

Lab Safety Guide/Manual - I

This training guide provides basic information for working safely with laboratory chemicals and equipment.

Responsibility for Laboratory Safety

- Ensure laboratory workers, including staff, students and volunteers, attend Laboratory Safety Training.
- Ensure laboratory workers understand the potential health and physical hazards of the chemicals and equipment used in the laboratory;
- Explain proper and safe procedures for handling, under all circumstances, the hazardous substances used in the laboratory;
- Provide appropriate engineering controls and personal protective equipment to allow laboratory workers to work safely: and
- Provide laboratory workers with the location and availability of the Departmental Chemical Hygiene Plan and reference materials, including material safety data sheets (MSDSs).
- Review and approve work with particularly hazardous substances.

Laboratory Workers

Each undergraduate, graduate student, faculty and staff member working in a research laboratory is expected to:

- Attend Laboratory Safety Training
- Review the departmental Chemical Hygiene Plan
- Follow procedures and laboratory practices outlined in the Chemical Hygiene Plan .
- Use engineering controls and personal protective equipment, as appropriate
- Report all accidents, near misses, and potential chemical exposures to your supervisor and/or Chemical Hygiene Officer

Environmental, Health and Safety Policy

College of Pharmacy, Jazan University is committed to providing a safe and healthful environment for its employees, students and visitors and managing the University in an environmentally sensitive and responsible manner. We further recognize an obligation to demonstrate safety and environmental leadership by maintaining the highest standards and serving as an example to our students as well as the community at large.

Laboratory Security Policy

Safeguarding University resources from unauthorized access, misuse or removal is a duty of all faculty and staff. In laboratories, this obligation rests primarily with the Principal Investigator; however, all laboratory personnel have a responsibility to take reasonable precautions against theft or misuse of materials, particularly those that could threaten the public. Any extraordinary laboratory security measures should be commensurate with the potential risks and imposed in a manner that does not unreasonably hamper research.

At a minimum, the institution expects all laboratory personnel to comply with the following security procedures:

- Question the presence of unfamiliar individuals in laboratories and report all suspicious activity immediately to the authority
- After normal business hours, all laboratories must be locked when not in use

Laboratory building exterior doors are secured after normal business hours. To minimize the likelihood of unauthorized access, all after-hours building users should:

- Avoid providing building access to unfamiliar individuals
- Secure doors behind them
- Immediately report any building security problem to the higher authority.

Research or other activities involving the use of lab space, materials or equipment without the knowledge and approval of the responsible Principal Investigator is strictly prohibited. Violation of this prohibition may result in disciplinary action up to and including termination.

SECTION 1: Emergency Procedures

- Fire Emergencies
- Chemical Exposures
- Emergency Information Posters
- Emergency Response Guidelines

For any emergency, including fires, chemical spills, injuries, accidents, explosions, and medical emergencies, call the doctor.

Fire Emergencies

In the event of a fire, Public Safety should be notified immediately and the following actions are recommended:

1. Put the fire out if you know how to do so without endangering yourself or others. University policy states that individuals are not required to fight fires, but that those who choose to do so may put out small, incipient stage fires (no bigger than a wastepaper basket) as long as they have been trained in the proper use of fire extinguishers.

- **If you have been trained in the use of a fire extinguisher**, fight the fire from a position where you can escape, only if you are confident that you will be successful. Small fires can often be extinguished. Be sure to use the correct fire extinguisher. See here for guidance.
- **A fire contained in a small vessel** can usually be suffocated by covering the vessel with a lid of some sort.



2. **If your clothing catches fire**, drop to the floor and roll to smother the fire. If a co-worker's clothing catches fire, get the person to the floor and roll him or her to smother the flames. Use a safety shower immediately thereafter.

3. **If the fire is large or spreading**, activate the fire alarm to alert building occupants. If possible, shut down any equipment which may add fuel to the fire. Do not turn off any hoods in the immediate area, as they will tend to keep the area free from smoke and fumes. Leave the fire area and prevent the fire's spread by closing the doors behind you.

4. **Evacuate** the building and await the arrival of Public Safety. Be prepared to inform them of the exact location, details of the fire, and chemicals that are stored and used in the area.

5. **Do not re-enter the building** until you are told to do so by Public Safety or the municipal fire official.

6. Contact Building Services to replace used fire extinguishers.

Chemical Exposures

The following procedures should be followed in the event of chemical exposure. In all cases, the incident should be reported to your laboratory manager, supervisor, or principal investigator, regardless of severity.

Chemicals on Skin

1. Immediately flush with water for no less than fifteen minutes. For larger spills the safety shower should be used. While using the safety shower, remove any contaminated jewelry or clothing. For pullover shirts and sweaters, it may be beneficial to cut garments off to prevent contamination of the eyes.



Hydrofluoric Acid: Flush with water for 5 minutes. Apply 2.5% calcium gluconate gel, a tube for your lab can be obtained prior through EHS. If not readily available, continue rinsing for 15 minutes. In all cases, seek medical attention immediately.

Phenol (>10%): Flush with water until affected area turns from white to pink. Apply a solution of 400 molecular weight polyethylene glycol if available. Do not use ethanol.

Water-reactive Solids: Brush off as much solid as possible. Proceed with rinsing.

2. If immediate medical attention is needed, call for an ambulance or transportation to hospital. Explain carefully what chemicals were involved.
3. Discard contaminated clothing or launder them separately. Do not reuse leather materials.

Chemicals in Eyes

1. Flush eye(s) with water for at least fifteen 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 eye wash fountain is desirable so hands are free to hold the eyes open. If no eyewash is available, rinse from the nose outward to avoid contaminating the unaffected eye.
2. Remove contact lenses while rinsing. Do not attempt to rinse and reinsert contact lenses.

Chemical Inhalation

1. Close containers, open windows or otherwise increase ventilation, and move to fresh air.
2. If symptoms, such as headaches, nose or throat irritation, dizziness, or drowsiness persist, seek medical attention by calling Public Safety. Explain carefully what chemicals were involved.



Accidental Ingestion of Chemicals

1. Immediately go to hospital or contact the Poison Control Center for instructions. Do not induce vomiting unless directed to do so by a health care provider. Explain carefully what chemicals were involved.

Accidental Injection of Chemicals

1. Wash the area with soap and water.
2. Seek medical attention, if necessary. Explain carefully what chemicals were involved.

Emergency Information Posters

When fires or other emergencies occur in University facilities, several agencies may respond, including the University's Department of Public Safety, the Princeton Police and Fire Departments, Hazardous Materials Response Teams from Trenton or Hamilton Township, the Princeton First Aid and Rescue Squad, or the New Jersey Department of Environmental Protection. In most instances, the individuals that respond have little or no familiarity with either the building or the specific activities that take place within.

The purpose of the Emergency Information Poster is to provide an easily recognizable and consistent means of displaying essential information about the status and content of laboratories or other facilities, primarily for the benefit of the emergency responders. Such information is not only important for the safety of emergency personnel, but is often of considerable value in evaluating and mitigating the emergency.

Emergency Information Posters are required for any room or space where there are hazardous materials used or stored. Posters may also be used for other rooms with lesser hazards at the discretion of the person responsible for that room.

During an emergency, the poster may be used as the primary source of information about a room or space. Therefore, the information on the poster should be complete and accurate. The following information should be supplied on every poster:

- Responsible individuals - List those who are most familiar with the activities in the room.
- Room diagram - A drawing of the room, showing important items such as fume hoods, storage cabinets, lab benches, etc.
- Hazard class - Hazardous materials found in the room should be identified and listed on the poster when quantities exceed the threshold levels.
- Posting/Review Dates - Posters should be reviewed to insure all information is current and initialed at six month intervals, and replaced every two years.
- Additional information - This allows narrative comments by the user on material, storage conditions, unusual hazards, etc.

A copy of the poster should be placed on or near every entrance to the room.

Emergency Response Guidelines

The Emergency Response Guidelines for Laboratory Workers booklet is intended to provide simple guidelines that may be useful in the event of a fire, medical emergency, chemical, biological or radiological spill or personal contamination in the laboratory.

The booklets are designed to be posted on the wall with Velcro® and should be located in each laboratory. The cover of the booklet lists the Department Safety Manager, Chemical Hygiene Officer and Evacuation Assembly Area for the appropriate building/department.

SECTION 2: General Information About Chemical Safety

- Routes of Entry
- Toxic Effects of Chemical Exposure
- High Acute Toxicity
- Carcinogens
- Reproductive Toxins

The decisions you make concerning the use of chemicals in the laboratory should be based on an objective analysis of the hazards, rather than merely the perception of the risks involved. Once this has been accomplished, a reasonable means of controlling the hazards through experimental protocol, work practices, ventilation, use of protective clothing, etc., can be evaluated. In order to assess the hazards of a particular chemical, both the physical and health hazards of the chemical must be considered.

The physical hazards of a chemical include its **flammability**, **corrosivity** and **reactivity**. **Flammability** is the tendency of a chemical to burn. The flashpoint, autoignition temperature and flammable limits of the material may be found in the material safety data sheet (MSDS), and are helpful in assessing the potential for a fire hazard under specified conditions. **Corrosivity** is a chemical's potential to degrade materials by a chemical reaction. Corrosivity of acidic and basic liquids is measured by their pH, or concentration of (H⁺) protons. **Reactivity** is the potential of the material to explode or react violently with air, water or other substances upon contact. The MSDS furnishes this information in the *Reactivity Data* section.

Before using any chemical, the MSDS or other appropriate source should be reviewed to determine what conditions of use might pose a hazard. Accidents with hazardous chemicals can happen quickly and may be quite severe. The key to prevention of these accidents is awareness. Once the hazards are known, the risk of an accident may be significantly reduced by using safe work practices.

2 A. Health Hazards of Chemicals

The health effects of hazardous chemicals are often less clear than the physical hazards. Data on the health effects of chemical exposure, especially from chronic exposure, are often incomplete. When discussing the health effects of chemicals, two terms are often used interchangeably - *toxicity* and *hazard*. However, the actual meanings of these words are quite different. *Toxicity* is an inherent property of a material, similar to its physical constants. It 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*. Thus, with proper handling, highly toxic chemicals can be used safely. Conversely, less toxic chemicals can be extremely hazardous if handled improperly.

RISK = TOXICITY X EXPOSURE

The health risk of a chemical is a function of the toxicity and the 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.

Routes of Entry

Skin and Eye 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 MSDS usually includes information regarding whether or not skin absorption is a significant route of exposure.



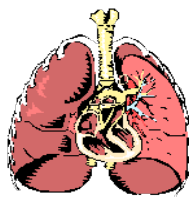
The absorption of a chemical through intact skin is influenced by the health of the skin and the properties of the chemical. Skin that is dry or cracked or has lacerations offers less resistance. Fat-soluble substances, such as many organic solvents, can easily penetrate skin and, in some instances,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

Wear gloves and other protective clothing to minimize skin exposure. See Section 3, Personal Protective Equipment for more information. Symptoms of skin exposure include dry, whitened skin, redness and swelling, rashes or blisters, and itching. In the event of chemical contact on skin, rinse the affected area with water for at least 15 minutes, removing contaminated clothing while rinsing, if necessary.

Chemical contact with eyes can be particularly dangerous, resulting in painful injury or loss of sight. Wearing safety glasses or chemical splash goggles can reduce the risk of eye contact. Eyes that have been in contact with chemicals should be rinsed immediately with water continuously for at least 15 minutes. Contact lenses should be removed while rinsing—do not delay rinsing to remove the lenses. Medical attention is necessary if symptoms persist. See Section 1, Emergency Procedures, for more information.

Inhalation

The respiratory tract is the most common route of entry for gases, vapors and particles. 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. The vapor pressure describes how quickly a substance evaporates into the air – 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. 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 over-exposure 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 to many solvents. In the event of exposure, close containers, open windows 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, preferably a fume hood, to reduce the potential of exposure. Occasionally, ventilation may not be adequate and a fume hood may not be practical, necessitating the use of a respirator. The use of a respirator is subject to prior review by EHS according to University policy, since the federal Occupational Safety and Health Administration Respiratory Protection Standard regulates their use. See Section 3, Personal Protective Equipment for more information.

Ingestion

The gastrointestinal tract is another possible route of entry for toxic substances. Although direct ingestion of a laboratory chemical is unlikely, exposure may occur as a result of ingesting contaminated food or beverages, touching the mouth with contaminated fingers, or swallowing inhaled particles which 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 as a result of the outdated and dangerous practice of mouth pipetting. In the event of accidental ingestion, immediately go to McCosh Health Center or contact the Poison Control Center, at 800-962-1253 for instructions. Do not induce vomiting unless directed to do so by a health care provider.

Injection



The final possible route of exposure to chemicals is by injection. Injection effectively bypasses the protection provided by intact skin and provides direct access to the bloodstream, thus, to internal organ systems. Injection may occur through mishaps with syringe needles, when handling animals, or through accidents with pipettes, broken glassware or other sharp objects that have been contaminated with toxic substances.

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

Toxic Effects Of Chemical Exposure

How a chemical exposure affects a person depends on many factors. The dose is the amount of a chemical that actually 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 Chemicals

The toxic effects of a chemical may be *local* or *systemic*. Local 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, alkalis 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 effect the central nervous system.

Certain chemicals may affect a target organ. For example, lead primarily affects the brain, kidney 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* toxicity results from a single, short exposure. Effects usually appear quickly and are usually 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. Acute and chronic effects are distinguished in the MSDS, usually with more information about acute exposures than chronic.

Evaluating Toxicity Data

The toxicity of a chemical is usually expressed as the *quantity* of the material or the *dose* required to exert a specific effect. It is difficult to obtain useful data on chemical toxicity. 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 LD50 (lethal dose 50) – the dose required to kill 50% of the test population. The LD50 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 LC50. See Table 1 for examples.

Table 1: Toxicity Ratings Based on LD50

| Class | LD50 | Lethal Dose based on a 70 kg person | Examples |
|------------------|--------------|--|------------------------------|
| Super Toxic | <5mg/kg | A taste (7 drops or less) | Dioxin, Botulinum |
| Extremely Toxic | 5-50mg/kg | 1 teaspoon | Arsenic trioxide, Strychnine |
| Very Toxic | 50-500 mg/kg | 1 ounce | Phenol, Caffeine |
| Moderately Toxic | 0.5-5g/kg | 1 pint | Aspirin, Sodium chloride |
| Slightly Toxic | 5-15g/kg | 1 quart | Ethanol, Acetone |

To estimate a lethal dose for a human based on animal tests, the LD50 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.

Very 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.

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.

Over a period of time, 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.

Particularly Hazardous Substances

The OSHA Laboratory Standard defines a particularly hazardous substance as “select carcinogens”, reproductive toxins, and substances that have a high degree of acute toxicity. The Chemical Hygiene Plan and Laboratory Safety Manual outline provisions for additional protection when working with these agents, including establishment of a designated area, use of containment devices such as a fume hood or glove box, procedures for safe removal of contaminated waste, and decontamination procedures. For more information on handling particularly hazardous substances, contact your departmental Chemical Hygiene Officer or Section 7.10 of the Lab Safety Manual.

High Acute Toxicity

Substances with high acute toxicity may be fatal or cause damage to a target organ as a result of a single exposure or an exposure of short duration. Examples include hydrogen cyanide, dimethylmercury, and diisopropyl fluorophosphate. Special care must be taken when working with these substances.

Carcinogens

Many chemicals have been evaluated for their ability to cause cancer. The latency period for most cancers ranges from twenty to forty years. The risk of developing cancer from exposure to a chemical increases with the length of exposure and with the exposure concentration.

It is important to understand the distinction between **human carcinogens** and **suspected human carcinogens**. The term *human carcinogen* is used when there is clear evidence of the ability to cause cancer in humans. *Suspected human carcinogen* refers to chemicals that have been shown to cause cancer in two or more animal species and are therefore suspect in humans. Prudent behavior dictates that a suspected human carcinogen be handled in the laboratory the same as a known human carcinogen.

Anyone who works with, or plans to work with carcinogens or suspected carcinogens must follow the guidelines outlined in the *Particularly Hazardous Substances* section of the Lab Safety Manual. Lists of known and suspected carcinogens may be found in the appendices of the Lab Safety Manual. For a particular substance, the *Toxicity Data* section of the Material Safety Data Sheet may be consulted to determine whether or not the substance is considered a carcinogen by the Occupational Safety and Health Administration (OSHA), the National Toxicology Program (NTP) or the International Association for Research on Cancer (IARC).

Reproductive Toxins

Reproductive toxins are chemicals which affect the reproductive system, including mutagens (those which cause chromosomal damage) and embryotoxins. Embryotoxins may be lethal to the fertilized egg, embryo or fetus, may be teratogenic (able to cause fetal malformations), may retard growth or may cause post-natal functional deficiencies. Other reproductive toxins may cause sterility or may affect sperm motility.



Some chemicals may cross the placenta, exposing the fetus. A developing fetus may be more sensitive to some chemicals than its pregnant mother, particularly during the first twelve weeks of pregnancy, when the mother may not know she is pregnant. Proper handling of chemicals and use of protective equipment is especially important to reduce fetal exposure to chemicals.

Known human teratogens include organic mercury compounds, lead compounds, glycol ethers, ionizing radiation, some drugs, alcohol ingestion, and cigarette smoking. Some substances that may cause adverse reproductive effects in males include 1,2-dibromo-3-chloropropane, cadmium, mercury, boron, lead, some pesticides, and some drugs. More than 800 chemicals have been shown to be teratogenic in animal models - many of these are suspected human teratogens. A partial list is included in the appendices of the Laboratory Safety Manual.

Laboratory workers who are contemplating pregnancy or are pregnant should review the toxicity of the chemicals in their laboratory and may consult with the departmental Chemical Hygiene Officer or EHS to determine whether any of the materials used in the laboratory pose additional risk during pregnancy. EHS provides confidential counseling to help determine what actions are recommended.

Where To Find Toxicity Information

Toxicity information may be found in Material Safety Data Sheets, under the "Health Hazard Data" section, on product labels, in the Registry of Toxic Effects of Chemical Substances (RTECS), or in many other sources listed in the Health and Safety Reference Guide in Appendix E. For more information, contact Environmental Health and Safety at x8-5294.

SECTION 2B: Chemical and Hazard Identification

- Labels
- Material Safety Data Sheets



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

Labels

The manufacturer's label should be kept intact. Do not intentionally deface or obscure the label or the hazard warnings. When a chemical is transferred from the original container into a secondary container for storage, the new container should be labeled with the name of the product, the chemical constituents and the primary hazard warnings.

All chemical manufacturers or distributors are required to conduct a hazard evaluation of their products and include the information on a material safety data sheet (MSDS). The manufacturer or distributor is required to provide an MSDS with the initial shipment of their products. Any MSDSs received by the laboratory must be maintained in a central location in the laboratory or

the department. Check with your Chemical Hygiene Officer to determine what to do with the MSDSs you receive.

If an MSDS is not on hand, check the EHS web page www.princeton.edu/sites/ehs/MSDS/msds.htm for connections to on-line sources of MSDSs. If the MSDS cannot be found, contact the manufacturer or distributor at the number listed on the container label and request an MSDS. If the manufacturer does not provide one within a few days, contact EHS for assistance.

If an MSDS is not on hand, check the MSDS page of the EHS web site for connections to on-line sources of MSDSs. If the MSDS cannot be found, contact the manufacturer or distributor at the number listed on the container label and request an MSDS. If the manufacturer does not provide one within a few days, contact EHS for assistance.

Appendix D of this guide provides guidance for interpreting the information contained in the MSDS.

SECTION 2C: Flammable Liquids

- Properties of Flammable and Combustible Liquids
- Storage Containers
- Storage Considerations
- Handling Precautions
- Flammable Aerosols

Properties of Flammable and Combustible Liquids (top)

To control the potential hazards posed by handling flammable and combustible liquids, several properties of these materials should be understood. Information on the properties of a specific liquid can be found in that liquid's Material Safety Data Sheet (MSDS), or other reference material.

It is the liquid's vapor rather than the liquid itself that ignites when mixed in certain proportions with air in the presence of an ignition source. Flammable and combustible liquids vaporize and form flammable mixtures with air when in open containers, when leaks occur, or when heated. **Volatility** is the tendency or ability of a liquid to vaporize. **Vapor pressure** is a measure of a liquid's volatility. A high vapor pressure usually is an indication of a volatile liquid, or one that readily vaporizes. The **boiling point** is the temperature at which the vapor pressure equals atmospheric pressure, such that the pressure of the atmosphere can no longer hold the liquid in a liquid state and bubbles begin to form. In general, a low boiling point indicates a high vapor pressure and, possibly, an increased fire hazard.

An important characteristic of any flammable or combustible liquid is its **flashpoint**. Flashpoint is the minimum temperature at which the vapor concentration near the surface of the liquid is

high enough to form an ignitable mixture. Any liquid with a flashpoint less than 100oF is considered to be a flammable liquid. A liquid with a flashpoint between 100oF and 200oF is combustible. In general, the relative hazard of a flammable liquid increase as the flashpoint decreases.

The proportion of vapor to air mixture that is ignitable is referred to as the *flammable range*, and is expressed in terms of percentage of vapor in air by volume. The flammable range is bounded by the *Lower Flammable Limit (LFL)* and the *Upper Flammable Limit (UFL)*. The LFL is the minimum concentration of flammable liquid vapor in air that will support the *propagation of flame*, or spread of flame through the entire volume of vapor-air mixture, upon contact with an ignition source. The UFL is the maximum concentration of vapor in air that will support the propagation of flame. It is important to note that vapor-air mixtures below the LFL may burn at the ignition source without propagating away from the point of ignition.

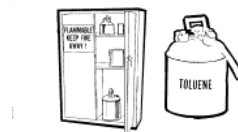
The *auto ignition temperature* is the minimum temperature at which a vapor-air mixture will spontaneously ignite, without the necessity of a spark or flame.

Vapor density is a measure of a vapor's weight when compared to air. Air is assigned a value of 1. Heavier, or denser, vapors tend to sink to floor level while lighter, less dense vapors tend to rise to ceiling level. This property must be taken into account when working with flammable or combustible liquids outside of fume hoods. Most flammable liquid vapors are heavier than air. These vapors can travel some distance and encounter ignition sources remote from the workstation.

Storage Containers

Flammable and combustible liquids should be stored in only certain types of approved containers. Approval for containers is based on specifications developed by organizations such as OSHA, National Fire Protection Association (NFPA), or American National Standards Institute (ANSI). Containers used by the manufacturers of flammable and combustible liquids generally meet these specifications.

Different types of containers are required depending on the quantities and classes of flammable or combustible liquids. 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. A closed container is one sealed by a lid or other device so that liquid and vapor cannot escape at ordinary temperatures.



A *flammable liquid storage cabinet* is an approved cabinet that has been designed and constructed to protect the contents from external fires. Storage cabinets are usually equipped with vents, which are plugged by the cabinet manufacturer. Venting is not required by any code or the local municipalities and may actually prevent the cabinet from protecting its

contents. Therefore, vents should remain plugged at all times. Storage cabinets must also be conspicuously labeled ***“FLAMMABLE – KEEP FIRE AWAY”***.

Use only those refrigerators that have been designed and manufactured for flammable liquid storage. Standard household refrigerators must not be used for flammable storage. Refrigerators must be prominently labeled as to whether or not they are suitable for flammable liquid storage.

Storage Considerations

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

- No more than 10 gallons of flammable and combustible liquids, combined, should be stored outside of a flammable storage cabinet unless safety cans are used. When safety cans are used up to 25 gallons may be stored without using a flammable storage cabinet.
- Storage of flammable liquids must not obstruct any exit.
- Flammable liquids should be stored separately from strong oxidizers, shielded from direct sunlight, and away from heat sources.

Handling Precautions

- Control all ignition sources in areas where flammable liquids are used. Smoking, open flames and spark producing equipment should not be used.
- Whenever possible use approved safety cans, plastic or metal containers.
- When working with open containers, use a laboratory fume hood to control the accumulation of flammable vapor.
- Use bottle carriers for transporting glass containers.
- 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.

Flammable Aerosols

Flammable aerosols are in pressurized containers that may rupture when exposed to fire. As with flammable liquids, these should be stored in a flammable storage cabinet.

SECTION 2D: Peroxide Forming Compounds and Reactives

- Recommended Work Practices
- Detection of Peroxides
- Removal of Peroxides

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

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.

Near the end of this section is a list of examples of peroxidizable compounds that should be extended to include primary and secondary alcohols, allylic-benzylic alcohols, ketones, and, possibly, aralkanes with benzylic hydrogens.

Recommended Work Practices

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

- Know the properties and hazards of all chemicals you are using through adequate research and study, including reading the label and MSDS.
- Inventory all chemical storage at least twice a year to detect forgotten items, leaking containers, and those that need to be discarded.
- Identify chemicals that form peroxides or otherwise deteriorate or become more hazardous with age or exposure to air. Label containers with the date first opened and the date for disposal as recommended by the supplier.
- Minimize peroxide formation in ethers by storing 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.
- Choose the size container that will ensure use of the entire contents within a short period of time.
- Require testing for peroxides of any opened containers before use.
- Clean up spills immediately (Section 8). The safest method is to absorb the material onto vermiculite or a similar loose absorbent.
- 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.
- 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.
- Do not use metal spatulas or magnetic stirring bars (which may leach out iron), since contamination with metals can lead to explosive decomposition. Ceramic, Teflon or wooden spatulas and stirring blades are usually safe to use.
- Do not use glass containers with screw-top lids or glass stoppers. Polyethylene bottles with screw-top lids may be used.

TABLE 2: Examples of Peroxidizable Compounds

| Peroxide Hazard on Storage: D i s c a r d A f t e r T h r e e M o n t h s | |
|---|---|
| Divinyl acetylene Divinyl ether Isopropyl ether | Potassium metal Sodium amide Vinylidene chloride |
| Peroxide Hazard on Concentration: D i s c a r d A f t e r O n e Y e a r | |
| Acetal Cumene Cyclohexene Cyclooxyene 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*: D i s c a r d A f t e r O n e Y e a r | |
| 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.

Detection of Peroxides

Peroxide test strips, which change color to indicate the presence of peroxides, may be purchased through most laboratory reagent distributors. For proper testing, reference the manufacturer's instruction. Do not perform a peroxide test on outdated materials

that potentially have dangerous levels of peroxide formation

Removal of Peroxides

If peroxides are anticipated, the safest route is to alert EHS and dispose of the material as hazardous waste. Attempting to remove peroxides may be very dangerous under some conditions.

SECTION 2E: Corrosives

- Chemicals
- Hydrofluoric Acid
- Phenol

Chemicals

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 to the gastrointestinal system by ingestion.

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. Keep in mind the concentration of the chemical directly affects its corrosive properties. Vinegar and glacial acetic acid are chemically identical. Both are solutions of acetic acid, vinegar-7%, glacial acetic acid-100%. Vinegar is found in salad dressing, whereas glacial acetic acid is very corrosive to human tissue and can even be ignited.

The following should be considered:

1. The eyes are particularly vulnerable. It is therefore essential that eye and face protection be worn in all laboratories where corrosive chemicals are handled.
2. Gloves and other chemically resistant protective clothing should be worn to protect against skin contact.
3. To avoid a flash steam explosion due to the large amount of heat evolved, always add acids or bases to water (and not the reverse).
4. Acids and bases should be segregated for storage.

5. Liquid corrosives should be stored below eye level.
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.

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.

1. 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.
2. Perform manipulations of materials that pose an inhalation hazard in a chemical fume hood to control exposure or wear appropriate respiratory protection.
3. Protect all exposed skin surfaces from contact with corrosive or irritating gases and vapors.

Hydrofluoric Acid

Hydrofluoric acid is particularly dangerous, since skin or eye contact with liquid or vapors may result in deep, painful, slow-healing burns. Burns from dilute solutions (< 50% HF) may not become apparent for several hours after contact. Hydrofluoric acid readily penetrates the skin, allowing the fluoride ion to destroy soft tissue and decalcify bone. Inhalation of hydrofluoric acid gas or vapor can seriously damage lungs and may be fatal.

In the event of hydrofluoric acid exposure to skin or eyes, immediately rinse with water for 5 minutes and apply calcium gluconate gel. If no gel is available, continue rinsing for 15 minutes. In both cases, seek medical attention. If hydrofluoric acid is ingested or inhaled, call 911 immediately for medical attention.

Calcium gluconate gel has a shelf life of approximately two years. Tubes of gel for your laboratory can be purchased directly from EHS.

Hydrofluoric acid reacts with glass, ceramics and some metals. Solutions should be stored in high-density polyethylene containers.

Spills of hydrofluoric acid may be soaked up with compatible spill pillows such as PowerSorb® or PolySorb®. Note that many spill pillows (e.g., Hazorb®, Chemsorb®) cannot be used for hydrofluoric acid. Be sure to have appropriate spill control materials available in sufficient quantity.

Phenol

Phenol is commonly used in many laboratories at Princeton. It is irritating to the skin, eyes and respiratory tract, but has a local anesthetic effect, so that no pain may be felt on initial contact. Normally, skin contact will result in whitening of the skin, which may later develop into severe burns.

Phenol is also rapidly absorbed through the skin, and toxic or even fatal amounts can be absorbed through relatively small areas. Exposure to phenol vapor from any route may cause nausea, vomiting, muscle weakness and coma. Eye exposure may lead to blindness.

In the event of skin exposure to concentrations of 10% or more phenol, flush with water for 15 minutes or until the affected area turns from white to pink. Apply a solution of 400 molecular weight polyethylene glycol, if available. Do not use ethanol. Seek medical attention. Alert medical personnel that skin exposure is a significant route for systemic exposure.

SECTION 2F: Compressed Gases

- Primary Hazards
- Handling Storage and Use of Gases
- Highly Toxic Gases
- Handling Leaking Cylinders

Compressed gases can be toxic, flammable, oxidizing, corrosive, inert, or some combination of these hazards. In addition to the chemical hazards, the amount of energy resulting from the compression of the gas makes a compressed gas cylinder a potential rocket. Appropriate care in the handling and storage of compressed gas cylinders is essential. Following are general recommendations.

1. **Know and Understand Gas Properties:** Know and understand the properties, uses, and safety precautions before using any gas or gas mixture. Consult Material Safety Data Sheets (MSDSs) for safety information on the gases that you will be using.
2. **Check Equipment:** Leak test lines and equipment before they are used. Lines and equipment should be designed and maintained to handle full cylinder pressure. Materials of construction should be compatible with the gases being used.
3. **When in Doubt, Contact Environmental Health & Safety:** If you are unfamiliar with the hazards associated with a particular gas or unsure of the correct handling and storage procedures, call Environmental Health & Safety at 8-5294.



Primary Hazards

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

- **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.
- **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 combustion of flammable 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.
- **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 tissue.
- **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.
- **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 flailing an air hose.
- **Improper Handling of Cylinders:** Compressed gas cylinders are heavy and awkward to handle. Improper handling of cylinders could result in sprains, strains, falls, bruises, and broken bones. Other hazards such as fire, explosion, chemical burns, poisoning, and cold burns could occur if gases accidentally escape from the cylinder due to mishandling.

Handling, Storage, and Use of Gases

Only persons familiar with the hazards should handle compressed gas cylinders. All cylinder movement should be done with material handling equipment. Always secure the cylinders when in storage or use. Safety glasses, work gloves, and appropriate work shoes should be worn.

Compressed gas cylinders should not be subjected to any mechanical shock that could cause damage to their valves or pressure relief devices. Cylinders should not be dropped, dragged, slid, or used as rollers for moving material or other equipment. Use cylinder carts to transport cylinders.

Cylinder caps perform two functions. First, they protect the valve on the top of the cylinder from damage if it is knocked over. Second, if gas is accidentally released through the valve, the cap will vent the gas out of both sides, minimizing the likelihood that the cylinder will topple. Cylinder caps should not be removed until the cylinder is secured in place and ready for use.

Cylinder Storage Precautions

Several precautions should be taken during storage of compressed gas cylinders. Full and empty cylinders should be stored separately. Cylinders should be stored upright and secured at all times. Oxidizers and flammable gases must be stored in areas separated by at least 20 feet or by a noncombustible wall.

All cylinders should either have a cylinder cap in place or be attached to a regulator. Do not store cylinders with nothing protecting the neck.

Do not store **acetylene** cylinders on their side. If an acetylene cylinder has tipped over or was stored on its side, carefully place the cylinder upright and do not use until the liquid has settled to the bottom. The rule of thumb is not to use the cylinder for as many minutes as the cylinder was on its side, up to 24 hours.

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

Things to Keep Away from Cylinders

Several precautions should be taken to prevent the release of high-pressure gases, fire, and explosion. Compressed gas cylinders should not be exposed to sparks, flames, or temperatures above 125°F. Cylinders should not be placed where they could come into contact with any electrical apparatus or circuits.

Smoking and open flames should not be permitted in areas used for storage of **oxygen** or flammable gas cylinders. Never permit oil, grease, or other combustible substances to come into contact with oxygen or other oxidizing gas cylinders, valves, and systems.

Returning Cylinders

When returning an empty cylinder, close the valve before shipment, leaving 25 psig of residual pressure in the cylinder. Replace the valve cap and any valve outlet caps or plugs originally shipped with the cylinder. If repair is needed on a cylinder or its valve, be sure to mark it and return it to the supplier.

Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed. Since many distributors and manufacturers do not take back lecture bottles, always check before purchasing the cylinder and opt for returnable or refillable cylinders. See

the EHS web page (www.princeton.edu/~ehs/lecturebottles.html) for a list of distributors that offer returnable or refillable cylinders

Highly Toxic Gases

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. Use of these materials requires written approval by the Principal Investigator or supervisor.

The following additional precautions must be taken:

- Use and store in a specially ventilated gas cabinet or fume hood.
- Use coaxial (double walled) tubing with nitrogen between the walls for feed lines operating above atmospheric pressure.
- Regulators should be equipped with an automatic shut-off to turn off gas supply in the event of sudden loss of pressure in the supply line.
- 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.
- Self-contained breathing apparatus (SCBA) may be appropriate for changing cylinders of highly toxic gases. Use of an SCBA requires enrollment in the Respiratory Protection Program and annual training and fit-testing.

Handling Leaking Cylinders

Most leaks occur at the valve in 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.

Where action can be taken without serious exposure to lab personnel, move the cylinder to an isolated, well-ventilated area (away from combustible materials if the cylinder contains a flammable or oxidizing gas) and contact Public Safety.

Whenever a large or uncontrollable leak occurs, evacuate the area and immediately contact Public Safety.

SECTION 2G: Cryogenics

- Handling Cryogenic Liquids
- Protective Clothing

Many of the safety precautions observed for compressed gases also apply to cryogenic liquids. Two important properties distinguish cryogenic liquids from compressed gases and present additional potential hazards:

- By definition, all cryogenic liquids exist at very low temperatures. The common cryogenic liquids include carbon dioxide, argon (-302°F), hydrogen (-423°F), nitrogen (-320°F), and oxygen (-297°F). Their cold boil-off vapor rapidly freezes human tissue. Most metals become stronger upon exposure to cold temperatures, but materials such as carbon steel, plastics, and rubber become brittle or even fracture under stress at these temperatures. Proper material selection is important. Cold burns and frostbite caused by cryogenic liquids can result in extensive tissue damage.
- All cryogenic liquids produce large volumes of gas when they vaporize. Liquid nitrogen will expand 696 times as it vaporizes. The expansion ratio of argon is 847:1, hydrogen is 851:1, and oxygen is 862:1. If these liquids vaporize in a sealed container, they can produce enormous pressures that could rupture the vessel. For this reason, pressurized cryogenic containers are usually protected with multiple pressure relief devices. Primary protection is usually a pressure relief valve; secondary protection is a frangible disc.

Vaporization of cryogenic liquids (except oxygen) in an enclosed area can cause asphyxiation. Vaporization of liquid oxygen can produce an oxygen-rich atmosphere. Although oxygen is not flammable, it is an oxidant and will support and accelerate the combustion of other materials. Vaporization of liquid hydrogen can form an extremely flammable mixture with air. **Do not purchase or plan to use liquid oxygen or liquid hydrogen without consulting EHS.**

Handling Cryogenic Liquids

Most cryogenic liquids are odorless, colorless, and tasteless when vaporized. When cryogenic liquids are exposed to the atmosphere, the cold boil-off gases condense the moisture in the air, creating a highly visible fog.

Always handle these liquids carefully. Because of their extremely low temperatures, they can produce cryogenic burns and frostbite. When spilled on a surface, they tend to cover it completely and, therefore, cool a large area. The vapors from these liquids are also extremely cold and can produce burns. Exposure that may be too brief to affect the skin of the face or hands may damage delicate tissues, such as the eyes.

Boiling and splashing always occur when charging or filling a warm container with cryogenic liquid or when inserting objects into these liquids. Perform these tasks slowly to minimize boiling and splashing. Use tongs to withdraw objects immersed in a cryogenic liquid.

Never touch uninsulated pipes or vessels containing cryogenic liquids. Flesh will stick to extremely cold materials. Even nonmetallic materials are dangerous to touch at low temperatures. In addition to the hazards of frostbite or flesh sticking to cold materials, objects that are soft and pliable at room temperature, such as rubber or plastic, become hard and brittle and break easily at these extremely low temperatures.

Protective Clothing

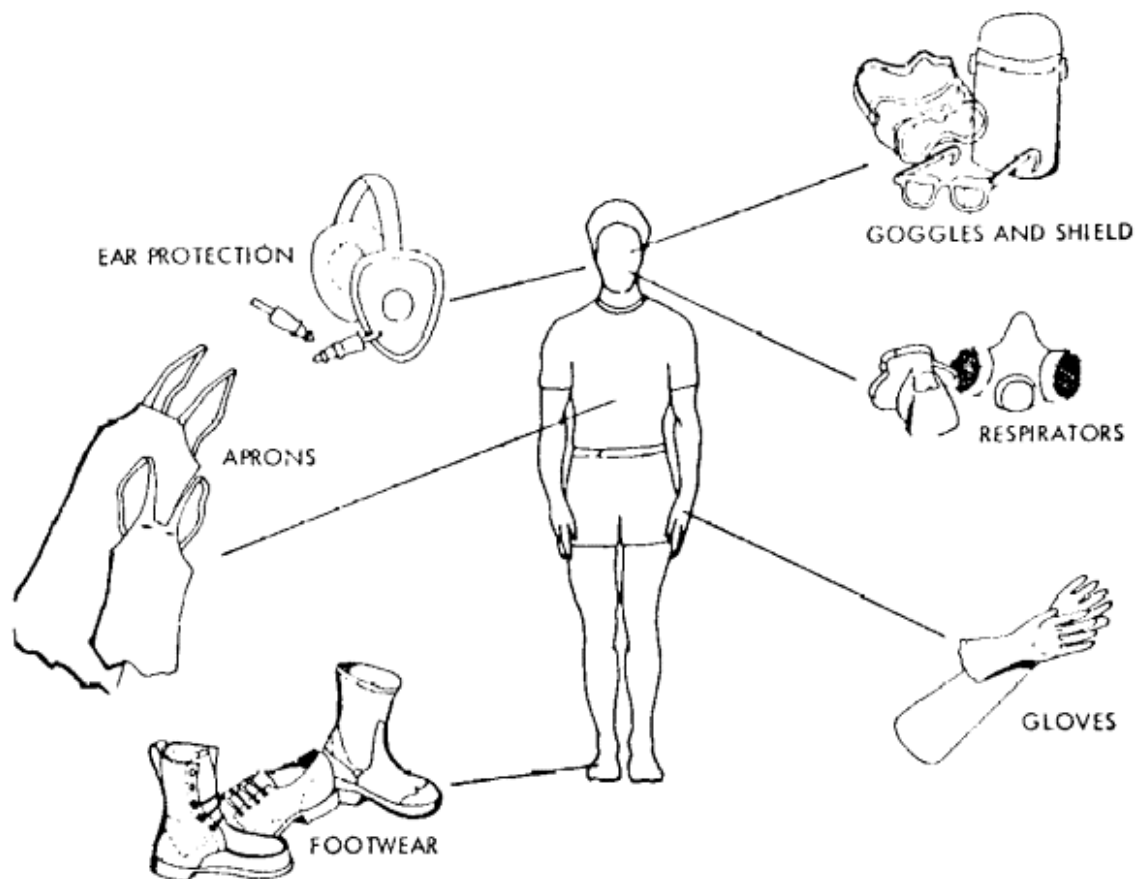
Face shields are recommended during transfer and handling of cryogenic liquids. If severe spraying or splashing could occur, safety glasses or chemical goggles will provide additional protection.

Wear loose-fitting, dry leather gloves or Cryo-gloves® when handling objects that come into contact with cryogenic liquids and vapor. Trousers should be worn on the outside of boots or work shoes.

SECTION 3: Personal Protective Equipment

- Gloves
- Respiratory Protection
- Eye Protection
- Protective Clothing and Footwear

Personal protective equipment (PPE) is special gear used to protect the wearer from specific hazards of a hazardous substance. It is a last resort protection system, to be used when substitution or engineering controls are not feasible. It should be understood that PPE does not reduce or eliminate the hazard. It only protects the wearer and does nothing for anybody else in the area or for any equipment exposed to the chemical.



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.

Gloves

Glove Selection And Use

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.

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

When Should Gloves Be Worn

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. When handling chemicals in a laboratory, disposable latex, vinyl or nitrile examination gloves are usually appropriate for most circumstances. These gloves will offer protection from incidental splashes or contact.



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 should be selected, based on chemical compatibility.

Selecting the Appropriate Glove Material

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

- degradation rating
- breakthrough time
- permeation rate

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. When looking at a chemical compatibility chart, degradation is usually reported as E (excellent), G (good), F (fair), P (poor), NR (not recommended) or NT (not tested).

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.

Permeation rate is the rate at which the test chemical passes through the glove material once 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. 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 permeation rate is not measured and is reported ND (none detected).

Manufacturers stress that permeation and degradation tests are done under laboratory test conditions, which can vary significantly from actual end-use conditions. 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 shortest 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. Poor for aliphatic, aromatic hydrocarbons, halogenated hydrocarbons, and gasoline. |
| Neoprene | Good for acids and bases, peroxides, fuels, hydrocarbons, alcohols, phenols. Poor for halogenated and aromatic hydrocarbons |
| 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 |
| PVC | Provides excellent abrasion resistance and protection from most fats, acids, and petroleum hydrocarbons. Poor for most organics. |
| PVA | Highly impermeable to gases. Excellent protection from aromatic and chlorinated solvents. Cannot be used in water or water-based solutions. |
| Viton | Exceptional resistance to chlorinated and aromatic solvents. Good resistance to cuts and abrasions. |
| Silver Shield | Resists a wide variety of toxic and hazardous chemicals. Provides the highest level of overall chemical resistance. |
| 4H | Same as Silver Shield, but offers better dexterity. |
| Natural (Latex) rubber | Good for very dilute acids and bases. Poor for organics. |

Where to Find Compatibility Information

Most glove manufacturers have chemical compatibility charts available for their gloves. These charts may be found in laboratory supply catalogs such as *Fisher Scientific* and *Lab Safety Supply*. Best Gloves offers copies of their glove compatibility charts upon request. To obtain a copy, call them directly at 800-241-0323. Best Gloves also offers an excellent on-line database for glove selection at www.bestglove.com.

Most material safety data sheets (MSDS) recommend the most protective glove material in their Protective Equipment section. There are MSDSs for many laboratory chemicals available on the web through the EHS home page.

EHS also has a computer program with glove compatibility information for hundreds of chemicals. Contact EHS at 258-5294 for more information.

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 actually be more of a hazard.

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, such as when wearing Silver Shield gloves, it may be possible to wear a tight-fitting glove over the loose glove to increase the overall dexterity.

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.

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.

Glove *size* may also be important. One size does not fit all. Gloves which are too tight tend to cause fatigue, while gloves which are too loose will have loose finger ends which 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.

Glove Inspection, Use and Care

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. 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.

Disposable gloves should be changed when there is any sign of contamination. Reusable gloves should be washed frequently if used for an extended period of time.

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 of touching the face, hair, and clothing as well.

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.

Latex Gloves and Related Allergies

Allergic reactions to natural rubber latex have been increasing since 1987, when the Center for Disease Control recommended the use of universal precautions to protect against potentially infectious materials, bloodborne pathogens and 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.

NIOSH studies indicate that 8-12% of healthcare workers regularly exposed to latex are sensitized, compared to 1-6% of the general population. 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.

NIOSH recommends the following actions to reduce exposure to latex:

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

Although latex gloves remain a popular glove in some laboratories, they do not offer good protection from many chemicals, including ethidium bromide. Consider nitrile or chloroprene gloves as an alternative.

Respiratory Protection



A respirator may only be used when engineering controls, such as general ventilation or a fume hood, are not feasible or do not reduce the exposure of a chemical to acceptable levels. The use of a respirator is subject to prior review by EHS, according to University policy, since their use is regulated by the OSHA Respiratory Protection Standard.

Any worker who believes that respiratory protection is needed must notify EHS for 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 record keeping. For more information, see Section C4, Respiratory Protection, in the Princeton University Health and Safety Guide.

Eye Protection

Safety glasses look very much like normal glasses but are designed to protect against flying particles. Safety glasses have lenses that are impact resistant and frames that are far stronger than standard street wear glasses. Safety glasses must have side shields and should be worn whenever there is the possibility of flying particles, glass, powders, etc. entering the eye.



Standard street wear eyeglasses fitted with side shields are not sufficient. Workers who are interested in obtaining prescription safety glasses should contact EHS at 8-5294.

Chemical Splash Goggles should be worn when there is potential for 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. They may be worn over prescription glasses.

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.

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, the lens should be removed immediately and discarded.

Protective Clothing & Footwear

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



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. Open-toed shoes or cloth sneakers should not be worn in laboratories or where mechanical work is performed

SECTION 4: Chemical Fume Hoods

- Hood Inspection Sticker
- Fume Hood Work Practices
- Other Laboratory Ventilation Equipment

One of the primary safety devices in laboratories where chemicals are used is the laboratory fume hood. A well designed fume hood, when properly installed and maintained, can provide a substantial degree of protection for the experimenter, provided its proper use and limitations are understood.

The determination that a hood is necessary for a particular experiment should be based on a hazard analysis of the experiment under consideration. Such an analysis would include a review of the physical characteristics, quantity, and toxicity of the materials to be used, the experimental procedure, the volatility of the materials present during the experiment, the probability of their release, and the number and sophistication of manipulations, etc. More subjective factors such as the skill and expertise of the individual performing the work should also be considered.

Chemical fume hoods are inspected annually by the Office of Environmental Health and Safety. Labels are affixed to the fume hood that indicate the sash height for adequate containment. All fume hoods are equipped with a magnehelic gauge or other continuous monitoring device to monitor the flow of air. Proper readings of the monitoring device can also be found on the inspection label.

Fume Hood Work Practices

The protection afforded by a fume hood is only as good as the work practices of the hood user. The following are general guidelines to be followed when working in the hood:

1. Know the toxic properties of the chemicals with which you work. Be able to identify signs and symptoms of overexposure.
2. 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 vapors from escaping the hood when air currents from people walking past the hood, etc. interfere with airflow at the face of the hood.
3. Keep the sash completely lowered anytime no “hands-on” part of an experiment is in progress or whenever the hood is on and unattended.
4. Never operate the hood unless there is some visual indication that the hood is operating. A tissue or Kimwipe® taped to the sash or inside the hood provides a good indicator of airflow.
5. Check the magnehelic gauge reading and compare it with the reading documented on the hood inspection sticker. If the reading differs significantly from that on the sticker, the hood may not be operating sufficiently.

6. The hood is not a substitute for personal protective equipment. Wear gloves, safety glasses, etc., as appropriate.
7. Visually inspect the baffles (openings at the top and rear of the hood) to be sure the slots are open and unobstructed.
8. Do not block baffles. If large equipment is in the hood, put it on blocks to raise it approximately two inches so that air may pass beneath it.
9. Do not use the hood as a storage cabinet. Keep only the materials necessary for the experiment inside the hood. If chemicals need to be stored in the hood for a period of time, install shelves on the sides of the hood, away from the baffles.
10. Keep the sash clean and clear.
11. Clean all chemical residues from the hood chamber after each use.
12. All electrical devices should be connected outside the hood to avoid sparks which may ignite a flammable or explosive chemical.
13. **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. Most special use hoods are labeled as to the uses for which they are designed. Radioactive materials may only be used in hoods specially labeled for radioactivity. If you have any questions about the capabilities of a particular hood, contact Joan Hutzly at 8-6251.

Other Laboratory Ventilation Equipment

Be aware of ventilation equipment in a laboratory that are not considered chemical fume hoods, such as laminar flow hoods, clean benches, biosafety cabinets or elephant trunks.

A laminar flow hood (see picture below) has air that washes down from top to bottom and are used to protect the working materials from contamination. These do not provide protection for the worker and should not be used for the manipulation of hazardous materials. Laminar flow hoods are not tested by EHS.



Similarly, a biosafety cabinet is used to protect the material from contamination, not the user. Most biosafety cabinets exhaust the contaminated air through high efficiency particulate air (HEPA) filters back into the laboratory. This type of filter will not contain most hazardous materials, particularly gases, fumes or vapors. 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.

Biosafety cabinets must be certified by an outside firm annually if they are being used to protect the user. If they are only being used for product protection, then the researcher must decide how often the cabinet gets certified.

SECTION 5: Electrical Safety

- Electrical Hazards
- Preventing Electrical Hazards
- Safe Work Practices

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. 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

Electrical Hazards

The major hazards associated with electricity are electrical shock and fire. 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.

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

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 amount of current for a 60-cycle hand-to-foot path of one second's duration of shock. While reading this chart, keep in mind that most electrical circuits can provide, under normal conditions, up to 20,000 milliamperes 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 |
| 1,000-4,300 Milliamperes | Ventricular fibrillation |
| 10,000+ Milliamperes | Cardiac arrest, severe burns, and probable death |

In addition to the electrical shock hazards, sparks from electrical equipment can serve as an ignition source for flammable or explosive vapors.

Even loss of electrical power can result in extremely hazardous situations. Flammable or toxic vapors may be released as a chemical warms when a refrigerator or freezer fails. 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.

Preventing Electrical Hazards

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:

- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
- Use safe work practices every time electrical equipment is used.

- Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
- Limit the use of extension cords. Use only for temporary operations. In all other cases, request installation of a new electrical outlet.
- Use only multi-plug adapters equipped with circuit breakers or fuses.
- Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind Plexiglas shields.
- Minimize the potential for water or chemical spills on or near electrical equipment.

Insulation

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 solvent vapors may erode the insulation.

Damaged cords should be repaired or taken out of service immediately.

Guarding

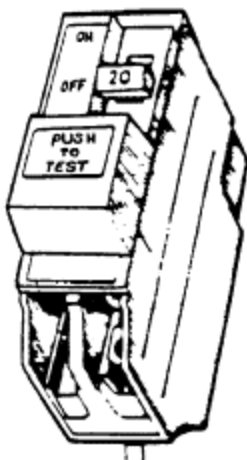
Live parts of electric equipment operating at 50 volts or more (i.e., electrophoresis devices) must be guarded against accidental contact. Plexiglas shields may be used to protect against exposed live parts.

Grounding



Only equipment with three-prong plugs should be used in the laboratory. The third prong provides a path to ground that helps prevent the buildup of voltages that may result in an electrical shock or spark. This does not guarantee that no one will receive a shock, be injured, or be killed. It will, however, substantially reduce the possibility of such accidents, especially when used in combination

with other safety measures.



Circuit Protection Devices

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. Fuses, circuit breakers, and ground-fault circuit interrupters are three well-known examples of such devices.

Fuses and circuit breakers prevent over-heating of wires and components that might otherwise create hazards for operators. 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.

The ground-fault circuit interrupter, or GFCI, is designed to shutoff electric power if a ground fault is detected. The GFCI is particularly useful near sinks and wet locations. Since GFCIs can cause equipment to shutdown 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.

Motors

In laboratories where volatile flammable materials are used, motor-driven electrical equipment should be equipped with non-sparking induction motors or air motors. Avoid series-wound motors, such as those generally found in 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, unless they are equipped with redundant safeguards for work in such environments.

Safe Work Practices

The following practices may reduce risk of injury or fire when working with electrical equipment:

- Avoid contact with energized electrical circuits.
- Disconnect the power source before servicing or repairing electrical equipment.
- 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.
- If it is not unsafe 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.
- 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.
- If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment.
- 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.

High Voltage or Current

Repairs of high voltage or high current equipment should be performed by trained electricians. Laboratory workers who are experienced in such tasks and would like to perform such work on

their own laboratory equipment must first receive specialized electrical safety related work practices training by EHS staff. Contact the University Safety Engineer at 258-5849 for more information.

The following additional precautions should be taken:

- Always assume a high voltage potential exists within a device while servicing it, even if it is de-energized and disconnected from its power source.
- Avoid becoming grounded by staying at least 6 inches away from walls, water, and all metal materials, including pipes.
- Use voltmeters and test equipment with ratings and leads sufficient to measure the highest potential voltage expected to be found inside the equipment being serviced.
- After servicing, check equipment with a multimeter or appropriate device to ensure it is grounded before reconnecting to the power source.
- Consider the need for shielding, particularly where exposure to an electrical arc is possible. Contact EHS for assistance.

SECTION 6: Pressure and Vacuum Systems

- Pressure Vessels
- Vacuum Apparatus
- Glass Vessels
- Rotary Evaporators

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.

Pressure Vessels

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. 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. Systems designed for use at elevated temperatures should be equipped with a positive temperature controller. Manual temperature control using a simple variable autotransformer, such as a Variac, should be avoided. The use of a back-up temperature controller capable of shutting the system down is strongly recommended.

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. 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 overtemperature. Contact the University Safety Engineer at 258-5294 for more information about hydrostatic testing.

Vacuum Apparatus

Vacuum work can result in an implosion and the possible hazards of flying glass, spattering chemicals, and fire. Personal protective equipment, 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.

Water, solvents, and corrosive gases should not be drawn into vacuum systems. Pumps should be protected by cold traps and their exhaust should be vented into an exhaust hood.

Glass Vessels



Although glass vessels are frequently used in pressure and vacuum systems, they can explode or implode violently, either spontaneously from the strain or from an accidental blow. Therefore, pressure and vacuum operations in glass vessels should be conducted behind adequate shielding. Glass vessels should be designed for the operation intended, and should be visually checked for star cracks, scratches, or etching marks before each use.

Rotary Evaporators

Glass components of the rotary evaporator should be made of Pyrex or similar glass and completely enclosed in a shield to guard against flying glass should the components implode. The rotation speed and application of vacuum should be done gradually when using a rotary evaporator.

SECTION 7: Ergonomics

- Pipetting
- Biological Safety Cabinets/ Fume Hoods
- Microscopy
- Computer Workstations

Ergonomics is the science of designing work areas or equipment for safe, comfortable and effective human use. Certain laboratory related tasks may place lab workers at an increased risk for developing repetitive straininjuries (RSI). Repetitive activities may cause discomfort and, if not properly modified, may lead to pain or reduced dexterity.

Not everyone performing the same job tasks will develop a RSI. Listed below are the most common factors that may increase the risk for a RSI:

- **Awkward Body Postures:** Any posture that places a body part out of a neutral position (i.e. twisting, poor posture, bending, over-reaching) may put increased strain on muscles, tendons, ligaments and joints.
- **Exertion:** Maintaining a specific body position or exertion for long periods of time may result in pressure or force being placed on the soft tissues.
- **Repetition:** Higher numbers of similar body movements over extended time periods may increase the risk of developing a RSI.
- **Contact Pressure:** Pressure resulting from leaning against or resting a body part on a sharp edge or hard surface can constrict blood flow.

Laboratory procedures may be repetitive or involve a variety of these risk factors.

Pipetting

Certain laboratory procedures require frequent pipetting for extended periods of time, resulting in repetitive force on the thumbs, hands, forearm, or fingers. Stresses may be reduced by varying pipetting with other lab tasks that use different motions and muscle groups or by taking frequent, small rest breaks. Place receptacles for used pipette tips close to the work area to avoid frequent reaching. If it is an option, replace manually operated pipettes with electronic ones for larger workloads.

Biological Safety Cabinets/Fume Hoods

Working in Biological Safety Cabinets (BSCs) or chemical fume hoods may require lab workers to bend forward frequently or assume awkward body postures. Users should take short breaks to alter their body posture, or to reduce contact pressure caused by leaning on sharp edges or hard surfaces. Keeping the viewing window of hood clean, and line of sight unobstructed, reduces eye strain and the need to assume awkward body positions.

Microscopy

Operating a microscope for long hours may put increased strain on the neck, shoulders, eyes, lower back, arms and wrists. If sitting, use an adjustable chair that provides support to the back and legs. Ensure that your feet are flat on the floor or supported by a footrest. Avoid raising your shoulders and bending your neck for long periods of time while looking through the microscope's eyepiece. Position the microscope as close as possible to reduce the need to bend forward. Take adequate small breaks, or vary microscopy with other job tasks.

Computer Workstations

The following guidelines are intended to help workers understand and reduce health risks associated with computer workstations:

- The keyboard and mouse should be directly in front of the operator at a height that favors a neutral posture. The objective is a posture with upper arms relaxed and wrists straight in line with the forearm.

- The monitor should be positioned at a distance of approximately arm's length and directly in front of the operator. The top of the screen should be no higher than eye level.
- A well designed chair will favorably affect posture, circulation, the amount of effort required to maintain good posture, and the amount of strain on the back. An adjustable seat back is best for support of the lumbar region. The user should be able to adjust seat height and seat pan angle from a seated position.
- Additional accessories may improve operator comfort. Document holders may minimize eye, neck and shoulder strain by positioning the document close to the monitor. A footrest should be used where the feet cannot be placed firmly on the floor. Task lamps should be used to illuminate source documents when room lighting is reduced.

SECTION 8: Chemical Spills

- Chemical Spills
- Mercury Spills
- Mercury Alternatives

Chemical Spills

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 equipment appropriate for the chemicals being handled readily available. There should be a sufficient quantity of absorbents or other types of materials to control any spill that can be reasonably anticipated. Vermiculite, lined 5-gallon pails and limited spill control materials are available at the loading docks of Lewis Thomas Lab, Frick, and E-Quad and in most science and engineering buildings outside elevators on the 100 level. [Click here for all EHS spill kit locations on campus.](#) Additional materials may be found in certain laboratories and the chemical stockrooms.

The following are general guidelines to be followed for a chemical spill. More detailed procedures may be available in your Departmental Chemical Hygiene Plan.

1. Immediately alert lab occupants and supervisor, and evacuate the area, if necessary.
2. If there is a fire or if medical attention is needed, contact Public Safety at 911.
3. Attend to any people who may be contaminated. Contaminated clothing must be removed immediately and the skin flushed with water for no less than fifteen minutes. Discard clothing or launder separately before reuse.
4. If a volatile, flammable material is spilled, immediately warn everyone, control sources of ignition and ventilate the area.
5. Don personal protective equipment, as appropriate to the hazards. Refer to the Material Safety Data Sheet or other references for information.

6. Using the chart below, 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, contact EHS at x8-5294 or Public Safety at 911.

1.

| Category | Size | Response | Treatment Materials |
|----------|--------------------|----------------------------------|--|
| Small | up to 300 cc | chemical treatment or absorption | neutralization or absorption spill kit |
| Medium | 300 cc-5 liters | absorption | absorption spill kit |
| Large | more than 5 liters | call Public Safety | outside help |

7. Consider the need for respiratory protection. The use of a respirator or self-contained breathing apparatus requires specialized training and medical surveillance. Never enter a contaminated atmosphere without protection or use a respirator without training. If respiratory protection is needed and no trained personnel are available, call EHS at x8-5294 or **Public Safety** at 911. If respiratory protection is available, be sure there is another person outside the spill area in communication, in case of an emergency. If no one is available, contact Public Safety.

8. Protect **floor drains** or other means for environmental release. Spill socks and absorbents may be placed around drains, as needed. If there had been a release to the environment, you **MUST** call Public Safety at 911.

9. Clean up the spill according to the table above.

Loose spill control materials should be distributed over the entire spill area, working from the outside, circling to the inside. This reduces the chance of splash or spreading of the spilled chemical.

Bulk absorbents and many spill pillows do not work with hydrofluoric acid. POLYZORB® products and their equivalent are formulated for hydrofluoric acid.

Many **neutralizer** spill kits for acids or bases have a color change to indicate when neutralization is complete. Those for solvents contain charcoal to reduce vapors and minimize the fire hazard.

10. When spilled materials have been absorbed, use a brush and scoop to place materials in an appropriate container. Polyethylene bags may be used for small spills. Five-gallon pails or 20-gallon drums with polyethylene liners may be appropriate for larger quantities.

11. Complete a hazardous waste sticker, identifying the material as Spill Debris involving XYZ Chemical, and affix onto the container. Remember that the use of an adsorbent does not alter the chemical properties of that chemical. Contact Steve Elwood at x8-6271 for advice on storage and packaging for disposal.

12. Place the container in a hood or other properly ventilated area of the lab until the next hazardous waste pickup.

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

14. Report all spills to your supervisor or the Principal Investigator.

15. Replenish spill control materials. If a building spill kit (blue drum or gray 5-gallon pail filled with spill control materials) was used, contact EHS at 8-5294 for replenishment.

Mercury Spills

Mercury spills from broken thermometers or other sources cannot easily be cleaned up with traditional spill control materials. To clean up a mercury spill:

1. Put on a pair of gloves and eye protection.

2. Pick up larger pieces of broken glass or debris taking care to avoid touching sharp edges. Place in a puncture-resistant container.

3. Clean up any remaining mercury and small debris.

- 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.
- Commercial products such as sponges and powders may also be used. The sponges and powders require the use of an activator solution (mildly acidic) to be effective.
- Sulfur powder indicates the presence of mercury by turning from yellow to brown when sprinkled on an affected surface.

4. 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”.

5. Please make sure to 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 waste. Bring the debris to the next scheduled waste pickup.

Precautions for Minimizing Mercury Incidents

- Do not use mercury thermometers as stirring rods.
- Replace mercury thermometers with non-mercury alternatives (see below)
- Use secondary containment or a tray under mercury-containing equipment.

Non-Mercury Alternatives

There are a number of non-mercury alternatives for mercury-containing devices, such as thermometers. **Consider replacing your mercury thermometers with non-mercury or digital thermometers.** In most cases, EHS will fund this replacement. Contact James Boehlert at 8-7882 for more information.

SECTION 9: Chemical Waste Disposal

- Classification of Waste as Hazardous
- Packaging Chemical Waste
- Labeling of Waste Containers⁹
- Disposal Procedures
- Special Wastes
- Sharp Implement Disposal
- General Recommendations
- Waste Minimization and Pollution Prevention

EHS coordinates disposal of chemical waste from University operations. The cost of waste disposal is borne by EHS, rather than the individual laboratories, in part to eliminate the incentive not to use this procedure for disposing of chemical waste.

This procedure applies to any chemical substances generated from University operations (including laboratories, administrative units, and physical plant operations) that are classified as hazardous based on the criteria described below. This procedure does not apply to the disposal of biohazardous or radioactive wastes. Contact EHS for more information about disposal of these materials.



The Waste Disposal section of the EHS web page contains more detailed information.

Classification of Waste as Hazardous

Waste is considered hazardous if:

- It is on either of two lists of specific chemical substances developed by the Federal Environmental Protection Agency (EPA). Most commonly used organic

solvents (e.g. acetone, methanol, toluene, xylene, methylene chloride etc.) are included. For a detailed listing contact Environmental Health & Safety.

- It is on a list of nonspecific sources that includes a broad range of spent halogenated and non-halogenated solvents.
- It is on a list of specific sources that includes primarily industrial processes.
- It exhibits any of the following characteristics as defined by the EPA (abbreviated definitions):

Ignitable: a liquid with a flash point less than 60 degrees Centigrade; not a liquid and 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 OR a liquid that corrodes steel at a rate greater than 0.250 inches per year at 55 degrees Centigrade.

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 initiation or under standard temperature and pressure; OR classified as a Department of Transportation explosive.

Toxicity Characteristic: an extract of the waste is found to contain certain metals, pesticides or selected organics above specified levels OR otherwise capable of causing environmental or health damage if improperly disposed (this is a judgment you must make based upon your knowledge of the material from the MSDS).

Packaging Chemical Wastes

Materials that are to be disposed of as hazardous waste should be placed in sealable containers. Waste disposal cost is based on volume, not weight, therefore, whenever possible, containers should be filled, leaving a headspace for expansion of the contents. Often the original container is perfectly acceptable. If you routinely generate significant quantities of compatible solvents, bulking of waste in five-gallon carboys provided by EHS may be practical.



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. flammable liquids).

Wastes from incompatible hazard classes should not be mixed (e.g., flammables with oxidizers). Certain metals also cause disposal problems when mixed with flammable liquids or other organic liquids (see Special Problems). Containers must be **kept closed** except during actual transfers. **Do not leave a hazardous waste container with a funnel in it.**

Chemical containers that have been emptied should be triple-rinsed and air-dried in a ventilated area. Once this has been accomplished, the container can be disposed of as regular recyclable trash. If the original contents were highly toxic the container should be rinsed first with an appropriate solvent and the washings disposed of as hazardous waste. More specific information about disposal of empty chemical containers can be found on the EHS web page.

Labeling of Waste Containers

Waste containers must be labeled with the words **HAZARDOUS WASTE** along with the names of the principal chemical constituents and the approximate percentage. Waste container labels can be obtained by contacting Environmental Health and Safety at x8-5294. Use of these labels is preferred, but not mandatory, unless the waste will be placed in storage before disposal. If you choose not to use the standard labels, the container still must bear the words **HAZARDOUS WASTE** and the chemical contents. Label the collection container as soon as accumulation begins.

| HAZARDOUS WASTE | | |
|--|--------------------|---|
| Federal & New Jersey Laws Prohibit Improper Disposal | | |
| Department _____ | Phone _____ | |
| Lab Group _____ | | |
| Responsible Individual _____ | | |
| Date Placed in 90 Day Storage _____ | | |
| | Contents | Approximate % |
| | _____ | _____ |
| | _____ | _____ |
| Use IUPAC | _____ | _____ |
| Nomenclature | _____ | _____ |
| | _____ | _____ |
| Hazard Class (if known) | | |
| 1. Poison | 4. Oxidizer | 7. Sensitive to Shock, Friction, Air or Water |
| 2. Flammable Liquid | 5. Corrosive | |
| 3. Flammable Solid | 6. Peroxide Former | |
| 896 | | |

Do not list reactants, only products. For example, if a 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. Use chemical names not symbols, structural diagrams or product trade names.

Labeling should be accurate and legible and should include the name of the generator, the name of the Lab Group or PI, and an extension where someone who is knowledgeable about that

specific waste can be reached **on the day of the pickup** in case questions arise during packaging for disposal.

Disposal Procedure

Chemical Waste Pickups are generally scheduled for the last Thursday of the month through the academic year. A notice of the pickup is distributed to Departmental Chemical Hygiene Officers, Department Safety Managers and other interested persons approximately one week in advance via the Waste Paper. Contact EHS at 8-5294 if you would like to receive this newsletter.

Pickups take place at four Main Campus locations:

Lewis Thomas Laboratory loading dock – for Molecular Biology, EEB and Geosciences

E-Quad (loading dock) – for SEAS and PMI

Frick loading dock – for Chemistry, Psychology and Visual Arts

Jadwin Room 124 – for Physics only

Specific arrangements for getting material to the pickup site are the responsibility of the individual departments. Refer questions of this nature to your Departmental Safety Manager or Chemical Hygiene Officer. Generally, wastes must be at the pickup site by 9 AM the day of the pickup to be included.

Special Wastes

Thallium, Beryllium, and Osmium pose special disposal problems - especially when in combination with other wastes. If you will be generating wastes containing these elements please contact EHS before you begin.

Metallic mercury is considered a recyclable, rather than hazardous waste. If you generate mercury waste or have mercury debris from a spill or equipment breakage, contact EHS to arrange a special pickup.



Ethidium Bromide usually does not need to be disposed 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. Ethidium bromide solutions may be neutralized and disposed down the drain. Neutralization procedures are outlined on the EHS web page (www.princeton.edu/~ehs/etbr.html).

Used Oil: Used oil is not disposed of as part of the Hazardous Waste program, with the following exceptions:

- Vacuum Pump Oil
- Cutting Oils
- PCB Contaminated Oil
- Oil mixed with hazardous wastes

EHS does not coordinate or pay for used oil disposal. For more information, see the EHS web page.

Silica gel, molecular sieves and dessicants are not considered hazardous waste unless they are grossly contaminated.

Uranium and thorium compounds, such as uranyl acetate, uranyl nitrate, uranyl formate, uranium oxide, thorium nitrate and thorium oxide, are considered radioactive waste, rather than chemical waste. See the Waste Disposal web page for more information.

Chemical wastes that are combined with **radioisotopes** are considered **mixed waste**. Contact the Radiation Safety Officer at 8-5294 before generating this type of waste. Mixed waste is difficult to dispose and should be minimized to the extent possible.

Do not bring wastes to the pickup site that are not properly identified. The disposal company can not legally transport or dispose of them. Arrangements for chemical analysis of **unknowns** can be made through EHS. Costs associated with improper management of hazardous waste (e.g. characterization of unknowns, special handling of peroxidizable compounds etc.) are charged back to the generator department.

Sharp Implement Disposal (top)

Many individuals on campus have occasional or routine need to dispose of sharp implements or “sharps”, such as razor blades or other cutting blades, broken glass, glass slides, syringes, or other items that can easily puncture the skin. It is important that these types of sharp implements **not be** placed directly into trash receptacles with other general trash **or** in the paper-recycling receptacle in order to prevent injury to those who must handle the general trash and recyclables coming from the offices, labs and shops.

Sharp implements must be placed in a puncture-resistant container, such as rigid plastic or corrugated cardboard. For example, an occasional razor blade that needs disposal could be placed in a disposable plastic container with a screw-top lid or could be wrapped in a piece of corrugated cardboard and secured with packaging tape. For sharps that are routinely generated, a sealable box or container should be used.

General Recommendations

- Don't purchase more of a chemical than you expect to use in the foreseeable future. The costs of disposal often exceed the purchase cost by a considerable margin.
- Scale down experiments to a practical minimum to reduce the total amount of waste generated.
- Consistent with safe practice, bulk compatible waste in containers up to five gallons in capacity to reduce disposal costs (consult with EHS first).
- Keep all chemical containers clearly and unambiguously labeled.
- Keep all containers of waste sealed except during filling. Do not leave funnels in containers.
- Dispose of your wastes at the completion of a project - don't abandon them for someone else to deal with later.

Waste Minimization and Pollution Prevention

Waste minimization is a national policy and the responsibility of each person who generate hazardous waste. Princeton University is committed to managing operations in an environmentally sensitive and responsible manner. Everyone must do his or her part in minimizing hazardous waste generation.

General principles for waste minimization, in order of priority, are:

1. **Elimination** - any modification that results in the elimination of waste generation.
2. **Substitution** - replacement of hazardous substances with less hazardous materials.
3. **Scale Reduction** - a reduction of the amount of hazardous materials used in a procedure.
4. **Recycling** - the reuse of waste materials either back into the same process or into a different process.
5. **Reclamation** - any process that allows materials to be used again after some sort of purification, such as solvent distillation.
6. **Treatment** - an additional step added to an experimental or analytical procedure to reduce or eliminate the toxicity of the waste.

Contact EHS for consultation on ways to reduce waste in your operations. Report any successful waste minimization projects to EHS in order to share these practices with other labs. See the Waste Disposal section of the EHS web page for more information.

APPENDIX A: *Chemical Hygiene Plan Summary*

- Introduction
 - Chemical and Hazard Identification
 - Standard Operating Procedures
 - Controlling Chemical Exposure
 - Control Measures
 - Fume Hood Performance Evaluation
 - Information and Training
 - Prior Approval for Laboratory Procedures
 - Medical Examinations and Consultations
 - Particularly Hazardous Substances
 - Laboratory Inspections and Audits
-

Introduction

Each department has a Chemical Hygiene Plan that provides guidelines for prudent work practices and procedures for the laboratory use of chemicals, with the goal of protecting laboratory workers from the potential health hazards of the chemicals they encounter in the workplace. The Chemical Hygiene Plan was written in response to the federal Occupational Safety and Health Administration's (OSHA) Occupational Exposure to Hazardous Chemicals in Laboratories (the OSHA Lab Standard).

The following is a brief summary of the Chemical Hygiene Plan, citing the Laboratory Standard requirements and where specific information may be found. Each science and engineering department has developed its own Chemical Hygiene Plan, based on a model prepared by Environmental Health and Safety, and has appointed a Chemical Hygiene Officer to oversee implementation of the plan. Copies of the departmental Chemical Hygiene Plans along with the names of all Chemical Hygiene Officers are available to every laboratory at all times.

The Laboratory Safety Manual is a supplemental web-based document that provides extensive information on a wide variety of laboratory issues.

Chemical and Hazard Identification

Departments describe their policies on Material Safety Data Sheets (MSDS), as well as the location and/or content of any other chemical safety resources maintained by the department.

Standard Operating Procedures

The Laboratory Safety Manual on the EHS web page (www.princeton.edu/~ehs/labmanual) provides general principles for working safely with hazardous chemicals. Principal investigators, laboratory managers and laboratory workers are encouraged to develop and implement more detailed guidelines for specific operations and chemicals in their laboratories.

Controlling Chemical Exposure

Exposure Monitoring

Exposure monitoring is conducted by EHS upon request if there is reason to believe that exposure levels for a particular substance may routinely exceed either the action level or the permissible exposure limit set forth by OSHA. Individuals may contact EHS directly at 8-5294 or notify the departmental Chemical Hygiene Officer.

Results of the monitoring will be made available by EHS to the individual(s) monitored, their supervisors, and the Chemical Hygiene Officer within 15 working days of the receipt of analytical results. Based on the monitoring results, periodic monitoring may be scheduled at the discretion of EHS, in accordance with applicable federal, state and local regulations.

Control Measures

Engineering controls are the primary means of control for exposure to hazardous chemicals. Local ventilation, including fume hoods, ducted biosafety cabinets, glove boxes, vented storage cabinets, and vented canopies are the most common types of engineering controls. Upon request, EHS provides assistance in determining the appropriate type of engineering controls for specific operations.

Protective equipment, including gloves, face shields, safety glasses, safety goggles, lab coats and aprons, are used when engineering controls are not sufficient to adequately control exposure. Specifically, this equipment is used to prevent exposure to the skin or eyes. Personal protective equipment is carefully selected to ensure that it is compatible with the chemicals used. Information about selection of appropriate protective equipment is available in the Laboratory Safety Manual at <http://www.princeton.edu/ehs/labmanual>.

When feasible engineering controls are not adequate to reduce inhalation exposure to acceptable levels, a respirator may be used to minimize exposure to airborne contaminants. Use of a respirator is subject to approval by EHS and must be in accordance with the University Respiratory Protection Policy. See Section C4 of the *Princeton University Health and Safety Guide* for more information.

It may be necessary to supplement engineering controls and protective equipment with administrative controls, such as restricting access to an area, or restricting use of a chemical to a limited number of people for a limited time.

Fume Hood Performance Evaluation

The Laboratory Safety Manual provides extensive details about the Fume Hood Program, including how a fume hood works, good work practices, common misuses and limitations, hood performance indices and evaluation and maintenance.

Information and Training

All laboratory workers must receive laboratory safety training when they are first assigned to a work area where hazardous chemicals are present and before assignments involving new exposure situations. General laboratory safety training is provided by EHS. The department Chemical Hygiene Plan provides details on more specific training for particular materials or operations in a particular work area.

Prior Approval for Laboratory Procedures

Individuals planning to use Particularly Hazardous Substances must complete a *Particularly Hazardous Substance Use Approval Form* and have it approved by the Principal Investigator or supervisor and the departmental Chemical Hygiene Officer prior to their initial use of the substance.

Responsibility for determining whether a chemical is a Particularly Hazardous Substance rests jointly with the supervisor and the individual planning to use the substance. See the Chemical Hygiene Plan for details.

Medical Examinations and Consultations

The Chemical Hygiene Plan describes the Medical Consultation Policy, procedures for reporting incidents and the procedure for obtaining a medical consultation.

Particularly Hazardous Substances

Work with particularly hazardous substances, such as carcinogens, reproductive toxins and highly toxic agents, may require special procedures and handling.

The *Particularly Hazardous Substances* section of the Chemical Hygiene Plan defines such substances and outlines procedures to follow in order to work with these substances safely.

Laboratory Inspections and Audits

The Chemical Hygiene Plan describes roles, responsibilities and schedules for inspecting laboratory facilities and systems. In addition, EHS conducts limited laboratory inspections annually.

APPENDIX B: *Princeton University Environmental, Health, and Safety Policy*

Princeton University is committed to providing a safe and healthful environment for its employees, students and visitors and managing the University in an environmentally sensitive and responsible manner. We further recognize an obligation to demonstrate safety and environmental leadership by maintaining the highest standards and serving as an example to our students as well as the community at large.

The University will strive to continuously improve our safety and environmental performance by adhering to the following policy objectives:

- Developing and improving programs and procedures to assure compliance with all applicable laws and regulations
- Ensuring that personnel are properly trained and provided with appropriate safety and emergency equipment
- Taking appropriate action to correct hazards or conditions that endanger health, safety, or the environment
- Considering safety and environmental factors in all operating decisions including planning and acquisition
- Engaging in sound reuse and recycling practices and exploring feasible opportunities to minimize the amount and toxicity of waste generated
- Using energy efficiently throughout our operations
- Encouraging personal accountability and emphasizing compliance with standards and conformance with University policies and best practices during employee training and in performance reviews
- Communicating our desire to continuously improve our performance and fostering the expectation that every employee, student, and contractor on University premises will follow this policy and report any environmental, health, or safety concern to Princeton University management.
- Monitoring our progress through periodic evaluations
- **APPENDIX C: *Training Matrix***

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|-----------------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Use Chemicals?* | X | X | | | | | | | | | | | | |
| Use Lasers? | X | X | | X | | | | | | | | | | |
| Class 3b or 4? | X | X | | X | X | | | | | | | | | |
| Repair lasers? | X | X | | X | X | X | | | | | | | | |
| Use Radioactive Materials? | X | X | | | | | X | X | | | | | | |
| Use x-ray? | X | X | | | | | | | X | | | | | |
| Use electro microscope? | | | | | | | | | X | | | | | |
| Use Respirator? | X | X | | | | | | | | X | | | | |
| Use SCBA? | | | | | | | | | | | | | X | |
| Use human blood or fluids? | X | X | | | | | | | | | X | | | |
| Work with Animals? | | | | | | | | | | | | X | | X |
| Lab Supervisor?*** | | X | X | | | | | | | | | | | |

- * Includes grad students, undergrads, faculty, and staff, paid or unpaid
- ** Includes principal investigators and laboratory managers
- *** Training required every 3 years
- **** Training required every year

- A: Lab Safety Training
- B: Laboratory Safety Refresher Training***
- C: Laboratory Supervisor Training
- D: Introduction to Laser Safety
- E: High Power Laser Safety Training
- F: Electrical Safety/LOTO Training
- G: Initial Radiation Safety Training
- H: Open Source User Refresher
- I: X-Ray Safety Training
- J: Respirator User Training
- K: Bloodborne Pathogen Training****
- L: Animal Facility Training
- M: SCBA Training****
- N: Materials Handling

APPENDIX D: Explanation Of Material Safety Data Sheet Information

- Product Identification
- Hazardous Ingredients of Mixtures
- Physical Data
- Fire and Explosion Hazard Data
- Health Hazard Data
- Emergency and First Aid Procedures
- Reactivity Data
- Spill, Leak, and Disposal Procedures
- Personal Protection Information

Per the federal Occupational Safety and Health Administration (OSHA) Laboratory Standard, laboratories are required to keep Material Safety Data Sheets (MSDSs) that are received from the manufacturer and maintain them in such a way that they are accessible to laboratory personnel. A system should be in place to catalogue MSDSs when received. If an MSDS is not received with a shipment, it may easily be obtained by requesting one from the manufacturer. In many cases, the MSDS may have been sent to the “Safety Officer”, and may have been received by the Chemical Hygiene Officer or EHS. Several chemical distributors have MSDSs available through the internet. The EHS web page has pointers to many of these sites at <http://www.princeton.edu/~ehs>. In addition, the Office of Environmental Health and Safety has a database of over 40,000 MSDSs. Contact EHS at 8-5294 for assistance.

Following is an explanation that is provided to help you interpret the information found on manufacturer’s MSDSs. While the format of these data sheets varies from manufacturer to manufacturer, certain components appear on each sheet.

Product Identification

This section gives the name and address of the manufacturer and an emergency phone number where questions about toxicity and chemical hazards can be directed.

| | |
|------------------------|---|
| <i>Product Name</i> | Commercial or marketing name |
| <i>Synonym</i> | Approved chemical name and/or synonyms |
| <i>Chemical Family</i> | Group of chemicals with related physical and chemical properties |
| <i>Formula</i> | Chemical formula, if applicable; i.e., the conventional scientific definition for a material. |
| <i>CAS Number</i> | Number assigned to chemicals or materials by the Chemical Abstracts Service, where applicable |

Hazardous Ingredients Of Mixtures

This section describes the percent composition of the substance, listing chemicals present in the mixture. If it was tested as a mixture, lists chemicals that contribute to its hazardous nature. Otherwise, lists ingredients making up more than 1% and all carcinogens.

The OSHA **permissible exposure limit (PEL)**, National Institute for Occupational Safety and Health (NIOSH)**recommended exposure limit (REL)**, and/or the American Conference of Governmental Industrial Hygienists (ACGIH)**threshold limit value (TLV)** will also be listed, if appropriate. The OSHA PEL is the regulated standard, while the others are recommended limits. The PEL is usually expressed in parts per million parts of air (ppm) or milligrams of dust or vapor per cubic meter of air (mg/m³). It is usually a **time weighted average (TWA)** - concentration averaged over an eight-hour day. Sometimes, a **STEL** or **short term exposure limit** may be listed. The STEL is a 15-minute TWA which should not be exceeded. A **ceiling limit**, is a concentration which may not be exceeded at any time. A **skin** notation means that skin exposure is significant in contributing to the overall exposure.

Physical Data

This section outlines the physical properties of the material. The information may be used to determine conditions for exposure. The following information is usually included:

Boiling Point: temperature at which liquid changes to vapor state

Melting Point: temperature at which a solid begins to change to liquid.

Vapor Pressure: a measure of how volatile a substance is and how quickly it evaporates. For comparison, the VP of water (at 20°C) is 17.5 mm Hg, Vaseline (non-volatile) is close to 0 mm Hg, and diethyl ether (very volatile) is 440 mm Hg.

Vapor Density (air=1): weight of a gas or vapor compared to weight of an equal volume of air. Density greater than 1 indicates it is heavier than air; less than 1 indicates it is lighter than air. Vapors heavier than air can flow along just above ground, where they may pose a fire or explosion hazard.

Specific Gravity (water=1): ratio of volume weight of material to equal volume weight of water.

Solubility in Water: percentage of material that will dissolve in water, usually at ambient temperature. Since the much of the human body is made of water, water-soluble substances more readily absorb and distribute.

Appearance/Odor: color, physical state at room temperature, size of particles, consistency, odor, as compared to common substances. Odor threshold refers to the concentration required in the air before vapors are detected or recognized.

% Volatile by Volume: Percentage of a liquid or solid, by volume, that evaporates at a temperature of 70°F.

Evaporation Rate: usually expressed as a time ratio with ethyl ether = 1, unless otherwise specified.

Viscosity: internal resistance to flow exhibited by a fluid, normally measured in centiStoke time or Saybolt Universal Secs.

Other Pertinent Physical Data: information such as freezing point is given, as appropriate.

Fire And Explosion Hazard Data

This section includes information regarding the flammability of the material and information for fighting fires involving the material.

Flashpoint: the lowest temperature at which a liquid gives off enough vapor to ignite when a source of ignition is present.

Autoignition Temperature: the approximate temperature at which a flammable gas-air mixture will ignite without spark or flame. Vapors and gases will spontaneously ignite at lower temperatures in oxygen than in air.

Flammable Limits: the lower explosive limit (LEL) and upper explosive limit (UEL) define the range of concentration of a gas or vapor in air at which combustion can occur. For instance, an automobile carburetor controls this mixture - too lean (not enough chemical) or too rich (not enough air, as when you flood your engine), will not ignite.

Extinguishing Media: appropriate extinguishing agent(s) for the material.

Fire-fighting Procedures: Appropriate equipment and methods are indicated for limiting hazards encountered in fire situations.

Fire or Explosion Hazards: Hazards and/or conditions that may cause fire or explosions are defined.

Health Hazard Data

This section defines the medical signs and symptoms that may be encountered with normal exposure or overexposure to this material or its components. Information on the toxicity of the substance may also be presented. Results of animal studies are most often given. i.e. LD50 (*mouse*)=250 mg/kg. Usually expressed in weight of chemical per kg of body weight. LD50 or *lethal dose 50* is the dose of a substance that will cause the death of half the experimental animals. LC50 is the concentration of the substance in air that will cause the death of half the experimental animals.

Health hazard information may also distinguish the effects of acute (short term) and chronic (long-term) exposure.

Emergency And First Aid Procedures

Based on the toxicity of the product, degree of exposure and route of contact (eye, skin, inhalation, ingestion, and injection), emergency and first aid procedures are recommended in this section.

Additional cautionary statements, i.e., *Note to Physician*, for first aid procedures, when necessary, will also appear here.

Reactivity Data

This section includes information regarding the stability of the material and any special storage or use considerations.

Stability: “unstable” indicates that a chemical may decompose spontaneously under normal temperatures, pressures, and mechanical shocks. Rapid decomposition produces heat and may cause fire or explosion. Conditions to avoid are listed in this section.

Incompatibility: certain chemicals, when mixed may create hazardous conditions. Incompatible chemicals should not be stored together.

Hazardous Decomposition Products: chemical substances that may be created when the chemical decomposes or burns.

Hazardous Polymerization: rapid polymerization may produce enough heat to cause containers to explode. Conditions to avoid are listed in this section.

Spill, Leak And Disposal Procedures

This section outlines general procedures, precautions and methods for cleanup of spills. Appropriate waste disposal methods are provided for safety and environmental protection.

Personal Protection Information

This section includes general information about appropriate personal protective equipment for handling this material. Many times, this section of the MSDS is written for large-scale use of the material. Appropriate personal protection may be determined by considering the amount of the material being used and the actual manipulations to be performed.

Eye Protection: recommendations are dependent upon the irritancy, corrosivity, and special handling procedures.

Skin Protection: describes the particular types of protective garments and appropriate glove materials to provide personnel protection.

Respiratory Protection: appropriate respirators for conditions exceeding the recommended occupational exposure limits.

Ventilation: airflow schemes (general, local) are listed to limit hazardous substances in the atmosphere.

APPENDIX E: Health And Safety Reference List

Additional references are available in the Laboratory Safety section of the EHS web page. References for radiation safety, laser safety, biological safety and work with animals are available through EHS.

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*available through the University Library System

APPENDIX F: *Laboratory Hazard Assessment Checklist*

- I. Pre-Operational Planning
- II. Experimental Scale and Design
- III. Spill/Emergency Planning
- IV. Waste Disposal

I. Pre-Operational Planning

| | |
|-----------------------------------|---|
| Toxicity | Including possible routes of exposure (inhalation, skin absorption, etc.) and symptoms of overexposure (see Material Safety Data Sheet) |
| Flammability | Flash point, boiling point, vapor pressure, explosive limits |
| Warning Properties | Can odor or irritation adequately warn of over-exposure (odor threshold vs. permissible exposure limit) |
| Laboratory Equipment | Are machine guards or interlocks in place and functioning (e.g. vacuum pumps) |
| Storage Precautions | Are safety cans or isolated storage required (should they be stored or disposed of) |
| Incompatible Materials | Should certain materials be segregated (e.g., flammables and oxidizers) |
| Reagent Instability/Decomposition | Should materials be dated for disposal (e.g., ethers); should materials be kept refrigerated to prolong shelf life |
| Protective Clothing | Is the material of choice relatively impervious to the substances in use |
| Gloves | Is permeability a consideration |
| Eye Protection | Is the eye protection suitable for the type of work being done, including protection against splashes, etc. |
| Heat Sources/Power Requirements | Can open flames be avoided |
| Electrical Equipment | Is it grounded properly and insulated or are ground fault interrupters appropriate |
| Circuit Protection | Are there properly sized fuses or circuit breakers |
| Vacuum/Pressure Systems | Have connections been leak tested, hydrostatically tested, properly vented, and traps installed when necessary |
| Ventilation/Containment | Does the work need to be done in a fume hood or a glove box to provide the needed level of containment |

II. Experimental Scale & Design

| | |
|--------------------|---|
| Quantity | Are there ways to minimize the amount of materials used without affecting results (e.g. microscale) |
| Ambient Conditions | Are special conditions necessary to carry out the reaction (e.g., cold room or dry box) |
| Time Constraints | Can the experiment be safely run unattended or overnight; should Public Safety be notified |

III. Spill/Emergency Planning

| | |
|-----------------------|--|
| Lab Personnel | Are others in the laboratory aware of what you are doing |
| Fire Extinguishers | Are special types required; are you aware of their location and proper use (e.g., Class D for metals) |
| Emergency Response | Do you have a response planned in the event of a spill; would evacuation be necessary |
| Spill Cleanup | Are materials on hand to absorb/neutralize; is the needed protective equipment (e.g., self-contained breathing apparatus) on hand and have you been trained on its use |
| Safety Shower/Eyewash | Are you aware of the locations and methods Fountain of operation |

IV. Waste Disposal

| | |
|-------------|---|
| Labeling | Are containers clearly, indelibly and accurately (IUPAC name when possible) labeled and dated when opened |
| Segregation | Are incompatible wastes kept segregated |
| Containers | Are suitable containers with adequate closures available |
| Quantities | Are quantities on hand kept to a minimum |
| Recycling | Is it feasible to safely recover/recycle used solvents |