MONTCLAIR STATE
UNIVERSITY

College Of Science and Mathematics

Laboratory Safety Manual

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Introduction

The College of Science and Mathematics is committed to providing a safe laboratory environment for its faculty, staff, students and visitors. The goal of the University 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 needed to work safely in the laboratory.

The three basic elements of the Laboratory Safety Program are:

- The departmental safety program led by the Chemical Hygiene Officer(s)
- Laboratory safety support and training by Environmental Health and Safety
- Instruction and oversight by an individual's supervisor or Principal Investigator

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

EH&S and the college safety committee provide training, resources and consultation for a variety of laboratory safety issues, including chemical safety, laser safety, biological safety, radiation safety, electrical safety and other topics. The EH&S web page offers a wide range of resources for many aspects of laboratory safety.

OSHA Laboratory Standard

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

The goal 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 (e.g., OSHA Permissible Exposure Limits).

All individuals who work with hazardous chemicals in science and engineering laboratories are obligated to comply with the Lab Standard. Work with chemicals outside of laboratories is covered by the OSHA Hazard Communication Standard.

For more information about how a particular department complies with the Laboratory Standard, see the Departmental Chemical Hygiene Plan.

Montclair State University Policies

Environmental, Health and Safety Policy

Montclair State University is committed to providing a safe and healthful environment for its employees, students and visitors and managing the University in an environmentally sensitive and responsible manner. We further recognize an obligation to demonstrate safety and environmental leadership by maintaining the highest standards and serving as an example to our students as well as the community at large. All entities utilizing University facilities are required to follow all University and Department policies.

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

- Developing and improving programs and procedures to assure compliance with all applicable laws and regulations
- Ensuring that personnel are properly trained and provided with appropriate safety and emergency equipment
- Taking appropriate action to correct hazards or conditions that endanger health, safety, or the environment
- Considering safety and environmental factors in all operating decisions including planning and acquisition
- Engaging in sound reuse and recycling practices and exploring feasible opportunities to minimize the amount and toxicity of waste generated
- Using energy efficiently throughout our operations

- Encouraging personal accountability and emphasizing compliance with standards and conformance with University policies and best practices during employee training
- 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 concerns
- 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 University Police by calling 5222
- After normal business hours, all laboratories must be locked when not in use

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

- Avoid providing building access to unfamiliar individuals
- Secure doors behind them
- Immediately report any building security problem to University Police at 5222.

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.

Roles and Responsibilities

Departmental Chemical Hygiene Officer

- Establish and implement a Chemical Hygiene Plan in association with EH&S.
- Review and update the Chemical Hygiene Plan annually.
- Investigate accidents and chemical exposures within the department in association with other appropriate personnel.
- Act as a liaison between the department and EH&S for laboratory safety issues.
- Ensure laboratory workers receive chemical and procedure-specific training.
- Review and approve use of particularly hazardous substances in association with the Laboratory Safety Committee.

Principal Investigators

- Ensure laboratory workers attend general training given by EH&S.
- 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.
- Ensure laboratory workers complete and submit *Particularly Hazardous Substance Use Approval* forms and submit them for approval to the Laboratory Safety Committee before using any particularly hazardous substance.
- Document specific operating procedures for work with particularly hazardous substances, including carcinogens, reproductive toxins and chemicals with high acute toxicity.
- Review and approve work with particularly hazardous substances.

Environmental Health and Safety (EH&S)

- Conduct exposure monitoring, as needed.
- Provide general training.
- Audit the departmental program periodically.
- Provide safe working guidelines for laboratory workers.
- Review the model Chemical Hygiene Plan at least annually.
- Coordinate annual fume hood inspections.
- Provide consultation for safe work practices for hazardous chemicals.
- Maintain records of training, exposure monitoring and medical examinations.

Laboratory Worker/Research Student

- 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 Chemical Hygiene Officer.
- Document specific operating procedures for work with particularly hazardous substances, including carcinogens, reproductive toxins and chemicals with high acute toxicity.

SECTION 2: Departmental Chemical Hygiene Plans

Each department has its own Chemical Hygiene Plan. This plan includes information about:

Roles and responsibilities for laboratory safety in the department

Chemical Hazard Identification

Controlling Chemical Exposures

Fume Hood Evaluations

Information and Training
Emergency Action Plans

Prior Approval for Laboratory Procedures

Medical Examinations and Consultations

Particularly Hazardous Substances

Laboratory Inspections and Audits
Department Facility Systems

SECTION 3: Emergency Procedures

For any emergency, including fires, chemical spills, injuries, accidents, explosions, and medical emergencies, dial 5222 from any University phone including blue-light phones, located in common areas throughout campus. If a University phone is unavailable or inaccessible during an emergency, dial (973) 655-5222 from a cell phone. University Police personnel will respond, determine whether additional assistance is needed and alert others who can help.

Fire

In the event of a fire, University Police should be notified immediately at 5222 and the following actions are recommended:

1. University policy states that 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 notify the building occupants verbally of the need to evacuate as you exit the building. 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 University Police. 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 University Police or the municipal fire official.

Medical Emergencies

In the event of any injury or illness where assistance is needed, contact University Police at 5222. If an ambulance is needed, University Police will arrange for one. University Police staff can transport individuals with minor injuries to University Health Center.

First Aid Kits

According to the Montclair State University Policy on First Aid, 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 the following personal protective equipment:
- at least two pair of large size examination or laboratory gloves

Treatment requiring more elaborate supplies should be sought at the University Health Center.

All work-related injuries or illnesses must be reported to supervisors and to Human Resources. Additional information regarding work related injuries or illnesses may be obtained from the Human Resources web site or by calling 5293.

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 department manager to determine whether or not an Accident Report 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 Material Safety Data Sheet (MSDS) 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, rinse with water for 5 minutes. Apply 2.5% calcium gluconate gel, a tube of which should be available in all labs utilizing hydrofluoric acid. If not readily available, continue rinsing for 15 minutes. In all cases, seek medical attention immediately. Immediately call University Police at 5222.

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 is needed, contact University Police at 5222. Explain carefully what chemicals were involved. If easily accessible, bring an MSDS.

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 University Police. Explain carefully what chemicals were involved.
3. Review the MSDS to determine what health effects are expected, including delayed effects.

Accidental Ingestion of Chemicals

1. Immediately contact University Police at 5222.
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.

Emergency Information Posters

Most laboratories or chemical storage areas must have a complete Emergency Information Poster affixed on or near each entrance to the room. A copy of the completed form must be sent to University Police. Laboratory workers must review the poster for accuracy every six months and replace it as necessary and at least every two years.

The following information should be supplied on every poster:

Responsible individuals - List those who are most familiar with the activities in the room.
Room diagram - A drawing of the room, showing important items such as fume hoods, storage cabinets, lab benches, etc.
Hazard class - Hazardous materials found in the room should be identified and listed on the poster when quantities exceed the threshold levels.
Additional information - This allows narrative comments by the user on material, storage conditions, unusual hazards, etc.

The purpose of the Emergency Information Poster 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.

Determining If Posting Is Necessary

An Emergency Information Poster is required if any of the quantities listed here are exceeded:

Class 1 - *Explosives* - any quantity
Class 2 - *Compressed Gas* (flammable, non-flammable, poison) - any compressed gas cylinder
Class 3 - *Flammable or Combustible Liquids* - 10 gallons
Class 4 - *Flammable Solids, Spontaneously Combustible, Dangerous When Wet Materials* - 2 pounds
Class 5.1 - *Oxidizers* - 40 pounds or 5 gallons
Class 5.2 - *Organic Peroxide* - 2 pounds
Class 6 - *Poisonous or Infectious Materials* - any quantity
Class 7 - *Radioactive* - any quantity
Class 8 - *Corrosive* - 40 pounds or 5 gallons
Class 9 - *Miscellaneous Hazardous Materials* - User's judgment. Include lasers and any uninterruptible power supply (UPS) systems.

For the purposes of the Emergency Information Poster, the U.S. Department of Transportation (DOT) Hazardous Material Classifications are used for determining the hazard class of materials. These classifications are numbered 1 through 9 and may be found on shipping labels, some material safety data sheets (MSDS), and container labels. If the actual class is not listed, descriptive words may be found on container labels or in the material's MSDS to assist in determining the hazard class.

Obtaining Posters

A poster pre-printed with the building name, room number and room diagram may be obtained from EH&S at 4367.

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 EH&S at 4367, regardless of whether or not signs or symptoms are noted. EH&S will contact the individual and lab manager to conduct an incident investigation.

Montclair State University EH&S 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.

If an individual calls from home to report a work-related injury or illness, the information necessary to complete the first report should be obtained at that time. Individuals who are unable to travel to University Health Center should be advised to call Human Resources (5293) for referrals to approved medical care providers.

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

Labels

The manufacturer's label should be kept intact. Do not intentionally deface or obscure the label or the hazard warnings 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.

Material Safety Data Sheets

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

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

If the MSDS cannot be found, contact the manufacturer or distributor at the number listed on the container label and request an MSDS. If the manufacturer does not provide one within a few days, contact EH&S at 4367 for assistance.

Other Chemical Information Resources

A number of books with chemical safety information are available. The following is a partial listing – titles available through the University Library are identified with an asterisk (*) (note that those available in the Library may not be the most up to date edition):

Armour, Margaret-Ann, ***Hazardous Laboratory Chemical Disposal Guide***, Lewis Publishers, NY, 1996

*Bretherick, I., ***Handbook of Reactive Chemical Hazards***, 4th ed., CRC Press, 1990.

British Cryogenic Council, ***Cryogenics Safety Manual***, 3rd ed., 1991.

*Clayton, George and F. Clayton, editors, ***Patty's Industrial Hygiene and Toxicology***, Wiley, Interscience, 1991.

Compressed Gas Association, Inc., ***Handbook of Compressed Gases***, 3rd ed., VanNostrand Reinhold Company, New York, 1990.

Forsberg, Krister and Lawrence Keith, ***Chemical Protective Clothing Performance Index***, Wiley and Sons, NY, 1999

Furr, A. Keith, ***Handbook of Laboratory Safety***, 5th ed., The Chemical Rubber Company, 2000.

Gosselin,et al, ***Clinical Toxicology of Commercial Products***, 5th ed., Williams & Wilkins, 1984.

Lewis, Richard J., ***The Condensed Chemical Dictionary***, 12th ed., Van Nostrand Reinhold Company, 1993.

Lewis, Richard J., ***Dangerous Properties of Industrial Materials***, 8th ed., Litton Educational Publishing Inc., 1992.

Meyer, Eugene, ***Chemistry of Hazardous Materials***, Prentice Hall, Englewood Cliffs, NJ, 1977

National Academy of Sciences, ***Prudent Practices for Handling Hazardous Chemicals in Laboratories***, 1995.

*National Institute of Occupational Safety and Health, ***Registry of Toxic Effects of Chemical Substances***, (published annually).

National Research Council, ***Prudent Practices in the Laboratory***, National Academy Press, Washington, DC 1995

Office of Technology Assessment Task Force, ***Reproductive Health***

Hazards in the Workplace, Science Information Resource Center, Philadephia, PA 1988

Patnaik, Pradyot, ***Comprehensive Guide to Hazardous Properties of Chemical Substances***, Wiley and Sons, NY, 1999

Pohanish, Richard, ***Rapid Guide to Chemical Incompatibilities***, Wiley & Sons, NY, 1997

U.S. Department of Health and Human Services, ***Occupational Health Guidelines for Chemical Hazards***,

NIOSH/OSHA.
Stull, Jeffrey, ***PPE Made Easy***, Government Institutes, Rockville, MD, 1998

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 material safety data sheet (MSDS) 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 × 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 MSDS usually includes information regarding whether or not skin absorption is a significant route of exposure.

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

Wear gloves and other protective clothing to minimize skin exposure. See *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 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 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 EH&S 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 go to McCosh Health Center or contact the Poison Control Center, at 800-962-1253 for instructions. Do not induce vomiting unless directed to do so by a health care provider.

Injection

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

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

Toxic Effects of Chemical Exposure

How a chemical exposure affects a person depends on many factors. The dose is the amount of a chemical that actually enters the body. The actual dose that a person receives depends on the concentration of the chemical and the frequency and duration of the exposure. The sum of all routes of exposure must be considered when determining the dose.

In addition to the dose, the outcome of exposure is determined by (1) the way the chemical enters the body, (2) the physical properties of the chemical, and (3) the susceptibility of the individual receiving the dose.

Toxic Effects of Chemicals

The toxic effects of a chemical may be *local* or *systemic*. Local injuries involve the area of the body in contact with the chemical and are typically caused by reactive or corrosive chemicals, such as strong acids, alkalis or oxidizing agents. Systemic injuries involve tissues or organs unrelated to or removed from the contact site when toxins have been transported through the bloodstream. For example, methanol that has been ingested may cause blindness, while a significant skin exposure to nitrobenzene may 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 MSDS, usually with more information about acute exposures than chronic.

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

Evaluating Toxicity Data

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

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

Susceptibility of Individuals

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

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

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 Material Safety Data Sheets, under the "Health Hazard Data" section, on product labels, in the *Registry of Toxic Effects of Chemical Substances* (RTECS), or in many other sources listed in the MSDS page.

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 MSDS 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. EH&S 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 conducted by EH&S according to established industrial hygiene practices. Results of the monitoring are made available to the individual monitored, his or her supervisor, and the departmental Chemical Hygiene Officer 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 EH&S, in accordance with applicable federal, state and local regulations.

EH&S maintains records of all exposure monitoring results. Departmental Chemical Hygiene Officers should keep records of monitoring conducted for their department operations.

SECTION 6: Controlling Chemical Exposures

General Principles

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, but with the exception of chemical fume hoods, may not be feasible in the laboratory.

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 involve rotating job assignments and adjusting work schedules so that workers are not overexposed to a chemical. Given the nature of work in a research laboratory, administrative controls are not usually a realistic approach to controlling exposure.

Personal Protective Equipment

When engineering 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: Controlling Chemical 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.

Hood Face Velocity

Based on a number of studies and the recommendations of several laboratory safety guidance documents, the following face velocity criteria is recommended:

- **Above 150** feet per minute (fpm): Unacceptable for laboratory use.
- **95-125** fpm: Provides adequate control of inhalation exposure to most hazardous substances, including radioactive materials and particularly hazardous substances.
- **80-95** and **125-150** fpm: Adequate for manipulation of laboratory quantities of hazardous materials except radioactive materials and particularly hazardous substances.
- **Below 80** fpm: Use approved by EH&S on case by case basis, based on activities, placement of hood, smoke tests, etc. **60-80** fpm: Acceptable for chemical storage.

Low Flow Hoods

Low flow fume hoods are specially engineered devices that provide user protection at face velocities below standard operating flow values. A typical hood face velocity for a low flow fume hood is approximately 80 fpm. Contact EH&S if you have questions regarding this type of hood.

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 Montclair State 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, as follow:

1. **Adequate planning and preparation are key.** The hood user should know the Standard Operating Configuration (SOC) of the hood and should design experiments so that the SOC can be maintained whenever hazardous materials might be released. The SOC refers to the position of the sash. A schematic drawing of the SOC is displayed on the front of each chemical fume hood.
2. Before using the hood, the hood user should check the hood survey sticker to determine if the face velocity is adequate for the particular use of a hood. For work with hazardous materials, the fume hood should have a face velocity of 95 - 125 feet per minute at a sash height that is adequate for the procedure.
3. The hood user should also check the magnehelic gauge or other hood performance indicator and compare its reading to the reading indicated on the hood survey sticker. If the reading differs significantly (15% or more for a magnehelic gauge) from that on the sticker, the hood may not be operating properly.

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

When using cylinders containing highly toxic or extremely odorous gases, obtain only the minimal practical quantity. Consider using a flow-restricting orifice to limit the rate of release in the event of equipment failure. In some circumstances, exhaust system control devices or emission monitoring in the exhaust stack may be appropriate.

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

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

    - Provide **catch basins** for containers that could break or spill, to minimize the spread of spilled liquids.
    - **Keep the sash completely lowered** any time an experiment is in progress and the hood is unattended. Note: Lowering the sash not only provides additional personal protection, but 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. For optimum performance, adjust the baffles when working with high temperature equipment and/or heavy gases or vapors. See figure below for suggested baffle positions.
    - **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.
    - **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. See *Common Misuses of Fume Hoods* for more information.

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 or Special Facilities supervisor. 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. See the Biosafety Manual for more information.
- **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 Survey Sticker

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

The ***Average Face Velocity*** is the average velocity with the hood sash in the Standard Operating Configuration (SOC).

The ***Opening for 100 fpm face velocity*** is the sash height, in inches, to which the sash must be lowered in order for the hood to achieve 100 fpm face velocity.

The ***Flow Monitor Reading*** is the reading of the magnehelic gauge or other continuous monitoring device at the time of the survey.

The ***Inspected on*** date is the date of the last hood survey. Hoods that have not been surveyed within the past year should not be used until tested.

The ***By*** line gives the name of the technician who surveyed the hood.

Evaluation and Maintenance Program

Hood Surveys

EH&S surveys each fume hood annually. The face velocity of the fume hood is measured with the sash in the Standard Operating Configuration (SOC) and this measurement, as well as the reading of the continuous monitoring device, is recorded on the hood sticker. A smoke test is done to further evaluate the containment of the hood.

When Problems are noted

There are several factors that can affect the performance of the hood, resulting in low face velocity or turbulent airflow. These include mechanical problems or exhaust slots blocked by large objects or excessive storage.

If a problem is found during the hood survey, a written notice will be provided on-site to the laboratory or taped to the sash of the fume hood. If the problem requires the need for work practice changes (e.g., blocked exhaust slots or excessive storage), the laboratory worker should make the recommended changes and call EH&S at 4367 to have the hood resurveyed.

If maintenance is necessary, the laboratory worker may send a copy of the written notice to EH&S.

Requesting Maintenance

Since the hood user is the person most aware of how a hood is being used on a day to day basis, it is the responsibility of the hood user to determine that maintenance is necessary and to request that it be performed.

If a hood user believes that the hood is not performing adequately, the following steps should be taken:

1. An inadequate face velocity may result from obstructions to the airflow in the hood. These may be caused by large quantities of equipment in the hood or by paper or other material drawn into the exhaust slots. The user should first check for such obstructions and remove or modify them.
2. The user may obtain initial maintenance through HVAC. If HVAC is unable to correct the problem, EH&S should be contacted.
3. The hood sash should be lowered until repairs are complete. Place a sign on the hood reminding users not to use the hood.

4. If maintenance efforts are not sufficient to correct the deficiency, engineering changes may be necessary.

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.

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.

Ductless Fume Hoods

Use of a "ductless fume hood" is strongly discouraged. These devices work by using a fan to draw air into a chamber, through one or more filters, and back into the laboratory.

EH&S and several professional safety and engineering organizations do not recommend the use of ductless fume hoods for several reasons. First, it is difficult to determine whether the filters are functioning adequately or need to be changed; thus, the potential for recirculating toxic materials into the laboratory is significant. In the event of a chemical spill, the hood is usually not able to contain the spilled material or the potentially high concentrations of chemical vapors.

Second, the face velocity of the hood is normally below 80 feet per minute. The hood is normally designed such that the air does not flow smoothly and evenly through the hood. Both of these characteristics make it likely for disruption of airflow or turbulence, causing unfiltered air to leak into the laboratory.

Clean Benches

Clean benches are similar to appearance as a fume hood however 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.

SECTION 6C: Controlling Chemical Exposure

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 buy 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. 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 particularly 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. For more information, see the American Optometric Association guidelines.

Protective Clothing & 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.

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.

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* and *Lab Safety Supply*.

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

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. Montclair State 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 and wind tunnels. EH&S 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. Some of the wind tunnels, particularly the supersonic wind tunnels, are capable of very high noise levels. Users should check with the principal investigator or EH&S to determine whether they need to be enrolled in the Hearing Conservation Program.

For more information about the Hearing Conservation Program, contact EH&S at 4367.

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 Montclair State is subject to prior review by EH&S, according to university policy.

Any worker who believes that respiratory protection is needed must notify EH&S 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 EH&S prior. Tight fitting respirators are typically made of silicone or rubber and have filter cartridges or supplied air for breathing.

SECTION 7: Safe Work Practices and Procedures

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 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.
- Chemical storage cabinets located outside the laboratory (e.g., in hallways) should be labeled with the name of the laboratory group that owns and uses it.

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 Compatibility Chart below, there are several resources available, both in print and on-line, including the National Oceanic and Atmospheric Administration Chemical Reactivity Worksheet.

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 CO2, 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 Perchlorates	Acids, aluminum, ammonium salts, cyanides, phosphorous, metal powders, oxidizable organics or other combustibles, sugar, sulfides, and sulfur.
Chlorine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, finely divided metals, sodium carbide, turpentine.

Chlorine Dioxide	Ammonia, methane, phosphine, hydrogen sulfide.
Chromic Acid	Acetic acid, naphthalene, camphor, alcohol, 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 oxiding 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, such as dinitroglycerine and germane, are shock-sensitive, meaning that they can rapidly decompose or explode when struck, vibrated or otherwise agitated. These compounds become more shock-sensitive with age.

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 weight 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.
- 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 Chemistry stockroom or from laboratory supply catalogs.
- Transport of hazardous chemicals in individual containers exceeding four liters between buildings is strongly discouraged.
- 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 0^{o}C. 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 Poster 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 supervise them at all times to contact University Police at 5222 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.

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, flammable range and autoignition temperatures must be understood. An explanation of these terms and other properties of flammable liquids is available the Laboratory Training Guide. Information on the properties of a specific liquid can be found in that liquid’s material safety data sheet (MSDS), 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. 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.

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 kits for quantitative or qualitative analysis. If you suspect that peroxides have formed, do not open the container to test since peroxides deposited on the threads of the cap could detonate.

Recommended Work Practices

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

- Know the properties and hazards of all chemicals you are using through adequate research and study, including reading the label and MSDS.
- Inventory all chemical storage at least twice a year to detect forgotten items, leaking containers, and those that need to be discarded.
- Identify chemicals that form peroxides or otherwise deteriorate or become more hazardous with age or exposure to air. Label containers with the date 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. Visitor specs are intended only for slight and brief exposure, and should not be used when working with peroxidizable compounds.
- Do not use solutions of peroxides in volatile solvents under conditions in which the solvent might be vaporized. This could increase the concentration of peroxide in the solution.
- Do not use metal spatulas or magnetic stirring bars (which may leach out iron) 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

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

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

Detection of Peroxides

If there is any suspicion that peroxide is present, do not open the container or otherwise disturb the contents. Call EH&S 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 the Department Chemical Hygiene Officer or EH&S for treatment and disposal** of the material. Attempting to remove peroxides may be very dangerous under some conditions.

7D: Corrosive Materials

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. See *Chemical Specific Issues* for specific corrosive liquids such as Hydrofluoric Acid and Phenol.

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.

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 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.
- 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 125°F. 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 material safety data sheets (MSDSs) 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. 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 and release the regulator pressure.

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 University Police at 5222.

Whenever a large or uncontrollable leak occurs, evacuate the area and immediately contact University Police at 5222.

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, diborane, fluorine, hydrogen cyanide, phosgene, and silane, can pose a significant health risk in the event of a leak. Use of these materials requires written approval by the Chemical Hygiene Officer using the *Particularly Hazardous Substances Use Approval* form.

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.

Gases Requiring Special Handling

The following gases present special hazards either due to their toxicity or physical properties. Review this information before using these gases.

Acetylene
Arsine
Diborane

Fluorine
Hydrogen Cyanide
Germane
Oxygen
Phosgene
Silane

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.

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.

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

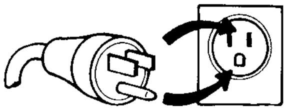
All electrical cords should have sufficient insulation to prevent direct contact with wires. In a laboratory, it is particularly important to check all cords before each use, since corrosive chemicals or solvents may erode the insulation.

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.

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 trained electricians. Contact Physical Plant for more information.

Altering Building Wiring and Utilities

Any modifications to existing electrical service in a laboratory or building must be completed by either the Facilities department or a Licensed Electrical Contractor approved by the University.

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. Contact EH&S at 4367 for more information about hydrostatic testing.

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. 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 at Montclair State 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

For most volatile liquids, a cold trap using a slush of dry ice and either isopropanol or ethanol is sufficient (to -78 deg. C). Avoid using acetone. Ethanol and isopropanol are cheaper and less likely to foam.

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

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.

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 compression, 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; “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. Steam-heated devices are generally preferred whenever temperatures of 100° C or less are required because they do not present shock or spark risks and can be left unattended with assurance that their temperature will never exceed 100° C. Ensure the supply of water for steam generation is sufficient prior to leaving the reaction for any extended period of time.

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 100° C 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. Contact EH&S for more info.

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.

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 425°C) and may have a high thermal stability (e.g., 540°C).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 100°C 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.

The heating element in a heat gun typically becomes red-hot during use and the on-off switches and fan motors are **not** usually spark-free.

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

- Any hand-held heating device of this type that will be used in a laboratory should have ground-fault circuit interrupter (GFCI) protection to ensure against electric shock.
- Never use a heat gun near flammable materials including open containers of flammable liquids, flammable vapors or hoods used to control flammable vapors.

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, either as part of the procedure or at day's end will drive off condensed water vapors or further prolong pump life.

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

7J: Particularly Hazardous Substances

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 of this manual. This list is not exhaustive; consult the material 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 (LD_{50}) of 50 mg or less per kg of body weight when administered orally to certain test populations.
  - A chemical with an LD_{50} 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 (LC_{50}) 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.

Approval Procedure

Laboratory workers planning to use a particularly hazardous substance must first receive explicit written approval from their Principal Investigator and/or Chemical Hygiene Officer, per the Departmental Chemical Hygiene Plan. The following steps must be taken:

1. The Principal Investigator must complete a *Particularly Hazardous Substance Use Approval* form. Information required on the form includes:

- Identity, physical characteristics, and health hazards of the substances involved
- Consideration of exposure controls such as fume hoods, glove boxes and personal protective equipment
- Designation of an area (hood, glove box, portion of lab, entire lab) specifically for experimental procedures with the substances involved
- Plans for storage and secondary containment
- Procedures for safe removal of contaminated waste
- Decontamination procedures

2. The Principal Investigator submits the form to the Chemical Hygiene Officer to receive approval.

3. The area where the PHS will be used is posted as a designated area. Signs for this purpose are available through EH&S or may be made by the department or laboratory worker, as long as it includes the following information:

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

4. The laboratory worker proceeds with the experiment, following the practices outlined in the *Particularly Hazardous Substance Use Approval* form, as well as the appropriate work practices included in the remainder of the *Safe Work Practices and Procedures* section of this manual. All work is conducted within the Designated Area.

5. The laboratory worker decontaminates all equipment and disposes of waste promptly, as outlined in the *Particularly Hazardous Substance Use Approval* form.

Working Safely with Particularly Hazardous Substances

The increased hazard risk associated with Particularly Hazardous Substances (PHS) calls for more strict 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 MSDS 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, contact EH&S at 4367 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. EH&S can assist in selecting the best methods available for disposal.

7K: Pyrophorics - Air and Water Reactives

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

Detailed information about transferring pyrophorics can be found in Aldrich technical bulletins "Handling Air-Sensitive Reagents" and "Handling Pyrophoric Reagents".

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 MSDS.

Select and obtain all necessary materials to dispense and use the reagent(s) safely.

- Dryboxes are used to supply an inert atmosphere to prevent pyrophoric reactions with air.
- Fumehoods 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 inot 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 CO2 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 University Police at 5222 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 University Police immediately.
- A MetL-X fire extinguisher or powdered lime should be available in the lab.
    - ABC and CO2 extinguishers can cause some pyrophorics to react more vigorously.
    - Powdered lime can be used to cover spills and slow the reaction with air/humidity.

Additional Related Resources

Detailed information about transferring pyrophorics can be found in Aldrich technical bulletins “Handling Air-Sensitive Reagents” and “Handling Pyrophoric Reagents”.

A peer-reviewed publication "Safe handling of organolithium compounds in the laboratory" made available by the Division of Chemical Health and Safety of the American Chemical Society.

SECTION 8: Chemical Spills

Spill Response and Clean-up Procedures

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

- Immediately alert area occupants and supervisor, and evacuate the area, if necessary.
- If there is a fire or medical attention is needed, contact University Police at 5222.
- 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.
- If a volatile, flammable material is spilled, immediately warn everyone, control sources of ignition and ventilate the area.
- Don personal protective equipment, as appropriate to the hazards. Refer to the Material Safety Data Sheet or other references for information.
- 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 EH&S at 4367 or University Police at 5222. If respiratory protection is used, be sure there is another person outside the spill area in communication, in case of an emergency.
- 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 EH&S at 4367 or University Police at 5222.

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

- Protect floor drains or other means for environmental release. Spill socks and absorbents may be placed around drains, as needed.
- 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.

- 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.
- 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 EH&S at 4367 for advice on storage and packaging for disposal.
- Decontaminate the surface where the spill occurred using a mild detergent and water, when appropriate.
- Report all spills to your supervisor or the Principal Investigator.

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.

- Review Material Safety Data Sheets (MSDSs) or other references for recommended spill cleanup methods and materials, and the need for personal protective equipment (e.g., respirator, gloves, protective clothing, etc.)
- 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. See Recommended Spill Control Materials Inventory for more details.
- Acquire recommended personal protective equipment and training in its proper use. For example, if an air purifying respirator or self-contained breathing apparatus are needed, personnel must be enrolled in the Respiratory Protection Program and attend annual training and fit-testing.
- Place spill control materials and protective equipment in a readily accessible location within or immediately adjacent to the laboratory.
- 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.

- Discuss the spill response plans with all employees in the area.

Recommended Spill Control Material Inventory

Your laboratory or work area should have access to sufficient quantity of absorbents or other types of materials to control any spill that can be reasonably anticipated.

Personal Protective Equipment

- 2 pairs chemical splash goggles
- 2 pairs of gloves (recommend Silver Shield or 4H)
- 2 pairs of shoe covers
- 2 plastic or Tyvek aprons and/or Tyvek suits

Absorption Materials

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

Neutralizing Materials

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

Mercury Spills

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

Clean-up Tools

- Polypropylene scoop or dust pan
- Broom or brush with polypropylene bristles
- 2 polypropylene bags
- sealing tape
- pH test papers
- waste stickers
- floor sign - DANGER Chemical Spill - Keep Away

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.

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 clean of needles equipment and clutter.
- 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 in the hallways such as between classes.
- Transport chemical containers in a chemical carrier or cart.
- Place absorbent plastic backed liners on bench tops or in fume hoods where spills can be anticipated. For volumes of liquid larger than what can be absorbed by liners, use trays.

SECTION 9: Laboratory Waste Disposal

EH&S coordinates disposal of chemical waste from University operations. The cost of waste disposal for academic labs is borne by EH&S, rather than the individual department, in part to eliminate any hesitation to properly manage chemical wastes.

The following procedures apply to any chemical substances generated from University operations (including laboratories, administrative units, and physical plant operations) that are classified as hazardous based on the criteria described below. This procedure does not apply to disposal of radioactive or biohazard wastes.

In order to responsibly manage chemical waste each employee must be familiar with the following:

Hazardous Waste Characteristics

Properly Packaging Waste Materials

Effective labeling

Waste Collection Protocol

Classification of Waste as Hazardous

Waste is considered hazardous if:

- It is on either of two lists of specific chemical substances developed by the Federal Environmental Protection Agency (EPA). Most commonly used organic solvents (e.g. acetone, methanol, toluene, xylene, methylene chloride etc.) are included. For further information contact Environmental Health & Safety.
- It is on a list of nonspecific sources that includes a broad range of spent halogenated and non-halogenated solvents.
- It is on a list of specific sources that includes primarily industrial processes.
- It exhibits any of the following characteristics as defined by the EPA (definitions are abbreviated):
  - Ignitable
    - a liquid with a flash point less than 60 degrees Centigrade
    - not a liquid and capable under normal conditions of causing fire through friction, absorption of moisture or spontaneous chemical changes
    - an ignitable compressed gas
    - an oxidizer
  - Corrosive
    - it is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5
    - It is a liquid and corrodes steel at a rate greater than 0.250 inches per year at 55 degrees Centigrade
  - Reactive
    - it is normally unstable
    - it reacts violently with water
    - it forms potentially explosive mixtures with water
    - it generates toxic gases, vapors or fumes when mixed with water
    - cyanide or sulfide wastes that generate toxic gases, vapors or fumes at pH conditions between 2 and 12.5
    - it is capable of detonation or explosive decomposition if subjected to strong initiation or under standard temperature and pressure
    - it is classified as a Department of Transportation explosive
  - Toxicity Characteristic
    - if an extract of the waste is found to contain certain metals, pesticides or selected organics above specified levels.
    - if it is otherwise capable of causing environmental or health damage if improperly disposed (this is a judgment you must make based upon your knowledge of the material from the Material Safety Data Sheet or the literature).

Packaging Chemical Wastes

Place hazardous waste in sealable containers. Waste disposal cost is based on volume, not weight, therefore, whenever possible, containers should be filled, leaving headspace for expansion of the contents. Often the original container is perfectly acceptable.

The container should not react with the waste being stored (e.g. no hydrofluoric acid in glass). Similar wastes may be mixed if they are compatible (e.g. non-halogenated solvents).

Whenever possible, *wastes from incompatible hazard classes should not be mixed* (e.g. organic solvents with oxidizers). Certain metals also cause disposal problems when mixed with flammable liquids or other organic liquids (see special wastes).

Containers must be **kept closed** except during actual transfers. **Do not leave a hazardous waste container with a funnel in it.** See Storage of Chemical Waste for more information.

Chemical containers that have been triple-rinsed and air-dried in a ventilated area can be placed in the trash or recycled. If the original contents were highly toxic, the container should be rinsed first with an appropriate solvent and the washings disposed of as hazardous waste. See Disposal of Empty Glass Chemical Containers for more information.

Labeling of Chemical Waste Containers

Containers containing hazardous waste must be labeled with the words ***HAZARDOUS WASTE*** along with the names of the principal chemical constituents and the approximate percentage.

Waste container labels can be obtained by contacting Environmental Health & Safety at 4367 or from the Department Chemical Hygiene Officer. Use of these labels is preferred but not mandatory unless the waste will be placed in storage before disposal. If you choose not to use the standard labels, the container still must be labeled with the words **HAZARDOUS WASTE**.

Do not list reactants, only products. For example, if a cyanide was used in a reaction but all of the material was oxidized to a cyanate before disposal, do not list cyanide on the label.

Use IUPAC or common names, not symbols, structural diagrams or product trade names.

Labeling should be accurate and legible and should include the name of the generator, the name of the lab group or PI, the department, and an extension where someone who is knowledgeable about that specific waste can be reached **on the day of the pickup** in case questions arise during packaging for disposal.

Special Wastes

Metallic mercury is a recyclable waste. Please refer to the Mercury Disposal procedures for more information.

Ethidium bromide usually does not need to be disposed as hazardous waste. Electrophoresis gels containing trace amounts of ethidium bromide (less than 0.1%) may be placed in regular laboratory trash. Gels containing more than 0.1% (usually dark pink or red color) should be placed in the medical waste boxes. Ethidium bromide solutions may be neutralized and disposed down the drain. See Ethidium Bromide Disposal for more information.

Used oil is not disposed as part of the hazardous waste program, with the following exceptions:

- vacuum pump oil
- cutting oils
- PCB contaminated oil
- oil mixed with hazardous waste

Do not label used oil as hazardous waste. Instead, label the container with the words "Used Oil", not "waste oil", along with the names of any other constituents. See Used Oil Disposal for more information.

Silica gel, molecular sieves and desiccants are not considered hazardous waste unless they are grossly contaminated. Contaminated silica gel can be recycled. See Disposal of Silica Gel, Molecular Sieves and Desiccants for more information.

Uranium and thorium compounds, such as uranyl acetate, uranyl nitrate, uranyl formate, uranium oxide, thorium nitrate and thorium oxide, are considered radioactive waste, rather than chemical waste. See Disposal of Uranium and Thorium Compounds for more information.

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

It is the chemical user's responsibility to identify and properly label all chemical wastes. The disposal company cannot legally transport or dispose of unidentified/unknown waste. See Unknown Chemicals for more information.

Disposal of Empty Chemical Containers

Chemical containers that have been emptied (generally this means drained of their contents by normal methods including pouring, pumping, aspirating, etc.) are not regulated as hazardous waste; however they should not necessarily be disposed of in the regular solid waste dumpsters. Generally, the primary container (the container that actually held the chemical, as opposed to a container that the primary chemical was packed in), must be triple rinsed with water or other suitable solvent and air-dried before disposal. For volatile organic solvents (e.g. acetone, ethanol, ethyl acetate, ethyl ether, hexane, methanol, methylene chloride, petroleum ether, toluene, xylene, etc.) not on the list of acutely hazardous wastes, the emptied container can be air-dried in a ventilated area (e.g. a chemical fume hood) without triple rinsing.

The waste generator must determine whether the washings must be collected and disposed of as hazardous waste. Generally, if the chemical is on the list of acutely hazardous wastes or if the material is known to have high acute toxicity, the washings must be collected.

Secondary Containers

Containers that were used as overpack for the primary chemical container may be placed in regular trash or recyclable trash. Any packing materials, such as vermiculite, perlite, clay, styrofoam, etc., may be placed in the regular trash unless it was contaminated with the chemical as a result of container breakage or leak. Packing materials contaminated with hazardous materials should be disposed of as hazardous waste.

If you have any questions, please contact EH&S or the Department Chemical Hygiene Officer.

Ethidium Bromide Disposal

Ethidium bromide is commonly used in molecular biology laboratories. While it is not regulated as hazardous waste, the mutagenic properties of this substance may present a hazard if it is poured down the drain untreated or placed in the trash.

Based on these considerations, the following are the recommended disposal procedures for ethidium bromide.

Electrophoresis Gels

Trace amounts of ethidium bromide in gels should not pose a hazard. Higher concentrations, e.g., when the color of the gel is dark pink or red, should not be placed in laboratory trash. The following procedures are recommended:

- Less than 0.1% ethidium bromide: place in laboratory trash
- More than or equal to 0.1%: place in biohazard box for incineration.

Ethidium Bromide Solutions

- Aqueous solutions containing <10ug/ml ethidium bromide can be released to the drain.
- Aqueous solutions containing >10ug/ml ethidium bromide should be filtered or deactivated using one of the methods described below.
- Solutions containing heavy metals, organics, cyanides or sulfides should be disposed as hazardous waste.

Charcoal Filtration

Filtering the aqueous ethidium bromide waste solutions, free of other contaminants, through a bed of activated charcoal is a relatively simple and effective method for removal of ethidium bromide. The filtrate may be poured down the drain.

There are two simple kits available for charcoal filtration:

Funnel Kit

Schleicher and Schuell supply a commercial filter funnel kit that uses a packaged charcoal disk that is graduated for easily tracking the amount of aqueous solution calculated for a fixed quantities of ethidium bromide residue. This is particularly useful for labs that generate large amounts of solutions at a time. The kit is available through Schleicher and Schuell or VWR.

- Filter the ethidium bromide solution through the charcoal filter.
- Pour filtrate down the drain.
- Place charcoal filter in a sealed bag (e.g., zip-lock) and place in biohazardous waste box for incineration.

The Green Bag

Another simple charcoal filtration method is the Green Bag, manufactured by BIO 101. The Green Bag® Kit allows rapid and trouble-free concentration of ethidium bromide from large volumes of solutions into a small "tea" bag containing activated carbon which is then conveniently disposed along with other solid hazardous wastes. One kit has the capacity to remove 500 mg of ethidium bromide from solutions (10mg EtBr/bag).

- Place the Green Bag into the ethidium bromide solution.
- Allow to sit for the allotted time.
- Pour filtrate down the drain.
- Dispose of the Green back in the biohazard waste box for incineration.

Green Bags are available through BIO101 (www.bio101.com).

Chemical Neutralization

Solutions containing ethidium bromide can be deactivated, neutralized and poured down the drain with copious amounts of water. Deactivation may be confirmed using UV light to detect fluorescence. There are three recognized methods for deactivation:

Armour Method

This is the simplest method, but is somewhat controversial. One study found traces of mutagenic reaction mixtures using this method. (Lunn, G. and E. Sansone, *Analytical Biochemistry*, vol. 162, pp. 453-458, 1987)

- Combine equal amounts of ethidium bromide solution and household bleach.
- Stir constantly for four hours or let sit for 2-3 days.
- Adjust pH to 4-9 with sodium hydroxide.
- Pour down drain with copious amounts of water.

Lunn and Sansone Method

For each 100 ml of ethidium bromide solution:

- Add 5% hypophosphorus acid.
- Add 12 ml of 0.5 M sodium nitrate.
- Stir briefly and let stand for 20 hours.
- Adjust pH to 4-9 using sodium hydroxide.
- Pour down drain with copious amounts of water.

Quillardet and Hoffnung Method

This method uses 0.5 M potassium permanganate and 2.5 M hydrochloric acid. Since chlorine gas may be released in significant concentration, this method is not recommended.

Gloves, Equipment and Debris

Gloves, test tubes, paper towels, etc., that are grossly contaminated with ethidium bromide should be placed in medical waste for incineration. Consider deactivating in bleach before disposal if the items are significantly contaminated.

Compressed Gas Disposal

Compressed gases should be returned to the vendor. If there are problems returning a cylinder, contact EHS.

Lecture Bottle Purchase and Disposal

Lecture bottles are very small compressed gas cylinders, typically 2-3 inches in diameter and 12-18 inches in height. While most gas supplier offer lecture bottles for purchase, many will not accept the empty or partially full cylinders back for disposal. Lecture bottle disposal can be very costly, depending on the original contents.

Montclair State University researchers should only purchase lecture bottles that can be returned to the distributor. Most distributors do offer a returnable cylinder, although in some cases, these cylinders are slightly larger than typical lecture bottles. Also, keep in mind that distributors’ policies toward lecture bottles are subject to change. In order to avoid costly disposal fees and potential hazards involved in emptying and cutting the cylinder, it is worthwhile to purchase a returnable cylinder, even if it is a bit more than what you need.

Disposing of Lecture Bottles

If you have unneeded lecture bottles, first call the manufacturer or distribute and ask that they pick up the cylinder for return, if they will not take the cylinder back, please call EH&S at 4367 for assistance.

Mercury Disposal

Waste metals that will be reclaimed are not considered hazardous waste per the New Jersey Department of Environmental Protection. Elemental mercury is one of the most common reclaimable metals found at Princeton.

Pure mercury liquid is sent directly to a reclamation facility for distillation and reuse. Mercury debris (e.g., broken thermometers, spill cleanup debris) is managed as hazardous waste, periodically collected by EH&S personnel, consolidated, and sent for mercury retorting. Mercury compounds will also be handled as hazardous waste.

Disposal Procedures

1. Collect pure liquid mercury in a sealable container. Label as "MERCURY FOR RECLAMATION"
2. Place broken thermometers and mercury debris in a sturdy sealable plastic bag, plastic or glass jar. Be sure that materials may be easily removed for consolidation. Label the container "Hazardous Waste - MERCURY SPILL DEBRIS".
3. Keep the material in your laboratory until the next scheduled waste pickup.

Broken Thermometers and Mercury Debris

In the event that a thermometer, manometer or similar mercury-containing device breaks, proceed as follows:

- Put on a pair of nitrile gloves and eye protection.
- Pick up larger pieces of broken glass or debris taking care to avoid touching sharp edges. Place in a puncture-resistant container.
- 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 zinc powder or coated sponges 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.
- 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”.
- Follow the mercury disposal procedures outlined above.

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.

Precautions for Minimizing Mercury Incidents

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

Used Oil Disposal

Used oil is not considered a hazardous waste, per the US Environmental Protection Agency and the NJ Department of Environmental Protection. Used oil is not picked up and disposed of as part of the hazardous waste pickups, with the following exceptions:

1. **Vacuum pump oil** from laboratories will be collected during the monthly hazardous waste pickups, due to the possibility of contamination with other chemicals. Containers must be labeled "USED OIL", not "hazardous waste."

2. Many **cutting oils** may not meet the definition of used oil. Contact EH&S at 4367 before disposing of cutting oils in order to determine whether they should be treated as used oil or hazardous waste.

3. **PCB contaminated oil** must be treated as hazardous waste. Contact EH&S if there is any suspicion of PCB contamination.

4. Oil mixed into any other hazardous wastes will be treated as hazardous waste.

Used Oil Collection Tips

- Minimize the amount of water in the oil.
- Keep all collection vessels, especially drums, sealed except when filling the container.
- Label containers "USED OIL", not "waste oil" or "hazardous waste".

Sharps Disposal

Sharps include razor blades or other cutting blades, broken glass, glass slides, needles or other items that can easily puncture the skin. In order to prevent injury to those who must handle the general trash coming from offices, labs and shops:

- Do not place directly into trash receptacles with other general trash or in paper recycling receptacles.
- Place in a puncture-resistant container, such as rigid plastic or corrugated cardboard.
- Seal the container before placing in regular trash.
- NOTE: If labs opt to use commercially available *Medical* or *Biohazardous* sharps containers, these containers must be disposed of in medical waste boxes.

Uranium and Thorium Compounds

All forms of uranium or thorium waste must be disposed of as radioactive waste, rather than as hazardous chemical waste. Examples include uranyl acetate, uranyl nitrate, uranyl formate, uranium oxide, thorium nitrate, and thorium oxide.

Even though these compounds are easy to obtain, they're not so easy to dispose of. Not only must all forms of uranium or thorium be disposed of as radioactive waste, but special arrangements must generally be made with the university's radioactive waste broker for their packaging, pickup and disposal. These materials are becoming more expensive and more difficult to dispose. Please dispose of any unneeded materials promptly and limit the amount that you order. If you have any questions regarding these compounds and their disposal please contact the University Radiation Safety Officer.

Unidentified Chemical Waste

Chemicals that cannot be identified should be considered unknown hazardous waste. Unknown wastes cannot be legally transported or disposed. In order to dispose of them safely and properly, our waste contractors will need to know as much about the material as possible and will then need to test the characteristics of the waste.

If you find unknown hazardous waste, please adhere to the following guidelines:

1. Contact the department Chemical Hygiene Officer immediately to inform them of the material.
2. Find out as much as you can about how the waste was generated. This might mean getting in touch with people who are no longer with the University. The more we know about the waste, the better we can characterize it for disposal.
3. Keep the material in your laboratory or work area. The Chemical Hygiene Officer, EH&S, or the waste contractor will remove the material from your laboratory.
4. Please **DO NOT**
    - pour unknown chemicals down the sink
    - mix unknown chemicals with any other chemicals for consolidation
    - abandon unknown chemicals in the work area

It is very easy to avoid generating future unknown hazardous waste by doing the following:

- Label all chemicals in the laboratory in a meaningful way. For example, it is fine to label something PIH as long as others in the lab understand what those initials indicate.
- Dispose of spent materials and chemicals with no foreseeable use promptly.

- Before moving out of a work area or leaving the University, go through the laboratory or work area with your supervisor or the new occupant to determine which chemicals need disposal and to identify anything that is ambiguously labeled.
- When relocating from one work area to another, do not leave any chemicals behind unless specific arrangements have been made with the new occupant.

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

Chemical Name	**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

B

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

C

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

D

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

E

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

F

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

G

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

H

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

I

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

K

Karathane	131-72-6	Reproductive Toxin

L

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

M

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-	Carcinogen

	2	
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

N

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

O

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

P

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

R

Reserpine	50-55-5	Carcinogen
RH-7592	---	Reproductive Toxin

S

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

T

Talc´ containing asbestiform fibers	---	Carcinogen
Testosterone and its esters	58-22-0	Carcinogen
2,3,7,8-Tetrachlorodibenzo-para-dioxin (TCDD)	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

U

Uracil mustard	66-75-1	Carcinogen
Urethane (Ethyl carbamate)	51-79-6	Carcinogen

V

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

X

2,6-Xylidine (2,6-Dimethylaniline)	87-62-7	Carcinogen

Z

Zineb	12122-67-7	Carcinogen

Appendix B: Reproductive Toxins

PLEASE NOTE: This list is not exhaustive. Please check the material safety data sheet to determine if the chemical is considered a reproductive toxin.

Chemical Name	**CAS Number**
Acetaldehyde	75-07-0
Anesthetic gases	---
Arsenic	7440-38-2
Aflotoxins	---
Aluminum chloride	7446-70-0
Benzene	71-43-2
Benzo(a)pyrene	50-32-8
Cadmium	7440-43-9
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Cellosolve	110-80-5
Chloroform	67-66-3
Chloroprene	126-99-8
Chromium trioxide	1333-82-0
Dimethyl formamide	68-12-2
Di-sec-octyl-phthalate	117-81-7
Ninitrooctyl phenol	63149-81-5
DBCP (1,2-dibromo-3-chloropropane)	96-12-8
Dithane	111-54-6
Epichlorhydrin	106-89-8
2-Ethoxy ethanol	110-80-5
2-Ethoxyethyl acetate	111-15-9
Ethylene dibromide	106-93-4
Ethylene glycol monoethyl ether	110-80-5
Ethylene glycol monomethyl ether	109-86-4

Ethylene oxide	75-21-8
Ethylene thiourea	96-45-7
2-Ethylhexanol	104-76-7
Formaldehyde	500-00-0
Glycol ethers	---
Halothane	151-67-7
Hexafluoroacetone	684-16-2
Hexamethylphosphoramide	680-31-9
Hormones	---
Hydrazine	302-01-2
Karathane	131-72-6
Lead (inorganic compounds)	7439-92-1
2-Methoxyethanol	109-86-4
2-Methoxyethyl acetate	110-49-6
Methyl cellosolve	109-86-4
Methyl chloride	74-87-3
N-Methyl-2-pyrrolidone	872-50-4
Propylene glycol monomethyl ether	107-98-2
Propylene glycol monomethyl ether acetate	108-65-6
Propylene oxide	75-56-9
RH-7592	---
Systhane/RH-3866	88671-89-0
Trichloroethylene	79-01-6
Vinyl chloride	75-01-4

Appendix C: Materials with High Acute Toxicity

NOTE: This list is not exhaustive. Please refer to the material safety data sheet to determine if other chemicals meet the specifications as high acute toxicity.

Acrolein	107-02-8
2-Aminopyridine	462-08-8
Arsenic pentafluoride gas	784-36-3
Arsine gas	7784-42-1
Benzyl chloride	100-44-7
Boron trifluoride	7637-07-2
Bromine	7726-95-6

Chlorine gas	7782-50-5
Chorine dioxide	10049-04-4
Chlorine trifluoride	7790-91-2
Cyanogen chloride	506-77-4
Decaborane	17702-41-9
Diazomethane gas	334-88-3
Diborane gas	19287-45-7
Dichloroacetylene	79-36-7
Dimethyl mercury	593-74-8
Dimethyl sulfate	77-78-1
Dimethyl sulfide	75-18-3
Ethylene chlorohydrin	107-07-3
Ethylene fluorohydrin	371-62-0
Fluorine gas	7681-49-4
2-Fluoroethanol	371-62-0
Hexamethylene diiosocyanate	822-06-0
Hydrogen cyanide	74-90-8
Hydrogen flouride	7664-39-3
Iron pentacarbonyl	13463-40-6
Isopropyl formate	625-55-8
Methacryloyl chloride	920-46-7
Methyl acrylonitrile	126-98-7
Methyl chloroformate	79-22-1
Methylene biphenyl isocyanate	101-68-9
Methyl fluoroacetate	453-18-9
Methyl fluorosulfate	421-20-5
Methyl hydrazine	60-34-4
Methyl mercury and other organic forms	---
Methyl trichlorosilane	75-79-6
Methyl vinyl ketone	78-94-4
Nickel carbonyl	13463-39-3
Nitrogen dioxide	10102-44-0
Nitrogen tetroxide	10544-72-6
Nitrogen trioxide	10544-73-7
Osmium tetroxide	20816-12-0
Oxygen difluoride gas	7783-41-7
Ozone	10028-15-6

Pentaborane	19624-22-7
Perchloromethlyl mercaptan	594-42-3
Phosgene gas	75-45-5
Phosphine gas	1498-40-4
Phosphorus oxychloride	10025-87-3
Phosphorus pentafluoride gas	7641-19-0
Phosphorus trichloride	7719-12-2
Sarin	107-44-8
Selenium hexafluoride gas	7783-79-1
Silicon tetrafluoride gas	7783-61-1
Sodium azide	26628-22-8
Sodium cyanide (and other cyanide salts)	143-33-9
Stibine gas	10025-91-9
Sulfur monochloride	10025-67-9
Sulfur pentafluoride	10546-01-7
Sulfur tetrafluoride gas	7783-60-0
Sulfuryl chloride	7791-25-5
Tellurium hexafluoride	7783-80-4
Tetramethyl succinonitrile	3333-52-6
Tetranitromethane	509-14-8
Thionyl chloride	7719-09-7
Toluene-2,4-diisocyanate	584-84-9
Trichloro(chlormethyl)silane	1558-25-4
Trimethyltin chloride	1066-45-1

Appendix D: P-List Waste

(for the most current list see 40 CFR 261.33)

P023	107–20–0	Acetaldehyde, chloro-
P002	591–08–2	Acetamide, N-(aminothioxomethyl)-
P057	640–19–7	Acetamide, 2-fluoro-
P058	62–74–8	Acetic acid, fluoro-, sodium salt
P002	591–08–2	1-Acetyl-2-thiourea
P003	107–02–8	Acrolein
P070	116–06–3	Aldicarb
P203	1646–88–4	Aldicarb sulfone.
P004	309–00–2	Aldrin
P005	107–18–6	Allyl alcohol
P006	20859–73–8	Aluminum phosphide (R,T)

P007	2763–96–4	5-(Aminomethyl)-3-isoxazolol
P008	504–24–5	4-Aminopyridine
P009	131–74–8	Ammonium picrate (R)
P119	7803–55–6	Ammonium vanadate
P099	506–61–6	Argentate(1-), bis(cyano-C)-, potassium
P010	7778–39–4	Arsenic acid H3 AsO4
P012	1327–53–3	Arsenic oxide As2 O3
P011	1303–28–2	Arsenic oxide As2 O5
P011	1303–28–2	Arsenic pentoxide
P012	1327–53–3	Arsenic trioxide
P038	692–42–2	Arsine, diethyl-
P036	696–28–6	Arsonous dichloride, phenyl-
P054	151–56–4	Aziridine
P067	75–55–8	Aziridine, 2-methyl-
P013	542–62–1	Barium cyanide
P024	106–47–8	Benzenamine, 4-chloro-
P077	100–01–6	Benzenamine, 4-nitro-
P028	100–44–7	Benzene, (chloromethyl)-
P042	51–43–4	1,2-Benzenediol, 4-[1-hydroxy-2-(methylamino)ethyl]-, (R)-
P046	122–09–8	Benzeneethanamine, alpha,alpha-dimethyl-
P014	108–98–5	Benzenethiol
P127	1563–66–2	7-Benzofuranol, 2,3-dihydro-2,2-dimethyl-, methylcarbamate.
P188	57–64–7	Benzoic acid, 2-hydroxy-, compd. with (3aS-cis)-1,2,3,3a,8,8a-hexahydro-1,3a,8-trimethylpyrrolo[2,3-b]indol-5-yl methylcarbamate ester (1:1).
P001	81–81–2	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenylbutyl)-, & salts, when present at concentrations greater than 0.3%
P028	100–44–7	Benzyl chloride
P015	7440–41–7	Beryllium powder
P017	598–31–2	Bromoacetone
P018	357–57–3	Brucine
P045	39196–18–4	2-Butanone, 3,3-dimethyl-1-(methylthio)-,O-[methylamino)carbonyl] oxime
P021	592–01–8	Calcium cyanide
P021	592–01–8	Calcium cyanide Ca(CN)2
P189	55285–14–8	Carbamic acid, [(dibutylamino)- thio]methyl-, 2,3-dihydro-2,2-dimethyl- 7-benzofuranyl ester.
P191	644–64–4	Carbamic acid, dimethyl-, 1-[(dimethyl-amino)carbonyl]- 5-methyl-1H- pyrazol-3-yl ester.
P192	119–38–0	Carbamic acid, dimethyl-, 3-methyl-1- (1-methylethyl)-1H-pyrazol-5-yl ester.
P190	1129–41–5	Carbamic acid, methyl-, 3-methylphenyl ester.
P127	1563–66–2	Carbofuran.
P022	75–15–0	Carbon disulfide
P095	75–44–5	Carbonic dichloride
P189	55285–14–8	Carbosulfan.
P023	107–20–0	Chloroacetaldehyde
P024	106–47–8	p-Chloroaniline
P026	5344–82–1	1-(o-Chlorophenyl)thiourea
P027	542–76–7	3-Chloropropionitrile
P029	544–92–3	Copper cyanide
P029	544–92–3	Copper cyanide Cu(CN)

P202	64–00–6	m-Cumenyl methylcarbamate.
P030		Cyanides (soluble cyanide salts), not otherwise specified
P031	460–19–5	Cyanogen
P033	506–77–4	Cyanogen chloride
P033	506–77–4	Cyanogen chloride (CN)Cl
P034	131–89–5	2-Cyclohexyl-4,6-dinitrophenol
P016	542–88–1	Dichloromethyl ether
P036	696–28–6	Dichlorophenylarsine
P037	60–57–1	Dieldrin
P038	692–42–2	Diethylarsine
P041	311–45–5	Diethyl-p-nitrophenyl phosphate
P040	297–97–2	O,O-Diethyl O-pyrazinyl phosphorothioate
P043	55–91–4	Diisopropylfluorophosphate (DFP)
P004	309–00–2	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa- chloro- 1,4,4a,5,8,8a,-hexahydro- (1alpha,4alpha,4abeta,5alpha,8alpha,8abeta)-
P060	465–73–6	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa- chloro- 1,4,4a,5,8,8a-hexahydro-, (1alpha,4alpha,4abeta,5beta,8beta,8abeta)-
P037	60–57–1	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9- hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2aalpha,3beta,6beta,6aalpha,7beta, 7aalpha)-
P051	1 72–20–8	2,7:3,6-Dimethanonaphth [2,3-b]oxirene, 3,4,5,6,9,9- hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2abeta,3alpha,6alpha,6abeta,7beta, 7aalpha)-, & metabolites
P044	60–51–5	Dimethoate
P046	122–09–8	alpha,alpha-Dimethylphenethylamine
P191	644–64–4	Dimetilan.
P047	534–52–1	4,6-Dinitro-o-cresol, & salts
P048	51–28–5	2,4-Dinitrophenol
P020	88–85–7	Dinoseb
P085	152–16–9	Diphosphoramide, octamethyl-
P111	107–49–3	Diphosphoric acid, tetraethyl ester
P039	298–04–4	Disulfoton
P049	541–53–7	Dithiobiuret
P185	26419–73–8	1,3-Dithiolane-2-carboxaldehyde, 2,4-dimethyl-, O-[(methylamino)- carbonyl]oxime.
P050	115–29–7	Endosulfan
P088	145–73–3	Endothall
P051	72–20–8	Endrin
P051	72–20–8	Endrin, & metabolites
P042	51–43–4	Epinephrine
P031	460–19–5	Ethanedinitrile
P194	23135–22–0	Ethanimidothioc acid, 2-(dimethylamino)-N-[[(methylamino) carbonyl]oxy]-2-oxo-, methyl ester.
P066	16752–77–5	Ethanimidothioic acid,N-[[(methylamino)carbonyl]oxy]-, methyl ester
P101	107–12–0	Ethyl cyanide
P054	151–56–4	Ethyleneimine
P097	52–85–7	Famphur
P056	7782–41–4	Fluorine

P057	640–19–7	Fluoroacetamide
P058	62–74–8	Fluoroacetic acid, sodium salt
P198	23422–53–9	Formetanate hydrochloride.
P197	17702–57–7	Formparanate.
P065	628–86–4	Fulminic acid, mercury(2+) salt (R,T)
P059	76–44–8	Heptachlor
P062	757–58–4	Hexaethyl tetraphosphate
P116	79–19–6	Hydrazinecarbothioamide
P068	60–34–4	Hydrazine, methyl-
P063	74–90–8	Hydrocyanic acid
P063	74–90–8	Hydrogen cyanide
P096	7803–51–2	Hydrogen phosphide
P060	465–73–6	Isodrin
P192	119–38–0	Isolan.
P202	64–00–6	3-Isopropylphenyl N-methylcarbamate.
P007	2763–96–4	3(2H)-Isoxazolone, 5-(aminomethyl)-
P196	15339–36–3	Manganese, bis(dimethylcarbamodithioato-S,S□)-,
P196	15339–36–3	Manganese dimethyldithiocarbamate.
P092	62–38–4	Mercury, (acetato-O)phenyl-
P065	628–86–4	Mercury fulminate (R,T)
P082	62–75–9	Methanamine, N-methyl-N-nitroso-
P064	624–83–9	Methane, isocyanato-
P016	542–88–1	Methane, oxybis[chloro-
P112	509–14–8	Methane, tetranitro- (R)
P118	75–70–7	Methanethiol, trichloro-
P198	23422–53–9	Methanimidamide, N,N-dimethyl-N□-[3-[[(methylamino)-carbonyl]oxy]phenyl]-, monohydrochloride.
P197	17702–57–7	Methanimidamide, N,N-dimethyl-N□-[2-methyl-4-[[(methylamino)carbonyl]oxy]phenyl]-
P050	115–29–7	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide
P059	76–44–8	4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-
P199	2032–65–7	Methiocarb.
P066	16752–77–5	Methomyl
P068	60–34–4	Methyl hydrazine
P064	624–83–9	Methyl isocyanate
P069	75–86–5	2-Methyllactonitrile
P071	298–00–0	Methyl parathion
P190	1129–41–5	Metolcarb.
P128	315–8–4	Mexacarbate.
P072	86–88–4	alpha-Naphthylthiourea
P073	13463–39–3	Nickel carbonyl
P074	557–19–7	Nickel cyanide
P075	54–11–5	Nicotine, & salts
P076	10102–43–9	Nitric oxide
P077	100–01–6	p-Nitroaniline
P078	10102–44–0	Nitrogen dioxide
P076	10102–43–9	Nitrogen oxide NO
P078	10102–44–0	Nitrogen oxide NO2
P081	55–63–0	Nitroglycerine (R)
P082	62–75–9	N-Nitrosodimethylamine

P084	4549–40–0	N-Nitrosomethylvinylamine
P085	152–16–9	Octamethylpyrophosphoramide
P087	20816–12–0	Osmium oxide OsO4, (T-4)-
P087	20816–12–0	Osmium tetroxide
P088	145–73–3	7-Oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid
P194	23135–22–0	Oxamyl.
P089	56–38–2	Parathion
P034	131–89–5	Phenol, 2-cyclohexyl-4,6-dinitro-
P048	51–28–5	Phenol, 2,4-dinitro-
P047	534–52–1	Phenol, 2-methyl-4,6-dinitro-, & salts
P020	88–85–7	Phenol, 2-(1-methylpropyl)-4,6-dinitro-
P009	131–74–8	Phenol, 2,4,6-trinitro-, ammonium salt (R)
P128	315–18–4	Phenol, 4-(dimethylamino)-3,5-dimethyl-, methylcarbamate (ester).
P199	2032–65–7	Phenol, (3,5-dimethyl-4-(methylthio)-, methylcarbamate
P202	64–00–6	Phenol, 3-(1-methylethyl)-, methyl carbamate.
P201	2631–37–0	Phenol, 3-methyl-5-(1-methylethyl)-, methyl carbamate.
P092	62–38–4	Phenylmercury acetate
P093	103–85–5	Phenylthiourea
P094	298–02–2	Phorate
P095	75–44–5	Phosgene
P096	7803–51–2	Phosphine
P041	311–45–5	Phosphoric acid, diethyl 4-nitrophenyl ester
P039	298–04–4	Phosphorodithioic acid, O,O-diethylS-[2-(ethylthio)ethyl] ester
P094	298–02–2	Phosphorodithioic acid, O,O-diethylS-[(ethylthio)methyl] ester
P044	60–51–5	Phosphorodithioic acid, O,O-dimethyl S-[2-(methylamino)-2-oxoethyl] ester
P043	55–91–4	Phosphorofluoridic acid, bis(1-methylethyl) ester
P089	56–38–2	Phosphorothioic acid, O,O-diethyl O-(4-nitrophenyl) ester
P040	297–97–2	Phosphorothioic acid, O,O-diethyl O-pyrazinyl ester
P097	52–85–7	Phosphorothioic acid,O-[4-[(dimethylamino)sulfonyl]phenyl] O,O-dimethyl ester
P071	298–00–0	Phosphorothioic acid, O,O,-dimethyl O-(4-nitrophenyl) ester
P204	57–47–6	Physostigmine.
P188	57–64–7	Physostigmine salicylate.
P110	78–00–2	Plumbane, tetraethyl-
P098	151–50–8	Potassium cyanide
P099	506–61–6	Potassium silver cyanide
P201	2631–37–0	Promecarb
P070	116–06–3	Propanal, 2-methyl-2-(methylthio)-,O-[(methylamino)carbonyl]oxime
P203	1646–88–4	Propanal, 2-methyl-2-(methyl-sulfonyl)-, O-[(methylamino)carbonyl] oxime.
P101	107–12–0	Propanenitrile
P027	542–76–7	Propanenitrile, 3-chloro-
P069	75–86–5	Propanenitrile, 2-hydroxy-2-methyl-
P081	55–63–0	1,2,3-Propanetriol, trinitrate (R)
P017	598–31–2	2-Propanone, 1-bromo-
P102	107–19–7	Propargyl alcohol
P003	107–02–8	2-Propenal
P005	107–18–6	2-Propen-1-ol
P067	75–55–8	1,2-Propylenimine

P102	107–19–7	2-Propyn-1-ol
P008	504–24–5	4-Pyridinamine
P075	54–11–5	Pyridine, 3-(1-methyl-2-pyrrolidinyl)-, (S)-, & salts
P204	57–47–6	Pyrrolo[2,3-b]indol-5-ol, 1,2,3,3a,8,8a-hexahydro-1,3a,8-trimethyl-,methylcarbamate (ester), (3aS-cis)-.
P114	12039–52–0	Selenious acid, dithallium(1+) salt
P103	630–10–4	Selenourea
P104	506–64–9	Silver cyanide
P105	26628–22–8	Sodium azide
P106	143–33–9	Sodium cyanide
P108	57–24–9	Strychnidin-10-one, & salts
P018	357–57–3	Strychnidin-10-one, 2,3-dimethoxy-
P108	57–24–9	Strychnine, & salts
P115	7446–18–6	Sulfuric acid, dithallium(1+) salt
P109	3689–24–5	Tetraethyldithiopyrophosphate
P110	78–00–2	Tetraethyl lead
P111	107–49–3	Tetraethyl pyrophosphate
P112	509–14–8	Tetranitromethane (R)
P062	757–58–4	Tetraphosphoric acid, hexaethyl ester
P113	1314–32–5	Thallium oxide Tl2 O3
P114	12039–52–0	Thallium(I) selenite
P115	7446–18–6	Thallium(I) sulfate
P109	3689–24–5	Thiodiphosphoric acid, tetraethyl ester
P045	39196–18–4	Thiofanox
P049	541–53–7	Thioimidodicarbonic diamide [(H2 N)C(S)]2 NH
P014	108–98–5	Thiophenol
P116	79–19–6	Thiosemicarbazide
P026	5344–82–1	Thiourea, (2-chlorophenyl)-
P072	86–88–4	Thiourea, 1-naphthalenyl-
P093	103–85–5	Thiourea, phenyl-
P185	26419–73–8	Tirpate.
P123	8001–35–2	Toxaphene
P118	75–70–7	Trichloromethanethiol
P119	7803–55–6	Vanadic acid, ammonium salt
P120	1314–62–1	Vanadium oxide V2 O5
P120	1314–62–1	Vanadium pentoxide
P084	4549–40–0	Vinylamine, N-methyl-N-nitroso-
P001	81–81–2	Warfarin, & salts, when present at concentrations greater than 0.3%
P205	137–30–4	Zinc, bis(dimethylcarbamodithioato-S,S□)-,
P121	557–21–1	Zinc cyanide
P122	1314–84–7	Zinc phosphide Zn3 P2, when present at concentrations greater than 10% (R,T)
P205	137–30–4	Ziram

Appendix E: U-List Waste

(for the most current list see 40 CFR 261.33)

U394	30558–43–1	A2213.
U001	75–07–0	Acetaldehyde (I)
U034	75–87–6	Acetaldehyde, trichloro-
U187	62–44–2	Acetamide, N-(4-ethoxyphenyl)-
U005	53–96–3	Acetamide, N-9H-fluoren-2-yl-
U240	94–75–7	Acetic acid, (2,4-dichlorophenoxy)-, salts & esters
U112	141–78–6	Acetic acid ethyl ester (I)
U144	301–04–2	Acetic acid, lead(2+) salt
U214	563–68–8	Acetic acid, thallium(1+) salt
U002	67–64–1	Acetone (I)
U003	75–05–8	Acetonitrile (I,T)
U004	98–86–2	Acetophenone
U005	53–96–3	2-Acetylaminofluorene
U006	75–36–5	Acetyl chloride (C,R,T)
U007	79–06–1	Acrylamide
U008	79–10–7	Acrylic acid (I)
U009	107–13–1	Acrylonitrile
U011	61–82–5	Amitrole
U012	62–53–3	Aniline (I,T)
U136	75–60–5	Arsinic acid, dimethyl-
U014	492–80–8	Auramine
U015	115–02–6	Azaserine
U010	50–07–7	Azirino[2′,3′ª3,4]pyrrolo[1,2-a]indole-4,7-dione, 6-amino-8-[[(aminocarbonyl)oxy]methyl]-1,1a,2,8,8a,8bhexahydro-8a-methoxy-5-methyl-, [1aS-(1aalpha, 8beta,8aalpha,8balpha)]-
U280	101–27–9	Barban.
U278	22781–23–3	Bendiocarb.
U364	22961–82–6	Bendiocarb phenol.
U271	17804–35–2	Benomyl.
U157	56–49–5	Benz[j]aceanthrylene, 1,2-dihydro-3-methyl-
U016	225–51–4	Benz[c]acridine
U017	98–87–3	Benzal chloride
U192	23950–58–5	Benzamide, 3,5-dichloro-N-(1,1-dimethyl-2-propynyl)-
U018	56–55–3	Benz[a]anthracene
U094	57–97–6	Benz[a]anthracene, 7,12-dimethyl-
U012	62–53–3	Benzenamine (I,T)
U014	492–80–8	Benzenamine, 4,4′-carbonimidoylbis[N,N-dimethyl-
U049	3165–93–3	Benzenamine, 4-chloro-2-methyl-, hydrochloride
U093	60–11–7	Benzenamine, N,N-dimethyl-4-(phenylazo)-
U328	95–53–4	Benzenamine, 2-methyl-
U353	106–49–0	Benzenamine, 4-methyl-
U158	101–14–4	Benzenamine, 4,4′-methylenebis[2-chloro-
U222	636–21–5	Benzenamine, 2-methyl-, hydrochloride
U181	99–55–8	Benzenamine, 2-methyl-5-nitro-
U019	71–43–2	Benzene (I,T)
U038	510–15–6	Benzeneacetic acid, 4-chloro-alpha-(4-chlorophenyl)-alpha-hydroxy-, ethyl ester

U030	101–55–3	Benzene, 1-bromo-4-phenoxy-
U035	305–03–3	Benzenebutanoic acid, 4-[bis(2-chloroethyl)amino]-
U037	108–90–7	Benzene, chloro-
U221	25376–45–8	Benzenediamine, ar-methyl-
U028	117–81–7	1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester
U069	84–74–2	1,2-Benzenedicarboxylic acid, dibutyl ester
U088	84–66–2	1,2-Benzenedicarboxylic acid, diethyl ester
U102	131–11–3	1,2-Benzenedicarboxylic acid, dimethyl ester
U107	117–84–0	1,2-Benzenedicarboxylic acid, dioctyl ester
U070	95–50–1	Benzene, 1,2-dichloro-
U071	541–73–1	Benzene, 1,3-dichloro-
U072	106–46–7	Benzene, 1,4-dichloro-
U060	72–54–8	Benzene, 1,1’-(2,2-dichloroethylidene)bis[4-chloro-
U017	98–87–3	Benzene, (dichloromethyl)-
U223	26471–62–5	Benzene, 1,3-diisocyanatomethyl- (R,T)
U239	1330–20–7	Benzene, dimethyl- (I,T)
U201	108–46–3	1,3-Benzenediol
U127	118–74–1	Benzene, hexachloro-
U056	110–82–7	Benzene, hexahydro- (I)
U220	108–88–3	Benzene, methyl-
U105	121–14–2	Benzene, 1-methyl-2,4-dinitro-
U106	606–20–2	Benzene, 2-methyl-1,3-dinitro-
U055	98–82–8	Benzene, (1-methylethyl)- (I)
U169	98–95–3	Benzene, nitro-
U183	608–93–5	Benzene, pentachloro-
U185	82–68–8	Benzene, pentachloronitro-
U020	98–09–9	Benzenesulfonic acid chloride (C,R)
U020	98–09–9	Benzenesulfonyl chloride (C,R)
U207	95–94–3	Benzene, 1,2,4,5-tetrachloro-
U061	50–29–3	Benzene, 1,1’-(2,2,2-trichloroethylidene)bis[4-chloro-
U247	72–43–5	Benzene, 1,1’-(2,2,2-trichloroethylidene)bis[4- methoxy-
U023	98–07–7	Benzene, (trichloromethyl)-
U234	99–35–4	Benzene, 1,3,5-trinitro-
U021	92–87–5	Benzidine
U202	81–07–2	1,2-Benzisothiazol-3(2H)-one, 1,1-dioxide, & salts
U278	22781–23–3	1,3-Benzodioxol-4-ol, 2,2-dimethyl-, methyl carbamate.
U364	22961–82–6	1,3-Benzodioxol-4-ol, 2,2-dimethyl-,
U203	94–59–7	1,3-Benzodioxole, 5-(2-propenyl)-
U141	120–58–1	1,3-Benzodioxole, 5-(1-propenyl)-
U367	1563–38–8	7-Benzofuranol, 2,3-dihydro-2,2-dimethyl-
U090	94–58–6	1,3-Benzodioxole, 5-propyl-
U064	189–55–9	Benzo[rst]pentaphene
U248	181–81–2	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenyl-butyl)-, & salts, when present at concentrations of 0.3% or less
U022	50–32–8	Benzo[a]pyrene
U197	106–51–4	p-Benzoquinone
U023	98–07–7	Benzotrichloride (C,R,T)
U085	1464–53–5	2,2’-Bioxirane
U021	92–87–5	[1,1’Biphenyl]-4,4’-diamine
U073	91–94–1	[1,1’-Biphenyl]-4,4’-diamine, 3,3’-dichloro-
U091	119–90–4	[1,1’-Biphenyl]-4,4’-diamine, 3,3’-dimethoxy-
U095	119–93–7	[1,1’-Biphenyl]-4,4’-diamine, 3,3’-dimethyl-

U225	75–25–2	Bromoform
U030	101–55–3	4-Bromophenyl phenyl ether
U128	87–68–3	1,3-Butadiene, 1,1,2,3,4,4-hexachloro-
U172	924–16–3	1-Butanamine, N-butyl-N-nitroso-
U031	71–36–3	1-Butanol (I)
U159	78–93–3	2-Butanone (I,T)
U160	1338–23–4	2-Butanone, peroxide (R,T)
U053	4170–30–3	2-Butenal
U074	764–41–0	2-Butene, 1,4-dichloro- (I,T)
U143	303–34–4	2-Butenoic acid, 2-methyl-, 7-[[2,3-dihydroxy-2-(1-methoxyethyl)-3-methyl-1-oxobutoxy]methyl]-2,3,5,7a-tetrahydro-1H-pyrrolizin-1-yl ester, [1S-[1alpha(Z),7(2S*,3R*),7aalpha]]-
U031	71–36–3	n-Butyl alcohol (I)
U136	75–60–5	Cacodylic acid
U032	13765–19–0	Calcium chromate
U372	10605–21–7	Carbamic acid, 1H-benzimidazol-2-yl, methyl ester.
U271	17804–35–2	Carbamic acid, [1-[(butylamino)carbonyl]-1H-benzimidazol-2-yl]-, methyl ester.
U280	101–27–9	Carbamic acid, (3-chlorophenyl)-, 4-chloro-2-butynyl ester.
U238	51–79–6	Carbamic acid, ethyl ester
U178	615–53–2	Carbamic acid, methylnitroso-, ethyl ester
U373	122–42–9	Carbamic acid, phenyl-, 1-methylethyl ester.
U409	23564–05–8	Carbamic acid, [1,2-phenylenebis (iminocarbonothioyl)]bis-, dimethyl ester.
U097	79–44–7	Carbamic chloride, dimethyl-
U389	2303–17–5	Carbamothioic acid, bis(1-methylethyl)-, S-(2,3,3-trichloro-2-propenyl) ester.
U387	52888–80–9	Carbamothioic acid, dipropyl-, S-(phenylmethyl) ester.
U114	111–54–6	Carbamodithioic acid, 1,2-ethanediylbis-, salts & esters
U062	2303–16–4	Carbamothioic acid, bis(1-methylethyl)-, S-(2,3-dichloro-2-propenyl) ester
U279	63–25–2	Carbaryl.
U372	10605–21–7	Carbendazim.
U367	1563–38–8	Carbofuran phenol.
U215	6533–73–9	Carbonic acid, dithallium(1+) salt
U033	353–50–4	Carbonic difluoride
U156	79–22–1	Carbonochloridic acid, methyl ester (I,T)
U033	353–50–4	Carbon oxyfluoride (R,T)
U211	56–23–5	Carbon tetrachloride
U034	75–87–6	Chloral
U035	305–03–3	Chlorambucil
U036	57–74–9	Chlordane, alpha & gamma isomers
U026	494–03–1	Chlornaphazin
U037	108–90–7	Chlorobenzene
U038	510–15–6	Chlorobenzilate
U039	59–50–7	p-Chloro-m-cresol
U042	110–75–8	2-Chloroethyl vinyl ether
U044	67–66–3	Chloroform
U046	107–30–2	Chloromethyl methyl ether
U047	91–58–7	beta-Chloronaphthalene
U048	95–57–8	o-Chlorophenol

U049	3165–93–3	4-Chloro-o-toluidine, hydrochloride
U032	13765–19–0	Chromic acid H2 CrO4, calcium salt
U050	218–01–9	Chrysene
U051		Creosote
U052	1319–77–3	Cresol (Cresylic acid)
U053	4170–30–3	Crotonaldehyde
U055	98–82–8	Cumene (I)
U246	506–68–3	Cyanogen bromide (CN)Br
U197	106–51–4	2,5-Cyclohexadiene-1,4-dione
U056	110–82–7	Cyclohexane (I)
U129	58–89–9	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1alpha,2alpha,3beta,4alpha,5alpha,6beta)-
U057	108–94–1	Cyclohexanone (I)
U130	77–47–4	1,3-Cyclopentadiene, 1,2,3,4,5,5-hexachloro-
U058	50–18–0	Cyclophosphamide
U240	1 94–75–7	2,4-D, salts & esters
U059	20830–81–3	Daunomycin
U060	72–54–8	DDD
U061	50–29–3	DDT
U062	2303–16–4	Diallate
U063	53–70–3	Dibenz[a,h]anthracene
U064	189–55–9	Dibenzo[a,i]pyrene
U066	96–12–8	1,2-Dibromo-3-chloropropane
U069	84–74–2	Dibutyl phthalate
U070	95–50–1	o-Dichlorobenzene
U071	541–73–1	m-Dichlorobenzene
U072	106–46–7	p-Dichlorobenzene
U073	91–94–1	3,3′-Dichlorobenzidine
U074	764–41–0	1,4-Dichloro-2-butene (I,T)
U075	75–71–8	Dichlorodifluoromethane
U078	75–35–4	1,1-Dichloroethylene
U079	156–60–5	1,2-Dichloroethylene
U025	111–44–4	Dichloroethyl ether
U027	108–60–1	Dichloroisopropyl ether
U024	111–91–1	Dichloromethoxy ethane
U081	120–83–2	2,4-Dichlorophenol
U082	87–65–0	2,6-Dichlorophenol
U084	542–75–6	1,3-Dichloropropene
U085	1464–53–5	1,2:3,4-Diepoxybutane (I,T)
U108	123–91–1	1,4-Diethyleneoxide
U028	117–81–7	Diethylhexyl phthalate
U395	5952–26–1	Diethylene glycol, dicarbamate.
U086	1615–80–1	N,N′-Diethylhydrazine
U087	3288–58–2	O,O-Diethyl S-methyl dithiophosphate
U088	84–66–2	Diethyl phthalate
U089	56–53–1	Diethylstilbesterol
U090	94–58–6	Dihydrosafrole
U091	119–90–4	3,3′-Dimethoxybenzidine
U092	124–40–3	Dimethylamine (I)
U093	60–11–7	p-Dimethylaminoazobenzene
U094	57–97–6	7,12-Dimethylbenz[a]anthracene
U095	119–93–7	3,3′-Dimethylbenzidine

U096	80–15–9	alpha,alpha-Dimethylbenzylhydroperoxide (R)
U097	79–44–7	Dimethylcarbamoyl chloride
U098	57–14–7	1,1-Dimethylhydrazine
U099	540–73–8	1,2-Dimethylhydrazine
U101	105–67–9	2,4-Dimethylphenol
U102	131–11–3	Dimethyl phthalate
U103	77–78–1	Dimethyl sulfate
U105	121–14–2	2,4-Dinitrotoluene
U106	606–20–2	2,6-Dinitrotoluene
U107	117–84–0	Di-n-octyl phthalate
U108	123–91–1	1,4-Dioxane
U109	122–66–7	1,2-Diphenylhydrazine
U110	142–84–7	Dipropylamine (I)
U111	621–64–7	Di-n-propylnitrosamine
U041	106–89–8	Epichlorohydrin
U001	75–07–0	Ethanal (I)
U404	121–44–8	Ethanamine, N,N-diethyl-
U174	55–18–5	Ethanamine, N-ethyl-N-nitroso-
U155	91–80–5	1,2-Ethanediamine, N,N-dimethyl-N′-2-pyridinyl-N′-(2-thienylmethyl)-
U067	106–93–4	Ethane, 1,2-dibromo-
U076	75–34–3	Ethane, 1,1-dichloro-
U077	107–06–2	Ethane, 1,2-dichloro-
U131	67–72–1	Ethane, hexachloro-
U024	111–91–1	Ethane, 1,1′-[methylenebis(oxy)]bis[2-chloro-
U117	60–29–7	Ethane, 1,1′-oxybis-(I)
U025	111–44–4	Ethane, 1,1′-oxybis[2-chloro-
U184	76–01–7	Ethane, pentachloro-
U208	630–20–6	Ethane, 1,1,1,2-tetrachloro-
U209	79–34–5	Ethane, 1,1,2,2-tetrachloro-
U218	62–55–5	Ethanethioamide
U226	71–55–6	Ethane, 1,1,1-trichloro-
U227	79–00–5	Ethane, 1,1,2-trichloro-
U410	59669–26–0	Ethanimidothioic acid, N,N′-thiobis[(methylimino)carbonyloxy]]bis-, dimethyl ester
U394	30558–43–1	Ethanimidothioic acid, 2-(dimethylamino)-N-hydroxy-2-oxo-, methyl ester.
U359	110–80–5	Ethanol, 2-ethoxy-
U173	1116–54–7	Ethanol, 2,2′-(nitrosoimino)bis-
U395	5952–26–1	Ethanol, 2,2′-oxybis-, dicarbamate.
U004	98–86–2	Ethanone, 1-phenyl-
U043	75–01–4	Ethene, chloro-
U042	110–75–8	Ethene, (2-chloroethoxy)-
U078	75–35–4	Ethene, 1,1-dichloro-
U079	156–60–5	Ethene, 1,2-dichloro-, (E)-
U210	127–18–4	Ethene, tetrachloro-
U228	79–01–6	Ethene, trichloro-
U112	141–78–6	Ethyl acetate (I)
U113	140–88–5	Ethyl acrylate (I)
U238	51–79–6	Ethyl carbamate (urethane)
U117	60–29–7	Ethyl ether (I)
U114	111–54–6	Ethylenebisdithiocarbamic acid, salts & esters

U067	106–93–4	Ethylene dibromide
U077	107–06–2	Ethylene dichloride
U359	110–80–5	Ethylene glycol monoethyl ether
U115	75–21–8	Ethylene oxide (I,T)
U116	96–45–7	Ethylenethiourea
U076	75–34–3	Ethylidene dichloride
U118	97–63–2	Ethyl methacrylate
U119	62–50–0	Ethyl methanesulfonate
U120	206–44–0	Fluoranthene
U122	50–00–0	Formaldehyde
U123	64–18–6	Formic acid (C,T)
U124	110–00–9	Furan (I)
U125	98–01–1	2-Furancarboxaldehyde (I)
U147	108–31–6	2,5-Furandione
U213	109–99–9	Furan, tetrahydro-(I)
U125	98–01–1	Furfural (I)
U124	110–00–9	Furfuran (I)
U206	18883–66–4	Glucopyranose, 2-deoxy-2-(3-methyl-3-nitrosoureido)-,
U126	765–34–4	Glycidylaldehyde
U163	70–25–7	Guanidine, N-methyl-N′-nitro-N-nitroso-
U127	118–74–1	Hexachlorobenzene
U128	87–68–3	Hexachlorobutadiene
U130	77–47–4	Hexachlorocyclopentadiene
U131	67–72–1	Hexachloroethane
U132	70–30–4	Hexachlorophene
U243	1888–71–7	Hexachloropropene
U133	302–01–2	Hydrazine (R,T)
U086	1615–80–1	Hydrazine, 1,2-diethyl-
U098	57–14–7	Hydrazine, 1,1-dimethyl-
U099	540–73–8	Hydrazine, 1,2-dimethyl-
U109	122–66–7	Hydrazine, 1,2-diphenyl-
U134	7664–39–3	Hydrofluoric acid (C,T)
U134	7664–39–3	Hydrogen fluoride (C,T)
U135	7783–06–4	Hydrogen sulfide
U096	80–15–9	Hydroperoxide, 1-methyl-1-phenylethyl- (R)
U116	96–45–7	2-Imidazolidinethione
U137	193–39–5	Indeno[1,2,3-cd]pyrene
U190	85–44–9	1,3-Isobenzofurandione
U140	78–83–1	Isobutyl alcohol (I,T)
U141	120–58–1	Isosafrole
U142	143–50–0	Kepone
U143	303–34–4	Lasiocarpine
U144	301–04–2	Lead acetate
U146	1335–32–6	Lead, bis(acetato-O)tetrahydroxytri-
U145	7446–27–7	Lead phosphate
U146	1335–32–6	Lead subacetate
U129	58–89–9	Lindane
U163	70–25–7	MNNG
U147	108–31–6	Maleic anhydride
U148	123–33–1	Maleic hydrazide
U149	109–77–3	Malononitrile
U150	148–82–3	Melphalan

U151	7439–97–6	Mercury
U152	126–98–7	Methacrylonitrile (I, T)
U092	124–40–3	Methanamine, N-methyl- (I)
U029	74–83–9	Methane, bromo-
U045	74–87–3	Methane, chloro- (I, T)
U046	107–30–2	Methane, chloromethoxy-
U068	74–95–3	Methane, dibromo-
U080	75–09–2	Methane, dichloro-
U075	75–71–8	Methane, dichlorodifluoro-
U138	74–88–4	Methane, iodo-
U119	62–50–0	Methanesulfonic acid, ethyl ester
U211	56–23–5	Methane, tetrachloro-
U153	74–93–1	Methanethiol (I, T)
U225	75–25–2	Methane, tribromo-
U044	67–66–3	Methane, trichloro-
U121	75–69–4	Methane, trichlorofluoro-
U036	57–74–9	4,7-Methano-1H-indene, 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-
U154	67–56–1	Methanol (I)
U155	91–80–5	Methapyrilene
U142	143–50–0	1,3,4-Metheno-2H-cyclobuta[cd]pentalen-2-one, 1,1a,3,3a,4,5,5,5a,5b,6-decachlorooctahydro-
U247	72–43–5	Methoxychlor
U186	504–60–9	1-Methylbutadiene (I)
U156	79–22–1	Methyl chlorocarbonate (I,T)
U226	71–55–6	Methyl chloroform
U157	56–49–5	3-Methylcholanthrene
U158	101–14–4	4,4′-Methylenebis(2-chloroaniline)
U068	74–95–3	Methylene bromide
U080	75–09–2	Methylene chloride
U159	78–93–3	Methyl ethyl ketone (MEK) (I,T)
U160	1338–23–4	Methyl ethyl ketone peroxide (R,T)
U161	108–10–1	Methyl isobutyl ketone (I)
U162	80–62–6	Methyl methacrylate (I,T)
U161	108–10–1	4-Methyl-2-pentanone (I)
U164	56–04–2	Methylthiouracil
U010	50–07–7	Mitomycin C
U059	20830–81–3	5,12-Naphthacenedione, 8-acetyl-10-[(3-amino-2,3,6-trideoxy)-alpha-L-lyxo-hexopyranosyl)oxy]-7,8,9,10-tetrahydro-6,8,11-trihydroxy-1-methoxy-, (8S-cis)-
U167	134–32–7	1-Naphthalenamine
U168	91–59–8	2-Naphthalenamine
U026	494–03–1	Naphthalenamine, N,N′-bis(2-chloroethyl)-
U165	91–20–3	Naphthalene
U047	91–58–7	Naphthalene, 2-chloro-
U166	130–15–4	1,4-Naphthalenedione
U236	72–57–1	2,7-Naphthalenedisulfonic acid, 3,3′-[(3,3′-dimethyl[1,1′-biphenyl]-4,4′-diyl)bis(azo)bis[5-amino-4-hydroxy]-, tetrasodium salt
U279	63–25–2	1-Naphthalenol, methylcarbamate.
U166	130–15–4	1,4-Naphthoquinone
U167	134–32–7	alpha-Naphthylamine

U168	91–59–8	beta-Naphthylamine
U217	10102–45–1	Nitric acid, thallium(1+) salt
U169	98–95–3	Nitrobenzene (I,T)
U170	100–02–7	p-Nitrophenol
U171	79–46–9	2-Nitropropane (I,T)
U172	924–16–3	N-Nitrosodi-n-butylamine
U173	1116–54–7	N-Nitrosodiethanolamine
U174	55–18–5	N-Nitrosodiethylamine
U176	759–73–9	N-Nitroso-N-ethylurea
U177	684–93–5	N-Nitroso-N-methylurea
U178	615–53–2	N-Nitroso-N-methylurethane
U179	100–75–4	N-Nitrosopiperidine
U180	930–55–2	N-Nitrosopyrrolidine
U181	99–55–8	5-Nitro-o-toluidine
U193	1120–71–4	1,2-Oxathiolane, 2,2-dioxide
U058	50–18–0	2H-1,3,2-Oxazaphosphorin-2-amine,N,N-bis(2-chloroethyl)tetrahydro-, 2-oxide
U115	75–21–8	Oxirane (I,T)
U126	765–34–4	Oxiranecarboxyaldehyde
U041	106–89–8	Oxirane, (chloromethyl)-
U183	608–93–5	Pentachlorobenzene
U184	76–01–7	Pentachloroethane
U185	82–68–8	Pentachloronitrobenzene (PCNB)
U161	108–10–1	Pentanol, 4-methyl-
U186	504–60–9	1,3-Pentadiene (I)
U187	62–44–2	Phenacetin
U188	108–95–2	Phenol
U048	95–57–8	Phenol, 2-chloro-
U039	59–50–7	Phenol, 4-chloro-3-methyl-
U081	120–83–2	Phenol, 2,4-dichloro-
U082	87–65–0	Phenol, 2,6-dichloro-
U089	56–53–1	Phenol, 4,4′-(1,2-diethyl-1,2-ethenediyl)bis-, (E)-
U101	105–67–9	Phenol, 2,4-dimethyl-
U052	1319–77–3	Phenol, methyl-
U132	70–30–4	Phenol, 2,2′-methylenebis[3,4,6-trichloro-
U411	114–26–1	Phenol, 2-(1-methylethoxy)-, methylcarbamate.
U170	100–02–7	Phenol, 4-nitro-
U150	148–82–3	L-Phenylalanine, 4-[bis(2-chloroethyl)amino]-
U145	7446–27–7	Phosphoric acid, lead(2+) salt (2:3)
U087	3288–58–2	Phosphorodithioic acid, O,O-diethyl S-methyl ester
U189	1314–80–3	Phosphorus sulfide (R)
U190	85–44–9	Phthalic anhydride
U191	109–06–8	2-Picoline
U179	100–75–4	Piperidine, 1-nitroso-
U192	23950–58–5	Pronamide
U194	107–10–8	1-Propanamine (I,T)
U111	621–64–7	1-Propanamine, N-nitroso-N-propyl-
U110	142–84–7	1-Propanamine, N-propyl- (I)
U066	96–12–8	Propane, 1,2-dibromo-3-chloro-
U083	78–87–5	Propane, 1,2-dichloro-
U149	109–77–3	Propanedinitrile
U171	79–46–9	Propane, 2-nitro- (I,T)

U027	108–60–1	Propane, 2,2¢-oxybis[2-chloro-
U193	1120–71–4	1,3-Propane sultone
U235	126–72–7	1-Propanol, 2,3-dibromo-, phosphate (3:1)
U140	78–83–1	1-Propanol, 2-methyl- (I,T)
U002	67–64–1	2-Propanone (I)
U007	79–06–1	2-Propenamide
U084	542–75–6	1-Propene, 1,3-dichloro-
U243	1888–71–7	1-Propene, 1,1,2,3,3,3-hexachloro-
U009	107–13–1	2-Propenenitrile
U152	126–98–7	2-Propenenitrile, 2-methyl- (I,T)
U008	79–10–7	2-Propenoic acid (I)
U113	140–88–5	2-Propenoic acid, ethyl ester (I)
U118	97–63–2	2-Propenoic acid, 2-methyl-, ethyl ester
U162	80–62–6	2-Propenoic acid, 2-methyl-, methyl ester (I,T)
U373	122–42–9	Propham.
U411	114–26–1	Propoxur.
U387	52888–80–9	Prosulfocarb.
U194	107–10–8	n-Propylamine (I,T)
U083	78–87–5	Propylene dichloride
U148	123–33–1	3,6-Pyridazinedione, 1,2-dihydro45
U196	110–86–1	Pyridine
U191	109–06–8	Pyridine, 2-methyl-
U237	66–75–1	2,4-(1H,3H)-Pyrimidinedione, 5-[bis(2-chloroethyl)amino]-
U164	56–04–2	4(1H)-Pyrimidinone, 2,3-dihydro-6-methyl-2-thioxo-
U180	930–55–2	Pyrrolidine, 1-nitroso-
U200	50–55–5	Reserpine
U201	108–46–3	Resorcinol
U202	81–07–2	Saccharin, & salts
U203	94–59–7	Safrole
U204	7783–00–8	Selenious acid
U204	7783–00–8	Selenium dioxide
U205	7488–56–4	Selenium sulfide
U015	115–02–6	L-Serine, diazoacetate (ester)
U206	18883–66–4	Streptozotocin
U103	77–78–1	Sulfuric acid, dimethyl ester
U189	1314–80–3	Sulfur phosphide (R)
U207	95–94–3	1,2,4,5-Tetrachlorobenzene
U208	630–20–6	1,1,1,2-Tetrachloroethane
U209	79–34–5	1,1,2,2-Tetrachloroethane
U210	127–18–4	Tetrachloroethylene
U213	109–99–9	etrahydrofuran (I)
U214	563–68–8	Thallium(I) acetate
U215	6533–73–9	Thallium(I) carbonate
U216	7791–12–0	Thallium(I) chloride
U217	10102–45–1	Thallium(I) nitrate
U218	62–55–5	Thioacetamide
U410	59669–26–0	Thiodicarb.
U153	74–93–1	Thiomethanol (I,T)
U244	137–26–8	Thioperoxydicarbonic diamide [(H2 N)C(S)]2 S2, tetramethyl-
U409	23564–05–8	Thiophanate-methyl.
U219	62–56–6	Thiourea
U244	137–26–8	Thiram

U220	108–88–3	Toluene
U221	25376–45–8	Toluenediamine
U223	26471–62–5	Toluene diisocyanate (R,T)
U328	95–53–4	o-Toluidine
U353	106–49–0	p-Toluidine
U222	636–21–5	o-Toluidine hydrochloride
U389	2303–17–5	Triallate.
U011	61–82–5	1H-1,2,4-Triazol-3-amine
U408	118–79–6	2,4,6-Tribromophenol.
U227	79–00–5	1,1,2-Trichloroethane
U228	79–01–6	Trichloroethylene
U121	75–69–4	Trichloromonofluoromethane
U404	121–44–8	Triethylamine.
U234	99–35–4	1,3,5-Trinitrobenzene (R,T)
U182	123–63–7	1,3,5-Trioxane, 2,4,6-trimethyl-
U235	126–72–7	Tris(2,3-dibromopropyl) phosphate
U236	72–57–1	Trypan blue
U237	66–75–1	Uracil mustard
U176	759–73–9	Urea, N-ethyl-N-nitroso-
U177	684–93–5	Urea, N-methyl-N-nitroso-
U043	75–01–4	Vinyl chloride
U248	81–81–2	Warfarin, & salts, when present at concentrations of 0.3% or less
U239	1330–20–7	Xylene (I)
U200	50–55–5	Yohimban-16-carboxylic acid, 11,17-dimethoxy-18-[(3,4,5-trimethoxybenzoyl)oxy]-, methyl ester, (3beta,16beta,17alpha,18beta,20alpha)-
U249	1314–84–7	Zinc phosphide Zn3 P2, when present at concentrations of 10% or less