Laboratory Safety Manual

CONTENTS

SECTION 1: LABORATORY SAFETY

INTRODUCTION

Baylor University is committed to providing a safe laboratory environment for its faculty, staff, students and visitors. The goal of the university's Laboratory Safety Program is to minimize the risk of injury or illness to laboratory workers by ensuring that they have the training, information, support and equipment necessary to work safely in the laboratory.

The three basic elements of the Laboratory Safety Program are:

- The departmental safety programs
- Laboratory safety support and training provided by Environmental Health and Safety
- Instruction and oversight by an individual supervisor or principal Investigator

All laboratory workers, including faculty, staff and most students are required to complete Laboratory Safety Training provided by the department of Environmental Health and Safety (EHS). This training gives an overview of general laboratory safety principles, as well as references and resources for additional safety information. This training supplements instruction given by supervisors and principal investigators regarding safe work practices in their specific laboratories.

EHS provides training, resources and consultation for a variety of laboratory safety issues, including chemical safety, radiation safety, laser safety, Biosafety and other topics. The EHS web page (www.baylor.edu/ehs) offers a wide variety of resources for many aspects of laboratory safety.

THE OSHA LABORATORY STANDARD

The Occupational Safety and Health Administration (OSHA) promulgated the regulation known as **Occupational Exposure to Hazardous Chemicals in Laboratories**, otherwise known as the Laboratory Standard.

The purpose of the Lab Standard is to ensure that laboratory workers are informed about the hazards of chemicals in their workplace and are protected from chemical exposures exceeding allowable levels (i.e. **OSHA Permissible Exposure Limits**)

All individuals who work with hazardous chemicals in laboratories where chemicals are manipulated for reactions are obligated to comply with the Lab Standard. Work with chemicals outside of laboratories, or in laboratories where chemical use is restricted to general usage such as cleaning apparatus, is covered by the **OSHA Hazard Communication Standard**.

POLICIES

Environmental Health and Safety Policy

Baylor 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. The university recognizes 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 continually 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
- 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 their supervisor or to the department of EHS.
- Monitoring our progress through periodic evaluations

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 Baylor University Police Department (Baylor PD) by calling 254-710-2222
- After normal business hours or when vacant, all laboratories must be locked when not in use

Laboratory building exterior doors are secured after scheduled 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 Baylor PD by calling 254-710-2222.

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/expulsion.

ROLES AND RESPONSIBILITIES

Principal Investigators

- Ensure laboratory workers attend general OSHA training given by EHS.
- Ensure laboratory workers understand how to work with chemicals safely. Provide chemical and procedure-specific training, as needed.
- Provide laboratory workers with appropriate **engineering controls** and personal protective equipment needed to work safely with hazardous materials. Ensure such equipment is used correctly.
- Review and approve work with **particularly hazardous substances**.

Environmental Health and Safety (EHS)

- Arrange for or conduct exposure monitoring, as needed.
- Provide general training.
- Audit the Laboratory Safety Program at least annually.
- Provide safe working guidelines for laboratory workers through the EHS web page.
- Ensure that laboratory Chemical Hygiene Plans are being reviewed annually.
- Provide consultation for safe work practices for hazardous chemicals
- Conduct laboratory safety audits at least annually.
- Develop and maintain the Laboratory Safety Manual.

Laboratory Worker

- Attend laboratory safety training.
- Review the **Chemical Hygiene Plan**.

- Follow procedures and laboratory practices outlined in the Chemical Hygiene Plan and Laboratory Safety Manual and as provided by supervisors and principal investigators.
- Use engineering controls and personal protective equipment, as appropriate.
- Report all incidents, accidents, potential chemical exposures and near miss situations to the principal investigator and the Laboratory Safety Program Manager at EHS.
- Document specific operating procedures for work with **particularly hazardous substances**, including carcinogens, reproductive toxins and chemicals with high acute toxicity.

SECTION 2: CHEMICAL HYGIENE PLANS (CHP)

Each laboratory that operates under the Lab Standard has its own Chemical Hygiene Plan (CHP). The purpose of the CHP is to provide guidelines for prudent practices and procedures for the use of chemicals in the laboratory. The Laboratory Standard requires that the CHP sets forth procedures, equipment, personal protection equipment (PPE) and work practices capable of protecting workers from the health hazards presented by chemicals used in the laboratory.

The following information must be included in each CHP:

- **Standard Operating Procedures (SOPs):** Prudent laboratory practices which must be followed when working with chemicals in a laboratory. These include general and laboratory-specific procedures for work with hazardous chemicals.
- **Criteria for Exposure Control Measures:** Criteria used by the employer to determine and implement control measures to reduce worker exposure to hazardous chemicals including engineering controls, the use of PPE and hygiene practices.
- **Adequacy and Proper Functioning of Fume Hoods and other Protective Equipment:** Specific measures that must be taken to ensure proper and adequate performance of protective equipment, such as fume hoods.
- **Information and Training:** The employer must provide information and training required to ensure that workers are apprised of the hazards of chemicals in their work areas and related information.
- **Requirement of Prior Approval of Laboratory Procedures:** The circumstances under which certain laboratory procedures or activities require approval from the employer or employer's designee before work is initiated.
- **Medical Consultations and Examinations:** Provisions for medical consultation and examination when exposure to a hazardous chemical has or may have taken place.
- **Laboratory Safety Coordinator Designation:** Identification of the Laboratory Safety Coordinator and outline of his or her role and responsibilities.
- **Particularly Hazardous Substances:** Outlines additional worker protections for work with particularly hazardous substances. These include select carcinogens, reproductive toxins, and substances which have a high degree of acute toxicity.

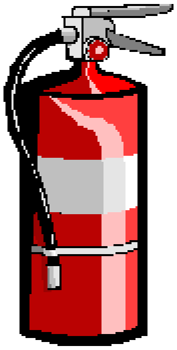
SECTION 3: EMERGENCY PROCEDURES

For any emergency, including fires, chemical spills, injuries, accidents, explosions, and medical emergencies, dial 2222 from any university phone or by using the **blue-light emergency phones**, located in common areas throughout campus. If a university phone is unavailable or inaccessible during an emergency, dial (254) 710-2222 from a cell phone. Baylor PD personnel will respond, determine whether additional assistance is needed and alert others who can help.

All accidents must be reported to the university on an **Incident Report Form.**

FIRE

In the event of a fire, Baylor PD should be notified immediately at 2222 from a campus phone or (254) 710-2222 from a cellular phone and the following actions are recommended:



1. Individuals are not required to fight fires; but that those who choose to do so may fight 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.
    - **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 the fire alarm does not work, or if the building is not equipped with one, notify the building occupants verbally of the need to evacuate. 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. **Close the door behind you** to prevent the fire's spread.
4. **Evacuate** the building and await the arrival of **Baylor PD**. 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 **Baylor PD** or the municipal fire official.

There are several types of fire extinguishers available. See the **Fire Extinguisher Advisory** to determine which type is best for a particular chemical or procedure

---

MEDICAL EMERGENCIES

In the event of any injury or illness where assistance is needed, contact Baylor PD at 2222 or (254) 710-2222. If an ambulance is needed, PD will arrange for one. Public Safety staff can transport individuals with minor injuries to the Student Life Center as appropriate.

First Aid Kits

First Aid Kits maintained by university departments and offices must:

- be kept in sanitary condition;
- be limited to simple household supplies such as band-aids and sterile gauze pads; and
- include at least one pair of large size examination or laboratory gloves. If gloves are not normally available in the laboratory.

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. Consult your supervisor to determine whether or not an **Incident Report Form** should be completed.

Chemicals on Skin or Clothing

1. Immediately flush with water for no less than 15 minutes (except for Hydrofluoric Acid, Flammable Solids or >10% Phenol). For larger spills, the safety shower should be used.
2. While rinsing, quickly remove all contaminated clothing or jewelry. **Seconds count. Do not waste time because of modesty.**
3. Use caution when removing pullover shirts or sweaters to prevent contamination of the eyes.
4. Check the Safety Data Sheet (SDS) to determine if any delayed effects should be expected.
5. Discard contaminated clothing or launder them separately from other clothing. Leather garments or accessories cannot be decontaminated and should be discarded.

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

For flammable solids on skin, first brush off as much of the solid as possible, then proceed as described above.

For hydrofluoric acid on skin, rinse with water for 5 minutes. Apply 2.5% calcium gluconate gel, a tube of which should be present in any lab working with hydrofluoric acid. If not readily available, continue rinsing for 15 minutes. ***In all cases, seek medical attention immediately.***

For phenol concentrations more than 10%, 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. Proceed as described above.

Chemicals in Eyes

1. Immediately 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 an eyewash is not available, pour water on the eye, rinsing from the nose outward to avoid contamination of the unaffected eye.
2. Remove contact lenses while rinsing. **Do not lose time removing contact lenses before rinsing.** Do not attempt to rinse and reinsert contact lenses.
3. Seek medical attention regardless of the severity or apparent lack of severity. If an ambulance or transportation to the Student life center or the hospital is needed, contact Baylor PD at 2222 or (254) 710-2222. Explain carefully what chemicals were involved. If easily accessible, bring an SDS.

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 **Baylor PD**. Explain carefully what chemicals were involved.
3. Review the SDS to determine what health effects are expected, including delayed effects.

Accidental Ingestion of Chemicals

1. Immediately contact **Baylor PD** and/or contact the Poison Control Center at 800-222-1222 for instructions.
2. **Do not induce vomiting** unless directed to do so by a health care provider.

Accidental Injection of Chemicals

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

EMERGENCY INFORMATION POSTINGS

Most laboratories or chemical storage areas must have a complete Emergency Information Posting affixed on or near each entrance to the room. The poster must be reviewed for accuracy every twelve months and replaced as necessary.

The following information should be supplied on every poster:

- **Lab Supervisor/PI** - List those who are most familiar with the activities in the room.
- **Potential Hazards** - Hazardous material categories found in the room should be identified by pictorial representation (GHS or DOT pictograms) on a map of the lab.
- **Date Posted/Updated** - Posters should be reviewed to insure all information is current and replaced as needed. This will often occur as part of the annual lab audit.

The purpose of the Emergency Information Posting is to provide an easily recognizable and consistent means of displaying essential information about the status and contents of laboratories and facilities, primarily for the benefit of persons attempting to cope with an explosion, fire, natural disaster, or other emergency. Such information is important for the safety of emergency personnel and is often of considerable value in evaluating and dealing with the emergency.

In the absence of current and accurate information, responders may take an extremely conservative approach to handling the emergency and the response may become disproportionate to the actual hazard. This may lead to a delayed response that could result in an emergency of greater magnitude or, at the very least, lengthen the disruption of normal activities.

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.

Contact EH&S if you have questions or need assistance with the emergency posting for your area.

REPORTING ACCIDENTS AND INJURIES

All accidents, injuries, or near-misses should be reported to your supervisor or Principal Investigator.

If a laboratory worker believes that he or she has been over-exposed to a chemical, the worker or supervisor should contact EHS at 710-2900, regardless of whether or not signs or symptoms are noted. EHS will contact the individual and lab manager to conduct an incident investigation.

Baylor University EHS encourages a culture of reporting all incidents and near misses. Incident investigations are conducted to work towards safer working environments and practices. These investigations are not to assign blame or responsibility for an accident.

SECTION 4: CHEMICAL AND HAZARD IDENTIFICATION

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 safety data sheet (SDS). Thus, the information found on the original container label and the SDS may provide a great deal of information about the identity of the chemical constituents and their health and physical hazards.

LABELS

The manufacturer's label should be kept intact. Do not intentionally deface or obscure the label or the hazard warnings until the container has been completely emptied. 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.

SAFETY DATA SHEETS

All chemical manufacturers or distributors are required to conduct a hazard evaluation of their products and include the information on a safety data sheet (SDS). The manufacturer or distributor is required to provide an SDS with the initial shipment of their products. Any SDSs received by the laboratory must be maintained in a central location in the laboratory. The **Chemical Hygiene Plan** states where the SDSs are kept in a particular laboratory.

SDSs are sometimes difficult to interpret. For more information about understanding and using an SDS, see the **Guide to Understanding SDS Information**.

If an SDS is not on hand, check the manufacturer's website to look up the chemical in their collection of SDSs. If the SDS cannot be found, contact the manufacturer or distributor at the number listed on the container label and request an SDS.

SECTION 5: HEALTH HAZARDS OF CHEMICALS

INTRODUCTION

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 determined.

In order to assess the hazards of a particular chemical, both the physical and health hazards of the chemical must be considered.

Before using any chemical, the SDS or other appropriate resource 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 reduced significantly by using safe work practices.

BASIC TOXICOLOGY

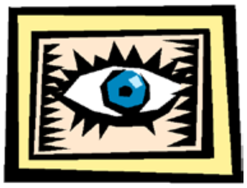
The health effects of hazardous chemicals are often less clear than the physical hazards. Data on the health effects of chemical exposure, especially from chronic exposure, are often incomplete. When discussing the health effects of chemicals, two terms are often used interchangeably - *toxicity* and *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 actual health risk of a chemical is a function of the toxicity and the actual 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 SDS usually includes information regarding whether or not skin absorption is a significant route of exposure.

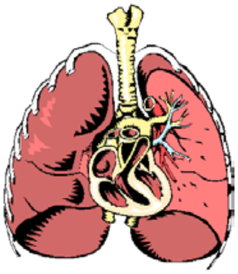
The absorption of a chemical through intact skin is influenced by the health of the skin and the properties of the chemical. Skin that is dry or cracked or has lacerations offers less resistance. Fat-soluble substances, such as many organic solvents, can easily penetrate skin and, in some instances,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

Wear **gloves** and other protective clothing to minimize skin exposure. See **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 clothing while rinsing, if necessary. Seek medical attention if symptoms persist.

Avoid the use of solvents for washing skin. They remove the natural protective oils from the skin and can cause irritation and inflammation. In some cases, washing with a solvent may facilitate absorption of a toxic chemical.

Chemical contact with eyes can be particularly dangerous, resulting in painful injury or loss of sight. Wearing **safety goggles** or a face shield 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.

Inhalation



The respiratory tract is the most common route of entry for gases, vapors, particles, and aerosols (smoke, mists and fumes). These materials may be transported into the lungs and exert localized effects, or be absorbed into the bloodstream. Factors that influence the absorption of these materials may include the vapor pressure of the material, solubility, particle size, its concentration in the inhaled air, and the chemical properties of the material. The vapor pressure is an indicator of how quickly a substance evaporates into the air and how high the concentration in air can become - higher concentrations in air cause greater exposure in the lungs and greater absorption in the bloodstream.

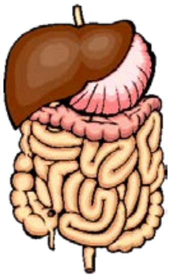
Most chemicals have an odor that is perceptible at a certain concentration, referred to as the odor threshold; however, there is no relationship between odor and toxicity. There is considerable individual variability in the perception of odor. Olfactory fatigue may occur

when exposed to high concentrations or after prolonged exposure to some substances. This may cause the odor to seem to diminish or disappear, while the danger of overexposure remains.

Symptoms of 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 many solvents. In the event of exposure, close containers or otherwise increase ventilation, and move to fresh air. If symptoms persist, seek medical attention.

Volatile hazardous materials should be used in a well-ventilated area, 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 Occupational Safety and Health Administration Respiratory Protection Standard regulates the use of respirators; thus, use of a respirator is subject to prior review by EHS according to university policy. See **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 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, and 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 affect the central nervous system.

Certain chemicals may affect a target organ. For example, lead primarily affects the central nervous system, 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 often reversible. *Chronic* toxicity results from repeated exposure over a long period of time. Effects are usually delayed and gradual, and may be irreversible. For example, the acute effect of alcohol exposure (ingestion) is intoxication, while the chronic effect is cirrhosis of the liver. Acute and chronic effects are distinguished in the SDS, usually with more information about acute exposures.

Relatively few chemicals have been evaluated for chronic effects, given the complexity of that type of study. Chronic exposure may have very different effects than acute exposure. Usually, studies of chronic exposure evaluate its cancer causing potential or other long-term health problems.

Evaluating Toxicity Data

Most estimates of human toxicity are based on animal studies, which may or may not relate to human toxicity. In most animal studies, the effect measured is usually death. This measure of toxicity is often expressed as an 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.

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.

Susceptibility of Individuals

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

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

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. Further information about working with Particularly Hazardous Substances is outlined in **Particularly Hazardous Substances**.

Where to Find Toxicity Information

Toxicity information may be found in Safety Data Sheets, under the "Health Hazard Data" section, on product labels, or in the **Registry of Toxic Effects of Chemical Substances**.

CHEMICAL EXPOSURE DETERMINATION

OSHA establishes exposure limits for several hundred substances. Laboratory workers must not be exposed to substances in excess of the permissible exposure limits (PEL) specified in OSHA Subpart Z, **Toxic and Hazardous Substances**. PELs refer to airborne concentrations of substances averaged over an eight-hour day. Some substances also have "action levels" below the PEL requiring certain actions such as medical surveillance or routine air sampling.

The SDS for a particular substance indicates whether any of the chemicals are regulated through OSHA and, if so, the permissible exposure limit(s) for the regulated chemical(s). This information is also available in the OSHA Table Z list of regulated chemicals.

Exposure Monitoring

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

When necessary, exposure monitoring is arranged by EHS according to established industrial hygiene practices. Results of the monitoring are made available to the individual monitored and his or her supervisor within 15 working days of the receipt of analytical results.

Based on the monitoring results, periodic air sampling may be scheduled at the discretion of EHS, in accordance with applicable federal, state and local regulations.

EHS maintains records of all exposure monitoring results.

SECTION 6A: CONTROLLING CHEMICAL EXPOSURE

GENERAL PRINCIPALS

There are three general methods for controlling one's exposure to hazardous substances:

- Engineering Controls
- Work Practices and Administrative Controls
- Personal Protective Equipment

In the laboratory, these methods or a combination of them can be used to keep exposure below permissible exposure limits.

Engineering Controls

Engineering controls include the following:

- Substitution of a less toxic material
- Change in process to minimize contact with hazardous chemicals
- Isolation or enclosure of a process or operation
- Use of wet methods to reduce generation of dusts or other particulates
- General dilution ventilation
- Local exhaust, including the use of fume hoods

The use of engineering controls is the preferred method for reducing worker exposure to hazardous chemicals.

Work Practice and Administrative Controls

Using good laboratory work practices, such as those outlined in this manual, help to reduce the risk of exposure to chemicals.

Administrative controls are those things put in place by the university that support the mandates of the OSHA Lab Standard. These include the Chemical Hygiene Plan and the Standard Operating Procedures. Conducting work according to what is set out in these documents will help minimize exposure to hazardous chemicals.

Personal Protective Equipment

When engineering and administrative controls are not sufficient to minimize exposure, personal protective equipment, including gloves, eye protection, respirators and other protective clothing should be used. See **Personal Protective Equipment** for more information.

SECTION 6B: FUME HOODS AND LABORATORY EXPOSURES

FUME HOODS AND LABORATORY VENTILATION

One of the primary safety devices in a laboratory is a chemical fume hood. A well-designed hood, when properly installed and maintained, can offer a substantial degree of protection to the user, provided that it is used appropriately and its limitations are understood.

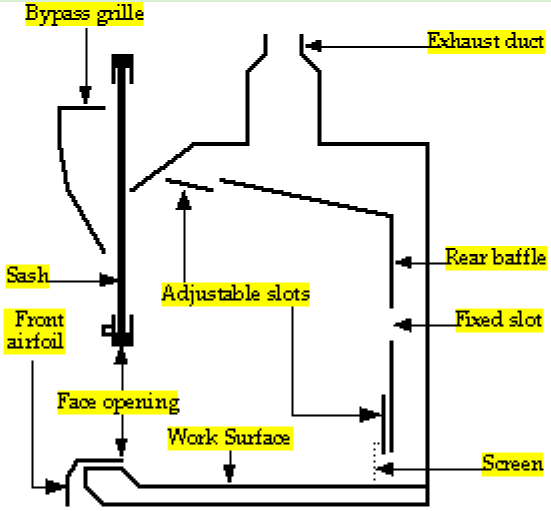
This section covers a number of topics aimed at helping laboratory workers understand the limitations and proper work practices for using fume hoods and other local ventilation devices safely.

There are basically two types of fume hoods at Baylor University, they are:

Constant volume – where the exhaust flowrate or quantity of air pulled through the hood is constant. Therefore, when the sash is lowered and the cross-sectional area of the hood opening decreases, the velocity of airflow (face velocity) through the hood increases proportionally. Thus, higher face velocities can be obtained by lowering the sash.

And **variable air volume** (VAV) - where the exhaust flowrate or quantity of air pulled through the hood varies as the sash is adjusted in order to maintain a set face velocity. Therefore, when the sash is lowered and the cross-sectional area of the hood opening decreases, the velocity of airflow (face velocity) through the hood stays the same while less total air volume is exhausted.

HOW A FUME HOOD WORKS



A fume hood is a ventilated enclosure in which gases, vapors and fumes are contained. An exhaust fan situated on the top of the laboratory building pulls air and airborne contaminants in the hood through ductwork connected to the hood and exhausts them to the atmosphere.

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

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

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

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

USING CHEMICAL FUME HOODS

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

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

When is a Fume Hood Necessary?

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

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

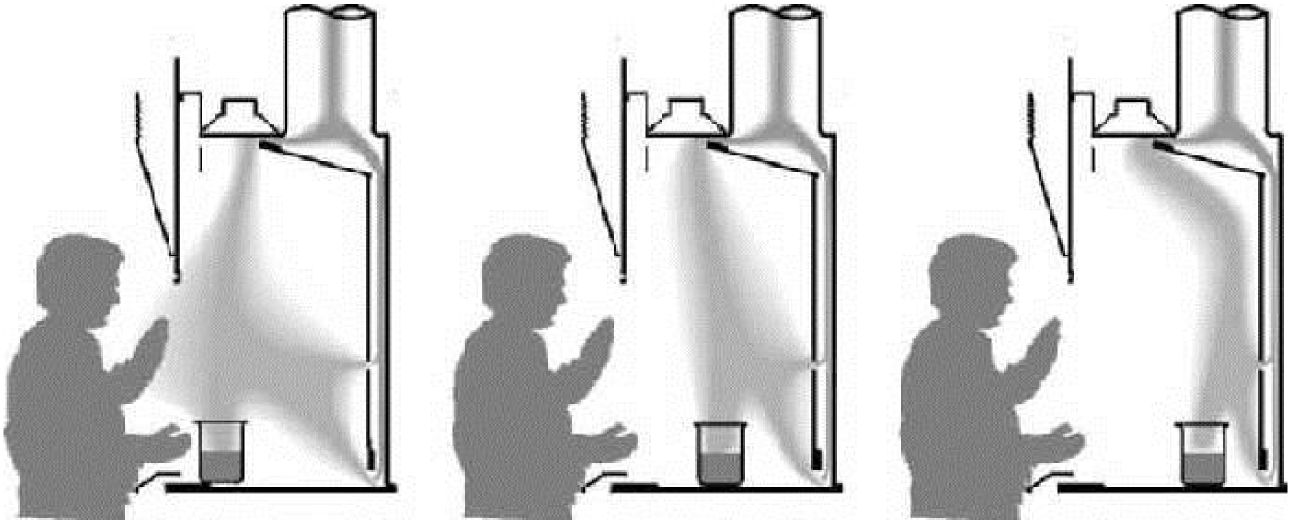
GOOD WORK PRACTICES

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

Items contaminated with odorous or hazardous materials should be removed from the hood only after decontamination or if placed in a closed outer container to avoid releasing contaminants into the laboratory air.

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

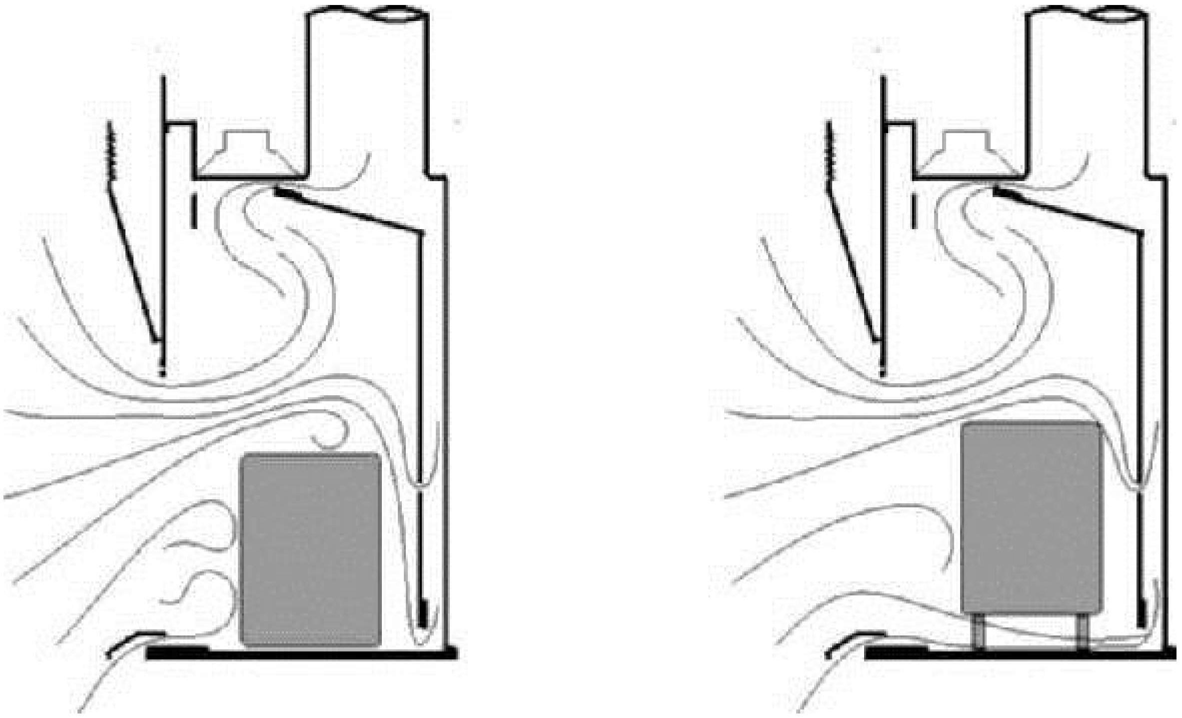
- **Mark a line** with tape 6 inches behind the sash and keep all chemicals and equipment behind that line during experiments. This will help to keep materials from escaping the hood when disturbances like air currents from people walking past the hood, etc., interfere with airflow at the face of the hood.



Images from Kewaunee Fume Hoods

Bad placement of materials. ***Good placement of materials.*** ***Best placement of materials.***

- Provide **catch basins** for containers that could break or spill, to minimize the spread of spilled liquids.
- **Keep the sash completely lowered** any time an experiment is in progress and the hood is unattended. *Note: Lowering the sash not only provides additional personal protection, but it also results in significant* ***energy conservation.***
- Never use a hood to control exposure to hazardous substances without first **verifying that it is operating properly**.
- **Visually inspect the baffles** (openings at the top and rear of the hood) to be sure that the slots are open and unobstructed.
- **Do not block slots**. If large equipment must be placed in the hood, put it on blocks to raise it approximately 2 inches above the surface so that air may pass beneath it. See figure below.



Images from Kewaunee Fume Hoods

Poor placement of large equipment ***Good placement of large equipment***

- **Place large or bulky equipment near the rear of the fume hood.** Large items near the face of the hood may cause excessive air turbulence and variations in face velocity.
- **Do not use the hood as a storage device.** Keep only the materials necessary for the experiment inside of the hood. If chemicals must be stored in the hood for a period of time, install shelves on the sides of the hood, away from the baffles. See **Use of Hood as a Storage Device** for more information.
- **Keep the hood sash clean and clear.**
- **Check area around the hood for sources of cross drafts,** such as open windows, supply air grilles, fans and doors. Cross drafts may cause turbulence that can allow leaks from the hood into the lab.
- **Extend only hands and arms into the hood and avoid leaning against it.** If the hood user stands up against the face of the hood, air currents produced by turbulent airflow may transport contaminants into the experimenter's breathing zone.
- **Clean all chemical residues** from the hood chamber after each use.
- **All electrical devices should be connected outside the hood** to avoid electrical arcing that can ignite a flammable or reactive chemical.
- **DO NOT USE A HOOD FOR ANY FUNCTION FOR WHICH IT WAS NOT INTENDED.** Certain chemicals or reactions require specially constructed hoods. Examples are perchloric acid or high pressure reactions. Most special use hoods are labeled with the uses for which they are designed.

COMMON MISUSES AND LIMITATIONS

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

- **Particulates:** A fume hood is not designed to contain high velocity releases of particulate contaminants unless the sash is fully closed.
- **Pressurized systems:** Gases or vapors escaping from pressurized systems may move at sufficient velocity to escape from the fume hood.
- **Explosions:** The hood is not capable of containing explosions, even when the sash is fully closed. If an explosion hazard exists, the user should provide anchored barriers, shields or enclosures of sufficient strength to deflect or contain it. Such barriers can significantly affect the airflow in the hood.
- **Perchloric Acid:** A conventional fume hood must not be used for perchloric acid. Perchloric acid vapors can settle on ductwork, resulting in the deposition of perchlorate crystals. Perchlorates can accumulate on surfaces and have been known to detonate on contact, causing serious injury to researchers and maintenance personnel. Specialized perchloric acid hoods, made of stainless steel and equipped with a washdown system must be used for such work.
- **Air Foil Sills:** Many fume hoods are equipped with flat or rounded sills or air foils which direct the flow of air smoothly across the work surface. Sills should not be removed or modified by the hood user. Objects should never be placed on these sills. Materials released from containers placed on the sills may not be adequately captured. In addition, an object on the sill may prevent the quick and complete closure of the sash in an emergency.
- **Spill Containment Lips:** Most modern fume hoods have recessed work surfaces or spill containment lips to help contain minor liquid spills. In many cases, these lips are several inches wide. Containers of liquids should not be placed on the hood lip.
- **Horizontal Sliding Sashes:** The hood user should never remove sliding sashes. Horizontal sash hoods are designed and balanced with no more than half the face open at any time. Removal of sashes may reduce the face velocity below acceptable levels.
- **Tubing for Exhaust:** Tubing is frequently used to channel exhaust to the hood from equipment located some distance away. This is not an effective control method.
- **Connections to the Exhaust System:** Occasionally, a researcher may need local exhaust ventilation other than that provided by an existing fume hood. A new device may not be connected to an existing fume hood without the explicit approval of the department's facilities manager. Adding devices to even the simplest exhaust system without adequate evaluation and adjustment will usually result in decreased performance of the existing hood and/or inadequate performance of the additional device.
- **Microorganisms:** Work involving harmful microorganisms should be done in a biosafety cabinet, rather than a chemical fume hood.
- **Highly Hazardous Substances:** A well designed fume hood will contain 0.999 - 0.9999% of the contaminants released within it when used properly. When working with

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

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

THE FUME HOOD AS A STORAGE DEVICE

Fume hoods are designed specifically to provide ventilation for the protection of lab occupants during chemical manipulations. The airflow they provide is greatly in excess of that needed for storage of closed containers of even the most toxic of volatile materials. Storing materials in this way is, therefore, a misuse of an expensive piece of equipment.

In general, the storage of chemicals in fume hoods is strongly discouraged. See **Flammable Materials** for more information about proper storage of flammable, toxic, or odorous chemicals.

The realities of available space and equipment in some laboratories may make it difficult or impossible to completely prohibit the use of hood workspaces for storage. In such a case, the following general policy is recommended:

Hoods Actively in Use for Experimentation

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

Hoods Not in Active Use

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

HOOD PERFORMANCE INDICATORS

Most fume hoods at Baylor University are equipped with some type of continuous airflow monitoring device. Some are equipped with alarms. The hoods also have a survey sticker with important information to help determine whether the particular hood is functioning properly and is appropriate for the work to be performed.

CONTINUOUS MONITORING DEVICES

Static Pressure Gauge (Magnehelic)

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

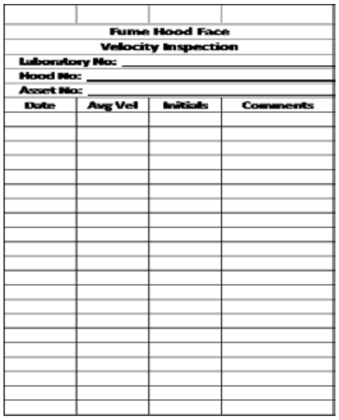
The gauge is a flow rate indicator with a scale that reads in units of pressure, rather than velocity. Changes in the magnehelic reading are not linearly proportional to changes in face velocity; therefore, it should only be used as an index of hood performance.

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

Face Velocity Monitors

Many of the newer hoods have constant face velocity measuring devices. An LED readout of the face velocity is found on the device on the top corner of the hood opening. The readout indicates the actual face velocity of the hood.

HOOD SURVEY STICKER



Fume Hood Face
Velocity Inspection

Laboratory No: ____________
Hood No: ____________
Asset No: ____________

Date	Avg Vel	Initials	Comments

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

The **Date** is the date of the last hood survey. Hoods that have not been surveyed within the past year should not be reported by work order to Facilities Services.

The **Hood Number** is a unique identifier for the particular hood. Refer to this number when discussing problems with a particular hood.

The **Average Velocity Reading (Avg Vel)** is the reading of the magnehelic gauge or other continuous monitoring device at the time of the survey.

Do not use a hood that does not have a survey sticker. If a survey is needed, place a work order with Facilities Services.

OTHER LABORATORY EXHAUST SYSTEMS

Many laboratories use equipment and apparatus that can generate airborne contaminants, but cannot be used within a fume hood. Examples include gas chromatographs, ovens, and vacuum pumps.

Other types of local exhaust ventilation systems may be required to control contaminants generated by these operations. Such systems must not be installed without explicit approval of the building facility manager and/or maintenance personnel. See **Common Misuses of a Fume Hood** for more information.

Snorkel

A snorkel is a flexible duct or hose connected to an exhaust system. It can only capture contaminants that are very close to the inlet of the hose, typically less than a distance equal to one half of the diameter of the duct.

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

Toxic Gas Cabinets

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

Gas cabinets should be connected to laboratory exhaust ventilation using hard duct, rather than snorkels, since such tubing is more likely to develop leaks.

Glove Box

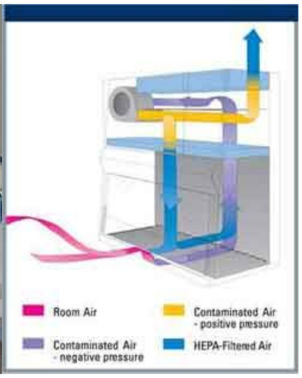
There are two general types of glove boxes, one operating under negative pressure, the other operating under positive pressure. Glove boxes consist of a small chamber with sealed openings fitted with arm-length gloves. The materials are placed inside the chamber and manipulated using the gloves.

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

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

Biosafety Cabinets

A conventional fume hood should not be used for work with viable biological agents. A biosafety cabinet is specially designed and constructed to offer protection to both the worker and the biological materials.



Similarly, a biosafety cabinet should generally not be used for work with hazardous chemicals. 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.

Clean Benches

Clean benches are similar to appearance as a fume hood; however, they do not exhaust air from the laboratory. A clean bench is a device that draws air from the lab through a HEPA filter and vents the filtered air downwards onto a work surface to keep the materials within free from particulate contamination. These devices are not to be used with hazardous materials as they provide no personal protection. Do not store materials on top of this hood as this will block the filter, overload the motor, and provide poor product protection.

STANDARD OPERATING CONDITIONS

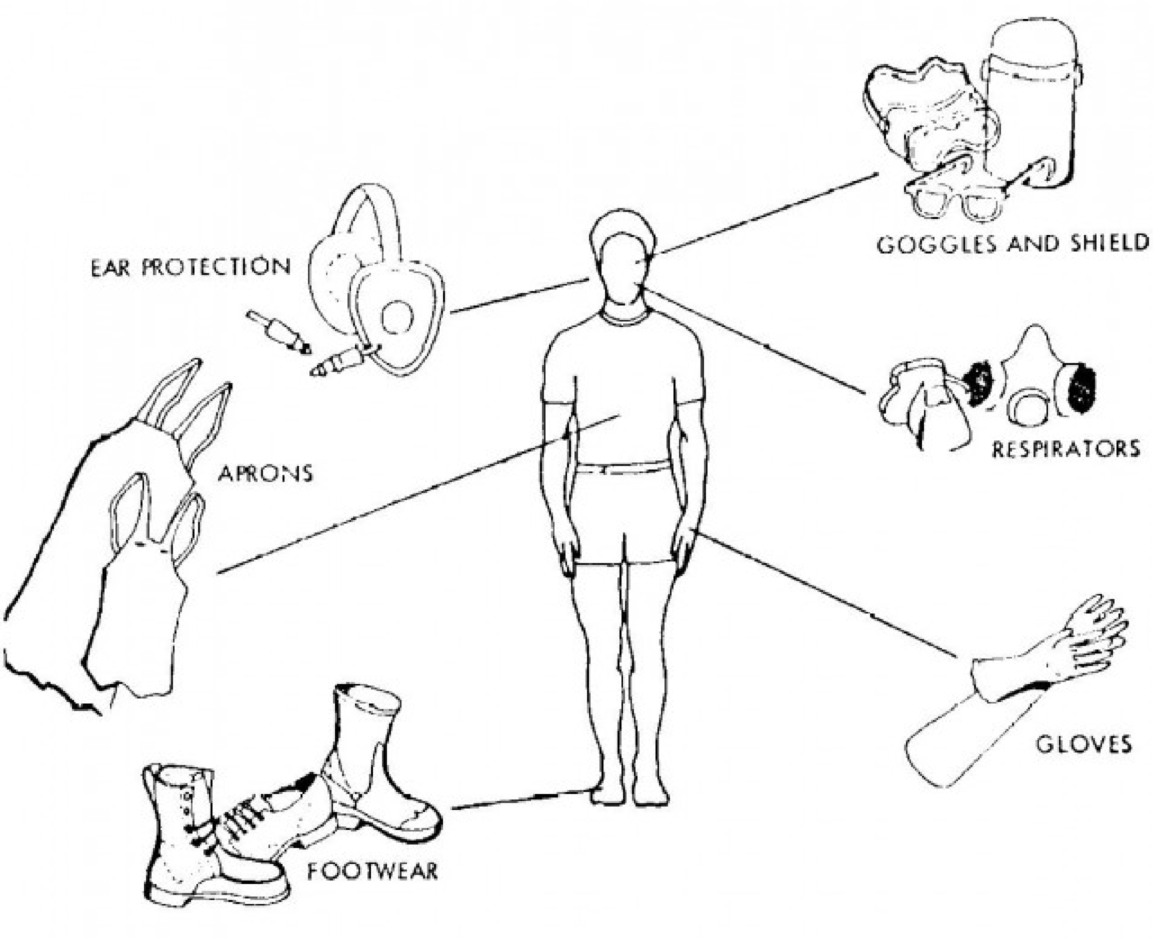
The Standard Operating Configuration (SOC) is the position at which the hood sash should be placed when the hood is actually in use as a containment device. Making such an assumption is unavoidable when designing a fume hood exhaust system since this determines the quantity of air the system must exhaust if an adequate face velocity is to be maintained.

In order to obtain the recommended face velocity, many fume hoods have an SOC which is less than a fully open sash. If a hood user does not use the hood with the sash at the SOC position, it is possible for that user to create a situation in which an otherwise properly operating hood has an insufficient face velocity. Most fume hoods are equipped with sash stops and/or alarm devices to designate the Standard Operating Configuration limit.

SECTION 6C: PERSONAL PROTECTIVE EQUIPMENT

PERSONAL PROTECTIVE EQUIPMENT

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. PPE does not reduce or eliminate the hazard, protects only the wearer, and does not protect anyone else.



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.

EYE PROTECTION

Safety Glasses

Safety glasses look very much like normal glasses but have lenses that are impact resistant and frames that are far stronger than standard streetwear glasses. Safety glasses with proper impact and shatter resistance will be marked "Z87" on the frame or lens. Safety glasses must have side shields and should be worn whenever there is the possibility of objects striking the eye, such as particles, glass, or metal shards. Many potential eye injuries have been avoided by wearing safety glasses.

Standard streetwear eyeglasses fitted with side shields are not sufficient. Workers who are interested in obtaining prescription safety glasses should consult their department. Safety glasses come in a variety of styles to provide the best fit and comfort, including some designed to fit over prescription glasses.

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

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

Chemical Splash Goggles

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. Some may be worn over prescription glasses.

Goggles come in a variety of styles for maximum comfort and splash protection. Visorgogs are a hybrid of a goggle and safety glasses. They offer more splash protection than safety glasses, but not as much as goggles. They fit close to the face, but do not seal at the bottom as goggles do.

Face Shields

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

Contact Lenses

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

This particular recommendation runs counter to what most of us were taught previously. However, studies have shown that contact lenses are safe to wear in the laboratory environment.

PROTECTIVE CLOTHING AND FOOTWEAR

Protective Clothing

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 solids contamination, 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.

Footwear

Closed-toed shoes should be worn at all times in buildings where chemicals are stored or used. Perforated shoes, sandals or cloth sneakers should not be worn in laboratories or where mechanical work is conducted. Such shoes offer no barrier between the laboratory worker and chemicals or broken glass.

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

Although generally not required in most laboratories, steel-toed safety shoes may be necessary when there is a risk of heavy objects falling or rolling onto the feet, such as in bottle-washing operations or animal care facilities.

GLOVES

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 also absorption through the skin can be a significant route of exposure to certain chemicals. Dimethyl sulfoxide (DMSO), nitrobenzene, and many solvents are examples of chemicals that can be readily absorbed through the skin into the bloodstream, where the chemical may cause harmful effects.

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. Resistance to permeation rate is usually reported as E (excellent), G (good), F (fair), P (poor) or NR (not recommended). If chemical breakthrough does not occur, then 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 conditions in the work environment. Users may opt to conduct their own tests, particularly when working with highly toxic materials.

For mixtures, it is recommended that the glove material be selected based on the 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.
Neoprene	Provides moderate abrasion resistance but good tensile strength and heat resistance. Compatible with many acids, caustics and oils.
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.
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.
Natural rubber	Provides flexibility and resistance to a wide variety of acids, caustics, salts, detergents and alcohols.

Where to Find Compatibility Information

Most glove manufacturers have chemical compatibility charts available for their gloves. These charts may be found in laboratory safety supply catalogs such as **Fisher Scientific**, **VWR**, and **Lab Safety Supply**. In addition, most Safety Data Sheets (SDS) recommend the most protective glove material in their Protective Equipment section.

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 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.

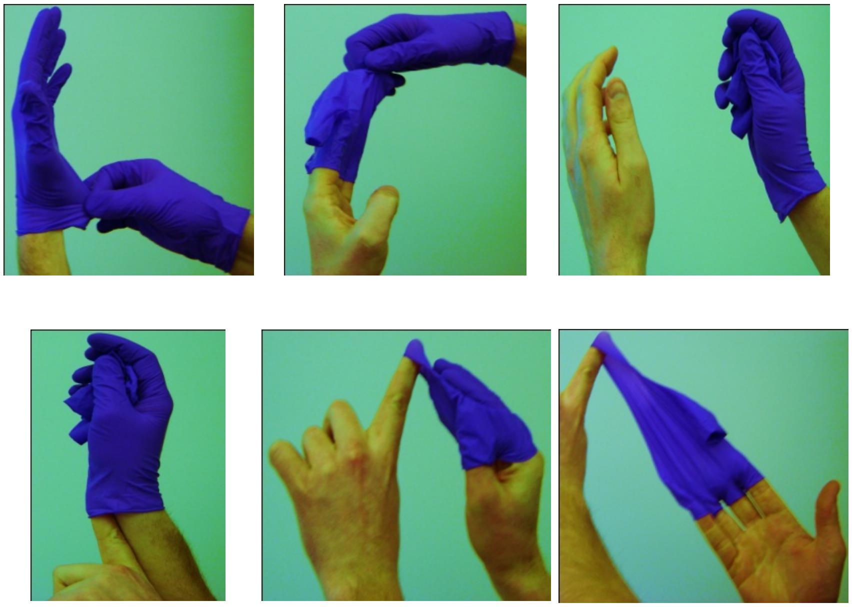
Before removing them, wash the outside of the glove. To avoid accidental skin exposure, remove the first glove by grasping the cuff and peeling the glove off the hand so that the glove is inside out. Repeat this process with the second hand, touching the inside of the glove cuff, rather than the outside. Wash hands immediately with soap and water.

Follow the manufacturer's instructions for washing and caring for reusable gloves.

PROPER GLOVE REMOVAL

Gloves should be removed avoiding skin contact with the exterior of the glove and possible contamination. Disposable gloves should be removed as follows:

- Grasp the exterior of one glove with your other gloved hand.
- Carefully pull the glove off your hand, turning it inside-out. The contamination is now on the inside.
- Ball the glove up and hold in your other gloved hand.
- Slide your ungloved finger into the opening of the other glove. Avoid touching the exterior.
- Carefully pull the glove off your hand, turning it inside out again. All contamination is contained.
- Discard appropriately.



Latex Gloves and Related Allergies

Allergic reactions to natural rubber latex have been increasing since 1987, when the Centers 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.

In June, 1997, the National Institute of Occupational Safety and Health (NIOSH) issued an alert **Preventing Allergic Reactions to Latex in the Workplace** (publication number DHHS (NIOSH) 97-135).

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:

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

HEARING PROTECTION

Most laboratory equipment and operations do not produce noise levels that require the use of hearing protection, with the exception of some wind tunnels, as described below. Baylor University has a Hearing Conservation Program in place for individuals who are exposed to noise levels equal to or exceeding the OSHA action level of 85 decibels (dBA) averaged over eight hours, per the OSHA Occupational Noise Standard. This program includes workplace monitoring, personal exposure monitoring, annual audiometric testing, use of hearing protection and annual training.

Laboratory workers who would like to use hearing protection for noise levels below the action level may do so without enrollment in the Hearing Conservation Program. Using hearing protection, such as earplugs, earmuffs or hearing bands, can improve communication or provide comfort to the worker in a noisy environment.

The most common noisy equipment in the laboratories are ultrasonicators. EHS has measured noise levels of several ultrasonicators used in the laboratories and found that noise levels were well below 85 dBA, averaged over eight hours.

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. Since the use of a respirator is regulated by the OSHA Respiratory Protection Standard, respirator use at Baylor is subject to prior review by EHS, according to university policy.

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 recordkeeping.

Use of a paper or cloth dust mask (left-most in above picture) is allowed without enrolling in the Respiratory Protection Program. However, if you believe you need to upgrade to a tight-fitting respirator, you must contact EHS prior. Tight fitting respirators are typically made of silicone or rubber and have filter cartridges or supplied air for breathing.

For more information, please contact Baylor EHS at 254-710-2900.

SECTION 7: SAFE WORK PRACTICES AND PROCEDURES

7A: GENERAL WORK PRACTICES

BEFORE YOU BEGIN

Every laboratory worker should observe the following rules:

1. Know the potential hazards and appropriate safety precautions before beginning work. Ask and be able to answer the following questions:
    - What are the hazards?
    - What are the worst things that could happen?
    - What do I need to do to be prepared?
    - What work practices, facilities or personal protective equipment are needed to minimize the risk?
2. Know the location and how to use emergency equipment, including safety showers and eyewash stations.
3. Never block safety equipment or doors and keep aisles clear and free from tripping hazards.
4. Familiarize yourself with the emergency response procedures, facility alarms and building evacuation routes.
5. Know the types of personal protective equipment available and how to use them for each procedure.
6. Be alert to unsafe conditions and actions and bring them to the attention of your supervisor or lab manager immediately so that corrections can be made as soon as possible.
7. Prevent pollution by following proper waste disposal procedures. Chemical reactions may require traps or scrubbing devices to prevent the release of toxic substances to the laboratory or to the environment.
8. Position and clamp reaction apparatus thoughtfully in order to permit manipulation without the need to move the apparatus until the entire reaction is completed. Combine reagents in the appropriate order and avoid adding solids to hot liquids.

CHEMICAL STORAGE

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

General Considerations

In general, store materials and equipment in cabinets and on shelving provided for such storage.

- Avoid storing materials and equipment on top of cabinets. If you must place things there, however, you must maintain a clearance of *at least 18 inches from the sprinkler heads* or (if no sprinkler heads are present) *24 inches from the ceiling*.
- Be sure that the weight of the chemicals does not exceed the load capacity of the shelf or cabinet.
- Wall-mounted shelving must have heavy-duty brackets and standards. This type of shelving is not recommended for chemical storage.
- Cabinets for chemical storage must be of solid, sturdy construction, preferably hardwood or metal.
- Do not store materials on top of high cabinets where they will be hard to see or reach.
- Do not store corrosive liquids above eye level.
- Provide a specific storage location for each type of chemical, and return the chemicals to those locations after each use.
- Avoid storing chemicals in the workspace within a laboratory hood, except for those chemicals currently in use.
- If a chemical does not require a ventilated cabinet, store it inside a closable cabinet or on a shelf that has a lip to prevent containers from sliding off in the event of an accident or fire.
- Do not expose chemicals to heat or direct sunlight.
- Observe all precautions regarding the storage of incompatible chemicals.
- Use corrosion resistant storage trays or secondary containers to collect materials if the primary container breaks or leaks.
- Distinguish between refrigerators used for chemical storage and refrigerators used for food storage. Each refrigerator should be labeled "No Food" or "Food Only".
- Do not store flammable liquids in a refrigerator unless it is approved for such storage. Such refrigerators are designed with non-sparking components to avoid an explosion.

Segregation of Chemicals

Incompatible chemicals should not be stored together. Storing chemicals alphabetically, without regard to compatibility, can increase the risk of a hazardous reaction, especially in the event of container breakage. In addition to the Chemical Incompatibility Chart below, there are additional resources available, both in print and on-line.

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

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

Segregate dry reagents as follows:

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

Segregate liquids as follows:

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

Segregate compressed gases as follows:

- Toxic gases
- Flammable gases
- Oxidizing and inert gases

Chemical Incompatibility Chart

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

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

Ammonia (anhydrous)	Bromine, chlorine, calcium hypochlorite, hydrofluoric acid, iodine, mercury, and silver.
Ammonium Nitrate	Acids, metal powders, flammable liquids, chlorates, nitrates, sulfur and finely divided organics or other combustibles.
Aniline	Hydrogen peroxide or nitric acid.
Bromine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, finely divided metals, sodium carbide, turpentine.
Calcium Oxide	Water
Carbon (activated)	Calcium hypochlorite, all oxidizing agents.
Caustic (soda)	Acids (organic and inorganic).
Chlorates or Perchlorate	Acids, aluminum, ammonium salts, cyanides, phosphorous, metal powders, oxidizable organics or other combustibles, sugar, sulfides, and sulfur.
Chlorine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, finely divided metals, sodium carbide, turpentine.
Chlorine Dioxide	Ammonia, methane, phosphine, hydrogen sulfide.
Chromic Acid	Acetic acid, naphthalene, camphor, alcohol, glycerine, turpentine and other flammable liquids.
Copper	Acetylene, hydrogen peroxide.
Cumene Hydroperoxide	Acids
Cyanides	Acids
Flammable Liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, bromine, chlorine, fluorine, iodine.

Fluorine	Isolate from everything.
Hydrazine	Hydrogen peroxide, nitric acid, and other oxidizing agents.
Hydrocarbons	Bromine, chlorine, chromic acid, fluorine, hydrogen peroxide, and sodium peroxide.
Hydrocyanic Acid	Nitric acid, alkali.
Hydrofluoric Acid	Ammonia, aqueous or anhydrous.
Hydrogen Peroxide (anhydrous)	Chromium, copper, iron, most metals or their salts, aniline, any flammable liquids, combustible materials, nitromethane, and all other organic material.
Hydrogen Sulfide	Fuming nitric acid, oxidizing gases.
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen.
Mercury	Acetylene, alkali metals, ammonia, fulminic acid, nitric acid with ethanol, hydrogen, oxalic acid.
Nitrates	Combustible materials, esters, phosphorous, sodium acetate, stannous chloride, water, zinc powder.
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, flammable gases and liquids, hydrocyanic acid, hydrogen sulfide and nitratable substances.
Nitrites	Potassium or sodium cyanide.
Nitroparaffins	Inorganic bases, amines.
Oxalic acid	Silver, mercury, and their salts.
Oxygen (liquid or enriched air)	Flammable gases, liquids, or solids such as acetone, acetylene, grease, hydrogen, oils, phosphorous.
Perchloric Acid	Acetic anhydride, alcohols, bismuth and its alloys, paper, wood, grease, oils or any organic materials and reducing agents.

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

	phosphorous oxychloride, phosphorous pentachloride, phosphorous pentoxide, sulfuric acid, sulfur trioxide.

Flammable Liquids

Flammable liquids require special storage considerations. See **Flammable Materials** for more information.

Acids

Mineral acids, including phosphoric, hydrochloric, nitric, sulfuric, and perchloric acid can be stored in a cabinet designed for Corrosive Acids. These non-metallic cabinets have no internal metallic parts, acid resistant coating and a cabinet floor constructed to be able to contain spillage. **Volatile acids**, such as oleum or fuming nitric acid, should be stored either in an acid cabinet or in a vented cabinet, such as the fume hood base, particularly after they have been opened. Concentrated mineral acids can be very reactive, even with each other. **Concentrated acids** can even react vigorously with dilute solutions of the same acid, if mixed together rapidly. For example: concentrated sulfuric acid mixed quickly with 1 molar sulfuric acid will generate a lot of heat. Different concentrated acids should be stored apart. If stored within the same cabinet, plastic trays, tubs or buckets work well to keep different acids apart within the cabinet.

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

Picric Acid can form explosive salts with many metals, or by itself when dry. **Perchloric Acid** is an extremely powerful oxidizer and must be kept away from all organic materials, including wood. See **Section 7d,** Corrosives for more information.

Unstable Chemicals

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

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

For any potentially unstable chemical:

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

More information about unstable chemicals is available in **Peroxide Forming Compounds and Reactives**.

Designated Areas

Any area where particularly hazardous substances, including carcinogens, acutely toxic chemicals and reproductive toxins, are stored or used must be posted as a Designated Area. These materials should be stored separately from other chemicals, as space permits. See **Particularly Hazardous Substances** for more information.

Compressed Gases

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

- All cylinders must be secured to a wall, bench or other support structure using a chain or strap. Alternatively, a cylinder stand may be used.
- Segregate cylinders by gas type (e.g., flammable, inert, etc.).
- Store cylinders away from heat sources and extreme weather conditions.

See **Compressed Gas Cylinders** for more information.

Combustible Materials

Common combustible materials, such as paper, wood, corrugated cardboard cartons and plastic labware, if allowed to accumulate, can create a significant fire hazard in the laboratory. Combustible materials not stored in metal cabinets should be kept to a minimum. Store large quantities of such supplies in a separate room, if possible.

PERSONAL BEHAVIOR

Professional standards of personal behavior are required in any laboratory:

- Avoid distracting or startling other workers
- Do not allow practical jokes or horseplay
- Use laboratory equipment only for its designated purpose
- Do not allow visitors, including children and pets, in laboratories where hazardous substances are stored or are in use or hazardous activities are in progress.
- Do not prepare, store (even temporarily), or consume food or beverages in any chemical laboratory
- Do not smoke in any chemical laboratory. Additionally, be aware that tobacco products in opened packages can absorb chemical vapors. Baylor University is a smoke free, tobacco free campus.
- Do not apply cosmetics when in the laboratory
- Never wear or bring lab coats or jackets into areas where food is consumed.

- Confine long hair and loose clothing in the laboratory. Wear shoes at all times. Open-toed shoes or sandals are not appropriate.
- Under no circumstances should mouth suction be used to pipette chemicals or to start a siphon. Use a pipette bulb or a mechanical pipetting device to provide a vacuum.
- Wash well before leaving the laboratory. Do not use solvents for washing skin.
- Keep work areas clean and free from obstruction. Clean up spills immediately.
- Do not block access to exits, emergency equipment, controls, electrical panels etc.
- Avoid working alone.

TRANSPORTING CHEMICALS

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

- Use a bottle carrier, cart or other secondary container when transporting chemicals in breakable containers (especially 250 ml or more) through hallways or between buildings. Secondary containers are made of rubber, metal or plastic, with carrying handle(s), and are large enough to hold the entire contents of the chemical containers in the event of breakage. A variety of such containers are available from the Baylor Science Building stockroom or from laboratory supply catalogs.
- Transport of hazardous chemicals between buildings is strongly discouraged.
- Transportation of hazardous chemicals in personal vehicles is strictly forbidden.
- When moving in the laboratory, anticipate sudden backing up or changes in direction by others. If you should stumble or fall while carrying glassware or chemicals, try to project them away from yourself and others.
- The individual transporting the chemical should be knowledgeable about the hazards of the chemical and should know how to handle a spill of the material.
- When transporting **compressed gas cylinders**, the cylinder should always be strapped in a cylinder cart and the valve protected with a cover cap. Do not attempt to carry or roll cylinders from one area to another.
- Transport chemicals in freight elevators rather than passenger elevators, if available.
- Keep chemicals in their original packing when transporting, if possible.

WORKING WITH SCALED-UP REACTIONS

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

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

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

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

UNATTENDED EXPERIMENTS

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

- Laboratory lights should be left on, and signs should be posted identifying the nature of the experiment and the hazardous substances in use.
- If appropriate, arrangements should be made for other workers to periodically inspect the operation.
- The Emergency Information Posting should include contact information for the responsible individual in the event of an emergency.
- Carefully examine how chemicals and apparatus are stored, considering the possibility for fire, explosion or unintended reactions.

WORKING ALONE

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

- If working alone is absolutely necessary, the worker should have a phone immediately available and should be in contact with another person (who knows that he or she is being relied upon) at least every 30 minutes.
- If no one from the laboratory is available, the worker should coordinate with another person in the building to check in on them periodically.
- If the research or operation is particularly hazardous such that a researcher could be severely injured or overcome by the process, a capable person must be present at all times and know to contact the Baylor Police Department at extension 2222 or (254) 710-2222 in event of an emergency.

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

SECTION 7B: FLAMMABLE MATERIALS

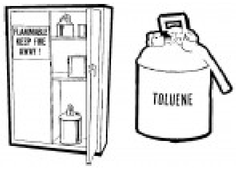
PROPERTIES OF FLAMMABLE AND COMBUSTIBLE LIQUIDS

Flammable and combustible liquids vaporize and form flammable mixtures with air when in open containers, when leaks occur, or when heated. To control these potential hazards, several properties of these materials, such as volatility, flashpoint, flammability range, and auto ignition temperatures must be understood. Information on the properties of a specific liquid can be found in that liquid's Safety Data Sheet (SDS), or other reference material.

STORAGE OF FLAMMABLE AND COMBUSTIBLE LIQUIDS

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

Safety Cans and Closed Containers



Many types of containers are required depending on the quantities and classes of flammable or combustible liquids in use. 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.

Flammable Liquid Storage Cabinets

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. Since venting is not required by any code or the by local municipalities and since venting may actually prevent the cabinet from protecting its contents, vents should remain plugged at all times – unless these vents are ducted to the building exhaust system. Storage cabinets must also be conspicuously labeled **"FLAMMABLE – KEEP FIRE AWAY".**

Refrigerators

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

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

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

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

Pouring flammable liquids can generate static electricity. The development of static electricity is related to the humidity levels in the area. Cold, dry atmospheres are more likely to facilitate static electricity. Bonding or using ground straps for metallic or non-metallic containers can prevent static generation.

- 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 plastic or metal containers or safety cans.
- When working with open containers, use a laboratory fume hood to control the accumulation of flammable vapor.
- Use bottle carriers for transporting glass containers.
- Use equipment with spark-free, intrinsically safe induction motors or air motors to avoid producing sparks. These motors must meet National Electric Safety Code (US DOC, 1993) Class 1, Division 2, Group C-D explosion resistance specifications. Many stirrers, Variacs, outlet strips, ovens, heat tape, hot plates and heat guns do not conform to these code requirements.
- Avoid using equipment with series-wound motors, since they are likely to produce sparks.

- Do not heat flammable liquids with an open flame. Steam baths, salt and sand baths, oil and wax baths, heating mantles and hot air or nitrogen baths are preferable.
- Minimize the production of vapors and the associated risk of ignition by flashback. Vapors from flammable liquids are denser than air and tend to sink to the floor level where they can spread over a large area.
- 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.
- When grounding non-metallic containers, contact must be made directly to the liquid, rather than to the container.
- In the rare circumstance that static cannot be avoided, proceed slowly to give the charge time to disperse or conduct the procedure in an inert atmosphere.

FLAMMABLE AEROSOLS

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

FLAMMABLE AND COMBUSTIBLE SOLIDS

Flammable solids often encountered in the laboratory include alkali metals, magnesium metal, metallic hydrides, some organometallic compounds, and sulfur. Many flammable solids react with water and cannot be extinguished with conventional dry chemical or carbon dioxide extinguishers.

- Ensure Class D extinguishers, e.g., Met-L-X, are available where flammable solids are used or stored.
- Sand can usually be used to smother a fire involving flammable solids. Keep a container of sand near the work area.
- If a flammable, water-reactive solid is spilled onto skin, brush off as much as possible, then flush with copious amounts of water.
- NEVER use a carbon dioxide fire extinguisher for fires involving lithium aluminum hydride (LAH). LAH reacts explosively with carbon dioxide.

CATALYST IGNITION

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

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

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

SECTION 7C: PEROXIDE FORMING COMPOUNDS AND REACTIVES

Certain chemicals can form dangerous peroxides on exposure to air and light. Since they are sometimes packaged in an atmosphere of air, peroxides can form even though the containers have not been opened. 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 test strips for quantitative or qualitative analysis. If you suspect that peroxides have formed, do not open the container to test since peroxides deposited on the threads of the cap could detonate.

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 Safety Data Sheet.
- 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 received, 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.
- Visually or chemically check for peroxides of any opened containers before use.
- Clean up spills immediately. 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.
- 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) with peroxide forming compounds, since contamination with metals can lead to explosive decomposition. Ceramic, Teflon or wooden spatulas and stirring blades are usually safe to use.

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

EXAMPLES OF PEROXIDIZABLE COMPOUNDS

<table>
<tr><th colspan="2">Peroxide Hazard on Storage: Discard After Three Months</th></tr>
<tr><td>Divinyl acetylene</td><td>Potassium metal</td></tr>
<tr><td>Divinyl ether</td><td>Sodium amide</td></tr>
<tr><td>Isopropyl ether</td><td>Vinylidene chloride</td></tr>
<tr><td colspan="2">Peroxide Hazard on Concentration: Discard After One Year</td></tr>
<tr><td>Acetal</td><td>Dioxane</td></tr>
<tr><td>Cumene</td><td>Ethylene glycol dimethyl ether (glyme)</td></tr>
<tr><td>Cyclohexene</td><td>Furan</td></tr>
<tr><td>Cyclooxyene</td><td>Methyl acetylene</td></tr>
<tr><td>Cyclopentene</td><td>Methylcyclopentane</td></tr>
<tr><td>Diacetylene</td><td>Methyl isobutyl ketone</td></tr>
<tr><td>Dicyclopentadiene</td><td>Tetrahydronaphtalene (Tetralin)</td></tr>
<tr><td>Diethyl ether</td><td>Tetrahydrofuran</td></tr>
<tr><td>Diethylene glycol dimethyl ether (diglyme)</td><td>Vinyl ethers</td></tr>
<tr><td colspan="2">Hazardous Due to Peroxide Initiation of Polymerization*: Discard After One Year</td></tr>
<tr><td>Acrylic acid</td><td>Styrene</td></tr>
<tr><td>Acrylonitrile</td><td>Tetrafluoroethylene</td></tr>
</table>

Butadiene	Vinyl acetylene
Chloroprene	Vinyl acetate
Chlorotrifluoroethylene	Vinyl chloride
Methyl methacrylate	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

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

If no peroxide is suspected but the chemical is a peroxide former, the chemical can be tested by the lab to ensure no peroxide has formed.

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 suspected, the safest route is to alert EHS for treatment and disposal of the material. Attempting to remove peroxides may be very dangerous under some conditions.

SECTION 7D: CORROSIVES

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

CORROSIVE LIQUIDS

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.

The following should be considered:

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

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.

4. Regulators and valves should be closed when the cylinder is not in use and flushed with dry air or nitrogen after use.
5. When corrosive gases are to be discharged into a liquid, a trap, check valve, or vacuum break device should be employed to prevent dangerous reverse flow.

CORROSIVE SOLIDS

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

1. Wear gloves and eye protection when handling corrosive solids.
2. When mixing with water, always slowly add the corrosive solid to water, stirring continuously. Cooling may be necessary.
3. If there is a possibility of generating a significant amount of dust, conduct work in a fume hood.

SECTION 7E: COMPRESSED GASES

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

HAZARDS

The following is an overview of the 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 organic materials. Increasing the concentration of an oxidizer accelerates the rate of combustion. Materials that are nonflammable under normal conditions may burn in an oxygen-enriched atmosphere.
- **Chemical Burns:** *Corrosive gases* can chemically attack various materials, including fire-resistant clothing. Some gases are not corrosive in their pure form, but can become extremely destructive if a small amount of moisture is added. Corrosive gases can cause rapid destruction of skin and eye tissue.
- **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 and property damage by propelling a cylinder or whipping a line.
- **Cylinder Weight:** A full size cylinder may weigh more than 130 pounds. Moving a cylinder manually may lead to back or muscle injury. Dropping or dragging a cylinder could cause serious injury.

HANDLING PRECAUTIONS

- Avoid dropping, dragging or sliding cylinders. Use a suitable hand truck or cart equipped with a chain or belt for securing the cylinder to the cart, even for short distances.
- Do not permit cylinders to strike each other violently. Cylinders should not be used as rollers for moving material or other equipment.
- Cylinder caps should be left on each cylinder until it has been secured against a wall or bench or placed in a cylinder stand, and is ready for installation of the regulator. Cylinder caps protect the valve on top of the cylinder from damage if knocked.
- Never tamper with pressure relief devices in valves or cylinders.
- Use only wrenches or tools provided by the cylinder supplier to remove a cylinder cap or to open a valve. Never use a screwdriver or pliers.
- Keep the cylinder valve closed except when in use.
- Position cylinders so that the cylinder valve is accessible at all times.
- Use compressed gases only in a well-ventilated area. Toxic, flammable and corrosive gases should be carefully handled in a hood or gas cabinet. Proper containment systems should be used and minimum quantities of these products should be kept on-site.
- When discharging gas into a liquid, a trap or suitable check valve should be used to prevent liquid from getting back into the cylinder or regulator.
- Where more than one type of gas is in use, label gas lines. This is particularly important when the gas supply is not in the same room or area as the operation using the gases.
- Do not use the cylinder valve itself to control flow by adjusting the pressure.

STORAGE OF COMPRESSED GAS CYLINDERS

- All cylinders must be secured to a wall, bench or fixed support using a chain or strap placed 2/3 of the way up. Cylinder stands are an alternative to straps.
- Cylinders should be strapped individually.
- Cylinders should not be stored with a regulator attached. Secure the proper gas cap to the threaded portion on the top of the cylinder to protect the valve.
- Do not store full and empty cylinders together.
- Oxidizers and flammable gases should be stored in areas separated by at least 20 feet or by a noncombustible wall.
- Cylinders should not be stored near radiators or other heat sources. If storage is outdoors, protect cylinders from weather extremes and damp ground to prevent corrosion.

- No part of a cylinder should be subjected to a temperature higher than 125F. A flame should never be permitted to come in contact with any part of a compressed gas cylinder.
- Do not place cylinders where they may become part of an electric circuit.
- Keep the number of cylinders in a laboratory to a minimum to reduce the fire and toxicity hazards.
- Lecture bottles should always be returned to the distributor or manufacturer promptly when no longer needed or discarded if at atmospheric pressure.
- Ensure that the cylinder is properly and prominently labeled as to its contents.
- NEVER place acetylene cylinders on their side.

USING COMPRESSED GAS CYLINDERS

Before using cylinders, read all label information and safety data sheets (SDSs) associated with the gas being used. The cylinder valve outlet connections are designed to prevent mixing of incompatible gases. The outlet threads vary in diameter; some are internal and some are external; some are right-handed and some are left-handed. Generally, right-handed threads are used for fuel gases.

To set up and use the cylinder, follow these steps:

1. Attach the closed regulator to the cylinder. **Never open the cylinder valve unless the regulator is completely closed.** Regulators are specific to the gas involved. A regulator should be attached to a cylinder without forcing the threads. Ensure the threads of both the regulator and main valve are clean. If the inlet of a regulator does not fit the cylinder outlet, no effort should be made to try to force the fitting. A poor fit may indicate that the regulator is not intended for use on the gas chosen.
2. Turn the delivery pressure adjusting screw counter-clockwise until it turns freely. This prevents unintended gas flow into the regulator.
3. Open the cylinder **slowly** until the inlet gauge on the regulator registers the cylinder pressure. If the cylinder pressure reading is lower than expected, the cylinder valve may be leaking.
4. With the flow control valve at the regulator outlet closed, turn the delivery pressure adjusting screw clockwise until the required delivery pressure is reached.
5. Check for leaks using *Snoop* or soap solution. At or below freezing temperatures, use a glycerin and water solution, such as *Snoop*, rather than soap. Never use an open flame to detect leaks.
6. When finished with the gas, close the cylinder valve, release the regulator pressure and replace the gas cap if it will not be used in the near future.

ASSEMBLY OF EQUIPMENT AND PIPING

- Do not force threads that do not fit exactly.
- Use Teflon tape or thread lubricant for assembly. Teflon tape should only be used for tapered pipe thread, not straight lines or metal-to-metal contacts.
- Avoid sharp bends of copper tubing. Copper tubing hardens and cracks with repeated bending.
- Inspect tubing frequently and replace when necessary.
- Tygon and plastic tubing are not appropriate for most pressure work. These materials can fail under pressure or thermal stress.
- Do not mix different brands and types of tube fittings. Construction parts are usually not interchangeable.
- Do not use oil or lubricants on equipment used with oxygen.
- Do not use copper piping for acetylene.
- Do not use cast iron piping for chlorine.

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:

1. Move the cylinder to an isolated, well-ventilated area (away from combustible materials if the cylinder contains a flammable or oxidizing gas).
2. Contact Baylor PD at 254-710-2222 or EHS at 254-710-2900.

Whenever a large or uncontrollable leak occurs, evacuate the area and immediately contact Baylor PD at 254-710-2222 or EHS at 254-710-2900.

EMPTY CYLINDERS

- Remove the regulator and replace the cylinder cap.
- Mark the cylinder as "empty" or "MT" and store in a designated area for return to the supplier.
- Do not store full and empty cylinders together.
- Do not have full and empty cylinders connected to the same manifold. Reverse flow can occur when an empty cylinder is attached to a pressurized system.
- Do not refill empty cylinders. Only the cylinder supplier should refill gases.
- Do not empty cylinders to a pressure below 25 psi (172 Kpa). The residual contents may become contaminated with air.

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

FLAMMABLE GASES

- Keep sources of ignition away from the cylinders.
- Oxidizers and flammable gases should be stored in areas separated by at least 20 feet or by a non-combustible wall.
- Bond and ground all cylinders, lines and equipment used with flammable compressed gases.

HIGHLY TOXIC GASES

Highly toxic gases, such as arsine, boron trifluoride, diborane, ethylene oxide, fluorine, germane, 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.
- Ensure storage and use areas are posted with Designated Area signage.

SECTION 7F: CRYOGENICS

Cryogenic liquids have boiling points less than -73ºC (-100ºF). Liquid nitrogen, liquid oxygen and carbon dioxide are the most common cryogenic materials used in the laboratory. Hazards may include fire, explosion, embrittlement, pressure buildup, frostbite and asphyxiation.

Many of the safety precautions observed for compressed gases also apply to cryogenic liquids. Two additional hazards are created from the unique properties of cryogenic liquids:

- **Extremely Low Temperatures –** The cold boil-off vapor of cryogenic liquids 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.
- **Vaporization** - 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.

Vaporization of cryogenic liquids (except oxygen) in an enclosed area can cause asphyxiation. Vaporization of liquid oxygen can produce an oxygen-rich atmosphere, which will support and accelerate the combustion of other materials. Vaporization of liquid hydrogen can form an extremely flammable mixture with air.

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 to avoid skin burns and frostbite. 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.

- Use wooden or rubber tongs to remove small items from cryogenic liquid baths. Cryogenic gloves are for indirect or splash protection only, they are not designed to protect against immersion into cryogenic liquids.
- Cylinders and dewars should not be filled to more than 80% of capacity, since expansion of gases during warming may cause excessive pressure buildup.
- Check cold baths frequently to ensure they are not plugged with frozen material.

PROTECTIVE CLOTHING

Face shields worn with safety glasses or chemical splash goggles are recommended during transfer and handling of cryogenic liquids.

Wear loose fitting, dry, insulated cryogenic 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.

COOLING BATHS AND DRY ICE

- Neither liquid nitrogen nor liquid air should be used to cool a flammable mixture in the presence of air, because oxygen can condense from the air, leading to an explosion hazard.
- Wear insulated, dry gloves and a face shield when handling dry ice.
- Add dry ice slowly to the liquid portion of the cooling bath to avoid foaming over. Do not lower your head into a dry ice chest, since suffocation can result from carbon dioxide buildup.

LIQUID NITROGEN COOLED TRAPS

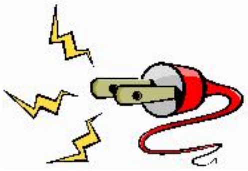
Traps that open to the atmosphere condense liquid air rapidly. If you close the system, pressure builds up with enough force to shatter glass equipment. Therefore, only sealed or evacuated equipment should use liquid nitrogen cooled traps.

SECTION 7G: ELECTRICAL SAFETY

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 or combustible materials.

Power Loss

Loss of electrical power can create 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 and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
- Multi-plug adapters must have circuit breakers or fuses.
- Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
- Minimize the potential for water or chemical spills on or near electrical equipment.

Insulation

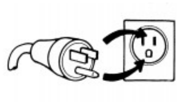
All electrical cords should have sufficient insulation to prevent direct contact with wires. In a laboratory, it is particularly important to check all cords before each use, since corrosive chemicals or solvents may erode the insulation.

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

Guarding

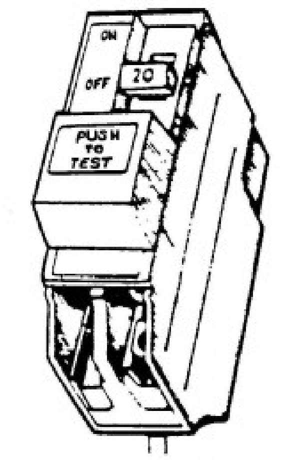
Live parts of electric equipment operating at 50 volts or more (i.e., electrophoresis devices) must be guarded against accidental contact. Plexiglas shields may be used to protect against exposed live parts.

Grounding



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

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

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

The ground-fault circuit interrupter, or GFCI, is designed to shutoff electric power if a ground fault is detected, protecting the user from a potential electrical shock. The GFCI is particularly useful near sinks and wet locations. Since GFCIs can cause equipment to 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. These motors must meet National Electric Safety Code (US DOC, 1993) Class 1, Division 2, Group C-D explosion resistance specifications. Many stirrers, Variacs, outlet strips, ovens, heat tape, hot plates and heat guns **do not** conform to these code requirements.

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

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

SAFE WORK PRACTICES

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

- Avoid contact with energized electrical circuits.
- Use guarding around exposed circuits and sources of live electricity.
- 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 safe to do so, work with only one hand, keeping the other hand at your side or in your pocket, away from all conductive material. This precaution reduces the likelihood of accidents that result in current passing through the chest cavity.
- 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 only by personnel trained to repair high voltage/current circuitry.

ALTERING BUILDING WIRING AND UTILITIES

Any modifications to existing electrical service in a laboratory or building must be approved through a work order and completed by Baylor Facility Services.

SECTION 7H: PRESSURE AND VACUUM SYSTEMS

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.

High 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 over temperature.

Vacuum Apparatus

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

- 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.
- Do not allow water, solvents and corrosive gases to be drawn into vacuum systems. Protect pumps with cold traps and vent their exhaust into an exhaust hood.
- Assemble vacuum apparatus in a manner that avoids strain, particularly to the neck of the flask.
- Avoid putting pressure on a vacuum line to prevent stopcocks from popping out or glass apparatus from exploding.
- Place vacuum apparatus in such a way that the possibility of being accidentally hit is minimized. If necessary, place transparent plastic around it to prevent injury from flying glass in case of an explosion.

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

Vacuum Trapping

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

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

There have been incidents where improper trapping caused vapor to be emitted from the exhaust of the house vacuum system, resulting in either re-entry into the building or potential exposure to maintenance workers. Unfortunately, this type of incident is not the worst that can happen. In 2001, at the University of California - Davis, two plumbers were injured when a house vacuum line burst after one of the plumbers attempted to solder a fitting on the copper line. Results of analysis found evidence of copper perchlorate (an oxidizer) and acetate, which created an explosive mixture upon heating by the torch.

Proper Trapping Techniques

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

- For **particulates**, use filtration capable of efficiently trapping the particles in the size range being generated
- For most **aqueous or non-volatile liquids**, a filter flask at room temperature is adequate to prevent liquids from getting to the vacuum source.
- For **solvents** and other volatile liquids, use a cold trap of sufficient size and cold enough to condense vapors generated, followed by a filter flask capable of collecting fluid that could be aspirated out of the cold trap.
- For **highly reactive, corrosive or toxic gases**, use a sorbent canister or scrubbing device capable of trapping the gas.

Cold Traps

Sufficient (to -78ºC). Avoid using acetone. Ethanol and isopropanol are cheaper and less likely to foam.

Liquid nitrogen may only be used with sealed or evacuated equipment, and then only with extreme caution. If the system is opened while the cooling bath is still in contact with the trap, oxygen may condense from the atmosphere and react vigorously with any organic material present.

Glass Vessels

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

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

Dewar Flasks

Dewar flasks are under vacuum to provide insulation and can collapse from thermal shock or slight mechanical shock.

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

Rotovaps

Rotovaps can implode under certain conditions. Since some Rotovaps contain components made of glass, this can be a serious hazard. See **Rotary Evaporators** for more information about their safe handling.

SECTION 7I: LABORATORY EQUIPMENT

REFRIGERATORS AND FREEZERS

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

Only refrigerators and freezers specified for laboratory use should be utilized for the storage of chemicals. These refrigerators have been constructed with special design factors, such as heavy-duty cords and corrosion resistant interiors to help reduce the risk of fire or explosions in the lab.

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

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

Only chemicals should be stored in chemical storage refrigerators; lab refrigerators should not be used for food storage or preparation. Refrigerators should be labeled for their intended purpose; labels reading "No Food or Drink to be Stored in this Refrigerator" or "Refrigerator For Food Only".

All materials in refrigerators or freezers should be labeled with the contents, owner, date of acquisition or preparation and nature of any potential hazard. Since refrigerators are often used for storage of large quantities of small vials and test tubes, a reference to a list outside of the refrigerator could be used. Labels and ink used to identify materials in the refrigerators should be water-resistant.

All containers should be sealed, preferably with a cap. Containers should be placed in secondary containers, or catch pans should be used.

Loss of electrical power can produce extremely hazardous situations. Flammable or toxic vapors may be released from refrigerators and freezers as chemicals warm up and/or certain reactive materials may decompose energetically upon warming. Proactive planning can avoid product loss and hazardous situations in event of an extended power outage. Dry ice or alternate power sources can be used to prevent refrigerator and freezer contents from warming.

STIRRING AND MIXING DEVICES

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

Only spark-free induction motors should be used in power stirring and mixing devices or any other rotating equipment used for laboratory operations. While the motors in most of the currently marketed stirring and mixing devices meet this criterion, their on-off switches and rheostat-type speed controls can produce an electrical spark because they have exposed electrical conductors. The speed of an induction motor operating under a load should not be controlled by a variable autotransformer.

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

HEATING DEVICES

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

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

- The actual heating element in any laboratory heating device should be enclosed in such a fashion as to prevent a laboratory worker or any metallic conductor from accidentally touching the wire carrying the electric current.
- Heating device becomes so worn or damaged that its heating element is exposed, the device should be either discarded or repaired before it is used again.
- Laboratory heating devices should be used with a variable autotransformer to control the input voltage by supplying some fraction of the total line voltage, typically 110 V.
- The external cases of all variable autotransformers have perforations for cooling by ventilation and, therefore, should be located where water and other chemicals cannot be spilled onto them and where they will not be exposed to flammable liquids or vapors.

Fail-safe devices can prevent fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent or loss of cooling. Some devices will turn off the electric power if the temperature of the heating device exceeds some preset limit or if the flow of cooling water through a condenser is stopped owing to the loss of water pressure or loosening of the water supply hose to a condenser.

Ovens

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

- Laboratory ovens should be constructed such that their heating elements and their temperature controls are physically separated from their interior atmospheres.
- Laboratory ovens rarely have a provision for preventing the discharge of the substances volatilized in them. Connecting the oven vent directly to an exhaust system can reduce the possibility of substances escaping into the lab or an explosive concentration developing within the oven.
- Ovens should not be used to dry any chemical sample that might pose a hazard because of acute or chronic toxicity unless special precautions have been taken to ensure continuous venting of the atmosphere inside the oven.
- To avoid explosion, glassware that has been rinsed with an organic solvent should be rinsed again with distilled water before being dried in an oven.
- Bimetallic strip thermometers are preferred for monitoring oven temperatures. Mercury thermometers should not be mounted through holes in the top of ovens so that the bulb hangs into the oven. Should a mercury thermometer be broken in an oven of any type, the oven should be closed and turned off immediately, and it should remain closed until cool. All mercury should be removed from the cold oven with the use of appropriate cleaning equipment and procedures in order to avoid mercury exposure.

Hot Plates

Laboratory hot plates are normally used for heating solutions to 100ºC or above when inherently safer steam baths cannot be used. Any newly purchased hot plates should be designed in a way that avoids electrical sparks. However, many older hot plates pose an electrical spark hazard arising from either the on-off switch located on the hot plate, the bimetallic thermostat used to regulate the temperature or both. Laboratory workers should be warned of the spark hazard associated with older hot plates.

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

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

Heating Mantles

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

- Always use a heating mantle with a variable autotransformer to control the input voltage. Never plug them directly into a 110-V line.
- Be careful not to exceed the input voltage recommended by the mantle manufacturer. Higher voltages will cause it to overheat, melt the fiberglass insulation and expose the bare heating element.
- If the heating mantle has an outer metal case that provides physical protection against damage to the fiberglass, it is good practice to ground the outer metal case to protect against an electric shock if the heating element inside the mantle shorts against the metal case.
- Some older equipment might have asbestos insulation rather than fiberglass. Contact EHS for proper disposal of this equipment.

Oil, Salt and Sand Baths

Electrically heated oil baths are often used to heat small or irregularly shaped vessels or when a stable heat source that can be maintained at a constant temperature is desired. Molten salt baths, like hot oil baths, offer the advantages of good heat transfer, commonly have a higher operating range (e.g., 200 to 425ºC) and may have a high thermal stability (e.g., 540ºC). There are several precautions to take when working with these types of heating devices:

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

Hot Air Baths and Tube Furnaces

Hot air baths are used in the lab as heating devices. Nitrogen is preferred for reactions involving flammable materials. Electrically heated air baths are frequently used to heat small or irregularly shaped vessels. One drawback of the hot air bath is that they have a low heat capacity. As a result, these baths normally have to be heated to 100ºC or more above the target temperature. Tube furnaces are often used for high-temperature reactions under pressure. Consider the following when working with either apparatus:

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

Heat Guns

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

Microwave Ovens

Microwave ovens used in the laboratory may pose several different types of hazards.

- As with most electrical apparatus, there is the risk of generating sparks that can ignite flammable vapors.
- Metals placed inside the microwave oven may produce an arc that can ignite flammable materials.
- Materials placed inside the oven may overheat and ignite.
- Sealed containers, even if loosely sealed, can build pressure upon expansion during heating, creating a risk of container rupture.

To minimize the risk of these hazards,

- Never operate microwave ovens with doors open in order to avoid exposure to microwaves.
- Do not place wires and other objects between the sealing surface and the door on the oven's front face. The sealing surfaces must be kept absolutely clean.
- Never use a microwave oven for both laboratory use and food preparation.
- Electrically ground the microwave. If use of an extension cord is necessary, only a three-wire cord with a rating equal to or greater than that for the oven should be used.

- Do not use metal containers and metal-containing objects (e.g., stir bars) in the microwave. They can cause arcing.
- Do not heat sealed containers in the microwave oven. Even heating a container with a loosened cap or lid poses a significant risk since microwave ovens can heat material so quickly that the lid can seat upward against the threads and containers can explode.
- Remove screw caps from containers being microwaved. If the sterility of the contents must be preserved, use cotton or foam plugs. Otherwise plug the container with kimwipes to reduce splash potential.

ULTRASONICATORS

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

Ultrasound through airborne conduction does not appear to pose a significant health hazard to humans. However, exposure to the associated high volumes of audible sound can produce a variety of effects, including fatigue, headaches, nausea and tinnitus. When ultrasonic equipment is operated in the laboratory, the apparatus must be enclosed in a 2-cm thick wooden box or in a box lined with acoustically absorbing foam or tiles to substantially reduce acoustic emissions (most of which are inaudible).

Direct contact of the body with liquids or solids subjected to high-intensity ultrasound of the sort used to promote chemical reactions should be avoided. Under sonochemical conditions, cavitation is created in liquids, and it can induce high-energy chemistry in liquids and tissues. Cell death from membrane disruption can occur even at relatively low acoustic intensities.

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

CENTRIFUGES

Centrifuges should be properly installed and must be operated only by trained personnel. It is important that the load is balanced each time the centrifuge is used and that the lid be closed while the rotor is in motion. The disconnect switch must be working properly to shut off the equipment when the top is opened, and the manufacturer's instructions for safe operating speeds must be followed.

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

ROTARY EVAPORATORS

Glass components of the rotary evaporator should be made of Pyrex or similar glass. Glass vessels should be completely enclosed in a shield to guard against flying glass should the components implode. Increase in rotation speed and application of vacuum to the flask whose solvent is to be evaporated should be gradual.

AUTOCLAVES

The use of an autoclave is a very effective way to decontaminate infectious waste. Autoclaves work by killing microbes with superheated steam. The following are recommended guidelines when using an autoclave:

- Do not put sharp or pointed contaminated objects into an autoclave bag. Place them in an appropriate rigid sharps disposal container.
- Use caution when handling an infectious waste autoclave bag, in case sharp objects were inadvertently placed in the bag. Never lift a bag from the bottom to load it into the chamber. Handle the bag from the top.
- Do not overfill an autoclave bag. Steam and heat cannot penetrate as easily to the interior of a densely packed autoclave bag. Frequently the outer contents of the bag will be treated but the innermost part will be unaffected.
- Do not overload an autoclave. An overpacked autoclave chamber does not allow efficient steam distribution. Considerably longer sterilization times may be required to achieve decontamination if an autoclave is tightly packed.
- Conduct autoclave sterility testing on a regular basis using appropriate biological indicators (B. stearothermophilus spore strips) to monitor efficacy. Use indicator tape with each load to verify it has been autoclaved.
- Do not mix contaminated and clean items together during the same autoclave cycle. Clean items generally require shorter decontamination times (15-20 minutes) while a bag of infectious waste (24" x 36") typically requires 45 minutes to an hour to be effectively decontaminated throughout.
- Always wear personal protective equipment, including heat-resistant gloves, safety glasses and a lab coat when operating an autoclave. Use caution when opening the autoclave door. Allow superheated steam to exit before attempting to remove autoclave contents.
- Be on the alert when handling pressurized containers. Superheated liquids may spurt from closed containers. Never seal a liquid container with a cork or stopper. This could cause an explosion inside the autoclave.
- Agar plates will melt and the agar will become liquefied when autoclaved. Avoid contact with molten agar. Use a secondary tray to catch any potential leakage from an autoclave bag rather than allowing it to leak onto the floor of the autoclave chamber.
- If there is a spill inside the autoclave chamber, allow the unit to cool before attempting to clean up the spill. If glass breaks in the autoclave, use tongs, forceps or other mechanical

means to recover fragments. Do not use bare or gloved hands to pick up broken glassware.
- Do not to leave an autoclave operating unattended for a long period of time. Always be sure someone is in the vicinity while an autoclave is cycling in case there is a problem.
- Autoclaves should be placed under preventive maintenance contracts to ensure they are operating properly.

ELECTROPHORESIS DEVICES

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

- Turn the power off before connecting the electrical leads
- Connect one lead at a time, using one hand only
- Ensure that hands are dry while connecting leads
- Keep the apparatus away from sinks or other water sources
- Turn off power before opening lid or reaching inside chamber
- Do not override safety devices
- Do not run electrophoresis equipment unattended.
- If using acrylamide, purchase premixed solutions or pre-weighed quantities whenever possible
- If using ethidium bromide, have a hand-held UV light source available in the laboratory. Check working surfaces after each use.
- Mix all stock solutions in a chemical fume hood.
- Provide spill containment by mixing gels on a plastic tray
- Decontaminate surfaces with ethanol. Dispose of all cleanup materials as hazardous waste.

GLASSWARE

Although glass vessels are frequently used in low-vacuum operations, evacuated glass vessels may collapse violently, either spontaneously from strain or from an accidental blow. Therefore, pressure and vacuum operations in glass vessels should be conducted behind adequate shielding. It is advisable to check for flaws such as star cracks, scratches and etching marks each time a vacuum apparatus is used. Only round-bottomed or thick-walled (e.g., Pyrex) evacuated reaction vessels specifically designed for operations at reduced pressure should be used. Repaired glassware is subject to thermal shock and should be avoided. Thin-walled, Erlenmeyer or round-bottomed flasks larger than 1 L should never be evacuated.

VACUUMS

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

The critical factors in vacuum pump selection are:

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

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

Vacuum pumps can pump vapors from air, water to toxic and corrosive materials like TFA and methylene chloride. Oil seal pumps are susceptible to excessive amounts of solvent, corrosive acids and bases and excessive water vapors. Pump oil can be contaminated quite rapidly by solvent vapors and mists. Condensed solvents will thin the oil and diminish its lubricating properties, possibly seizing the pump motor. Corrosives can create sludge by breaking down the oil and cause overheating. Excess water can coagulate the oil and promotes corrosion within the pump. Proper trapping (cold trap, acid trap) and routine oil changes greatly extend the life of an oil seal vacuum. Pump oil should be changed when it begins to turn a dark brown color.

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

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

SECTION 7J: PARTICULARLY HAZARDOUS MATERIALS

As a matter of good practice, and to satisfy regulatory requirement, particularly hazardous substances require additional planning and considerations.

A list of particularly hazardous substances is available in Appendix A. This list is not exhaustive; consult the safety data sheet to determine whether a particular chemical may be considered a carcinogen, reproductive hazard or substance with a high acute toxicity.

DEFINITIONS

The OSHA Laboratory Standard defines particularly hazardous substances as:

- **Carcinogens** - A carcinogen is a substance capable of causing cancer. Carcinogens are chronically toxic substances; that is, they cause damage after repeated or long-duration exposure, and their effects may become evident only after a long latency period.

  A chemical is considered a carcinogen, for the purpose of the Laboratory Safety Manual, if it is included in any of the following carcinogen lists:

  - OSHA-regulated carcinogens as listed in Subpart Z of the OSHA standards. The current list of substances that OSHA regulates as carcinogens or potential carcinogens follows:
    - asbestos
    - 4-Nitrobiphenyl
    - alpha-Naphthylamine
    - Methyl chloromethyl ether
    - 3,3'-Dichlorobenzidine (and its salts)
    - bis-Chloromethyl ether
    - beta-Naphthylamine
    - Benzidine
    - 4-Aminodiphenyl
    - Ethyleneimine
    - beta-Propiolactone
    - 2-Acetylaminofluorene
    - 4-Dimethylaminoazobenzene
    - N-Nitrosodimethylamine
    - Vinyl chloride
    - Inorganic arsenic
    - Cadmium
    - Benzene
    - Coke oven emissions
    - 1,2-dibromo-3-chloropropane
    - Acrylonitrile

    - Ethylene oxide
    - Formaldehyde
    - Methylenedianiline
    - 1,3-Butadiene
    - Methylene Chloride
  - Under the category "known to be carcinogens" in the Annual Report of Carcinogens published by the National Toxicology Program(NTP) latest edition
  - Group 1 ("carcinogenic to humans") of the International Agency for Research on Cancer (IARC), latest edition. Chemicals listed in Group 2A or 2B ("reasonably anticipated to be carcinogens") that cause significant tumor incidence in experimental animals under specified conditions are also considered carcinogens under the OSHA Laboratory Standard.
- **Reproductive Toxins** - Reproductive toxins are substances that have adverse effects on various aspects of reproduction, including fertility, gestation, lactation, and general reproductive performance. When a pregnant woman is exposed to a chemical, the fetus may be exposed as well because the placenta is an extremely poor barrier to chemicals. Reproductive toxins can affect both men and women. Male reproductive toxins can in some cases lead to sterility.
- **Substances with a High Acute Toxicity** - High acute toxicity includes any chemical that falls within any of the following OSHA-defined categories:
  - A chemical with a median lethal dose (LD50) of 50 mg or less per kg of body weight when administered orally to certain test populations.
  - A chemical with an LD50 of 200 mg less per kg of body weight when administered by continuous contact for 24 hours to certain test populations.
  - A chemical with a median lethal concentration (LC50) in air of 200 parts per million (ppm) by volume or less of gas or vapor, or 2 mg per liter or less of mist, fume, or dust, when administered to certain test populations by continuous inhalation for one hour, provided such concentration and/or condition are likely to be encountered by humans when the chemical is used in any reasonably foreseeable manner.

WORKING SAFELY WITH PARTICULARLY HAZARDOUS SUBSTANCES

The increased hazard risk associated with Particularly Hazardous Substances (PHS) calls for stricter operating procedures in the laboratory:

Work Habits

- There should be no eating, drinking, smoking, chewing of gum or tobacco, application of cosmetics or storage of utensils, food or food containers in laboratory areas where PHS are used or stored.
- All personnel should wash their hands and arms immediately after the completion of any procedure in which a PHS has been used and when they leave the laboratory.

- Each procedure should be conducted with the minimum amount of the substance, consistent with the requirements of the work.
- The laboratory worker should keep records of the amounts of each highly hazardous material used, the dates of use and the names of the users.
- Work surfaces, including fume hoods, should be fitted with a removable liner of absorbent plastic-backed paper to help contain spilled materials and to simplify subsequent cleanup and disposal.

Personal Protective Equipment

- PHS may require more stringent use of personal protective equipment. Check the SDS for information on proper gloves, lab clothing and respiratory protection.
- Proper personal protective equipment must be worn at all times when handling PHS.
- Lab clothing that protects street clothing, such as a fully fastened lab coat or a disposable jumpsuit, should be worn when PHS are being used. Laboratory clothing used while manipulating PHS should not be worn outside the laboratory area.
- When methods for decontaminating clothing are unknown or not applicable, disposable protective clothing should be worn. Disposable gloves should be discarded after each use and immediately after overt contact with a PHS.

Ventilation/Isolation

- Most PHS work should be performed in a fume hood, glove box, or other form of ventilation. If the chemical may produce vapors, mists or fumes, or if the procedure may cause generation of aerosols, use of a fume hood is required.
- A fume hood used for PHS must have an average face velocity of between 95 and 125 feet per minute. This measurement is noted on the hood survey sticker. If the hood has not been inspected within the past year, place a work order with Facilities Services for re-inspection before using the hood.
- A glove box should be used if protection from atmospheric moisture or oxygen is needed or when a fume hood may not provide adequate protection from exposure to the substance; e.g., a protection factor of 10,000 or more is needed.
- Highly toxic gases must be used and stored in a vented gas cabinet connected to a laboratory exhaust system. Gas feed lines operating above atmospheric pressure must use coaxial tubing.

Storage and Transportation

- Stock quantities of PHS should be stored in a designated storage area or cabinet with limited access. Additional storage precautions (i.e., a refrigerator, a hood, a flammable liquid storage cabinet) may be required for certain compounds based upon other properties.
- Containers must be clearly labeled.
- Double containment should also be considered. Double containment means that the container will be placed inside another container that is capable of holding the contents in

the event of a leak and provides a protective outer covering in the event of contamination of the primary container.

- Containers should be stored on trays or pans made of polyethylene or other chemically resistant material.
- Persons transporting PHS from one location to another should use double containment to protect against spills and breakage.

Vacuum Lines and Services

- Each vacuum service, including water aspirators, should be protected with an absorbent or liquid trap to prevent entry of any PHS into the system.
- When using volatile PHS, a separate vacuum pump should be used. The procedure should be performed inside a fume hood.

Decontamination and Disposal

- Contaminated materials should either be decontaminated by procedures that decompose the PHS to produce a safe product or be removed for subsequent disposal.
- All work surfaces must be decontaminated at the end of the procedure or work day, whichever is sooner.
- Prior to the start of any laboratory activity involving a PHS, plans for the handling and ultimate disposal of contaminated wastes and surplus amounts of the PHS should be completed. EHS can assist in selecting the best methods available for disposal.

SECTION 7K: PYROPHORICS

Certain stock reagents and in-situ products are pyrophoric, reacting violently when exposed to water and humid or dry air. These chemicals are useful to research and many are essential to catalyze certain reactions or are incorporated into final products. To handle these materials safely, review the Aldrich technical bulletins **"Handling Air-Sensitive Reagents"** and **"Handling Pyrophoric Reagents"**. Some examples of pyrophoric materials include:

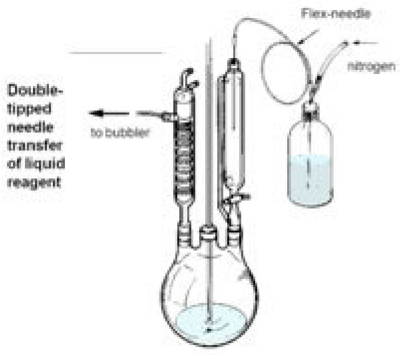
- organo-metallic reagents (i.e. Grignard reagents)
- alkali earth elements (sodium, potassium, cesium)
- finely divided metals (Raney nickel, aluminum powder, zinc dust)
- metal hydrides (sodium hydride, germane, lithium aluminum hydride)
- alkyl metal hydrides (butyllithium, trimethylaluminum, triethylboron)
- metal carbonyls (nickel carbonyl, iron pentacarbonyl)
- gases (arsine, diborane, phosphine, silane)
- silicon halides (dichloromethylsilane)

Exposure to air or moisture can cause these materials to evolve heat, fire, flammable or corrosive byproducts by violent decomposition. Since they are typically packaged and stored under an inert atmosphere, under oil, or within a solvent, appropriate methods must be utilized to preserve the material during storage and while dispensing. See Section 7E **Highly Toxic Gases** for work with pyrophoric gases.

REQUIRED WORK PRACTICES

The following general guidelines must be followed while working with pyrophoric materials.

- Know the properties and hazards of all chemicals you are using through adequate research and study, including reading the label and SDS.
- Select and obtain all necessary materials to dispense and use the reagent(s) safely.
  - Dry boxes are used to supply an inert atmosphere to prevent pyrophoric reactions with air.
  - Fume hoods do not supply an inert atmosphere; however, they can be used for ventilation and staging the reaction apparatus. The sash should be kept lowered to assist with containment in event of a violent reaction and to provide a barrier between the lab worker and the reaction.
  - Flex syringes (double-tipped needles) can be used for transferring materials.
    - Flex Syringes are constructed of tubing with needles attached to both ends for materials transfer through septa. A supply of low-pressure inert gas can be used to introduce the material to a reaction vessel, graduated addition funnel or graduated syringe. Tubing with a single needle may be needed to introduce the inert gas.



  - Appropriate glassware and reaction equipment
    - Ensure your glassware is DRY before assembly and introducing pyrophorics
    - Thoroughly purge all air from the apparatus with the proper inert gas
    - Use secure fittings, keep air-tight with a light coat of vacuum grease
    - Secure septa to all addition/withdrawal orifices
    - Incorporate bubblers filled with mineral oil to prevent air backflow
    - Use pressure rated glassware and fittings for pressurized reactions
  - Inert gas for purging air and material transfer
    - Nitrogen is not suitable for all materials, consult the MSDS
- Syringes may also be used to withdraw small quantities of liquid reagent (<50 mL) from containers when a supply of inert gas is provided to displace the quantity withdrawn.
  - Ensure the syringe is completely DRY and purged with appropriate inert gas
  - Insert a line into the septum, connected to a mineral oil-filled bubbler to prevent overpressure (not shown in picture below)
  - Insert a low-pressure inert gas source line into the septum
  - Insert an extraction syringe into the septum and slowly withdraw reagent

  - Select and <u>use</u> the appropriate personal protective equipment.
  - Never work alone with pyrophorics. Ensure someone can see or hear you.
  - Purchase quantities that will ensure use of the entire product within one year.
  - Use containers with transfer septa (i.e. Aldrich Sure/Seal) for liquid reagents.
    - septa prevent exposure to air and moisture and allow you to safely transfer the pyrophoric material when an inert working atmosphere is not available.
  - Visually check the container and reaction vessel septa for degradation before use.
  - A MetL-X fire extinguisher or powdered lime should be available in the lab.
    - ABC and CO_2 extinguishers can cause some pyrophorics to react more vigorously.
    - Powdered lime can be used to cover spills and slow the reaction with air/humidity.
      - Lime is hydroscopic; keep storage containers closed to prevent absorption of atmospheric moisture.
  - Do not clean up spills. Contain the spill and/or extinguish the fire only if you can do so safely. Evacuate the lab and contact Baylor PD (2222 from a campus or 254-710-2222 from a cell phone) immediately.

RECOMMENDED PERSONAL PROTECTIVE EQUIPMENT

- Wear closed toed shoes made of a nonporous material, leather is preferred.
- Use a face shield and chemical splash goggles to protect your face.
- Wear a cloth lab coat or apron that can be quickly removed if needed.
  - Do not use plastic that can melt and adhere to your clothing/skin in event of a fire.
- Use gloves made of a material resistant to the solvent/reagent.
- Fire-resistant outer gloves with good dexterity are recommended.
- Know where the nearest safety shower is from the reaction area.

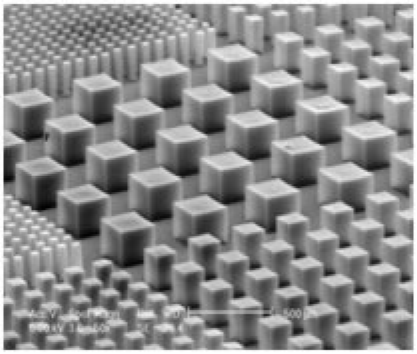
IN THE EVENT OF AN EMERGENCY

- If there is fire on your clothing or skin, stop-drop-and roll, unless you are within a few feet of a safety shower.
- Keep in mind that unreacted materials may reignite until they are washed off.
- If you are contaminated with a pyrophoric, remove your contaminated clothing while using the safety shower. The copious amounts of water will flush away the heat of reaction. If you have significant amounts of dry reactive compound on your body, you may brush off the bulk of it before you enter the shower, however only if it is not reacting.
- Do not clean up spills. Contain the spill and/or extinguish the fire only if you can do so safely. Evacuate the lab and contact Baylor PD (2222 from a campus or 254-710-2222 from a cell phone) immediately.

- A MetL-X fire extinguisher or powdered lime should be available in the lab.
    - ABC and CO_2 extinguishers can cause some pyrophorics to react more vigorously.
    - Powdered lime can be used to cover spills and slow the reaction with air/humidity.

SECTION 7L: NANOMATERIALS

DEFINITION AND EXAMPLES



Nanotechnology is the field of science dealing with material specifically engineered to sizes of 100 nanometers or less. Nanoparticles are produced for their unique characteristics not attributed to common material dimensions. The different types of materials that are used in nanotechnology research and application varies widely; however, here are a few of the more common ones:

- carbon
- silver
- gold
- silica
- titanium
- polymers

Although many of these new hazards are still being investigated and toxicology research is in progress, few solid conclusions have been made about many nanomaterials. There are many things that we still do not know about this new technology. To properly protect against the unknown hazards that are involved while working with nanoparticles, conservative measures and best management practices must be exercised.

POTENTIAL HAZARDS

NIOSH (National Institute for Occupational Safety and Health) has determined the following potential exposure and health concerns:

- The potential for nanomaterials to enter the body is among several factors that scientists examine in determining whether such materials may pose an occupational health hazard. Nanomaterials have the greatest potential to enter the body through the respiratory system if they are airborne and in the form of respirable-sized particles (nanoparticles). They may also come into contact with the skin or be ingested.
- Based on results from human and animal studies, airborne nanoparticles can be inhaled and deposit in the respiratory tract; and based on animal studies, nanoparticles can enter the blood stream, and translocate to other organs.
- Experimental studies in rats have shown that equivalent mass doses of insoluble incidental nanoparticles are more potent than large particles of similar composition in

causing pulmonary inflammation and lung tumors. Results from in vitro cell culture studies with similar materials are generally supportive of the biological responses observed in animals.
- Studies in workers exposed to aerosols of some manufactured or incidental microscopic (fine) and nanoscale (ultrafine) particles have reported adverse lung effects including lung function decrements and obstructive and fibrotic lung diseases. The implications of these studies to engineered nanoparticles, which may have different particle properties, are uncertain.

Nanoparticle gold solutions

RECOMMENDED WORK PRACTICES

- Conduct a thorough risk assessment and take conservative measures to prevent exposure
- Work with nanomaterials in liquid media whenever possible
- Wear impervious gloves, lab coats or cleanroom suits, chemical splash goggles
- Use enclosed control systems, such as a glovebox, for work with dry nanoparticles or when potential aerosol generation exists
- HEPA filtration and wet wiping methods are both effective means of removing nanoparticle contamination

ADDITIONAL RELATED RESOURCES

- **NIOSH - Approaches to Safe Nanotechnology**
- **Strategic Plan for NIOSH Nanotechnology Research and Guidance**
- **IRSST - Best Practices Guide to Synthetic Nanoparticle Risk Management**

SECTION 8: CHEMICAL SPILLS

Pre-planning is essential. Before working with a chemical, the laboratory worker should know how to proceed with spill cleanup and should ensure that there are adequate spill control materials available. For more information, see related links.

Preventing Spills

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

- Place chemical containers being used in a hood or lab bench area that reduces the possibility of accidentally knocking over a container.
- Keep all unused reagents in their appropriate storage area and keep your work area as uncluttered as possible.
- Plan your movements. Look where you are reaching to ensure you will not cause a spill.
- Avoid transporting chemicals from the stockroom during periods of high traffic, such as between classes.
- Transport chemical containers in a chemical carrier or cart.
- Place absorbent plastic backed liners on benchtops or in fume hoods where spills can be anticipated. For volumes of liquid larger than what can be absorbed by liners, use trays.

SPILL RESPONSE AND CLEAN-UP PROCEDURES

In the event of a chemical spill, the individuals who caused the spill are responsible for prompt and proper clean-up. It is also their responsibility to have spill control and personal protective equipment appropriate for the chemicals being handled readily available. See Developing a Spill Response Plan for more information.

The following are general guidelines to be followed for a chemical spill. More detailed procedures may be available in your lab’s Chemical Hygiene Plan or Spill Response Plan.

1. Immediately alert area occupants and supervisor, and evacuate the area, if necessary.
2. If there is a fire or medical attention is needed, contact the Baylor Police Department at extension 2222 or 254-710-2222.
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. Clothing must be laundered 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 Safety Data Sheet or other references for information.
6. 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 the Baylor Police at extension 2222 or 254-710-2222. If respiratory protection is used, be sure there is another person outside the spill area in communication, in case of an emergency. If no one is available, contact the Baylor Police.

7. 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 Baylor Police at extension 2222.

Category	Size	Response	Treatment Materials
Minor	up to 300cc	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

- <u>Minor and medium Chemical Spills</u>
  - Alert people in the immediate area of spill.
  - Avoid breathing vapors from spill.
  - Turn off ignition and heat sources if spilled material is flammable.
  - Put on appropriate protective equipment, such as safety goggles, suitable gloves, and long sleeved lab coat.
  - Confine spill to small area.
  - Use appropriate kit to neutralize and absorb organic acids and bases.
  - Use appropriate kit or spill pads.
  - Collect residue, place in appropriate container and dispose as chemical waste (call EHS at 254-710-2900 for emergency waste pickup)
  - Clean spill area with water.
- <u>Major Chemical Spills</u>
  - Alert people in the area to evacuate.
  - Turn off ignition and heat sources if spilled material is flammable.
  - Initiate fire alarm or call the Baylor Police at 254-710-2222.
  - Attend to injured or contaminated persons and remove them from exposure.
  - Have person knowledgeable of area assist emergency personnel.
- <u>Chemical Spill on Body</u>
  - Immediate response is dependent on the specific chemical and the guidelines contained in the SDS for chemicals and should be your first

        response. This emphasizes the importance of consulting the SDS before accidents.
        - If water flushing is recommended by the SDS, flood exposed area with running water from faucet or safety shower for at least 15 minutes.
        - Remove all contaminated clothing and shoes.
        - Obtain medical attention, if necessary.
        - Report incident to supervisor.
    - <u>Hazardous Material Splashed in the Eye</u>
        - Immediately rinse eyeball and inner surface of eyelid with water continuously for 15 minutes.
        - Forcibly hold eye open to effectively wash behind eyelids.
        - **Obtain medical attention.**
        - Report incident to supervisor.

8. Protect floor drains or other means for environmental release. Spill socks and absorbents may be placed around drains, as needed.
9. Contain and 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 spread of the spilled chemical.
    - **Bulk absorbents** and many spill pillows do not work with hydrofluoric acid. POWERSORB (by 3M) products and their equivalent will handle hydrofluoric acid. Specialized hydrofluoric acid kits also are available.
    - Many **neutralizers** for acids or bases have a color change indicator to show when neutralization is complete.
10. When spilled materials have been absorbed, use 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. Spill control materials will probably need to be disposed of as hazardous waste. Contact EHS at 254-710-2900 for advice on storage and packaging for disposal.
12. Decontaminate the surface where the spill occurred using a mild detergent and water, when appropriate.
13. Report all spills to your supervisor or the Principal Investigator.

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. Contact EHS for waste pick up.

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.**

DEVELOPING A SPILL RESPONSE PLAN

An effective spill response procedure should consider all of the items listed below. The complexity and detail of the plan will, of course depend upon the physical characteristics and volume of materials being handled, their potential toxicity, and the potential for releases to the environment.

1. Review Safety Data Sheets (SDSs) or other references for recommended spill cleanup methods and materials, and the need for personal protective equipment (e.g., gloves, protective clothing, etc.)
2. Acquire sufficient quantities and types of appropriate spill control materials to contain any spills that can be reasonably anticipated. The need for equipment to disperse, collect and contain spill control materials (e.g., brushes, scoops, sealable containers, etc.) should also be reviewed.
3. Acquire the recommended personal protective equipment, providing you are trained to use it. For example, if an air purifying respirator or self-contained breathing apparatus is

needed, you must be enrolled in the Respiratory Protection Program and attend annual training and fit-testing in order to use it. If you are not trained, do not attempt to use it.

4. Place spill control materials and protective equipment in a readily accessible location within or immediately adjacent to the laboratory.
5. Develop a spill response plan that includes:
    - Names and telephone numbers of individuals to be contacted in the event of a spill.
    - Evacuation plans for the room or building, as appropriate.
    - Instructions for containing the spilled material, including potential releases to the environment (e.g., protect floor drains).
    - Inventory of spill control materials and personal protective equipment.
    - Means for proper disposal of cleanup materials (in most cases, as hazardous waste) including contaminated tools and clothing.
    - Decontamination of the area following the cleanup.
6. Discuss the spill response plans with all employees in your area.

SECTION 9: LABORATORY WASTE DISPOSAL

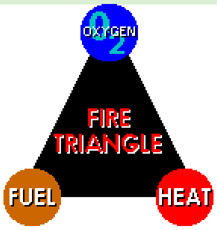
For information on the disposal of laboratory waste, please refer to the Hazardous Waste Disposal Guide, located on the EHS website: www.baylor.edu/ehs

SECTION 10: FIRE EXTINGUISHERS AND FIRE SAFETY

INTRODUCTION

Since fire is a common hazard that one faces in a science and engineering laboratory, it is important to be prepared and to know how to deal with a fire emergency. Fire extinguishers are a first line of defense, only if used properly, and under the right conditions. Fire extinguishers are appropriate for small, incipient stage fires, no bigger than a wastepaper basket. **University policy states that individuals are not required to fight fires, but those who choose to do so must have been trained in the proper use of fire extinguisher.** Training can be arranged through the Baylor Office of Emergency Management.

FIRE TRIANGLE



A fire needs three elements to survive: **oxygen**, **heat** and **fuel**. This is known as the fire triangle. Fires are extinguished by removing one of the three elements of the triangle.

Oxygen	Makes up about 21% if the air that we breathe. To sustain a fire, a ratio of 16% oxygen or greater is needed
Fuel	Can be combustible or flammable material, and may be solid, a liquid or a gas
Heat	Is needed both to initially ignite the fire and also to sustain the fire.

FIRE CLASSIFICATIONS

Fires are classified based on the type of fuel that is burning.

- **Class A** - Wood, paper, cloth, trash and plastics (solid combustible materials that are not metals)
- **Class B** - Flammable liquids such as gasoline, oil, kerosene and solvents
- **Class C** - Electrical equipment (as long as it's "plugged in" it is considered a Class C fire)
- **Class D** - Combustible Metals such as magnesium, potassium and sodium as well as organometallic reagents such as alkyllithiums, Grignards and diethylzine.

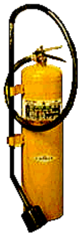
TYPES OF FIRE EXTINGUISHERS

1. **Pressurized Water - Class A fire only**
    - Water stored under air pressure - 2.5 gallon cylinder
    - Discharge approximately 1 minute, with a range of 10-20 feet
    - Extinguishes the fire by removing heat WATER-FILLED EXTINGUISHERS ARE NOT ACCEPTABLE FOR LABORATORY USE.
    - If you have a water-filled extinguisher, have it replaced immediately by calling Baylor Facilities Services at 254-710-1361.

2. **Dry Chemical - Class A, B & C fires**
    - Dry chemical powder (ABC - Ammonium phosphate, BC Sodium or potassium bicarbonate) stored under nitrogen pressure
    - Discharge approximately 8 to 15 seconds, with a range of 6-15 feet
    - Extinguishes fire by removing the oxygen through smothering
    - Dry chemical fire extinguishers are suitable for labs, but can cause tremendous mess.
    - Dry chemical powder can infiltrate sensitive electrical equipment and ruin optics, mirrors and other laboratory equipment.

3. **Carbon Dioxide (CO_2) - Class B & C fires**
    - CO_2 stored under pressure
    - Discharge approximately 8 to 15 seconds, range 3-5 feet
    - Extinguishes fire by reducing the amount of oxygen around the fire
    - WARNING: CO_2 can cause severe chemical burns and freezing of body parts. DO NOT HOLD THE HORN - grip the handle part of the extinguisher
    - WARNING: CO_2 can reduce the percent of oxygen in air when in a confined area.
    - Use only in well ventilated areas.

4. **Dry Powder (Sodium Chloride/Sand) - Class D fires**
    - This agent can be stored in both extinguishers and storage bins.
    - The agent is applied gently at a sufficient amount to cover the burning metal
    - Extinguishes fires by forming a crust over the burning metal, thus smothering it.



COMPONENTS OF A FIRE EXTINGUISHER

- **Cylinder** - Holds extinguishing agent and expelling gases
- **Handle** - Used to carry and hold extinguisher
- **Trigger** - When pressed, releases extinguishing agent through hose and nozzle
- **Nozzle or Horn** - Agent expelled through these items

- **Pressure Gauge** - Shows pressure of the extinguishing agent being stored in the cylinder. The indicator should be in the green area. CO2 extinguishers do not have a pressure gauge.

RULES FOR FIGHTING FIRES

The Baylor Police Department should be notified immediately at 254-710-2222. If the fire is large or spreading, alert building occupants verbally **and** activate the fire alarm.

NEVER FIGHT A FIRE IF:

- You don't know what is burning
- The fire is spreading rapidly beyond the spot where it started
- You don't have adequate or appropriate equipment
- You may inhale toxic smoke
- Your instincts tell you not to
- *Always* position yourself with an exit or means of escape at your back before you attempt to extinguish a fire.
- If the fire is not out after you have completely discharged the extinguisher, exit the building immediately.

PASS PROCEDURE

P ull the Pin - This unlocks the operating lever and allows the agent to discharge from the extinguisher

A im Low - Point the nozzle at the base of the fire

S queeze the Lever - Discharge the agent from the extinguisher. If you release the lever, the discharge stops.

S weep from Side to Side - Move carefully toward the fire, keeping the extinguisher aimed at the base of the fire. Sweep back and forth until the fire is out.

NEVER TURN YOUR BACK ON THE FIRE!

APPENDIX A: PARTICULARLY HAZARDOUS SUBSTANCES

NOTE: This list is not exhaustive. Please refer to the material safety data sheet to determine whether a chemical is a carcinogen, reproductive toxin or chemical with high acute toxicity.

A-C

Chemical	**CAS Number**	**Hazard**
A-alpha-C (2-Amino-9H-pyrido{2,3-b]indole)	26148-68-5	Carcinogen
Acetaldehyde	76-07-0	Carcinogen, Reproductive Toxin
Acetamide	60-35-5	Carcinogen
Acetochlor	34256-82-1	Carcinogen
2-Acetylaminofluorene	53-96-3	Carcinogen
Acifluorfen	62476-59-9	Carcinogen
Acrolein	107-02-8	High acute toxicity
Acrylamide	79-06-1	Carcinogen
Acrylonitrile	107-13-1	Carcinogen
Actinomycin D	50-76-0	Carcinogen
Adriamycin (Doxorubicin hydrochloride)	23214-92-8	Carcinogen
AF-2; [2-(2-furyl)-3-(5-nitro-2-furyl)]acrylamide	3588-53-7	Carcinogen

Aflatoxins	----	Carcinogen, Reproductive Toxin
Alachlor	15972-60-8	Carcinogen
Aldrin	309-00-2	Carcinogen
Allyl chloride	107-05-1	Carcinogen
Aluminum chloride	7446-70-0	Reproductive Toxin
2-Aminoanthraquinone	117-79-3	Carcinogen
p-Aminoazobenzene	60-09-3	Carcinogen
ortho-Aminoazotoluene	97-56-3	Carcinogen
4-Aminobiphenyl (4-aminodiphenyl)	92-67-1	Carcinogen
3-Amino-9-ethylcarbazole hydrochloride	6109-97-3	Carcinogen
1-Amino-2-methylanthraquinone	82-28-0	Carcinogen
2-Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole	712-68-5	Carcinogen
2-Aminopyridine	462-08-8	High acute toxicity
Amitrole	61-82-5	Carcinogen
Anesthetic gases	---	Reproductive Toxin
ortho-Anisidine	90-04-0	Carcinogen

ortho-Anisidine hydrochloride	134-29-2	Carcinogen
Antimony oxide (Antimony trioxide)	130-96-4	Carcinogen
Aramite	140-57-8	Carcinogen
Arsenic (inorganic arsenic compounds)	---	Carcinogen
Arsenic	7440-38-2	Reproductive Toxin
Arsenic pentafluoride gas	784-36-3	High Acute Toxicity
Arsine gas	7784-42-1	High Acute Toxicity
Asbestos	1332-21-4	Carcinogen
Auramine	492-80-8	Carcinogen
Azaserine	115-02-6	Carcinogen
Azathioprine	446-86-6	Carcinogen
Azacitidine	320-67-2	Carcinogen
Azobenzene	103-33-3	Carcinogen
Benz[a]anthracene	56-55-3	Carcinogen
Benzene	71-43-2	Carcinogen, Reproductive Toxin
Benzidine [and its salts]	92-87-5	Carcinogen

Benzo [b] fluoranthene	205-99-2	Carcinogen
Benzo [j] fluoranthene	205-82-3	Carcinogen
Benzo [k] fluoranthene	207-08-9	Carcinogen
Benzofuran	271-89-6	Carcinogen
Benzo [a] pyrene	50-32-8	Carcinogen, Reproductive Toxin
Benzotrichloride	98-07-7	Carcinogen
Benzyl chloride	100-44-7	Carcinogen, High Acute Toxicity
Benzyl violet 4B	1694-09-3	Carcinogen
Beryllium and beryllium compounds	---	Carcinogen
Betel quid with tobacco	---	Carcinogen
Bis(2-chloroethyl)ether	111-44-4	Carcinogen
N,N,-Bis(2-chloroethyl)-2-naphthylamine (Chlornapazine)	494-03-1	Carcinogen
Bischloroethyl nitrosourea (BCNU) (Carmustine)	154-93-8	Carcinogen
Bis (chloromethyl) ether	542-88-1	Carcinogen
Bitumens, extracts of steam-refined and air-refined	---	Carcinogen

Boron trifluoride	7637-07-2	High Acute Toxicity
Bracken fern	---	Carcinogen
Bromine	7726-95-6	High Acute Toxicity
Bromodichloromethane	75-27-4	Carcinogen
Bromoform	75-25-2	Carcinogen
1,3-Butadiene	106-99-0	Carcinogen
1,4-Butanediol dimethanesulfonate (Busulfan)	55-98-1	Carcinogen
Butylated hydroxyanisole	25013-16-5	Carcinogen
vbeta-Butyrolactone	3068-88-0	Carcinogen
Cadmium and cadmium compounds	---	Carcinogen, Reproductive Toxin
Captafol	2425-06-1	Carcinogen
Captan	133-06-2	Carcinogen
Carbon disulfide	75-15-0	Reproductive Toxin
Carbon tetrachloride	56-23-5	Carcinogen, Reproductive Toxin
Carbon-black extracts	---	Carcinogen
Cellosolve	110-80-5	Reproductive Toxin

Ceramic fibers	---	Carcinogen
Chlorambucil	305-03-3	Carcinogen
Chloramphenicol	56-75-7	Carcinogen
Chlordane	57-74-9	Carcinogen
Chlordecone (Kepone)	143-50-0	Carcinogen
Chlordimeform	115-28-6	Carcinogen
Chlorendic acid	115-28-6	Carcinogen
Chlorinated paraffins	108171-26-2	Carcinogen
Chlorine gas	7782-50-5	High Acute Toxicity
Chorine dioxide	10049-04-4	High Acute Toxicity
Chlorine trifluoride	7790-91-2	High Acute Toxicity
Chlorodibromethane	124-48-1	Carcinogen
Chloroethane (Ethyl chloride)	75-00-3	Carcinogen
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea	13010-47-4	Carcinogen
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (Methyl-CCNU)	13909-09-6	Carcinogen
Chloroform	67-66-3	Reproductive Toxin

Chloromethyl methyl ether	107-30-2	Carcinogen
3-Chloro-2-methylpropene	563-47-3	Carcinogen
4-Chloro-ortho-phenylenediamine	95-83-0	Carcinogen
p-Chloro-o-toluidine	95-69-2	Carcinogen
Chloroprene	126-99-8	Reproductive Toxin
Chlorothalonil	1897-45-6	Carcinogen
Chlorozotocin	54749-90-5	Carcinogen
Chromium (hexavalent)	---	Carcinogen
Chromium trioxide	1333-82-0	Carcinogen, Reproductive Toxin
Chrysene	18-01-9	Carcinogen
C. I. Acid Red 114	6459-94-5	Carcinogen
C. I. Basic Red 9 monohydrochloride	569-61-9	Carcinogen
Ciclosporin (Cyclosporin A; Cyclosporine)	59865-13-3;79217-60-0	Carcinogen
Cinnamyl anthranilate	87-29-6	Carcinogen
Cisplatin	15663-27-1	Carcinogen
Citrus Red No. 2	6358-53-8	Carcinogen

Cobalt metal powder	7440-48-4	Carcinogen
Cobalt [II] oxide	1307-96-6	Carcinogen
Conjugated estrogens	---	Carcinogen
Creosotes	---	Carcinogen
para-Cresidine	120-71-8	Carcinogen
Cupferron	135-20-6	Carcinogen
Cyanogen chloride	506-77-4	High Acute Toxicity
Cycasin	14901-08-7	Carcinogen
Cyclophosphamide (anhydrous)	50-18-0	Carcinogen
Cyclophosphamide (hydrated)	6055-19-2	Carcinogen

top

D-F

D&C Orange No. 17	46-83-1	Carcinogen
D&C Red No. 8	2092-56-0	Carcinogen
D&C Red No. 9	5160-02-1	Carcinogen
D&C Red No. 19	81-88-9	Carcinogen
Dacarbazine	4342-03-4	Carcinogen
Daminozide	1596-84-5	Carcinogen
Dantron (Chrysazin; 1,8-Dihydroxyanthraquinone)	117-10-2	Carcinogen
Daunomycin	20830-81-3	Carcinogen
DDD (Dichlorodiphenyldichloroethane)	72-54-8	Carcinogen
DDE (Dichlorodiphenyldichloroethylene)	72-55-9	Carcinogen
DDT (Dichlorodiphenyltrichloroethane)	50-29-3	Carcinogen
DDVP (Dichlorvos)	62-73-7	Carcinogen
Decaborane	17702-41-9	High Acute Toxicity

N,N'-Diacetylbenzidine	613-35-4	Carcinogen
2,4-Diaminoanisole	615-05-4	Carcinogen
2,4-Diaminoanisole sulfate	39156-41-7	Carcinogen
4,4'-Diaminodiphenyl ether (4,4'-Oxydianiline)	101-80-4	Carcinogen
2,4-Diaminotoluene	95-80-7	Carcinogen
Diaminotoluene (mixed)	---	Carcinogen
Diazomethane gas	334-88-3	High Acute Toxicity
Dibenz[a,h]acridine	226-36-8	Carcinogen
Dibenz[a,j]acridine	224-42-0	Carcinogen
Dibenz[a,h]anthracene	53-70-3	Carcinogen
7H-Dibenzo[c,g]carbazole	194-59-2	Carcinogen
Dibenzo[a,e]pyrene	192-65-4	Carcinogen
Dibenzo[a,h]pyrene	189-64-0	Carcinogen
Dibenzo[a,I]pyrene	189-55-9	Carcinogen
Dibenzo[a,l]pyrene	191-30-0	Carcinogen
Diborane gas	19287-45-7	High Acute Toxicity

1,2-Dibromo-3-chloropropane (DBCP)	96-12-8	Carcinogen, Reproductive Toxin
Dichloroacetylene	79-36-7	
p-Dichlorobenzene	106-46-7	Carcinogen
3,3'-Dichlorobenzidine	91-94-1	Carcinogen
1,4-Dichloro-2-butene	764-41-0	Carcinogen
3,3'-Dichloro-4,4'-diaminodiphenyl ether	28434-86-8	Carcinogen
1,1-Dichloroethane	75-34-3	Carcinogen
1,2-Dichloropropane	78-87-5	Carcinogen
1,3-Dichloropropene	542-75-6	Carcinogen
Dieldrin	60-57-1	Carcinogen
Dienestrol	84-17-3	Carcinogen
Diepoxybutane	1464-53-5	Carcinogen
Diesel engine exhaust	---	Carcinogen
Di(2-ethylhexyl)phthalate	117-81-7	Carcinogen
1,2-Diethylhydrazine	1615-80-1	Carcinogen
Diethylnitrosamine	55-18-5	Carcinogen

Diethyl sulfate	64-67-5	Carcinogen
Diethylstilbestrol	56-53-1	Carcinogen
Diglycidyl resorcinol ether (DGRE)	101-90-6	Carcinogen
Dihydrosafrole	94-58-6	Carcinogen
3,3'-Dimethoxybenzidine (ortho-Dianisidine)	119-90-4	Carcinogen
3,3'-Dimethoxybenzidine dihydrochloride(ortho-Dianisidine dihydrochloride)	20325-40-0	Carcinogen
Dimethylcarbamoyl chloride	79-44-7	Carcinogen
Dimethyl formamide	68-12-2	Reproductive Toxin
1,1-Dimethylhydrazine (UDMH)	57-14-7	Carcinogen
1,2-Dimethylhydrazine	540-73-8	Carcinogen
Dimethylvinylchloride	513-37-1	Carcinogen
Dimethyl mercury	593-74-8	High Acute Toxicity
Dimethyl sulfate	77-78-1	Carcinogen, High Acute Toxicity
Dimethyl sulfide	75-18-3	High Acute Toxicity
Dinitrooctyl phenol	63149-81-5	Reproductive Toxin

1,6-Dinitropyrene	42397-64-8	Carcinogen
1,8-Dinitropyrene	42397-65-9	Carcinogen
2,4-Dinitrotoluene	121-14-2	Carcinogen
Diphenylhydantoin (Phenytoin)	57-41-0	Carcinogen
Diphenylhydantoin (Phenytoin), sodium salt	630-93-3	Carcinogen
Direct Black 38 (technical grade)	1937-37-7	Carcinogen
Direct Blue 6 (technical grade)	2602-46-2	Carcinogen
Direct Brown 95 (technical grade)	16071-86-6	Carcinogen
Di-sec-octyl-phthalate	117-81-7	Reproductive Toxin
Disperse Blue	1 2475-45-8	Carcinogen
Dithane	111-54-6	Reproductive Toxin
Epichlorohydrin	106-89-8	Carcinogen, Reproductive Toxin
Erionite	12510-42-8	Carcinogen
Estradiol 17ß	50-28-2	Carcinogen

Estrone	53-16-7	Carcinogen
Ethinylestradiol	57-63-6	Carcinogen
2-Ethoxy ethanol	110-80-5	Reproductive Toxin
2-Ethoxyethyl acetate	111-15-9	Reproductive Toxin
Ethyl acrylate	140-88-5	Carcinogen
Ethyl methanesulfonate	62-50-0	Carcinogen
Ethyl-4-4'-dichlorobenzilate	510-15-6	Carcinogen
Ethylene chlorohydrin	107-07-3	High Acute Toxicity
Ethylene dibromide	106-93-4	Carcinogen, Reproductive Toxin
Ethylene dichloride (1,2-Dichloroethane)	107-06-2	Carcinogen
Ethylene fluorohydrin	371-62-0	High Acute Toxicity
Ethylene glycol monoethyl ether	110-80-5	Reproductive Toxin
Ethylene glycol monomethyl ether	109-86-4	Reproductive Toxin
Ethylene oxide	75-21-8	Carcinogen, Reproductive Toxin
Ethylene thiourea	96-45-7	Carcinogen, Reproductive Toxin
Ethyleneimine	151-56-4	Carcinogen

2-Ethyhexanol	104-76-7	Reproductive Toxin
Fluorine gas	7681-49-4	High Acute Toxicity
2-Fluoroethanol	371-62-0	High Acute Toxicity
Folpet	133-07-3	Carcinogen
Formaldehyde	50-00-0	Carcinogen, Reproductive Toxin
2-(2-Formylhydrazino)-4-(5-nitro-2-furyl)thiazole	3570-75-0	Carcinogen
Furazolidone	67-45-8	Carcinogen
Furmecyclox	60568-05-0	Carcinogen

top

G-M

Glu-P-1 (2-Amino-6-methyldipyrido[1,2-a:3',2'-d]imidazole)	67730-11-4	Carcinogen
Glycidaldehyde	765-34-4	Carcinogen
Glycidol	556-52-5	Carcinogen
Glycol ethers	---	Reproductive Toxin
Griseofulvin	126-07-8	Carcinogen
Gyromitrin (Acetaldehyde methylformylhydrazone)	16568-02-8	Carcinogen
Halothane	151-67-7	Reproductive Toxin
HC Blue 1	2784-94-3	Carcinogen
Heptachlor	76-44-8	Carcinogen
Heptachlor epoxide	1024-57-3	Carcinogen
Hexachlorobenzene	118-74-1	Carcinogen
Hexachlorocyclohexane (technical grade)	---	Carcinogen
Hexachlorodibenzodioxin	34465-46-8	Carcinogen
Hexachloroethane	67-72-1	Carcinogen

Hexafluoroacetone	684-16-2	Reproductive Toxin
Hexamethylene diiosocyanate	822-06-0	High Acute Toxicity
Hexamethylphosphoramide	680-31-9	Carcinogen, Reproductive Toxin
Hormones	---	Reproductive Toxin
Hydrazine	302-01-2	Carcinogen, Reproductive Toxin
Hydrazine sulfate	10034-93-2	Carcinogen
Hydrazobenzene (1,2-Diphenylhydrazine)	122-66-7	Carcinogen
Hydrogen Cyanide	74-90-8	High Acute Toxicity
Hydrogen Fluoride	7664-39-3	High Acute Toxicity
Indeno [1,2,3-cd]pyrene	193-39-5	Carcinogen
Iodine (inhalation only)	7553-56-2	High Acute Toxicity
IQ (2-Amino-3-methylimidazp[4,5-f]quinoline)	76180-96-6	Carcinogen
Iron dextran complex	9004-66-4	Carcinogen
Iron pentacarbonyl	13463-40-6	High Acute Toxicity

Isopropyl formate	625-55-8	High Acute Toxicity
Isosafrole	120-58-1	Carcinogen
Karathane	131-72-6	Reproductive Toxin
Lactofen	77501-63-4	Carcinogen
Lasiocarpine	303-34-4	Carcinogen
Lead (inorganic compounds)	7439-92-1	Reproductive Toxin
Lead acetate	301-04-2	Carcinogen
Lead phosphate	7446-27-7	Carcinogen
Lead subacetate	1335-32-6	Carcinogen
Lindane	---	Carcinogen
Mancozeb	8018-01-7	Carcinogen
Maneb	12427-38-2	Carcinogen
Me-A-alpha-C (2-Amino-3-methyl-9H-pyrido[2,3-b]indole)	68005-83-7	Carcinogen
Medroxyprogesterone acetate	71-58-9	Carcinogen
Melphalan	148-82-3	Carcinogen

Merphalan	531-76-0	Carcinogen
Mestranol	72-33-3	Carcinogen
Methacryloyl chloride	920-46-7	High Acute Toxicity
2-Methoxyethanol	109-86-4	Reproductive Toxin
2-Methoxyethyl acetate	110-49-6	Reproductive Toxin
8-Methoxypsoralen with ultraviolet A therapy	298-81-7	Carcinogen
5-Methoxypsoralen with ultraviolet A therapy	484-20-8	Carcinogen
Methyl acrylonitrile	126-98-7	High Acute Toxicity
2-Methylaziridine (Propyleneimine)	75-55-8	Carcinogen
Methylazoxymethanol	590-96-5	Carcinogen
Methylazoxymethanol acetate	592-62-1	Carcinogen
Methyl cellosolve	109-86-4	Reproductive Toxin
3-Methylcholanthrene	56-49-5	Carcinogen
5-Methylchrysene	369-72-43	Carcinogen
Methyl chloride	74-87-3	Reproductive Toxin
Methyl chloroformate	79-22-1	High Acute Toxicity

4,4'-Methylene bis(2-chloroaniline)	101-14-4	Carcinogen
4,4'-Methylene bis(N,N-dimethyl)benzenamine	101-61-1	Carcinogen
4,4'-Methylene bis(2-methylaniline)	838-88-0	Carcinogen
Methylene biphenyl isocyanate	101-68-9	High Acute Toxicity
4,4'-Methylenedianiline	01-77-9	Carcinogen
4,4'-Methylenedianiline dihydrochloride	13552-44-8	Carcinogen
Methyl fluoroacetate	453-18-9	High Acute Toxicity
Methyl fluorosulfate	421-20-5	High Acute Toxicity
Methylhydrazine and its salts	13552-44-8	Carcinogen, High Acute Toxicity
Methyl mercury and other organic forms	---	High Acute Toxicity
Methyl methanesulfonate	66-27-3	Carcinogen
2-Methyl-1-nitroanthraquinone	129-15-7	Carcinogen
N-Methyl-N'-nitro-N-nitrosoguanidine	70-25-7	Carcinogen
N-Methylolacrylamide	924-42-5	Carcinogen
N-Methyl-2-pyrrolidone	872-50-4	Reproductive Toxin

Methylthiouracil	560-4-2	Carcinogen
Methyl trichlorosilane	75-79-6	High Acute Toxicity
Methyl vinyl ketone	78-94-4	High Acute Toxicity
Metiram	9005-42-2	Carcinogen
Metronidazole	443-48-1	Carcinogen
Michler's ketone	90-94-8	Carcinogen
Mirex	2385-85-5	Carcinogen
Mitomycin C	50-07-7	Carcinogen
Monocrotaline	315-22-0	Carcinogen
5-(Morpholinomethyl)-3-[(5-nitro-furfurylidene)-amino]-2 oxalolidinone	139-91-3	Carcinogen
Mustard Gas	505-60-2	Carcinogen

top

N-Z		
Nafenopin	3771-19-5	Carcinogen
1-Naphthylamine	124-32-7	Carcinogen
2-Naphthylamine	91-59-8	Carcinogen
Nickel and certain nickel compounds	---	Carcinogen
Nickel carbonyl	13463-39-3	Carcinogen, High Acute Toxicity
Nickel subsulfide	12035-72-2	Carcinogen
Niridazole	61-47-4	Carcinogen
Nitrilotriacetric acid	139-13-9	Carcinogen
Nitrilotriacetric acid, trisodium salt monohydrate	18662-53-8	Carcinogen
5-Nitroacenaphthene	602-87-9	Carcinogen
5-Nitro-o-anisidine	99-59-2	Carcinogen
4-Nitrobiphenyl	93-93-3	Carcinogen
6-Nitrochrysene	7496-02-8	Carcinogen
Nitrofen (technical grade)	1836-75-5	Carcinogen

2-Nitrofluorene	607-57-8	Carcinogen
Nitrofurazone	59-87-0	Carcinogen
1-[5-Nitrofurfurylidene)-amino]-2-imidazolidinone	555-84-0	Carcinogen
N-[4-(5-Nitro-2-furyl)-2-thiazolyl]acetamide	531-82-8	Carcinogen
Nitrogen dioxide	10102-44-0	High Acute Toxicity
Nitrogen mustard (Mechlorethamine)	51-75-2	Carcinogen
Nitrogen mustard hydrochloride (Mechlorethamine hydrochloride)	55-86-7	Carcinogen
Nitrogen mustard N-oxide	126-85-2	Carcinogen
Nitrogen mustard N-oxide hydrochloride	302-70-5	Carcinogen
Nitrogen tetroxide	10544-72-6	High Acute Toxicity
Nitrogen trioxide	10544-73-7	High Acute Toxicity
2-Nitropropane	79-46-9	Carcinogen
1-Nitropyrene	5522-43-0	Carcinogen

4-Nitropyrene	57835-92-4	Carcinogen
N-Nitrosodi-n-butylamine	924-16-3	Carcinogen
N-Nitrosodiethanolamine	1116-54-7	Carcinogen
N-Nitrosodiethylamine	55-18-5	Carcinogen
N-Nitrosodimethylamine	62-75-9	Carcinogen
p-Nitrosodiphenylamine	156-10-5	Carcinogen
N-Nitrosodiphenylamine	86-30-6	Carcinogen
N-Nitrosodi-n-propylamine	621-64-7	Carcinogen
N-Nitroso-N-ethylurea	759-73-9	Carcinogen
3-(N-Nitrosomethylamino)propionitrile	60153-49-3	Carcinogen
4-(N-Nitrosomethylamino)-1-(3-pyridyl)1-butanone	64091-91-4	Carcinogen
N-Nitrosomethylethylamine	10595-95-6	Carcinogen
N-Nitroso-N-methylurea	684-93-5	Carcinogen
N-Nitroso-N-methylurethane	615-53-2	Carcinogen
N-Nitrosomethylvinylamine	4549-40-0	Carcinogen

N-Nitrosomorpholine	59-89-2	Carcinogen
N-Nitrosonornicotine	16543-55-8	Carcinogen
N-Nitrosopiperidine	100-75-4	Carcinogen
N-Nitrosopyrrolidine	930-55-2	Carcinogen
N-Nitrososarcosine	13256-22-9	Carcinogen
Nitrous Oxide		
Norethisterone (Norethindrone)	68-22-4	Carcinogen
Ochratoxin A	303-47-9	Carcinogen
Osmium tetroxide	20816-12-0	High Acute Toxicity
Oxadiazon	19666-30-9	Carcinogen
Oxygen difluoride gas	7783-41-7	High Acute Toxicity
Oxymetholone	434-07-1	Carcinogen
Ozone	10028-15-6	High Acute Toxicity
Panfuran S	---	Carcinogen
Pentachlorophenol	87-86-5	Carcinogen

Phenacetin	62-44-2	Carcinogen
Phenazopyridine	94-78-0	Carcinogen
Phenazopyridine hydrochloride	136-40-3	Carcinogen
Phenesterin	3546-10-9	Carcinogen
Phenobarbital	50-06-6	Carcinogen
Phenoxybenzamine	59-96-1	Carcinogen
Phenoxybenzamine hydrochloride	63-92-3	Carcinogen
Phenyl glycidyl ether	22-60-1	Carcinogen
Phenylhydrazine and its salts	---	Carcinogen
o-Phenylphenate, sodium	132-27-4	Carcinogen
Phosgene	75-44-5	High Acute Toxicity
Phosphine gas	1498-40-4	High Acute Toxicity
Phosphorus oxychloride	10025-87-3	High Acute Toxicity
Phosphorus pentafluoride gas	7641-19-0	High Acute Toxicity
Phosphorus trichloride	7719-12-2	High Acute Toxicity

Polybrominated biphenyls	---	Carcinogen
Polychlorinated biphenyls	---	Carcinogen
Polygeenan	53973-98-1	Carcinogen
Ponceau MX	3761-53-3	Carcinogen
Ponceau 3R	3564-09-8	Carcinogen
Potassium bromate	7758-01-2	Carcinogen
Procarbazine	671-16-9	Carcinogen
Procarbazine hydrochloride	366-70-1	Carcinogen
Progesterone	57-83-0	Carcinogen
1,3-Propane sultone	1120-71-4	Carcinogen
beta-Propiolactone	57-57-8	Carcinogen
Propylene glycol monomethyl ether	107-98-2	Reproductive Toxin
Propylene oxide	75-56-9	Carcinogen
Propylthiouracil	51-52-5	Carcinogen
Reserpine	50-55-5	Carcinogen

RH-7592	---	Reproductive Toxin
Saccharin	81-07-2	Carcinogen
Saccharin, sodium	128-44-9	Carcinogen
Safrole	94-59-7	Carcinogen
Selenium sulfide	7446-34-6	Carcinogen
Silica, crystalline	---	Carcinogen
Sodium azide	26628-22-8	High Acute Toxicity
Sodium cyanide (and other cyanide salts)	143-33-9	High Acute Toxicity
Streptozotocin	18883-66-4	Carcinogen
Styrene oxide	96-09-3	Carcinogen
Sulfallate	95-06-7	Carcinogen
Systhane/RH-3866	8867-89-0	Reproductive Toxin
Talc´ containing asbestiform fibers	---	Carcinogen
Testosterone and its esters	58-22-0	Carcinogen
2,3,7,8-Tetrachlorodibenzo-para-dioxin (TCDD)v	1746-01-6	Carcinogen

1,1,2,2-Tetrachloroethane	79-34-5	Carcinogen
Tetrachloroethylene (Perchloroethylene)	127-18-4	Carcinogen
p-a, a, a-Tetrachlorotoluene	5216-25-1	Carcinogen
Tetranitromethane	509-14-8	Carcinogen
Thioacetamide	62-55-5	Carcinogen
4,4´ - Thiodianiline	139-65-1	Carcinogen
Thiourea	62-56-6	Carcinogen
Thorium dioxide	1314-20-1	Carcinogen
TOK (herbicide)	1836-75-5	Reproductive Toxin
Toluene diisocyanate	26471-62-5	Carcinogen
ortho-Toluidine	95-53-4	Carcinogen
ortho-Toluidine hydrochloride	636-21-5	Carcinogen
para-Toluidine	106-49-0	Carcinogen
Toxaphene (Polychorinated camphenes)	8001-35-2	Carcinogen
Trasulfan	299-75-2	Carcinogen

Trichlormethine (Trimustine hydrochloride)	817-09-4	Carcinogen
2,4,6-Trichlorophenol	88-06-2	Carcinogen
Trimethyltin chloride	1066-45-1	High Acute Toxicity
Triphenyltin hydroxide	76-87-9	Carcinogen
Trichloroethylene	79-01-6	Carcinogen
Tris (aziridinyl)-para-benzoquinone (Triaziquone)	68-76-8	Carcinogen
Tris (1-aziridinyl) phosphine sulfide (Thiotepa)	52-24-4	Carcinogen
Tris (2-chloroethyl) phosphate	115-96-8	Carcinogen
Tris (2,3-dibromopropyl) phosphate	126-72-7	Carcinogen
Trp-P-1 (Tryptophan-P-1)	62450-06-0	Carcinogen
Trp-P-2 (Tryptophan-P-2)	62450-07-1	Carcinogen
Trypan blue (commercial grade)	72-57-1	Carcinogen
Uracil mustard	66-75-1	Carcinogen
Urethane (Ethyl carbamate)	51-79-6	Carcinogen
Vinyl bromide	593-60-2	Carcinogen

Vinyl chloride	75-01-4	Carcinogen, Reproductive Toxin
4-Vinyl-1-cyclohexene diepoxide (Vinyl cyclohexene dioxide)	106-87-6	Carcinogen
Vinyl trichloride (1,1,2-Trichloroethane)	79-00-5	Carcinogen
2,6-Xylidine (2,6-Dimethylaniline)	87-62-7	Carcinogen
Zineb	12122-67-7	Carcinogen