there is a reason to believe that exposure levels for a particular substance may routinely exceed either the action level or the PEL. The EH&S Department and the supervisor may use professional judgment, based on the information available about the hazards of the substance and the available control measures, to determine whether exposure monitoring must be conducted.

When necessary, exposure monitoring is managed by EH&S according to established industrial hygiene practices. Results of the monitoring are made available to the individual monitored and his or her supervisor. Based on the monitoring results, periodic air sampling may be scheduled at the discretion of EH&S, in accordance with applicable federal, state, and local regulations. The EH&S Department maintains records of all exposure-monitoring results.

6.0 HEALTH HAZARDS OF BIOLOGICAL AGENTS

6.1 Introduction

Biological agents include bacteria, viruses, fungi, other microorganisms, and their associated toxins. They could adversely affect human health in a variety of ways, ranging from relatively mild allergic reactions to serious medical conditions, even death. A laboratory risk assessment of each biological agent may be performed by EH&S and the supervisor. A risk assessment should identify the following:

- Pathogenicity of the material includes disease incidence and severity.
- Routes of transmission: absorption, injection, ingestion, and inhalation.
- Agent stability: how easily the material can be decontaminated.
- Infectious dose and concentration of working quantities.
- Risks from method procedures: including production of aerosols, use of sharps.
- Material origin.
- Availability of prophylaxis (vaccination).
- Medical surveillance programs and exposure management (post-exposure prophylaxis).
- How can exposure occur?

Refer to: *Biosafety in Microbiological and Biomedical Laboratories* https://www.cdc.gov/labs/pdf/SF__19_308133-A_BMBL6_00-BOOK-WEB-final-3.pdf for additional information.

6.2 Basic Toxicology

The principal hazardous characteristics of a biological agent are 1) its capability to infect and cause disease in a susceptible human host (pathogenicity); 2) its virulence as measured by the severity of disease; and 3) the availability of preventive measures and effective treatments for the disease.

- Pathogenicity and virulence include disease incidence and severity (i.e., mild morbidity versus high mortality, acute versus chronic disease). The more severe the potentially acquired disease, the higher the risk. For example, *Staphylococcus aureus* only rarely causes severe or life-threatening disease in a laboratory situation and is relegated to Biosafety Level (BSL-2).
- The most common form of prophylaxis is immunization with an effective vaccine or a regimen of antibiotics.

Biological agents are divided into two general categories:

- Category 1 - Lower risk of disease transmission
  Biological materials in risk group 1 (BSL-1) agents and human materials
- Category 2 – higher risk of disease transmission
  Infectious agents within Risk group 2 (BSL-2) or higher

These categories are based on the perceived risk of exposure and approximate titer of the potential exposure.

Other hazardous characteristics of an agent include probable routes of transmission of laboratory infection, infective dose, stability in the environment, concentration, and its endemic nature.

- Routes of transmission include the absorption, injection, ingestion, and inhalation of biological agents (see Section 5.3, Routes of Entry). Agents that can be transmitted by the aerosol route have caused most laboratory infections. The greater the aerosol potential, the higher the risk.
- Infective dose of the agent can vary from one to hundreds of thousands of units. The complex nature of the interaction of microorganisms and the host presents a significant challenge even to the healthiest immunized laboratory worker and may pose a serious risk to those with lesser resistance. The laboratory worker's immune status is directly related to his/her susceptibility to disease when working with an infectious agent.
- Agent stability is a consideration that involves not only aerosol infectivity (e.g., from spore-forming bacteria) but also the agent's ability to survive over time in the environment. Factors such as desiccation, exposure to sunlight or ultraviolet light, or exposure to chemical disinfectants must be considered.
- Endemic nature of infection relates to its method of transmission from one person to another and whether the environment is viable for its transmission.
- Biological toxicity can be difficult to measure because the "threshold dose" may be a single organism. Theoretically, one viral particle, bacterial vegetative cell, or spore can reproduce to cause a serious infection. However, in a host with an intact immune system, the inherent toxicity of the organism is balanced by the host's ability to fight back; the effective toxicity is then a combination of both parts of the relationship. A similar situation is also present with other types of toxic agents. As with chemical hazards, Risk = Toxicity x Exposure (see Section 5.2, Basic Toxicology).

Due to the potentially infectious nature of biological agents, being aware of the exposure has a direct relationship to the level of risk. An individual who is aware of their exposure (e.g., accidental injection) can identify the agent and take immediate action. However, without such knowledge, incubation of the infectious agent occurs until the first appearance of symptoms associated with the infection. As a result, immediate identification, isolation, and treatment of the infected individual go ignored with potentially severe consequences to the individual and others exposed to the individual. Therefore, the need for biosafety cannot be understated.

6.3 Levels of Biosafety

The CDC-NIH has established **four levels of biosafety**, based on the degree of hazard associated with an organism, to describe the combination of laboratory practices and techniques, safety equipment, and facilities needed to protect against exposure. These four biosafety levels (BSL) require successively more restrictive practices and facilities as work moves from the least restrictive BSL1 to work with the highest hazard level of BSL4. The CSN Biology laboratories typically utilize biological agents that fall within BSL-1 and BSL-2.

- **Biosafety Level 1 (BSL-1)** is the basic level of protection and is appropriate for agents that are not known to cause disease in normal, healthy humans. BSL-1 requires good microbiological practice with no special primary or secondary barriers required. This includes such organisms as the bacteria *Bacillus subtilis* or host/vector strains of *E. coli*.
- **Biosafety Level 2 (BSL-2)** applies to work with a broad spectrum of moderate-risk agents that are generally present in the environment at large and are associated with human disease of varying severity by ingestion or through percutaneous or mucous membrane exposure. This includes such organisms as adenovirus, *Salmonella* spp., and *Legionella pneumophila.*

6.4 Routes of Entry

The predominant probable routes of transmission in the laboratory are: 1) direct skin, eye, or mucosal membrane exposure (absorption) to an agent; 2) parenteral inoculation (injection) by a syringe needle or other contaminated sharp; 3) ingestion of liquid suspension of an infectious agent, or by contaminated hand to mouth exposure, and 4) inhalation of infectious aerosols.

An awareness of the routes of transmission for the natural human disease helps identify probable routes of transmission in the laboratory and the potential for any risk to public health. However, it is important to remember that the nature and severity of disease caused by a laboratory infection and the probable laboratory route of transmission of the infectious agent may differ from the route of transmission and severity associated with the naturally acquired disease.

Absorption: Transmission of an infectious agent through the skin is influenced by the health of the skin. Skin that is cracked or has lacerations offers less resistance, providing a pathway for biological agents to enter the body’s circulatory system.

Transmission of an infectious agent is more likely through the mucosal membranes of the nose and eyes through tactile transference. To eliminate exposure, wear gloves and safety goggles. Do not touch eyes, nose, or other body parts without first leaving the infectious area, removing all personal protective equipment, and washing thoroughly with disinfectant soap.

Ingestion: Direct ingestion of a biological agent may occur because of ingesting contaminated food or beverages, touching the mouth with contaminated fingers, or swallowing inhaled particles that have been cleared from the respiratory system.

Exposure by this route may be reduced by not eating, drinking, smoking, or storing food in the laboratory, by removing/discarding all PPE after leaving the laboratory, and proper decontamination prior to leaving the laboratory. Never perform mouth pipetting in the laboratory. In the event of accidental ingestion, contact emergency medical services (see Section 3).

Injection: Injection effectively bypasses the protection provided by intact skin with direct access to the body’s circulatory system and internal organ systems.

Injection may occur through mishaps with syringe needles, pipettes, broken glassware, or other sharp objects that have been contaminated with biological agents in the laboratory.

Inhalation: As infectious agents can be acquired (transmitted by direct contact with discharges from respiratory mucous membranes of infected persons), a laboratory worker is at risk of infection from mucosal membrane exposure to droplets generated while handling that agent.

Procedures that impart energy to a microbial suspension, such as pipetting, sonicating, or vortex mixing will produce aerosols.

Small particles stay airborne and, if not contained, are easily dispersed throughout the laboratory. When inhaled, these particles are retained in the lungs creating an exposure hazard for the person performing the operation, coworkers in the laboratory, and a potential hazard for persons occupying adjacent spaces open to airflow from the laboratory.

Larger particle droplets rapidly fall out of the air, contaminating gloves, the immediate work area, and the mucous membranes of unprotected staff.

Inhalation exposure to biological agents can be greatly reduced using a biosafety cabinet, goggles, gloves, and other PPE. Routinely change and wash reusable PPE, such as lab coats and goggles. Decontaminate reusable laboratory equipment, including cabinets and countertops. Decontamination of reusable laboratory equipment shall be in accordance with Section 8.11.

7.0 CONTROLLING EXPOSURES TO CHEMICALS AND BIOLOGICAL AGENTS

There are three general methods for controlling exposure to hazardous substances. In the laboratory, these methods, or a combination of them can be used to keep exposure below permissible exposure limits.

Engineering Controls	**Work Practice and Administrative Controls**	**Personal Protective Equipment**
The Controls Are: • Substitution of a less hazardous material • Change in the process to minimize contact with hazardous chemicals • Isolation or enclosure of a process or operation • Use of wet methods to reduce the generation of dust or other particulates • General dilution • Ventilation • Local exhaust, including the use of fume hoods and biosafety cabinets	Using good laboratory work practices, such as those outlined in this manual, helps to reduce the risk of exposure to chemicals and biological agents.	To minimize exposure PPE including gloves, eye protection, respirators, and other protective clothing should be used.
The use of engineering controls is the preferred method for reducing worker exposure to hazardous	Administrative controls involve rotating job assignments and adjusting work schedules so that staff are not overexposed to a	Typically, PPE is the last method of exposure control after engineering and administrative controls have been implemented.

chemicals and biological agents, but except for fume hoods, may not be feasible in the laboratory.	chemical or biological agent. Given the nature of work in a laboratory, administrative controls are not usually a realistic approach to controlling exposure.	

7.1 Engineering Controls – Fume Hoods and Laboratory Ventilation

7.1.1 General

One of the primary safety devices in a laboratory is a chemical fume hood. A well-designed hood, when properly installed and maintained, can offer a substantial degree of protection to the user, provided it is used appropriately, and its limitations are understood. This section discusses the operation, limitations, and proper work practices for the safe use of chemical fume hoods and other local ventilation devices.

7.1.2 How a Fume Hood Works

A fume hood is a ventilated enclosure where chemical gases, vapors, and fumes are contained or removed to a sequestering mechanism. An exhaust fan situated on the top of the laboratory building pulls air and airborne contaminants in the hood through ductwork connected to the hood and are dispersed into the atmosphere.

The typical fume hood is equipped with a movable front sash and an interior baffle. Depending on its design, the sash may move vertically, horizontally, or a combination of the two and provide some protection to the hood user by acting as a barrier between the worker and the experiment.

The slots and baffles direct the air being exhausted. In many hoods, they may be adjusted to allow the most even flow. It is important that the baffles are not closed or blocked since this blocks the exhaust path.

The airfoil or beveled frame around the hood face allows more even airflow into the hood by avoiding sharp curves that can create turbulence.

In most hood installations, the exhaust flow rate or quantity of air pulled through the hood is constant. Therefore, when the sash is lowered and the cross-sectional area of the hood opening decreases, the velocity of airflow (face velocity) through the hood increases proportionally. Thus, higher face velocities can be obtained by lowering the sash.

7.1.3 Hood Face Velocity

Based on multiple studies and the recommendations of several laboratory safety guidance documents (see Section 11), the following face velocity criteria are recommended:

- **Above 150** feet per minute (fpm): Unacceptable for laboratory use.
- **95-125** fpm: Provides adequate control of inhalation exposure to most hazardous substances, including radioactive materials and particularly hazardous substances.
- **80-95** and **125-150** fpm: Adequate for manipulation of laboratory quantities of hazardous materials except for radioactive materials and particularly hazardous substances.

7.1.4 Using Chemical Fume Hoods

7.1.4.1 A fume hood is used to minimize exposure of the hood user and lab occupants to hazardous or odorous chemicals and prevent their release into the laboratory. A secondary purpose is to limit the effects of a spill by partially enclosing the work area and drawing air into the enclosure by means of an exhaust fan. This inward flow of air creates a dynamic barrier that minimizes the movement of material out of the hood and into the lab.

7.1.4.2 In a well-designed, properly functioning fume hood, only about 0.0001% to 0.001% of the material released into the air within the hood escapes from the hood and enters the laboratory.

7.1.4.3 The determination that a fume hood is necessary for a particular experiment should be based on hazard analysis of the planned work and SDS recommendations. Such an analysis should include:

- A review of the physical characteristics, quantity, and toxicity of the materials to be used.
- The experimental procedure.
- The volatility of the materials presents during the experiment.
- The probability of their release.
- The number and sophistication of manipulations.
- The skill and expertise of the individual performing the work.

7.1.5 Good Work Practices

The level of protection provided by a fume hood is affected by the way the fume hood is used. No fume hood, however well designed, can provide adequate containment unless good laboratory practices are used.

- **The key is adequate planning and preparation.** The hood user should know the Standard Operating Configuration (SOC) of the hood and should design experiments so that the SOC can be maintained whenever hazardous materials might be released. The SOC refers to the position of the sash. A schematic drawing of the SOC is displayed on the front of each chemical fume hood. Also, a safety latch is installed in most hoods, so the sash cannot be inadvertently raised above a safe level.
- Before using the hood, check the hood survey sticker to determine if the face velocity is adequate for the particular use of a hood. For work with hazardous materials, the fume hood should have a face velocity of 80 - 125 fpm at a sash height that is adequate for the procedure.
- The hood user should also check the Magnehelic gauge or other hood performance indicator and compare its reading to the reading indicated on the hood survey sticker. If the reading differs significantly (15% or more for a Magnehelic gauge) from that on the sticker, the hood may not be operating properly.

- Items contaminated with odorous or hazardous materials should be removed from the hood only after decontamination or if placed in a closed outer container to avoid releasing contaminants into the air.
- When using cylinders containing highly toxic or extremely odorous gases, obtain only the minimal practical quantity. Consider using a flow-restricting orifice to limit the rate of release in the event of equipment failure. In some circumstances, exhaust system control devices or emission monitoring in the exhaust stack may be appropriate.

7.1.5.1 To optimize the performance of the fume hood, follow the practices listed below:

- **Mark a line** with tape 6 inches behind the sash and keep all chemicals and equipment behind that line during experiments. This will help to keep materials from escaping the hood when disturbances like air currents from people walking past the hood, etc., interfere with airflow at the face of the hood.
- Provide **catch basins** for containers that could break or spill, to minimize the spread of spilled liquids.
- **Keep the sash completely lowered** any time an experiment is in progress and the hood is unattended. Note: Lowering the sash not only provides additional personal protection but also results in significant energy conservation. Post a **"DO NOT DISTURB"** sign on the sash to notify others when an experiment is in progress.
- Never use a hood to control exposure to hazardous substances without first **verifying that it is operating properly.**
- **Visually inspect the baffles** (openings at the top and rear of the hood) to be sure that the slots are open and unobstructed. For optimum performance, adjust the baffles when working with high-temperature equipment and/or heavy gases or vapors.
- **Do not block slots**. If large equipment must be placed in the hood, put it on blocks to raise it approximately 2 inches above the surface so that air may pass beneath it.
- **Place large or bulky equipment near the rear of the fume hood.** Large items near the face of the hood may cause excessive air turbulence and variations in face velocity.
- **Do not use the hood as a storage device.** Keep only the materials necessary for the work inside of the hood.
- **Keep the hood sash clean and clear.**
- **Check areas around the hood for sources of cross drafts**, such as supply air grilles, fans, and doors. Cross drafts may cause turbulence that can allow leaks from the hood into the lab.
- **Extend only hands and arms into the hood and avoid leaning against it.** If the user stands up against the face of the hood, air currents produced by turbulent airflow may transport contaminants into the user's breathing zone.
- **Clean all chemical residues** from the hood chamber after each use.
- **Electrical devices should be connected outside the hood** to avoid electrical arcing that can ignite a flammable or reactive chemical.
- **DO NOT USE A HOOD FOR ANY FUNCTION FOR WHICH IT WAS NOT INTENDED**. Certain chemicals or reactions require specially constructed hoods. Examples are perchloric acid or high-pressure reactions.

7.1.5.2 Common Misuses and Limitations

Used appropriately, a fume hood can be a very effective device for the containment of hazardous materials, as well as providing some protection from splashes and minor explosions. Even so, the average fume hood does have several limitations.

- **Particulates** – A fume hood is not designed to contain high-velocity releases of particulate contaminants unless the sash is fully closed.
- **Pressurized systems** – Gases or vapors escaping from pressurized systems may move at sufficient velocity to escape from the fume hood.
- **Explosions** – The hood is not capable of containing explosions, even when the sash is fully closed. If an explosion hazard exists, the user should provide anchored barriers, shields, or enclosures of sufficient strength to deflect or contain it. Such barriers can significantly affect the airflow in the hood.
- **Perchloric Acid** – A conventional fume hood must not be used for perchloric acid. Perchloric acid vapors can settle on ductwork, resulting in the deposition of perchlorate crystals. Perchlorates can accumulate on surfaces and have been known to detonate on contact, causing serious injury. Specialized perchloric acid hoods, made of stainless steel and equipped with a wash down system must be used for such work.
- **Airfoil Sills** – Many fume hoods are equipped with flat or rounded sills or airfoils that direct the flow of air smoothly across the work surface. Sills should not be removed or modified by the hood user. Objects should never be placed on these sills. Materials released from containers placed on the sills may not be adequately captured. In addition, an object on the sill may prevent the quick and complete closure of the sash in an emergency.
- **Spill Containment Lips** – Most modern fume hoods have recessed work surfaces or spill containment lips to help contain minor liquid spills. In many cases, these lips are several inches wide. Containers of liquids should not be placed on the hood lip.
- **Horizontal Sliding Sashes** – The hood user should never remove sliding sashes. Horizontal sash hoods are designed and balanced with no more than half the face open at any time. Removal of sashes may reduce the face velocity below acceptable levels.
- **Tubing for Exhaust** – Tubing is frequently used to channel exhaust to the hood from equipment located some distance away. This is not an effective control method.
- **Connections to the Exhaust System** – Occasionally, lab personnel may need local exhaust ventilation other than that provided by an existing fume hood. A new device may not be connected to an existing fume hood without explicit approval from the lab supervisor or manager and facilities management. Adding devices to even the simplest exhaust system without adequate evaluation and adjustment will usually result in decreased performance of the existing hood and/or inadequate performance of the additional device.
- **Microorganisms** – Work involving harmful microorganisms should be done in a biosafety cabinet, rather than a chemical fume hood.
- **Highly Hazardous Substances** – A well-designed fume hood will contain 99.9999 – 99.999% of the contaminants released within it when used properly. When

working with highly dangerous substances needing more containment than a fume hood offers, consider using a glove box.

- **Pollution Control** – An unfiltered fume hood is not a pollution control device. All contaminants that are removed by the ventilating system are released directly into the atmosphere. Apparatus used in hoods should be fitted with condensers, traps, or scrubbers to contain and collect waste solvents or toxic vapors or dusts.
- **Waste Disposal** – A fume hood should not be used for waste disposal. It is a violation of environmental regulations to intentionally send waste up the hood stack. As described above, the hood is not a pollution control device.

7.1.5.3 The Fume Hood as a Storage Device

Fume hoods are designed specifically to provide ventilation for the protection of lab occupants during chemical manipulations. The airflow they provide is greatly in excess of that needed for the storage of closed containers of even the most toxic of volatile materials.

In general, the storage of chemicals in fume hoods is not recommended, however, if chemicals must be stored in the hood, the following general policy is recommended:

7.1.5.3.1 Hoods Actively in Use

Storage of materials should be minimized or eliminated altogether. Materials stored in the hood can adversely affect the containment provided. In addition, the hood is frequently the focus of the most hazardous activities conducted in the laboratory. The presence of stored flammable or volatile materials that are highly toxic can only exacerbate the problems resulting from an explosion or fire in the hood. Even if they are not directly involved in such an event, attempts to control or extinguish a fire may result in the spilling of stored materials.

7.1.5.3.2 Hoods Not in Active Use

Materials requiring ventilated storage (e.g., volatile and highly toxic, or odorous substances) may be stored in a hood if they are properly segregated and the hood is posted to prohibit its use for experimental work.

7.1.5.3.3 Hood Performance Indicators

All fume hoods are equipped with some type of continuous airflow monitoring device, either in the form of a Magnehelic gauge, a color-coded flow indicator, or a face velocity monitor. Some are equipped with alarms. Each hood also has a survey sticker or performance certification with important information to help determine whether the particular hood is functioning properly and is appropriate for the work to be performed.

7.2 Engineering Controls – Biosafety Cabinets

7.2.1 Laboratory Use Requirements

7.2.1.1 A conventional fume hood should not be used for work with viable biological agents. In laboratories that work with BSL-1 and BSL-2 biological agents, a certified open-fronted Class II biosafety cabinet provides an aseptic environment for handling and containing potentially hazardous biological materials, including aerosolized contaminates.

7.2.1.2 The Class II Biosafety Cabinet (BSC) also provides protection from external contamination of the materials (e.g., cell cultures, microbiological stocks) being manipulated inside the cabinet. Requirements for Class II biological safety cabinets are established by the National Sanitation Foundation (NSF)/ American National Standards Institute (ANSI) Standard No. 49.

7.2.1.3 This section discusses the operation, limitations, and proper work practices for the safe use biosafety cabinets.

7.2.2 How a Biosafety Cabinet Works

7.2.2.1 Biosafety Cabinets are ventilated, partially enclosed cabinets primarily intended for working safely with infectious microorganisms. A high-efficiency particulate air (HEPA) filter is used to remove particles (such as bacteria, viruses, pollen, etc.) from the cabinet's interior. Class II biosafety cabinets are the most common type used in laboratories and provide personal, product, and environmental protection.

7.2.2.2 Biosafety cabinets contain biological contaminants by providing clean air to the working area and by providing a constant flow of air out of the work area to prevent room air from entering. The air flowing out from the hood suspends and removes contaminants introduced into the work area.

7.2.2.3 The major difference between Class II biosafety cabinets is air delivery and exhaust alternatives.

7.2.2.3.1 **Horizontal laminar flow** – Air enters the cabinet below the work surface through a pre-filter. A blower draws the air up and horizontally through a HEPA filter across the work surface.

7.2.2.3.2 **Vertical laminar flow** – Air enters the cabinet from the top and is pushed downward vertically through a supply HEPA filter. A blower draws the air below the work surface to the back of the cabinet and upward through a HEPA exhaust filter.

7.2.2.4 **A high-efficiency bacteria-retentive filter** is the most important part of a biosafety cabinet. Room air is taken into the unit and passed through a pre-filter to remove gross contaminants (lint, dust, etc.). The air is then compressed and channeled up behind and through the HEPA filter in a laminar flow fashion; that is, the purified air flows out over the entire work surface in parallel lines at a uniform velocity. The HEPA filter removes nearly all of the bacteria from the air.

7.2.2.5 Type A1 and A2 cabinets usually return their filtered exhaust air to the room and may not be connected to the building exhaust system. HEPA filtered exhaust air from a Class II hood can be safely re-circulated back into the laboratory environment if the cabinet is tested and certified at least annually and operated according to the manufacturer's recommendations.

7.2.2.6 Provisions to assure proper safety cabinet performance and air system operation must first be verified before installation.

7.2.3 Using Biosafety Cabinets

7.2.3.1 Class II, Type A2 biosafety cabinets shall provide the following criteria:

7.2.3.1.1 Maintain a minimum average inflow velocity of 100 fpm (0.5 m/s) through the work access opening;

7.2.3.1.2 Have HEPA filtered downflow air that is a portion of the mixed downflow and inflow air from a common exhaust plenum;

7.2.3.1.3 May exhaust HEPA filtered air back into the laboratory or to the environment through an exhaust canopy; and

7.2.3.1.4 Have all biologically contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums.

7.2.3.2 Type A2 hoods must have an air inflow nominal set-point of 105 ± 5 fpm and a downflow nominal set-point of 60 ± 5 fpm four (4) inches above the plane of the window with lights removed.

7.2.3.3 Class II cabinets offer protection to laboratory personnel and the environment when used with good microbiological techniques.

7.2.3.4 To optimize the performance of a biosafety cabinet, follow the practices listed below:

- Disinfect all working surfaces with denatured alcohol prior to use. Close the cabinet and turn on the germicidal ultraviolet (UV) light. Allow the UV light to disinfect surfaces for several minutes.
- Turn off the UV light. Turn on the blower and working light. Raise the hood slowly until resistance is felt, and then stop. Raising the hood beyond this point reduces the negative airflow. Check Magnehelic gauge to measure suction pressure reading.
- Pre-plan the work operation. Place all work items needed for the procedure, including waste containers, in the cabinet toward the front so there is no interference of airflow at the back. Segregate clean materials from dirty materials.

- Allow the unit to purge the airflow at least three minutes before beginning any procedure to allow sufficient time for the cabinet air to purge airborne contamination from the work area.
- Minimize arm movement within the cabinet as well as removal and re-entry of arms.
- Decontaminate all working surfaces after the procedure is complete. Remove all equipment from the cabinet.
- If a spill of a biological hazard occurs, leave the unit running and close the sash. If the spill involves a volatile liquid or gas, turn the unit off and close the sash. In both cases, report the incident to UPD (702-895-3669) and to EH&S (x7445), as well as to the appropriate work area supervisor at the earliest opportunity. Refer to section 9.0.

7.2.4 Limitations

7.2.4.1 It is easy to overcome the established airflow velocity and introduce reverse currents that can re-introduce contaminants into the work area. Optimally, biosafety cabinets should remain on 24 hours a day. If turned off for any reason, it should be on for at least 30 minutes and thoroughly cleaned before reuse.

7.2.4.2 A direct and unobstructed path must be maintained between the filter and the area inside the hood where the manipulations are being performed. Air downstream from non-sterile objects (such as solution containers, hands, etc.) becomes contaminated from particles blown off these objects.

7.2.4.3 HEPA filters do not capture gases or vapors. Biosafety cabinets should be used only with low-hazard chemicals. Even when connected to the building exhaust system, a ducted biosafety cabinet may not achieve a face velocity of 95 – 125 feet per minute, making it inappropriate for use with hazardous chemicals.

7.2.4.4 Change HEPA filters at regular intervals to maintain their effectiveness. Follow manufacturer’s specifications when changing filters.

7.3 Engineering Controls – Other Laboratory Systems

7.3.1 General

7.3.1.1 The laboratory uses equipment and apparatus that can generate airborne contaminants but cannot be used within a fume hood. Examples include gas chromatographs, ovens, and vacuum pumps.

7.3.1.2 Other types of local exhaust ventilation systems are required to control contaminants generated by these operations. Such systems must not be installed without the explicit approval from the CSN Facilities Management Technical Services Department. See *Common Misuses of a Fume Hood* (section 7.1.5.2) for more information.

7.3.2 Elephant Trunks or Snorkels

7.3.2.1 An elephant trunk or snorkel is a flexible duct or hose connected to an exhaust system. It can be positioned directly over the work being performed on a workbench. Each arm is served by an individual exhaust fan.

7.3.2.2 It can only capture contaminants that are very close to the inlet of the hose, typically less than a distance equal to one-half of the diameter of the duct. The throat velocity should be between 800 – 1200 fpm but will depend on the number of snorkels being used at any one time.

7.3.2.3 Elephant trunks or snorkels can be effective for capturing discharges from gas chromatographs, pipe nipples, or the end of the tubing. However, the effectiveness of the elephant trunk should be carefully evaluated before they are used to control releases of hazardous substances.

7.3.3 Canopy Hoods

7.3.3.1 A canopy hood in the laboratory is constructed in a similar fashion to the overhead canopy hoods seen in kitchens. In order for the canopy hood to be able to capture contaminants, the hood requires a relatively large volume of air movement (usually balanced to 1000 fpm capture velocity).

7.3.3.2 Canopies are served by individual exhaust fans. They work best when the thermal or buoyant forces exist to move the contaminant up to the hood capture zone.

7.3.3.3 One of the biggest problems with canopy hoods is that, in most cases, they are designed such that the contaminated air passes through the individual's breathing zone. The airflow is easily disrupted by crosscurrents of air.

7.3.3.4 For the most part, canopy hoods should only be used for the exhaust of nonhazardous substances.

7.3.4 Slot Hoods

7.3.4.1 There are many types of slot hoods, each suited for different types of operations. In general, a slot hood requires less airflow than a canopy hood and is much more effective than an elephant trunk or canopy hood, when installed properly.

7.3.4.2 Slot hoods are best used for operations that require more working room than a fume hood and where a limited number of low toxicity chemicals are used. The placement of the opening(s) and the velocity of airflow are based on the application, particularly dependent upon the vapor density of the chemical(s).

7.3.4.3 Examples of good uses for slot hoods are darkrooms and acid dipping operations.

7.3.5 Downdraft Hoods

7.3.5.1 Downdraft hoods or downdraft tables are specially designed work areas with ventilation slots on the sides of the work area. This type of system is useful for animal perfusions and other uses of chemicals with vapor densities heavier than air.

7.3.6 Toxic Gas Cabinets

7.3.6.1 Highly toxic or odorous gases should be used and stored in gas cabinets. In the event of a leak or rupture, a gas cabinet will prevent the gas from contaminating the laboratory.

7.3.6.2 Gas cabinets should be connected to laboratory exhaust ventilation using a hard duct, rather than elephant tubing since such tubing is more likely to develop leaks. Coaxial tubing should be used for delivering gas from the cylinder to the apparatus. Coaxial tubing consists of an internal tube containing the toxic gas, inside another tube. In between the two sets of tubing is nitrogen, which is maintained at a pressure higher than the delivery pressure of the toxic gas. This ensures that, in the event of a leak in the inner tubing, the gas will not leak into the room.

7.3.7 Glove Box

7.3.7.1 There are two general types of glove boxes, one operating under negative pressure, and the other operating under positive pressure. Glove boxes consist of a small chamber with sealed openings fitted with arm-length gloves. The materials are placed inside the chamber and manipulated using gloves.

7.3.7.2 A glove box operating under negative pressure is used for highly toxic gases when a fume hood might not offer adequate protection. A rule of thumb is that a fume hood will offer protection for up to 10,000 times the immediately hazardous concentration of a chemical. The airflow through the box is relatively low, and the exhaust usually must be filtered or scrubbed before release into the exhaust system.

7.3.7.3 A glove box operating under positive pressure may be used for analyses that require protection from moisture or oxygen. If this type of glove box is to be used with hazardous chemicals, the glove box must be tested for leaks before each use. A pressure gauge should be installed to be able to check the integrity of the system.

7.4 Continuous Hood Monitoring Devices

7.4.1 Static Pressure Gauge (Magnehelic)

7.4.1.1 Fume hoods and biosafety cabinets are equipped with static pressure gauges that measure the difference in static pressure across an orifice in the duct or between the laboratory and the fume hood exhaust duct. Most of the devices are aneroid pressure gauges, such as magnehelics, that are mounted on the front of the hood above the sash.

7.4.1.2 The gauge is a flow rate indicator with a scale that reads in units of pressure (psi), rather than velocity. Changes in the Magnehelic reading are not linearly proportional to changes in face velocity; therefore, it should only be used as an index of hood performance.

7.4.1.3 The Magnehelic gauge reading at the time of the most recent hood survey is shown on each fume hood evaluation sticker. A difference of 15% or more in the Magnehelic reading from that shown on the sticker is an indication that the flow rate in the duct, and thus the face velocity, may have changed significantly since the last survey. If the user notices such a change or has any other reason to suspect that the hood is not operating properly, the user must contact their immediate supervisor.

7.4.2 Color Coded Flow Indicators

7.4.2.1 Some hoods are equipped with flow-safe devices, rather than Magnehelic gauges. This device constantly measures the face velocity of the hood and, using a needle that either points to green (for good) or red, indicates whether the hood is functioning properly. Currently, color-coded flow indicators are not used in the laboratory.

7.4.3 Face Velocity Monitors

7.4.3.1 Some of the newer hoods have constant face velocity measuring devices. Light-Emitting Diode (LED) readout of the face velocity is found on the device on the top corner of the hood opening. The readout indicates the actual face velocity of the hood and should be a negative number to reflect that the direction of flow is negative - into the hood, rather than positive - out of the hood.

7.4.4 Alarm-Equipped Hoods

7.4.4.1 Both fume hoods and biosafety cabinets are designed to operate with the hood sash lowered to the height specified in the manufacture’s guidelines, in order to conserve energy by exhausting air at a lower flow rate than would otherwise be necessary.

7.4.4.2 When the sash is raised above the manufacture’s set point, a buzzer sounds, and a red light flashes, alerting the hood user and other laboratory occupants that the hood face velocity is now likely to be below 100 fpm.

7.4.4.3 In the event that the sash must be raised above the set point, such as when large equipment must be installed or removed, the buzzer can be turned off manually, but the light continues flashing until the sash is lowered below the set point mark.

7.4.4.4 Whenever allowable, all chemical manipulations performed in an alarm-equipped hood should be done with the sash opening at the manufacture’s recommended height.

7.4.5 Hood Survey Sticker

7.4.5.1 Every fume and biosafety cabinet should have a survey sticker or performance certification affixed to the front of the hood in a conspicuous location. The sticker contains basic information about hood performance as of the most recent survey and should be consulted each time the hood or cabinet is used.

- The hood or cabinet's serial number is a unique identifier for the particular hood. Refer to this number when discussing problems with a particular hood.
- The **Average Face Velocity** is the average velocity with the hood sash in the SOC.
- The **Opening for 100 fpm face velocity** is the sash height, in inches, to which the sash must be lowered in order for the hood to achieve 100 fpm face velocity.
- The **Flow Monitor Reading** is the reading of the Magnehelic gauge or other continuous monitoring device at the time of the survey.
- The "**Inspected on"** date is the date of the last hood survey. Hoods that have not been surveyed within the past year should not be used until tested by a certified contractor (hereafter, contractor).
- The "**By"** line gives the name of the contractor who surveyed the hood.
- If hood performance is judged to be unsuitable for use with hazardous chemicals or potentially infectious agents, a sticker with this information is placed on the hood instead of the survey sticker.
- Do not use a hood or cabinet that does not have a survey sticker.

7.5 Hood Evaluations and Maintenance Programs

7.5.1 Hood and Cabinet Surveys

7.5.1.1 Each fume and biosafety cabinet is certified annually by a contractor.

7.5.1.2 Ensuring that the hoods and biosafety cabinets are certified each year is the responsibility of the Technical Services department (hoods) and Environmental Health and Safety department (biosafety cabinets). After each performance survey, any deficiencies that render the hood unsafe to operate are discussed with the appropriate supervisor. Refer to section 7.4.2 regarding hood maintenance. Affected laboratory personnel will be notified when the hood is restored to safe operation status.

7.5.1.3 If a problem is found during the survey, a written notice will be provided on-site to the laboratory or taped to the sash of the fume hood or biosafety cabinet.

7.5.2 Requesting Maintenance

7.5.2.1 Laboratory personnel who experience problems with hood operation are required to report it immediately to their supervisor and place an out-of-service tag on the hood.

7.5.2.2 Maintenance will be performed by a certified contractor. If maintenance of the hood is required, the hood must be certified prior to returning the hood to service.

7.6 Personal Protective Equipment

7.6.1 General

7.6.1.1 PPE is a special gear used to protect the user from specific substance hazards. It is a last resort protection system, to be used when substitution or engineering controls are not feasible. PPE does not reduce or eliminate the hazard, but rather protects only the individual user and does not protect anyone else.

7.6.1.2 Supervisors shall conduct a hazard assessment of general safety conditions and items in the laboratory (section 2.1). Based on that assessment, PPE requirements shall be submitted to EH&S for review and approval.

7.6.1.3 PPE includes gloves, respiratory protection, eye protection, and protective clothing. The need for PPE is dependent upon the type of operations and the nature and quantity of the materials in use and must be assessed on a case-by-case basis. Workers who rely on PPE must understand the functioning, proper use, and limitations of the PPE used.

7.6.1.4 Inadequate training in the proper use of PPE may reduce its effectiveness, provide a false sense of security, and increase the risk to laboratory workers.

7.6.2 Responsibilities

7.6.2.1 Managers and Supervisors

7.6.2.1.1 Determine PPE required to perform assigned work.
7.6.2.1.2 Procure all necessary PPE.
7.6.2.1.3 Ensure employees receive training for the proper use, wear, limitation, and care of PPE. Training shall be documented, and copies of training documents forwarded to EH&S.
7.6.2.1.4 Issue PPE to employees.
7.6.2.1.5 Ensure employees use appropriate PPE when required.
7.6.2.1.6 Ensure co-workers wear PPE.

7.6.2.2 Employees

7.6.2.2.1 Attend required trainings and demonstrations, as needed, for PPE use and application.
7.6.2.2.2 Comply with proper PPE use, maintenance, and disposal.
7.6.2.2.3 Inform a supervisor of the need to repair or replace PPE.

7.6.3 Eye Protection

7.6.3.1 Safety Glasses

7.6.3.1.1 Safety glasses must be worn in all laboratory spaces and when handling corrosives, hazardous wastes, and potentially infectious materials in any facility location.

7.6.3.1.2 They must meet the ANSI Z87.1 standard. When ordering safety glasses, be sure that this standard is referenced for the product.

7.6.3.1.3 Standard streetwear eyeglasses fitted with side shields are not sufficient. CSN employees who are interested in obtaining prescription safety glasses should contact EH&S for assistance.

7.6.3.1.4 Safety glasses do not provide adequate protection from significant chemical splashes. They may be adequate when the potential splash is minimal, such as when opening Eppendorf tubes; but safety glasses do not seal to the face, resulting in gaps at the top, bottom, and sides, where chemicals may seep through.

7.6.3.1.5 Safety glasses are also not appropriate for dusts and powders, which can get by the glasses in ways similar to those described above. Safety goggles are best used for this type of potential exposure.

7.6.3.2 Chemical Splash Goggles

Chemical Splash Goggles should be worn when there is potential for a splash from a hazardous material. Like safety glasses, goggles are impact resistant. Chemical splash goggles should have indirect ventilation so hazardous substances cannot drain into the eye area. Some may be worn over prescription glasses.

7.6.3.3 Face Shields

Face shields are in order when working with large volumes of hazardous materials, either for protection from splash to the face or flying particles. Face shields must be used in conjunction with safety glasses or goggles.

7.6.3.4 Contact Lenses

7.6.3.4.1 Contact lenses may be worn in the laboratory but do not offer any protection from chemical contact. If a contact lens becomes contaminated with a hazardous chemical, rinse the eye(s) using an eyewash for at least 15 minutes and remove the lens immediately. Contact lenses that have been contaminated with a chemical must be discarded.

7.6.4 Protective Clothing

7.6.4.1 When the possibility of chemical contamination exists, protective clothing that resists physical and chemical hazards should be worn over street clothes.

7.6.4.2 Lab coats are appropriate for minor chemical splashes and spills, while plastic or rubber aprons are best for protection from corrosive or irritating liquids. Disposable outer garments (i.e., *Tyvek* suits) may be useful when cleaning and decontamination of reusable clothing are difficult.

7.6.4.3 Lab coats are required when working around potentially infectious materials and shall be removed after leaving the laboratory.

7.6.4.4 Loose clothing (such as overlarge lab coats or ties), skimpy clothing (such as shorts), torn clothing, and unrestrained hair may pose a hazard in the laboratory.

7.6.5 Footwear

7.6.5.1 Perforated shoes and sandals should not be worn in laboratories or where mechanical work is conducted. Such shoes do not offer an adequate safety barrier between the laboratory worker and chemicals, broken glass, or heavy or sharp objects.

7.6.5.2 Chemical resistant overshoes or boots may be used to avoid possible exposure to corrosive chemical or large quantities of solvents or water that might penetrate normal footwear (e.g., during spill cleanup). Leather shoes tend to absorb chemicals and may have to be discarded if contaminated with hazardous material.

7.6.5.3 Although generally not required in most laboratories, composite or safety-toed shoes may be worn when there is a risk of heavy objects falling or rolling onto the feet, such as in bottle-washing operations or moving gas cylinders. Safety footwear shall meet the requirements of ASTM F2413-11 for impact and compression resistance. CSN will supply safety shoes if there is a need. If safety shoes are needed, contact your supervisor.

7.6.6 Gloves

7.6.6.1 Choosing the appropriate hand protection can be a challenge in a laboratory setting. Considering the fact that dermatitis or inflammation of the skin accounts for 40-45% of all work-related diseases, selecting the right glove for the job is important.

7.6.6.2 Not only can many chemicals cause skin irritation or burns, but absorption through the skin can also be a significant route of exposure to certain chemicals. Dimethyl sulfoxide (DMSO), nitrobenzene, and many solvents are examples of chemicals that can be readily absorbed through the skin into the bloodstream where the chemical may cause harmful effects.

7.6.6.3 When Should Gloves Be Worn:

7.6.6.3.1 Protective gloves should be worn when handling hazardous materials, chemicals of unknown toxicity, corrosive materials, rough or sharp-edged objects, and very hot or very cold materials. Disposable latex, vinyl, or nitrile examination gloves are usually appropriate for most circumstances when handling chemicals in a laboratory. These gloves will offer protection from incidental splashes or contact.

7.6.6.3.2 When working with chemicals with high acute toxicity, working with corrosives in high concentrations, handling chemicals for extended periods of time, or immersing all or part of a hand into a chemical, the appropriate glove material must be selected, based on chemical compatibility.

7.6.6.4 Selecting the Appropriate Glove Material:

7.6.6.4.1 When selecting the appropriate glove, the following characteristics should be considered:

- Degradation rating
- Breakthrough time
- Permeation rate

7.6.6.4.2 **Degradation** is the change in one or more of the physical properties of a glove caused by contact with a chemical. Degradation typically appears as hardening, stiffening, swelling, shrinking, or cracking of the glove. Degradation ratings indicate how well a glove will hold up when exposed to a chemical. Degradation on a chemical compatibility chart is usually reported as E (excellent), G (good), F (fair), P (poor), NR (not recommended), or NT (not tested).

7.6.6.4.3 **Breakthrough time** is the elapsed time between the initial contact of the test chemical on the surface of the glove and the analytical detection of the chemical on the inside of the glove.

7.6.6.4.4 **Permeation rate** is the rate at which the test chemical passes through the glove material once a breakthrough has occurred and equilibrium is reached. Permeation involves absorption of the chemical on the surface of the glove, diffusion through the glove, and desorption of the chemical on the inside of the glove. Resistance to permeation rate is usually reported as E (excellent), G (good), F (fair), P (poor), or NR (not recommended). If chemical breakthrough does not occur, then the permeation rate is not measured and is reported as ND (non-detect).

7.6.6.5 Manufacturers stress that permeation and degradation tests are performed under laboratory test conditions, which can vary significantly from conditions found in the work environment. Users may opt to conduct their own tests, particularly when working with highly toxic materials. For mixtures, it is recommended that the glove material be selected based on the longest breakthrough time. The following table includes major glove types and their general uses. This list is not exhaustive.

Glove Material	**General Uses**
Butyl	Offers the highest resistance to permeation by most gases and water vapor. Especially suitable for use with esters and ketones. Advantages: Specialty gloves, polar organics Disadvantages: Expensive, poor vs. hydrocarbons, chlorinated solvents Use Against: Glycol ethers, ketones, ethers
Neoprene	Provides moderate abrasion resistance but good tensile strength and heat resistance. Compatible with many acids, caustics, and oils. Advantages: Medium cost, medium chemical resistance, medium physical properties Disadvantages: N/A Use Against: Oxidizing acid, anilines, phenol, glycol ethers
Nitrile	Excellent general duty glove. Provides protection from a wide variety of solvents, oils, petroleum products, and some corrosives. Excellent resistance to cuts, snags, punctures, and abrasions. Advantages: Low cost, excellent physical properties, dexterity, long service life Disadvantages: Poor vs. benzene, methylene chloride, trichloroethylene, and many ketones Use Against: Oils, greases, aliphatic chemicals, xylene, perchloroethylene, trichloroethane; fair vs. toluene
Polyvinyl Chloride (PVC)	Provides excellent abrasion resistance and protection from most fats, acids, and petroleum hydrocarbons. Advantages: Low cost, very good physical properties, medium chemical resistance Disadvantages: Plasticizers can be stripped; frequently imported may be poor quality Use Against: Strong acids and bases, salts, other water solutions, alcohols
Polyvinyl Alcohol (PVA)	Highly impermeable to gases. Excellent protection from aromatic and chlorinated solvents. Cannot be used in water or water-based solutions. Advantages: Specialty glove, resists a very broad range of organics, good physical properties Disadvantages: Very expensive, water sensitive, poor vs. light alcohols Use Against: Aliphatic, aromatics, chlorinated solvents, ketones (except acetone), esters, ethers
Fluoroelastomer (Viton)	Exceptional resistance to chlorinated and aromatic solvents. Good resistance to cuts and abrasions. Advantages: Specialty glove, organic solvents Disadvantages: Extremely expensive, poor physical properties, poor vs. some ketones, ester, amines Use against: Aromatics, chlorinated solvents, also Aliphatics and alcohols
Silver Shield	Resists a wide variety of toxic and hazardous chemicals. Provides the highest level of overall chemical resistance.
Natural Rubber (Latex)	Provides flexibility and resistance to a wide variety of acids, caustics, salts, detergents, and alcohols. Advantages: Low cost, good physical properties, dexterity Disadvantages: poor vs. oils, greases, organics frequently imported, may be poor quality Use Against: Bases, alcohols, dilute water solutions, fair vs. aldehydes, ketones

Natural Rubber Blends	Advantages: Low cost, dexterity, better chemical resistance than natural rubber vs. some chemicals Disadvantages: Physical properties frequently inferior to natural rubber Use Against: Bases, alcohols, dilute water solutions, fair vs. aldehydes, ketones

7.6.6.6 Where to Find Compatibility Information

Most glove manufacturers have chemical compatibility charts available for their gloves. These charts may be found in laboratory safety supply catalogs such as *Fisher Scientific* and *Grainger*, or in the OSHA Glove Selection Chart (See Appendix D) . Most SDSs recommend the most protective glove material under the *Protective Equipment* section. Refer to section 4.6 Safety Data Sheets.

7.6.6.7 Other Considerations

There are several factors besides glove material to consider when selecting the appropriate glove. The amount of dexterity needed to perform a particular manipulation must be weighed against the glove material recommended for maximum chemical resistance. In some cases, particularly when working with delicate objects where fine dexterity is crucial, a bulky glove may pose more of a hazard.

7.6.6.7.1 Where fine dexterity is needed, consider double gloving with a less compatible material, immediately removing and replacing the outer glove if there are any signs of contamination. In some cases, (e.g., Silver Shield gloves) it may be possible to wear a tightfitting glove over the loose glove to increase dexterity.

7.6.6.7.2 Glove thickness, usually measured in mils or gauge, is another consideration. A 10-gauge glove is equivalent to 10 mils or 0.01 inches. Thinner, lighter gloves offer better touch sensitivity and flexibility but may provide shorter breakthrough times. Generally, doubling the thickness of the glove quadruples the breakthrough time.

7.6.6.7.3 Glove length should be chosen based on the depth to which the arm will be immersed or where chemical splash is likely. Gloves longer than 14 inches provide extra protection against splash or immersion.

7.6.6.7.4 Glove size may also be important. One size does not fit all. Gloves that are too tight tend to cause fatigue, while gloves that are too loose will have loose finger-ends that will make work more difficult. The circumference of the hand, measured in inches, is roughly equivalent to the reported glove size. Glove color, cuff design, and lining should also be considered for some tasks.

7.6.6.8 Glove Inspection: Use and Care

7.6.6.8.1 All gloves should be inspected for signs of degradation or puncture before use. Test for pinholes by blowing or trapping air inside and rolling them out. If the gloves are powdered, do not blow into them because there is the potential for inhalation of particulates. Do not fill them with water, as this makes the gloves uncomfortable and may make it more difficult to detect a leak when wearing the glove.

7.6.6.8.2 Disposable gloves should be changed when there is any sign of contamination and between handling different types of potentially infectious materials. Reusable gloves should be washed frequently if used for an extended period of time.

7.6.6.8.3 While wearing gloves, be careful not to handle anything but the materials involved in the procedure. Touching equipment, phones, wastebaskets, or other surfaces may cause contamination. Be aware not to touch the face, hair, and clothing as well.

7.6.6.8.4 Before removing them, wash the outside of the glove. To avoid accidental skin exposure, remove the first glove by grasping the cuff and peeling the glove off the hand so that the glove is inside out. Repeat this process with the second hand, touching the inside of the glove cuff, rather than the outside. Wash hands immediately with soap and water. Follow the manufacturer’s instructions for washing and caring for reusable gloves.

7.6.6.9 Latex Gloves and Related Allergies

7.6.6.9.1 Allergic reactions to natural rubber latex have been increasing since 1987 when the CDC recommended the use of universal precautions to protect against potentially infectious materials, bloodborne pathogens, and Human Immunodeficiency Virus (HIV). Increased glove demand also resulted in higher levels of allergens due to changes in the manufacturing process. In addition to skin contact with the latex allergens, inhalation is another potential route of exposure. Latex proteins may be released into the air along with the powders used to lubricate the interior of the glove.

7.6.6.9.2 In June 1997, the NIOSH issued an alert *Preventing Allergic Reactions to Latex in the Workplace* [publication number DHHS (NIOSH) 97-135; see reference 11.5.

7.6.6.9.3 Latex exposure symptoms include skin rash and inflammation, respiratory irritation, asthma, and shock. The amount of exposure needed to sensitize an individual to natural rubber latex is not known, but when exposures are reduced, sensitization decreases.

7.6.6.9.4 NIOSH recommends the following actions to reduce exposure to latex:

- Whenever possible, substitute another glove material.
- If latex gloves must be used, choose reduced-protein, powder-free latex gloves.
- Wash hands with mild soap and water after removing latex gloves.

7.6.7 Hearing Protection

7.6.7.1 Most laboratory equipment and operations do not produce noise levels that require the use of hearing protection. CSN has a Hearing Conservation Program in place for individuals who are exposed to noise levels equal to or exceeding the OSHA action level of 85 decibels (DBA) averaged over eight hours, per the OSHA Occupational Noise Standard. This program includes workplace monitoring, personal exposure monitoring, annual audiometric testing, use of hearing protection, and annual training. Exposure to noise at or above the action level requires the use of hearing protection.

7.6.7.2 Laboratory workers who would like to use hearing protection for noise levels below the action level may do so without enrollment in the Hearing Conservation Program. Using hearing protection, such as earplugs, earmuffs, or hearing bands, can improve communication or provide comfort to the worker in a noisy environment.
For more information about the Hearing Conservation Program, please contact EH&S Department.

7.6.8 Respiratory Protection

7.6.8.1 Routine use of a respirator may be required when engineering controls, such as general ventilation or a fume hood, are not feasible or do not reduce the hazard.

7.6.8.2 A respirator is also required as outlined in the Chemical Hygiene Plan (CHP) and waste disposal procedures.

7.6.8.3 Any worker who believes that respiratory protection is needed shall work with their supervisor to notify EH&S for an evaluation of the hazard and enrollment in the Respiratory Protection Program. This program involves procedures for respirator selection, medical assessment of employee health, employee training, proper fitting, respirator inspection and maintenance, and recordkeeping.

7.6.9 Exposure to Bloodborne Pathogens

7.6.9.1 The potential for exposure to bloodborne pathogens exist for employees in certain job classifications (refer to Bloodborne Pathogens Exposure Control Plan for a complete list); as well as when encountering spilled human blood and body fluids, contaminated sharps, performing custodial duties, or rendering first aid.

7.6.9.2 Use universal precautions as methods of control.

- Consider any blood or other potentially infectious material (OPIM) as contagious.
- Routinely use appropriate barrier precautions to prevent skin and mucous membrane exposure when contact with an OPIM is anticipated. When not avoidable, use mouthpieces, resuscitation bags, or other ventilation devices.
- If contamination occurs, wash hands and other skin surfaces immediately and thoroughly with disinfectant soap. Wash gloves prior to their removal with disinfectant soap.

7.6.9.3 Utilize engineering controls (section 7.0) and work practice controls (section 8.0).

7.6.9.4 Post all work areas containing blood or OPIM with the appropriate Biohazard signing.

7.6.9.5 Affix labels to all containers of blood or OPIM, refrigerators and freezers containing blood or OPIM, and on other containers used to store or transport blood or OPIM. Red bags or containers may be substituted for labels on containers of infectious waste.

8.0 SAFE WORK PRACTICES AND PROCEDURES

8.1 General Work Practices

8.1.1 Before Beginning Work

Every laboratory worker shall observe the following rules:

8.1.1.1 Know the potential hazards and appropriate safety precautions. Ask and be able to answer the following questions:

- What are the hazards?
- What are the worst things that could happen?
- What do I need to do to be prepared?
- What work practices, facilities, or PPE are needed to minimize the risk?

8.1.1.2 Know the location and how to use emergency equipment, including safety showers and eyewash stations.

8.1.1.3 Be familiar with the emergency response procedures, facility alarms, and building evacuation routes.

8.1.1.4 Know the types of PPE available and how to use them for each procedure.

8.1.1.5 Minimize exposure to hazardous substances. Be familiar with all applicable SDS.

8.1.1.6 Be alert to unsafe conditions and actions and immediately bring them to the attention of your supervisor (or *Report a Safety Concern or Near Miss* on the EH&S webpage) so that corrections can be made as soon as possible.

8.1.1.7 Use proper storage containers and maintain a cover on all containers.

8.1.1.8 Prevent pollution by following waste disposal procedures (see section 10.0). Chemical reactions may require traps or scrubbing devices to prevent the release of toxic substances to the laboratory or the environment.

8.1.1.9 Position and clamp reaction apparatus thoughtfully in order to permit manipulation without the need to move the apparatus until the entire reaction is completed. Combine reagents in the appropriate order and avoid adding solids to hot liquids.

8.1.1.10 Know the location and operation of the fire extinguisher closest to your work area. Ensure that the proper type of fire extinguisher is available to handle all potential fire hazards.

8.1.1.11 Disconnect all electrical equipment prior to maintenance and repair. Follow all Logout/Tagout (LOTO) procedures to control hazardous energy sources to disable equipment and machines. Ensure that only qualified personnel perform equipment maintenance and repair.

8.1.1.12 Never use equipment with frayed cords or with prongs that have had the grounding prong removed. Use the proper receptacle for each appliance and equipment. Use extension cords properly.

8.1.1.13 Select laboratory equipment that is appropriate for the work being performed; for example, verify that the equipment can withstand extreme temperatures and/or pressures without damage.

8.1.1.14 Do not perform unauthorized experiments.

8.1.2 Ongoing Personal Behavior

The following professional standards of personal behavior are required in any laboratory:

8.1.2.1 Avoid distracting or startling other workers.

8.1.2.2 Do not allow practical jokes or horseplay.

8.1.2.3 Use laboratory equipment only for its designated purpose.

8.1.2.4 Do not allow unattended visitors, including children and pets, in laboratories where hazardous substances are stored or are in use or where hazardous activities are in progress. Note that service animals are not pets. They are highly trained and may be present in a laboratory. However, a clean, safe area should be provided where the animal can wait.

8.1.2.5 Do not prepare, store (even temporarily), or consume food or beverages in any laboratory space.

8.1.2.6 Do not smoke in any laboratory space. Additionally, be aware that tobacco products in opened packages can absorb chemical vapors.

8.1.2.7 Do not apply cosmetics when in the laboratory, including lip balm.

8.1.2.8 Do not chew gum when in the laboratory.

8.1.2.9 Do not take medicine when in the laboratory.

8.1.2.10 Never wear or bring lab coats or jackets into areas where food is consumed.

8.1.2.11 Confine long hair and loose clothing in the laboratory. Wear closed-toe shoes at all times. Open-toed shoes or sandals are not appropriate (see sections 7.6.4. and 7.6.5.).

8.1.2.12 Under NO circumstances should mouth suction be used to pipette chemicals or to start a siphon. Use a pipette bulb or a mechanical pipetting device to provide a vacuum.

8.1.2.13 Wash hands and arms thoroughly before leaving the laboratory. Do not use solvents for washing skin.

8.1.2.14 Keep work areas clean and free from obstruction.

8.1.2.15 Immediately clean up spills (see section 9.0).

8.1.2.16 Do not block access to exits, emergency equipment, controls, electrical panels, etc.
8.1.2.17 Avoid working alone if possible (see section 8.2.8).

8.1.2.18 Practice good housekeeping habits (see section 8.1.3).

8.1.2.19 Practice safe lifting and carrying techniques. Verify that the object is within safe lifting weight limits and free of additional hazards (e.g., sharp edges, grease, water). Verify the route over which the object will be carried is free of obstacles and hazards. Use team lifting or mechanical aids when needed.

8.1.2.20 Practice good office safety, including use, maintenance, and storage of office equipment.

8.1.3 Housekeeping

8.1.3.1 Dispose of all waste materials as outlined in section 10.0.

8.1.3.1.1 Properly dispose of all waste materials into their appropriate waste containers (see section 10.0).

8.1.3.1.2 Dispose of contaminated sharps immediately after use into an appropriate container.

8.1.3.1.3 Properly store or discard all chemical and biological products and samples after their use (see section 10).

8.1.3.2 Disinfect all work surfaces immediately before starting work, before restarting work after a break, and after performing work with a potential microbial contaminant and decontaminate after any spill of an OPIM. Use a freshly diluted bleach solution (10% hypochlorite), 70% ethanol, or other approved disinfectant for decontamination of biohazards. Dispose of all cleaning materials in accordance with section 10.0.

8.1.3.3 Place all reusable laboratory equipment into an appropriate collection tub for decontamination and/or cleaning. Decontaminate all reusable laboratory equipment that has been exposed to an OPIM prior to washing, recycling, or disposal.

8.1.3.4 Immediately clean up any broken glassware. Contaminated broken glassware may be cleaned up using mechanical means (e.g., broom and dustpan or tongs). Disinfect the mechanical devices immediately after use.

8.1.3.5 Keep fume and biosafety cabinets clean and uncluttered. Do not place objects within any hood that will block hood airflow.

8.1.3.6 Maintain covers on water baths, centrifuges, balances, and other laboratory equipment to minimize contamination.

8.1.3.7 Contact the custodial staff to disinfect any contaminated laboratory public areas (e.g., break room, restrooms, cubicles, etc.).

8.1.3.8 Safely locate and provide power connections to appliances and equipment, including those for non-laboratory use (e.g., coffee pots, space heaters, electrical decorations), to prevent electrical and combustion hazards. Ensure that all appliances and equipment do not hamper or block access.

8.2 Safe Work Practices and Procedures for Chemicals

8.2.1 Chemical Storage

Many local, state, and federal regulations have specific requirements that affect the handling and storage of chemicals in laboratories.

8.2.1.1 General Considerations

8.2.1.1.1 In general, store materials and equipment in the appropriate cabinet and on shelving provided for such storage. Ensure that cabinets and shelves are properly labeled.

8.2.1.1.2 Avoid storing materials and equipment on top of cabinets. These items may be difficult to see or reach. If items must be placed there, a clearance of at least 18 inches from sprinkler heads or (if no sprinkler heads are present) 24 inches from the ceiling must be strictly followed.

8.2.1.1.3 Ensure that the weight of the chemical and its container does not exceed the load capacity of the shelf or cabinet.

8.2.1.1.4 Wall-mounted shelving must have heavy-duty brackets and standards. This type of shelving is not recommended for chemical storage.

8.2.1.1.5 Cabinets for chemical storage must be of solid, sturdy construction, preferably hardwood or metal.

8.2.1.1.6 Provide a specific labeled storage location for each type of chemical and return the chemicals to those locations after each use. Chemical storage cabinets located outside the laboratory (e.g., in storage rooms) should be labeled with the name of the laboratory group that owns and uses it.

8.2.1.1.7 Avoid storing chemicals in the workspace within a laboratory hood (see section 7.1.5), except for those chemicals currently in use.

8.2.1.1.8 If a chemical does not require a ventilated cabinet, store it inside a closable cabinet or on a shelf that has a lip. This will prevent containers from sliding off in the event of an accident or fire.

8.2.1.1.9 Do not expose chemicals to heat or direct sunlight.

8.2.1.1.10 Observe all precautions regarding the storage of incompatible chemicals (see section 8.2.1.2).

8.2.1.1.11 Do not store corrosive liquids (see section 8.5) above eye level.

8.2.1.1.12 Use corrosion-resistant storage trays or secondary containers to collect materials if the primary container breaks or leaks.

8.2.1.1.13 Do not store flammable liquids in a refrigerator unless it is approved for such storage. Such refrigerators are designed with non-sparking components to avoid an explosion.

8.2.1.1.14 NEVER put food in refrigerators used for chemical storage. Each refrigerator should be labeled "No Food".

8.2.1.1.15 Do not use cellular phones where flammable vapors are present.

8.2.1.2 Segregation of Chemicals

8.2.1.2.1 Incompatible chemicals should not be stored together. Storing chemicals alphabetically, without regard to compatibility, can increase the risk of a hazardous reaction, especially in the event of container breakage. In addition to the Chemical Segregation and Storage Table (see Appendix E) and the Compatible Storage Group Classification (see Appendix F), there are several resources available; both in print and online, including the National Oceanic and Atmospheric Administration (NOAA) Chemical Reactivity Worksheet (see reference 11.12).

8.2.1.2.2 Use common sense when setting up chemical storage. The segregation that disrupts normal workflow can increase the potential for spills.

8.2.1.2.3 There are several possible storage plans for segregation. In general, dry reagents, liquids, and compressed gases should be stored separately; then by hazard class; then alphabetically (if desired).

Segregate dry reagents as follows:

- Oxidizing salts
- Flammable solids
- Water-reactive solids
- All other solids

Segregate liquids as follows:

- Acids: separate mineral acids (hydrochloric, sulfuric) from organic acids (picric, acetic)
- Bases
- Oxidizers
- Perchlorates
- Flammable or combustible liquids
- All other liquids

Segregate compressed gases as follows:

- Toxic gases
- Flammable gases
- Oxidizing and inert gases

8.2.1.3 Chemical Incompatibility Chart

Mixing these chemicals purposely or as a result of a spill can result in heat, fire, explosion, and/or toxic gases. The following chart is a partial list.

Chemical Incompatibility Chart	
Acetic Acid	Chromic Acid, nitric acid, hydroxyl-containing compounds, ethylene glycol, perchloric acid, peroxides, and permanganates.
Acetone	Bromine, chlorine, nitric acid, sulfuric acid, and hydrogen peroxide.
Acetylene	Bromine, chlorine, copper, mercury, fluorine, iodine, and silver.
Alkaline and Alkaline Earth Metals such as: calcium, lithium, magnesium, sodium, potassium, powdered aluminum	Carbon dioxide, carbon tetrachloride and other chlorinated hydrocarbons, water, bromine, chlorine, fluorine, and iodine. **Do not use CO_2, water, or dry chemical extinguishers. Use a Class D extinguisher (e.g., Met-L-X) or dry sand.**
Aluminum and its Alloys (especially powders)	Acid or alkaline solutions, ammonium persulfate and water, chlorates, chlorinated compounds, nitrates, and organic compounds in nitrate/nitrite salt baths.
Ammonia (anhydrous)	Bromine, chlorine, calcium hypochlorite, hydrofluoric acid, iodine, mercury, and silver.

Chemical Incompatibility Chart

Ammonium Nitrate	Acids, metal powders, flammable liquids, chlorates, nitrates, sulfur, and finely divided organics or other combustibles.
Aniline	Hydrogen peroxide or nitric acid.
Bromine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, finely divided metals, sodium carbide, turpentine.
Calcium Oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents.
Caustic (soda)	Acids (organic and inorganic).
Chlorates or Perchlorates	Acids, aluminum, ammonium salts, cyanides, phosphorous, metal powders, oxidizable organics or other combustibles, sugar, sulfides, and sulfur.
Chlorine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, finely divided metals, sodium carbide, turpentine.
Chlorine Dioxide	Ammonia, methane, phosphine, hydrogen sulfide.
Chromic Acid	Acetic acid, naphthalene, camphor, alcohol, glycerin, turpentine and other flammable liquids.
Copper	Acetylene, hydrogen peroxide.
Cumene Hydroperoxide	Acids
Cyanides	Acids
Flammable Liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, bromine, chlorine, fluorine, iodine.
Fluorine	Isolate from everything.
Hydrazine	Hydrogen peroxide, nitric acid and other oxidizing agents.
Hydrocarbons	Bromine, chlorine, chromic acid, fluorine, hydrogen peroxide and sodium peroxide.
Hydrocyanic Acid	Nitric acid, alkali.
Hydrofluoric Acid	Ammonia, aqueous or anhydrous.
Hydrogen Peroxide (anhydrous)	Chromium, copper, iron, most metals or their salts, aniline, any flammable liquids, combustible materials, nitromethane and all other organic material.
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases.
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen.
Mercury	Acetylene, alkali metals, ammonia, fulminic acid, nitric acid with ethanol, hydrogen, oxalic acid.
Nitrates	Combustible materials, esters, phosphorous, sodium acetate, stannous chloride, water, zinc powder.
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, flammable gases and liquids, hydrocyanic acid, hydrogen sulfide and nitratable substances.
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, flammable gases and liquids, hydrocyanic acid, hydrogen sulfide and nitratable substances.
Nitrites	Potassium or sodium cyanide.
Nitroparaffins	Inorganic bases, amines.
Oxygen (liquid or enriched air)	Flammable gases, liquids, or solids such as acetone, acetylene; grease; hydrogen; oils; phosphorous.

Chemical Incompatibility Chart	
Perchloric Acid	Acetic anhydride, alcohols, bismuth and its alloys, paper, wood, grease, oils or any organic materials and reducing agents.
Peroxides (organic)	Acid (inorganic or organic). Also, avoid friction and store cold.
Phosphorus (white)	Air, oxygen.
Phosphorus pentoxide	Alcohols, strong bases, water.
Potassium	Air (moisture and/or oxygen) or water, carbon tetrachloride, carbon dioxide.
Potassium Chlorate	Sulfuric and other acids.
Potassium Perchlorate	Acids.
Potassium Permanganate	Benzaldehyde, ethylene glycol, glycerol, sulfuric acid.
Silver and silver salts	Acetylene, oxalic acid, tartaric acid, fulminic acid, ammonium compounds.
Sodium	See Alkali Metals
Sodium Chlorate	Acids, ammonium salts, oxidizable materials and sulfur.
Sodium Nitrite	Ammonia compounds, ammonium nitrate or other ammonium salts.
Sodium Peroxide	Any oxidizable substances, such as ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerol, ethylene glycol, ethyl acetate, methyl acetate, furfural, etc.
Sulfides	Acids.
Sulfur	Any oxidizing materials.
Sulfuric Acid	Chlorates; perchlorates; permanganates; compounds with light metals such as sodium, lithium, and potassium.
Water	Acetyl chloride; alkaline and alkaline earth metals, their hydrides and oxides; barium peroxide; carbides; chromic acid; phosphorous oxychloride; phosphorous pentachloride; phosphorous pentoxide; sulfuric acid; sulfur trioxide.

8.2.1.4 Flammable Liquids

Flammable liquids require special storage considerations. See *Flammable Materials* (section 8.3) for more information.

8.2.1.5 Mineral Acids

8.2.1.5.1 Mineral Acids, including phosphoric, hydrochloric, nitric, sulfuric, and perchloric acid can be stored in a cabinet designed for Corrosive Acids. These non-metallic cabinets have no internal metallic parts, an acid-resistant coating, and a cabinet floor constructed to be able to contain spillage. Nitric and hydrochloric acids should be stored in separate secondary containment within such a cabinet.

8.2.1.5.2 Volatile acids, such as nitric or sulfuric acid, should be stored either in an acid cabinet or in a vented cabinet, such as the fume hood base, particularly after they have been opened.

8.2.1.5.3 Concentrated mineral acids can be very reactive, even with each other. Concentrated acids can even react vigorously with dilute solutions of the same acid if mixed together rapidly (e.g., concentrated sulfuric acid mixed quickly with 1 molar sulfuric acid will generate a lot of heat). Different concentrated acids should be stored apart. If stored within the same cabinet, plastic trays, tubs, or buckets work well to keep different acids apart within the cabinet.

8.2.1.6 Other Acids

8.2.1.6.1 Acetic acid is an organic acid and should be stored separately from mineral acids. Since it is also flammable, it is best stored with other flammable liquids.

8.2.1.6.2 Picric Acid can form explosive salts with many metals or by itself when dry.

8.2.1.6.3 Perchloric Acid is an extremely powerful oxidizer and must be kept away from all organic materials, including wood. See section 8.5, *Corrosives*, for more information.

8.2.1.7 Unstable Chemicals

8.2.1.7.1 Ethers, some ketones, and olefins may form peroxides when exposed to air or light. Since they may have been packaged in an air atmosphere, peroxides can form even if the container has not been opened.

8.2.1.7.2 Some chemicals, such as dinitroglycerine and germane, are shock-sensitive, meaning that they can rapidly decompose or explode when struck, vibrated, or otherwise agitated. These compounds become more shock-sensitive with age.

8.2.1.7.3 For any potentially unstable chemical:

- On the label, write the date the container was received and the date it was opened.
- Discard containers within 6 months of opening them.
- Discard unopened containers after one year, unless an inhibitor was added.

8.2.1.7.4 More information about unstable chemicals is available in *Peroxide Forming Compounds and Reactives* (see section 8.4).

8.2.2 Designated Areas for Particularly Hazardous Chemicals

8.2.2.1 Any area where particularly hazardous substances (including carcinogens, acutely toxic chemicals, and reproductive toxins) are stored or used shall be posted as a *Designated Area* (see section 8.10).

8.2.2.2 Particularly hazardous materials should be stored separately from other chemicals, as space permits. See *Particularly Hazardous Materials* (see section 8.10) for more information.

8.2.3 Compressed Gases

8.2.3.1 Compressed gases pose a chemical hazard due to the gases themselves and a high-energy source hazard due to the great amount of pressure in the cylinder. Large cylinders may weigh 130 pounds or more and can also pose a potential crushing hazard to hands and feet.

8.2.3.2 Upon receipt of cylinders from the supplier, ensure that each cylinder is clearly marked to identify its contents, cubic capacity, owner's name, registration number and that all markings comply with DOT requirements.

- **Red DOT** label: Gases categorized as flammable (e.g., acetylene, methane).
- **Green DOT** label: Gases categorized as non-flammable (e.g., argon, carbon dioxide, nitrogen).
- **Yellow DOT** label: Gases categorized as oxidizers (e.g., oxygen). As these types of gases intensify combustion, they must be kept away from flammable gases.

8.2.3.3 All cylinders must be secured to a wall, bench, or other support structure using a chain or strap. Alternatively, a cylinder stand may be used.

8.2.3.4 Segregate cylinders by gas type (e.g., flammable, inert, etc.). Do not store oxygen cylinders within 20 feet of cylinders containing flammable gases or other highly combustible materials.

8.2.3.5 Store cylinders in a well-ventilated area away from heat sources and extreme weather conditions.

8.2.3.6 Store cylinders away from elevators, stairwells, or other places where they can be knocked down or damaged.

8.2.3.7 Every cylinder will be provided with a protective cap to protect the valve. The cap will have a vent sufficient to prevent any gas pressure from accumulating inside the cap. Secure the cap on all stored full or empty cylinders.

8.2.3.8 Keep all cylinder fittings used for oxygen and other oxidizing gases free from oil and grease.

8.2.3.9 Verify there is sufficient gas in the cylinder before using. Open cylinder valves slowly.

8.2.3.10 Mark all empty cylinders as "Empty".

8.2.3.11 If a leak occurs, contact the UPD at 702-895-3669, or 7-911 from a campus phone.

8.2.3.12 See section 8.6 for more information about compressed gases.

8.2.4 Combustible Materials

8.2.4.1 Common combustible materials, such as paper, wood, corrugated cardboard cartons, and plastic labware, if allowed to accumulate, can create a significant fire hazard in the laboratory.

8.2.4.2 Combustible materials not stored in metal cabinets should be kept to a minimum. If possible, store large quantities of such supplies in a separate room.

8.2.4.3 Maintain a minimum 18-inch distance between any heat-producing appliance or equipment and combustible materials.

8.2.5 Transporting Chemicals

Spills and chemical exposure can occur if chemicals are transported incorrectly, even when moving chemicals from one part of the laboratory to another. To avoid this type of incident, consider the following:

8.2.5.1 Use a bottle carrier, cart, or other secondary container when transporting chemicals in breakable containers (especially 250 mL or more) through hallways or between buildings. Secondary containers should be made of rubber, metal, or plastic, with carrying handle(s), and should be large enough to hold the entire contents of the chemical containers in the event of breakage. A variety of such containers are available from laboratory supply catalogs.

8.2.5.2 Transport of hazardous chemicals in individual containers exceeding four liters (4 L) between buildings is strongly discouraged. The maximum amount of common hazardous material (e.g., solvents) in each package is 30 kg (66 lbs.) for solids or 30 L (8 gal) for liquids.

8.2.5.3 When moving chemicals in the laboratory, anticipate sudden backing up or changes in direction by others. Move cautiously and deliberately, and select a path having the least number of interferences. If you should stumble or fall while carrying glassware or chemicals, try to project them away from yourself and others.

8.2.5.4 The individual transporting the chemical should be knowledgeable about the hazards of the chemical and should know how to handle a spill of the material.

8.2.5.5 To transport a compressed gas cylinder, always securely strap the cylinder in a cylinder cart and protect the valve with a cover cap. Do not attempt to carry, drag, or roll cylinders from one area to another. Do not lift cylinders by their protective caps.

8.2.5.6 Keep chemicals in their original packing when transporting, if possible. Containers or packages shall be leak-tight for liquids and gases and sift-proof for solids.

Containers and packages shall be securely closed, secured against movement, and protected against damage.

8.2.5.7 When transporting any quantity of hazardous materials on an elevator, only the minimum number of persons necessary to accomplish the task safely shall be allowed in the elevator. All other persons should be excluded from an elevator while hazardous materials are present. Transport of flammable, corrosive, toxic or highly toxic gases, cryogenic cylinders or dewars, or dry ice, and similar oxygen-depleting compounds should always be done with no one in the elevator. When possible, use elevator reserved exclusively for freight. Use of stairways for transport of small quantities of hazardous materials should be minimized.

8.2.6 Working with Scaled-Up Reactions

8.2.6.1 Scale-up of reactions from those producing a few milligrams (mg) or grams (g) to those producing more than 100 g of a product may represent several orders of magnitude of added risk. The attitudes, procedures, and controls applicable to large-scale laboratory reactions are fundamentally the same as those for smaller-scale procedures. However, differences in heat transfer, stirring effects, times for dissolution, and effects of concentration, and the fact that substantial amounts of materials are being used introduce the need for special vigilance for scaled-up work. Careful planning and consultation with experienced workers to prepare for any eventuality are essential for large-scale laboratory work.

8.2.6.2 Although it is not always possible to predict whether a scaled-up reaction has increased risk, hazards should be evaluated if the following conditions exist:

- The starting material and/or intermediates contain functional groups that have a history of being explosive (e.g., N—N, N—O, N—halogen, O—O, and O—halogen bonds) or that could explode to give a large increase in pressure.
- A reactant or product is unstable near the reaction or work-up temperature. A preliminary test consists of heating a small sample in a melting point tube.
- A reaction is delayed; that is, an induction period is required.
- Gaseous by-products are formed.
- A reaction is exothermic. Consider what can be done to provide cooling if the reaction begins to run away.
- A reaction requires a long reflux period. Consider what could happen if the solvent is lost owing to poor condenser cooling.
- A reaction requires temperatures below 0°C. Consider what could happen if the reaction warms to room temperature.

8.2.6.3 In addition, thermal phenomena that produce significant effects on a larger scale may not have been detected in smaller-scale reactions and therefore could be less obvious than toxic and/or environmental hazards. Thermal analytical techniques should be used to determine whether any process modifications are necessary.

8.2.7 Unattended Work

Laboratory operations involving hazardous substances are sometimes carried out continuously or overnight with no one present. It is the responsibility of the worker to design this work so as to prevent the release of hazardous substances in the event of interruptions in utility services such as electricity, cooling water and inert gas.

8.2.7.1 Laboratory lights should be left on, and signs should be posted identifying the nature of the experiment, the hazardous substances in use, and the contact information for the person conducting the work (in the event of an emergency).

8.2.7.2 If appropriate, arrangements should be made for other workers to periodically inspect the operation.

8.2.7.3 Carefully examine how chemicals and apparatus are stored, considering the possibility of fire, explosion, or unintended reactions.

8.2.8 Working Alone

Individuals using hazardous chemicals should not work alone. Another individual capable of coming to the aid of the worker should be in visual or audio contact.

8.2.8.1 If working alone is absolutely necessary, the worker should have a phone immediately available and should be in contact with another person (who knows that he or she is being relied upon) at least every 30 minutes.

8.2.8.2 If no one from the laboratory is available, contact UPD at 702-895-3669 and request that Police Services check back by phone at regular intervals.

8.2.8.3 The supervisor is responsible for determining whether the work requires special precautions, such as having two people in the same room for particular operations.

8.3 Flammable Materials

8.3.1 Properties of Flammable and Combustible Liquids

8.3.1.1 Flammable and combustible liquids vaporize and form flammable mixtures with air when in open containers, when leaks occur, or when heated.

8.3.1.2 To control these potential hazards, several properties of these materials, such as volatility, flashpoint, flammable range, and auto-ignition temperatures must be understood.

- A flammable liquid is any liquid having a flashpoint at or below 140°F (60°C).
- A combustible liquid is any liquid having flashpoints above 140°F (60°C) and at or below 199.4°F (93°C).

8.3.1.3 Information on the properties of a specific liquid can be found in that liquid's SDS, or other reference material (refer to section 4.6).

8.3.2 Storage of Flammable and Combustible Liquids

Flammable and combustible liquids should be stored only in approved containers. Approval for containers is based on specifications developed by organizations such as DOT, OSHA, the NFPA, or ANSI. Containers used by the manufacturers of flammable and combustible liquids generally meet these specifications.

8.3.2.1 Safety Cans and Closed Containers

8.3.2.1.1 Many types of containers are required depending on the quantities and classes of flammable or combustible liquids in use. Ensure that all storage containers are in good condition.

8.3.2.1.2 A **safety can** is an approved container of not more than 5 gallons capacity that has a spring closing lid and spout cover. Safety cans are designed to safely relieve internal pressure when exposed to fire conditions.

8.3.2.1.3 A **closed container** is one sealed by a lid or other device so that liquid and vapor cannot escape at ordinary temperatures.

8.3.2.1.4 Label all flammable and combustible containers with the chemical name and the physical and/or health hazards associated with the chemical.

8.3.2.2 Flammable Liquid Storage Cabinets

8.3.2.2.1 A **flammable liquid storage cabinet** is an approved cabinet that has been designed and constructed to protect the contents from external fires.

8.3.2.2.2 Storage cabinets are usually equipped with vents, which are plugged by the cabinet manufacturer. Since venting is not required by any code or by the local municipalities and since venting may actually prevent the cabinet from protecting its contents, vents should remain plugged at all times.

8.3.2.2.3 Storage cabinets must also be conspicuously labeled:
"FLAMMABLE – KEEP FIRE AWAY".

8.3.2.2.4 No more than three flammable liquid cabinets can be located in the same room or area unless there is a minimum separation of 100 feet between each group of three cabinets. Up to six cabinets may be stored together if the room or area is protected by an automatic sprinkler system.

8.3.2.3 Refrigerators

8.3.2.3.1 Use only those refrigerators that have been designed and manufactured for flammable liquid storage. Standard household refrigerators must not be used for flammable storage because internal parts could spark and ignite.

8.3.2.3.2 Refrigerators must be prominently labeled as to whether or not they are suitable for flammable liquid storage.

8.3.2.4 Storage Considerations

8.3.2.4.1 Quantities stored should be limited to the amount necessary for the work in progress.

8.3.2.4.2 No more than 1 gallon of flammable and combustible liquids, combined, should be stored per room, or area, outside of a fume hood or flammable liquids cabinet. When safety cans are used, up to 15 gallons per room may be stored without using a flammable storage cabinet. Flammable liquids in containers greater than 25 gallons shall be stored with secondary containment. Containers of flammable or combustible materials that are in use, such as feeding liquid to analytical equipment, are not subject to this section regarding chemical storage.

8.3.2.4.3 Do not store flammable and combustible liquids on the floor. Storage of flammable liquids must not obstruct any exit.

8.3.2.4.4 Flammable liquids should be stored separately from strong oxidizers, shielded from direct sunlight, and away from heat sources.

8.3.2.4.5 Routinely inspect storage areas and cabinets for hazardous conditions (e.g., spills, leaks, loss of container integrity).

8.3.2.4.6 Ensure there is a functional fire extinguisher in the area where flammable or combustible liquids are stored and used. The fire extinguisher should be classed for type A, B, and C fires.

8.3.2.4.7 Post appropriate warning signs at entrances to areas where flammable and combustible liquids are stored. Room doors must remain closed unless the doors are equipped with automatic hold-open/closure devices that release in the event of a fire and air-balancing is not affected by open doors.

8.3.3 Handling Precautions

8.3.3.1 The main objective of working safely with flammable and combustible liquids is to avoid the accumulation of vapors and to control sources of ignition.

8.3.3.2 Be aware of and control all potential sources of ignition.

8.3.3.2.1 Besides the more obvious ignition sources, such as open flames from Bunsen burners, matches, and cigarette smoking; less obvious sources, such as electrical equipment, static electricity, and gas-fired heating devices should be considered.

8.3.3.2.2 Some electrical equipment, including switches, stirrers, motors, and relays can produce sparks that can ignite vapors. Although some newer equipment has spark-free induction motors, the on-off switches and speed controls may be able to produce a spark when they are adjusted because they have exposed contacts. One solution is to remove any switches located on the device and insert a switch on the cord near the plug end.

8.3.3.2.3 Avoid using equipment with series-wound motors since they are likely to produce sparks. Use equipment with spark-free, intrinsically safe induction motors or air motors to avoid producing sparks. These motors must meet National Electric Safety Code (US DOC, 1993) Class 1, Division 2, Group C-D explosion resistance specifications. Many stirrers, Variacs, outlet strips, ovens, heat tape, hot plates, and heat guns **do not** conform to these code requirements.

8.3.3.3 Do not heat flammable liquids with an open flame. Steam baths, salt and sand baths, oil and wax baths, heating mantles, and hot air or nitrogen baths are preferable.

8.3.3.4 Pouring flammable liquids can generate static electricity. The development of static electricity is related to the humidity levels in the area. Cold, dry atmospheres are more likely to facilitate static electricity. Bonding or using ground straps for metallic or non-metallic containers can prevent static generation. In the rare circumstance that static cannot be avoided, proceed slowly to give the charge time to disperse or conduct the procedure in an inert atmosphere.

8.3.3.5 Whenever possible use plastic or metal containers or safety cans.

8.3.3.6 Electrically bond metal containers when transferring flammable liquids from one to another. Bonding can be direct, as a wire attached to both containers; or indirect, as through a common ground system.

8.3.3.7 When grounding non-metallic containers, contact must be made directly to the liquid, rather than to the container.

8.3.3.8 When working with open containers, use a laboratory fume hood to control the accumulation of flammable vapor below 25% of the lower explosive limit.

8.3.3.9 Minimize the production of vapors and the associated risk of ignition by flashback. Vapors from flammable liquids are denser than air and tend to sink to the floor level where they can spread over a large area.

8.3.3.10 Use bottle carriers for transporting glass containers.

8.3.4 Flammable Aerosols

Flammable liquids in pressurized containers may rupture and aerosolize when exposed to heat, creating a highly flammable vapor cloud. As with flammable liquids, these should be stored in a flammable storage cabinet.

8.3.5 Flammable and Combustible Solids

8.3.5.1 Flammable solids often encountered in the laboratory include alkali metals, magnesium metal, metallic hydrides, some organometallic compounds, and sulfur.

8.3.5.2 Many flammable solids react with water and cannot be extinguished with conventional dry chemical or carbon dioxide extinguishers.

8.3.5.3 Ensure Class D extinguishers (e.g., Met-L-X) are available where flammable solids are used or stored.

8.3.5.4 Sand can usually be used to smother a fire involving flammable solids. Keep a container of sand near the work area.

8.3.5.5 If a flammable, water-reactive solid is spilled onto skin, brush off as much as possible and then flush with copious amounts of water.

8.3.5.6 **NEVER** use a carbon dioxide fire extinguisher for fires involving lithium aluminum hydride (LAH). LAH reacts explosively with carbon dioxide.

8.3.6 Catalyst Ignition

8.3.6.1 Some hydrogenated catalysts, such as palladium, platinum oxide, and Raney nickel, when recovered from hydrogenation reactions, may become saturated with hydrogen and present a fire or explosion hazard.

- Carefully filter the catalyst.
- Do not allow the filter cake to become dry.
- Place the funnel containing moist catalyst into a water bath immediately.

8.3.6.2 Purge gases, such as nitrogen or argon, may be used so that the catalyst can be filtered and handled in an inert atmosphere.

8.4 Peroxide Forming Compounds and Reactives

8.4.1 Understanding the Danger

8.4.1.1 Certain chemicals can form dangerous peroxides on exposure to air and light. Since they are sometimes packaged in an atmosphere of air, peroxides can form even though the containers have not been opened.

8.4.1.2 Peroxides may detonate with extreme violence when concentrated by evaporation or distillation, when combined with other compounds, or when disturbed by unusual heat, shock, or friction. The formation of peroxides in ethers is accelerated in opened and partially emptied containers. Refrigeration will not prevent peroxide formation and stabilizers will only retard formation.

8.4.1.3 Peroxide formation may be detected by visual inspection for crystalline solids or viscous liquids, or by using chemical methods or specialized kits for quantitative or qualitative analysis. If you suspect that peroxides have formed, do not open the container to test since peroxides deposited on the threads of the cap could detonate.

8.4.2 Recommended Work Practices

The following recommendations should be followed to control the hazards of peroxides:

8.4.2.1 Know the properties and hazards of all chemicals being used through adequate research and study, including reading the label and SDS.

8.4.2.2 Inventory all chemical storage at least twice a year to detect forgotten items, leaking containers, and those that need to be discarded.

8.4.2.3 Identify chemicals that form peroxides or otherwise deteriorate or become more hazardous with age or exposure to air. Label containers (see section 4.3) with the date received, the date first opened, and the date for disposal as recommended by the supplier.

8.4.2.4 Minimize peroxide formation in ethers by storing them in tightly sealed containers placed in a cool place in the absence of light. Do not store ethers at or below the temperature at which the peroxide freezes or the solution precipitates.

8.4.2.5 Choose the size of the container that will ensure the use of the entire contents within a short period of time.

8.4.2.6 Visually or chemically check for peroxides of any opened containers before use.

8.4.2.7 Clean up spills immediately (see section 9.0). The safest method is to absorb the material onto vermiculite or a similar loose absorbent.

8.4.2.8 When working with peroxidizable compounds wear impact-resistant safety eyewear and face shields. Visitor specs are intended only for slight and brief exposure and should not be used when working with peroxidizable compounds.

8.4.2.9 Do not use solutions of peroxides in volatile solvents under conditions in which the solvent might be vaporized. This could increase the concentration of peroxide in the solution.

8.4.2.10 Do not use metal spatulas or magnetic stirring bars (which may leach out iron) with peroxide forming compounds, since contamination with metals can lead to explosive decomposition. Ceramic, Teflon, or wooden spatulas and stirring blades are usually safe to use.

8.4.2.11 Do not use glass containers with screw-top lids or glass stoppers. Polyethylene bottles with screw-top lids may be used.

8.4.3 Examples of Peroxidizable Compounds

Peroxide Hazard on Storage: ***Dispose of After Three Months***	
Divinyl acetylene Divinyl ether Isopropyl ether	Potassium metal Sodium amide Vinylidene chloride
Peroxide Hazard on Concentration: ***Dispose of After One Year***	
Acetal Cumene Cyclohexene Cyclooxyene Cyclopentene Diacetylene Dicyclopentadiene Diethyl ether Diethylene glycol dimethyl ether (diglyme)	Dioxane Ethylene glycol dimethyl ether (glyme) Furan Methyl acetylene Methylcyclopentane Methyl isobutyl ketone Tetrahydronaphthalene (Tetralin) Tetrahydrofuran Vinyl ethers
Hazardous Due to Peroxide Initiation of Polymerization*: ***Dispose of After One Year***	
Acrylic acid Acrylonitrile Butadiene Chloroprene Chlorotrifluoroethylene Methyl methacrylate	Styrene Tetrafluoroethylene Vinyl acetylene Vinyl acetate Vinyl chloride Vinyl pyridine

* Under storage conditions in the liquid state, the peroxide-forming potential increases and certain of these monomers (especially butadiene, chloroprene, and tetrafluoroethylene) should be discarded after three months.

8.4.4 Detection of Peroxides

8.4.4.1 If there is any suspicion that peroxide is present, do not open the container or otherwise disturb the contents. The container and its contents must be handled with extreme care. If solids, especially crystals, for example, are observed either in the liquid or around the cap, peroxides are most likely present.

8.4.4.2 If no peroxide is suspected but the chemical is a peroxide former, the following procedures can detect most peroxides:

8.4.4.2.1 Prepare reagent by adding 100 mg sodium iodide (NaI) or potassium iodide (KI) crystals to 1.0 mL of glacial acetic acid. Add 0.5 to 1.0 mL of material being tested to an equal volume of reagent. A yellow color indicates a low concentration (~ 0.1%) and brown a high concentration of peroxide in the sample. A blank should be run, using some non-peroxidizable compound such as pure n-hexane.

8.4.4.2.2 Peroxide test strips, which change color to indicate the presence of peroxides, may be purchased through most laboratory reagent distributors. For proper operation, the strips must be air-dried until the solvent evaporates and then exposed to moisture.

8.4.5 Removal of Peroxides

There are two effective methods for removing peroxides safely:

8.4.5.1 Pass the solvent through a short column of activated alumina. No water is thereby introduced. The alumina catalyzes the decomposition of many peroxides, but it is possible that some peroxide will be retained unchanged on the column. The alumina should therefore be disposed of as a flammable material.

8.4.5.2 Make up a reducing solution from 60g ferrous sulfate ($FeSO_4$), 6 mL concentrated sulfuric acid (H_2SO_4), and 110 mL water. Shake the sample with this solution to remove the peroxide.

8.5 Corrosives

Many chemicals commonly used in the laboratory are corrosive or irritating to body tissue. They present a hazard to the eyes and skin by direct contact, to the respiratory tract by inhalation, or the gastrointestinal system by ingestion.

8.5.1 Corrosive Liquids

8.5.1.1 Corrosive liquids (e.g., mineral acids, alkali solutions, and some oxidizers) represent a very significant hazard because skin or eye contact can readily occur from splashes and their effect on human tissue generally takes place very rapidly. Bromine, sodium hydroxide, sulfuric acid, and hydrogen peroxide are examples of highly corrosive liquids.

8.5.1.2 The following precautions should be considered:

8.5.1.2.1 The eyes are particularly vulnerable. It is therefore essential that approved eye and face protection be worn in all laboratories where corrosive chemicals are handled.

8.5.1.2.2 Gloves and other chemically resistant protective clothing (e.g., face shield, rubber apron) should be worn to protect against skin contact.

8.5.1.2.3 To avoid a flash steam explosion due to a large amount of heat evolving, always add acids or bases to water (and not the reverse).

8.5.1.2.4 Acids and bases should be segregated for storage.

8.5.1.2.5 Liquid corrosives should be stored below eye level.

8.5.1.2.6 Adequate quantities of spill control materials should be readily available. Specialized spill kits for acids and bases are available through most chemical and laboratory safety supply catalogs.

8.5.1.2.7 Wherever corrosives are stored or used, ensure that a working safety shower and eyewash station are readily accessible. Refer to section 9.4.3.2 in the event of exposure to a corrosive chemical.

8.5.2 Corrosive Gases and Vapors

8.5.2.1 Corrosive gases and vapors are hazardous to all parts of the body; certain organs (e.g., the eyes and the respiratory tract) are particularly sensitive. The magnitude of the effect is related to the solubility of the material in the body fluids. Highly soluble gases (e.g., ammonia, hydrogen chloride) cause severe nose and throat irritation, while substances of lower solubility (e.g., nitrogen dioxide, phosgene, sulfur dioxide) can penetrate deep into the lungs.

8.5.2.2 Warning properties such as odor or eye, nose, or respiratory tract irritation may be inadequate with some substances. Therefore, they should not be relied upon as a warning of overexposure.

8.5.2.3 Perform manipulations of materials that pose an inhalation hazard in a chemical fume hood to control exposure or wear appropriate respiratory protection.

8.5.2.4 Protect all exposed skin surfaces from contact with corrosive or irritating gases and vapors.

8.5.2.5 Regulators and valves should be closed when the cylinder is not in use and flushed with dry air or nitrogen after use.

8.5.2.6 When corrosive gases are to be discharged into a liquid; a trap, check valve, or vacuum break device should be employed to prevent dangerous reverse flow.

8.5.3 Corrosive Solids

8.5.3.1 Corrosive solids, such as sodium hydroxide and phenol, can cause burns to the skin and eyes. Dust from corrosive solids can be inhaled and cause irritation or burns to the respiratory tract. Many corrosive solids, such as potassium hydroxide and sodium hydroxide, can produce considerable heat when dissolved in water.

8.5.3.2 The following precautions should be considered:

8.5.3.2.1 Wear gloves and eye protection when handling corrosive solids.

8.5.3.2.2 When mixing with water, always slowly add the corrosive solid to water, stirring continuously. Cooling may be necessary.

8.5.3.3 If there is a possibility of generating a significant amount of dust, conduct work in a fume hood.

8.6 Compressed Gases

8.6.1 Compressed gases can be toxic, flammable, oxidizing, corrosive, inert, or a combination of hazards. In addition to the chemical hazards, compressed gases may be under a great deal of pressure. The amount of energy in a compressed gas cylinder makes it a potential rocket. Appropriate care in the handling and storage of compressed gas cylinders is essential.

8.6.2 Hazards

The following is an overview of the hazards to be avoided when handling and storing compressed gases:

8.6.2.1 Asphyxiation – Simple asphyxiation is the primary hazard associated with inert gases. Because inert gases are colorless and odorless, they can escape into the atmosphere undetected and quickly reduce the concentration of oxygen below the level necessary to support life. The use of oxygen monitoring equipment is strongly recommended for enclosed areas where inert gases are being used.

8.6.2.2 Fire and Explosion – Fire and explosion are the primary hazards associated with flammable gases, oxygen, and other oxidizing gases. Flammable gases can be ignited by static electricity or by a heat source, such as a flame or a hot object. Oxygen and other oxidizing gases do not burn but will support the combustion of organic materials. Increasing the concentration of an oxidizer accelerates the rate of combustion. Materials that are nonflammable under normal conditions may burn in an oxygen-enriched atmosphere.

8.6.2.3 Chemical Burns – Corrosive gases can chemically attack various materials, including fire-resistant clothing. Some gases are not corrosive in their pure form but can become extremely destructive if a small amount of moisture is added. Corrosive gases can cause rapid destruction of skin and eye tissue.

8.6.2.4 Chemical Poisoning – Chemical poisoning is the primary hazard of toxic gases. Even in very small concentrations, brief exposure to these gases can result in serious poisoning injuries. Symptoms of exposure may be delayed.

8.6.2.5 High Pressure – All compressed gases are potentially hazardous because of the high pressure stored inside the cylinder. A sudden release of pressure can cause injuries by propelling a cylinder or whipping a line.

8.6.2.6 Cylinder Weight – A full-size cylinder may weigh more than 130 pounds. Moving a cylinder manually may lead to back or muscle injury. Dropping or dragging a cylinder could cause serious injury.

8.6.3 Handling Procedures

8.6.3.1 Avoid dropping, dragging, or sliding cylinders. Use a suitable hand truck or cart equipped with a chain or belt for securing the cylinder to the cart, even for short distances.

8.6.3.2 Do not permit cylinders to strike each other violently. Cylinders should not be used as rollers for moving material or other equipment. In addition, cylinders should never be used as a prop to hold anything open.

8.6.3.3 Cylinder caps should be left on each cylinder until it has been secured against a wall or bench or placed in a cylinder stand and is ready for installation of the regulator. Cylinder caps protect the valve on top of the cylinder from damage if knocked over.

8.6.3.4 Never tamper with pressure relief devices in valves or cylinders.

8.6.3.5 Use only wrenches or tools provided by the cylinder supplier to remove a cylinder cap or to open a valve. Never use a screwdriver or pliers.

8.6.3.6 Keep the cylinder valve closed except when in use.

8.6.3.7 Position cylinders so that the cylinder valve is accessible at all times.

8.6.3.8 Use compressed gases only in a well-ventilated area. Toxic, flammable, and corrosive gases should be carefully handled in a hood or gas cabinet. Proper containment systems should be used, and minimum quantities of these products should be kept on-site.

8.6.3.9 When discharging gas into a liquid, a trap or suitable check valve should be used to prevent liquid from getting back into the cylinder or regulator.

8.6.3.10 Label gas lines when more than one type of gas is in use. This is particularly important when the gas supply is not in the same room or area as the operation using the gases.

8.6.3.11 Do not use the cylinder valve itself to control flow by adjusting the pressure.

8.6.4 Storage of Compressed Gas Cylinders

8.6.4.1 Secure all cylinders to a wall, bench or fixed support using a chain or strap placed 2/3 of the way up. Cylinder stands are an alternative to straps.

8.6.4.2 Cylinders should be strapped individually.

8.6.4.3 Do not store full and empty cylinders together.

8.6.4.4 Oxidizers and flammable gases should be stored in areas separated by at least 20 feet or by a non-combustible wall.

8.6.4.5 Cylinders should not be stored near radiators or other heat sources. If storage is outdoors, protect cylinders from weather extremes and damp ground to prevent corrosion.

8.6.4.6 No part of a cylinder should be subjected to a temperature higher than 125°F. A flame should never be permitted to come in contact with any part of a compressed gas cylinder.

8.6.4.7 Do not place cylinders where they may become part of an electric circuit.

8.6.4.8 Keep the number of cylinders in a laboratory to a minimum to reduce the fire and toxicity hazards.

8.6.4.9 Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed or discarded if at atmospheric pressure.

8.6.4.10 Ensure that the cylinder is properly and prominently labeled as to its contents.

8.6.4.11 NEVER place acetylene cylinders on their side.

8.6.5 Using Compressed Gas Cylinders

8.6.5.1 Before using gas cylinders, read all label information and SDS associated with the gas being used.

8.6.5.2 Cylinder valve outlet connections are designed to prevent the mixing of incompatible gases. The outlet threads vary in diameter; some are internal, and some are external; some are right-handed, and some are left-handed. Generally, right-handed threads are used for fuel gases.

8.6.5.3 Follow these steps to set up and use a gas cylinder:

8.6.5.3.1 Attach the closed regulator to the cylinder. **Never open the cylinder valve unless the regulator is completely closed.** Regulators are specific to the gas involved. A regulator should be attached to a cylinder without forcing the threads. If the inlet of a regulator does not fit the cylinder outlet, no effort should be made to try to force the fitting. A poor fit may indicate that the regulator is not intended for use on the gas chosen.

8.6.5.3.2 Turn the delivery pressure adjusting screw counterclockwise until it turns freely. This prevents unintended gas flow into the regulator.

8.6.5.3.3 Open the cylinder **slowly** until the inlet gauge on the regulator registers the cylinder pressure. If the cylinder pressure reading is lower than expected, the cylinder valve may be leaking.

8.6.5.3.4 With the flow control valve at the regulator outlet closed, turn the delivery pressure adjusting screw clockwise until the required delivery pressure is reached.

8.6.5.3.5 Check for leaks using a commercial leak-detection solution or soap solution. At or below freezing temperatures, use a glycerin and water solution rather than a soap solution. Never use an open flame to detect leaks.

8.6.5.3.6 When finished with the gas, close the cylinder valve and release the regulator pressure.

8.6.6 Assembly of Equipment Piping

8.6.6.1 Do not force threads that do not fit exactly.

8.6.6.2 Use Teflon tape or thread lubricant for assembly. Teflon tape should only be used for tapered pipe thread, not straight lines or metal-to-metal contacts.

8.6.6.3 Avoid sharp bends of copper tubing. Copper tubing hardens and cracks with repeated bending.

8.6.6.4 Inspect tubing frequently and replace when necessary.

8.6.6.5 Tygon and plastic tubing are not appropriate for most pressure work. These materials can fail under pressure or thermal stress.

8.6.6.6 Do not mix different brands and types of tube fittings. Construction parts are usually not interchangeable.

8.6.6.7 Do not use oil or lubricants on equipment used with oxygen.

8.6.6.8 Do not use copper piping for acetylene.

8.6.6.9 Do not use cast iron piping for chlorine.

8.6.7 Leaking Cylinders

8.6.7.1 Most leaks occur at the valve at the top of the cylinder and may involve the valve threads valve stem, valve outlet, or pressure relief devices. Lab personnel should not attempt to repair leaking cylinders.

8.6.7.2 Where action can be taken without serious exposure to lab personnel:

8.6.7.2.1 Move the cylinder to an isolated, well-ventilated area (away from combustible materials if the cylinder contains a flammable or oxidizing gas).

8.6.7.2.2 Contact UPD (702-895-3669 or x7911).

8.6.7.2.3 Whenever a large or uncontrollable leak occurs, evacuate the area and immediately contact UPD (702-895-3669 or x7911), then notify EH&S (x7445).

8.6.8 Empty Cylinders

8.6.8.1 Remove the regulator and replace the cylinder cap.

8.6.8.2 Mark the cylinder as empty or “MT” and store it in a designated area for return to the supplier.

8.6.8.3 Do not store full and empty cylinders in the same location.

8.6.8.4 Do not have full and empty cylinders connected to the same manifold. Reverse flow can occur when an empty cylinder is attached to a pressurized system.

8.6.8.5 Do not refill empty cylinders. Only the cylinder supplier should refill the gases.

8.6.8.6 Do not empty cylinders to a pressure below 25 psi. The residual contents may become contaminated with air.

8.6.8.7 Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed. Do not purchase lecture bottles that cannot be returned.

8.6.9 Flammable Gases

8.6.9.1 Keep sources of ignition away from the cylinders.

8.6.9.2 Oxidizers and flammable gases should be stored in areas separated by at least 20 feet or by a non-combustible wall.

8.6.9.3 Bond and ground all cylinders, lines, and equipment used with flammable compressed gases.

8.6.10 Highly Toxic Gases

8.6.10.1 Highly toxic gases, such as arsine, diborane, fluorine, hydrogen cyanide, phosgene, and silane, can pose a significant health risk in the event of a leak.

8.6.10.2 The following additional precautions must be taken:

8.6.10.2.1 Use and store in a specially ventilated gas cabinet or fume hood.

8.6.10.2.2 Use coaxial (double-walled) tubing with nitrogen between the walls for feed lines operating above atmospheric pressure.

8.6.10.2.3 Regulators should be equipped with an automatic shut-off to turn off the gas supply in the event of a sudden loss of pressure in the supply line.

8.6.10.2.4 An alarm system should be installed to check for leaks in routinely used gases with poor warning properties. The alarm level must be set at or lower than the permissible exposure limit of the substance.

8.6.10.2.5 Ensure storage and use areas are posted with “Designated Area” signage.

8.7 Electrical Safety

8.7.1 General

8.7.1.1 Electrically powered equipment, such as hot plates, stirrers, vacuum pumps, electrophoresis apparatus, lasers, heating mantles, ultrasonicators, power supplies, and microwave ovens are essential elements of many laboratories. These devices can pose a significant hazard to laboratory workers, particularly when mishandled or not maintained.

8.7.1.2 Many laboratory electrical devices have high voltage or high-power requirements, carrying even more risk. Large capacitors found in many laser flash lamps and other systems are capable of storing lethal amounts of electrical energy and pose a serious danger even if the power source has been disconnected.

8.7.2 Electrical Hazards

8.7.2.1 Major hazards associated with electricity are electrical shock and fire.

8.7.2.2 Electrical shock

8.7.2.2.1 Electrical shock occurs when the body becomes part of the electric circuit, either when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor.

8.7.2.2.2 The severity and effects of an electrical shock depend on a number of factors, such as the pathway through the body, the amount of current, the length of time of the exposure, and whether the skin is wet or dry.

8.7.2.2.3 Water is a great conductor of electricity, allowing current to flow more easily in wet conditions and through wet skin.

8.7.2.2.4 The effect of the shock may range from a slight tingle to severe burns to cardiac arrest. The chart below shows the general relationship between the degree of injury and the amount of current for a 60-cycle hand-to-foot path of one second's duration of the shock. While reading this chart, keep in mind that most electrical circuits can provide, under normal conditions, up to 20,000 milliamperes (mA) of current flow.

Current	**Reaction**
1 Milliampere	Perception level
5 Milliamperes	Slight shock felt; not painful but disturbing
6-30 Milliamperes	Painful shock; "let-go" range
50-150 Milliamperes	Extreme pain, respiratory arrest, severe muscular contraction
1000-4,300 Milliamperes	Ventricular fibrillation
10,000+ Milliamperes	Cardiac arrest, severe burns, and probable death

8.7.2.3 Power Loss

8.7.2.3.1 Loss of electrical power can create hazardous situations. When a refrigerator or freezer fails, flammable or toxic vapors may be released as a chemical warms. Fume hoods may cease to operate, allowing vapors to be released into the laboratory. If magnetic or mechanical stirrers fail to operate, safe mixing of reagents may be compromised.

8.7.3 Preventing Electrical Hazards

8.7.3.1 There are various ways of protecting people from the hazards caused by electricity, including insulation, guarding, grounding, and electrical protective devices. Laboratory workers can significantly reduce electrical hazards by following some basic precautions:

8.7.3.1.1 Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.

8.7.3.1.2 Use safe work practices every time electrical equipment is used. Refer to section 8.1.1.

8.7.3.1.3 Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off the equipment in the event of a fire or electrocution.

8.7.3.1.4 Limit the use of extension cords. Use only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.

8.7.3.1.5 Multiplug adapters must have circuit breakers or fuses.

8.7.3.1.6 Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.

8.7.3.1.7 Minimize the potential for water or chemical spills on or near electrical equipment.

8.7.3.2 Insulation

8.7.3.2.1 All electrical cords should have sufficient insulation to prevent direct contact with wires. In a laboratory, it is particularly important to check all cords before each use since corrosive chemicals or solvents may erode the insulation.

8.7.3.2.2 Damaged cords should be repaired or taken out of service immediately, especially in wet environments such as cold rooms and near water baths.

8.7.3.3 Guarding

8.7.3.3.1 Live parts of electric equipment operating at 50 volts or more (i.e., electrophoresis devices) must be guarded against accidental contact. Plexiglas shields may be used to protect against exposed live parts.

8.7.3.4 Grounding

8.7.3.4.1 Only equipment with three-prong plugs should be used in the laboratory. The third prong provides a path to the ground for internal electrical short circuits, thereby protecting the user from a potential electrical shock.

8.7.3.5 Circuit Protection Devices

8.7.3.5.1 Circuit protection devices are designed to automatically limit or shut off the flow of electricity in the event of a ground-fault, overload, or short circuit in the wiring system. Ground-fault circuit interrupters, circuit breakers, and fuses are three well-known examples of such devices.

8.7.3.5.2 Fuses and circuit breakers prevent over-heating of wires and components that might otherwise create fire hazards. They disconnect the circuit when it becomes overloaded. This overload protection is very useful for equipment that is left on for extended periods of time, such as stirrers, vacuum pumps, drying ovens, Variacs, and other electrical equipment.

8.7.3.5.3 A ground-fault circuit interrupter (GFCI) is designed to shut off electric power if a ground fault is detected, protecting the user from a potential electrical shock. The GFCI is particularly useful near sinks and wet locations. Since GFCIs can cause equipment to shut down unexpectedly, they may not be appropriate for certain apparatus. Portable GFCI adapters (available in most safety supply catalogs) may be used with a non-GFCI outlet.

8.7.3.6 Motors

8.7.3.6.1 In laboratories where volatile flammable materials are used, motor-driven electrical equipment should be equipped with non-sparking induction motors or air motors. These motors must meet National Electric Safety Code (US

DOC, 1993) Class 1, Division 2, Group C-D explosion resistance specifications. Many stirrers, Variacs, outlet strips, ovens, heat tape, hot plates, and heat guns **do not** conform to these code requirements.

8.7.3.6.2 Avoid series-wound motors, such as those generally found in some vacuum pumps, rotary evaporators, and stirrers. Series-wound motors are also usually found in household appliances such as blenders, mixers, vacuum cleaners, and power drills. These appliances should not be used unless flammable vapors are adequately controlled.

8.7.3.6.3 Although some newer equipment has spark-free induction motors, the on-off switches, and speed controls may be able to produce a spark when they are adjusted because they have exposed contacts. One solution is to remove any switches located on the device and insert a switch on the cord near the plug end.

8.7.4 Safe Work Practices

The following practices may reduce the risk of injury or fire when working with electrical equipment (refer to section 8.1.1):

8.7.4.1 Avoid contact with energized electrical circuits.

8.7.4.2 Disconnect the power source before servicing or repairing electrical equipment.

8.7.4.3 When it is necessary to handle equipment that is plugged in, be sure hands are dry and, when possible, wear nonconductive gloves and shoes with insulated soles.

8.7.4.4 If it is safe to do so, work with only one hand, keeping the other hand at your side or in your pocket, away from all conductive material. This precaution reduces the likelihood of accidents that result in current passing through the chest cavity.

8.7.4.5 Minimize the use of electrical equipment in cold rooms or other areas where condensation is likely. If equipment must be used in such areas, mount the equipment on a wall or vertical panel.

8.7.4.6 If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment before cleaning up the spill.

8.7.4.7 If an individual comes in contact with a live electrical conductor, do not touch the equipment, cord, or person. Disconnect the power source from the circuit breaker or pull out the plug using a leather belt.

8.7.5 High Voltage or Current

Repairs of high voltage or high current equipment must be performed only by trained electricians.

8.7.6 Altering Building Wiring and Utilities

Modifications to existing electrical service in any CSN facility must be completed or coordinated by Facilities Management Department personnel.

8.8 Pressure and Vacuum Systems

8.8.1 General

8.8.1.1 Working with hazardous chemicals at high or low pressures requires planning and special precautions. Procedures should be implemented to protect against explosion or implosion through appropriate equipment selection and the use of safety shields. Care should be taken to select glass apparatus that can safely withstand designated pressure extremes.

8.8.2 High-Pressure Vessels

8.8.2.1 High-pressure operations should be performed only in pressure vessels appropriately selected for the operation, properly labeled and installed, and protected by pressure-relief and necessary control devices.

8.8.2.2 Vessels must be strong enough to withstand the stresses encountered at the intended operating temperatures and pressures and must not corrode or otherwise react when in contact with the materials it contains.

8.8.2.3 Systems designed for use at elevated temperatures should be equipped with a positive temperature controller. Manual temperature control using a simple variable autotransformer (e.g., Variac) should be avoided. The use of a backup temperature controller capable of shutting the system down is strongly recommended.

8.8.2.4 All pressure equipment should be inspected and tested at intervals determined by the severity of the equipment's usage. Visual inspections should be accomplished before each use.

8.8.2.5 Hydrostatic testing should be accomplished before equipment is placed in initial service. Hydrostatic testing should be re-accomplished every ten years thereafter, after significant repair or modification, or if the vessel experiences overpressure or over-temperature.

8.8.3 Vacuum Apparatus

8.8.3.1 Vacuum work can result in an implosion and the possible hazards of flying glass, splattering chemicals, and fire. All vacuum operations must be set up and operated with careful consideration of the potential risks. Equipment at reduced pressure is especially prone to fluctuations. Such conditions can force liquids through an apparatus, sometimes with undesirable consequences.

8.8.3.2 The following practices may reduce the risk of injury or fire when working with vacuum apparatus:

8.8.3.2.1 PPE, such as safety glasses or chemical goggles, face shields, and/or an explosion shield should be used to protect against the hazards of vacuum procedures, and the procedure should be carried out inside a hood.

8.8.3.2.2 Do not allow water, solvents, and corrosive gases to be drawn into vacuum systems. Protect pumps with cold traps and vent their exhaust into an exhaust hood.

8.8.3.2.3 Assemble vacuum apparatus in a manner that avoids strain, particularly to the neck of the flask.

8.8.3.2.4 Avoid putting pressure on a vacuum line to prevent stopcocks from popping out or glass apparatus from exploding.

8.8.3.2.5 Place vacuum apparatus in such a way that the possibility of it being accidentally hit is minimized. If necessary, place transparent plastic around it to prevent injury from flying glass in case of an explosion.

8.8.3.2.6 When possible, avoid using mechanical vacuum pumps for distillation or concentration operations using large quantities of volatile materials. A water aspirator or steam aspirator is preferred. This is particularly important when large quantities of volatile materials are involved.

8.8.3.3 Vacuum Trapping

8.8.3.3.1 When using a vacuum source, it is important to place a trap between the experimental apparatus and the vacuum source. The vacuum trap:

- Protects the pump and the piping from the potentially damaging effects of the material
- Protects people who must work on the vacuum lines or system, and
- Prevents vapors and related odors from being emitted back into the laboratory or system exhaust.

8.8.3.3.2 Proper Trapping Techniques:

To prevent contamination, all lines leading from the experimental apparatus to the vacuum source should be equipped with filtration or other trapping as appropriate.

- For **particulates**, use filtration capable of efficiently trapping the particles in the size range being generated
- For most **aqueous or non-volatile liquids**, a filter flask at room temperature is adequate to prevent liquids from getting to the vacuum source.

- For **solvents** and other volatile liquids, use a cold trap of sufficient size and cold enough to condense vapors generated, followed by a filter flask capable of collecting fluid that could be aspirated out of the cold trap.
- For **highly reactive, corrosive, or toxic gases**, use a sorbent canister or scrubbing device capable of trapping the gas.

8.8.3.3.3 Cold Traps:

For most volatile liquids, a cold trap, using a slush of dry ice and either isopropanol or ethanol, is sufficient (to -78°C).

- Avoid using acetone. Ethanol and isopropanol are cheaper and less likely to foam.
- Liquid nitrogen may only be used with sealed or evacuated equipment, and then only with extreme caution. If the system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere and react vigorously with any organic material present.

8.8.4 Glass Vessels

8.8.4.1 Although glass vessels are frequently used in pressure and vacuum systems, they can explode or implode violently, either spontaneously from stress failure or an accidental blow.

8.8.4.2 The following practices may reduce the risk of injury or fire when working with glass vessels:

- Conduct pressure and vacuum operations in glass vessels behind adequate shielding.
- Ensure the glass vessel is designed for the intended operation.
- Carefully check glass vessels for star cracks, scratches, or etching marks before each use. Cracks can increase the likelihood of breakage or may allow chemicals to leak into the vessel.
- Seal glass centrifuge tubes with rubber stoppers clamped in place. Wrap the vessel with friction tape and shield it with a metal screen. Alternatively, wrap with friction tape and surround the vessel with multiple layers of loose cloth, then clamp behind a safety shield.
- Glass tubes with high-pressure sealers should be no more than 3/4 full.
- Sealed bottles and tubes of flammable materials should be wrapped in cloth, placed behind a safety shield, and then cooled slowly, first with an ice bath, then with dry ice.
- Never rely on corks, rubber stoppers, or plastic tubing as pressure-relief devices.
- Glass vacuum desiccators should be made of *Pyrex* or similar glass and wrapped partially with friction tape to guard against flying glass. Plastic desiccators are a good alternative to glass but still require shielding.
- Never carry or move an evacuated desiccator.

8.8.5 Dewar Flasks

8.8.5.1 Dewar flasks are under pressure and can collapse from thermal shock or slight mechanical shock.

8.8.5.2 The following practices may reduce the risk of injury or fire when working with Dewar flasks:

- Shield flasks with friction tape or enclose in a wooden or metal container to reduce the risk of flying glass.
- Use metal flasks if there is a significant possibility of breakage.
- Styrofoam buckets offer a short-term alternative to Dewar flasks.

8.8.6 Rotovaps

Rotovaps can implode under certain conditions. Since some Rotovaps contain components made of glass, this can be a serious hazard.

8.9 Laboratory Equipment

8.9.1 Refrigerators and Freezers

8.9.1.1 The potential hazards posed by laboratory refrigerators and freezers involve vapors from the contents, the possible presence of incompatible chemicals, and spillage.

8.9.1.2 Whenever possible, refrigerators and freezers specified for laboratory use should be utilized for the storage of chemicals. These refrigerators have been constructed with special design factors, such as heavy-duty cords and corrosion-resistant interiors to help reduce the risk of fire or explosions in the lab. Only refrigerators that have been UL- or FM (Factory Mutual)-approved for flammable storage should be used for this purpose.

8.9.1.3 Standard refrigerators have electrical fans and motors that make them potential ignition sources for flammable vapors. Do not store flammable liquids in a refrigerator unless it is approved for such storage. Flammable liquid-approved refrigerators are designed with spark-producing parts on the outside to avoid accidental ignition. If refrigeration is needed inside a flammable-storage room, use an explosion-proof refrigerator.

8.9.1.4 Frost-free refrigerators should also be avoided. Many of them have a drain or tube or hole that carries water and possibly any spilled materials to an area near the compression, which may spark. Electric heaters used to defrost the freezing coils can also spark.

8.9.1.5 Refrigerate chemicals only in chemical storage refrigerators; lab refrigerators should not be used for food storage or preparation. Clearly label all refrigerators containing chemicals.

8.9.1.6 All materials in refrigerators or freezers should be labeled with the contents, owner, date of acquisition or preparation, and nature of any potential chemical or potentially infectious hazard.

8.9.1.7 All containers should be sealed, preferably with a cap. Containers should be placed in secondary containers, or catch pans should be used, whenever indicated by the SDS.

8.9.1.8 Loss of electrical power can produce extremely hazardous situations. Flammable or toxic vapors may be released from refrigerators and freezers as chemicals warm up and/or certain reactive materials may decompose energetically upon warming.

8.9.2 Stirring and Mixing Devices

8.9.2.1 Stirring and mixing devices commonly found in laboratories include stirring motors, magnetic stirrers, shakers, small pumps for fluids, and rotary evaporators for solvent removal. These devices are typically used in laboratory operations that are performed in a hood, and they must be operated in a way that precludes the generation of electrical sparks.

8.9.2.2 Only spark-free induction motors should be used in power stirring and mixing devices or any other rotating equipment used for laboratory operations. While the motors in most of the currently marketed stirring and mixing devices meet this criterion, their on-off switches, and rheostat-type speed controls can produce an electrical spark because they have exposed electrical conductors.

8.9.2.3 Because stirring and mixing devices, especially stirring motors and magnetic stirrers, are often operated for fairly long periods without constant attention; the consequences of stirrer failure, electrical overload, or blockage of the motion of the stirring impeller should be considered.

8.9.3 Heating Devices

8.9.3.1 Most labs use at least one type of heating device, such as ovens, hot plates, heating mantles and tapes, water baths, oil baths, salt baths, sand baths, air baths, hot-tube furnaces, hot-air guns, and microwave ovens.

8.9.3.2 Steam-heated devices are generally preferred whenever temperatures of 100°C or less are required because they do not present shock or spark risks and can be left unattended with the assurance that their temperature will never exceed 100°C.

8.9.3.3 A number of general precautions need to be taken when working with heating devices in the laboratory. When working with heating devices, consider the following:

8.9.3.3.1 The actual heating element in any laboratory heating device should be enclosed in such a fashion as to prevent a laboratory worker or any metallic conductor from accidentally touching the wire carrying the electric current.

8.9.3.3.2 If a heating device becomes so worn or damaged that its heating element is exposed, the device should be either discarded or repaired before it is used again.

8.9.3.3.3 Laboratory heating devices should be used with a variable autotransformer to control the input voltage by supplying some fraction of the total line voltage, typically 110 volts.

8.9.3.3.4 The external cases of all variable autotransformers have perforations for cooling by ventilation and, therefore, should be located where water and other chemicals cannot be spilled onto them and where they will not be exposed to flammable liquids or vapors.

8.9.3.4 Fail-safe Devices

8.9.3.4.1 Fail-safe devices can prevent fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent, or loss of cooling.

8.9.3.4.2 Some devices will turn off the electric power if the temperature of the heating device exceeds some preset limit or if the flow of cooling water through a condenser is stopped owing to the loss of water pressure or loosening of the water supply hose to a condenser.

8.9.3.5 Ovens

8.9.3.5.1 Electrically heated ovens are commonly used in the laboratory to remove water or other solvents from chemical samples and to dry laboratory glassware. **Never use laboratory ovens for human food preparation.**

8.9.3.5.2 Laboratory ovens should be constructed such that their heating elements and their temperature controls are physically separated from their interior atmospheres.

8.9.3.5.3 Laboratory ovens rarely have a provision for preventing the discharge of the substances volatilized in them. Connecting the oven vent directly to an exhaust system can reduce the possibility of substances escaping into the lab or an explosive concentration developing within the oven.

8.9.3.5.4 Ovens should not be used to dry any chemical sample that might pose a hazard because of acute or chronic toxicity unless special precautions have been taken to ensure continuous venting of the atmosphere inside the oven.

8.9.3.5.5 To avoid explosion, glassware that has been rinsed with an organic solvent should be thoroughly rinsed again with distilled water before being dried in an oven.

8.9.3.5.6 Use the following precautions when working with mercury thermometers:

- Mercury thermometers should not be mounted through holes in the top of ovens so that the bulb hangs into the oven.
- Should a mercury thermometer be broken in an oven of any type, the oven should be closed and turned off immediately and it should remain closed until cool.
- All mercury should be removed from the cold oven with the use of appropriate cleaning equipment and procedures in order to avoid mercury exposure.
- Consider using bimetallic strip thermometers to monitor oven temperatures. Teflon-coated, spirit-filled oven thermometers are preferred.

8.9.3.6 Hot Plates

8.9.3.6.1 Laboratory hot plates are normally used for heating solutions to 100°C or above when inherently safer steam baths cannot be used.

8.9.3.6.2 Any newly purchased hot plates should be designed in a way that avoids electrical sparks. However, many older hot plates pose an electrical spark hazard arising from either the on-off switch located on the hot plate, the bimetallic thermostat used to regulate the temperature, or both. Laboratory workers should be warned of the spark hazard associated with older hot plates.

8.9.3.6.3 In addition to the spark hazard, old and corroded bimetallic thermostats in these devices can eventually fuse shut and deliver full, continuous current to a hot plate.

- Do not store volatile flammable materials near a hot plate.
- Limit or avoid use of older hot plates for flammable materials.
- Check for corrosion of thermostats. Corroded bimetallic thermostats can be repaired or reconfigured to avoid spark hazards.

8.9.3.7 Heating Mantles

8.9.3.7.1 Heating mantles are commonly used for heating round-bottomed flasks, reaction kettles, and related reaction vessels. These mantles enclose a heating element in a series of layers of fiberglass cloth. As long as the fiberglass coating is not worn or broken, and as long as no water or other chemicals are spilled into the mantle, heating mantles pose no shock hazard.

8.9.3.7.2 Always use a heating mantle with a variable autotransformer to control the input voltage. Never plug them directly into a 110-volt line.

8.9.3.7.3 Be careful not to exceed the input voltage recommended by the mantle manufacturer. Higher voltages will cause it to overheat, melt the fiberglass insulation and expose the bare heating element.

8.9.3.7.4 If the heating mantle has an outer metal case that provides physical protection against damage to the fiberglass, it is good practice to ground the outer metal case to protect against an electric shock if the heating element inside the mantle shorts against the metal case.

8.9.3.7.5 Some older equipment might have asbestos insulation rather than fiberglass.

8.9.3.8 Water, Oil, Salt, and Sand Baths

8.9.3.8.1 Electrically heated water and oil baths are often used to heat small or irregularly shaped vessels or when a stable heat source that can be maintained at a constant temperature is desired. Molten salt baths, like hot oil baths, offer the advantages of good heat transfer, commonly have a higher operating range (e.g., 200 to 425°C), and may have high thermal stability (e.g., 540°C).

8.9.3.8.2 There are several precautions to take when working with these types of heating devices:

- Take care with hot oil baths not to generate smoke or have the oil burst into flames from overheating.
- Always monitor oil baths by using a thermometer or other thermal sensing devices to ensure that their temperature does not exceed the flashpoint of the oil being used.
- Fit oil baths left unattended with thermal sensing devices that will turn off the electric power if the bath overheats.
- Mix oil baths well to ensure that there are no “hot spots” around the elements that take the surrounding oil to unacceptable temperatures.
- Contain heated oil in a vessel that can withstand an accidental strike by a hard object.
- Mount baths carefully on stable horizontal support such as a laboratory jack that can be raised or lowered without danger of the bath tipping over. Iron rings are not acceptable supports for hot baths.
- Clamp equipment high enough above a hot bath that if the reaction begins to overheat, the bath can be lowered immediately and replaced with a cooling bath without having to readjust the equipment setup.
- Provide secondary containment in the event of a spill of hot oil.
- Wear heat-resistant gloves when handling a hot bath.
- The reaction container used in a molten salt bath must be able to withstand a very rapid heat-up to a temperature above the melting point of salt. Take care to keep salt baths dry since they are hygroscopic, which can cause hazardous popping and splattering if the absorbed water vaporizes during heat-up.

8.9.3.9 Hot Air Baths and Tube Furnaces

8.9.3.9.1 Hot air baths may be used in the lab as heating devices. Electrically heated air baths are frequently used to heat small or irregularly shaped vessels.

8.9.3.9.2 One drawback of the hot-air bath is that they have a low heat capacity. As a result, these baths normally have to be heated to 100°C or more above the target temperature. Tube furnaces are often used for high-temperature reactions under pressure.

8.9.3.9.3 Nitrogen is preferred for reactions involving flammable materials.

8.9.3.9.4 Consider the following when working with either apparatus:

- Ensure that the heating element is completely enclosed.
- For air baths constructed of glass, wrap the vessel with heat-resistant tape to contain the glass if it should break.
- Sand baths are generally preferable to air baths.
- For tube furnaces, carefully select glassware and metal tubes and joints to ensure they can withstand the pressure.
- Follow safe practices outlined for both electrical safety and pressure and vacuum systems.

8.9.3.10 Heat Guns

8.9.3.10.1 Laboratory heat guns are constructed with a motor-driven fan that blows air over an electrically heated filament. They are frequently used to dry glassware or to heat the upper parts of a distillation apparatus during distillation of high-boiling point.

8.9.3.10.2 The heating element in a heat gun typically becomes red-hot during use and the on-off switches and fan motors are usually not spark-free. For these reasons, heat guns almost always pose a serious spark hazard.

8.9.3.10.3 Household hair dryers may be substituted for laboratory heat guns only if they have a grounded plug or are double insulated.

8.9.3.10.4 Any hand-held heating device of this type that will be used in a laboratory should have GFCI protection to ensure protection against electric shock.

8.9.3.10.5 Never use a heat gun near flammable materials including open containers of flammable liquids, flammable vapors, or hoods used to control flammable vapors.

8.9.3.11 Microwave Ovens

8.9.3.11.1 Microwave ovens, as with most electrical apparatus, pose a risk of generating sparks that can ignite flammable vapors.

8.9.3.11.2 **Never place metals in a microwave.** Metals placed inside the microwave oven may produce an arc that can ignite flammable materials.

8.9.3.11.3 Materials placed inside the oven may overheat and ignite.

8.9.3.11.4 Sealed containers, even if loosely sealed, can build pressure upon expansion during heating, creating a risk of container rupture.

8.9.3.11.5 To minimize the risk of these hazards:

- Never operate microwave ovens with doors open in order to avoid exposure to microwaves.
- Do not place wires and other objects between the sealing surface and the door on the oven’s front face. The sealing surfaces must be kept absolutely clean.
- Never use a microwave oven for both laboratory use and food preparation.
- Electrically ground the microwave. If the use of an extension cord is necessary, only a three-wire cord with a rating equal to or greater than that for the oven should be used.
- Do not use metal containers and metal-containing objects (e.g., stir bars) in the microwave. They can cause arcing.
- Do not heat sealed containers in the microwave oven. Even heating a container with a loosened cap or lid poses a significant risk, since microwave ovens can heat material so quickly that the lid can seat upward against the threads and containers can explode.
- Remove screw caps from containers being microwaved. If the sterility of the contents must be preserved, use cotton or foam plugs. Otherwise, plug the container with *Kimwipes* to reduce splash potential.

8.9.4 Ultrasonicators

8.9.4.1 Human exposure to ultrasound with frequencies between 16 and 100 kilohertz (kHz) can be divided into three distinct categories: airborne conduction, direct contact through a liquid coupling medium, and direct contact with a vibrating solid.

8.9.4.2 Airborne conduction

8.9.4.2.1 Ultrasound through airborne conduction does not appear to pose a significant health hazard to humans. However, exposure to the associated high volumes of audible sound can produce a variety of effects, including fatigue, headaches, nausea, and tinnitus.

8.9.4.2.2 When ultrasonic equipment is operated in the laboratory, the apparatus must be enclosed in a 2-cm thick wooden box or in a box lined with acoustically absorbing foam or tiles to substantially reduce acoustic emissions (most of which are inaudible).

8.9.4.3 Direct contact through a liquid coupling medium.

8.9.4.3.1 Direct contact of the body with liquids or solids subjected to high-intensity ultrasound of the sort used to promote chemical reactions should be avoided.

8.9.4.3.2 Under sonochemical conditions, cavitation is created in liquids, and it can induce high-energy chemistry in liquids and tissues. Cell death from membrane disruption can occur even at relatively low acoustic intensities.

8.9.4.4 Direct contact with a vibrating solid.

8.9.4.4.1 Exposure to ultrasonically vibrating solids, such as an acoustic horn, can lead to rapid frictional heating and potentially severe burns.

8.9.5 Centrifuges

8.9.5.1 Centrifuges should be properly installed and must be operated only by trained personnel.

8.9.5.2 It is important that the load is balanced each time the centrifuge is used and that the lid is closed while the rotor is in motion.

8.9.5.3 The disconnect switch must be working properly to shut off the equipment when the top is opened, and the manufacturer’s instructions for safe operating speeds must be followed.

8.9.5.4 For flammable and/or hazardous materials, the centrifuge should be under negative pressure to a suitable exhaust system.

8.9.6 Rotary Evaporators (Rotovaps)

8.9.6.1 Glass components of the rotary evaporator should be made of *Pyrex* or similar glass.

8.9.6.2 Glass vessels should be completely enclosed in a shield to guard against the flying glass, should the components implode.

8.9.6.3 Increase in rotation speed and application of vacuum to the flask whose solvent is to be evaporated should be gradual.

8.9.7 Autoclaves

8.9.7.1 The use of an autoclave is a very effective way to decontaminate biohazardous waste. Autoclaves work by killing microbes with superheated steam.

8.9.7.2 The following are recommended guidelines when using an autoclave:

8.9.7.2.1 Do not put sharp or pointed contaminated objects into an autoclave bag. Place them in an appropriate rigid sharps disposal container.

8.9.7.2.2 Use caution when handling a biohazard waste autoclave bag, in case sharp objects were inadvertently placed in the bag. Never lift a bag from the bottom to load it into the chamber. Handle the bag from the top.

8.9.7.2.3 Do not overfill an autoclave bag. Steam and heat cannot penetrate as easily to the interior of a densely packed autoclave bag. Frequently the outer contents of the bag will be treated but the innermost part will be unaffected.

8.9.7.2.4 Do not overload an autoclave. An overpacked autoclave chamber does not allow efficient steam distribution. Considerably longer sterilization times may be required to achieve decontamination if an autoclave is tightly packed.

8.9.7.2.5 Conduct autoclave sterility testing on a regular basis using appropriate biological indicators (*B. stearothermophilus* spore strips) to monitor efficacy. Use indicator tape with each load to verify it has been autoclaved.

8.9.7.2.6 Do not mix contaminated and clean items together during the same autoclave cycle. Clean items generally require shorter decontamination times (15-20 minutes) while a bag of infectious waste (24" x 36") typically requires 45 minutes to an hour to be effectively decontaminated throughout.

8.9.7.2.7 Always wear PPE, including heat-resistant gloves, safety glasses, and a lab coat when operating an autoclave. Use caution when opening the autoclave door. Allow superheated steam to exit before attempting to remove autoclave contents.

8.9.7.2.8 Be on the alert when handling pressurized containers. Superheated liquids may spurt from closed containers. Never seal a liquid container with a cork or stopper. This could cause an explosion inside the autoclave.

8.9.7.2.9 Agar plates will melt, and the agar will become liquefied when autoclaved. Sterilize media in glass bottles. Avoid contact with molten agar. Use a secondary tray to catch any potential leakage from an autoclave bottle rather than allowing it to leak onto the floor of the autoclave chamber.

8.9.7.2.10 If there is a spill inside the autoclave chamber, allow the unit to cool before attempting to clean up the spill. If glass breaks in the autoclave, use tongs, forceps, or other mechanical means to recover fragments. Do not use bare or gloved hands to pick up broken glassware.

8.9.7.2.11 Do not leave an autoclave operating unattended for a long period of time. Always be sure someone is in the vicinity while an autoclave is cycling, in case there is a problem.

8.9.7.2.12 Autoclaves should be placed under preventive maintenance contracts to ensure they are operating properly.

8.9.8 Electrophoresis Devices

8.9.8.1 Precautions to prevent electric shock must be followed when conducting procedures involving electrophoresis. Lethal electric shock can result when operating at high voltages such as in Deoxyribonucleic acid (DNA) sequencing or low voltages such as in agarose gel electrophoresis (e.g., 100 volts at 25 milliamps).

8.9.8.2 The following are recommended guidelines when using electrophoresis devices:

8.9.8.2.1 Turn the power off before connecting the electrical leads.

8.9.8.2.2 Connect one lead at a time, using one hand only.

8.9.8.2.3 Ensure that hands are dry while connecting leads.

8.9.8.2.4 Keep the apparatus away from sinks or other water sources.

8.9.8.2.5 Turn off power before opening the lid or reaching inside the chamber.

8.9.8.2.6 Do not override safety devices.

8.9.8.2.7 Do not run electrophoresis equipment unattended.

8.9.8.2.8 If using acrylamide, purchase premixed solutions or pre-weighed quantities whenever possible

8.9.8.2.9 If using ethidium bromide, have a hand-held UV light source available in the laboratory. Check working surfaces after each use.

8.9.8.2.10 Mix all stock solutions in a chemical fume hood.

8.9.8.2.11 Provide spill containment by mixing gels on a plastic tray.

8.9.8.2.12 Decontaminate surfaces with ethanol. Dispose of all cleanup materials as hazardous waste.

8.9.9 Glassware

8.9.9.1 Although glass vessels are frequently used in low-vacuum operations, evacuated glass vessels may collapse violently, either spontaneously from strain or from an accidental blow.

8.9.9.2 The following are recommended guidelines when using glassware:

8.9.9.2.1 Pressure and vacuum operations in glass vessels should be conducted behind adequate shielding.

8.9.9.2.2 It is advisable to check for flaws such as star cracks, scratches, and etching marks each time a vacuum apparatus is used.

8.9.9.2.3 Only round-bottomed or thick-walled (e.g. *Pyrex*) evacuated reaction vessels specifically designed for operations at reduced pressure should be used.

8.9.9.2.4 Repaired glassware is subject to thermal shock and should be avoided. Thin-walled, Erlenmeyer or round-bottomed flasks larger than 1 L should never be evacuated.

8.9.10 Vacuums

8.9.10.1 Vacuum pumps are used in the lab to remove air and other vapors from a vessel or manifold. The most common usages are on rotary evaporators, drying manifolds, centrifugal concentrators (“speedvacs”), acrylamide gel dryers, freeze dryers, vacuum ovens, tissue culture filter flasks and aspirators, desiccators, filtration apparatus, and filter/degassing apparatus.

8.9.10.2 The critical factors in vacuum pump selection are:

- Application the pump will be used on.
- Nature of the sample (air, chemical, moisture).
- Size of the sample(s).

8.9.10.3 When using a vacuum pump on a rotary evaporator, a dry ice alcohol slurry cold trap or a refrigerated trap is recommended. A Cold Trap should be used in line with the pump when high vapor loads from drying samples will occur. Consult manufacturer for specific situations. These recommendations are based on keeping evaporating flask on a rotary evaporator at 400°C. Operating at a higher temperature allows the Dry Vacuum System to strip boiling point solvents with acceptable evaporation rates.

8.9.10.4 Vacuum pumps can pump vapors from air, water to toxic and corrosive materials like trifluoroacetic acid (TFA) and methylene chloride. Oil seal pumps are susceptible to excessive amounts of gas, corrosive acids and bases, and excessive water vapors. Too much air mass over time is compressed by these pumps and overheats the oil, cooing it into a viscous sludge that can eventually freeze the pumping motor. Corrosives can also create sludge by breaking down the oil. Excess water thins the lubricating properties of the oil, which then overheats. Proper trapping (cold trap, acid trap) and routine oil changes greatly extend the life of an oil seal vacuum.

8.9.10.5 Diaphragm pumps are virtually impervious to attack from laboratory chemical vapors. They are susceptible to the physical wearing of the membrane if excessive chemical vapors are allowed to condense and crystallize in the pumping chambers. A five-minute air purge, either as part of the procedure or at the day’s end, will drive off condensed water vapors and further prolong pump life.

8.9.10.6 Hazardous chemicals can escape from the vacuum pump and the pump should be placed in the hood. Cold traps and acid traps can be helpful, but if allowed to thaw or saturate, they can lose their effectiveness.

8.10 Particularly Hazardous Materials

As a matter of good practice, and to satisfy regulatory requirements, particularly hazardous substances require additional planning and considerations. Consult the SDS to determine whether a particular chemical may be considered a carcinogen, reproductive hazard, or substance with high acute toxicity.

8.10.1 Definitions

OSHA Laboratory Standard defines particularly hazardous substances as follows:

8.10.1.1 **Carcinogens** – A carcinogen is a substance capable of causing cancer. Carcinogens are chronically toxic substances; that is, they cause damage after repeated or long-duration exposure and their effects may become evident only after a long latency period. A chemical is considered a carcinogen, for the purpose of the Laboratory Safety Manual, if it is included in any of the following carcinogen lists:

8.10.1.1.1 OSHA-regulated carcinogens as listed in Subpart Z of the OSHA standards.

8.10.1.1.2 Under the category "known to be carcinogens" in the *Annual Report of Carcinogens* published by the National Toxicology Program (**NTP**), the latest edition.

8.10.1.1.3 Group 1 ("carcinogenic to humans") of the International Agency for Research on Cancer (**IARC**), latest edition.

8.10.1.1.4 Chemicals listed in Group 2A or 2B by IARC and under the category "reasonably anticipated to be carcinogens" by NTP cause significant tumor incidence in experimental animals under specified conditions are also considered carcinogens under the OSHA Laboratory Standard.

8.10.1.2 **Reproductive Toxins –** Reproductive toxins are substances that have adverse effects on various aspects of reproduction, including fertility, gestation, lactation, and general reproductive performance. When a pregnant woman is exposed to a chemical, the fetus may be exposed as well because the placenta is an extremely poor barrier to chemicals. Reproductive toxins can affect both men and women. Exposure to reproductive toxins can in some cases lead to sterility.

8.10.1.3 Substances with High Acute Toxicity – Substances with a high degree of acute toxicity are those that can cause death, disability, or serious injury after a single, relatively low-level exposure. Certain biological substances can also present a highly acute hazard. High acute toxicity includes any chemical that falls within any of the following OSHA-defined categories:

8.10.1.3.1 A chemical with a median LD_{50} of 50 mg or less per kg of body weight when administered orally to certain test populations.

8.10.1.3.2 A chemical with an LD_{50} of 200 mg or less per kg of body weight when administered by continuous contact for 24 hours to certain test populations.

8.10.1.3.3 A chemical with a median lethal concentration (LC_{50}) in the air of 200 parts per million (ppm) by volume or less of gas, 2.0 mg/L or less of vapor, or 0.5 mg/L or less of dust and mist, when administered to certain test populations by continuous inhalation for one hour, provided such concentration and/or condition are likely to be encountered by humans when the chemical is used in any reasonably foreseeable manner.

8.10.1.4 Mutagens – Mutagens are chemicals that cause permanent changes in the amount or structure of the genetic material in a cell.

8.10.2 Approval Procedure

8.10.2.1 Laboratory workers planning to use a particularly hazardous substance (PHS) must first receive explicit written approval from the CSN EH&S Director.

8.10.2.2 Laboratory workers must supply the following information to the director:

8.10.2.2.1 Identity, physical characteristics, and health hazards of the substances involved.

8.10.2.2.2 Consideration of exposure controls such fume hood or biosafety cabinet, glove boxes, and personal protective equipment.

8.10.2.2.3 Designation of an area (hood, glove box, portion of lab, entire lab) specifically for experimental procedures with the substances involved.

8.10.2.2.4 Plans for storage and secondary containment.

8.10.2.2.5 Procedures for safe removal of contaminated waste.

8.10.2.2.6 Decontamination procedures.

8.10.2.3 The area where the PHS will be used is posted as a designated area. Signs shall include the following information:

DANGER
DESIGNATED AREA
for select carcinogens, reproductive toxins, and high acute toxicity chemicals
AUTHORIZED PERSONNEL ONLY

8.10.2.4 The laboratory worker shall proceed with the experiment following the appropriate safety practices in the remainder of the *Safe Work Practices and Procedures* section of this manual. All work shall be conducted within the Designated Area.

8.10.2.5 The laboratory worker shall decontaminate all equipment and disposes of waste promptly.

8.10.3 Working Safely with Particularly Hazardous Substances

The increased hazard risk associated with PHS calls for stricter operating procedures in the laboratory.

8.10.3.1 Work Habits

8.10.3.1.1 There shall be no eating, drinking, smoking, chewing of gum or tobacco, application of cosmetics, or storage of utensils, food, food utensils, or food containers in laboratory areas where PHS are used or stored.

8.10.3.1.2 All personnel should wash their hands and arms immediately after the completion of any procedure in which a PHS has been used and when they leave the laboratory.

8.10.3.1.3 Each procedure should be conducted using the minimum amount of the substance, consistent with the requirements of the work.

8.10.3.1.4 The laboratory worker should keep records of the amounts of each highly hazardous material used, the dates of use, and the names of the users.

8.10.3.1.5 Worksurfaces, including fume hoods and biosafety cabinets, should be fitted with a removable liner of absorbent plastic-backed paper to help contain spilled materials and to simplify subsequent cleanup and disposal.

8.10.4 Personal Protective Equipment

8.10.4.1 PHS may require more stringent use of personal protective equipment. Check the SDS for information on proper gloves, lab clothing, and respiratory protection.

8.10.4.2 Proper PPE must be worn at all times when handling PHS.

8.10.4.3 Lab clothing that protects street clothing, such as a fully fastened lab coat or a disposable jumpsuit, should be worn when PHS is being used. Laboratory clothing used while manipulating PHS should not be worn outside the laboratory area.

8.10.4.4 When methods for decontaminating clothing are unknown or not applicable, disposable protective clothing should be worn. Disposable gloves should be discarded after each use and immediately after overt contact with a PHS.

8.10.5 Ventilation/Isolation

8.10.5.1 Most PHS work should be performed in a fume or biosafety cabinet, glove box, or other form of ventilation. If the chemical may produce vapors, mists, or fumes, or if the procedure may cause the generation of aerosols, the use of a fume hood is required.

8.10.5.2 A fume hood used for PHS must have an average face velocity of between 95 and 125 fpm. This measurement is noted on the hood survey sticker. If the hood has not been inspected within the past year, contact the lab supervisor or manager.

8.10.5.3 A glove box should be used if protection from atmospheric moisture or oxygen is needed or when a fume hood may not provide adequate protection from exposure to the substance (e.g., a protection factor of 10,000 or more is needed).

8.10.5.4 Highly toxic gases must be used and stored in a vented gas cabinet connected to a laboratory exhaust system. Gas feed lines operating above atmospheric pressure must use coaxial tubing.

8.10.6 Storage and Transportation

8.10.6.1 Stock quantities of PHS should be stored in a designated storage area or cabinet with limited access. Additional storage precautions (i.e., a refrigerator or freezer, a hood a flammable liquid storage cabinet) may be required for certain compounds based upon other properties.

8.10.6.2 Containers must be clearly labeled (see section 4.3).

8.10.6.3 Double containment should also be considered. Double containment means that the container will be placed inside another container that is capable of holding the contents in the event of a leak and provides a protective outer covering in the event of contamination of the primary container.

8.10.6.4 Containers should be stored on trays or pans made of polyethylene or other chemically resistant material.

8.10.6.5 Persons transporting PHS from one location to another should use double containment to protect against spills and breakage.

8.10.7 Vacuum Lines and Services

8.10.7.1 Each vacuum service, including water aspirators, should be protected with an absorbent or liquid trap to prevent the entry of any PHS into the system.

8.10.7.2 When using volatile PHS, a separate vacuum pump should be used. The procedure should be performed inside a fume hood.

8.10.8 Decontamination and Disposal

8.10.8.1 Contaminated materials should either be decontaminated by procedures that decompose the PHS to produce a safe product or be removed for subsequent disposal.

8.10.8.2 All work surfaces must be decontaminated at the end of the procedure or workday, whichever is sooner.

8.10.8.3 Prior to the start of any laboratory activity involving a PHS, plans for the handling and ultimate disposal of contaminated wastes and surplus amounts of the PHS should be completed. EH&S can assist in selecting the best methods available for disposal.

8.10.8.4 Refer to section 10.0 for waste decontamination and disposal guidelines.

8.11 Disinfection of Reusable Laboratory Equipment

8.11.1 Disinfection Methods

Lab personnel should disinfect reusable laboratory equipment using one or more of the following methods on a routine basis. However, some laboratories may need professionals to properly decontaminate their equipment.

8.11.1.1 Cleaning is the first (and most basic) level. Essentially, cleaning is the first line of defense in decontamination. Basically, this involves using soap and water and scrubbing to remove any visible residue. Cleaning will remove any soil or organic matter from the surface. And it will also reduce the number of microorganisms on any surface.

8.11.1.2 Disinfection involves the use of chemicals or heat application. This second method of decontamination reduces the number of microbes on an object or surface. Furthermore, while it greatly reduces the number of microbes it does not eliminate them. A disinfectant will limit the number of organisms enough to eliminate the risk of infections. In fact, the surface will not be decontaminated if it is not properly cleaned prior to disinfection.

8.11.1.3 Sterilization is the third level of decontamination. Sterilization uses a physical or chemical procedure to destroy all microbial life. This includes highly resistant bacterial endospores. Basically, the methods used to properly sterilize include heat, gas, or steam such as the use of an autoclave.

8.11.2 List Laboratory Equipment that Require Disinfection

8.11.2.1 Various laboratory equipment can (in some cases) be a breeding ground for bacteria or other harmful agents during normal use or from spills. The following laboratory equipment should be cleaned and disinfected on a periodic basis. Refer to the manufacturer's instructions for proper disinfection procedures. Some equipment may require trained professionals to decontaminate:

- **Refrigerators/Freezers:**
- **Biosafety Cabinets**
- **Centrifuges**
- **Fume Hoods**
- **Ovens**
- **Incubators**
- **water baths**
- **scales**
- **chemical storage cabinets**
- **dehydrating units**

8.11.3 Reusable Lab Coats

Laboratory coats should never be brought home to launder given safety and regulatory considerations even if not knowingly contaminated. Regulations dictate that the employer must provide a means for cleaning and decontaminating the laboratory coats. Disposable laboratory coats should be immediately discarded into the proper waste stream for the contaminant. However, if reusable laboratory coats become contaminated, follow these guidelines:

8.11.3.1 Use of laundry service vendor: If your department uses a vendor to service and clean reusable laboratory coats, it is your responsibility to verify with the laundry contractor that they are capable and willing to launder contaminated lab coats. Biologically contaminated lab coats being sent out to a vendor, must be bagged separately from soiled lab coats. The contaminated lab coat is required to be placed into a red bag.

8.11.3.2 In-house laundry facility: If your department does not utilize a vendor to clean the lab coats, a facility to clean the lab coats on campus must be available (an in-house laundry facility). Some departments have a washer and dryer provided for this purpose. Contaminated materials must be laundered separately from routine laundering.

8.11.3.3 Decontamination of Reusable Laboratory Coats: Reusable laboratory coats can be decontaminated with an appropriate disinfectant or by autoclaving prior to using a laundry service or in-house laundry facility. Laboratory coats potentially contaminated with microorganisms in spore form must be autoclaved. If the laboratory coat is contaminated with category 2 materials or there is considerable contamination with category 1 materials, the clothes should be autoclaved (see Section 6.2 for definitions).

If using disinfection as a means of decontamination, treat area of contamination and surrounding area with disinfectant for label-specified dilution and contact time. If autoclaving, laboratory coats can be placed in a tray or bag. As a reminder, do not to overfill the bag or autoclave.

9.0 SPILLS AND EXPOSURES

9.1 Developing a Spill and Exposure Response Plan

An effective spill and exposure response procedure should be included in any job hazard analysis. The complexity and detail of the plan will, of course, depend upon the physical characteristics and volume of materials being handled, their potential toxicity, and the potential for releases to the environment. Consider all of the items listed below when developing a spill exposure plan for a specific laboratory.

9.1.1 Review the SDS or other references (e.g., ATCC certified reference materials) for recommended spill cleanup methods and materials, and PPE needs (e.g., respirator, gloves, protective clothing, etc.).

9.1.2 Acquire sufficient quantities and types of appropriate spill and exposure control materials to contain any spills that can be reasonably anticipated. The need for equipment to disperse, collect and contain spill and exposure control materials (e.g., brushes, scoops, spill socks, sealable containers, respirators, etc.) should also be reviewed.

9.1.3 Acquire recommended PPE and training in its proper use. For example, if an air-purifying respirator or self-contained breathing apparatus is needed, personnel must be enrolled in the Respiratory Protection Program and attend annual training and fit-testing.

9.1.4 Place spill control materials and protective equipment in a readily accessible location within or immediately adjacent to the laboratory.

9.1.5 Develop a spill and exposure-response plan that includes:

9.1.5.1 Names and telephone numbers of individuals to be contacted in the event of a spill.

9.1.5.2 Evacuation plans for the room or building, as appropriate.

9.1.5.3 Instructions for containing the spilled or exposed material, including potential releases to the environment (e.g., protect floor drains).

9.1.5.4 Inventory of spill and exposure control materials and PPE.

9.1.5.5 Means for proper disposal of cleanup materials (in most cases, as hazardous waste) including contaminated tools and clothing.

9.1.5.6 Decontamination plan of the area following the cleanup.

9.2 Recommended Chemical Spill and Exposure Control Material Inventory

The laboratory or work area should have access to a sufficient quantity of absorbents or other types of materials to control any spill that can be reasonably anticipated. The following sections outline example materials and supplies that may be needed to control a spill in the laboratory.

9.2.1 Personal Protective Equipment

- 2 pairs chemical splash goggles
- 2 pairs of gloves (recommend Silver Shield or 4H)
- 2 pairs of shoe covers
- 2 plastic or *Tyvek* aprons and/or *Tyvek* suits
- 2 disposable respirators if individually assigned and approved by EH&S
- First aid kit

9.2.2 Absorption Materials

- 4 3M POWERSORB spill pillows (or equivalent)
- 1 3M POWERSORB spill sock
- 2 DOT pails (5 gallon) with polyethylene liners
  - 1 filled with loose absorbents, such as vermiculite or clay
  - 1 with a minimum amount of loose absorbent in the bottom

9.2.3 Neutralizing Materials

- Acid Neutralizer
- Caustic Neutralizer
  - Commercial neutralizers, such as *Neutrasorb* (for acids) and *Neutracit-2* (for bases) have built-in a color change to indicate complete neutralization
- Solvent Neutralizer
  - Commercial solvent neutralizers, such as *Solusorb*, act to reduce vapors and raise the flashpoint of the mixture
- Reagent water

9.2.4 Mercury (Hg) Spills

- Small mercury vacuum to pick up large drops (optional)
- Hg Absorb Sponges - amalgamate mercury residue
- Hg Absorb Powder - amalgamates mercury
- Hg Vapor Absorbent - reduces the concentration of vapor in hard to reach areas
- Mercury Indicator - powder identifies the presence of mercury

9.2.5 Clean-up Tools

- Polypropylene scoop or dustpan
- Broom or brush with polypropylene bristles
- 2 polypropylene bags

- Sealing tape
- pH test papers
- Waste stickers
- Floor sign – “DANGER Chemical Spill - Keep Away”

9.3 Recommended Biological Agent Spill and Exposure Control Material Inventory

The consequences of any spill of biological material can be minimized by performing all work on a plastic-backed absorbent liner to absorb spills. A simple spill kit should be readily available and should include the following items:

- Chlorine bleach or some other concentrated disinfectant
- Package or roll of paper towels
- Autoclavable bag
- Latex or nitrile gloves
- Forceps for picking up broken glass
- Reagent water
- First aid kit
- Respirators, if individually assigned and approved by EH&S
- Floor sign – “DANGER Biological Spill – Keep Away”

9.4 Controlling and Responding to Chemical and Biological Agent Spills and Exposures

9.4.1 Preventing Spills

Most spills are preventable. The following are some tips that could help to prevent or minimize the magnitude of a spill:

9.4.1.1 Place chemical and biological material containers in a hood or lab bench in a manner that reduces the possibility of accidentally knocking over a container.

9.4.1.2 Plan your movements. Look where you are reaching to ensure you will not cause a spill.

9.4.1.3 Follow the procedures outlined for safely transporting chemicals and biological materials.

9.4.1.4 The consequences of any chemical or biological material spill can be minimized by placing absorbent plastic-backed liners on benchtops, in fume hoods, and in biological safety cabinets where spills can be anticipated. Perform all work on the plastic-backed liners to absorb spills. For volumes of chemical liquids larger than what can be absorbed by liners, use trays.

9.4.2 Chemical Spill Response and Clean-up Procedures

9.4.2.1 In the event of a chemical spill, the individual(s) who caused the spill is responsible for prompt and proper clean-up. It is also their responsibility to have spill control and personal protective equipment appropriate for the chemicals being handled readily available.

9.4.2.2 Immediately alert area occupants and supervisor, and evacuate the area, if necessary.

9.4.2.3 If there is a fire or medical attention is needed, dial x 7911 from a campus phone or 702-895-3669 from a cellphone to notify University Police Services.

9.4.2.4 Attend to any people who may be contaminated. Contaminated clothing must be removed immediately and the skin flushed with water for no less than 15 minutes. Clothing must be laundered before reuse.

9.4.2.5 If a volatile, flammable material is spilled, immediately warn everyone, control sources of ignition and ventilate the area.

9.4.2.6 If the material spilled is non-flammable, ensure that all forms of the local exhaust (e.g., fume hoods or fans) are operating to evacuate fumes.

9.4.2.7 Wear PPE, as appropriate to the hazards. Refer to the SDS or other references for information.

9.4.2.8 Use the chart below to determine the extent and type of spill. If the spill is large, if there has been a release to the environment, or if there is no one knowledgeable about spill clean-up available; call EH&S at 702-651-7445, or UPD 702-895-3669 if after hours.

Category	Size	Response	Treatment Materials
Small	up to 300 ml	chemical treatment or absorption	neutralization or absorption spill kit
Medium	300 ml - 5 liters	absorption	absorption spill kit
Large	more than 5 liters	call EH&S or UPD	outside help

9.4.2.9 Do not use cellular phones where flammable vapors are present.

9.4.2.10 Small Spills or Leaks (Less than 5 Liters)

9.4.2.10.1 The purpose of this procedure is to describe the protocols and procedures to follow in the event of a spill or release of oil or minor releases of hazardous materials.

9.4.2.10.2 Take immediate action to stop the spills and prevent free liquid from escaping. Attempt to capture as much liquid as possible.

9.4.2.10.3 Place leaking containers into a larger, secure container that is appropriate for the type of leaking material.

9.4.2.10.4 Protect floor drains or other means for environmental release by placing spill socks and other absorbents (e.g., towels, pads, mats, pillows) around drains, as needed.

9.4.2.10.5 Loose spill control materials should be distributed over the entire spill area, working from the outside perimeter, circling to the center. This reduces the chance of splash or spread of the spilled chemical. Bulk absorbents and many spill pillows do not work with hydrofluoric acid. POWERSORB (by 3M) products and their equivalent will handle hydrofluoric acid. Specialized hydrofluoric acid kits also are available.

9.4.2.10.6 For corrosive spills, spread a neutralizing agent over the surface of the spill. Many neutralizers for acids or bases have a color change indicator to show when neutralization is complete.

9.4.2.10.7 When spilled materials have been absorbed, use a brush and scoop to place materials into an appropriate container. Include all cleanup materials in the container. Polyethylene bags may be used for small spills.

9.4.2.10.8 Complete a hazardous waste sticker, identifying the material as “Spill Debris” involving “XYZ Chemical”, and affix onto the container. Dispose of spill control materials as hazardous waste (see section 10.0 and *Hazardous Waste Management Procedure*).

9.4.2.10.9 Decontaminate the surface where the spill occurred using a mild detergent and water, when appropriate.

9.4.2.11 Large Spills or Leaks (Greater than 5 Liters)

9.4.2.11.1 In the event of a large spill or leak, notify the immediate supervisor and call EH&S at 702-651-7445 or UPD 702-895-3669, if after hours.

9.4.2.11.2 Remain in the immediate vicinity until UPD or EH&S personnel arrive on-site and relieve you from duty.

9.4.3 Medical Response to Chemical Exposures

9.4.3.1 In all cases of chemical exposure, the incident shall be reported to the immediate supervisor regardless of the severity. Consult the supervisor/manager when completing the ***C-1 Notice of Injury Form.*** **This form must be completed regardless of whether or not signs or symptoms are noted.**

9.4.3.2 Chemicals on Skin or Clothing

9.4.3.2.1 For minor spills, immediately flush with water for no less than 15 minutes [except for Flammable Solids (see section 8.3.5), Hydrofluoric Acid, or greater than 10% Phenol]. For larger spills, the safety shower should be used.

9.4.3.2.2 For Flammable Solids on the skin, first brush off as much of the solids as possible and then proceed as described above.

9.4.3.2.3 For Hydrofluoric Acid, rinse with water for 5 minutes and apply calcium gluconate gel, then get immediate medical attention. If no gel is available, rinse for 15 minutes and go immediately to the emergency room.

9.4.3.2.4 For Phenol concentrations greater than 10%, flush with water for 15 minutes or until the affected area turns from white to pink. Apply polyethylene glycol, if available. Do not use ethanol. Proceed as described above.

9.4.3.2.5 While rinsing, quickly remove all contaminated clothing or jewelry. Seconds count. Do not waste time because of modesty.

9.4.3.2.6 Use caution when removing pullover shirts or sweaters to prevent contamination of the eyes.

9.4.3.2.7 Check the SDS to determine if any delayed effects should be expected.

9.4.3.2.8 Discard contaminated clothing or launder them separately from other clothing. Leather garments or accessories cannot be decontaminated and should be discarded.

9.4.3.2.9 Do not use solvents to wash skin. They remove the natural protective oils from the skin and can cause irritation and inflammation. In some cases, washing with a solvent may facilitate the absorption of a toxic chemical.

9.4.3.3 Chemicals in Eyes

9.4.3.3.1 Immediately flush eye(s) with cool water for at least 15 minutes. The eyes must be forcibly held open to wash, and the eyeballs must be rotated so all surface area is rinsed. The use of an eyewash fountain is desirable, so hands are free to hold the eyes open. If an eyewash is not available, pour water on the eye, rinsing from the nose outward to avoid contamination of the unaffected eye.

9.4.3.3.2 Remove contact lenses while rinsing. **Do not lose time removing contact lenses before rinsing.** Do not attempt to rinse and reinsert contact lenses.

9.4.3.3.3 Seek immediate medical attention regardless of the severity or apparent lack of severity. If an ambulance is needed, see the procedure in section 3.1. Explain carefully what chemicals were involved.

9.4.3.4 Chemical Inhalation

9.4.3.4.1 Close containers, open windows, or otherwise increase ventilation, and move to fresh air.

9.4.3.4.2 If symptoms, such as headaches, nose or throat irritation, dizziness, or drowsiness persist, seek immediate medical attention. Explain carefully what chemicals were involved.

9.4.3.4.3 Review the SDS to determine what health effects are expected, including delayed effects.

9.4.3.5 Accidental Ingestion of Chemicals

9.4.2.5.1 Immediately call Poison Control Center at 9-800-222-1222 for instructions.

9.4.2.5.2 **Do not induce vomiting** unless directed to do so by a health care provider.

9.4.2.5.3 Refer to section 4 of the SDS for appropriate First-Aid Measures.

9.4.3.6 Accidental Injection of Chemicals

9.4.3.6.1 Wash the area with soap and water and seek immediate medical attention, if necessary.

9.4.4 Biological Agent Spill Clean-up Procedures

9.4.4.1 Biological Agent (BSC 1 or 2) Spills Inside a Biological Safety Cabinet:

9.4.4.1.1 Leave the cabinet turned on.

9.4.4.1.2 Wearing gloves and a lab coat, use a disinfectant equivalent to 1:10 bleach solution or other approved disinfectant spray on cabinet walls, work surfaces, and equipment.

9.4.4.1.3 Wait at least 20 minutes. Then soak up disinfectant and spill with paper towels.

9.4.4.1.4 Drain catch basin into a container. Lift the front exhaust grill and tray and wipe all surfaces. Ensure that no paper towels or solid debris are blown into the area beneath the grill.

9.4.4.1.5 Autoclave all clean-up materials in the biohazard waste container before disposal (see *Hazardous Waste Management Procedure*).

9.4.4.1.6 Wash hands and any exposed surfaces thoroughly after the clean-up procedure.

9.4.4.2 Small (less than 500 mL) Biological Agent (BSC 1 or 2) spill outside a Biological Safety Cabinet:

9.4.4.2.1 Wearing gloves, safety glasses, and a lab coat cover the spill with paper towels and gently apply disinfectant, proceeding from the outer edge of the spill to its center.

9.4.4.2.2 Leave in place for 20 minutes. Then pick up and discard paper towels into a biohazard container. Use forceps to pick up any broken glass and place them into a sharps container.

9.4.4.2.3 Re-spray the contaminated area with disinfectant and re-wipe with clean paper towels. Place all paper towels into the biohazard container.

9.4.4.2.4 Remove gloves and place them in the biohazard container. Thoroughly wash hands and any exposed surfaces after the clean-up procedure.

9.4.4.2.5 Autoclave all clean-up materials in the biohazard waste container before disposal (see *Hazardous Waste Management Procedure*).

9.4.4.3 Large (more than 500 mL) Biological Agent (BSC 1 and 2) spill outside a Biological Safety Cabinet:

9.4.4.3.1 **HOLD YOUR BREATH AND LEAVE THE ROOM IMMEDIATELY.** Inform your supervisor about the spill.

9.4.4.3.2 Warn others to stay out of the spill area to prevent the spread of contamination and post a sign on the door warning others of the biological materials spill.

9.4.4.3.3 Remove any contaminated clothing and put it into a biohazard bag for later autoclaving.

9.4.4.3.4 Wash hands and exposed skin.

9.4.4.3.5 Put on protective clothing (lab coat, gloves, mask, eye protection, shoe covers) and assemble clean-up materials.

9.4.4.3.6 Wait 30 minutes before re-entering the contaminated area to allow dissipation of aerosols.

9.4.4.3.7 Cover the spill with paper towels and gently apply disinfectant, proceeding from the outer edge of the spill to its center.

9.4.4.3.8 Leave in place for at least 20 minutes, wipe up the spill and discard paper towels into a biohazard container. Use forceps to pick up any broken glass and place them into a sharps container.

9.4.4.3.9 Re-spray the contaminated area with disinfectant and re-wipe with clean paper towels. Place all paper towels into the biohazard container.

9.4.4.3.10 Remove gloves and place them in the biohazard container. Thoroughly wash hands and any exposed skin after the clean-up procedure.

9.4.4.3.11 Autoclave all clean-up materials in the biohazard waste container before disposal (see *Hazardous Waste Management Procedure*).

9.4.5 Medical Response to Biological Agent Exposure

9.4.5.1 General

9.4.5.1.1 In all cases of exposure to biological agents, the incident shall be reported to your immediate supervisor regardless of the severity. Consult the supervisor/manager when completing the ***C-1 Notice of Injury Form.*** **This form must be completed regardless of whether or not signs or symptoms are noted.**

9.4.5.1.2 Do not eat, drink, smoke, apply cosmetics, and/or handle contact lenses after exposure.

9.4.5.2 Biological Agents on Intact Skin

9.4.5.2.1 Remove contaminated clothing.

9.4.5.2.2 Vigorously wash contaminated skin for 1 minute with soap and water.

9.4.5.3 Biological agents on broken, cut or damaged skin, or puncture wound

9.4.5.3.1 Remove contaminated clothing.

9.4.5.3.2 Vigorously wash contaminated skin for 5 minutes with soap and water.

9.4.5.4 Biological agents in eyes

9.4.5.4.1 Immediately flush eyes for at least 15 minutes with water, preferably using an eyewash station.

9.4.5.4.2 If no eyewash is available, pour water on the eye(s) for 15 minutes, rinsing from the nose outward to avoid contamination of the unaffected eye.

9.4.5.4.3 Hold eyelids away from your eyeball and rotate your eyes so that all surfaces may be washed thoroughly.

9.4.5.5 Ingestion or Inhalation of Biological Agents

9.4.5.5.1 Do not induce vomiting unless advised to do so by a health care provider.

9.4.5.6 Injection of Biological Agents

9.4.5.6.1 If an accidental injection occurs, disinfect the surface area with germicidal soap and water and seek immediate medical attention.

10.0 LABORATORY WASTE DISPOSAL AND EQUIPMENT HANDLING

10.1 Policies and Procedures

10.1.1 General Procedures

10.1.1.1 EH&S works with waste generators in each department on what rules and regulations apply to managing and storing waste properly. The ultimate responsibility to ensure proper storage and management remains with the department that created the waste.

10.1.1.2 The following procedures apply to any chemical or biological substances generated that are classified as hazardous based on the criteria described below.

10.1.2 Hazardous Waste Characteristics

To responsibly manage hazardous waste and contaminated laboratory equipment, each employee must be familiar with the following:

10.1.2.1 Chemical Waste – Chemical waste is considered hazardous if:

10.1.2.1.1 It is on either of two lists of specific chemical substances developed by the U.S. Environmental Protection Agency (EPA). Most commonly used organic solvents (e.g., acetone, methanol, toluene, xylene, methylene chloride, etc.) are included. For further information, contact EH&S regarding hazardous waste listings, or visit: http://www.epa.gov/epawaste/hazard/wastetypes/

10.1.2.1.2 It is on a list of nonspecific sources that includes a broad range of spent halogenated and non-halogenated solvents.

10.1.2.1.3 It is on a list of specific sources that includes primarily industrial processes.

10.1.2.1.4 It exhibits any of the following characteristics as defined by the EPA (definitions are abbreviated):

Ignitable

- A liquid with a flash point less than 60°C;
- A solid or gas capable under normal conditions of causing fire through friction, absorption of moisture or spontaneous chemical changes, an ignitable compressed gas, or an oxidizer.

Corrosive

- Aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5;
- A liquid and corrodes steel at a rate greater than 0.250 inches per year at 55°C.

Reactive

- Normally unstable;
- Reacts violently with water;
- Forms potentially explosive mixtures with water;
- Generates toxic gases, vapors, or fumes when mixed with water;
- Cyanide or sulfide wastes that generate toxic gases, vapors, or fumes at pH conditions between 2 and 12.5;
- Capable of detonation or explosive decomposition if subjected to strong ignition or under standard temperature and pressure
- Classified as a DOT explosive.

10.1.2.1.5 It exhibits toxicity characteristics:

- An extract of the waste is found to contain certain metals, pesticides, or selected organics above specified levels.
- It is otherwise capable of causing environmental or health damage if improperly disposed of (this is a judgment you must make based upon your knowledge of the material from the SDS or the literature).

10.1.2.1.6 Discarded and Expired Chemical Products and Residues:

- Any commercial chemical product having a generic name listed in 40 CFR 261.33 (e) and (f)
- Any off-specification or expired chemical product, having a name listed in 40 CFR 261.33 (e) and (f)
- Any residue remaining in a container of inner liner removed from a container that held a commercial chemical product having a name listed in 40 CFR 261.33 (e) and (f), unless the container is determined as empty as outlined in Section 10.1.8.
- Any spilled material or residue contaminating soil, water, or other debris resulting from the clean-up of a spill having a name listed in 40 CFR 261.33 (e) and (f).

10.1.2.2 **Biohazard Waste** – The following biological waste is considered hazardous under OSHA regulations:

10.1.2.2.1 All sharps (e.g., glass implements, needles, syringes, blades) used around infectious materials.

10.1.2.2.2 Biologically-cultured stocks and plates, human blood, or tissues.

10.1.2.2.3 All other disposable (e.g., gloves, slides, towels) and nondisposable (e.g., bottles, filtration hoses) laboratory equipment used around infectious materials.

10.1.3 Properly Packaging Waste Material

10.1.3.1 Wear appropriate PPE while performing waste disposal and equipment cleaning procedures.

10.1.3.2 Place all hazardous waste in a labeled and sealable container that is material appropriate.

10.1.3.2.1 The container should not react with the waste being stored (e.g., no hydrofluoric acid in glass). Similar wastes may be mixed if they are compatible (e.g., non-halogenated solvents).

10.1.3.2.2 Wastes from incompatible chemical hazard classes must not be mixed (e.g., organic solvents with oxidizers) unless researched and cleared with EH&S. Certain metals also cause disposal problems when mixed with flammable liquids or other organic liquids.

10.1.3.2.3 Containers must be **kept closed** except during actual transfers. **Do not leave a hazardous waste container with a funnel in it.**

10.1.3.3 Place all biohazard waste and equipment into plastic biohazard containers lined with biohazard bags that are appropriate for sterilizing.

10.1.3.4 Handle all chemical and biohazard equipment collection tubs as contaminated equipment prior to their cleaning or disinfection.

10.1.4 Effective Labeling

10.1.4.1 Containers containing hazardous chemical waste shall be labeled with the words **HAZARDOUS WASTE** along with a **hazard warning label**, and the names of the principal chemical constituents and the approximate percentage.

10.1.4.1.1 Do not list reactants, only products. For example, if cyanide was used in a reaction but all of the material was oxidized to a cyanate before disposal; do not list cyanide on the label.

10.1.4.1.2 Use common names, not symbols, structural diagrams, or product trade names.

10.1.4.1.3 Labeling should be accurate and legible and should also include notification of the fact that neutralization of the waste has occurred.

10.1.4.1.4 Once secondary containers have been emptied at the bulk hazardous waste storage area, original labels are to be removed upon return to waste containment areas of the lab.

10.1.4.2 Affix labels to all containers of blood or OPIM, refrigerators and freezers containing blood or OPIM, and on other containers used to store or transport blood or OPIM. Red bags or containers may be substituted for labels on containers of infectious waste.

10.1.5 Chemical Waste Collection Protocol

10.1.5.1 Mercury, Thallium, Beryllium, and Osmium pose special disposal problems, especially when in combination with other wastes. If wastes containing these elements are being generated, please contact EH&S before beginning work.

10.1.5.2 Metallic mercury is recyclable waste. Please refer to the section 10.2.1.2 for more information.

10.1.5.3 Ethidium bromide usually does not need to be disposed of as hazardous waste. Electrophoresis gels containing trace amounts of ethidium bromide (less than 0.1%) may be placed in regular laboratory trash. Gels containing more than 0.1% (usually dark pink or red color) should be placed in the medical waste boxes.

10.1.5.4 Silica gel, molecular sieves, and desiccants are not considered hazardous waste unless they are grossly contaminated. Contaminated silica gel can be recycled.

10.1.6 Storage of Chemical Wastes

Containers of hazardous chemical waste may be stored in an area of a laboratory or facilities operation near the point of generation. This area must be controlled by EH&S and employees responsible for the generation and disposal of hazardous waste. State and federal regulations stipulate how chemical waste may be stored and require the following:

10.1.6.1 Any container used to store hazardous waste shall be labeled (see 10.1.4) with the words **HAZARDOUS WASTE** as well as the waste's **hazard warning label** (regardless of its location) as soon as accumulation begins.

10.1.6.2 Verify that the container is compatible with the chemical waste.

10.1.6.3 Use containers that are made of or lined with materials that will not react with, and are otherwise compatible with, the hazardous chemical waste to be stored. For example, do not place hydrofluoric acid in glass. Often the original container is suitable.

10.1.6.4 Waste containers shall be always closed, except when being filled. Do not leave funnels in the containers.

10.1.6.5 Verify that containers in the waste storage area do not leak. Secondary containment, such as a tray, larger container, or basin is required. If a leaking container is found, immediately clean up any spilled material according to established spill cleanup procedures (see section 9.4.2) and transfer the waste into a container that is in good condition.

10.1.6.6 No more than one quart of an acutely hazardous waste or 55 gallons of other hazardous wastes may be stored in a single laboratory or room. If this threshold quantity is reached, the worker must transfer the waste to a 90-day storage area. The container must bear a hazardous waste label with the accumulation date (either the date the threshold quantity was reached or the date it was placed in the 90-day storage area) marked on the container.

10.1.6.7 Like any chemical storage in the laboratory or work area, be sure to segregate the containers according to the type of waste.

10.1.6.8 Chemical waste stored near drains (floor, sink, cup sink) shall have secondary containment. If a sink or drain is not in use, contact maintenance to explore possibilities for plugging or sealing the drain. Secondary containers shall be compatible with the waste.

10.1.6.9 Do not store chemical wastes with flammable vapors near heat-producing appliances or equipment. Maintain a minimum distance of 18-inches.

10.1.7 Storage of Biohazard Wastes

10.1.7.1 Store solid and liquid biohazard wastes in collection buckets lined with a biohazard bag.

10.1.7.2 Store sharp objects exposed to biohazards in a designated collection container for broken glass. Cardboard collection boxes shall be lined with a plastic bag. Plastic collection containers for sharp objects shall be available within each biosafety cabinet.

10.1.8 Disposal of Empty Chemical Containers

10.1.8.1 Chemical containers that have been emptied (generally this means drained of their contents with no more than 3 percent by weight remaining of the total capacity of the container by normal methods including pouring, pumping, aspirating, etc.) are not regulated as hazardous waste; however, they should not necessarily be disposed of in the regular solid waste dumpsters.

10.1.8.1.1 Generally, the primary container (the container that actually held the chemical, as opposed to a container that the primary chemical was packed in) must be triple rinsed with water or other suitable solvent and air-dried before disposal, **only if the container held a discarded chemical product listed as an acute hazardous waste in 40 CFR 261.33 (e).**

10.1.8.1.2 For volatile organic solvents (e.g., acetone, ethanol, ethyl acetate, ethyl ether, hexane, methanol, methylene chloride, petroleum ether, toluene, xylene, etc.), the emptied container can be airdried in a ventilated area (e.g., a chemical fume hood) without triple rinsing.

10.1.8.2 Lab personnel, in consultation with EH&S, shall determine whether the washing must be collected and disposed of as hazardous waste. Generally, if the chemical is an acute hazardous waste or if the material is known to have high acute toxicity, the washings shall be collected.

10.1.8.3 Glass Containers

10.1.8.3.1 Glass containers shall be triple-rinsed with water or other suitable solvent and air-dried to ensure that they are free of liquid or other visible chemical residue.

10.1.8.3.2 **If the glass container has visible residue** and this residue is hazardous, the container should be disposed of as biohazard waste.

10.1.8.3.3 **Broken glass containers** that are free of chemical residue should be placed in broken glass receptacles or placed in a puncture-resistant container, such as a rigid plastic container or corrugated cardboard box. The plastic container or box should be sealed and placed in regular laboratory trash.

10.1.8.4 Metal Containers

10.1.8.4.1 Metal containers shall be triple-rinsed with water or other suitable solvent and air-dried. If the container is free of hazardous chemical residues, it may be placed in regular laboratory trash. Otherwise, it should be disposed of as biohazard waste.

10.1.8.5 Secondary Containers

Containers that were used as over-pack for the primary chemical container may be placed in regular trash or recyclable trash. Any packing materials (e.g., vermiculite, perlite, clay, Styrofoam, etc.) may be placed in the regular trash unless it was contaminated with the chemical as a result of container breakage or leak. Packing materials contaminated with hazardous materials should be disposed of as hazardous waste.

10.1.9 Waste Minimization

10.1.9.1 All laboratory workers are asked to consider pollution prevention opportunities for all their operations. This includes reducing or eliminating chemical use and chemical waste production, substituting less hazardous materials, conservation of water or electricity, and any other means of reducing environmental impact.

10.1.9.2 Cleaning

10.1.9.2.1 Avoid using fresh solvents for cleaning glassware. Filter and reuse solvents for this purpose or use Alconox and elbow grease.

10.1.9.2.2 If solvents are needed for cleaning, minimize the amount by not simply using the force of flow from a squeeze bottle.

10.1.9.2.3 Do not use chromium-based glass cleaners (e.g., Chromerge). No-Chromix, Micro 90, enzymatic cleaners, detergents, etc. can be just as effective.

10.1.9.2.4 For sterilizing equipment, use quaternary amine detergents instead of isopropyl alcohol.

10.1.9.2.5 Use ethanol instead of methanol in dehydrating and rinsing processes.

10.1.9.2.6 Use ultrasonicators instead of solvents for cleaning.

10.1.9.2.7 Purchase better brushes to reduce the temptation of opting for **a solvent for cleaning.**

10.1.9.2.8 Keep extra glassware on hand and/or use a drying oven to reduce the need for rinsing with a solvent to hasten the drying of glassware.

10.1.9.3 Equipment Modifications

10.1.9.3.1 Upgrade instrumentation or move to automation to conserve energy and chemical resources.

10.1.9.3.2 Use capillary columns instead of micropore or large-diameter columns in gas chromatographs or high-performance liquid chromatography (HPLC) equipment.

10.1.9.3.3 Use diaphragm pumps, instead of that requiring water circulation, to conserve water.

10.1.9.3.4 Replace traditional thermal distillation apparatus with newer “push”, dry solvent purification systems for purifying or drying solvents. Eliminates the need for a fume hood and conserves energy, water, and solvents. Minimizes waste production and significantly reduces the fire hazard.

10.1.9.4 Neutralization/Deactivation/Recovery

10.1.9.4.1 Neutralization of acids and bases can only be done when the waste is regulated solely because it exhibits the characteristic of corrosivity (e.g., pH of less than or equal to 2.0 or greater than or equal to 12.5). The neutralized waste must have a pH between 6 and 9 and cannot contain any other hazardous waste such as solvents before being disposed of in the sanitary sewer.

10.1.9.4.2 Neutralizing large volumes (greater than 1 gallon) of concentrated acid or base is discouraged, since it generates significant heat and fumes which pose serious safety risks.

10.1.9.4.3 Add a treatment or deactivation step to experimental procedures to reduce or eliminate hazardous waste production.

10.1.9.4.4 Clean up and neutralize spills such that all or most of the waste can be disposed of via the drain or regular trash (see section 9.4.2).

10.1.9.4.5 Use charcoal filtration, such as funnel kits or Green Bags, to remove ethidium bromide from solutions. This minimizes the amount of waste and eliminates the disposal of bleach solutions down the drain or the use of other potentially hazardous chemicals for deactivating the ethidium bromide.

10.1.9.5 Reduction/Substitution

10.1.9.5.1 Whenever possible, replace benzene or carbon tetrachloride as reagents or solvents.

10.1.9.5.2 Simplify procedures to potentially eliminate a step that utilizes chemicals.

10.1.9.5.3 Use chilled water loops instead of continuously running water for cooling.

10.1.9.6 Administrative

10.1.9.6.1 Review chemical inventory annually; review biological inventory monthly. Such review can help avoid the purchase of materials already on hand (but forgotten) and can help ensure prompt disposal of unneeded materials. Review can also avoid inventory of expired biological materials.

10.1.9.6.2 Purchase smaller quantities to reduce leftover, unusable chemicals. The American Chemical Society (ACS) estimates that 40% of waste generated in research labs consists of unused chemicals.

10.1.9.6.3 Purchase or prepare appropriate volumes of media, reagents, and culture stocks to avoid the expiration of unused materials.

10.1.9.6.4 Review laboratory procedures annually. Look for ways to reduce or eliminate the use of hazardous chemicals.

10.1.9.6.5 Centralize chemical and biological purchasing in the lab. Assigning one person to purchase can help reduce duplicate orders and excess inventory.

10.1.9.6.6 Share unused, unopened containers or unused portions of materials with other labs.

10.1.9.7 Other

10.1.9.7.1 Seal containers of volatile materials well. Verify that pumps fit the container opening to prevent loss of material from evaporation and prevent spills.

10.1.9.7.2 Turn off equipment that is not in use (e.g., turn off the rotary arm of a rotovap when not in use).

10.1.9.7.3 Be prepared for spills (see section 9.4.2). Cleaning up spills can generate a lot of waste. Minimize the likelihood of spills by using secondary containers. Have the right kind of spill control materials to minimize the amount of debris. Consider whether gloves or other protective equipment are truly contaminated enough to warrant disposal as hazardous waste.

10.2 Specific Wastes

10.2.1 Mercury Disposal

10.2.1.1 Disposal procedures for mercury-containing materials to be managed as universal waste (e.g., intact thermometers, switches, thermostats, or electronic circuitry).

10.2.1.1.1 Place items in a sturdy leak-proof container and in a manner to minimize damage or potential for a spill or leak. Keep the container closed. Do not mix different types of items in the same outer container.

10.2.1.1.2 Label the outer container “Universal Waste – Mercury-Containing Equipment”, including the date the first item was placed in the container. Waste mercury cannot be stored on-site for longer than one year and must be sent to an authorized recycler.

10.2.1.1.3 Do not disassemble any mercury-containing item.

10.2.1.1.4 Contact EH&S for waste pick up no later than six months after the device was taken out of service or discarded. Keep the material in the laboratory until pickup is scheduled.

10.2.1.2 Disposal procedures for mercury-containing chemical formulations and residues from a spill or release of elemental mercury, organo-mercury complexes, and mercury salts are to be managed as hazardous waste.

10.2.1.2.1 Wear PPE, including gloves and eye protection.

10.2.1.2.2 Collect mercury in a sealable container. Place broken thermometers or similar materials in a sealable plastic bag or plastic or glass jar. Keep the amount of debris to a minimum. Be sure that materials may be easily removed for consolidation.

10.2.1.2.3 Label the container "**MERCURY SPILL DEBRIS**".

10.2.1.2.4 Pick up any broken glass or debris and place it in a puncture-resistant container. Use mechanical means to pick up fragments (e.g., tongs, forceps, broom and dustpan, etc.), never use your bare or gloved hands.

10.2.1.2.5 Clean up any remaining mercury. Begin by picking up the droplets. Use an index card or scraper to consolidate the droplets, and pick up the pool using a pipette, syringe, or vacuum pump. Do not use the house vacuum system without a charcoal filter trap. Small droplets can be picked up with adhesive tape or wet paper towels.

10.2.1.2.6 Commercial products such as sponges and powders may also be used; however, sponges are typically not very effective. Also, sulfur is not a very effective means of cleaning up mercury.

10.2.1.2.7 Place the mercury in a glass or plastic jar or a sturdy plastic bag. Only add visibly contaminated debris. Seal the bag and affix a label identifying the material as “mercury spill debris”.

10.2.1.2.8 Follow the mercury disposal procedures outlined above.

10.2.1.2.9 Minimize the amount of debris involved. If gloves or other debris do not visibly contain mercury, they do not need to be included with the other mercury waste.

10.2.1.3 Precautions for Minimizing Mercury Incidents

10.2.1.3.1 Do not use mercury thermometers as stirring rods.

10.2.1.2.2 Replace mercury thermometers with non-mercury alternatives (e.g., non-mercury or digital thermometers).

10.2.1.2.3 Use secondary containment or a tray under mercury-containing equipment.

10.2.1.2.4 Use a protective metal jacket on thermometers.

10.2.2 Compressed Gases

Return unused or empty or expired compressed gases to the vendor.

10.2.3 Silica Gel Recycling

10.2.3.1 Used silica gel, molecular sieves and desiccants that are contaminated with solvents or other hazardous chemicals must be disposed of as hazardous waste. Place the material in a bag or container and dispose of it properly.

10.2.3.2 This policy applies to all used adsorbents, grossly contaminated or otherwise. Used silica gel that appears free-flowing and dry still may have chemical contamination significant enough to classify it as hazardous waste according to the EPA. Only unused silica gel, molecular sieves or desiccants that have not been in contact with hazardous chemicals may be disposed of in the regular trash within a sealed container.

10.2.3.3 If large quantities of this material are generated, use large containers and adhere to the following procedures:

- Label the drum with the yellow hazardous waste sticker as soon as it is in use.
- Use only the liner provided with the drum if any. Red-colored or Biohazard bags are NOT acceptable.
- Do not fill the drum to more than 3/4 of the drum's capacity.

10.2.4 Unknown Chemicals

10.2.4.1 Chemicals that cannot be identified should be considered unknown hazardous waste. Federal, state, and local regulations specifically prohibit the transportation, storage, or disposal of wastes of unknown identity. Hazardous waste disposal companies will not accept unknowns without proper analysis; all chemicals must be characterized sufficiently for safe transportation off-site. Analysis of laboratory unknowns is expensive, the cost of characterization will be charged back to the department that generated the waste.

10.2.4.2 If unknown hazardous waste is found, adhere to the following guidelines:

10.2.4.2.1 Contact the EH&S department to inform them of the material in question.

10.2.4.2.2 Attempt to determine how the waste was generated. This might mean getting in touch with people who are no longer with the laboratory. The more is known about the waste, the better it can be characterized for disposal.

10.2.4.2.3 Keep the material in the laboratory or work area. EH&S or the waste contractor will remove the material from the laboratory.

10.2.4.3 **DO NOT**:

10.2.4.3.1 Pour unknown chemicals down the sink.

10.2.4.3.2 Mix unknown chemicals with any other chemicals for consolidation.

10.2.4.3.3 Bring unknown chemicals to a regular waste pickup unless instructed by EH&S to do so.

10.2.4.3.4 Abandon unknown chemicals in the work area.

10.2.4.4 **Avoid generating unknown hazardous waste by doing the following:**

10.2.4.4.1 Properly label all chemicals in the laboratory.

10.2.4.4.2 Promptly dispose of spent materials and chemicals with no foreseeable use.

10.2.4.4.3 When relocating from one work area to another, do not leave any chemicals behind unless specific arrangements have been made with the new occupant.

10.2.5 Universal Wastes

10.2.5.1 Types of Universal Wastes

Hazardous wastes that may be managed and disposed of as a Universal Waste include:

- **Lamps** that are hazardous wastes because they contain leachable quantities of hazardous elements (e.g., fluorescent lamps, metal halide lamps, mercury vapor, lamps, and sodium lamps).
- **Batteries** (mostly the rechargeable types) that are hazardous wastes because they contain leachable quantities of hazardous elements (e.g., lead-acid batteries, lithium and lithium-ion batteries, NiCd batteries).
- **Mercury-containing equipment** (i.e., a device or part of a device (including thermostats but excluding batteries and lamps) that contains elemental mercury integral to its function).
- **Pesticides** (recalled or unused).

10.2.5.1 Storage and Handling

In general, universal wastes must be managed to prevent the release of any universal waste or waste component to the environment. If containers are required (i.e., for leaking batteries, uncontained mercury, pesticides, and/or breakable lamps), each container must be:

- Kept closed except when adding or removing waste,
- Structurally sound and reasonably able to prevent release of its contents,
- Compatible with the external and internal components of the wastes, and
- Free of evidence of leakage, spillage, or damage that could cause leakage under reasonably foreseeable conditions.

Universal wastes and/or containers used for storing universal wastes must, at a minimum, include the following label information:

  - Universal Waste – [insert waste type] (e.g., lamps, batteries, pesticides, mercury-containing equipment)
  - Container Start Date: [insert date]

11.0 REFERENCES

11.1 Princeton University, Department of Environmental Health and Safety, *Laboratory Safety Manual*, https://ehs.princeton.edu/laboratory-research/laboratory-safety/laboratory-safety-manual

11.2 Centers for Disease Control and Prevention (CDC), 1600 Clifton Rd. Atlanta, GA 30333, National Institute of Occupational Safety and Health (NIOSH) http://www.cdc.gov/niosh/

11.3 Occupational Safety and Health Administration (OSHA) https://www.osha.gov/

11.4 OSHA Subpart Z, Toxic and Hazardous Substances, https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1000TABLEZ1

11.5 Preventing Allergic Reactions to Latex in the Workplace [publication number DHHS (NIOSH) 97-135, https://www.cdc.gov/niosh/docs/97-135/default.html

11.6 University of Minnesota, Department of Environmental Health and Safety, https://bohd.umn.edu/biosafety-occupational-health/biosafety

11.7 American Type Culture Collection (ATCC), 10801 University Blvd., Manassas, VA 20110, (2012) http://www.atcc.org/

11.8 CDC Publication *Biosafety in Microbiological and Biomedical Laboratories (BMBL)*, 5th Edition, U.S. Department of Health & Human Services (HHS Publication No. 21-1112, Revised Dec. 2009, https://www.cdc.gov/labs/pdf/CDC-BiosafetyMicrobiologicalBiomedicalLaboratories-2009-P.PDF

11.9 National Cancer Institute-Frederick, Institutional Biosafety Committee, *Laboratory Biological Safety Manual and SOP Guidance Document*, U.S. Army at Ft. Detrick, Frederick, MD, http://ncifrederick.cancer.gov/Ehs/Ibc/Policies.aspx

11.10 National Science Foundation (NSF) International Standard/American National Standard for Biosafety Cabinetry – Class II (laminar flow) biosafety cabinetry, prepared by The NSF Joint Committee on Biosafety Cabinetry, http://www.nsf.org/services/by-industry/pharma-biotech/biosafety-cabinetry/nsf-ansi-49-biosafety-cabinetry-certification

11.11 The University of Alabama at Birmingham (UAB), Occupational Health and Safety Department Biosafety Manual, Revised 1/22/2009, http://www.uab.edu/ohs/images/docs/bio/biosafetymanual.pdf

11.12 Center for Chemical Process Safety (CCPS), The Chemical Reactivity Worksheet, January 7, 2008, Revised 7/1/2019, https://www.aiche.org/ccps/resources/chemical-reactivity-worksheet

11.13 Princeton University, Department of Environmental Health and Safety, *Biological Safety Manual*, Revised 5/31/2012, https://ehs.princeton.edu/laboratory-research/biological-safety/biosafety-manual

11.14 National Sanitation Foundation (NSF)/ American National Standards Institute (ANSI) Standard No. 49 –2008, “Biosafety Cabinetry: Design, Construction, Performance, and Field Certification”, http://www.nsf.org/services/by-industry/pharma-biotech/biosafety-cabinetry/nsf-ansi-49-biosafetycabinetry-certification

APPENDIX A

TRAINING FORM – LABORATORY SAFETY MANUAL

TRAINING FORM – LABORATORY SAFETY MANUAL

PRINT NAME:	**DATE:**	**INITAIL** here if you have read and understand the Laboratory Safety Plan

Supervisor’s Signature: ____ Date: _________________________

APPENDIX B

INDIVIDUAL LABORATORY SAFETY PLAN

INDIVIDUAL LABORATORY SAFETY PLAN

This Laboratory Safety Plan (LSP) is used to support the CSN Laboratory Safety Manual and provide laboratory specific safety roles and responsibilities, safety information, safe laboratory practices, and emergency procedures unique to an individual lab, course, or research project. The content of this LSP must be approved by the Laboratory Supervisor, Instructor, or other designee and should be reviewed and updated annually.

Date: ______________________ **Campus:** ___________________ **Building:** _________________ **Room#:** _________________

Department: ______________________________ **Course:** ____________________ **Instructor:** _________________________

Laboratory Supervisor: ____ **Phone Number:** _____________________________

Safety Coordinator: ____ **Phone Number:** _____________________________

Emergency Contact #1: ____ **Phone Number:** _____________________________

Emergency Contact #2: ____ **Phone Number:** _____________________________

Emergency Contact #3: ____ **Phone Number:** _____________________________

A. ROLES AND RESPONSIBILITIES

Describe all laboratory safety roles and responsibilities of laboratory personnel associated with work being performed. Each role description should include the associated chemical/laboratory safety responsibilities (see Section 2.0 Roles and Responsibilities in the CSN Laboratory Safety Manual for reference).

Laboratory Supervisor or Instructor:
Safety Coordinator:
Laboratory Personnel, Researchers, Students:

B. EMERGENCY AND SPILL PROCEDURES

Provide the location of the following emergency supplies and equipment (see Section 3.0 Emergency Procedures Section in the CSN Laboratory Safety Manual for reference).

Location of First Aid Kit(s):
Eyewash/Shower Location(s):
Fire Extinguisher(s):

Describe lab-specific emergency procedures involving injuries, fires and explosions, and spills and exposures (see Section 9.0 Spills and Exposures Section in the CSN Laboratory Safety Manual for reference).

Emergency Alarm:
Fire and or Explosion:
Chemical Spill or Exposure:
Injuries:

C. HAZARD IDENTIFICATION

Identify the chemicals and/or biological materials used in the laboratory, course, or research project and their associated hazards. If needed, identify the secondary container labeling format (see the associated Safety Data Sheet and Section 4.0 Chemical and Biological Hazard Identification in the CSN Laboratory Safety Manual for reference).

No.	**Chemical or Product Name**	**Associated Hazards** *(Check all that apply)*	
		☐ Non-Hazardous ☐ Flammable ☐ Oxidizer ☐ Compressed Gas ☐ Corrosive	☐ Toxic ☐ Health Hazard ☐ Category A Infectious Substance ☐ Category B Biological Substance ☐ Other:
		☐ Non-Hazardous ☐ Flammable ☐ Oxidizer ☐ Compressed Gas ☐ Corrosive	☐ Toxic ☐ Health Hazard ☐ Category A Infectious Substance ☐ Category B Biological Substance ☐ Other:
		☐ Non-Hazardous ☐ Flammable ☐ Oxidizer ☐ Compressed Gas ☐ Corrosive	☐ Toxic ☐ Health Hazard ☐ Category A Infectious Substance ☐ Category B Biological Substance ☐ Other:
		☐ Non-Hazardous ☐ Flammable ☐ Oxidizer ☐ Compressed Gas ☐ Corrosive	☐ Toxic ☐ Health Hazard ☐ Category A Infectious Substance ☐ Category B Biological Substance ☐ Other:
		☐ Non-Hazardous ☐ Flammable ☐ Oxidizer ☐ Compressed Gas ☐ Corrosive	☐ Toxic ☐ Health Hazard ☐ Category A Infectious Substance ☐ Category B Biological Substance ☐ Other:
		☐ Non-Hazardous ☐ Flammable ☐ Oxidizer ☐ Compressed Gas ☐ Corrosive	☐ Toxic ☐ Health Hazard ☐ Category A Infectious Substance ☐ Category B Biological Substance ☐ Other:
		☐ Non-Hazardous ☐ Flammable ☐ Oxidizer ☐ Compressed Gas ☐ Corrosive	☐ Toxic ☐ Health Hazard ☐ Category A Infectious Substance ☐ Category B Biological Substance ☐ Other:

Secondary Container Labeling Format:

All labels must identity the name of the chemical and the appropriate hazard warnings (no abbreviations allowed).

☐ **GHS** ☐ **NFPA** ☐ **HMIS** ☐ **CHEMICAL NAME AND HAZARD WARNING**

Use additional sheets as necessary.

D. HAZARD IDENTIFICATION (Cont.)

Identify any additional hazards that may be present in the laboratory, course, or research project such as respiratory hazards, fall hazards, heat producing equipment, electrical hazards, confined spaces, or other unique hazards.

No.	Brief Description	**Hazards** *(Check all that apply)*
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:
		☐ Respiratory Hazards ☐ Skin Hazards ☐ Eye/Face Hazards ☐ Physical Hazards ☐ Electrical Hazards ☐ Fall Hazards ☐ Heat or Radiation Hazards ☐ Other:

Use additional sheets as necessary.

Page _____of _____

E. ENGINEERING CONTROLS

Identify the appropriate engineering controls (if any) used to protect workers from the hazards identified in Section C. Examples of engineering controls include, but are not limited to, general room ventilation, chemical fume hoods, glove boxes, biological safety cabinets, downdraft tables, “elephant trunks” (or “snorkels”), gas cabinets, and ventilated balance enclosures (see Section 7.0 Engineering Controls in the CSN Laboratory Safety Manual for reference).

Hazard No.	**Hazard Description**	**Required Engineering Controls** *(Check all that apply)*	
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Machine Guarding ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:
		☐ Local Ventilation ☐ Fume Hood ☐ Biological safety Cabinet ☐ Glove Box	☐ Downdraft Table ☐ Curtain or Partition ☐ Gas Cabinet ☐ Other:

Use additional sheets as necessary.

D. ADMINISTRATIVE CONTROLS

Provide a brief procedure for the following administrative controls, where applicable. Include what is and what is not acceptable, and any restrictions. Include NA in the box if not applicable. (see Section 8.0 Safe Work Practices and Procedures in the CSN Laboratory Safety Manual for reference).

Location of Safety Data Sheets: *(Describe or reference where to access Safety Data Sheets for materials used in the laboratory)*
Working Alone in the Laboratory: *(Describe or reference any work alone procedures and specify what is and what is not acceptable, restrictions, notifications, etc.)*
Worker Rotation: *(Describe or reference any worker rotation procedures needed to protect workers from hazards)*
Laboratory Security: *(Describe how access to the laboratory is controlled and/or personnel unauthorized in the laboratory, if applicable)*
Lab Specific Training Requirements: *(Describe or reference any specialized training that is required to operate equipment, perform procedures, or repair equipment, etc.)*
Safe Use of Laboratory Equipment: *(Describe or reference any special precautions or safety information when operating any lab-specific equipment)*

E. ADMINISTRATIVE CONTROLS (Cont.)

Materials Requiring Prior Approval: *(Describe or reference any lab-specific materials, equipment, or services that require prior approval before purchase)*
Restricted Activities, Areas, or Materials: *(Describe or reference any lab-specific restrictions, regulated areas, and/or material quantity limits in the laboratory)*
Shared Equipment: *(Describe or reference any lab-specific equipment that is shared by workers, as applicable)*
Unattended Operations: *(Describe or reference any procedures when equipment or processes can be left unattended specify time limits, restrictions, notifications, etc.)*
Data Security: *(Describe or reference any lab-specific procedures and protocols to ensure reliable data storage and theft protection)*
Food and Beverages: *(Describe or reference any lab-specific procedures where food and beverages can or cannot be consumed, as well as where they can or cannot be stored, if applicable)*
Other Procedures: *(Describe or reference any other lab-specific procedures needed or applicable)*

F. PERSONAL PROTECTIVE EQUIPMENT (PPE)

Describe the PPE requirements for the hazards identified in Section C Hazard Identification (see Section 7.6 Personal Protective Equipment in the CSN Laboratory Safety Manual or the associated Safety Data Sheet for reference).

Hazard No.	Hazard Description	PPE Required *(Check all that apply)*		
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:
		☐ Safety Glasses ☐ Goggles ☐ Face Shield ☐ Hand Protection	☐ Respirator ☐ Hearing Protection ☐ Welding Shield ☐ Protective Clothing	☐ Lab Coat ☐ Safety Shoes ☐ Fall Protection ☐ Other:

Use additional sheets as necessary.

G. EQUIPMENT AND INSTRUMENTATION

Provide a brief procedure for operating the following equipment and instrumentation, where applicable. Include what is and what is not acceptable, and any restrictions. Include NA in the box if not applicable. (see Section 8.0 Safe Work Practices and Procedures in the CSN Laboratory Safety Manual for reference).

Shutdown Procedures: *(Describe or reference any lab-specific equipment shutdown procedures for planned utility outages)*
Lockout-Tagout (LOTO): *(Describe any lab-specific equipment that must be de-energized as well as locked out and/or tagged out for servicing and/or repair)*
Specialized Equipment: *(Describe or reference any procedures needed to optimize the function of specialized equipment and define any important safety precautions)*
Equipment and Tools: *(Describe or reference lab-specific equipment and tool safety procedures. Examples include lab equipment, shop tools, chemical safe refrigerators, or freezers)*
Machine Guarding: *(Describe or reference lab-specific where guarding on machines or tools is required)*
Other Procedures: *(Describe or reference any other lab-specific procedures needed or applicable)*

H. HAZARDOUS WASTE DISPOSAL

Summarize lab-specific hazardous waste requirements including details such as waste container locations, frequency of disposal, labeling, etc. Include NA in the box if not applicable. (see Section 10.0 Laboratory Waste Disposal and Equipment Handling in the CSN Laboratory Safety Manual for reference).

Chemical Wastes: *(Describe or reference lab-specific procedures for the management and disposal of hazardous and non-hazardous wastes)*
Biological Wastes: *(Describe or reference lab-specific procedures for the management and disposal of biological wastes)*
Solid Wastes: *(Describe or reference lab-specific procedures for the management and disposal of solid wastes, such as broken glass, paper, plastics, etc.)*
Universal Wastes: *(Describe or reference lab-specific procedures for the management and disposal of universal wastes, such as batteries, lamps, mercury-containing equipment, and/or pesticides etc.)*

I. Annual Review and Updates

I affirm that this Laboratory Safety Plan is accurate and that it provides information for the health and safety of personnel in this area.

Instructor/Laboratory Supervisor:

____________________	____________________	____________________
Printed Name	Signature	Date

APPENDIX C

LABORATORY INSPECTION PROCEDURE

CSN Procedure	Facilities Management
Category: Environmental Health and Safety	**Effective Date: 1/24/2022**

Laboratory Inspection Procedure

I. PURPOSE

The purpose of this procedure is to assure a healthy and safe working environment at the College of Southern Nevada (CSN) laboratories. Its purpose is to improve regulatory compliance, increase campus awareness, and correct environmental, health and safety issues found in CSN laboratories.

II. SCOPE

This procedure applies to all CSN faculty, staff, students, volunteers, space licensees, and contractors that work in CSN teaching and research laboratories.

III. OVERVIEW

This procedure establishes a program for correcting deficiencies and issues of non-compliance. All CSN employees directly involved in or in support of instructional and research laboratory activities are responsible for the implementation and adherence to this procedure.

IV. DEFINITIONS

Laboratory: An academic facility or location where the laboratory use of hazardous chemicals, materials or equipment occurs; and where the physical, biological, or chemical use processes or the use or storage of the materials or equipment may present a potential hazard. It includes but is not limited to: Research laboratories, teaching laboratories, waste accumulation areas/locations including solid waste, hazardous waste, universal waste, cold rooms, laboratory storage rooms, and analytical laboratories.

Laboratory Supervisor: Any faculty or employee, who is responsible for the operations of a CSN laboratory. It includes employees who may have authority to hire personnel, evaluate performance, direct work assignments, apply progressive discipline, and direct resources to correct identified safety issues.

Laboratory Worker: For purposes of this procedure, any individual who actively performs work functions with hazardous materials or equipment in a laboratory. A worker may be a faculty, staff, student, visitor, volunteer, or anyone else assisting or performing an experiment, research, or any process in a laboratory.

Imminent Danger: Any conditions or practices in any place of employment which are such that a danger exists which could reasonably be expected to cause death or serious physical harm immediately or before the imminence of such danger can be eliminated.

Major Finding: A finding of non-compliance that requires immediate corrective action due the nature of the finding and the immediate risk to human health and the environment.

Minor Finding: A finding of non-compliance that does not present an immediate risk to human health or the environment. An example might include the need to update a laboratory standard operating procedure. *(Note: repeated minor laboratory findings can become systemic issues that could become major laboratory findings).*

Principal Investigator: Individual who has primary responsibility for the design, execution and management of a research project.

V. PROCEDURE

The following procedures will be followed to ensure proper monitoring, assessment, and assurance of laboratory safety compliance.

A. Responsibilities

1. Environmental Health & Safety

   - Ensure administration of this procedure; conduct periodic reviews and updates.
   - Ensure compliance with environmental, health and safety regulations through implementation of this procedure.
   - Conduct annual laboratory safety inspections in accordance with this procedure.
   - Review and analysis of incident/accident/injury reports.
   - Monitor and report findings, deficiencies, and trends to affected departments.
   - Maintain inspection records for up to three years.

2. Managers, Supervisors, and Faculty of Department with Applicable Laboratories

   - Ensure application of proper safety procedures and required training in accordance with the procedures identified herein.
   - Support practices that provide self-inspection of laboratories on a periodic basis during those months that classes are in session and/or when research is in process.
   - Ensure laboratory users maintain a safe and healthy work environment. They are in the best position to know the hazards inherent in their work and implement appropriate controls.

B. Procedures

1. Laboratory Inspections

   - Laboratory Supervisors must monitor their laboratory workers for adherence to safe work practices on an ongoing basis in the laboratory.

   - Generally, laboratory inspections cover the following areas:

     - General laboratory safety
     - Chemical storage and handling
     - Fire safety
     - Personal protective equipment
     - Emergency equipment
     - Biological and chemical waste disposal
     - Compressed gases
     - Biological safety
     - Machinery and equipment safety

   - All laboratories shall be inspected during regular use, with a formal written and documented inspection on the following schedule:

     - Research Laboratories: Laboratory Supervisors, Principal Investigators or designee shall conduct an annual self-inspection of their laboratory operations. These self-inspections should take place sometime during the months of January and February of each year.

     - Teaching Laboratories: Laboratory Supervisors, or designee shall conduct a self-inspection at least once with the opening period of the fall, spring, and summer semesters, where applicable.

   - If new research is conducted or the scope of the laboratory work changes significantly, an additional self-inspection must be conducted prior to start of work. EHS can assist with any additional inspections, if required.

   - Laboratory Supervisors must take appropriate and effective corrective actions in a timely manner. Major findings are required to be corrected within 48-hours; minor findings must be corrected within 30-days. If a condition is found to pose an imminent danger, the operation must be suspended immediately and EHS must be notified to oversee the corrective action.

- At a minimum, EHS will conduct an annual inspection of each laboratory typically during the months of June, July, and August of each year. Additional inspections may be required as, needed. EHS will provide the affected department with advance notice of the annual inspection.

- It is recommended, but not required, that staff responsible for the laboratory accompany the annual EHS inspection. If the designated laboratory staff is not available, the individual accompanying EHS on the inspection should be familiar with all the activities occurring in the laboratories.

- EHS can assist with correcting findings and verify that corrective actions have been completed.

2. Inspection Documentation

   - All departmental self-inspections and EHS annual inspections will be conducted using the *Laboratory Inspection Checklist (Biological & Physical Sciences / Health Sciences) [Appendix A]* or the *Laboratory Safety Inspection Checklist (Applied Technologies / Art & Design) [Appendix B].*

   - Completed inspection forms and the actions recommended and/or taken to correct identified unsafe conditions shall be maintained on file for a minimum of three (3) years.

   - Completed copies of inspection forms are to be forwarded to the department chairperson, EHS, and respective Dean to monitor report findings, deficiencies, and corrective actions.

VI. APPENDICIES:

Appendix A – Laboratory Safety Inspection Checklist
(Biological & Physical Sciences / Health Sciences)

Appendix B – Laboratory Safety Inspection Checklist
(Applied Technologies / Art & Design)

Appendix A - Laboratory Safety Inspection Checklist (Biological & Physical Sciences / Health Sciences)

LABORATORY SAFETY INSPECTION CHECKLIST

Date:	Inspected By:	
Department:	Supervisor:	
Campus:	Building:	Room:

For each item check Yes, No, or N/A. Be sure to retain all documentation regarding inspections, including findings and corrective actions taken for any “No” responses, for a minimum of 3 years. Contact EH&S for questions or additional information.

GENERAL SAFETY	**YES**	**NO**	**N/A**
1. Laboratory Safety Plan is present, updated (annual review required), and includes emergency information?			
2. CSN Chemical Hygiene Plan available in the lab?			
3. Emergency contact numbers posted in the laboratory?			
4. Lab is maintained secure; door is locked when no one is in lab?			
5. Lab floors, aisles, exits and adjacent hallways unobstructed?			
6. Broken glassware is not in use; glassware is properly discarded in designated containers?			
7. Lab is adequately organized and cleaned to provide sufficient workspace for operations without spills, accidents, or other preventable incidents?			
8. Floors dry and free of slip hazards?			
9. No evidence of food or drink storage or consumption?			
10. Appropriate warning signs posted on outside of door?			
11. *No Food or Drink’ or ‘Not for Human Consumption’* warning signs posted on outside of refrigerators, ice machines, and microwaves?			
12. Hand washing sink is available with towels and soap present?			
13. All equipment guards are in place?			
14. Laboratory electrical panels accessible and unobstructed?			
15. Extension cords only used temporarily, and power strips not daisy-chained together?			
16. Equipment with motors, heaters, and other high amperage needs plugged directly into a wall receptacle?			
17. Electrical or extension cords free of exposed wiring?			
CHEMICAL STORAGE & HANDLING	**YES**	**NO**	**N/A**
18. Lab personnel know how to access Chemical Inventory and Safety Data Sheets?			
19. Appropriate labels are found on all chemical containers and secondary containers (No abbreviations/formulas)?			
20. Chemical containers are kept closed when not in use?			
21. No corroded/compromised chemical containers?			
22. Benchtops, fume hoods, biosafety cabinets organized and clean?			
23. Chemical storage cabinets properly labeled and kept closed when not in use?			
24. Storage cabinets clean and free from spilled material?			

LABORATORY SAFETY INSPECTION CHECKLIST

25. Incompatible materials stored separately?			
26. Peroxide forming chemicals labeled with expiration date and not expired?			
27. Chemical containers stored away from sinks or floor drains?			
28. No corrosive liquids storage above eye level?			
29. Hazardous materials storage is available and adequate, if required?			
30. Food and drinks stored and consumed away from toxic materials?			
31. Lab free of chemicals that are old or no longer needed?			
32. Fume hoods kept uncluttered and rear ventilation is not blocked or covered?			
33. Processes that emit vapors, gases, or fumes adequately captured by local ventilation (hoods, snorkel)?			
FIRE SAFETY	**YES**	**NO**	**N/A**
34. Fire extinguishers are charged and unobstructed?			
35. Flammable liquids are stored in appropriate containers?			
36. No more than 10 gallons of flammable liquids stored outside of cabinets?			
37. Flammable materials requiring refrigeration are placed in explosion-proof or flammables refrigerators only?			
38. No excess combustible material near ignition sources?			
39. Suspended ceilings have all their ceiling tiles in place?			
40. Laboratory doors kept closed when unoccupied?			
41. All objects stored at least 18 inches away from fire sprinklers?			
42. Evacuation maps are posted where required?			
PERSONAL PROTECTIVE EQUIPMENT	**YES**	**NO**	**N/A**
43. Appropriate attire (no shorts or sandals) worn by everyone in lab?			
44. Adequate gloves available and in use?			
45. Adequate eye protection available and in use?			
46. Lab coats available for use?			
47. Areas requiring the use of PPE have adequate signage posted and enforced?			
EMERGENCY EQUIPMENT	**YES**	**NO**	**N/A**
48. First aid kit is present and stocked?			
49. Shower/eyewash free of obstructions and in good working order?			
50. Shower/eyewash available within 10 seconds travel (approx. 50ft.)?			
51. At least one fire blanket is available and accessible?			
52. Chemical/biological spill kits available?			
BIOLOGICAL AND CHEMICAL WASTES	**YES**	**NO**	**N/A**
53. Waste containers are clean, structurally sounds, and closed when not in use?			
54. Waste containers are labeled “Hazardous Waste” with the proper hazard warning label?			
55. Waste containers are in good condition (not leaking, rusted, bulging or damaged)?			

LABORATORY SAFETY INSPECTION CHECKLIST

56. Waste containers marked with full chemical names identifying the contents stored inside (no abbreviations or formulas)?			
57. Incompatible chemical wastes segregated by hazard class?			
58. Biohazardous waste placed in appropriate red bags and labeled containers?			
59. Biohazard waste autoclaved in a timely manner?			
60. Sharps placed in a designated sharps container?			
COMPRESSED GASES	**YES**	**NO**	**N/A**
61. Correct compressed gas regulators used?			
62. Compressed gas cylinders are secured from falling?			
63. Compressed gas cylinders away from heat sources?			
64. Compressed gas cylinders capped when not in active use?			
65. Compressed gas cylinders are properly labeled and legible?			
66. Incompatible compressed gases in storage segregated?			
67. Empty compressed gas cylinders are marked or tagged “EMPTY”?			
BIOLOGICAL SAFETY	**YES**	**NO**	**N/A**
68. Biohazard signs present on doors?			
69. Biohazard labels present where biological materials are stored?			
70. Biological Safety Cabinets not being used to store items or have equipment that is blocking the cabinet’s airflow?			
71. Appropriate disinfectants present in lab for spill decontamination and bench top cleaning?			
72. Autoclave is routinely maintained or serviced as recommended by manufacturer?			
73. Log maintained for ultra-centrifuge rotor use, if recommended by manufacturer?			

Inspector’s Signature:

Date:

Appendix A - Laboratory Safety Inspection Checklist (Corrective Actions)

INSPECTION CORRECTIVE ACTIONS

Record corrective action(s) for all "No" findings listed above. Additional sheets may be needed.

Finding #	Corrective Actions	Date Corrected

Inspector's Signature:

Date:

Appendix B – Laboratory Safety Inspection Checklist (Applied Technologies/Art & Design)

LABORATORY SAFETY INSPECTION CHECKLIST

Date:

Inspected By:

Department:

Supervisor:

Campus:

Building:

Room:

For each item check Yes, No, or N/A. Be sure to retain all documentation regarding inspections, including findings and corrective actions taken for any "No" responses, for a minimum of 3 years. Contact EH&S for questions or additional information.

GENERAL SAFETY	**YES**	**NO**	**N/A**
1. Laboratory Safety Plan is present, updated (annual review required), and includes emergency information?			
2. Emergency contact numbers posted in the laboratory?			
3. Laboratory is maintained secure; door is locked when no one is in the laboratory?			
4. Laboratory floors, aisles, exits and adjacent hallways unobstructed?			
5. Broken glassware is not in use; glassware is properly discarded in designated containers?			
6. Laboratory is adequately organized and cleaned to provide sufficient workspace for operations without spills, accidents, or other preventable incidents?			
7. Floors dry and free of slip hazards?			
8. Food and drinks are kept in the designated area at all times? (Note: closed drink containers are permitted work areas).			
9. Appropriate warning signs posted on outside of door?			
10. Refrigerators/freezers labeled with food and drink specifications?			
11. Hand washing sink is available with towels and soap present?			
12. All equipment guards are in place?			
13. **Laboratory electrical panels accessible and unobstructed?**			
14. Extension cords only used temporarily, and power strips not daisy-chained together?			
15. **Equipment with motors, heaters, and other high amperage needs plugged directly into a wall receptacle?**			
16. **Electrical or extension cords free of exposed wiring?**			
CHEMICAL STORAGE & HANDLING	**YES**	**NO**	**N/A**
17. Laboratory personnel know how to access Chemical Inventory and Safety Data Sheets?			
18. Appropriate labels are found on all chemical containers and secondary containers (No abbreviations/formulas)?			
19. Chemical containers are kept closed when not in use?			
20. No corroded/compromised chemical containers?			
21. Desk, work, and storage areas organized and clean?			
22. Chemical storage cabinets properly labeled and kept closed when not in use?			
23. Storage cabinets clean and free from spilled material?			
24. Incompatible materials stored separately?			

Appendix B – Laboratory Safety Inspection Checklist (Applied Technologies/Art & Design)

LABORATORY SAFETY INSPECTION CHECKLIST

25. Chemical containers stored away from sinks or floor drains?			
26. No corrosive liquids storage above eye level?			
27. Hazardous materials storage is available and adequate, if required?			
28. Food and drinks stored and consumed away from toxic materials?			
29. Lab free of chemicals that are old or no longer needed?			
30. **Processes that emit vapors, gases, or fumes adequately captured by local ventilation (hoods, snorkel)?**			
FIRE SAFETY	**YES**	**NO**	**N/A**
31. Fire extinguishers are charged and unobstructed?			
32. Flammable liquids are stored in appropriate containers?			
33. No more than 10 gallons of flammable liquids stored outside of cabinets?			
34. Flammable materials requiring refrigeration are placed in explosion-proof or flammables refrigerators only?			
35. No excess combustible material near ignition sources?			
36. Suspended ceilings have all their ceiling tiles in place?			
37. Laboratory doors kept closed when unoccupied?			
38. All objects stored at least 18 inches away from fire sprinklers?			
39. Evacuation maps are posted where required?			
PERSONAL PROTECTIVE EQUIPMENT	**YES**	**NO**	**N/A**
40. Are all lab users wearing long pants, sleeved shirts and appropriate footwear and are loose clothing, hair and jewelry restricted while working in the lab?			
41. Adequate gloves available and in use?			
42. Adequate eye protection available and in use?			
43. Personnel are wearing appropriate PPE for tasks being performed?			
44. Areas requiring the use of PPE have adequate signage posted and enforced?			
EMERGENCY EQUIPMENT	**YES**	**NO**	**N/A**
45. First aid kit is present and stocked?			
46. Shower/eyewash free of obstructions and in good working order?			
47. Shower/eyewash available within 10 seconds travel (approx. 50ft.)?			
48. At least one fire blanket is available and accessible, if required?			
49. Appropriate spill kits, PPE and decontamination material available where needed?			
HAZARDOUS WASTE	**YES**	**NO**	**N/A**
50. Waste containers are clean, structurally sounds, and closed when not in use?			
51. Waste containers are labeled “Hazardous Waste” with the proper hazard warning label?			
52. Waste containers are in good condition (not leaking, rusted, bulging or damaged)?			
53. Waste containers marked with full chemical names identifying the contents stored inside (no abbreviations or formulas)?			
54. **Incompatible chemical wastes segregated by hazard class?**			
55. Sharps and blades placed in a designated sharps container for disposal?			

LABORATORY SAFETY INSPECTION CHECKLIST

COMPRESSED GASES	YES	NO	N/A
56. Correct compressed gas regulators used?			
57. Compressed gas cylinders are secured from falling?			
58. Compressed gas cylinders away from heat sources?			
59. Compressed gas cylinders capped when not in active use?			
60. Compressed gas cylinders are properly labeled and legible?			
61. Incompatible compressed gases in storage segregated?			
62. Empty compressed gas cylinders are marked or tagged “EMPTY”?			
WELDING	**YES**	**NO**	**N/A**
63. Compressed gas cylinders secured upright with a double chain and valve protector caps?			
64. Welding ventilation systems are operational and clean, and filters regularly changed?			
65. Welding curtains are available and used when appropriate?			
66. Welding rod holders are empty and properly stored when not in active use?			
67. Compressed gas cylinders and hoses free from cracks or dents?			
68. Cylinders, valves, couplings, regulators, hoses, and apparatus are kept clean and free from residue?			
69. Valves are kept closed whenever cylinders are not in active use?			
70. Welding hoses are properly color coded (fuel gas-red, oxygen-green, inert gas-black)?			
MACHINERY & EQUIPMENT	**YES**	**NO**	**N/A**
71. Written standard operating procedures (SOPs) or operating manual available for each machine and executed by all users?			
72. All machines have guards to protect against points of operation, nip points, rotating parts, moving parts, flying chips, sparks, etc.?			
73. All emergency stops, safety guards, and safety devices located on equipment and tools working and adjusted properly?			
74. Tools and equipment are in good condition and broken tools are removed from service?			
75. Sharp and pointed tools are shielded to prevention accidental contact?			
76. Damaged/malfunctioning equipment promptly reported, tagged “OUT OF SERVICE”, and repaired?			
77. Start, stop, emergency and other operating controls within the operator’s reach?			

Inspector’s Signature:

Date:

Appendix B – Laboratory Safety Inspection Checklist (Corrective Actions)

INSPECTION CORRECTIVE ACTIONS

Record corrective action(s) for all "No" findings listed above. Additional sheets may be needed.

Finding #	Corrective Actions	Date Corrected

Inspector's Signature:

Date:

APPENDIX D

OSHA GLOVE SELECTION CHART

OSHA GLOVE SELECTION CHART

The following table from the U.S. Department of Energy (Occupational Safety and Health Technical Reference Manual) rates various gloves as being protective against specific chemicals and will help you select the most appropriate gloves.
The ratings are abbreviated as follows: **VG**: Very Good; **G**: Good; **F**: Fair; **P**: Poor (not recommended).
Chemicals marked with an asterisk (*) are for limited service.

OSHA GLOVE SELECTION CHART				
***Limited service**	**VG= Very Good**	**G= Good**	**F=Fair**	**P=Poor (not recommended)**
Chemical	**Neoprene**	**Natural Latex or Rubber**	**Butyl**	**Nitrile Latex**
*Acetaldehyde	VG	G	VG	G
Acetic acid	VG	VG	VG	VG
*Acetone	G	VG	VG	P
Ammonium hydroxide	VG	VG	VG	VG
*Amyl acetate	F	P	F	P
Aniline	G	F	F	P
*Benzaldehyde	F	F	G	G
*Benzene	F	F	F	P
Butyl acetate	G	F	F	P
Butyl alcohol	VG	VG	VG	VG
Carbon disulfide	F	F	F	F
*Carbon tetrachloride	F	P	P	G
Castor oil	F	P	F	VG
*Chlorobenzene	F	P	F	P
*Chloroform	G	P	P	P
Chloronaphthalene	F	P	F	F
Chromic Acid (50%)	F	P	F	F
Citric acid (10%)	VG	VG	VG	VG
Cyclohexanol	G	F	G	VG
*Dibutyl phthalate	G	P	G	G
Diesel fuel	G	P	P	VG
Diisobutyl ketone	P	F	G	P
Dimethylformamide	F	F	G	G
Dioctyl phthalate	G	P	F	VG
Dioxane	VG	G	G	G
Epoxy resins, dry	VG	VG	VG	VG
*Ethyl acetate	G	F	G	F
Ethyl alcohol	VG	VG	VG	VG
Ethyl ether	VG	G	VG	G
*Ethylene dichloride	F	P	F	P
Ethylene glycol	VG	VG	VG	VG
Formaldehyde	VG	VG	VG	VG
Formic acid	VG	VG	VG	VG

OSHA GLOVE SELECTION CHART

*Limited service	VG= Very Good	G= Good	F=Fair	P=Poor (not recommended)

Chemical	Neoprene	Natural Latex or Rubber	Butyl	Nitrile Latex
Freon 11	G	P	F	G
Freon 12	G	P	F	G
Freon 21	G	P	F	G
Freon 22	G	P	F	G
*Furfural	G	G	G	G
Gasoline, leaded	G	P	F	VG
Gasoline, unleaded	G	P	F	VG
Glycerine	VG	VG	VG	VG
Hexane	F	P	P	G
Hydrochloric acid	VG	G	G	G
Hydrofluoric acid (48%)	VG	G	G	G
Hydrogen peroxide (30%)	G	G	G	G
Hydroquinone	G	G	G	F
Isooctane	F	P	P	VG
Isopropyl alcohol	VG	VG	VG	VG
Kerosene	VG	F	F	VG
Ketones	G	VG	VG	P
Lacquer thinners	G	F	F	P
Lactic acid (85%)	VG	VG	VG	VG
Lauric acid (36%)	VG	F	VG	VG
Lineoleic acid	VG	P	F	G
Linseed oil	VG	P	F	VG
Maleic acid	VG	VG	VG	VG
Methyl alcohol	VG	VG	VG	VG
Methylamine	F	F	G	G
Methyl bromide	G	F	G	F
*Methyl chloride	P	P	P	P
*Methyl ethyl ketone	G	G	VG	P
*Methyl isobutyl ketone	F	F	VG	P
Methyl methacrylate	G	G	VG	F
Monoethanolamine	VG	G	VG	VG
Morpholine	VG	VG	VG	G
Naphthalene	G	F	F	G
Naphthas, aliphatic	VG	F	F	VG
Naphthas, aromatic	G	P	P	G
*Nitric acid	G	F	F	F
Nitromethane (95.5%)	F	P	F	F
Nitropropane (95.5%)	F	P	F	F
Octyl alcohol	VG	VG	VG	VG
Oleic acid	VG	F	G	VG

OSHA GLOVE SELECTION CHART				
***Limited service**	**VG= Very Good**	**G= Good**	**F=Fair**	**P=Poor (not recommended)**
Chemical	**Neoprene**	**Natural Latex or Rubber**	**Butyl**	**Nitrile Latex**
Oxalic acid	VG	VG	VG	VG
Palmitic acid	VG	VG	VG	VG
Perchloric acid (60%)	VG	F	G	G
Perchloroethylene	F	P	P	G
Petroleum distillates (naphtha)	G	P	P	VG
Phenol	VG	F	G	F
Phosphoric acid	VG	G	VG	VG
Potassium hydroxide	VG	VG	VG	VG
Propyl acetate	G	F	G	F
Propyl alcohol	VG	VG	VG	VG
Propyl alcohol (iso)	VG	VG	VG	VG
Sodium hydroxide	VG	VG	VG	VG
Styrene	P	P	P	F
Stryene (100%)	P	P	P	F
Sulfuric acid	G	G	G	G
Tannic acid (65%)	VG	VG	VG	VG
Tetrahydrofuran	P	F	F	F
*Toluene	F	P	P	F
Toluene diisocyanate	F	G	G	F
*Trichloroethylene	F	F	P	G
Triethanolamine	VG	G	G	VG
Tung oil	VG	P	F	VG
Turpentine	G	F	F	VG
*Xylene	P	P	P	F

APPENDIX E

CHEMICAL SEGRIGATION AND STORAGE TABLE

CHEMICAL SEGRIGATION AND STORAGE TABLE

Chemical Segregation and Storage Table

Class of Chemicals	Common Chemical Examples	Additional Concerns and Storage Recommendations	Common Incompatible Chemical Types	Possible Reaction if Mixed/Health Concerns
Corrosive Acids-Organic 	Acetic Acid Glacial Acetic Acid Butyric Acid Trifluoroacetic Acid Picric Acid Propionic Acid Formic Acid	Store in ventilated corrosives cabinet on protected shelving using secondary containment, keep away from water sources *Do not store under the sink *Do not store acids on metal shelving	Flammable Liquids Flammable Solids Bases Oxidizers Inorganic Acids Cyanides Sulfides Poisons/Toxins	Heat Gas Generation Violent Reaction *DO NOT POUR WATER INTO ACID
Corrosive Acids-Inorganic 	Nitric Acid Sulfuric Acid Perchloric Acid Phosphoric Acid Hydrochloric Acid Chromic Acid Hydrofluoric Acid	Store concentrated Nitric acid (≥68%) and Sulfuric acid (≥93%) in a secondary container. Store in a corrosive cabinet labeled “Acid” or on shelving using a secondary containment. *Do not store under the sink *Do not store acids on metal shelving *Hydrofluoric acid should be stored in an area accessible only by authorized personnel; do not store in glass; use plastic containers and secondary containment	Flammable Liquids Flammable Solids Bases Oxidizers Organic Acids Cyanides Sulphides Poisons/Toxins	Heat Gas Generation Violent Reaction *DO NOT POUR WATER INTO ACID *Perchloric acid vapor can form explosive compounds within fume hood ducts *Hydrofluoric acid can result in severe burns to skin and lungs
Corrosive Bases-Organic/Caustic 	Hydroxylamine Tetramethylethylamine Diamine Triethylamine	Store in separate cabinet, preferably with ventilation, corrosive cabinet or storage area with a spill tray, away from potential water sources (DO NOT store under the sink)	Acids Oxidizers Flammable Liquids Flammable Solids Inorganic Bases Poisons/Toxins	Heat Gas Generation Violent Reaction
Corrosive Bases-Inorganic/Caustics 	Ammonium Hydroxide Potassium Hydroxide Sodium Hydroxide Calcium Hydroxide	Store in separate cabinet preferably with ventilation, corrosive cabinet or storage area with a spill tray, away from potential water sources (DO NOT store under the sink); Store solutions of inorganic hydroxides in labeled polyethylene containers	Acids Oxidizers Flammable Liquids Flammable Solids Organic Bases Poisons/Toxins	Heat Gas Generation Violent Reaction

Chemical Segregation and Storage Table

Class of Chemicals	Common Chemical Examples	Additional Concerns and Storage Recommendations	Common Incompatible Chemical Types	Possible Reaction if Mixed/Health Concerns
Flammable Solids 	Charcoal Carbon Paraformaldehyde Phosphorus Magnesium	Keep in a dry, cool area away from oxidizers and corrosives	Acids Bases Oxidizers Poisons/Toxins	Fire Hazard Violent Reaction
Flammable Liquids 	Ethanol, Ethyl Acetate, Methanol, Acetone, Benzene, Xylene, Toluene Diethyl Ether Tetrahydrofuran Acetonitrile Glacial Acetic Acid Acetone liquids with flashpoints < 100 F	Flammable storage cabinet or refrigerator rated for flammable/ hazardous storage/explosion proof *Peroxide-forming chemicals must be dated upon delivery and opening (two dates)	Oxidizers Acids Bases Reactives Poisons/Toxins	Fire Hazard Heat Violet Reaction
Poisons/Toxins 	Chloroform Cyanides Heavy metal compounds (e.g., Cadmium, Mercury, Osmium, Oxalic Acid, Phenol, Formic Acid), Formamide, Carbon Tetracholride, 2- Mercaptoethanol Phenol, *Hydrofluoric Acid - Hydrofluoric Acid is a highly acute poison Acrylamide Ethidium Bromide Sodium Azide	Store in a dark, dry, ventilated, cool area in an unbreakable chemically resistant secondary container (polyethylene) * Store volatile toxins with evaporation rate above 1.0 - (ether =1.0) in flammable cabinet; Store non-volatile liquid poisons in a refrigerator or cabinet; amounts less than 1 liter can be stored in a cabinet above bench level, ONLY if the cabinet has sliding doors (not swinging)	Flammable liquids Acids Bases Reactives Oxidizers Corrosives Please consult EHS Department for assistance *Hydrofluoric Acid should be stored in an area accessible only by authorized personnel; do not store in glass; use plastic containers and secondary containment	Generation of Toxic and Flammable Gas Combustion Heat Fire Hazard Explosion Hazard Violent Reaction Chloroform explosively reacts with chemically-reactive metals (e.g., Aluminum or Magnesium powder, Sodium, and Lithium), Strong Oxidizers, Strong Caustics (e.g., Alkalis), and decomposes in sunlight
Explosives 	Picric Acid Ammonium Nitrate Nitro Urea Trinitroaniline Benzoyl Peroxide Trinitrobenzene Trinitrobenzoic Acid Trinitrotoluene	Store in a secure location away from other chemicals; store in an area away from friction or shock	Please consult the SDS and EHS Department	Explosion Hazard Violent Reaction Heat Shock Friction

Chemical Segregation and Storage Table

Class of Chemicals	Common Chemical Examples	Additional Concerns and Storage Recommendations	Common Incompatible Chemical Types	Possible Reaction if Mixed/Health Concerns
	Urea Nitrate Trinitrophenol Diazoisbutylnitrile			
Oxidizers 	Peroxides, Nitrates, Perchlorates Permanganates Sodium Hypochlorite Ethyl Acetate, Iodine, Benzoyl Peroxide Potassium Dichromate Chlorates, Bromates, and Superoxides, Ammonium Persulfate, Ferric chloride	Store in secondary containment separately from combustibles and flammable materials	Combustibles Flammables Organic Materials Reducing Agents	Fire Hazard Gas Generation Toxic Gas
Peroxide Formers 	Acrylonitrile Isopropyl Alcohol Ethers (e.g., Diethyl ether, Isopropyl Ether), Acetals and Ketals, especially Cyclic Ethers and those with primary and/or secondary Alkyl groups Aldehydes (e.g., Acetaldehyde, Benzaldehyde) Vinyl and Vinylidene compounds, Dienes Tetrahydrofuran Dioxane Butylated Hydroxytoluene (BHT) Isopropyl Ether	Store in airtight bottles, away from light and heat in a dark, cool dry area; avoid using containers with loose-fitting lids and ground glass stoppers; crystallization, discoloration, and formation or deposition of layers are signs a peroxide former may have become shock sensitive; do not use or move such containers: contact EHS; all bottles of peroxide-forming chemicals must have the received date marked on the container; when the bottle is first opened, the container must be marked with the date opened	Always consult the Safety Data Sheet (SDS) and EHS Department	Explosion Hazard Violent Reaction Shock Sensitive Combustion (Exothermic Reaction) If an old or expired container of a peroxide-forming chemical or reactive is found, do not move it. Contact EHS for assistance in disposing of the container
Water Reactive 	Sodium Metals Lithium Metals Potassium Metals Sodium Borohydride Alkali Metal Hydrides	Store in a dry, cool area away from potential spray from fire sprinklers and other water sources (DO NOT store under the sink) Label this area for water-reactive storage	Aqueous solutions Oxidizers Please consult the Safety Data Sheet (SDS) and EHS Department	Heat Violent Reaction
Flammable Compressed Gases	Methane Acetylene Butane Propane Hydrogen Silane	Handle flammable compressed gases in a chemical fume hood Store in well-ventilated areas; store away from oxidizers, open flames, sparks, and other	Oxidizers Toxic Compressed Gases	Fire Hazard Explosion Hazard

Chemical Segregation and Storage Table

Class of Chemicals	Common Chemical Examples	Additional Concerns and Storage Recommendations	Common Incompatible Chemical Types	Possible Reaction if Mixed/Health Concerns
	Ethane Arsine Germane	sources of heat ignition; post NO SMOKING signs around storage area(s) or entrance(s) to storage room(s); flammable gases stored outdoors where ambient temperatures exceed 125 deg F (51.7 deg C) shall be protected from direct sunlight Use a spark proof wrench to attach regulators and make other connections; install a flame/flash arrestor at the regulator outlet flow valve		
Oxidizing Compressed Gases 	Oxygen Chlorine Fluorine Nitrogen oxides Gas mixtures containing Oxygen higher than atmospheric concentrations	Store oxidizers separately from flammable gas containers or combustible materials; minimum separation requirement from these materials is 20 ft or a 5 ft noncombustible barrier with a fire resistance rating of at least 30 minutes Clean equipment used for oxygen and nitrous oxide with oxygen-compatible materials free from oils, greases, and other contaminants Fluorine shall be handled in specially passivated containers and associated equipment	Flammable Compressed Gases Toxic Compressed Gases	Fire Hazard Explosion Hazard
Toxic Compressed Gases 	Carbon Monoxide Hydrogen Chloride Hydrogen Sulfide Nitrogen Dioxide	Handle toxic compressed gases in a chemical fume hood Indoor storage or use of toxic compressed gases shall be provided with a gas cabinet, exhausted enclosure, or gas room Refer to the SDS information for additional guidance on the storage and compatibility requirements	Flammable Compressed Gases Oxidizing Compressed Gases	Release of Toxic Gas Hydrogen Sulfide is a colorless, flammable, extremely hazardous gas with a "rotten egg" smell; Prolonged exposure may cause nausea, tearing of the eyes, headaches

Chemical Segregation and Storage Table

Class of Chemicals	Common Chemical Examples	Additional Concerns and Storage Recommendations	Common Incompatible Chemical Types	Possible Reaction if Mixed/Health Concerns
		Contact EHS department to determine if a fail-safe valve and/or continuous monitoring for toxic gas may be required during use		or loss of sleep, airway problems (bronchial constriction) in some asthma patients; possible fatigue, loss of appetite, headache, irritability, poor memory, dizziness and slight conjunctivitis
Strong Reducing Agents	Acetyl Chloride Thionyl Chloride Maleic Anhydride Ferrous Sulfide	Store in cool, dry, well-ventilated location Water reactive Segregate from all other chemicals	Please consult the specific SDS and EHS Department	Please consult the specific SDS and EHS Department
Carcinogens 	Benzidine Beta-Naphthylamine Benzene Methylene Chloride Beta-Propiolactone Carbon Tetrachloride	Label all containers as "Cancer Suspect Agents" or the equivalent. Store according to the hazardous nature of the chemical, using appropriate security when necessary	Please consult the specific SDS and EHS Department	Please consult the specific SDS and EHS Department
Teratogens 	Lead Compounds Mercury Compounds Benzene Aniline	Label all containers as "Suspect Reproductive Hazard" or “Reproductive Effecter” Store according to the hazardous nature of the chemical, using appropriate security when necessary	Aniline incompatible with Nitric Acid and Hydrogen Peroxide Please consult the specific SDS and EHS Department	Please consult the specific SDS and EHS Department
General Stock Chemicals	Sodium Bicarbonate Sodium Chloride Agar Salt buffer Most non-reactive salts	Store on shelves, or laboratory benches or shelving preferably behind glass doors and below eye level with like chemicals	Please consult the specific SDS and EHS Department	Please consult the specific SDS and EHS Department

Adapted from Prudent Practices in the Laboratory: Handling and Disposal of Chemicals, National Research Council, 1995, University of Texas/Health Science at Houston and Boston University Environmental Health & Safety.

APPENDIX F

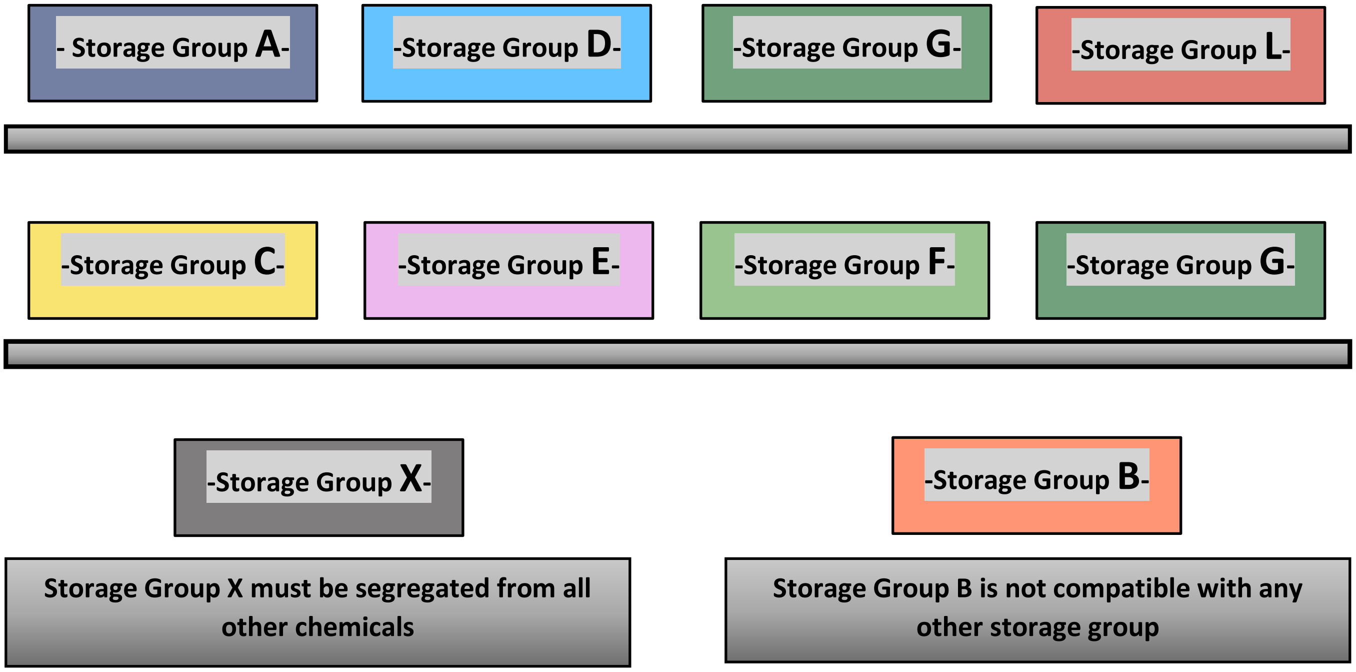
COMPATIBLE STORAGE GROUP CLASSIFICATION

COMPATIBLE STORAGE GROUP CLASSIFICATION

Compatible Storage Group Classification System should be used in conjunction with specific storage conditions taken from the manufacturer's label and SDS.

If space does not allow Storage Groups to be kept in separate cabinets, multiple groups can be stored on the same shelf or within the same cabinet if each group is stored in its own secondary container.

The following scheme can be used with extra care taken to provide stable, uncrowded, and carefully monitored conditions:



Storage Groups

A	Compatible Organic Bases
B	Compatible Pyrophoric & Water Reactive Materials
C	Compatible Inorganic Bases
D	Compatible Organic Acids
E	Compatible Oxidizers including Peroxides
F	Compatible Inorganic Acids (not including Oxidizers or Combustible)
G	Not Intrinsically Reactive or Flammable or Combustible
J*	Poison Compressed Gases
K*	Compatible Explosive or other highly Unstable Material
L	Non-Reactive Flammable and Combustible, including solvents
X*	Incompatible with ALL other storage groups

***Storage Groups J, K, and X:** Contact EHS x7445.
For specific storage - consult manufacturer's SDS

- **Groups A, B, C, D, E, F, L, and X**: must be stored below eye-level.
- **Group G**: can be stored above eye-level
- **Groups A, D, G, and L**: can be stored on the same shelf
- **Groups C, E, F, and G**: can be stored on the same shelf
- **Group B**: not compatible with any other storage group
- **Group X**: Incompatible with ALL other chemicals (including other chemicals within X)

COMPATIBLE STORAGE GROUP CLASSIFICATION

Storage Group A: Compatible Organic Bases

Name	CAS #	Group
Benzylamine	100-46-9	A
Benzyltrimethylammonium hydroxide	100-85-6	A
Cyclohexylamine	108-91-8	A
Diethanolamine	111-42-2	A
Diethylamine	109-89-7	A
Ethylamine	75-04-7	A
Ethylenediamine	107-15-3	A
Piperidine	110-89-4	A
Triethanolamine	102-71-6	A
Triethylamine	121-44-8	A

Storage Group B: Compatible Pyrophoric & Water Reactive Materials

Name	CAS #	Group
Antimony pentafluoride	7783-70-2	B
Benzoyl chloride	98-88-4	B
Boron trifluoride compound with methyl ether (1:1)	353-42-4	B
Tert-Butyllithium	594-19-4	B
Calcium cyanamide	156-62-7	B
Lithium aluminum hydride	16853-85-3	B
Lithium diisopropylamide	4111-54-0	B
Lithium hydride	7580-67-8	B
Lithium metal (e.g., in THF)	7439-93-2	B
Methanesulfonyl chloride	124-63-0	B
Methyllithium solution (and other alkyls)	917-54-4	B
Potassium metal	7440-09-7	B
Potassium amide	17242-52-3	B
Sodium borohydride	16940-66-2	B
Sodium hydride	7646-69-7	B
Zinc (fume or dust)	7440-66-6	B

Storage Group C: Compatible Inorganic Bases

Name	CAS #	Group
Ammonium hydroxide	1336-21-6	C
Barium hydroxide	17194-00-2	C
Calcium hydroxide	1305-62-0	C
Cesium hydroxide	21351-79-1	C
Lithium hydroxide	1310-65-2	C
Potassium hydroxide	1310-58-3	C
Rubidium hydroxide	1310-82-3	C
Sodium hydroxide	1310-73-2	C
Strontium hydroxide	18480-07-4	C

Storage Group D: Compatible Organic Acids

Name	CAS #	Group
Acetic acid	64-19-7	D
Acrylic acid	79-10-7	D
Benzoic acid	65-85-0	D
Benzotrichloride	98-07-7	D
Benzoyl chloride	98-88-4	D
Boric acid	10043-35-3	D
Chloroacetic acid	79-11-8	D
Chloroethyl chloroformate	627-11-2	D
Citric acid	77-92-9	D
Dimethylcarbamoyl chloride	79-44-7	D
Formic acid	64-18-6	D
Malic acid	6915-15-7	D
Maleic anhydride	108-31-6	D
Nitric acid	7697-37-2	D
Nitrilotriacetic acid	139-13-9	D
Propionic acid	79-09-4	D
Selenious acid	7783-00-8	D
Trifluoroacetic acid (TFA)	76-05-1	D
Trichloroacetic acid	76-03-9	D

Storage Group E: Compatible Oxidizers, Including Peroxides

Name	CAS #	Group
9-BBN	21205-91-4	E
Aluminum nitrate	13473-90-0	E
Ammonium dichromate	7789-09-5	E
Ammonium perchlorate	7790-98-9	E
Ammonium permanganate	13446-10-1	E
Ammonium persulfate	7727-54-0	E
Barium nitrate	10022-31-8	E
Calcium nitrate	10124-37-5	E
Calcium peroxide	1305-79-9	E
Cupric nitrate	19004-19-4	E
Guanidine nitrate	506-93-4	E
3-Chloroperoxybenzoic acid	937-14-4	E
Hydrogen peroxide	7722-84-1	E
Lead nitrate	10099-74-8	E
Lithium hypochlorite	13840-33-0	E
Magnesium nitrate	10377-60-3	E
Magnesium perchlorate	10034-81-8	E
Nickel nitrate	13138-45-9	E
Nitric acid	7697-37-2	E
Peracetic acid	79-21-0	E
Perchloric acid	7601-90-3	E
Potassium dichromate	7778-50-9	E
Potassium nitrate	7757-79-1	E

Storage Group E: Compatible Oxidizers, Including Peroxides		
Name	**CAS #**	**Group**
Potassium permanganate	7722-64-7	E
Potassium persulfate	7727-21-1	E
Potassium superoxide	17014-71-0	E
Silver nitrate	7761-88-8	E
Sodium carbonate peroxide	15630-89-4	E
Sodium chlorate	7775-09-9	E
Sodium chlorite	7758-19-2	E
Sodium dichloro-s-triazinetrione	2893-78-9	E
Sodium dichromate	10588-01-9	E
Sodium hypochlorite	7681-52-9	E
Sodium nitrate	7631-99-4	E
Sodium nitrite	7632-00-0	E
Sodium permanganate	10101-50-5	E
Sodium peroxide	1313-60-6	E
Sodium persulfate	7775-27-1	E
Strontium chlorate	7791-10-8	E
Strontium nitrate	10042-76-9	E
Strontium peroxide	1314-18-7	E
Trichloro-s-triazinetrione (Trichloroisocyanuric acid, TCCA)	87-90-1	E

Storage Group F: Compatible Inorganic Acids, Not Including Oxidizers or Combustibles		
Name	**CAS #**	**Group**
Chloric acid	7790-93-4	F
Hydriodic acid	10034-85-2	F
Hydrochloric acid	7647-01-0	F
Hydrogen fluoride solution	7664-39-3	F
Phosphoric acid	7664-38-2	F
Sulfuric acid	7664-93-9	F

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible		
Name	**CAS #**	**Group**
Abamectin [avermectin b1]	71751-41-2	G
Acetamide, 2-fluoro-	640-19-7	G
Acetic acid, fluoro-, sodium salt	62-74-8	G
Acetone thiosemicarbazide	1752-30-3	G
2-Acetylaminofluorene	53-96-3	G
Acrylamide	79-06-1	G
Acryloyl chloride	814-68-6	G
Adiponitrile	111-69-3	G
Aldrin	309-00-2	G
4-Aminoazobenzene	60-09-3	G
4-Aminodiphenyl	92-67-1	G

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible		
Name	**CAS #**	**Group**
1-Amino-2-methylanthraquinone	82-28-0	G
Aminopterin	54-62-6	G
4-Aminopyridine	504-24-5	G
Amitrole	61-82-5	G
Anilazine [4, 6-dichloro-*N*-(2-chlorophenyl)-1, 3, 5-triazin-2-amine]	101-05-3	G
o-Anisidine	90-04-0	G
Antimony	7440-36-0	G
Arsenic	7440-38-2	G
Arsenic pentoxide	1303-28-2	G
Arsenic trichloride	7784-34-1	G
Arsenic trioxide	1327-53-3	G
Azinphos-methyl	86-50-0	G
Barium	7440-39-3	G
Benz[a]anthracene	56-55-3	G
Benzal chloride	98-87-3	G
Benzamide	55-21-0	G
Benzenamine, 3-(trifluoromethyl)-	98-16-8	G
Benzene, 1-(chloromethyl)-4-nitro-	100-14-1	G
Benzenearsonic acid	98-05-5	G
Benzenethiol	108-98-5	G
Benzidine	92-87-5	G
Benzo[a]pyrene	50-32-8	G
Benzoic acid, 2-hydroxy-, compound with (3as-cis)-1,2,3,3a,8,8a hexahydro-1,3a,8-trimethylpyrrolo[2,3,b]indol-5-ylmethylcarbamate ester (1:1)	57-64-7	G
Benzyl chloride	100-44-7	G
Benzyl cyanide	140-29-4	G
Beryllium powder	7440-41-7	G
Beta-naphthylamine	91-59-8	G
Bifenthrin	82657-04-3	G
Biphenyl	92-52-4	G
Bis(chloromethyl) ketone	534-07-6	G
Bis(chloromethyl)ether	542-88-1	G
Bromadiolone	28772-56-7	G
Bromoform (tribromomethane)	75-25-2	G
Bromomethane	74-83-9	G

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible

Name	CAS #	Group
Bromotrifluoromethane (halon 1301)	75-63-8	G
C.I. Food red 15 (Rhodamine B)	81-88-9	G
C.I. Solvent yellow 3	97-56-3	G
Cadmium	7440-43-9	G
Cadmium oxide	1306-19-0	G
Cadmium stearate	2223-93-0	G
Calcium arsenate	7778-44-1	G
Cantharidin	56-25-7	G
Carbachol chloride	51-83-2	G
Carbamic acid, dimethyl-, 1-[(dimethylamino)carbonyl]-5-methyl-1h-pyrazol-3-yl ester	644-64-4	G
Carbaryl [1-naphthalenol, methylcarbamate]	63-25-2	G
Carbofuran	1563-66-2	G
Carbon tetrachloride	56-23-5	G
Chlordane	57-74-9	G
Chlorendic acid	115-28-6	G
2-Chloroacetophenone	532-27-4	G
1-(3-Chloroallyl)-3,5,7-triaza-1-azoniaadamantane chloride	4080-31-3	G
Chlorodifluoromethane (HCFC-22)	75-45-6	G
Chloroform	67-66-3	G
Chloromethyl methyl ether	107-30-2	G
1-(o-Chlorophenyl)thiourea	5344-82-1	G
3-Chloropropionitrile	542-76-7	G
Chlorotetrafluoroethane	63938-10-3	G
2-Chloro-1,1,1-trifluoro-ethane (HCFC-133a)	75-88-7	G
Chlorotrifluoromethane (CFC-13)	75-72-9	G
Chloroxuron	1982-47-4	G
Chromic chloride	10025-73-7	G
Chromium	7440-47-3	G
Colchicine	64-86-8	G
Coumaphos	56-72-4	G
Coumatetralyl	5836-29-3	G
Cresol (mixed isomers)	1319-77-3	G
o-Cresol	95-48-7	G
Crimidine	535-89-7	G
Crotonaldehyde	4170-30-3	G
(e)-Crotonaldehyde	123-73-9	G
m-Cumenyl methylcarbamate	64-00-6	G
Cyanazine	21725-46-2	G
Cyanogen bromide	506-68-3	G
Cyanogen iodide	506-78-5	G
Cyanuric fluoride	675-14-9	G
Cycloheximide	66-81-9	G
2,4-D (2,4-Dichlorophenoxyacetic acid)	94-75-7	G
2,4-D Chlorocrotyl ester	2971-38-2	G
2,4-D Isopropyl ester	94-11-1	G
2,4-DB	94-82-6	G
Demeton-s-methyl	919-86-8	G
4,4'-Diaminodiphenyl ether	101-80-4	G
4,4'-Diaminodiphenylmethane	101-77-9	G
2,4-Diaminoanisole	615-05-4	G
2,4-Diaminotoluene	95-80-7	G
Diaminotoluene (mixed isomers)	25376-45-8	G
Diazinon	333-41-5	G
Dibenzo(a, h)anthracene	53-70-3	G
Dibenzofuran	132-64-9	G
1,2-Dibromo-3-chloropropane	96-12-8	G
1,2-Dibromoethane (ethylene dibromide)	106-93-4	G
Dibutyl phthalate	84-74-2	G
Dichloran [2, 6-dichloro-4-nitroaniline]	99-30-9	G
1,2-Dichlorobenzene	95-50-1	G
1,3-Dichlorobenzene	541-73-1	G
1,4-Dichlorobenzene	106-46-7	G
3,3'-Dichlorobenzidine	91-94-1	G
Dichlorobromomethane	75-27-4	G
1,4-Dichloro-2-butene	764-41-0	G
Dichlorodifluoromethane (cfc-12)	75-71-8	G
Dichloroethyl ether	111-44-4	G
Dichloromethane (methylene chloride)	75-09-2	G
3,3'-Dimethoxybenzidine-4,4'-diisocyanate	91-93-0	G
3,3'-Dimethyl-4,4'-diphenylene diisocyanate	91-97-4	G
Dichloropentafluoropropane	127564-92-5	G

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible

Name	CAS #	Group
Dichlorophene [2, 2'-methylene-bis(4-chlorophenol)]	97-23-4	G
2,4-Dichlorophenol	120-83-2	G
2,4-Dimethylphenol	105-67-9	G
Dichlorophenylarsine	696-28-6	G
Dichlorotetrafluoroethane (cfc-114)	76-14-2	G
Dichlorvos	62-73-7	G
Diepoxybutane	1464-53-5	G
Diethatyl ethyl	38727-55-8	G
Diethyl chlorophosphate	814-49-3	G
O,O-Diethyl *O*-pyrazinyl phosphorothioate	297-97-2	G
O,O-Diethyl *S*-[2-(diethylamino)ethyl] phosphorothiolate	78-53-5	G
Digitoxin	71-63-6	G
Diglycidyl resorcinol ether	101-90-6	G
Dihydrosafrole	94-58-6	G
Diisopropylfluorophosphate (DFP)	55-91-4	G
Dimethoate	60-51-5	G
4-Dimethylaminoazobenzene	60-11-7	G
7,12-Dimethylbenz[a]anthracene	57-97-6	G
3,3'-Dimethoxybenzidine-4,4'-diisocyanate	91-93-0	G
Dimethyl chlorothiophosphate	2524-03-0	G
3,3'-Dimethyl-4,4'-diphenylene diisocyanate	91-97-4	G
2,4-Dimethylphenol	105-67-9	G
Dimethyl phthalate	131-11-3	G
Dimethyl sulfate	77-78-1	G
Dimethylamine dicamba	2300-66-5	G
4,6-Dinitro-*o*-cresol	534-52-1	G
Dioxathion	78-34-2	G
Diphacinone	82-66-6	G
Diphenamid	957-51-7	G
Diphenylamine	122-39-4	G
Diphosphoric acid, tetraethyl ester	107-49-3	G
Dithiobiuret	541-53-7	G
Endrin	72-20-8	G

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible

Name	CAS #	Group
Ergocalciferol	50-14-6	G
Ethion	563-12-2	G
Ethoprop	13194-48-4	G
Ethyl chloroformate	541-41-3	G
Ethyl dipropylthiocarbamate [EPTC]	759-94-4	G
Ethylene fluorohydrin	371-62-0	G
Ethylene glycol	107-21-1	G
Ethylene thiourea	96-45-7	G
Ethylthiocyanate	542-90-5	G
Famphur	52-85-7	G
Fenthion [*o*, *o*-dimethyl *o*-[3-methyl-4-(methylthio)phenyl]ester, phosphorothioic acid]	55-38-9	G
Fluoroacetic acid	144-49-0	G
Fluoroacetyl chloride	359-06-8	G
Fluorouracil	51-21-8	G
Fonofos	944-22-9	G
Formaldehyde cyanohydrin	107-16-4	G
Formetanate hydrochloride	23422-53-9	G
Freon 113 [ethane, 1, 1, 2-trichloro-1, 2, 2-trifluoro-]	76-13-1	G
Heptachlor	76-44-8	G
Hexachloro-1, 3-butadiene	87-68-3	G
Hexachlorobenzene	118-74-1	G
Hexachlorocyclopentadiene	77-47-4	G
Hexachloroethane	67-72-1	G
Hexachloronaphthalene	1335-87-1	G
Hexachlorophene	70-30-4	G
Hexamethylene-1, 6-diisocyanate	822-06-0	G
Hexazinone	51235-04-2	G
Hn2 (nitrogen mustard-2)	51-75-2	G
Hn3 (nitrogen mustard-3)	555-77-1	G
Hydrazinecarbothioamide	79-19-6	G
Hydroquinone	123-31-9	G
Isocyanic acid, 3,4-dichlorophenyl ester	102-36-3	G
Isodrin	465-73-6	G
Isophorone diisocyanate	4098-71-9	G
Isopropyl chloroformate	108-23-6	G
4,4'-Isopropylidenediphenol	80-05-7	G
Isosafrole	120-58-1	G

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible

Name	CAS #	Group
Lactonitrile	78-97-7	G
Lead	7439-92-1	G
Lindane	58-89-9	G
Lithium carbonate	554-13-2	G
Malathion	121-75-5	G
Malononitrile	109-77-3	G
Mecoprop	93-65-2	G
Mephosfolan	950-10-7	G
2-Mercaptobenzothiazole (MBT)	149-30-4	G
1,1-Methylene bis(4-isocyanatocyclohexane)	5124-30-1	G
Mercuric acetate	1600-27-7	G
Mercuric chloride	7487-94-7	G
Mercuric oxide	21908-53-2	G
Mercury	7439-97-6	G
Methacrylic anhydride	760-93-0	G
Methacryloyl chloride	920-46-7	G
Methacryloyloxyethyl isocyanate	30674-80-7	G
Methanesulfonyl fluoride	558-25-8	G
Methidathion	950-37-8	G
Methomyl	16752-77-5	G
Methoxone (4-chloro-2-methylphenoxy) acetic acid (MCPA))	94-74-6	G
Methoxychlor [benzene, 1, 1'-(2, 2, 2-trichloroethylidene)bis[4-methoxy-]]	72-43-5	G
Methoxyethylmercuric acetate	151-38-2	G
Methyl 2-chloroacrylate	80-63-7	G
3-Methylcholanthrene	56-49-5	G
Methyl chloride	74-87-3	G
4,4'-Methylenebis(2-chloroaniline) (mboca)	101-14-4	G
4,4'-Methylenebis(N,N-dimethyl) benzenamine	101-61-1	G
Methyl hydrazine	60-34-4	G
Methyl iodide	74-88-4	G
N-Methylolacrylamide	924-42-5	G
Methyl parathion	298-00-0	G
Methyl phosphonic dichloride	676-97-1	G
Methyl thiocyanate	556-64-9	G

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible

Name	CAS #	Group
Methylmercuric dicyanamide	502-39-6	G
Mevinphos	7786-34-7	G
Michler's ketone	90-94-8	G
Mitomycin c	50-07-7	G
Molybdenum trioxide	1313-27-5	G
Monochloropentafluoroethane (CFC-115)	76-15-3	G
Monocrotophos	6923-22-4	G
1,5-Naphthalene diisocyanate	3173-72-6	G
Nicotine	54-11-5	G
Nicotine sulfate	65-30-5	G
4-Nitrobiphenyl	92-93-3	G
Nitroglycerine	55-63-0	G
2-Nitrophenol	88-75-5	G
4-Nitrophenol	100-02-7	G
N-Nitrosodimethylamine	62-75-9	G
N-Nitrosodi-*N*-propylamine	621-64-7	G
N-Nitrosodiphenylamine	86-30-6	G
N-Nitrosomorpholine	59-89-2	G
N-Nitrosopiperidine	100-75-4	G
5-Nitro-*o*-toluidine	99-55-8	G
Ouabain	630-60-4	G
Oxetane, 3,3-bis(chloromethyl)-	78-71-7	G
p-anisidine	104-94-9	G
Parathion	56-38-2	G
Paris green	12002-03-8	G
p-chloroaniline	106-47-8	G
p-chloro-*o*-toluidine	95-69-2	G
p-cresol	106-44-5	G
p-dinitrobenzene	100-25-4	G
Pentachloroethane	76-01-7	G
Pentachlorophenol (PCP)	87-86-5	G
Perchloromethylmercaptan	594-42-3	G
Phenanthrene	85-01-8	G
Phenol	108-95-2	G
Phenol, 2-(1-methylpropyl)-4,6-dinitro- (dinoseb)	88-85-7	G
Phenoxarsine, 10,10'-oxydi-	58-36-6	G
1,2-Phenylenediamine	95-54-5	G
1,3-Phenylenediamine	108-45-2	G
1,4-Phenylenediamine dihydrochloride	624-18-0	G
1,4-Phenylene diisocyanate	104-49-4	G

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible		
Name	**CAS #**	**Group**
Phenylhydrazine hydrochloride	59-88-1	G
Phenylmercury acetate	62-38-4	G
2-Phenylphenol	90-43-7	G
Phenylsilatrane	2097-19-0	G
Phenylthiourea	103-85-5	G
Phenytoin	57-41-0	G
Phosfolan	947-02-4	G
Phosphamidon	13171-21-6	G
Physostigmine	57-47-6	G
Picrotoxin	124-87-8	G
Piperonyl butoxide	51-03-6	G
p-nitroaniline	100-01-6	G
Potassium arsenite	10124-50-2	G
Potassium silver cyanide	506-61-6	G
p-phenylenediamine	106-50-3	G
Pronamide	23950-58-5	G
Propane sultone	1120-71-4	G
Propiophenone, 4'-amino	70-69-9	G
Propyl chloroformate	109-61-5	G
Pyrene	129-00-0	G
Quinoline	91-22-5	G
Quinone	106-51-4	G
Quintozene [pentachloronitrobenzene]	82-68-8	G
S,S,S-tributyltrithiophosphate (DEF)	78-48-8	G
Saccharin (manufacturing, no supplier notification)	81-07-2	G
Safrole	94-59-7	G
Silver	7440-22-4	G
Sodium arsenate	7631-89-2	G
Sodium arsenite, solid	7784-46-5	G
Sodium cacodylate	124-65-2	G
Sodium dimethyldithiocarbamate	128-04-1	G
Sodium selenate	13410-01-0	G
Sodium selenite	10102-18-8	G
Sodium tellurite	10102-20-2	G
Strychnine	57-24-9	G
Sulfur mustard (mustard gas H)	505-60-2	G
Tabun	77-81-6	G
Tetrabromobisphenol A	79-94-7	G
1,1,1,2-Tetrachloroethane	630-20-6	G
1,1,2,2-Tetrachloroethane	79-34-5	G

Storage Group G: Not Intrinsically Reactive or Flammable or Combustible		
Name	**CAS #**	**Group**
Tetracycline hydrochloride	64-75-5	G
Tetraethyl lead	78-00-2	G
Tetraethyldithiopyrophosphate	3689-24-5	G
Tetraethyltin	597-64-8	G
Tetrahydronaphthalene	119-64-2	G
Tetramethyllead	75-74-1	G
Thallium	7440-28-0	G
Thallous carbonate	6533-73-9	G
Thioacetamide	62-55-5	G
Thiodicarb	59669-26-0	G
Thiourea	62-56-6	G
Thiourea, (2-methylphenyl)-	614-78-8	G
Thiram	137-26-8	G
Thorium dioxide	1314-20-1	G
o-Toluidine	95-53-4	G
Toxaphene	8001-35-2	G
Triaziquone [2, 5-cyclohexadiene-1, 4-dione, 2, 3, 5-tris(1-aziridinyl)-]	68-76-8	G
Triazophos	24017-47-8	G
Tributyltin fluoride	1983-10-4	G
Trichlorfon [phosphonic acid, (2, 2, 2-trichloro-1-hydroxyethyl)-, dimethyl ester]	52-68-6	G
Trichloro(chloromethyl)silane	1558-25-4	G
1,1,1-Trichloroethane (methyl chloroform)	71-55-6	G
1,2,4-Trichlorobenzene	120-82-1	G
1,1,2-Trichloroethane	79-00-5	G
Trichlorofluoromethane (CFC-11)	75-69-4	G
Trichloronate	327-98-0	G
2,4,6-Trichlorophenol	88-06-2	G
1,2,3-Trichloropropane	96-18-4	G
2,4,6-Trimethyl-aniline	88-05-1	G
Trimethylolpropane phosphite	824-11-3	G
Triphenyltin hydroxide	76-87-9	G
Urethane (ethyl carbamate)	51-79-6	G
Vanadium pentoxide	1314-62-1	G
Warfarin	81-81-2	G
Warfarin sodium	129-06-6	G
2,6-Xylidine	87-62-7	G
Xylylene dichloride	28347-13-9	G

Storage Group J*: Poison Compressed Gases

Name	CAS #	Group
Hexafluoropropylene	116-15-4	J
Sulfur dioxide	7446-09-5	J

Storage Group K*: Compatible Explosives or Other Highly Unstable Materials

Name	CAS #	Group
Nitroguanidine	556-88-7	K
Picric acid, dry (<10% water)	88-89-1	K
Tetrazole	288-94-8	K
Urea nitrate	124-47-0	K

Storage Group L: Non-Reactive Flammable & Combustible, Including Solvents

Name	CAS #	Group
Acetonitrile	75-05-8	L
Acetophenone	98-86-2	L
Acrylonitrile, inhibited	107-13-1	L
Allyl ether	557-40-4	L
Benzene	71-43-2	L
Benzyl ether	103-50-4	L
Beta-isopropoxypropionitrile	110-47-4	L
Butadiene	106-99-0	L
2-Butanol	78-92-2	L
n-Butanol	71-36-3	L
tert-Butanol	75-65-0	L
2-Butanone (MEK)	78-93-3	L
Butyl acrylate	141-32-2	L
Creosote	8001-58-9	L
Cyclohexane	110-82-7	L
Cyclohexanol	108-93-0	L
Cyclohexene	110-83-8	L
Cyclooctene	931-87-3	L
Cyclopentene	142-29-0	L
Decahydronaphthalene	91-17-8	L
Dichlorofluoromethane (HCFC-21)	75-43-4	L
Dicyclopentadiene	77-73-6	L
Diethoxymethane	462-95-3	L
Diethylene glycol dimethyl ether	111-96-6	L
Dimethoxymethane	109-87-5	L
Dimethylamine	124-40-3	L
N,*N*-Dimethylformamide	68-12-2	L
Dimethyl-*p*-phenylenediamine	99-98-9	L
2,4-Dinitrophenol	51-28-5	L
Dioxane	123-91-1	L
Divinyl acetylene	821-08-9	L
2-Ethoxyethanol	110-80-5	L
Ethyl acrylate	140-88-5	L
Ethyl chloride	75-00-3	L
Ethyl cyanide	107-12-0	L
Ethyl ether	60-29-7	L
Ethylbenzene	100-41-4	L
Ethylene	74-85-1	L
Ethylene glycol dimethyl ether	110-71-4	L
Ethylidene dichloride	75-34-3	L
Ethyltrichlorosilane	115-21-9	L
Furan	110-00-9	L
Isobutyronitrile	78-82-0	L
Isopropyl benzene	98-82-8	L
Isopropyl ether	108-20-3	L
Methacrylonitrile	126-98-7	L
Methanol	67-56-1	L
2-Methoxyethanol	109-86-4	L
Methyl acetylene	74-99-7	L
Methyl acrylate	96-33-3	L
Methanol	67-56-1	L
Methyl cyclopentane	96-37-7	L
Methylisobutyl ketone (MIBK)	108-10-1	L
Methyl methracrylate	80-62-6	L
2-Methylpyridine	109-06-8	L
N-Methyl-2-pyrrolidone	872-50-4	L
Methyl *tert*-butyl ether	1634-04-4	L
Naphthalene	91-20-3	L
Nitrocyclohexane	1122-60-7	L
2-Nitropropane	79-46-9	L
2-Propanol	67-63-0	L
Propargyl alcohol	107-19-7	L
Propionaldehyde	123-38-6	L
Pyridine	110-86-1	L
Styrene	100-42-5	L
Tetrahydrofuran	109-99-9	L
Toluene	108-88-3	L
Vanadium (except when contained in an alloy)	7440-62-2	L
Vinyl acetate	108-05-4	L
Vinyl ether	109-93-3	L
Xylene (mixed isomers)	1330-20-7	L
o-Xylene	95-47-6	L
p-Xylene	106-42-3	L

Storage Group X*: Incompatible with All Other Storage Groups

Name	CAS #	Group
Acrolein	107-02-8	X

Storage Group X*: Incompatible with All Other Storage Groups

Name	CAS #	Group
Allyl alcohol	107-18-6	X
Allyl chloride	107-05-1	X
Allylamine	107-11-9	X
Aluminum	7429-90-5	X
Aniline	62-53-3	X
Benzyl azide	622-79-7	X
Bromine	7726-95-6	X
Butyllithium	109-72-8	X
Chloroethanol	107-07-3	X
Chloropicrin	76-06-2	X
p-Chlorophenyl isocyanate	104-12-1	X
Cobalt carbonyl	10210-68-1	X
Diazomethane	334-88-3	X
2,3-Dichloropropene	78-88-6	X
Diethyl sulfate	64-67-5	X
Dimethyldichlorosilane	75-78-5	X
1,1-Dimethylhydrazine	57-14-7	X
m-Dinitrobenzene	99-65-0	X
2,4-Dinitrotoluene	121-14-2	X
2,6-Dinitrotoluene	606-20-2	X
Dinitrotoluene (mixed isomers)	25321-14-6	X
Epichlorohydrin	106-89-8	X
Ethyleneimine	151-56-4	X
Hydrazine	302-01-2	X
Hydrogen cyanide	74-90-8	X
Hydrogen fluoride	7664-39-3	X
Iron, pentacarbonyl-	13463-40-6	X
Isothiocyanatomethane	556-61-6	X
Methyl chloroformate	79-22-1	X
Methyl isocyanate	624-83-9	X
2-Methyllactonitrile	75-86-5	X
Methyl mercaptan	74-93-1	X
Methyl vinyl ketone	78-94-4	X

Storage Group X*: Incompatible with All Other Storage Groups

Name	CAS #	Group
Methylene bromide	74-95-3	X
Methylenebis(phenylisocyanate) (MDI)	101-68-8	X
Nitrobenzene	98-95-3	X
Perchloric acid	7601-90-3	X
Phenyltrichlorosilane	98-13-5	X
Phosphorus	7723-14-0	X
Phosphorus oxychloride	10025-87-3	X
Phosphorus pentachloride	10026-13-8	X
Phosphorus trichloride	7719-12-2	X
Phthalic anhydride	85-44-9	X
Picric acid, moist (10-40% water)	88-89-1	X
Potassium cyanide	151-50-8	X
β-Propiolactone	57-57-8	X
Red phosphorus	7723-14-0	X
Sodium azide	26628-22-8	X
Sodium hydrogen sulfide	64568-18-9	X
Strychnine, sulfate	60-41-3	X
Sulfur trioxide	7446-11-9	X
Toluene-2,4-diisocyanate	584-84-9	X
Toluene-2,6-diisocyanate	91-08-7	X
Toluenediisocyanate (mixed isomers)	26471-62-5	X
Trichloroethylene	79-01-6	X

Appendix G

TRANSPORTING BIOLOGICAL MATERIALS IN PRIVATE MOTOR VEHICLES